Analyzing Sustainable Energy Opportunities for a Small Scale Off-Grid Facility: A Case Study at Experimental Lakes Area (ELA), Ontario

By

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A Thesis
Submitted to the Faculty of Graduate Studies
In Partial Fulfillment of the Requirements
For the Degree of

Master of Natural Resources
Management

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Abstract

This thesis explored the opportunities to reduce energy demand and renewable energy feasibility at an off-grid science "community" called the Experimental Lakes Area (ELA) in Ontario. Being off-grid, ELA is completely dependent on diesel and propane fuel supply for all its electrical and heating needs, which makes ELA vulnerable to fluctuating fuel prices. As a result ELA emits a large amount of greenhouse gases (GHG) for its size. Energy efficiency and renewable energy technologies can reduce energy consumption and consequently energy cost, as well as GHG.

Energy efficiency was very important to ELA due to the elevated fuel costs at this remote location. Minor upgrades to lighting, equipment and building envelope were able to reduce energy costs and reduce load. Efficient energy saving measures were recommended that save on operating and maintenance costs, namely, changing to LED lights, replacing old equipment like refrigerators and downsizing of ice makers. This resulted in a 4.8% load reduction and subsequently reduced the initial capital cost for biomass by $27,000, by $49,500 for wind power and by $136,500 for solar power.

Many alternative energies show promise as potential energy sources to reduce the diesel and propane consumption at ELA including wind energy, solar heating and bio-mass. A biomass based CHP system using the existing diesel generators as back-up has the shortest pay back period of the technologies modeled. The biomass based CHP system has a pay back period of 4.1 years at $0.80 per liter of diesel, as diesel price approaches $ 2.00 per liter the pay back period reduces to 0.9 years, 50% the generation cost compared to present generation costs. Biomass has been successfully tried and tested in many off-grid communities particularly in a small-scale off-grid setting in North America and internationally. Also, the site specific solar and wind data show that ELA has potential to harvest renewable resources and produce heat and power at competitive rates compared to diesel and propane.

Acknowledgements

I would like thank Dr. Shirley Thompson for her guidance and support throughout this project. I would also like to thank my committee members Mr. Denis DePape and Dr. Eric Bibeau for their guidance and suggestions. This project would not have been possible without the financial support from the Department of Fisheries and Oceans (DFO). I would like to thank Paul Herage, Ray Pambrun, Ken Beaty, Duane Jordan for their support and in-kind contribution towards this project.

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Glossary of Terms

CHP – Combined Heat and power

ELA – Experimental Lakes Area

GHG – Green House Gases

O&M – Operations and Maintenance

PV – Photovoltaic

R -12 – Thermal Resistance Factor

RET – Renewable Energy Technologies

SPV – Solar Photovoltaic

CHAPTER 1: INTRODUCTION

1.1 Background

As the sixth largest energy consumer of energy in the world (Environment Canada, 2005), and with the second highest per capita energy consumption rate among the G-8 nations (International Energy Agency, 2004), Canada needs to explore sustainable energy opportunities for urban and rural developments and reduce energy consumption to make a steady shift towards demand reduction and renewable energy technologies. Industry and government interests have channeled most of the demand reduction and renewable energy research at highly populated, developed, and urbanized establishments like cities, business, sub-urban residences, industries and neglected remote communities. However, with over 300 off-grid communities in Canada and with a combined population of ~200,000 across the country operating on fossil fuels it is also important that these communities meet their energy requirements in a sustainable and cleaner manner (EIA, 2005a; Ah-You & Leng, 1999). This research explores demand reduction through energy efficiency, as well as renewable energy technologies, at one off-grid location.

Clean renewable energy sources have potential for implementation in small off-grid facilities because they presently require diesel generation to generate electricity, bulky to ship and costly to consume; however, with numerous renewable energy sources a complete economic and technological analysis is required to identify the most suitable and efficient resources (Ah-You & Leng, 1999). Suitable energy efficient measures and viable renewable energy technologies must be evaluated before being considered to realize the huge potential for application in off-grid facilities. As the quality of renewable energy resources vary with the location it is necessary to perform a site-specific analysis to compare renewable energy resource considered applicable to this specific site.

Energy is a driving force in any off-grid community. Existing heat and power generation technologies and energy usage patterns create negative environmental impacts such as green house gas production (Khan and Islam, 2003a, 2003b, 2004, 2005a), particularly at Experimental Lakes Area (ELA) where diesel is used. Therefore, an energy profile to determine sustainability should consider efficiency, cleanliness of energy, reliability and reliable and ready-to-use energy source for any off-grid[1] diesel establishment to satisfy the two most important amenities for operation, namely heat and electrical power that are necessary for steady and dependable operation of the facility (PWGSC, 2007). A sustainable energy plan for ELA will be a collective approach consisting of two key components, which are energy efficiency and renewable energy (REEEP, 2005). The research will consider: 1) the feasibility of efficiency measures by energy conservation; and 2) renewable energy technology feasibility.

Energy efficiency measures can yield significant savings for off-grid communities by reducing fuel use (PWGSC, 2007). The existing heating and electrical systems at ELA are inefficient, expensive to operate and maintain and completely dependent on diesel and propane fuels. The overall energy costs are dictated by diesel and propane prices, which in turn are dependent on fluctuating global oil prices. Based on the trend for diesel and propane prices, the energy cost at ELA are expected to increase thus making renewable energy more feasible in the future.

With increasing oil prices, Renewable Energy Technologies (RETs) are attractive options for off-grid communities and are becoming a reality in many off-grid communities across Europe and Asia. However, as every off-grid facility has unique resource availability and

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[1] Off-grid refers to a single or cluster of buildings or community that is not connected to the provincial electrical grid

varying base loads[2] there is no “one size fits all”. Each site has to be individually assessed for energy resources, energy requirements needs and demand reduction by identifying retrofitting opportunities. By implementing demand reduction measures and adopting renewable energy technology ELA creates an opportunity not only to reduce its energy cost but also to mitigate its environmental footprint. The desirable features for a sustainable energy system for ELA were identified as:

- reduced demand for heat and power
- reduced GHG emissions
- lower and stable energy costs
- cleaner technology
- autonomous supply of heat and power minimum consumption of fossil fuels
- reduced risk from fuel spills and leaks during storage and transportation
- lower operating & maintenance (O&M) costs

Figure 1.1 represents the current energy model at ELA. A 100% diesel based power generation system with propane heating set-up has been chosen because of low capital cost and common availability of the technology. Limited random and incomplete energy efficiency measures have been implemented that lead to high energy cost and high GHG emissions. This model also requires large amounts of fuel to be stored on site that increases the risk of a fuel spill, which would be very damaging to the environment and expensive to clean up. Complete dependency on an inefficient system for diesel and propane is unsustainable in the long run as these fossil fuels are prone to fluctuation in fuel price and transportation costs. The aim of this thesis is to propose an improved energy system that incorporates a hybrid power generation using local renewable sources

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[2] Base load is the minimum level of demand on an electrical supply system over 24-hours, the load that exists 24 hours a day

and mitigating the dependency on fossil fuel while reducing the energy cost and GHG emissions.

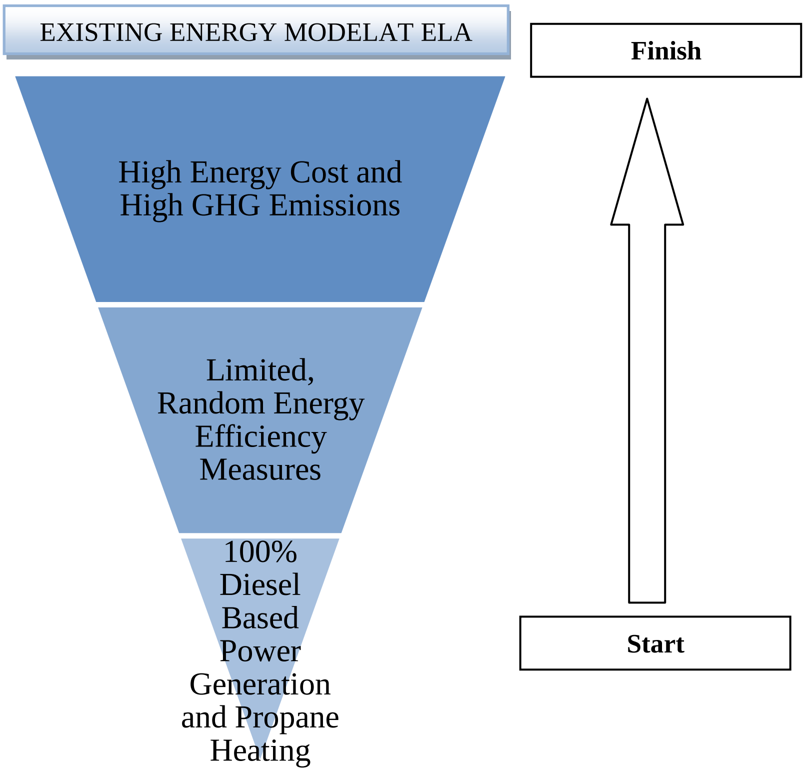

Figure 1.1 Existing Energy Model at ELA

Figure 1.2 portrays various parameters of the analysis of sustainable energy development at ELA considering energy efficiency and renewable energy.

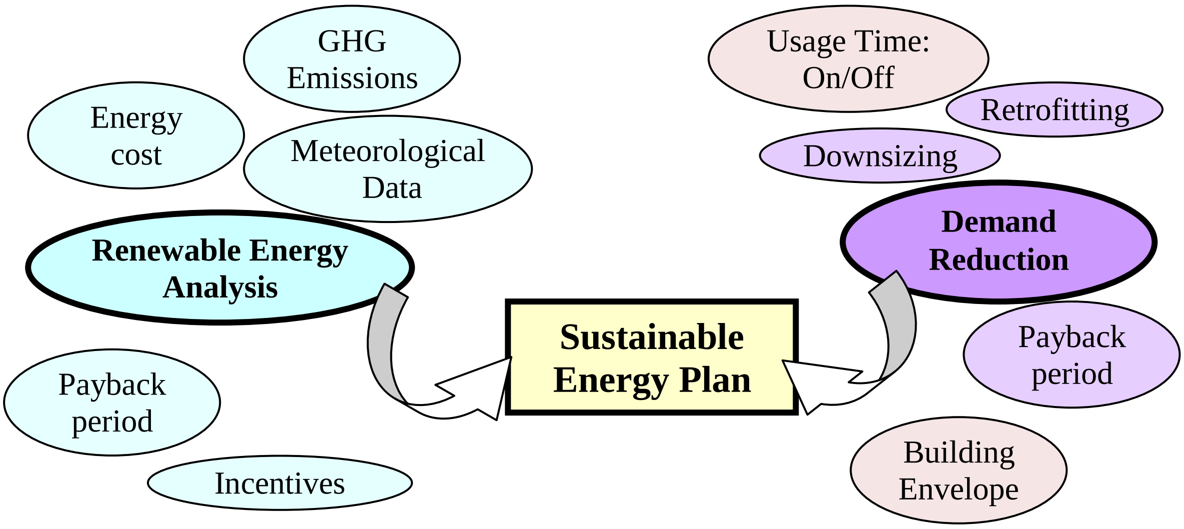

Figure 1.2 Parameters Considered for Sustainable Energy Analysis at ELA

1.2 Study Area

The study area is the experimental lakes area (ELA) field station located at 50 km south of Kenora, Ontario (See Figure 1.2) in Canada.

Figure 1.3 Location of ELA on provincial map of Ontario

Source: http://www.umanitoba.ca/institutes/fisheries/location.html

This northern location of ELA is latitude 49 degrees, 47 minutes and 15 seconds north. The weather at this latitude varies from +30 degrees Celsius in the summer to -30 degrees Celsius in the long winter. The field station includes 20 buildings, which are mainly clustered around the laboratory and kitchen as shown in Figure 1.3. The total laboratory space is about 6,900.00 square feet. Although some buildings date back to 1968, in 2001 three new buildings were added to the facility, namely, a new laboratory and two R-2000 energy efficient residences. These residences provide common areas and about ten single rooms.

Study Location Information:

Latitude: between 49^o 34' and 49^o 47’ North
Longitude: between 93^o 36' and 93^o 52' West
Elevation: 411m
Heating Design Temperature: - 29.8 °C
Cooling Design Temperature: 27.3 °C

Figure 1.4 Ariel view of field station surrounded by woods and lakes

DFO (Department of Fisheries and Oceans) operates this unique facility in the remote region of northwestern Ontario year round. It has very limited occupancy (about 4 to 5 people) during the winter/fall and spring months from October to April but houses about 40 people from mid-May to September (Pambrun, Personal Communication). The primary purpose of the facility is to accommodate researchers and students to carry out research experiments in the lakes, which requires collecting samples and then analyzing them. The on-site meteorological station has a range of measuring instruments, which are monitored and recorded on a daily basis (Beaty, Personal Communication). Energy for the facility is currently provided by a diesel power generator.

1.3 Purpose and Objectives

The main purpose of this thesis is to explore improvements that can be made through energy efficiency measures and to evaluate renewable energy opportunities compared to the current diesel situation. This thesis will attempt to answer the following research questions:

1. What is the current form of energy supply and what are the resulting environmental and economic impacts?

2. Are there any opportunities to reduce energy consumption by improving energy efficiency that result in savings and a short payback period?
3. What type of renewable energy technologies would be most cost-effective at providing a consistently stable and reliable energy supply at the scale and geographical location of the facility?

The project's three objectives, derived based on the above mentioned research questions are as follows:

1. To understand the existing energy set up at ELA by creating an energy profile of ELA and to develop a base case scenario for the year 2006/2007.
2. To identify and recommend energy saving opportunities using demand reduction approach and to estimate the resulting savings.
3. To perform a renewable energy analysis that compares different renewable energy resources to identify the most feasible renewable technology for the site and to integrate it with identified energy efficiency measures.

1.4 Significance of Research

This thesis is significant as it applies RETScreen to compare different renewable energies for the same site. It is also one of the few research analysis of renewable energy that considers energy efficiency prior to assessing renewable energy. This research is also applied and, as such, may have environmental and economic benefits to ELA. Being a long-term off-grid research establishment, which was built in wilderness, ELA has the responsibility to conduct research in an environmentally friendly manner to maintain the ecological and biological integrity of the surrounding ecosystem. Economically, it contributes to the potential reduction in heat and power generation cost with improved efficiency. Overall, this work will contribute by discovering the potential opportunities for communities, particularly off-grid but with applications to on-grid communities, to make them more sustainable.

1.5 Research Limitations

There are certain limitations on this study due to the lack of baseline data and facility status,

- *Lack of baseline data:* Although some studies have carried out renewable energy analysis for wind, solar radiation and biomass there was no study that has carried energy analysis from a demand reduction point of view.
- *Energy Monitoring:* No energy monitoring systems exist at ELA to provide an indication of energy usage between different buildings or different equipment.

1.6 Research Approach

The research objectives were met through collection of primary data using a walk-through survey, informal discussions with DFO people, literature review and analysis by RETScreen. Further explanation of these methods is presented in Chapter 3.

1.7 Assumptions

The following assumptions were made:

- The demand for power and heat would remain constant through the study period independent of number of occupants (assuming that heating needs in winter for building maintenance would balance the increased electrical needs in summer).
- The efficiency of the diesel power generators is assumed to remain constant for the period of study.
- The fuel price for diesel and propane remain constant throughout the study period and therefore the cost per kWh remains constant.

- The mechanical efficiency of the generators, appliances and HVAC systems do not change over the study period.
- The ELA facility has four main areas where most of the daily activities are carried out and therefore are assumed to be the major consumers of heat and power, namely:
    - Kitchen and dining hall
    - Chemistry lab
    - General workshop
    - Residence buildings.

1.8 Thesis Organization

This thesis is organized into six chapters. Chapter 1 provides a general introduction. Chapter 2 is the literature review of energy management in small off-grid communities in Canada and of renewable energy technologies. Chapter 3 outlines the study methods. Chapter 4 discusses the results of the demand reduction analysis for ELA and provides recommendations. Chapter 5 consists of the renewable energy analysis. Chapter 6 summarizes and concludes considering the overall significance of this thesis work.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Energy management at a small off-grid community is an important issue driven mainly by economic factors like fuel cost, equipment efficiency, operation and maintenance costs, greenhouse gas (GHG) emissions and environmental risk (e.g. fuel spill). There are also efficiency issues of off-grid communities that contribute to higher demand like poorly insulated buildings in low quality housing, inefficient lighting and equipment. Historically, off-grid facilities in Canada have always had higher energy costs primarily due to expensive operations and maintenance (O&M) costs which are dictated by fuel prices, high cost for shipping and also due to diesel generation being an inefficient heat and power generation system. These communities consume large quantities of fossil fuels every year in order to meet their energy needs and as a result, emit large quantities of greenhouse gas (GHG) emissions contributing to the national emissions (affordable power in rural Alaska, 1996). As a result the energy use in these communities would be even higher than that of the average Canadian. Canadians use more energy per person than people in any other industrialized nation and on average, each citizen accounts for about 21 tonnes of greenhouse gases per year (Natural Resources Canada, 2008).

Regardless of the climate, higher energy costs and environmental impacts occur at off-grid facilities that use fossil fuels (diesel and propane) for heat and power generation (Isherwood et. al, 2000). Heat and power generation from diesel and propane is not only expensive in a remote setup for reasons like higher transportation cost for fuel, smaller population base, higher O&M cost and greater need for space heating but also carries a higher environmental risk of fuel spill during transportation and storage (Chapman, 1996). These challenges are exclusive to any off-grid facility and are to be overcome in order to make the desired shift towards sustainable energy.

2.2 Climate Change

There is strong evidence that levels of greenhouse gases in the atmosphere are increasing and that the world is getting warmer (Ayalon et al., 2001; IPCC, 1996). Climate change has unpredictable and far reaching environmental, economic and social consequences. The changes in temperature impact climate patterns such as wind, snow and storm intensity. Impacts include flooding and erosion, increased risk of forest fires, water shortages and drought.

2.2.1 Contributing Factors

Activities that contribute to greenhouse gas emissions are as follows.

- energy generation, particularly coal-based and fossil fuel based generation, such as the diesel at ELA;
- heating and cooling;
- transportation; and,
- high energy use

The six main greenhouse gases covered under the *Kyoto Protocol* are carbon dioxide, methane, nitrous oxide, hydroflurocarbons (HFC), perflourocarbons and sulphur hexafluoride. Of all the above mentioned gases, carbon dioxide is the main concern as it is closely associated with human activities and is thought to be the main contributor to climate change, especially through burning of fossil fuels like coal, gasoline, diesel, and propane. The concentrations of carbon dioxide in the atmosphere have increased by 30 percent and concentrations of methane and nitrous oxide have increased by 145 percent and 17 percent respectively (Goudie, 2001). In Canada GHG emissions in 2000 were 15 percent greater than they were in 1990. Canada is the third largest per capita emitter of these gases, after the United States and Australia (Turton, et.al, 2002).

2.2.2 Northern Impacts of Climate Change

The impact of climate change is likely to be more severe in the polar regions than near the equator. Rising global temperatures are melting glaciers and decreasing ice cover, affecting the way of life for northern communities. Many northern communities rely on winter ice roads during a brief window of time during the winter season that allows for safe transport of people and material. Should climate change progress significantly the reliability of these routes are threatened. Due to this the energy costs are significantly higher due to the high cost of transporting fuel to sites, if they have to be flown in, and also due to accessibility issues like long, cold winters and short hours of daylight.

2.2.3 Measures

The purpose of this chapter is to provide an overview of literature regarding the energy situation in small off-grid communities. This chapter is divided into three sections that look at the key areas of energy management that are relevant to this project. The three sections are: **Energy generation, Energy efficiency and Renewable energy**.

2.3 Energy Generation in Off-Grid Communities

Many off-grid communities in Canada produce power from diesel and heat from propane fuels. Diesel is combusted to produce electricity and propane is combusted in furnaces to produce hot water and space heating. The fuel is shipped into the community through trucks and is stored in large capacity storage tanks. Table 2.1 gives the general characteristics of a diesel based power generation.

Table 2.1 Characteristics of Diesel Power Generation

	Diesel Engine
Capacity Range	5 kW – 20 MW
Electrical Efficiency (%)	35 – 45
Overall Efficiency (%)	65 – 90
Power to heat ratio	0.8 – 2.4
Noise	Loud (Continuous)
CO_2 emissions (Kg/MWh)	650
NO_x emissions (Kg/MWh)	10
Availability (%)	95
Part load performance	Good
Life cycle (yr)	20
Average cost investment ($/kW)	340 – 1000
O & M cost ($/kWh)	0.0075 – 0.015

Source: Adapted from Wu and Wang, 2006

2.3.1 Reasons for Diesel Power Generation

Reciprocating engines are a proven technology with a range of sizes and the lowest initial capital costs. In addition to fast start-up capability and good operating reliability, high efficiency at partial load operation give a flexible power source, allowing for a range of different energy applications - especially for off-grid locations. Reciprocating engines are by far the most commonly used power generation equipment under 1 MW capacity (Wu and Wang, 2006). Hanley & Nevin (1999) identified the major characteristics that contribute for existing system of generation as:

- fuel has been cheap historically;
- readily available reliable reciprocating engine technology;

- physical access constraints to connect to grid;
- lack of infrastructure; and
- lack of knowledge and high price of renewable energy equipment.

These communities have long been neglected due to small populations, lack of political clout and poverty, which prevented a connection to the provincial grid. The power companies do not see a business case in connecting the small remote communities to their grid.

2.3.2 Disadvantages

Although reciprocating engines are a mature technology, obvious drawbacks exist. Relatively high vibrations require shock absorption and shielding measures to reduce acoustic noise. A large number of moving parts and the requirement of frequent maintenance intervals increase maintenance costs and strongly offset any fuel efficiency advantages. Moreover, these systems produce toxic air emissions, particularly nitrogen oxides (Wu and Wang, 2006). There are various economic, as well as environmental disadvantages that result from this technology being used in heat and power generation. Some of the important disadvantages are listed below according to their category of economic, environmental and social:

Economic:

- Higher energy cost
- Energy cost totally and directly dependent on global oil price
- Low efficiency
- Poor energy security (No diversity in energy sources)

Environmental:

- Greenhouse gas emissions
- Particulate emissions
- Noise pollution
- Environmental risk associated with transportation and storage of fuels (Spillage and Cleanup)
- Larger environmental footprint

Social:

- provide limited local employment initiatives
- contamination of land and food supplies due to fuel spills

2.4 Energy Efficiency

Many opportunities exist to improve energy efficiency using current off-the-shelf commercial technologies. Such technical and economic opportunities are considered “win-win” as their advantages include reducing energy consumption and by indicators of their cost effectiveness, such as cost of conserved energy, simple pay-back time, and economic rate of return (Martinot and McDoom, 2000). Large number of scientific studies combined with the extensive practical experience of the past 30 years point to many technology applications that meet cost-effectiveness criteria (such as 20% rate of return on investment or five-year simple payback time), and that offer large potential for CO_2 emissions reduction. There are many innovative technologies that enable us to meet the energy efficiency requirements. Some of these technologies are energy efficient Heating Ventilation and Air Conditioning, LED lighting, waste heat recovery and Energy Star rating standards. In many sectors, 10 to 30 percent (or more) of energy consumption can be saved using measures that have already been commercialized and that are cost-effective to consumers and society (Martinot and McDoom, 2000).

2.5 Small Scale Renewable Energy

Though many provinces in Canada have been producing hydroelectric power, the oil crises of the 1970s ignited a strong interest in some other forms of renewable energy. With its extensive geography, Canada has vast renewable energy resources (Islam, et. al., 2004). Renewable-energy technologies that are already or nearly commercialized include solar, small-scale biomass power generation and small scale off-grid wind power. Renewable energy potential depends on geographic resources such as wind speeds, solar radiation, and biomass residues from agriculture and other industries. If good geographic resources are present, several applications offer plentiful opportunities for cost-competitive commercial or near-commercial renewable energy (Martinot and McDoom, 2000).

In remote locations, renewable energy technologies (RETs), coupled with state-of-the-art energy storage methods (e.g. batteries), can economically compete favorably with conventional fossil fuel generation when the comparisons include environmental quantitative and qualitative parameters for the entire integrated energy system (i.e., heating along with electrical power). RETs apply particularly well where electric costs are high because of fuel transportation expense, there is a reasonable renewable resource available (e.g., wind, biomass, solar) and there is no inter-connection to a large-scale power grid (Isherwood, et. al, 2000). Renewable energy combined with energy storage also has the potential to provide the important benefit of increased system reliability; this has been recognized as one of the highest priorities in the design of remote power systems (Brown et. al, 1996).

2.5.1 Small Scale Wind

Wind power is considered a clean renewable energy. The high cost of energy in diesel powered communities combined with a desire to become more self-sufficient has led to an interest in wind energy systems from communities, governments and utilities (Timothy & Adrian, 2008). However, wind power fails to be a stable power source as wind behavior is intermittent and undispatchable[3]. To compensate for this instability of wind, wind-diesel hybrid systems have been developed. This reduces diesel consumption, reducing at least 30% of the final cost of the electricity. Small wind turbine generators that are connected to batteries provide sufficient electricity for rural dwellings, remote communications and other isolated areas. Figure 1 shows the wind atlas for the study area between 49^{o} 34' and 49^{o} 47' north latitude, and between 93^{o} 36' and 93^{o} 52' west longitude. The wind map (Figure 2.1) shows that on an average 5 to 6 m/s wind speeds are available for power generation at ELA.

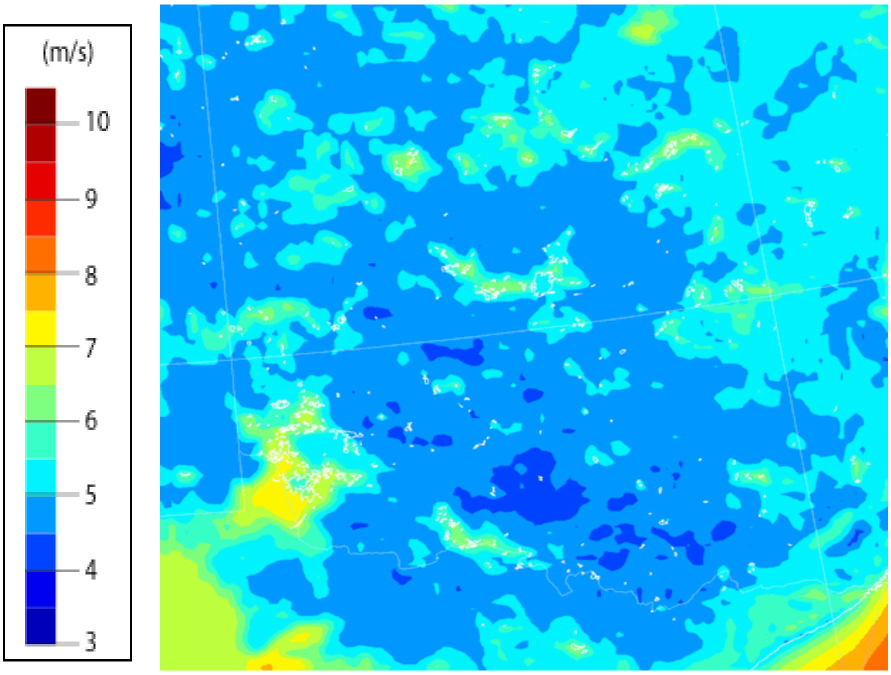

Figure 2.1 Wind map for ELA Study Area at 50m Hub Height

Source: Canadian Wind Energy Atlas, 2008

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[3] To produce electricity when needed

Below are listed the important advantages and disadvantages of wind energy technology with rest to remote off-gird locations:

Advantages:

- each megawatt-hour of electricity generated by wind energy helps to reduce 0.8 to 0.9 tonnes of greenhouse gas emissions that are produced by coal or diesel fuel generation each year (NRC, 2006)
- wind energy does not release carbon dioxide, nitrogen oxide, sulphur dioxide or mercury into the atmosphere like many traditional forms of electrical generation does therefore contributes in decreasing GHG emissions

Disadvantages

- the wind speed is not constant, varying from zero meters/sec to storm force, which means that wind turbines do not produce the same amount of electricity all the time and there will be times when they produce no electricity at all.
- maintenance is a problem in remote regions without qualified personnel to perform annual or seasonal maintenance checks on the tower and turbine

2.5.2 Solar Power

Sun's energy has long been used for common activities such as preserving food for long-term storage and for drying different materials. Today technology allows us to utilize the sun's energy for diverse applications like: *Photovoltaic systems, solar air and water heating systems and passive solar systems.* Solar radiation energy can be converted to electricity or heat. A photovoltaic (PV) cell made of semiconductor materials (e.g. silicon), can convert solar energy to electricity with 15-20% efficiency. Currently, Solar Photovoltaic (SPV) modules generate electricity for homes, cottages, and are effective in meeting power needs in remote locations and as an alternative to transmission lines or diesel generators.

Photovoltaic's (PV): Photovoltaic cells convert suns energy into electricity for use in homes, buildings or remote applications (off-grid communities). The efficiency of PV modules increases in colder temperatures and is well suited for Canada climate. PV technology is still relatively expensive but the costs are predicted to come down with less expensive technologies being developed. PV systems are most cost-effective in small load applications in remote areas.

Solar Air and Water Heating Systems: The sun's energy can be used for space heat in buildings. The solar wall is one application. When sunlight hits a dark metal it is absorbed heating the air space and therefore preheating the air drawn into the building's main heating system. Use of the solar wall is most cost effective in northern locations where the sunlight reflects off the snow to improve the solar gain. Similarly, solar water heaters collect the suns energy to heat water for domestic uses like cooking, washing, etc as well as for space heating.

Passive Solar: Passive solar is a method of building construction that takes advantage of the solar radiation through placement of windows and use of materials that absorb, reflect and store solar radiation as needed to regulate the temperatures indoor. It is not necessary to live in a hot climate to take advantage of solar energy; in fact, some technologies operate more efficiently in cold climates. Important relevant factors in evaluating feasibility of solar renewable energy technology include number of hours of sunshine on a daily basis and the intensity of the solar radiation.

Advantages

- solar energy systems are virtually maintenance free and will last for decades. Once installed, there are no recurring costs.

- solar energy systems operate silently, have no moving parts, do not release offensive smells and do not require you to add any fuel and more solar panels can easily be added in the future when the need arises.
- solar energy systems can operate independently without a connection to a power grid at all. Systems can therefore be installed in remote locations, making it more practical and cost-effective than the supply of utility electricity.

Disadvantages

- the initial cost of installing a solar energy system is high because of the expensive cost of the semi-conducting materials required for it
- the efficiency of the system also relies on the location of the sun, which is overcome by the installation of motors to change the direction of the solar panel
- the production of solar energy is influenced by the presence of clouds or pollution in the air

2.5.3 Biomass

With over 2.4 million km^2 of forest area, Canada has the world's third largest forest area that supports a massive wood-based sector consisting of timber, pulp and paper and other associated products (World Energy Council, 2001). Approximately 6% of Canada's primary energy is from Biomass energy in the form of combustion of wood and wood derivatives for industrial process heat, generation of electricity, and space heating (Natural Resources Canada, 2002). Wood based energy generation units can use the surplus residue to produce heat and power simultaneously in a system called Combined Heat and Power (CHP). ELA location provides an abundant supply for bio-mass like waste lumber from the forest and waste wood from nearby urban areas. Biomass for decentralized power generation for off-grid communities has broad load range application. The following are some of important factors that are to be considered for Biomass based CHP system.

Scaling

Some technologies are better suited for smaller scales of energy production. For example, a combustion furnace or wood stove is appropriate for space heating. Any proponent of a proposed biomass facility must undertake an analysis to determine the most appropriate technology to use. Combined heat and power (CHP) biomass facilities (typically using the Rankine Cycle) are able to achieve high levels of efficiency only by capturing low-quality heat for uses such as space and water heating (combined with using high quality heat to produce electricity). Biomass facilities that do not fully capture heat produced result in a waste of energy resources, and will put an unnecessary strain on a sustainable supply of fuel wood. Therefore, it is imperative that heat production from CHP biomass facilities be considered and paired with requirements for such heat during project design and development.

Transportation

A large portion of the cost of feedstock acquired by biomass based energy plants are transportation costs (Combs, 2008). A study in Wisconsin has shown that, the use of switch-grass as fuel in a CHP system contributes to 10% increase in production costs of energy for every 30 miles (48 km) increase in fuel transportation (Porter et al, 2008). Similar transportation distance limitations likely apply for wood. Therefore, any biomass facility must be located near sufficient fuel sources, such as wood processing facilities, or properly managed forests to yield a positive energy balance. The rise in the cost of fossil-derived transportation fuels, and the high costs of highway maintenance, encourage the location of biomass facilities near biomass sources.

Advantages

- sources are commonly available, locally produced and variable including: wood, wood chips, switch grass, wheat straw, etc
- carbon neutral technology in the case that new plants are grown to replace the ones harvested for fuel

Disadvantages

- maintaining a steady supply of wood can be difficult, therefore, need masses of storage space and sheds for wood storage for continuous operation and also need to maintain a large inventory of biomass to avoid fuel supply irregularities

2.6 Chapter Summary

Energy management is becoming critical in moving towards a more sustainable community. It permeates all aspects of a community from transportation to building design. Having a sustainable energy plan in place, one that includes energy efficiency objectives as well as renewable energy, will enable a community to better manage the impacts of rising fuel costs, greenhouse gases and energy cost while becoming less dependent on diesel and propane.

The literature review identifies how energy efficiency and renewable energy (though best suited for large towns and cities) could benefit small off-grid communities. Energy efficiency measures need not be prohibitively expensive as they can be customized based on budget and payback period constraints of the community. Sustainable energy evaluation for a small off-grid community provides both challenges and opportunities. Challenges in terms of lack of base line data, energy monitoring, remote location and opportunities in terms of demand reduction through energy efficiency measures, reduced GHG emissions. The literature points out that energy efficiency and renewable energy analysis can be applied not only to large on-grid communities but also to small scale off-grid communities that form the central focus of this study. Unlike sustainable energy plans for large communities with a few thousand people (where utility companies design a program and implement on a large scale), for small communities a strategy with closer attention is required examining the small details that add up to important savings.

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CHAPTER 3: RESEARCH METHODS

3.1 Introduction

The research method primarily consists of two parts: 1) demand reduction analysis and 2) alternative energy feasibility study. Figure 3.1 outlines the steps in the method used to determine the demand reduction, considering no cost and low cost options.

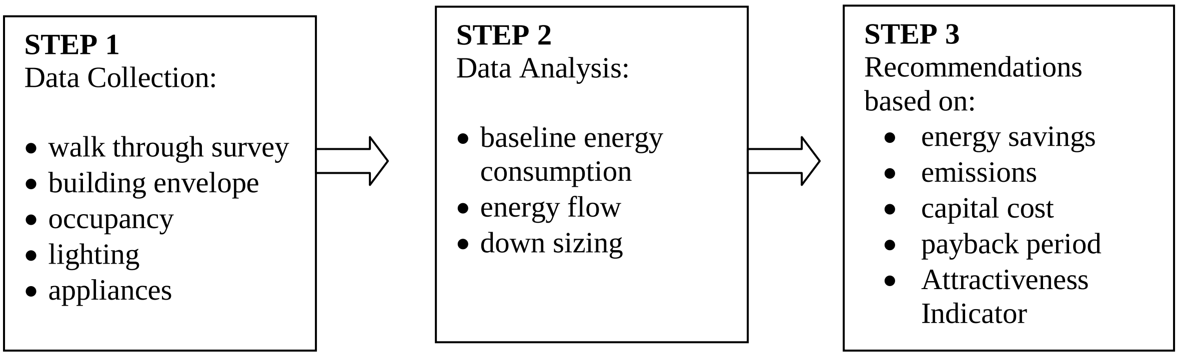

Figure 3.1 Methodology to Determine Demand Reduction

RETScreen® International 4.0 was used to model renewable energy feasibility. Figure 4 outline the steps of the study method used for renewable energy analysis using RETScreen 4.0 energy modeling software.

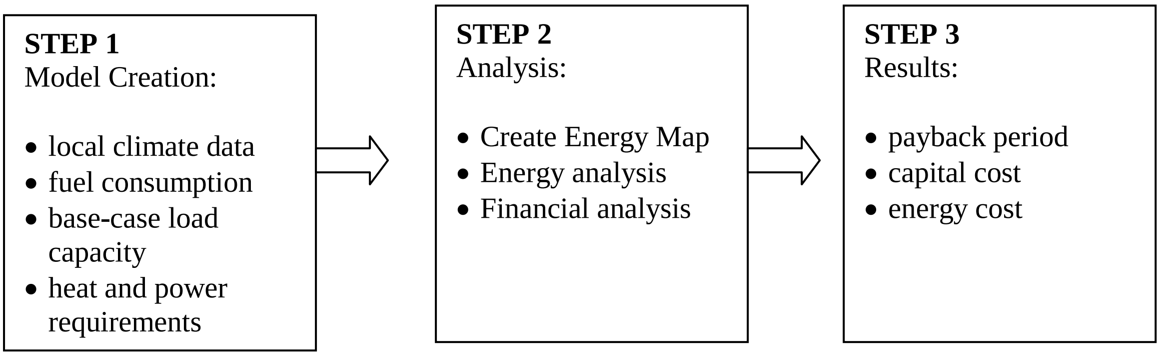

Figure 3.2 Study Methodology to Analyze Renewable Energy Technologies

Due to lack of energy meters at ELA, the researcher had no access to actual energy use at the study site. However, previous energy evaluation reports provided by Department of Fisheries and Oceans (DFO) had some information about the location and purpose of the facility.

3.2 Research Steps

3.2.1 Energy Efficiency Analysis

In order to perform the energy efficiency analysis a walk through survey (See Appendix - I) was conducted in selected high energy consumption buildings suggested by the building manager. The survey (Refer to Appendix – I) is a modified version of Manitoba Hydro for office buildings was used to gather all the information about the energy generation and building and equipment usage. As part of this research a NRI class of eight students was enlisted to perform a detailed walk through survey at the field station by Dr. Thompson with my assistance. The walk through survey recorded all the various loads in the building and other important parameters required for the analysis, namely:

- Bulk fuel analysis
- Lighting
- Building Envelope
- HVAC
- Office and Lab Equipment
- Miscellaneous Equipment

Once the survey data was gathered it was compiled to identify opportunities that fit the research objectives outlined i.e. low-cost and no-cost retrofit opportunities for energy efficiency. Relevant opportunities were selected based on the following criteria that:

- initial investment for any single retrofit recommended should be less than $ 2,000.00
- pay-back period for the recommended retrofit should be less than 2 years
- low-skill level required to carry out the retrofits

3.2.2 RETScreen 4.0 Analysis

RETScreen is a comprehensive product of its kind, allowing engineers, architects, and financial planners to model and analyze any clean energy project. Decision-makers can conduct a five step standard analysis, including energy analysis, cost analysis, emission analysis, financial analysis, and sensitivity/risk analysis. This standardized and integrated renewable energy project analysis software evaluates the energy production, life-cycle costs and GHG emission reductions for various types of RETs. RETScreen is used by more than 240,000 people in 222 countries and territories, thus proving to be a very accurate and efficient tool for RET analysis. Though there are other RET analysis software available, RETScreen's suitability to allow for off-grid power generation set-up makes it a preferred tool. The model's meteorological inputs are shown in Table 3.1.

The other suitable program available for RET analysis is HOMER. HOMER is a stand alone program, and as such it can handle a much denser simulation. While RETScreen splits the model into monthly chunks, HOMER can handle fluctuations on an hourly basis. This makes HOMER useful for modeling the intermittency of solar and wind power. HOMER is also capable of doing brute-force system optimization, given a number of variables. While HOMER is more powerful than RETScreen, it requires much more in the way of data inputs. Since, ELA was not metered and there was no utility power data available, RETScreen 4.0 provided the better choice for this simulation. Also, the economic modeling is the strength of RETScreen which is better than that of HOMER.

The RET Analysis is carried out in four steps as laid out in this section. RETScreen International 4.0® was used to compare the feasibility of three different RETs to diesel generation. RETScreen is a renewable energy decision-support and capacity-building tool developed by Natural Resources Canada (NRC) with the contribution of 85 experts including from United Nations Environment Programme (UNEP) and the National Aeronautics & Space Administration (NASA®). The computer program, RETScreen® 4.0, provides a common platform ideal for educational purposes and industry/market analysis and development purposes and is free of charge (Ackermann et.al, 1999).

Table 3.1 Meteorological data of ELA field station for the year 2007

Month	Daily Solar Radiation ($kWh/m^2/d$)	Mean Temp (°C)	Wind speed @ 10m (m/s)
Jan	1.48	-17.8	3.9
Feb	2.51	-14.1	3.9
Mar	4.12	-6.2	4.2
Apr	5.35	3.3	4.4
May	5.96	11.2	4.2
Jun	6.01	16.4	4.2
Jul	5.99	19.6	3.9
Aug	5.01	17.9	3.9
Sep	3.43	11.8	4.2
Oct	2.19	5.5	4.4
Nov	1.36	-4.5	4.2
Dec	1.13	-14.4	3.9
Annual Avg.	**3.72**	**2.5**	**4.1**

Source: NASA® Global Climate 2007

The following four steps were applied in the RETScreen analysis:

Step 1: Evaluated the present energy, economic and environmental situation by referring to ELA fuel bills, manuals, and audit reports. Data on diesel, propane, and gasoline consumption were gathered from the facility log books. Preliminary data about installed electrical and mechanical equipment were gathered from manufacturer's manuals, previous studies and interviews with the field manager and other key personnel at ELA. Data from different consultant's reports on alternative energies were gathered (Research Facilities, 2008; Planning Study for Experimental Lakes Area filed station for Public Works and Government Services Canada, 2003; Phase I/II Environmental Site Assessment, 2002) but none of these reports considered biomass or demand reduction.

Step 2: Performed a modified Manitoba Hydro energy efficiency audit of the field station that involved lighting efficiency and determining equipment loads for six buildings. This audit included interviews and a walk through tour noting characteristics, usage and amounts of: 1) bulk fuel use; 2) building envelope (quality of sealing of windows, doors); 3) lighting (load); 4) heating, ventilation and air conditioning (kW/hr); 5) office and lab equipment (usage and quantity); and 6) other machines and equipment (usage and quantity). The current energy consumption was estimated from the audit, as no metering was installed on site, to identify direct low cost energy conservation measures.

Step 3: Applied the present-day load of 115 kW minus the 4.8% energy efficiency determined in step 2 to RETScreen. RETScreen analysis was undertaken to ascertain the technological, cost, emissions and risk analysis on the three RETs namely wind, solar and biomass.

Step 4: The three different RET scenarios were calculated based on parameters in Table 2. As well the following were considered:

1. local climatic data (solar radiation, wind speed, ambient air temperature, humidity)
2. the assumption that any new load will be balanced by increased energy efficiencies

3 diesel price of \$0.80/liter, propane price of \$0.45/liter

4 higher heating value (HHV[4]) setting is used as ELA is in a northern climatic zone with an average winter temperature of -17.4°C and reaches above 30°C in the summer for reference year 2006. The occupancy varies from full capacity of 40 to 45 people in the summer to about 3 to 5 people in winter.

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[4] *ELAs geological location requires the model to be simulated in a higher heating value setting.*

CHAPTER 4: DEMAND REDUCTION FINDINGS REGARDING LOW-COST AND NO-COST RETROFIT ALTERNATIVES

4.1 Introduction

Energy efficiency retrofits of existing buildings are the best way to reduce energy use and greenhouse gas emissions in off grid communities. Although some buildings may have had some efficiency upgrades in the past, there is almost always room for improvement. New technologies, increased awareness and changing energy prices often mean that measures rejected in the past as not being cost-effective are viable today. The rationale for an energy retrofit can go far beyond just energy savings. Energy retrofits often introduce new technologies or operating controls that can improve occupant comfort. New, energy efficient T8 lighting is a good example of this, providing reduced flicker and hum with improved light quality that can reduce occupant eyestrain. Energy retrofits also provide an opportunity to replace aging equipment, down size equipment and repair or upgrade old systems.

In this chapter we are concerned only about the *Operating Energy* of the ELA buildings. Building *Operating Energy* is the energy associated with the normal operation of the building for space heating, domestic water heating and operating lights and appliances. Operating energy is to be impacted by retrofit measures. The main factors that affect operational energy of buildings are location, occupant density, occupant behavior and building technology. Retrofits to improve the operational efficiency of buildings generally relate to: building envelope, glazing and door technologies, higher efficiency space and water heating system and appliance upgrade *or* downsize.

4.2 Energy Retrofits of Existing Buildings

Energy efficiency improvements are the most cost-effective way to reduce greenhouse gas emissions and help reduce energy demand. Many energy efficiency measures yield great returns on investment and can be repaid within one to three years. Unlike most capital projects, energy efficiency projects provide a monetary return through the energy savings they generate. This means they can be viewed as investments, rather than as simply expenditures (CAEE, 2007). As for any large investment, when investing in energy efficiency it is appropriate to perform a full lifecycle cost analysis (CAEE, 2007). A life cycle cost analysis takes into account the energy savings over the life of the project, deferred maintenance and equipment replacement costs. In spite of being large financial investments, energy projects are often assessed solely in terms of simple payback (cost divided by annual savings), with expectations that paybacks will be very short. This type of analysis does not reflect the true long-term value of a project. More sophisticated indicators such as net present value (NPV) and internal rate of return will more accurately reflect the benefit of the investment. When fully accounted for over their life cycle, projects with simple paybacks as long as 15 to 20 years may still show a positive net present value and be a good investment. However, the manager at ELA mentioned that they are interested in short-term and minimum investment energy efficiency improvements and that they require basic indicators like payback period and energy cost savings to move ahead. The following section deals with retrofits that are Low-Cost or No-Cost, discussing their suitability for ELA.

4.2.1 Low-Cost and No-Cost Retrofits Vs Comprehensive Retrofits

Small communities and companies undertaking energy retrofits tend to seek quick payback measures in order to keep project costs down. Comprehensive retrofits are another consideration with additional advantages beyond financial returns. As they involve all the civic facilities, they result in a coordinated approach throughout. This means consistent lighting and control systems as well as consistent documentation. They may also result in reduced workload for staff, as the project is completed quickly rather than ongoing for years. And the scale of the project will result in lower costs, both in construction capital and engineering design. Although the initial payback may be longer, a comprehensive retrofit will usually have a better financial return when looked at over the life cycle cost. However, for ELA, given the nature of operation and occupancy levels a Low-Cost & No-Cost retrofit option approach makes more sense both financially and operationally. Table 4.1 compares both types of retrofits and their suability to ELA circumstances.

Table 4.1 Comparison of Low-Cost & No-Cost Retrofits Vs Comprehensive Retrofits

Low-Cost & No-Cost Retrofits	Comprehensive Retrofits
Initial Cost: Zero or Very Low in most cases. Usually ranges between a few hundreds of dollars to a few thousand dollars.	**Initial Cost:** High Initial Cost. Most cases require a significant initial amount in the range of few thousands of dollars to a hundred of thousands of dollars.
Payback Period: Short to Medium payback period. Ranges from few months to up to 3 years	**Payback Period:** Medium to Long payback period. Can range from 4 to 8 years based on the retrofit.
Annual Savings: Low	**Annual Savings:** High
Easy to implement and monitor.	Implementation and monitoring require a significant time and resources.
Skill Level Required: Low	**Skill Level Required:** Medium to High or Professional

Source: Community Action on Energy and Emissions (CAEE) manual, 2007

4.3 Base Case Characteristics

Diesel, Propane, and gasoline data were gathered from the facility for the past available three years and a base-case scenario was developed to evaluate against wind, solar and biomass analysis. Preliminary data has been gathered about site and installed electrical and mechanical appliances from manufactures manuals, previous studies and interview with field manger and other key personnel at ELA. A walk through survey (see Appendix-I) was conducted at the facility buildings to estimate the current energy consumption and identify. The survey also estimated the annual energy demand at site and annual base load profile. Table 4.2 identifies the general characteristics of ELA.

Table 4.2 General Characteristics

Summer	Characteristic	Winter
April-Oct	*Duration*	Nov-Mar
35 to 40	*Occupancy (No of persons)*	4 to 5
All	*No. of buildings in use*	1 to2
Maximum (~100 kW)	*Power demand*	Minimum (~25 kW)

Summer to winter inhabitants' ratio: **8.75**

Source: Personal Communication with Ray Pambrun ELA, 2007

4.4 Demand Reduction at ELA

Energy management at off grid locations is an important issue driven mainly by economical factors like fuel cost, equipment efficiency, operation and maintenance cost. These issues concern the supply side management. Apart from supply side management there are also issues like poorly insulated buildings, inefficient lighting and equipment which further constitute to the poor overall energy situation.

4.4.1 Current Energy Sources and Distribution

Overall the fuel profile consists of 61% diesel, 33% propane and 6% gasoline as shown in Figure 4.1.

Table 4.3 Fuel characteristics of Existing Energy System (2006)

Fuel used	Purpose	Fuel cost ($/L)	Annual Consumption (L)
Diesel	Electricity	0.80	112,151.10
Propane	Heat (space and water)	0.47	60,377.70
Gasoline	Transportation	0.88	11,531.20

Sources: Personal Communication with Ray Pambrun, ELA 2007

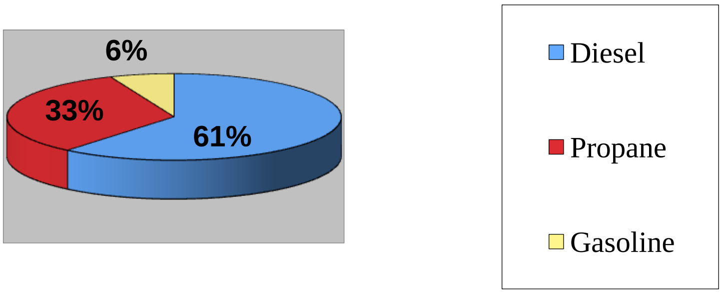

Figure 4.1 Fuel Consumption Breakdown at ELA

4.4.2 Cost of Electrical energy derived from diesel generators

ELA has an average electrical load of approx. 50 to 60 kW/hr; with peak supply close to 100 kW during maximum occupancy from April to October.

Average weekly consumption of diesel fuel: **2,600 liters**

Cost of diesel (per liter): **$0.80**

Based on the above information, I calculated the following:

- Daily diesel consumption: 2,600/7 = **371.43 lit/day** (or 11,142.66 lit/month)
- Cost of diesel per month: 11,142.66L X 0.80 = **$8,914.29** (or $106,971.48 per year)

- Total kWh supplied in a month: 55kw X 720hr = **39,600 kWh**

- Cost per kWh = ($8,914.29 / 39,600) = **0.225 $/kWh**

The annual cost of running the Laboratories for 2006/2007: 63% X $65,937.60 (average annual diesel cost) = **$41,540.68/yr** (varies with diesel price).

Table 4.4 Base-Case Characteristics

Grid Type & Technology	Off grid / Reciprocating engine
Fuel Type & Cost ($/L)	Diesel @ 0.80
Capacity (kW)	115
Heat Rate5 (kJ/kWh)	11,000 (or) ~25% efficient
Electricity rate ($/kWh)	0.225

4.5 Lighting System

Lighting constitutes 22% of the total power consumed by the building and perhaps this is the simplest and easiest area to make necessary changes without affecting the operations in any way and without major renovation.

Recommendations:

1. Two potential areas have been identified where small modifications can result in reduction of energy cost for the laboratory with a reasonable payback period for lighting. Changing the existing exit lamps with LED backlights next time would result in savings of approx. $289.43/yr. (Ref Table.4.5).

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[5] Heat Rate is the amount of energy input (in kJ or Btu) from the fuel required to produce 1kWh of electricity (RET Screen, 2008)

Table 4.5 Replacement costs for upgrading existing exit lamp with LED

	Annual Expenditure ($)
5 X 30 watt incandescent	434.15
Replace with 5 X 10 watt LED	144.72
Potential Savings	289.43
Approx. Capital cost of replacement @ $45/LED X 5	225.00
Pay Back	< 1 yr

2. Occupant behavioral changes will also contribute to the energy conservation. Fans and lights in the laboratory
3. Lights in laboratory were observed to be on without anybody using them. New people visit ELA every year and if they were educated about this facility as a high energy conservation facility this would mould their behavior with ease

4.6 Laboratory Equipment

Specialty equipment could provide energy conservation opportunities in three ways:

1. Replacement of existing equipment with more energy efficient equipment

2. Downsizing to suite the task 3. Efficient usage

Recommendations:

1. Down size the icemaker to a more appropriate scale to match lab needs and if possible decommission the unit during winter. The existing ice maker is of 1100 watts with an annual operating expenditure of about $1215.00.

Table 4.6 Potential savings by switching to a smaller ice maker

	Annual Expenditure ($)
Ice Maker (1100watts)	1,214.14
Replace with Ice Maker (575 watts)	6,34.66
Potential Savings	579.48
Approx. Capital cost of replacement	2,500.00
Pay Back	4.3 yrs

2. When replacing or upgrading any existing laboratory equipment consider buying energy efficient equipment and make it a priority.
3. The two ovens are operated exclusively at 90°C while the units are clearly oversized as they can heat to over 600°C. Also it's known that ovens are run overnight irrespective of their need thus increasing the annual operating cost. A simple solution would be to just turn OFF one of the ovens overnight and leave only one of them ON so that it can be used. The following table explains the annual cost that can be saved. (Refer to Table 4.7)

Table 4.7 Potential savings by turning one of the 600° C ovens OFF overnight

	Annual Expenditure ($)
2 X 1300 watt	1,749.20
1 X 1300 watt (one off overnight)	1,311.90
Potential Savings	437.30
Capital Cost	0.00

4. Down size the oven to a more appropriate scale to match lab needs and if possible decommission the unit during winter. The existing ovens are of 1300 watts each with an annual operating expenditure of about $1,725.87. By downsizing to a new smaller oven of 350 watts the potential energy savings are $1,250.93. The cost of new equipment is estimated to be $1,425.71 with a pay-back period of 1.1 years. (Refer to Table 4.8)

Table 4.8 Energy cost saved by downsizing to a smaller more efficient oven

	Annual Expenditure ($)
2 X 1300 watt 90° C	1,721.87
1 X 350 watt	470.94
Potential Savings	1,250.93
Approx. Capital Cost of new equipment	1,425.71
Payback period	1.1 yrs

4.6 Building Envelope

The chemistry laboratory building surveyed was built with many energy efficient features. However, the building envelope has the potential to be further improved in the areas of insulation and better door drafts insulation.

4.6.1 Air Leakage

Air leakage from the building due to improper sealing can increase the heating or cooling cost by up to 25%. Figures 4.2 and 4.3 expose the cracks and incomplete air sealing found in the building. Air leakage through these cracks and holes can increase the heating or cooling cost for the building (BC Hydro, 2004a).

<u>*Recommendations:*</u>

1. Caulking any openings and cracks is easy and a low cost approach to prevent heat loss through them thus saving substantial amounts of heating or cooling bill.
2. Other option is aerosol foam sealants; these can be used for sealing larger cracks and openings around pipe and wire penetrations and at the foundation sill joint. These foams provide a good tight seal by expanding in the cracks.

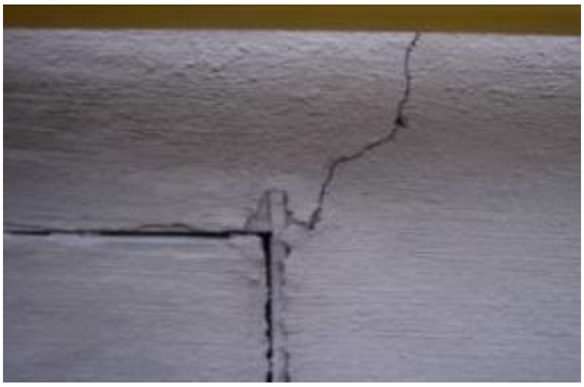

Photo: Daniel Gagne 2007

Figure 4.2 Cracks found on the outer wall in the Laboratory building

Photo: Daniel Gagne 2007

Figure 4.3 Air Conditioning cable holes can be better insulated in laboratory building

4.6.2 Insulation

Incomplete insulation work in the basement can cause heat loss through the walls.

Figures 4.4, 4.5 and 4.6 show where improvements can be made.

Photo: Daniel Gagne 2007

Figure 4.4 Indicates that basements can still be improved for better sealing

Photo: Daniel Gagne 2007

Figure 4.5 Potential areas where basement insulation can be improved

Photo: Daniel Gagne 2007

Figure 4.6 Outside vent foundation with exposed wood foundation

<u>*Recommendations:*</u>

1. The chemistry lab basement is not using rigid foam board insulation, extending it down below the frost line to about 0.6 meters (2 feet) will greatly reduce the basement losses (BC Hydro 2004b)
2. For insulating the exterior using several inches of foam board insulation (enough to achieve R-12) down to the footing should give adequate insulation.

4.6.3 Infiltration Losses

Sealing joints and surfaces that move, such as where doors or windows meet frames, is a huge concern for any building manager. As seen in Figure 4.7 and 4.8 the entrance and exit doors of the building had brush insulation and a draft was palpable, indicating the need for better insulation (BC Hydro, 2004b)

Photo: Daniel Gagne 2007

Figure 4.7 Doors were found to have been installed with brush insulation these could be replaced with magnetic strips that provides better insulation

Photo: Daniel Gagne 2007

Figure 4.8 Other doors where drafts were noticed

Recommendations:

1. Using weather stripping techniques can mitigate drafts. Vinyl V-strip and spring metal weather stripping have a life span of at least five years. All exterior doors or doors between conditioned and unconditioned spaces such as basements, attics, or garages can benefit from the application of weather-stripping. The air-conditioned "clean room" door in the chemistry lab should also be considered.
2. Incorporating magnetic weather-stripping, similar to the seal on a refrigerator door can cut air leakage significantly.

4.7 Chapter Summary

In this chapter I have looked at achieving energy efficiency through low-cost and no-cost retrofits. A walk through survey has been conducted at the study site to identify all the potential opportunities for energy efficiency at four key high-occupancy and high-usage buildings. The data from the survey has been analyzed for potential energy savings, payback period, and d capital cost for all the recommendations. Table 4.9 summarizes the potential savings and associated with the potential retrofits.

Considering the situation and circumstances at ELA an attractive index based on payback period has been developed that helps decide on retrofits that can be done with minimal cost and low skill level. All the retrofits that have a payback period of less than or equal to two years and that require a capital cost of less than $2,000.00 are considered to be high priority. For example, problem identified No. 2 in the Table 4.9 is all the seven exit lamps are incandescent lamps, the recommended retrofit is to replace all the seven exit lamps with LED exit lamps. LED exit lamps use considerably minimal power for operation compared to the existing incandescent lamps. The estimated energy savings from this retrofit are 613.2 kWh and the estimated cost savings are $153.00. The payback for this retrofit is approximately two years. Because this retrofit complies with the preset attractiveness index rules, its attractiveness index is rated as **High**. Similarly, all the problems identified from the walk though survey are analyzed and are presented in the Table 4.9 with their respective attractiveness index.

Table 4.9 Summary of potential savings with Potential Retrofits and Attractive Indicator

Problem Identified	**Potential Retrofits**	**Capital cost of recommendation**	**Energy Savings in kWh**	**Estimated cost savings per year**	**Pay Back period**	**Attractiveness Indicator**
1. Lighting in the laboratory	Replace the 5 existing incandescent lights with CFL (Compact Fluorescent Lamps)	$35	396	$99.00	Under 4months	**High**
2. Exit lamps	Replace all 7 existing exit lamps with LED exit lamps	$315	613.2	$153.00	approx 2years	**High**
3. Two, old 40 cubic foot refrigerators	Replace both with Energy star units	2 X apprx. $7500.00 = $15000.00	20%[6] saving on 9,066.6 (existing) = 7,253.28, A saving of 1813.32	$518.00	>20yrs	Low
4. Two small refrigeration units	Replace them with a single bigger energy star unit	approx $7500.00	20% savings on 3679.2 (existing) = 2943.36, A saving of 735.84	$762.00	10yrs	Low
5. Oversized ice maker (1100 Watts)	Downsize to a smaller (575 watts) unit	approx $2500.00	50% savings on 4876.7 = 2438.35, A saving of 2438.35	$580.00	4.3yrs	Medium
6. Two 90°C ovens run continuously overnight	a) Turn off one oven during nights	Nil	25% savings on 6832.8 = 5124.6, A saving of 1708.2	$437.00	nil	**High**
			---(OR)----			
	b) Unplug one 1300 watts oven and downsize the other to a 350 watts unit	approx $1425.00	75% savings on 5142.6 = 1285.6, A saving of 3856.95	$1,250.00	1.1yrs	**High**
7. Organic waste incineration generates smoke and	Setup bear proof garbage bins and ship waste to the	approx $250-$350 ranging from	n/a	Safer disposal of waste resulting in a cleaner	n/a	

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[6] Energy star appliances save 20% of standard equipment

particulate matter affecting the air quality samples	nearest landfill	64 to 95 gallons		environment at ELA		**High**
8. Infiltration losses at doors (Improper door seals)	Use weather stripping techniques to mitigate this problem. Replace existing brush insulation strips with magnetic or metal strips	Less than $25 per door	n/a	n/a	Less than a year	**High**
9. Basement Insulation	Use rigid foam board insulation and extending it down below the frost line to about 0.6 meters (2 feet) will greatly reduce the basement losses (BC Hydro 2004b)	Between $1.50 and $2.00 per Sq. foot	n/a	n/a	Less than a year	**High**
10. Heat and power generation	Switch to a greener and more efficient generation technology	further study under review	n/a	n/a	n/a	Low
11.Space heating	Geothermal heating analyzed, may not be suitable for ELA	approx $26,000.00	n/a	$6,696.28	4.7yrs	Medium
Total		**$51,628.00** (excluding the basement insulation cost and the cost a new downsized refrigerator)	**7704.91**	**$9,245.28** (excludes the savings from installing a new downsized refrigerator)	**Avg. 5.4 yrs**	

By adopting the recommendations with **High** attractive index in Table 4.9, ELA can easily identify energy savings with minimum investment and relatively quick payback period without significant labor and equipment costs. These retrofit measures have the combined potential of reducing the demand at ELA by 4.8%.

Acknowledgements

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CHAPTER 5: FEASIBILITY STUDY OF RENEWABLE ENERGY TECHNOLOGIES AT ELA

5.1 Introduction

Since the early 1990’s there have been significant developments in various RETs for commercial, industrial and residential sectors making them ever more competitive with fossil fuels. RETs have advantages over non-renewable energy technologies that include low energy-cost, oil independence and pollution free generation, but also have disadvantages, that include reduced reliability and high initial costs. Energy sources, such as wind and solar require back-up by a stable source, if there is no grid connection (due to their intermittent nature) to guarantee reliable power supply (Weis et.al, 1998). A reserve capacity is necessary to act as a back up to overcome fluctuations and reliability issues with wind and solar intermittent sources that don’t generate energy when the wind is not blowing or the sun is not shining (Ah-You, 1999). Although RETs do not burn fossil fuels, they often require back-up systems that do. All renewable energies require that resource availability be compared to the loads to determine if the site specific production meets the local need. RETs combined with energy storage systems provide a reliable energy supply is the highest priority in the design of an isolated power system (Weis et.al, 1998). Natural energy flows vary and make the techno-economic performance of renewable energy conversion highly site specific. There are a host of renewable energies, including wind power, solar PV, biomass, etc, but are any feasible at the ELA location? The benefits and applications of these RETs in Canada will be profiled to consider their feasibility.

Wind power is a clean renewable energy but is intermittent requiring wind-diesel hybrid systems to provide a stable capacity. At ELA, wind power is considered feasible because mean annual wind speeds are5 m/s to 6 m/s. With a battery storage unit the hybrid wind power system, with a back-up diesel system, could mitigate diesel consumption by about 30% to 40% annually. Currently, solar PV modules with battery back-up are effective in meeting power needs in remote locations for homes, cottages as an alternative to installing new transmission lines or diesel generators. The solar resource in Canada compares favorably with other regions of the world, due in part to its ‘‘clear-sky’’ climate. At ELA, solar radiation is approximately 3.72 kWh/m^2/day (Huang et.al, 2001). Although there are many possible applications of solar energy including water heating, passive heating and space cells made of semiconductor materials like silicon, can convert solar energy to electricity with 10% to 20% efficiency (Bernotat et.al, 2004). Solar generation is a good match to energy demands at ELA as during summer; when ELA has the highest power demands, extended daylight hours of as much as 17 hours produce the maximum power; while in winter shorter daylight hours produce minimum power when power loads at ELA are small.

Wood based energy generation units can use the surplus bio-residue to produce heat and power simultaneously in a system called combined heat and power (CHP). In biomass based CHP, both heat and power are generated from biomass with a back-up system of diesel generators to handle peak load demands. Biomass resources are typically forestry products such as wood waste or wood pellets but can include agricultural residues, landfill gas, municipal solid wastes and energy crops. Small scale biomass CHP have been used extensively in space and water heating for housing, process heat for industry since the 1940’s in Sweden, Finland and other Baltic states like Latvia, Estonia, and Lithuania **(**Sims et.al, 2003). Approximately 6% of Canada’s primary energy is from biomass energy in the form of combustion of wood and wood derivatives for industrial process heat, generation of electricity, and space heating. Canada, with over 2.4 million km^2 of forests, has many of its remote areas surrounded by forest, a renewable source of energy (Mustafa Omer, 2008). At ELA, dead wood from the nearby forest could provide sufficient biomass and their collection would reduce the risk of forest fire and reduce the cost of maintenance for fire suppression system and clearing cost.

5.2 Findings

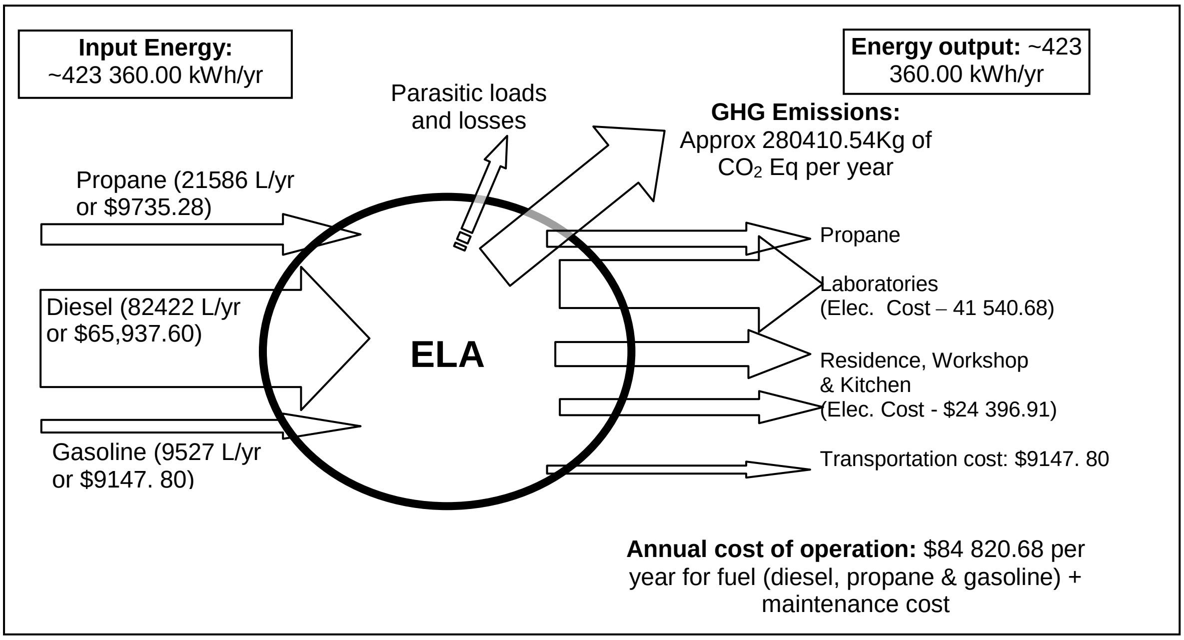

Figure 5.1 Energy Map of ELA revealing the flow of energy through the facility for the 2006/2007 fiscal year

The demand for electricity could be reduced with energy an efficiency measure that decreases the cost of capital equipment. Figure 5.1 is an energy map summarizing the annual total input and output energy at ELA for the 2006/2007 fiscal year. The existing system has a total peak power generation of nearly 115 kW and a total operating cost of $84,821/yr. Most of GHG emissions and energy costs at ELA are for electricity production from diesel fuel. Only one-fifth of the fuel costs are from heating with propane.

5.2.1 Energy Efficiency

With almost majority of fuel being consumed for electricity production, demand reduction can make a difference in energy requirements. Table 5.2 shows many opportunities to reduce energy, identifying key areas for energy measures including changing every exit light in the 20 ELA buildings to light emitting diode (LED) lights, changing incandescent lights to compact fluorescents, changing old refrigerators and ice maker to energy efficient types and turning off ovens, that run continuously, although almost empty. Demand reduction can reduce energy demand by up to 4.8% of the existing energy consumption, which amounts to 14,130.37 kWh or about $2,567.32 in savings annually. Table 5.2 identifies all the recommendations that fit the selection criteria for energy efficiency retrofits.

Table 5.1 Selection of Demand Reduction Recommendations with High Attractiveness Index

Problem Identified	**Recommendation**	**Capital cost of recommendation**	**Energy Savings in kWh**	**Estimated savings per year**	**Pay Back period**	**Attractiveness Indicator**
1. Lighting in the laboratory	Replace the 5 existing incandescent lights with CFL (Compact Fluorescent Lamps)	$35	396	$99.00	Under 4months	**High**
2. Exit lamps	Replace all 7 existing exit lamps with LED exit lamps	$315	613.2	$153.00	approx 2years	**High**
3. Two 90°C ovens run continuously overnight	a) Turn off one oven during nights	Nil	25% savings on 6832.8 = 5124.6, A saving of 1708.2	$437.00	nil	**High**
			---(OR)----			
	b) Unplug one 1300 watts oven and downsize the other to a 350 watts unit	approx $1425.00	75% savings on 5142.6 = 1285.6, A saving of 3856.95	$1,250.00	1.1yrs	**High**

4. Infiltration losses at doors (Improper door seals)	Use weather stripping techniques to mitigate this problem. Replace existing brush insulation strips with magnetic or metal strips	Less than $25 per door	n/a	n/a	Less than a year	**High**
5. Basement Insulation	Use rigid foam board insulation and extending it down below the frost line to about 0.6 meters (2 feet) will greatly reduce the basement losses (BC Hydro 2004b)	Between $1.50 and $2.00 per Sq. foot	n/a	n/a	Less than a year	**High**

The demand reduction savings are expected to be higher as not all buildings were analyzed. Other areas such as the building envelope appeared adequate.

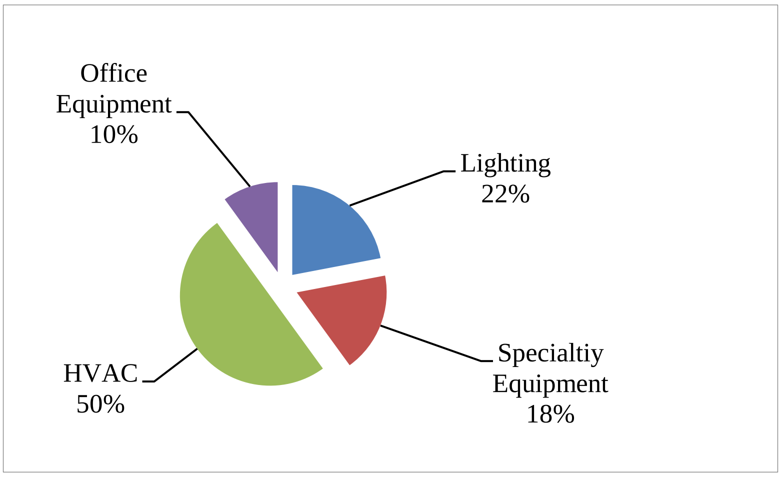

Figure 5.2 Electrical energy breakdown indicates that HVAC and lighting combined consume 2/3^{rds} of the total power

RET analysis results for the three models are shown in Table 5.5 along with existing diesel generator and new replacement diesel generator. Renewable energy technologies were economically competitive with the diesel system, particularly the biomass CHP system. At $0.80 per liter, biomass combined heat and power (CHP) payback period was 4.1 years with a capital cost of $ 2,162.9/kW compared to wind's 6.1 years due to its higher initial cost of $ 3,300/kW and solar energies' 13.5 years due to its high initial cost of $ 9,100/kW. The CHP had an initial cost for equipment (hopper, conveyor belt and gasifier but not including piping for district heating) at $ 2,162.9/kW with an energy cost of 0.12 $/kW. The payback for CHP is much less at higher diesel prices of $1.20/liter and $2.00/liter respectively at 1.8 years and 0.9 years. Table 5.1 shows the economic and financial parameters for the model. Please refer to Appendix – II for RETScreen Analysis.

Table 5.2 Economic and Financial parameters for RETs

Parameter	Wind-Diesel Hybrid	Solar PV-Diesel Hybrid	Biomass
Fuel cost–Proposed case ($/yr)	41 449	56 139	63 729*
Fuel cost–Base case ($/yr)	98 067	97 071	151 881*
Debit Ratio (%)	75	75	75
Debt Interest rate (%)	7.00	7.00	7.00
Debt Term (Yrs)	10	10	10

** Includes propane heating cost*

When a liter of diesel approaches $1.20, power generation by diesel generation costs as much as $0.70 per kW. When the price of diesel is at $2.00/l the cost of electricity from diesel is approaching $0.89/kWh. This is twice as expensive as wind generation, seven to eight times as expensive as biomass generation and about nineteen times as expensive as solar power per kWh. Other fuels become affordable and the payback periods are reduced at these higher diesel prices. At $1.20/kWh to $2.00/kWh for diesel, the payback periods (years) of different RETs are, respectively: 1.8 years to 0.9 years for CHP, 3.6 years to 1.8 years for wind, and 6.7 years to 3.2 years for solar.

RETs will reduce greenhouse gas (GHG) emissions considerably by an estimated 187 tons per year by a wind-diesel hybrid system, 134 tons per year by a solar PV-diesel hybrid system and 497 tons per year by the biomass system. Biomass CHP is a reliable technology and burning wood is considered a sustainable cycle as the carbon burned will be used up when new trees replace them, as long as the forested area's land use is unchanged from forest. Concerning power generation, the existing diesel system is inefficient at ~25% and is expensive to generate at $0.23/kW, which is much higher than wind power at $0.14/kW, solar power at $0.045/kW and biomass at $0.12/kW. Wind and solar technologies are considered to have zero emission technologies during power generation while both diesel and biomass emit pollution including GHG at the site of generation. However, biomass based power generation is a carbon neutral technology, as trees that replace those burned take up the carbon emitted during combustion if the land remains forest. Based on the initial cost for equipment, solar PV at $9,100/kW is the most expensive among the technologies, requiring a long payback period of 13.5 years. At $3,300/kW, wind power is more expensive than installing a new diesel generator or implementing a biomass system. Heat is a byproduct of the biomass CHP system that could replace the propane expense of almost $9,150 for heating the residences and laboratories. Geothermal reduces propane use by two-thirds typically by using the earth's heat, whereas CHP heat is waste heat, not requiring any additional fuel.

5.2.2 Impacts of RETs on GHG Emissions

The average annual gasoline expenses for the year 2006/2007 are approx. $9,147.80 for transportation by automobiles (vehicles leaving to Fresh Water Institute (FWI) Winnipeg), out boats, ATVs (All Terrain Vehicles) and other equipment like portable generators. Switching from conventional automobiles to hybrid vehicles has the potential to reduce the gasoline cost and also would mitigate GHG emissions. Table 5.3 shows the GHG emissions from the three different types of fuels consumed at ELA.

Table 5.3 GHG emissions from fuels combusted at ELA

Fuel	**CO_2** *(Carbon dioxide)*	**CH_4** *(Methane)*	**N_2O** *(Nitrous Oxide)*
Diesel	2.730 kg/l	0.00013 kg/l	0.0004 kg/l
Propane	1.500 kg/l	0.000024 kg/l	0.000108 kg/l
Gasoline	2.360 kg/l	0.00025 kg/l	0.00026 kg/l

Source: Community Energy Planning, A resource guide for remote communities in Canada 2005

<u>GHG Emissions at ELA for year 2006/2007 based on Table 5.3</u>

From Diesel: 82,422*2.730= 225,012.06kg CO_2

82,422*0.00013= 10.71kg CH_4

82,422*0.0004= 32.96kg N_2O

From Propane: 21,586*1.500=32,379.00kg CO_2

21,586*0.000024= 0.518kg CH_4

21,586*0.000108= 0.233kg N_4O

From Gasoline: 9527*2.360=22,483.72kg CO_2

9527* 0.00025= 2.38kg CH_4

9527* 0.00026= 2.47kg N_4O

Total CO_2 Emissions: **279,874.78 Kg**

Total CH_4 Emissions**: 13.608Kg ~ 285.76Kg of CO_2**

(Note: Methane is 21 times more powerful than CO_2 in terms of greenhouse effect)

Total N_4O Emissions: **35.663Kg**

Therefore, total GHG emissions from ELA are Approx. **280,410.54 Kg of CO_2 Eq per year**.

5.3 Chapter Summary

Three renewable energy technologies (RETs) were analyzed for their feasibility for a small off-grid research facility dependent on diesel for power and propane for heat.

Presently, the electrical load for this facility is 115 kW but a demand reduction achieved through energy audit which revealed that 4.8% reduction was possible. This reduces the peak load to 110 kW which subsequently reduced the capital costs by $27,000 for biomass, $49,500 for wind and $136,500 for solar.

The RETScreen International 4.0® model compared the economic and environmental costs of generating 125 kW of electricity for three RETs compared to the current (0 cost) and a replacement ($160/kW) diesel equipment. Biomass was the most feasible at all the different diesel prices analyzed at. At 80 cents per liter, biomass' payback period was 4.1 years with a capital cost of $ 2,162.9/kW compared to wind power payback period of 6.1 years due to its higher initial cost of $ 3,300/kW. Solar PV had a payback of 13.5 years due to its high initial cost of $ 9,100/kW. A biomass system would reduce annual energy costs by $ 63,729 per year, and mitigate GHG emissions by over 98% to 10 t CO_2 from 507 t CO_2. Diesel price increases to $1.20 or $2.00/liter will decrease the payback period in years dramatically to 1.8 and 0.9 for CHP, 3.6 and 1.8 for wind, and 6.7 and 3.2 years for solar, respectively.

Some RETs, particularly CHP at ELA, are feasible in off-grid communities, according to this study, and may soon be feasible in grid communities if fossil fuel prices increase. The utility of applying demand reduction prior to sizing RETs was demonstrated at ELA by reducing capacity from 115 kW to 100 kW, that reduced initial costs by $26,000 for CHP, $49,500 for wind and $136,500 for solar. This study shows that demand reduction and RET can be applied effectively to dramatically improve the energy situation at ELA resulting in lower energy cost and cleaner energy production. Demand reduction had the potential of shaving 4.8% from the existing energy consumption, amounting to

14,130.37 kWh or $ 2,567.32 in annual savings. Table 5.4 summarizes the three renewable technologies that are analyzed.

The table consolidates the model results for: 1) solar-PV – diesel hybrid, 2) wind-diesel hybrid, and, 3)biomass CHP system. For all these fuel sources the pay back period, cost of energy, reliability of the system, availability of the resource, capital cost, GHG emissions and annual fuel cost are compared. The pay back period on Solar PV hybrid is 13.5 yrs at $0.80 per liter of diesel due to the capacity factor of the hybrid system. The hybrid system has been modeled at 10 (PV): 90 (Diesel) capacity factor and also the load in summer is low and in winter the load at station is only a tenth of the peak load in summer. As the diesel price increases the system pay back decreases and at $ 2.00 per liter of diesel the payback is as low as 3.2 years. The wind-diesel hybrid system has been modeled at 30 (wind): 70 (diesel) capacity factor. This system has a pay back of 6.6 years at the diesel price of $ 0.8 per liter and as the diesel price increases to $ 2.00 per liter the pay back period reduces to 1.8 years. The biomass based CHP system modeled, however, is a stand alone system with the existing diesel generators as back-up. It has the shortest pay back period of the technologies modeled. The biomass based CHP system has a pay back period of 4.1 years at $0.80 per liter of diesel, as diesel price approaches $ 2.00 per liter the pay back period reduces to 0.9 years. All the systems show as the price of fossil fuel increases the hybrid RET systems become more feasible.

Table 5.4 RETScreen analysis of the three scenarios at different diesel prices

	Electricity				**Heat & Power**	**Heating**	
RET **Para-Meters**	**Solar Power 125kW**	**Wind Power 125kW**	**Diesel Power 115kW (existing)**	**New Diesel Generators 115kW**	**Biomass 125kW**	**Geothermal Heating**	**Propane Heating**
Reliability	Low-Moderate	Low-Moderate	High	High	High	High	High
Availability	~25-30%	~25%-30%	< 95%	<95%	< 95%	-	< 95%
Avg. Initial Cost ($/kW)	9100	3300	-	~160	2162.9	n/a	n/a
Cost of power (in $/kW)	0.045	0.145	0.225	0.200	0.120	0.083	0.454
Efficiency	12.3%	~30%	~25%	~30%	~85%	> 85%	~85%
Equity payback Period (yrs) at different diesel prices	13.5 @ $0.8/l 6.7 @ $1.20/l 3.2 @ $2.0/l	6.6 @ $0.8/l 3.6 @ $1.20/l 1.8 @ $ 2.0/l	-	-	4.1@ $0.8/l 1.8@ $1.2/l 0.9@ $2.0/l	4.7	-
Capital Cost ($)	1,137,500	412,500	-	16 000	270362.50 without district heating network	26 000	-
Annual fuel cost ($) at different diesel prices	Nil	Nil	$65937.60 @ $0.8/l $98906.40 @ $1.2/l $164 844.00 @ $2.0/l	$65937.60 @ 0.8/l $98906.40 @ $1.2/l $164 844.00 @ $2.0/l	~6500.00	3039.00	$9735.28 @ 0.8/l $25 903.20 @ 1.2/l $43 172.00 @ 2.0/l
GHG Emission reduction (t CO_2)	187	134			497		
Carbon tax savings @ $10/ton/year	$1870	$1340			$4970		
Carbon tax savings @ $50/ton/year	$9350	$6700			$24 850		

Of the three RETs analyzed, biomass was found to be more economically and environmentally feasible than wind and solar for ELA. A biomass CHP system would reduce annual energy costs by $63,729 per year. *This is direct cost saving from mitigated diesel and propane fuel consumption annually.* GHG emissions were mitigated by over

98% to 10 t CO_2 from 507 t CO_2. Wind power generation is very competitive with biomass if not for its high initial cost and moderate reliability. Solar has the lowest feasibility due to the long payback period and high initial cost. Biomass based CHP can achieve savings of about 50% with 4.8% demand reduction. Also, with the existing diesel generators coming towards the end of their operating life, ELA is in an ideal situation to shift from fossil fuel towards a renewable fuel. As well, this approach would be relevant to other off-grid communities with good biomass resources.

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CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

Growing concerns about climate change, peak oil and rising energy costs, require that oil dependent communities, particularly off-grid communities, explore renewable energies. The historic price trend of diesel and gasoline shows that increasing demand and political instability together push the oil prices ever higher. Power generation is one of the largest contributors to GHG emissions that fuels global climate change particularly for small-scale diesel-generators (50 kW to 100 kW) that are only 25% to 35% efficient. Since costs for fuel in the remote off-grid communities, with diesel generation and freight costs, are three times more expensive than fuel prices elsewhere in Canada, due to transportation costs, renewable energy technologies (RETs) may make more economic sense in remote off-grid communities. Currently at ELA, diesel generates electrical power at the high energy cost of $0.230/kW, resulting in GHG emissions of ~280 tons CO_2 annually. In addition, propane heats most building at an additional cost. ELA is considering reducing its emissions and costs through demand reduction and using RETs. This thesis looked at the feasibility of sustainable, reliable energy supply in off-grid communities by conducting a life-cycle analysis of northern Ontario's Experimental Lakes Area (ELA). Demand reduction measures including energy saving measures, retrofitting, and downsizing of equipment have been analyzed. The thesis also iterates that due to the expensive nature of RETs they are always require that demand be reduced to be considered to reduce the peak load, therefore decreasing the initial costs, as well as on-going fuel costs.

6.2 Summary

A feasibility study of energy efficiency and renewable energy technology was conducted at a small off-grid community in Ontario. The objectives of the study were met, namely: 1) To understand the existing energy set up at ELA by creating an energy profile of ELA and to develop a base case scenario for the year 2006/2007; 2) To identify and recommend energy saving opportunities using demand reduction approach and to estimate the resulting annual savings and; 3) To perform a renewable energy analysis for a suitable site specific renewable energy resources and to identify the most feasible renewable technology and to integrate it with identified energy efficiency measures. This research provided an assessment of the existing energy management system at ELA.

6.3 Conclusion

This thesis shows that improvements in energy efficiency can be made through low cost and no cost retrofitting. Renewable energy for off-grid communities plays a vital role in future as it is not feasible to connect all the off-grid communities to the grid or to displace the communities. At off-grid facilities most of GHG emissions and energy cost are from electricity production followed by heating and transportation. Of the three technologies analyzed, biomass at almost 50% of existing generation cost and neutral GHG emissions is found to be more economically and environmentally feasible than wind and solar for ELA in the long term. Biomass CHP would bring significant benefits in term of emission and environmental risk reduction as well as mitigate fossil fuel consumption.

This thesis also shows that demand reduction and renewable energy technology can be used effectively to dramatically improve the energy situation at ELA resulting in lower energy cost and cleaner energy production. With the existing diesel generators coming towards the end of their operating life, ELA is in an ideal situation to take advantage of the continuously expanding biomass energy market to make the shift from fossil fuel towards a renewable fuel and mitigate fossil fuel consumption. Based on both economics and environmental considerations, a biomass based energy system would be more optimal than wind and solar power systems for ELA. However, due to large variations in engineering, development and other miscellaneous costs there is a need for further cost analysis to consider on-site seasonal load variability, prospective biomass technologies and a reliable biomass fuel supplier or labor for producing biomass.

Table 6.1 lists a few examples of Biomass CHP system that have been operating successfully in North America and Europe are listed below.

Table 6.1 Comparison of Small-Scale Biomass CHP Systems

	Output (kW)	**Overall Efficiency**	**Fuel Type**	**Fuel Used/Hr**	**Investment CAD$ / kWh**	**Status**
CPC Biomax 25, US	25	70 - 80%	Wood chips, pellets, shells, etc	22 dry kg/hr	4700 - 7300	Fully commercial
Tervola, Entimos Oy, Finland	470	81.5%	Sawmill wood residues (bark, saw dust, etc)	unknown	3480	Fully operational (2002)
Xylowatt, xW 300, Belgium	300	75%	Wood residue, agricultural waste	300-600 kg/hr	unknown	Fully commercial

Source: Potential for Small-Scale, Community Based Biomass Energy Projects in Nova Scotia Dale Prest, Jamie Simpson, October 2009.

The examples provided in Table 6.1 demonstrate that decentralized small scale biomass benefits are already being realized in parts of North America and internationally. While some of the technologies are just entering commercial production, they represent what is possible in the very near future.

6.4 Recommendations for Diesel Off-Grid Community

This research provides an assessment of the existing energy management system at ELA a small scale off-grid community. Analysis based on key factors like energy consumption, fuel cost, retrofitting and payback period shows that the current load at ELA can be reduced by 4.8% by low-cost and no-cost retrofitting. The general conclusions based on the study objectives are detailed below:

6.4.1 Current System

The energy management system at ELA as currently practiced is unsustainable in the long run. The current system lacks energy monitoring system and has no consistent energy efficiency method to achieve load reduction. The study shows that when it comes to energy efficiency small changes make a big difference in off-grid communities.

6.4.2 Proposed Energy Management System

Figure 6.1 compares the existing energy model at ELA to the recommended model. The chief difference between the models is the way they approach about the energy management in a small off-grid community where small changes can add up to make a considerable saving in energy cost and maintenance.

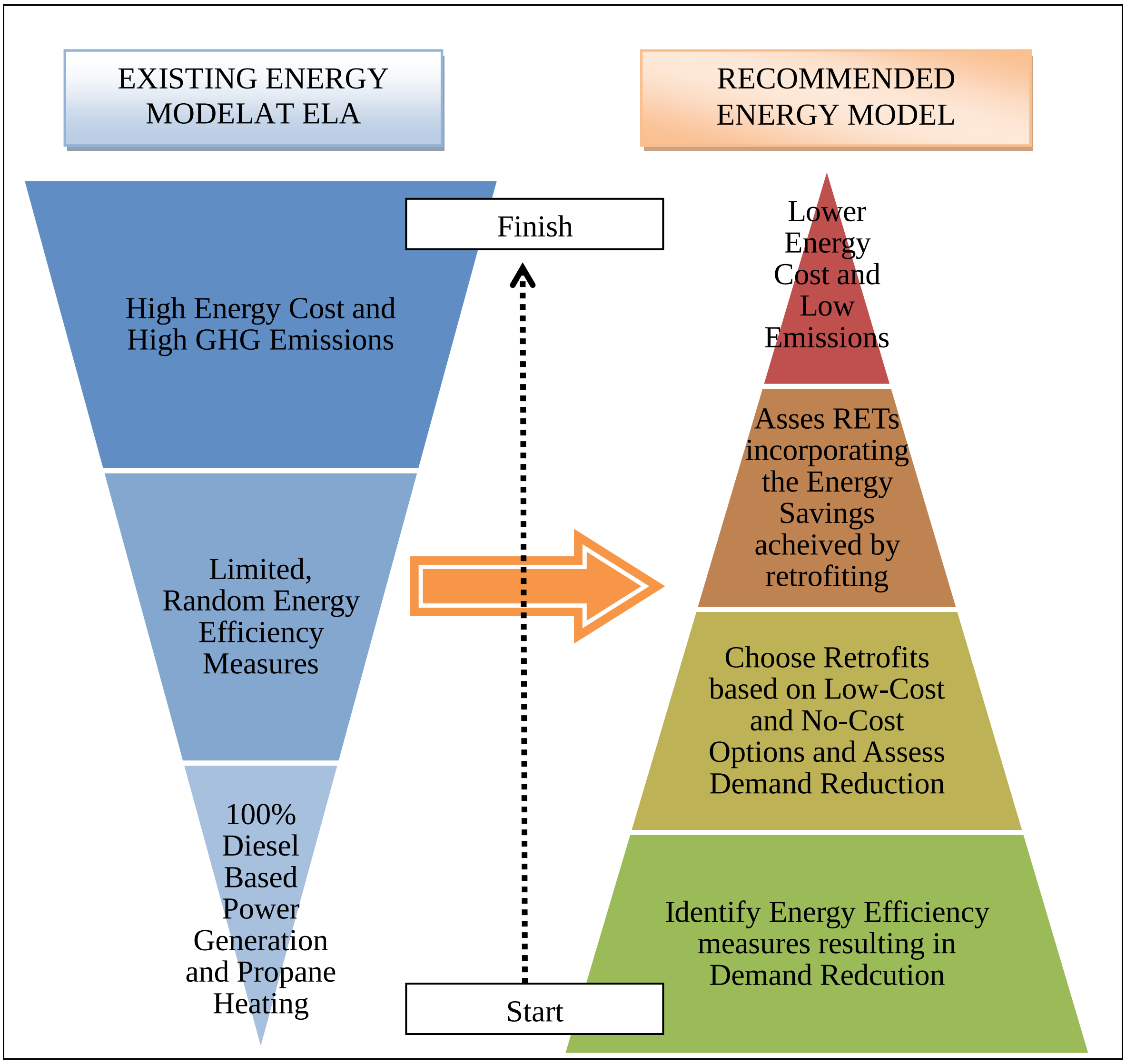
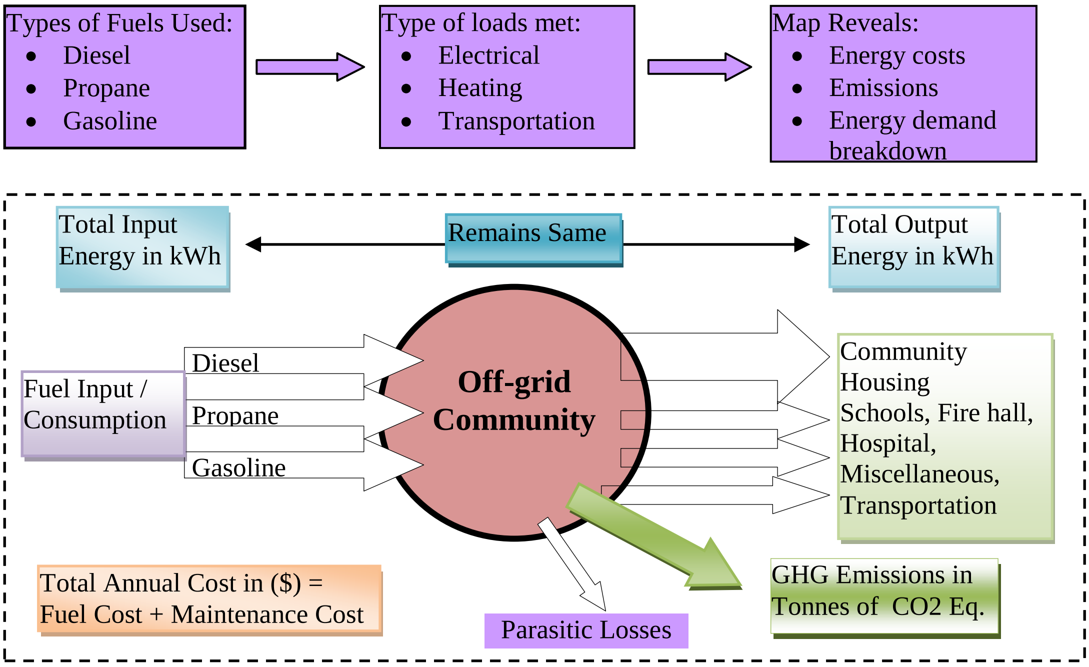


Figure 6.1 Comparison of Existing Energy Model and the Recommended Energy Model

The Figure 6.2 shows that a little cost and energy management focus at the beginning of the energy plan (RET fuel sources and energy efficiency measures) ends up with low energy costs and environmental costs. The research shows that the right-side up pyramid to be much more stable and sustainable design that rests on a sustainable energy management foundation than unsustainable energy management. The recommended model is aptly suitable for small off-gird communities that are remote and difficult to access thus making this model scalable to other larger off-gird diesel communities in Canada. Figure 6.2 lays out a three step template resulting from this study that can be replicated for other off-grid communities in Canada that depend exclusively on fossil fuels for power and heat.

STEP 1: Create Energy Map of Community:



STEP 2: Demand Reduction:

i. Perform Walk Through Energy Audit
ii. List all the demand reduction opportunities
iii. Identify all low-cost and no-cost opportunities with guidance of an attractiveness index.
(Note: Attractiveness index is based on the capital investment affordability of the community and payback period that they seek)
iv. Implement all the changes with High attractiveness index
v. Reduce Demand (by 5 to 20%)

STEP 3: Renewable Energy Technology Analysis:

i. Identify Potential Renewable Energy
ii. Perform RET Analysis using RETScreen 4.0 software on identified sources
(Note: Considering the new reduce demand achieved from energy efficiency)
iii. Compare payback period, cost per KW, emissions and efficiency
iv. Compare with the existing power generation system
v. Choose the RET based on payback, initial cost and resource availability

Figure 6.2 Layout of Sustainable Energy Plan for Small Off-Grid Diesel Communities

6.5 General Recommendations

Based on the study the following recommendations are drawn keeping in mind the overall energy management for small off-grid communities:

Energy Monitoring and Targeting: *"You cannot manage what you can't measure"*. By employing energy monitoring and targeting technique communities can identify where energy savings are and see results of energy management projects. This energy efficiency technique helps in:

- identifying and explain increase or decrease in energy use
- obtain weekly or monthly energy consumption trends
- determine future energy use
- identify specific areas where energy is wasted
- develop performance targets for energy management programs

Identify Small Changes: *"Small changes add up"*. Having shown that small changes in energy efficiency add up, the research recommends identifying small and miscellaneous loads that are usually over looked and the focus moves on to a more efficient Heating Ventilation and Air Conditioning (HVAC) units, or other big equipment.

Set Targets and Goals: Establish an energy consumption base line and set targets to improve the base line. This is a continuous way to improve the base line by setting future targets for better overall energy performance. Try to keep the consumption below or equal to the historical average is good starting point.

Community Involvement/Education: Occupant education and involvement is an important factor in achieving the goals set in the energy program. Let the occupants know the energy savings resulted from their actions.

The recommendations made in this thesis are basic and easily applicable in the off-gird diesel community. Emphasis should be given to a detailed evaluation of the current energy management system and not to ignore small and continuous loads, which can make a considerable impact in the overall energy strategy.

Appendix – I

Energy Efficiency Walk Through Survey

Date: __________

The first step is to record all energy consumption from utility bills for the last 12-months. Then walk through the facility and identify all the equipment and processes that use or cause the use of energy. Note size of the equipment, operating hours and temperatures, condition of insulation and weather-stripping, gaps around doors and windows etc.

General Information:

(Please circle units used where applicable)

Facility Name:_____________________________________

Mailing Address:____

Town:____Postal Code:________

Name of Facility Operator:____

Title:______________________________________

Phone Number:______________________________Fax Number:___________________

Name of person completing this form:______________________________

Title:______________________________________

Phone Number:____________

Brief Description of Function or Use of Facility:__________________________________

____

____

Total Floor area of Facility (sq. m. /sq. ft.):______________________________________

Bulk Fuel Worksheet

Complete one form for each bulk fuel (propane, oil, coal, wood, etc.) used in your facility. The completed form is necessary, as part of the information needed to establish your energy usage and GHG baselines. This information will also provide you with a much better understanding of what your actual energy costs are.

Facility Name:____

Fuel Company Name: ____

Fuel Type: _______ Fuel Delivery Units (litres, tonnes cords etc.): __________

Account Number: ______________________ Fuel cost / Unit: ______________

Fuel Use (Entire Facility, Area, Equipment, Etc.): ________

Year: _________ No. Of Months: ________ First Month: ___________

Provincial Tax (%): ___________GST (%): ___________City Tax (%): _____________

Fuel Type: _______

Month/Year Fuel Delivered	**Monthly Fuel** Consumption **Units_______**	**Total Cost $**
Total		

Lighting

Facility:_______________________________Location of Lights:______________________

Existing lights and controls:

	Type 1	Type 2	Type 3	Type4
Type of fixtures (see legend):				
Number of fixtures:				
Number of lamps per fixture:				
If fluorescent indicate length of lamps (2 ft, 3ft, 4ft, 8ft):				
Watts per fixture: (Include ballast wattage if known)				
Fixture height from work surface(ft/m)				
Foot-candle level (if known) – measured at work surface - foot candles				
Present operation of lights - hours/day				
Present operation of lights - days/week				
Present operation of lights – weeks/year				
Present operation of lights - hours/day				
Present operation of lights - days/week				
Present operation of lights - weeks/year				

Present light levels: Bright ________________Adequate _________________Dim____

Reflectance of walls and ceilings: Good _______ Average ____________Poor _________

Can lights be switched on and off as desired? Yes______ No____ Comment:__________________

Can lower wattage lamps be installed? Yes_____ No____Comment:_________________________

Can existing lamps/fixtures be retrofitted? Yes__ No____ Comment:_________________________

Is there an automatic timer? Yes_______ No_____ Is it set properly? Yes_______ No___________

Is there an occupancy sensor? Yes___ No___ If No, can an occupancy sensor be installed? Yes ___No __

Lighting Legend

A. – Incandescent; B. - Fluorescent T-12; C. - Fluorescent T-12 HO (High Output); D. - Compact Fluorescent; E. - Mercury Vapour; F. - Fluorescent T-12 VHO (VH Output); G. - High Pressure Sodium; H. - Low Pressure Sodium; I. - Metal Halide (White Light) ; J.- Fluorescent T-8; K.- Quartz Halogen ; L.- Exit lamp – incandescent ; M. - Exit lamp - compact fluor.; N. - Exit lamp – LED; O. Other-specify _________________

Building Envelope

Facility:_____________________________________**Direction Wall Faces**____________

For each wall area of facility (front, sides and back of a building) please use one sheet.

Windows (Please circle appropriate Yes or No)

Are storm windows used?	Number of glazings	Description of window type (double hung, slider, casement, etc)	Do windows open?	Window fit (poor, fair, good)	Number of windows
Yes No			Yes No		
Yes No			Yes No		
Yes No			Yes No		

Doors (Please circle appropriate Yes or No) **(**Please circle units used)

Are storm doors used?	Is door Insulated?	Description of door type (overhead, insulated metal, wood, etc)	Condition of door (warped, cracked)	Door Fit (poor, good)	Number of doors
Yes No	Yes No				
Yes No	Yes No				
Yes No	Yes No				

Number/Location of broken or cracked windows:_______________________________________

____

Description of door or window repairs or replacements needed (including door closers):_________

____

Caulking: _________________________ft/metres required

Weather-stripping: __________________ft/meters required

Inside (Please circle appropriate Yes or No)

Insulation	Insulated?	Present Thickness	Insulation Types
Location			
Ceiling (Attic)	Yes No		
Walls	Yes No		
Basement/Crawlspace walls	Yes No		
Floor / slab	Yes No		

Location of drafts (use strip of tissue to locate):e.g. doors, windows, elec. outlets, attic hatches cracks etc. ____

____

Is attic ventilation installed? Yes _____ No ____

Comments______________________________________

Heating Ventilating and Air Conditioning (HVAC)

Facility Name:____

Please use another sheet id required

Controls/Use (Please circle units used)

Location(s) and description of thermostats:____

Location of setback clock/setback thermostat:____________________________________

Cold weather thermostat setting: ______ºC/ºF. Is temperature setback at night and on weekends?

If Yes what are setback times and temperatures for: nighttime ________________ weekend____________

Is temperature setback automatic ___________________or manual?_________________

Hot weather thermostat setting: _______ºC/ºF. Is temperature setup at night and on weekends?__________

If Yes what are setup times and temperatures for: nighttime _________________ weekend____________

Is temperature setup automatic ______________or manual?_________________

How many hours a week and weeks per year is the system used?

Hours & weeks in hot weather_______________Hours & weeks in cold weather_____________________

When is system turned on/off in relation to daily occupancy (i.e., before, after, by how long)?

____

Fans (Supply, Return, Exhaust, Circulating etc.) (Please circle appropriate Yes or No)

Function: (supply, return etc)	Area served:	Fan operating hours			Can fans be cycled to reduce operating times?
		hours / day	days / week	weeks/ year	
					Yes No
					Yes No
					Yes No
					Yes No
					Yes No
					Yes No
					Yes No

Office and Lab Equipment

(Computers, printers, photocopiers, etc)

Facility Name:________________________________

Please use more sheets if required

Office machine:

Machine type, location____

Wattage (nameplate watts or amps x volts):____

Is it left on overnight?___________________________Over weekends?__________________

Daily hours of operation:__________________Hours per day it could be turned off:__________

Office machine:

Machine type, location____

Wattage (nameplate watts or amps x volts):____

Is it left on overnight?___________________________Over weekends?__________________

Daily hours of operation:__________________Hours per day it could be turned off:__________

Office machine:

Machine type, location____

Wattage (nameplate watts or amps x volts):____

Is it left on overnight?___________________________Over weekends?__________________

Daily hours of operation:__________________Hours per day it could be turned off:__________

Office machine:

Machine type, location____

Wattage (nameplate watts or amps x volts):____

Is it left on overnight?___________________________Over weekends?__________________

Daily hours of operation:__________________Hours per day it could be turned off:__________

Office machine:

Machine type, location____

Wattage (nameplate watts or amps x volts):____

Is it left on overnight?___________________________Over weekends?__________________

Daily hours of operation:__________________Hours per day it could be turned off:__________

Office machine:

Machine type, location____

Wattage (nameplate watts or amps x volts):____

Is it left on overnight?___________________________Over weekends?__________________

Daily hours of operation:__________________Hours per day it could be turned off:__________

Machines and Equipment

Facility Name:_______________________________________

Please use another sheet if required

Refrigeration and Freezing (Please circle units used)

Type, age, energy used:______________

Compressor rating: __________hp; age: ______years Present temperature: ºC/ºF____________

Hours per day of use:__________Weeks per year equipment is used____________

Do doors close completely, by themselves?____________Condition of door seals:___________

Refrigeration and Freezing (Please circle units used)

Type, age, energy used:______________

Compressor rating: __________hp; age: ______years Present temperature: ºC/ºF____________

Hours per day of use:__________Weeks per year equipment is used____________

Do doors close completely, by themselves?____________Condition of door seals:___________

Refrigeration and Freezing (Please circle units used)

Type, age, energy used:______________

Compressor rating: __________hp; age: ______years Present temperature: ºC/ºF____________

Hours per day of use:__________Weeks per year equipment is used____________

Do doors close completely, by themselves?____________Condition of door seals:___________

Cooking (Range, oven, grill, etc) (Please circle units used)

Type, age, energy used:___________________________Temperature now used: ºC/ºF_________

Is this the lowest possible temperature? Yes ____No ___Is equipment turned off when possible?_

Are exhaust hoods installed over all cooking equipment? Yes __________No __________

Cooking (Range, oven, grill, etc) (Please circle units used)

Type, age, energy used:___________________________Temperature now used: ºC/ºF_________

Is this the lowest possible temperature? Yes ____No ___Is equipment turned off when possible?
_Are exhaust hoods installed over all cooking equipment? Yes ________No __________

Cooking (Range, oven, grill, etc) (Please circle units used)

Type, age, energy used:___________________________Temperature now used: ºC/ºF_________

Is this the lowest possible temperature? Yes ____No ___Is equipment turned off when possible?_

Are exhaust hoods installed over all cooking equipment? Yes __________No __________

Miscellaneous Equipment

Facility Name:____

Please use another sheet if required
Washer Dyer (If applicable)

Type, age, energy used:__________________________________

Temperature now used: Hot__________Warm_______Cold_________

Are machines fully and properly loaded? Yes __________No __________

Can lower washing/rinse water temperatures be used? Yes _________No __________

Dish Washing (If applicable)

Type, age, energy used:__________________________________

Temperature now used: Hot__________Warm_______Cold_________

Are machines fully and properly loaded? Yes __________No __________

Can lower washing/rinse water temperatures be used? Yes _________No __________

Dish Washing (If applicable)

Type, age, energy used:__________________________________

Temperature now used: Hot__________Warm_______Cold_________

Are machines fully and properly loaded? Yes __________No __________

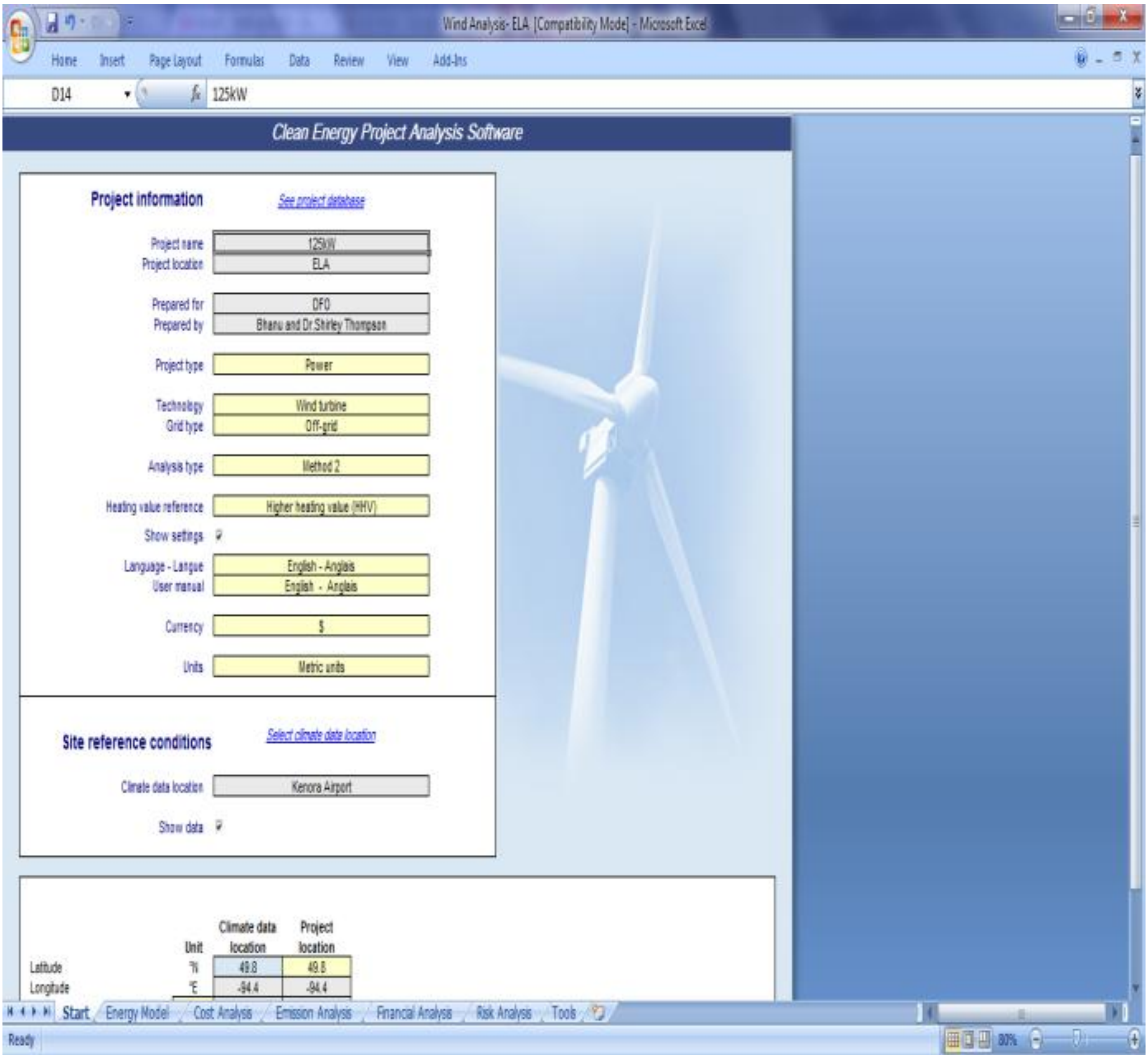
Can lower washing/rinse water temperatures be used? Yes _________No __________

Notes

Appendix – II

RETScreen 4.0: Wind Analysis

Project Information:



D14 f_x 125kW

Clean Energy Project Analysis Software

Project information See project database

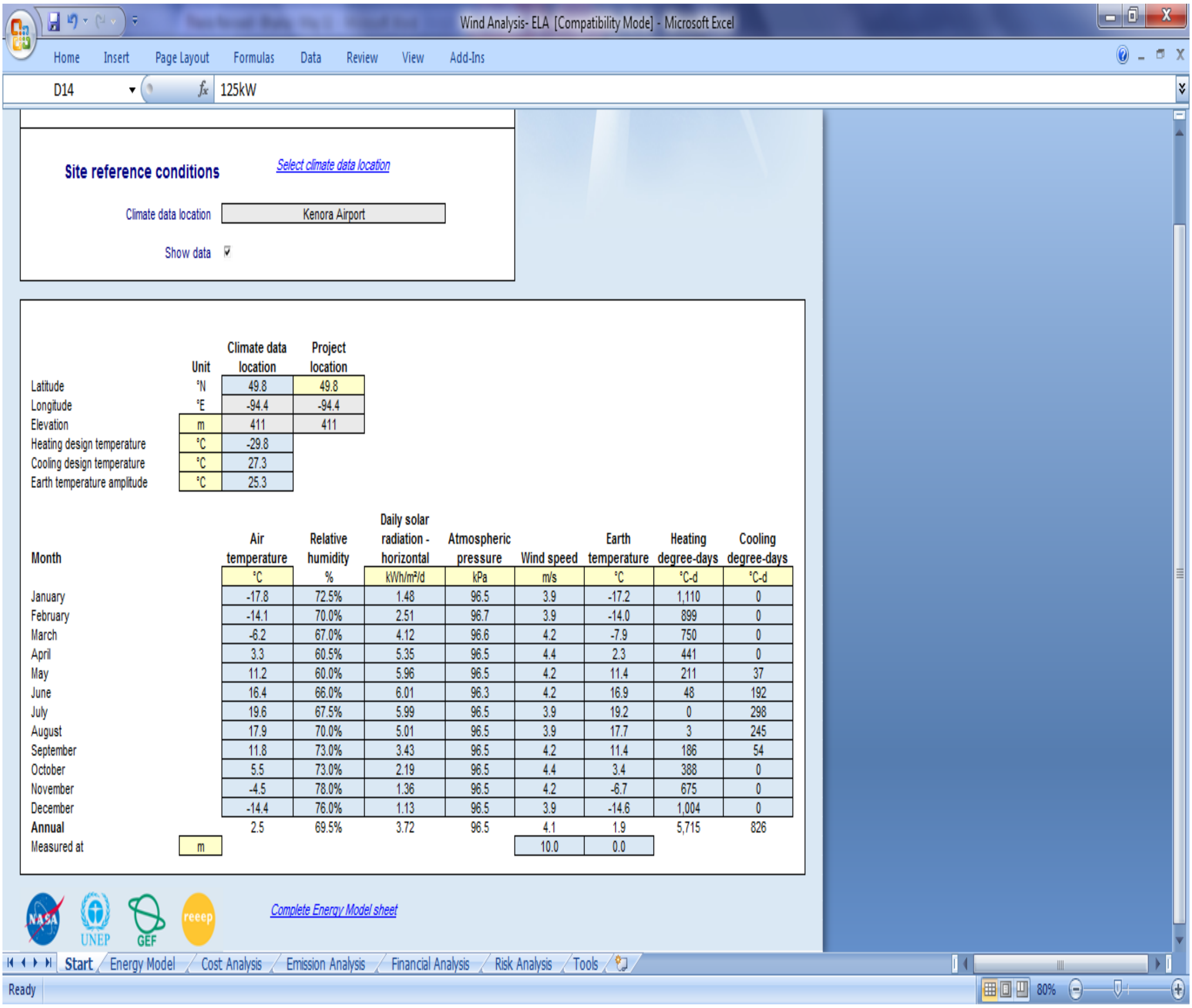
Project name	125kW
Project location	ELA
Prepared for	DFO
Prepared by	Bhanu and Dr Shirley Thompson
Project type	Power
Technology	Wind turbine
Grid type	Off-grid
Analysis type	Method 2
Heating value reference	Higher heating value (HHV)
Show settings	☑
Language - Langue	English - Anglais
User manual	English - Anglais
Currency	$
Units	Metric units

Site reference conditions Select climate data location

Climate data location	Kenora Airport
Show data	☑

	Unit	Climate data location	Project location
Latitude	°N	49.8	49.8
Longitude	°E	-94.4	-94.4

Site Conditions:



D14 f_x 125kW

Site reference conditions

Select climate data location

Climate data location: Kenora Airport

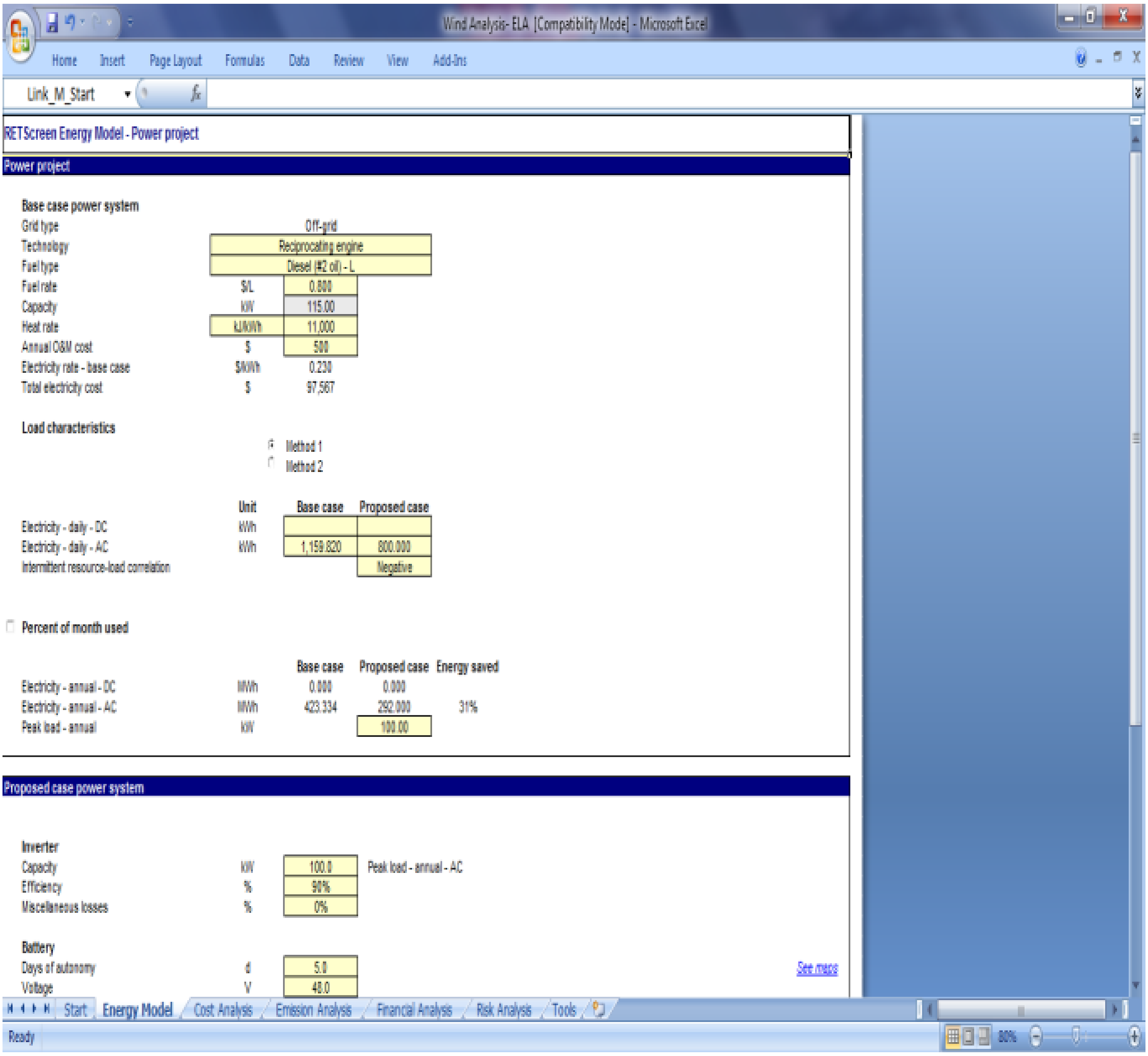
Show data ☑

	Unit	Climate data location	Project location
Latitude	°N	49.8	49.8
Longitude	°E	-94.4	-94.4
Elevation	m	411	411
Heating design temperature	°C	-29.8	
Cooling design temperature	°C	27.3	
Earth temperature amplitude	°C	25.3	

Month		Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
		°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January		-17.8	72.5%	1.48	96.5	3.9	-17.2	1,110	0
February		-14.1	70.0%	2.51	96.7	3.9	-14.0	899	0
March		-6.2	67.0%	4.12	96.6	4.2	-7.9	750	0
April		3.3	60.5%	5.35	96.5	4.4	2.3	441	0
May		11.2	60.0%	5.96	96.5	4.2	11.4	211	37
June		16.4	66.0%	6.01	96.3	4.2	16.9	48	192
July		19.6	67.5%	5.99	96.5	3.9	19.2	0	298
August		17.9	70.0%	5.01	96.5	3.9	17.7	3	245
September		11.8	73.0%	3.43	96.5	4.2	11.4	186	54
October		5.5	73.0%	2.19	96.5	4.4	3.4	388	0
November		-4.5	78.0%	1.36	96.5	4.2	-6.7	675	0
December		-14.4	76.0%	1.13	96.5	3.9	-14.6	1,004	0
Annual		2.5	69.5%	3.72	96.5	4.1	1.9	5,715	826
Measured at	m					10.0	0.0		

Complete Energy Model sheet

Power Project:



RETScreen Energy Model - Power project

Power project

Base case power system

Grid type		Off-grid
Technology		Reciprocating engine
Fuel type		Diesel (#2 oil) - L
Fuel rate	$/L	0.800
Capacity	kW	115.00
Heat rate	kJ/kWh	11,000
Annual O&M cost	$	500
Electricity rate - base case	$/kWh	0.230
Total electricity cost	$	97,567

Load characteristics

● Method 1
○ Method 2

	Unit	Base case	Proposed case
Electricity - daily - DC	kWh		
Electricity - daily - AC	kWh	1,159.820	800.000
Intermittent resource-load correlation			Negative

☐ **Percent of month used**

		Base case	Proposed case	Energy saved
Electricity - annual - DC	MWh	0.000	0.000	
Electricity - annual - AC	MWh	423.334	292.000	31%
Peak load - annual	kW		100.00	

Proposed case power system

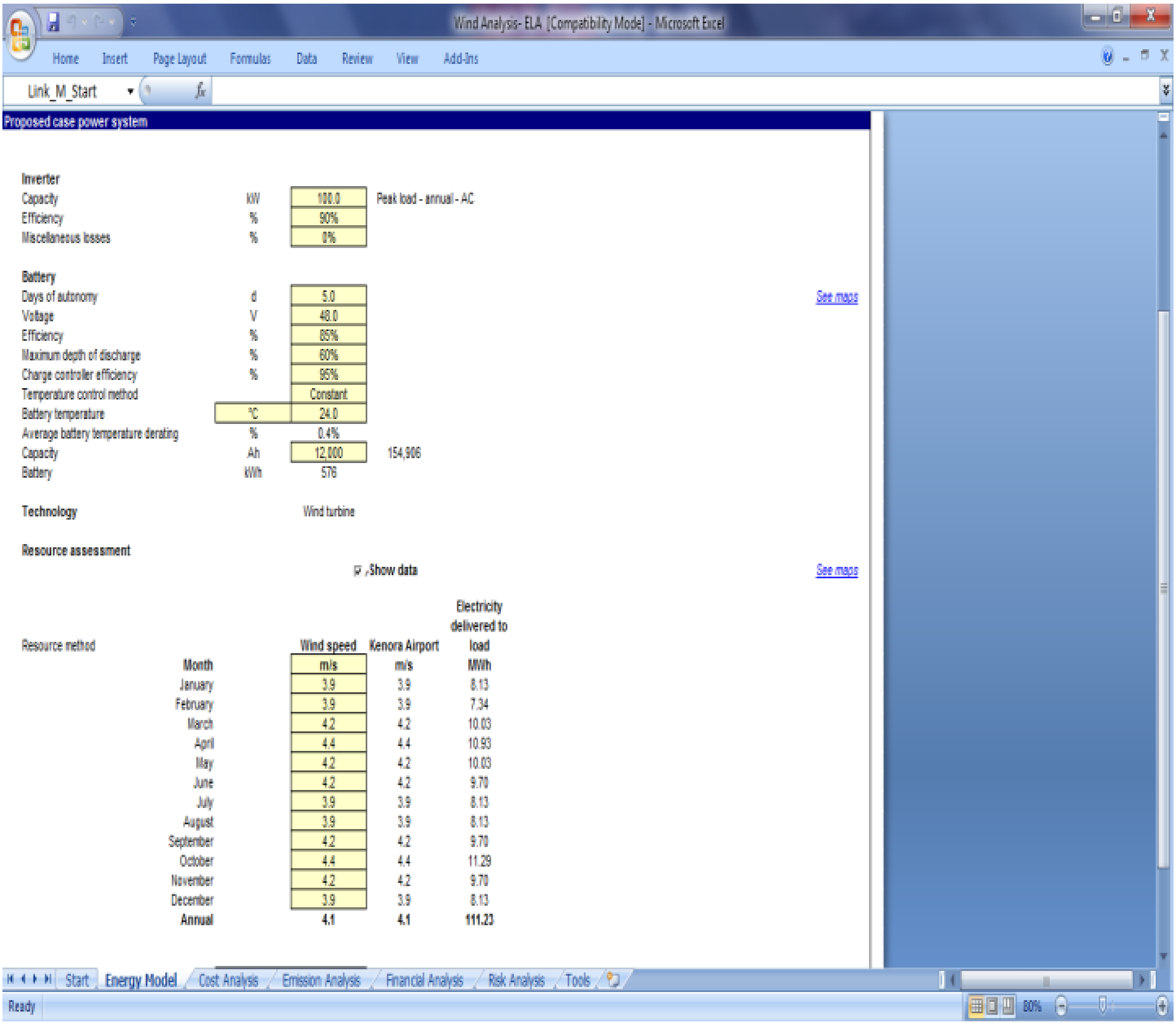
Inverter

Capacity	kW	100.0	Peak load - annual - AC
Efficiency	%	90%	
Miscellaneous losses	%	0%	

Battery

Days of autonomy	d	5.0
Voltage	V	48.0

Proposed Case:



Proposed case power system

Inverter

Capacity	kW	100.0	Peak load - annual - AC
Efficiency	%	90%	
Miscellaneous losses	%	0%	

Battery

Days of autonomy	d	5.0	
Voltage	V	48.0	
Efficiency	%	85%	
Maximum depth of discharge	%	60%	
Charge controller efficiency	%	95%	
Temperature control method		Constant	
Battery temperature	°C	24.0	
Average battery temperature derating	%	0.4%	
Capacity	Ah	12,000	154,906
Battery	kWh	576	

See maps

Technology Wind turbine

Resource assessment

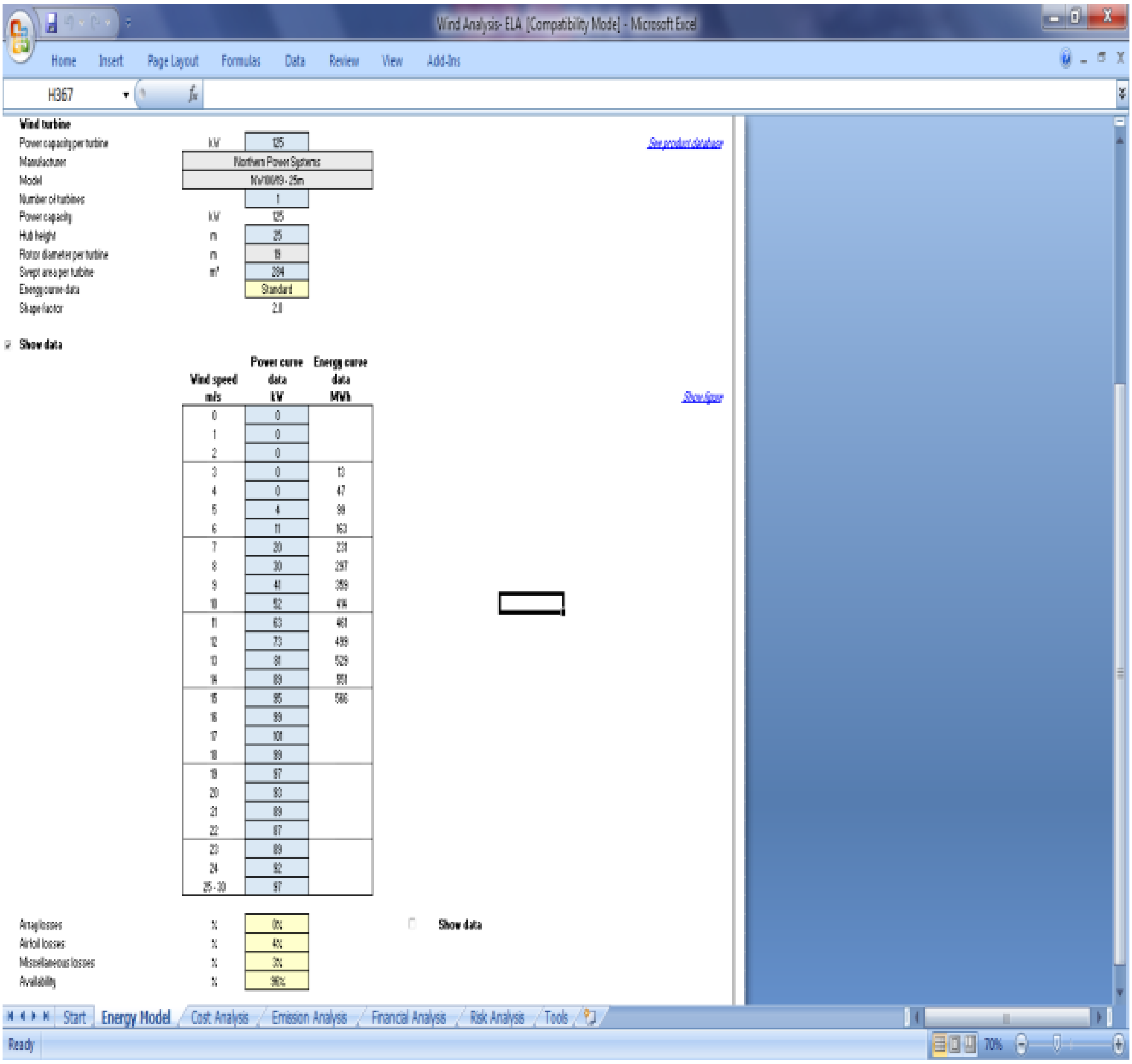
☑ Show data

See maps

Resource method

Month	Wind speed m/s	Kenora Airport m/s	Electricity delivered to load MWh
January	3.9	3.9	8.13
February	3.9	3.9	7.34
March	4.2	4.2	10.03
April	4.4	4.4	10.93
May	4.2	4.2	10.03
June	4.2	4.2	9.70
July	3.9	3.9	8.13
August	3.9	3.9	8.13
September	4.2	4.2	9.70
October	4.4	4.4	11.29
November	4.2	4.2	9.70
December	3.9	3.9	8.13
Annual	**4.1**	**4.1**	**111.23**

Wind Data:



Wind turbine

Power capacity per turbine	kW	125
Manufacturer		Northern Power Systems
Model		NW100/19 - 25m
Number of turbines		1
Power capacity	kW	125
Hub height	m	25
Rotor diameter per turbine	m	19
Swept area per turbine	m²	284
Energy curve data		Standard
Shape factor		2.0

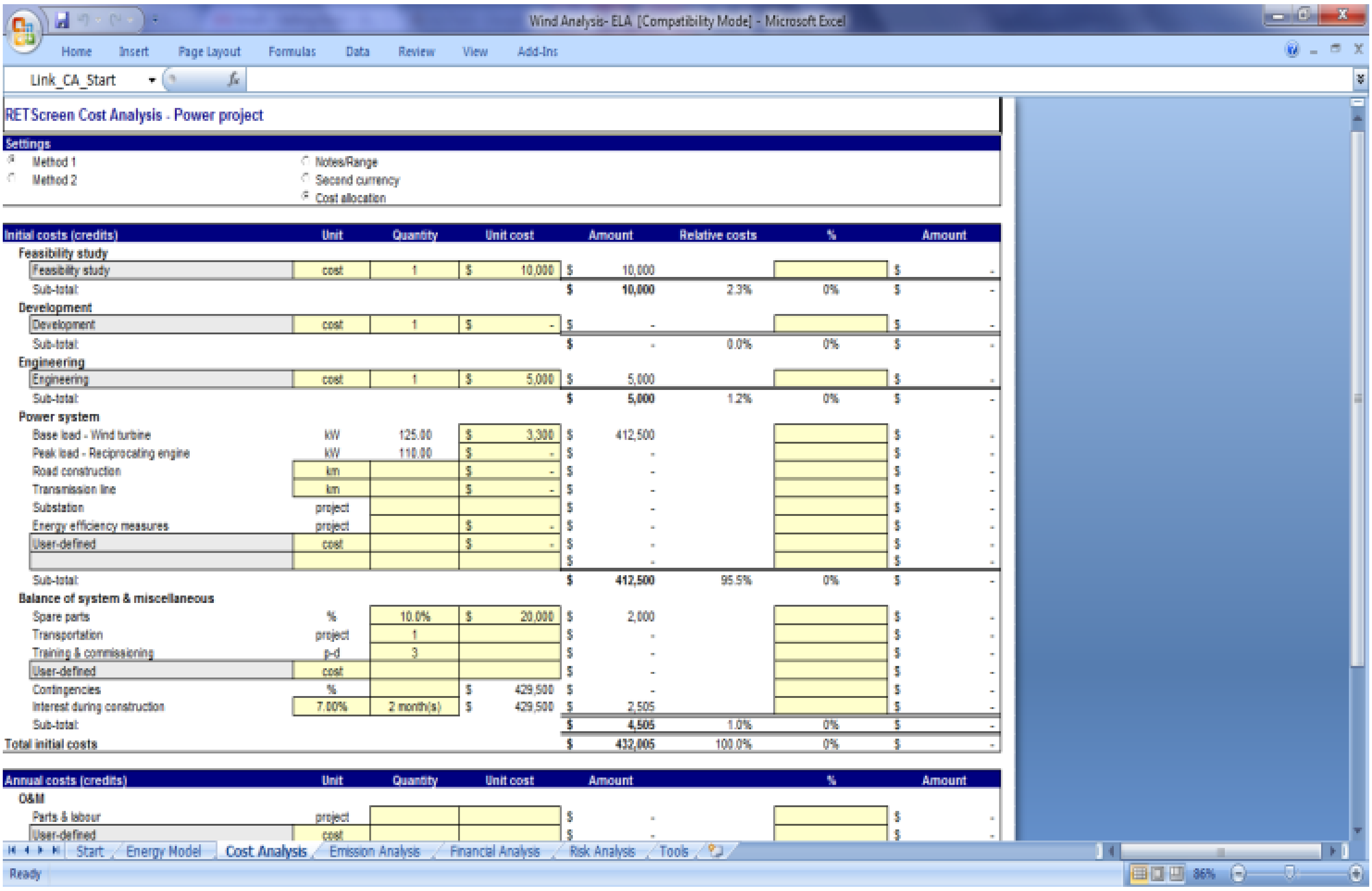
☑ **Show data**

Wind speed m/s	**Power curve data kW**	**Energy curve data MWh**
0	0	
1	0	
2	0	
3	0	13
4	0	47
5	4	99
6	11	163
7	20	231
8	30	297
9	41	359
10	52	414
11	63	461
12	73	499
13	81	529
14	89	551
15	95	566
16	99	
17	101	
18	99	
19	97	
20	93	
21	89	
22	87	
23	89	
24	92	
25 - 30	97	

Array losses	%	0%
Airfoil losses	%	4%
Miscellaneous losses	%	3%
Availability	%	98%

☐ **Show data**

Cost Analysis:



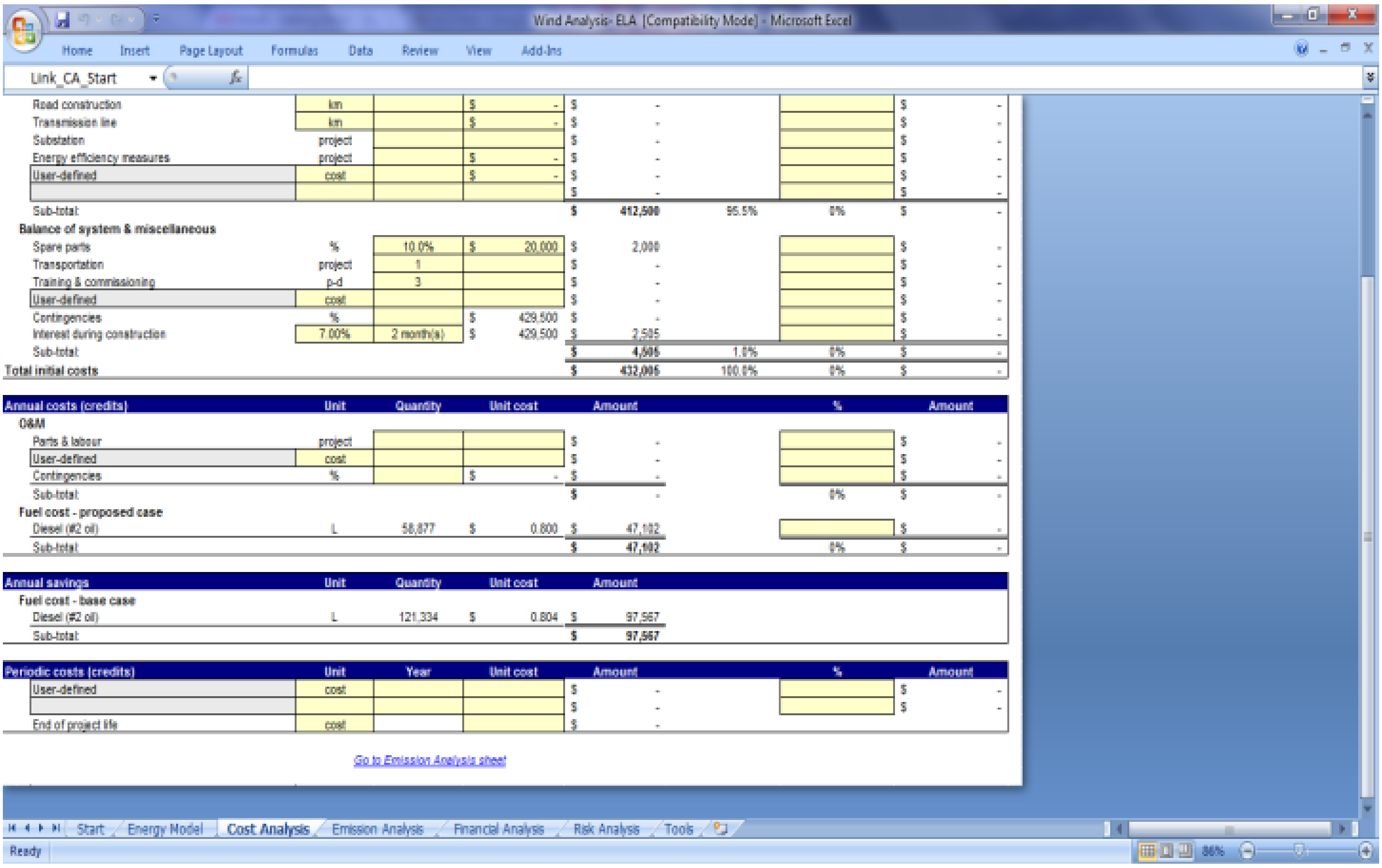
RETScreen Cost Analysis - Power project

Settings

● Method 1
○ Method 2
○ Notes/Range
○ Second currency
● Cost allocation

Initial costs (credits)	Unit	Quantity	Unit cost	Amount	Relative costs	%	Amount
Feasibility study							
Feasibility study	cost	1	$ 10,000	$ 10,000			$ -
Sub-total:				$ **10,000**	2.3%	0%	$ -
Development							
Development	cost	1	$ -	$ -			$ -
Sub-total:				$ -	0.0%	0%	$ -
Engineering							
Engineering	cost	1	$ 5,000	$ 5,000			$ -
Sub-total:				$ **5,000**	1.2%	0%	$ -
Power system							
Base load - Wind turbine	kW	125.00	$ 3,300	$ 412,500			$ -
Peak load - Reciprocating engine	kW	110.00	$ -	$ -			$ -
Road construction	km		$ -	$ -			$ -
Transmission line	km		$ -	$ -			$ -
Substation	project			$ -			$ -
Energy efficiency measures	project		$ -	$ -			$ -
User-defined	cost		$ -	$ -			$ -
				$ -			$ -
Sub-total:				$ **412,500**	95.5%	0%	$ -
Balance of system & miscellaneous							
Spare parts	%	10.0%	$ 20,000	$ 2,000			$ -
Transportation	project	1		$ -			$ -
Training & commissioning	p-d	3		$ -			$ -
User-defined	cost			$ -			$ -
Contingencies	%		$ 429,500	$ -			$ -
Interest during construction	7.00%	2 month(s)	$ 429,500	$ 2,505			$ -
Sub-total:				$ **4,505**	1.0%	0%	$ -
Total initial costs				$ **432,005**	100.0%	0%	$ -

Annual costs (credits)	Unit	Quantity	Unit cost	Amount		%	Amount
O&M							
Parts & labour	project			$ -			$ -
User-defined	cost			$ -			$ -



Road construction	km		$ -	$ -			$ -
Transmission line	km		$ -	$ -			$ -
Substation	project			$ -			$ -
Energy efficiency measures	project		$ -	$ -			$ -
User-defined	cost		$ -	$ -			$ -
				$ -			$ -
Sub-total:				$ **412,500**	95.5%	0%	$ -
Balance of system & miscellaneous							
Spare parts	%	10.0%	$ 20,000	$ 2,000			$ -
Transportation	project	1		$ -			$ -
Training & commissioning	p-d	3		$ -			$ -
User-defined	cost			$ -			$ -
Contingencies	%		$ 429,500	$ -			$ -
Interest during construction	7.00%	2 month(s)	$ 429,500	$ 2,505			$ -
Sub-total:				$ **4,505**	1.0%	0%	$ -
Total initial costs				$ **432,005**	100.0%	0%	$ -

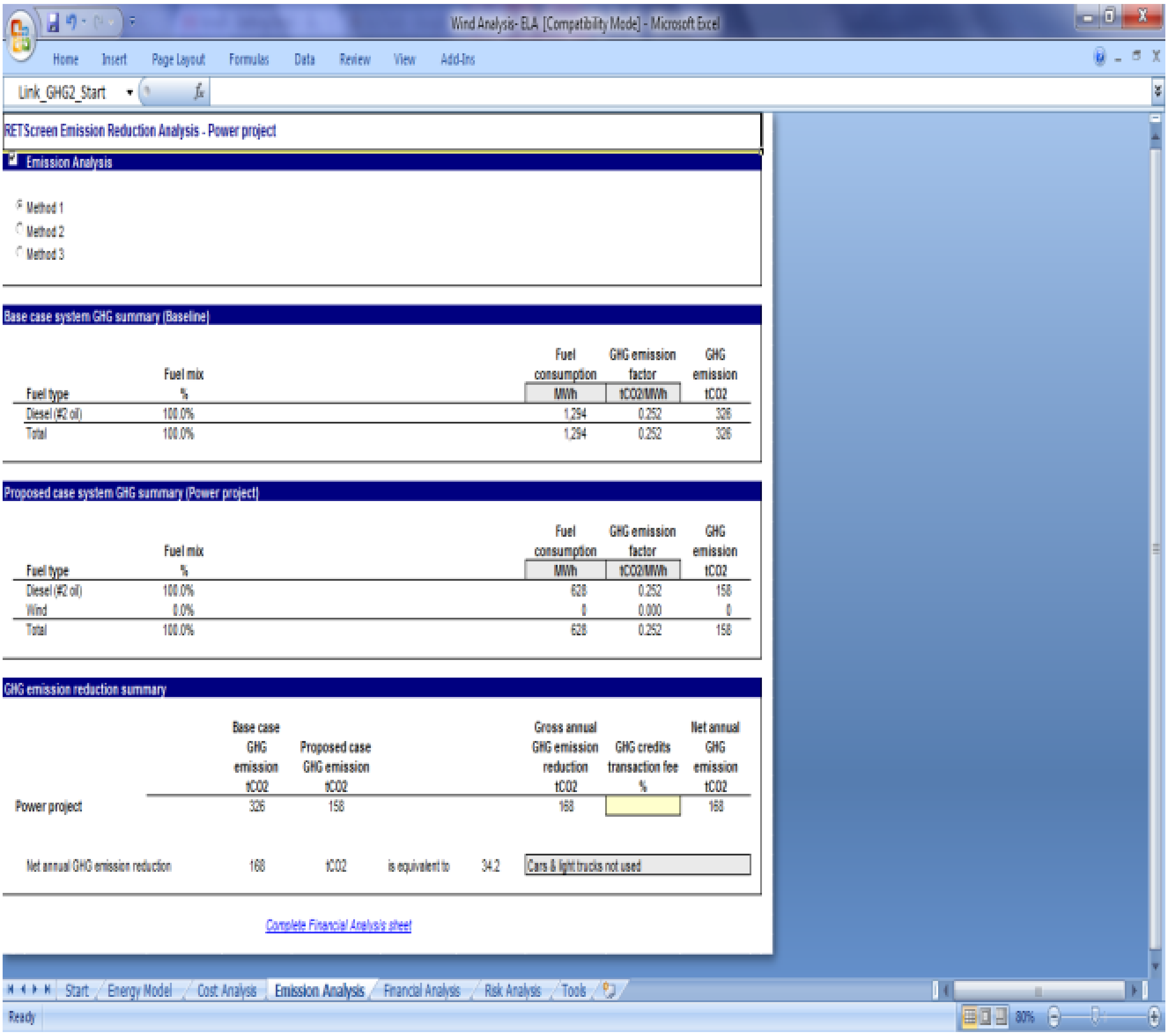
Annual costs (credits)	Unit	Quantity	Unit cost	Amount	%	Amount
O&M						
Parts & labour	project			$ -		$ -
User-defined	cost			$ -		$ -
Contingencies	%		$ -	$ -		$ -
Sub-total:				$ -	0%	$ -
Fuel cost - proposed case						
Diesel (#2 oil)	L	58,877	$ 0.800	$ 47,102		$ -
Sub-total:				$ **47,102**	0%	$ -

Annual savings	Unit	Quantity	Unit cost	Amount
Fuel cost - base case				
Diesel (#2 oil)	L	121,334	$ 0.804	$ 97,567
Sub-total:				$ **97,567**

Periodic costs (credits)	Unit	Year	Unit cost	Amount	%	Amount
User-defined	cost			$ -		$ -
				$ -		$ -
End of project life	cost			$ -		

Go to Emission Analysis sheet

GHG Emission Analysis:



RETScreen Emission Reduction Analysis - Power project

☑ Emission Analysis

● Method 1
○ Method 2
○ Method 3

Base case system GHG summary (Baseline)

Fuel type	Fuel mix %	Fuel consumption MWh	GHG emission factor tCO2/MWh	GHG emission tCO2
Diesel (#2 oil)	100.0%	1,294	0.252	326
Total	100.0%	1,294	0.252	326

Proposed case system GHG summary (Power project)

Fuel type	Fuel mix %	Fuel consumption MWh	GHG emission factor tCO2/MWh	GHG emission tCO2
Diesel (#2 oil)	100.0%	628	0.252	158
Wind	0.0%	0	0.000	0
Total	100.0%	628	0.252	158

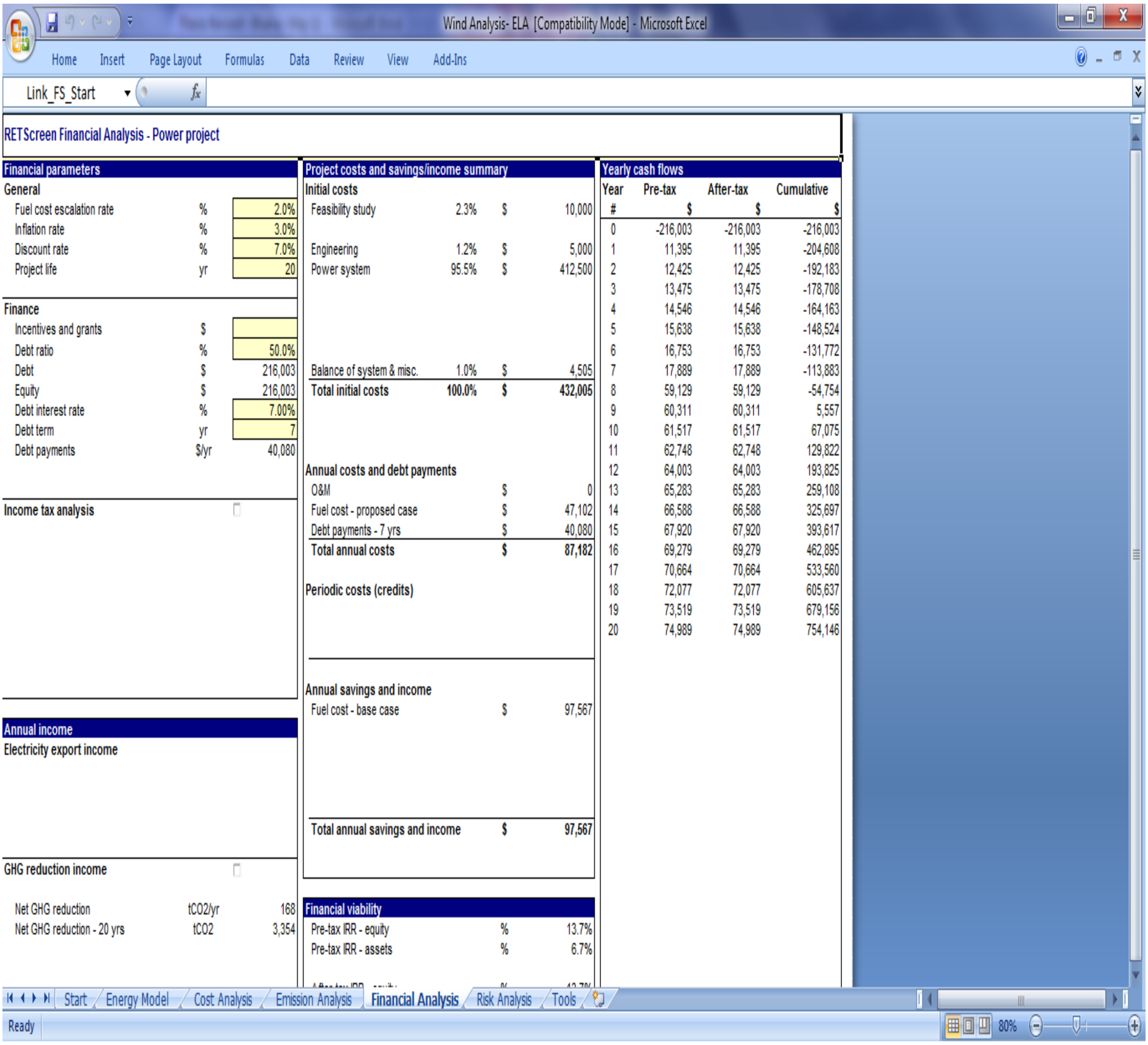
GHG emission reduction summary

	Base case GHG emission tCO2	Proposed case GHG emission tCO2	Gross annual GHG emission reduction tCO2	GHG credits transaction fee %	Net annual GHG emission tCO2
Power project	326	158	168		168

Net annual GHG emission reduction 168 tCO2 is equivalent to 34.2 Cars & light trucks not used

Complete Financial Analysis sheet

Financial Analysis:



RETScreen Financial Analysis - Power project

Financial parameters

General

Fuel cost escalation rate	%	2.0%
Inflation rate	%	3.0%
Discount rate	%	7.0%
Project life	yr	20

Finance

Incentives and grants	$	
Debt ratio	%	50.0%
Debt	$	216,003
Equity	$	216,003
Debt interest rate	%	7.00%
Debt term	yr	7
Debt payments	$/yr	40,080

Income tax analysis ☐

Annual income

Electricity export income

GHG reduction income ☐

Net GHG reduction	tCO2/yr	168
Net GHG reduction - 20 yrs	tCO2	3,354

Project costs and savings/income summary

Initial costs

Feasibility study	2.3%	$	10,000
Engineering	1.2%	$	5,000
Power system	95.5%	$	412,500
Balance of system & misc.	1.0%	$	4,505
Total initial costs	**100.0%**	**$**	**432,005**

Annual costs and debt payments

O&M	$	0
Fuel cost - proposed case	$	47,102
Debt payments - 7 yrs	$	40,080
Total annual costs	**$**	**87,182**

Periodic costs (credits)

Annual savings and income

Fuel cost - base case	$	97,567
Total annual savings and income	**$**	**97,567**

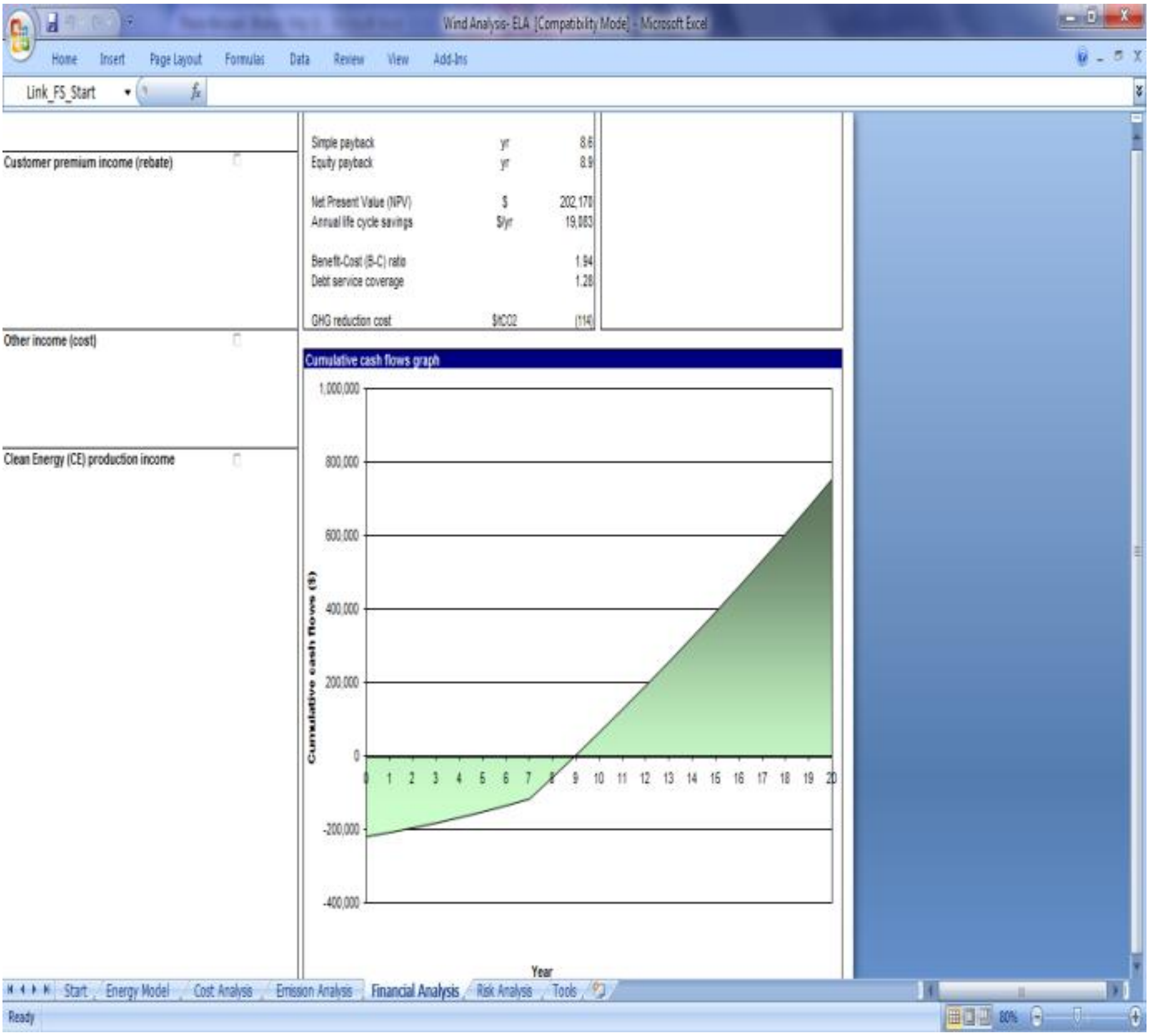
Financial viability

Pre-tax IRR - equity	%	13.7%
Pre-tax IRR - assets	%	6.7%

Yearly cash flows

Year #	Pre-tax $	After-tax $	Cumulative $
0	-216,003	-216,003	-216,003
1	11,395	11,395	-204,608
2	12,425	12,425	-192,183
3	13,475	13,475	-178,708
4	14,546	14,546	-164,163
5	15,638	15,638	-148,524
6	16,753	16,753	-131,772
7	17,889	17,889	-113,883
8	59,129	59,129	-54,754
9	60,311	60,311	5,557
10	61,517	61,517	67,075
11	62,748	62,748	129,822
12	64,003	64,003	193,825
13	65,283	65,283	259,108
14	66,588	66,588	325,697
15	67,920	67,920	393,617
16	69,279	69,279	462,895
17	70,664	70,664	533,560
18	72,077	72,077	605,637
19	73,519	73,519	679,156
20	74,989	74,989	754,146

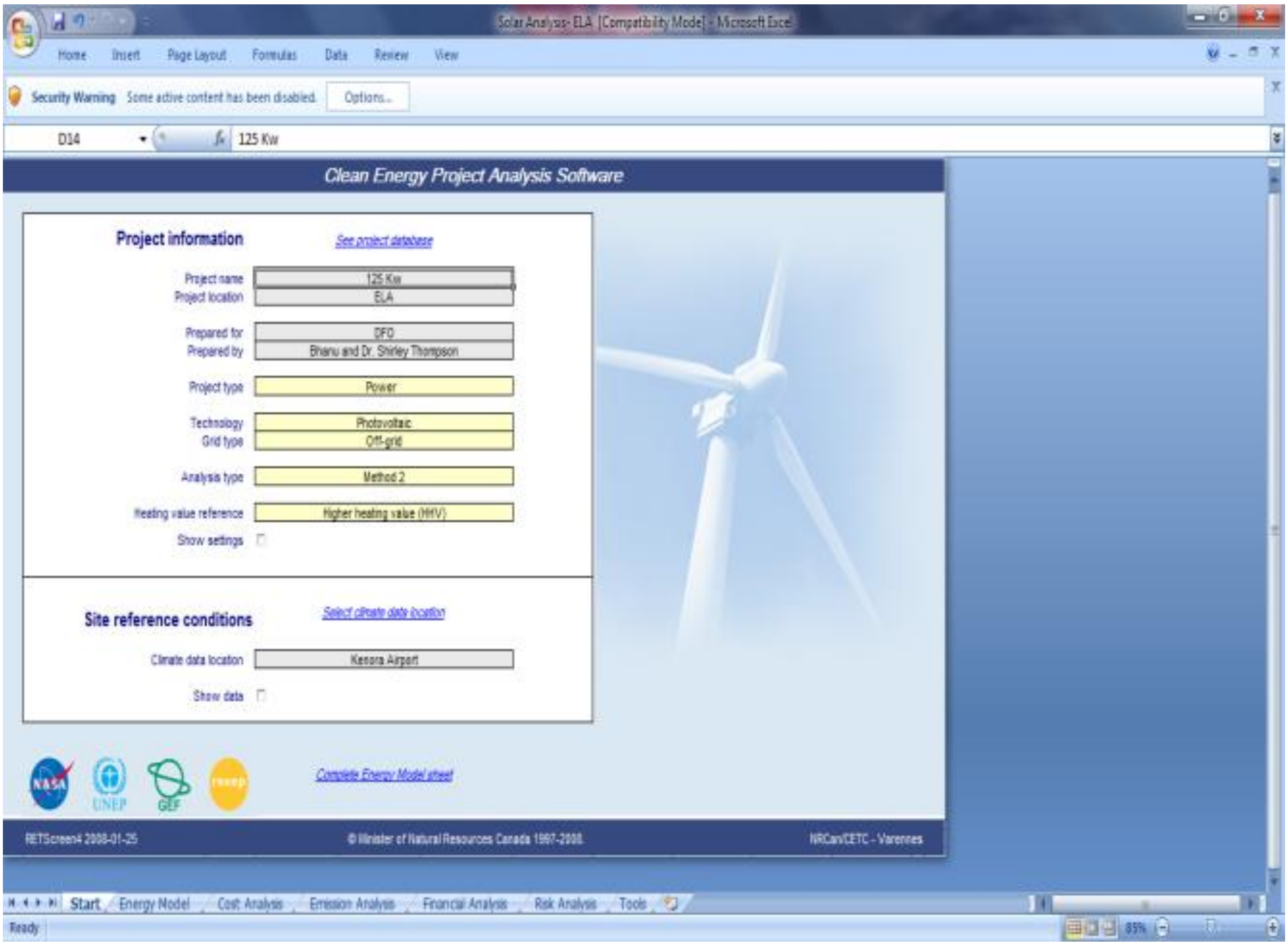
Financial Analysis:



Simple payback	yr	8.6
Equity payback	yr	8.9
Net Present Value (NPV)	$	202,178
Annual life cycle savings	$/yr	19,083
Benefit-Cost (B-C) ratio		1.94
Debt service coverage		1.28
GHG reduction cost	$/tCO2	(114)

RETScreen 4.0: Solar Analysis

Project Information:



125 Kw

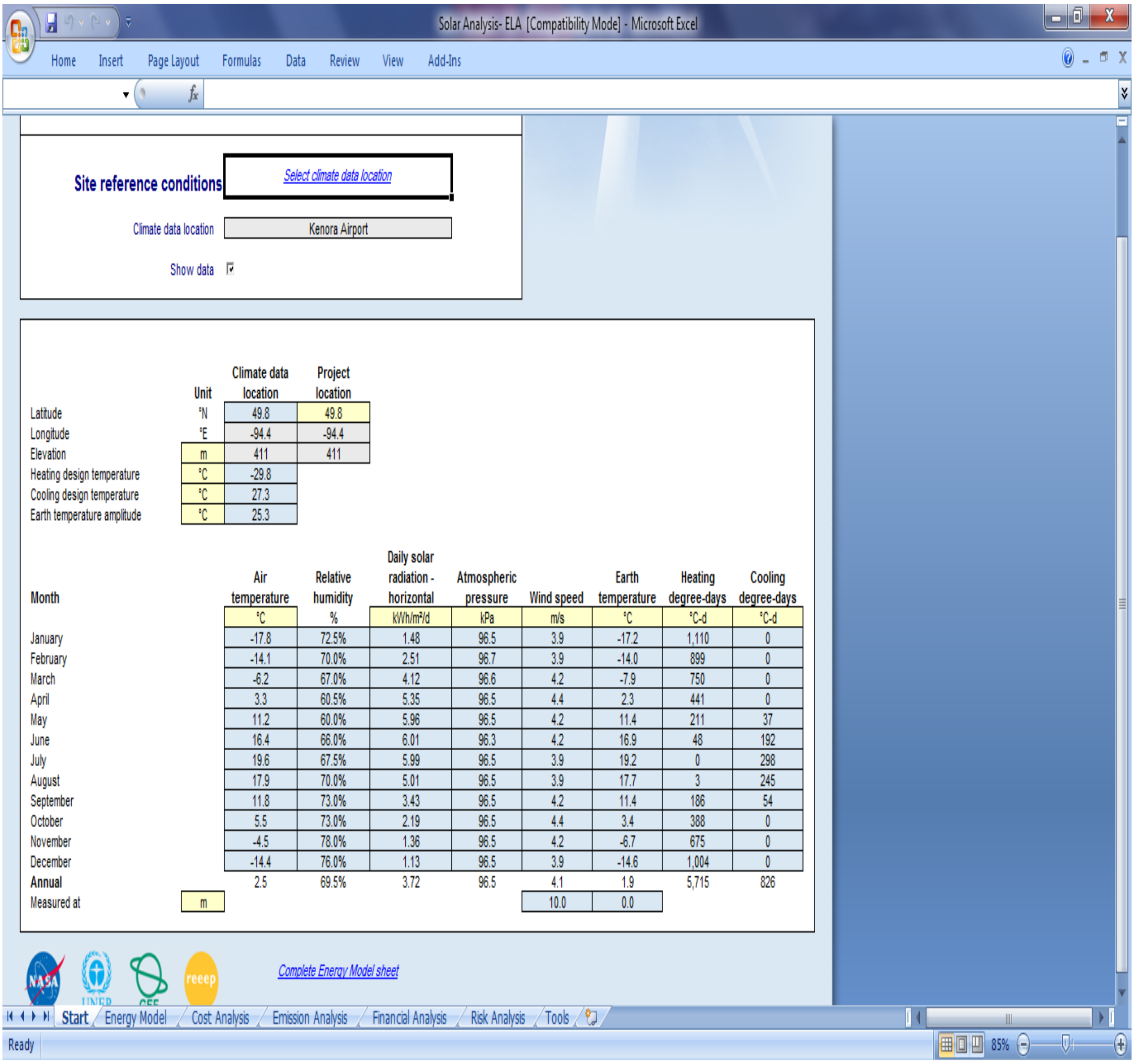
Project information

Project name: 125 Kw
Project location: ELA
Prepared for: DFO
Prepared by: Bhanu and Dr. Shirley Thompson
Project type: Power
Technology: Photovoltaic
Grid type: Off-grid
Analysis type: Method 2
Heating value reference: Higher heating value (HHV)
Show settings ☐

Site reference conditions

Climate data location: Kenora Airport
Show data ☐

Site Conditions:



Site reference conditions

Select climate data location

Climate data location: Kenora Airport

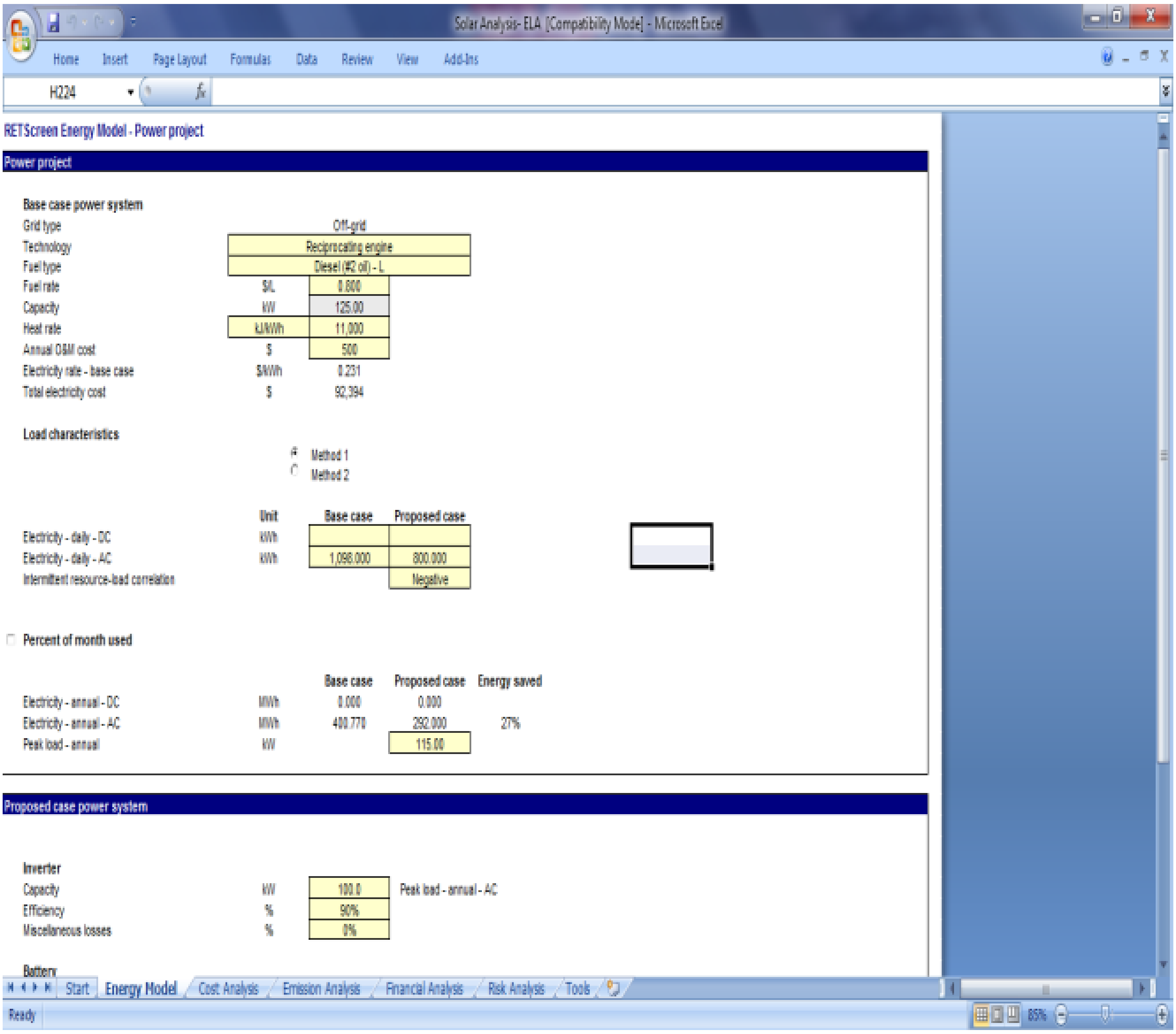
Show data ☑

	Unit	Climate data location	Project location
Latitude	°N	49.8	49.8
Longitude	°E	-94.4	-94.4
Elevation	m	411	411
Heating design temperature	°C	-29.8	
Cooling design temperature	°C	27.3	
Earth temperature amplitude	°C	25.3	

Month		Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
		°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January		-17.8	72.5%	1.48	96.5	3.9	-17.2	1,110	0
February		-14.1	70.0%	2.51	96.7	3.9	-14.0	899	0
March		-6.2	67.0%	4.12	96.6	4.2	-7.9	750	0
April		3.3	60.5%	5.35	96.5	4.4	2.3	441	0
May		11.2	60.0%	5.96	96.5	4.2	11.4	211	37
June		16.4	66.0%	6.01	96.3	4.2	16.9	48	192
July		19.6	67.5%	5.99	96.5	3.9	19.2	0	298
August		17.9	70.0%	5.01	96.5	3.9	17.7	3	245
September		11.8	73.0%	3.43	96.5	4.2	11.4	186	54
October		5.5	73.0%	2.19	96.5	4.4	3.4	388	0
November		-4.5	78.0%	1.36	96.5	4.2	-6.7	675	0
December		-14.4	76.0%	1.13	96.5	3.9	-14.6	1,004	0
Annual		2.5	69.5%	3.72	96.5	4.1	1.9	5,715	826
Measured at	m					10.0	0.0		

Complete Energy Model sheet

Power Project:



RETScreen Energy Model - Power project

Power project

Base case power system

Grid type		Off-grid
Technology		Reciprocating engine
Fuel type		Diesel (#2 oil) - L
Fuel rate	$/L	0.800
Capacity	kW	125.00
Heat rate	kJ/kWh	11,000
Annual O&M cost	$	500
Electricity rate - base case	$/MWh	0.231
Total electricity cost	$	92,394

Load characteristics

● Method 1
○ Method 2

	Unit	Base case	Proposed case
Electricity - daily - DC	kWh		
Electricity - daily - AC	kWh	1,098.000	800.000
Intermittent resource-load correlation			Negative

☐ **Percent of month used**

		Base case	Proposed case	Energy saved
Electricity - annual - DC	MWh	0.000	0.000	
Electricity - annual - AC	MWh	400.770	292.000	27%
Peak load - annual	kW		115.00	

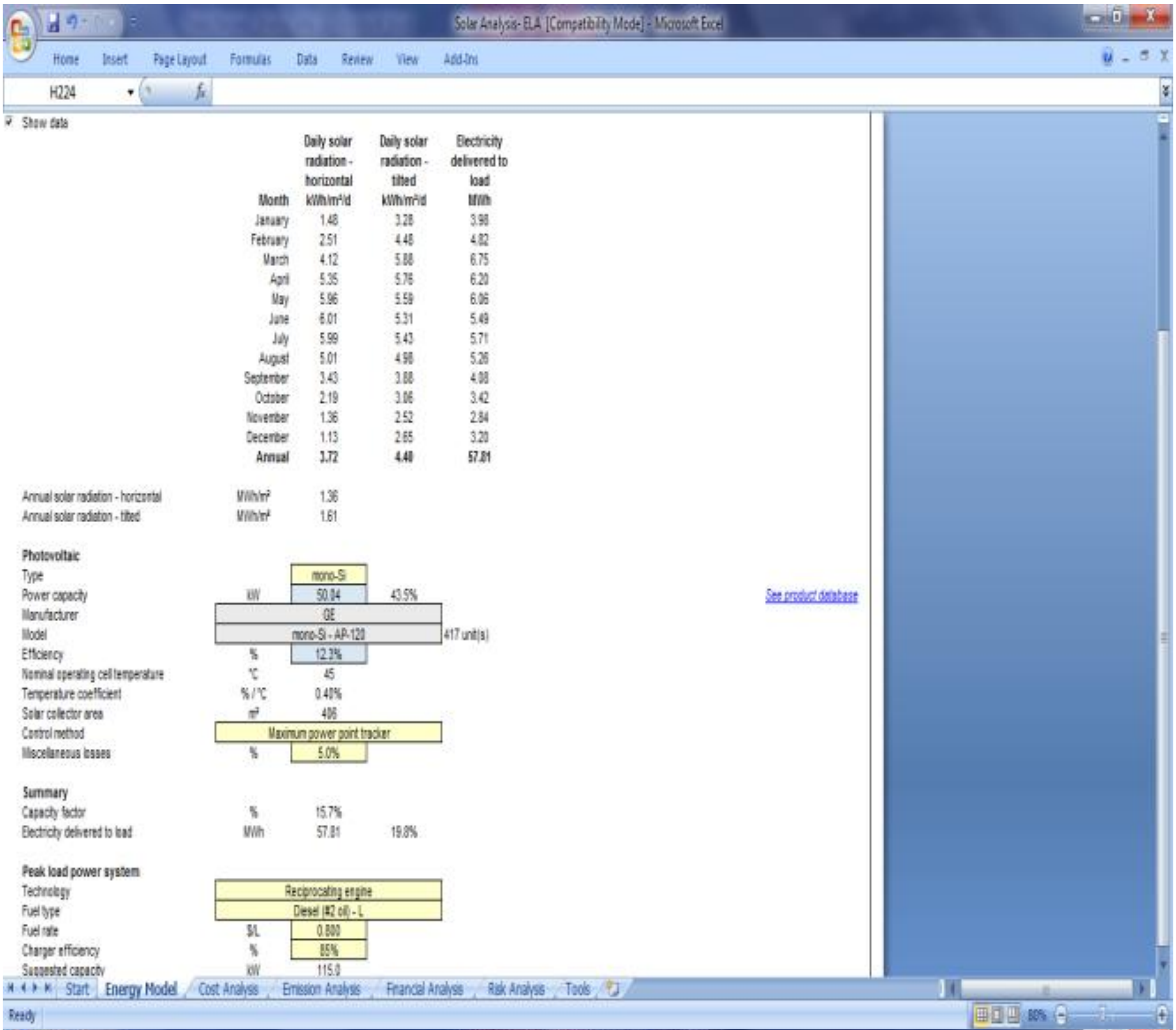
Proposed case power system

Inverter

Capacity	kW	100.0	Peak load - annual - AC
Efficiency	%	90%	
Miscellaneous losses	%	0%	

Battery

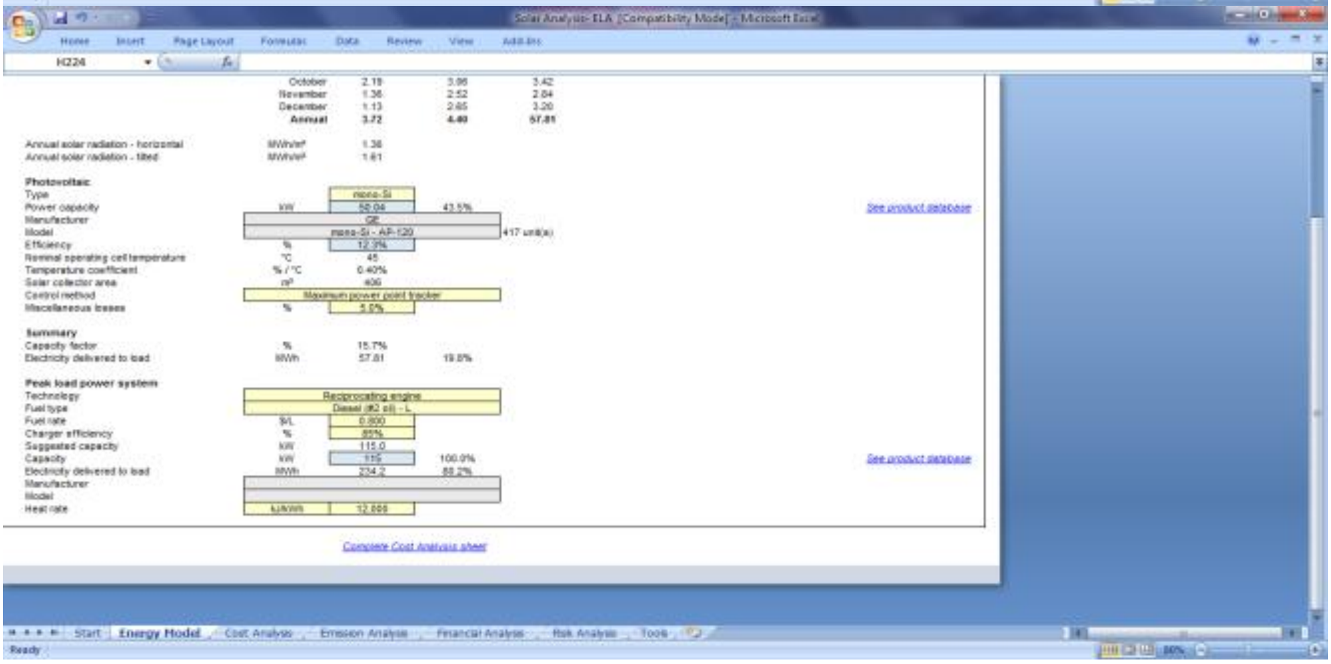
Proposed Case:



☑ Show data

Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity delivered to load MWh
January	1.48	3.28	3.98
February	2.51	4.48	4.82
March	4.12	5.88	6.75
April	5.35	5.76	6.20
May	5.96	5.59	6.06
June	6.01	5.31	5.49
July	5.99	5.43	5.71
August	5.01	4.98	5.26
September	3.43	3.88	4.08
October	2.19	3.06	3.42
November	1.36	2.52	2.84
December	1.13	2.65	3.20
Annual	**3.72**	**4.40**	**57.81**

Annual solar radiation - horizontal	MWh/m²	1.36		
Annual solar radiation - tilted	MWh/m²	1.61		
Photovoltaic				
Type		mono-Si		
Power capacity	kW	50.04	43.5%	See product database
Manufacturer		GE		
Model		mono-Si - AP-120	417 unit(s)	
Efficiency	%	12.3%		
Nominal operating cell temperature	°C	45		
Temperature coefficient	% / °C	0.40%		
Solar collector area	m²	406		
Control method		Maximum power point tracker		
Miscellaneous losses	%	5.0%		
Summary				
Capacity factor	%	15.7%		
Electricity delivered to load	MWh	57.81	19.8%	
Peak load power system				
Technology		Reciprocating engine		
Fuel type		Diesel (#2 oil) - L		
Fuel rate	$/L	0.800		
Charger efficiency	%	85%		
Suggested capacity	kW	115.0		

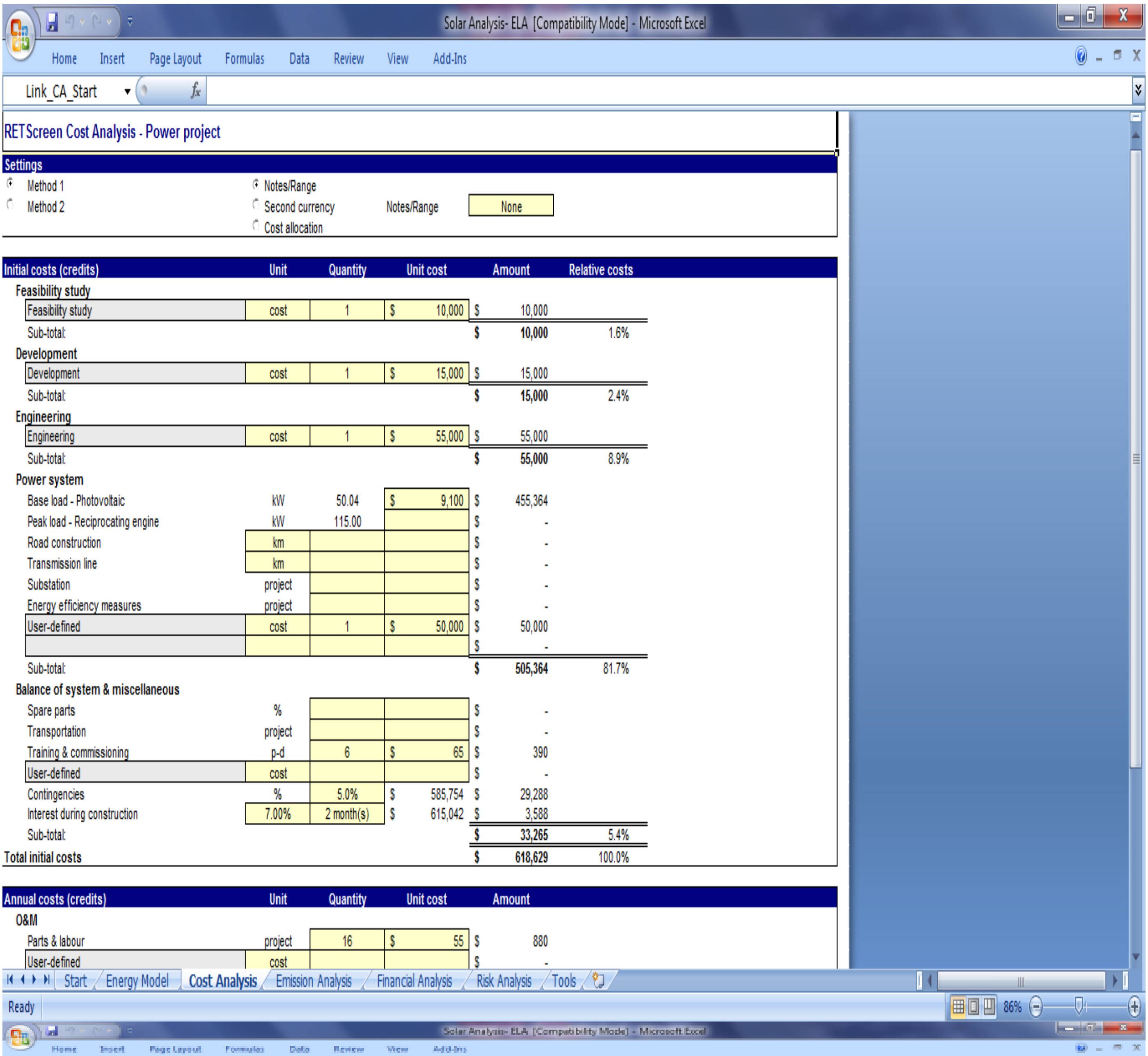


Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity delivered to load MWh
October	2.19	3.06	3.42
November	1.36	2.52	2.84
December	1.13	2.65	3.20
Annual	**3.72**	**4.40**	**57.81**

Annual solar radiation - horizontal	MWh/m²	1.36		
Annual solar radiation - tilted	MWh/m²	1.61		
Photovoltaic				
Type		mono-Si		
Power capacity	kW	50.04	43.5%	See product database
Manufacturer		GE		
Model		mono-Si - AP-120	417 unit(s)	
Efficiency	%	12.3%		
Nominal operating cell temperature	°C	45		
Temperature coefficient	% / °C	0.40%		
Solar collector area	m²	406		
Control method		Maximum power point tracker		
Miscellaneous losses	%	5.0%		
Summary				
Capacity factor	%	15.7%		
Electricity delivered to load	MWh	57.81	19.8%	
Peak load power system				
Technology		Reciprocating engine		
Fuel type		Diesel (#2 oil) - L		
Fuel rate	$/L	0.800		
Charger efficiency	%	85%		
Suggested capacity	kW	115.0		
Capacity	kW	115	100.0%	See product database
Electricity delivered to load	MWh	234.2	80.2%	
Manufacturer				
Model				
Heat rate	kJ/kWh	12,000		

Complete Cost Analysis sheet

Cost Analysis:



RETScreen Cost Analysis - Power project

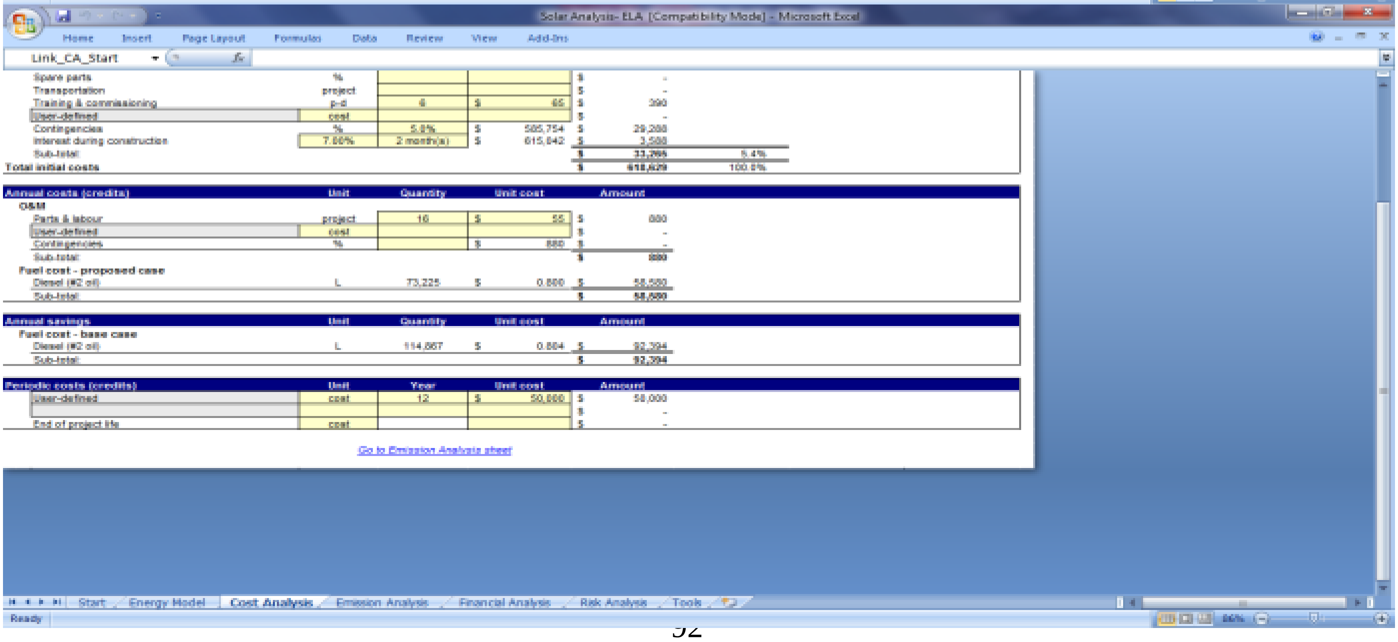
Settings

● Method 1
○ Method 2

● Notes/Range
○ Second currency
○ Cost allocation

Notes/Range: None

Initial costs (credits)	Unit	Quantity	Unit cost	Amount	Relative costs
Feasibility study					
Feasibility study	cost	1	$ 10,000	$ 10,000	
Sub-total:				$ 10,000	1.6%
Development					
Development	cost	1	$ 15,000	$ 15,000	
Sub-total:				$ 15,000	2.4%
Engineering					
Engineering	cost	1	$ 55,000	$ 55,000	
Sub-total:				$ 55,000	8.9%
Power system					
Base load - Photovoltaic	kW	50.04	$ 9,100	$ 455,364	
Peak load - Reciprocating engine	kW	115.00		$ -	
Road construction	km			$ -	
Transmission line	km			$ -	
Substation	project			$ -	
Energy efficiency measures	project			$ -	
User-defined	cost	1	$ 50,000	$ 50,000	
				$ -	
Sub-total:				$ 505,364	81.7%
Balance of system & miscellaneous					
Spare parts	%			$ -	
Transportation	project			$ -	
Training & commissioning	p-d	6	$ 65	$ 390	
User-defined	cost			$ -	
Contingencies	%	5.0%	$ 585,754	$ 29,288	
Interest during construction	7.00%	2 month(s)	$ 615,042	$ 3,588	
Sub-total:				$ 33,265	5.4%
Total initial costs				$ 618,629	100.0%



Spare parts	%			$ -	
Transportation	project			$ -	
Training & commissioning	p-d	6	$ 65	$ 390	
User-defined	cost			$ -	
Contingencies	%	5.0%	$ 585,754	$ 29,288	
Interest during construction	7.00%	2 month(s)	$ 615,042	$ 3,588	
Sub-total:				$ 33,265	5.4%
Total initial costs				$ 618,629	100.0%

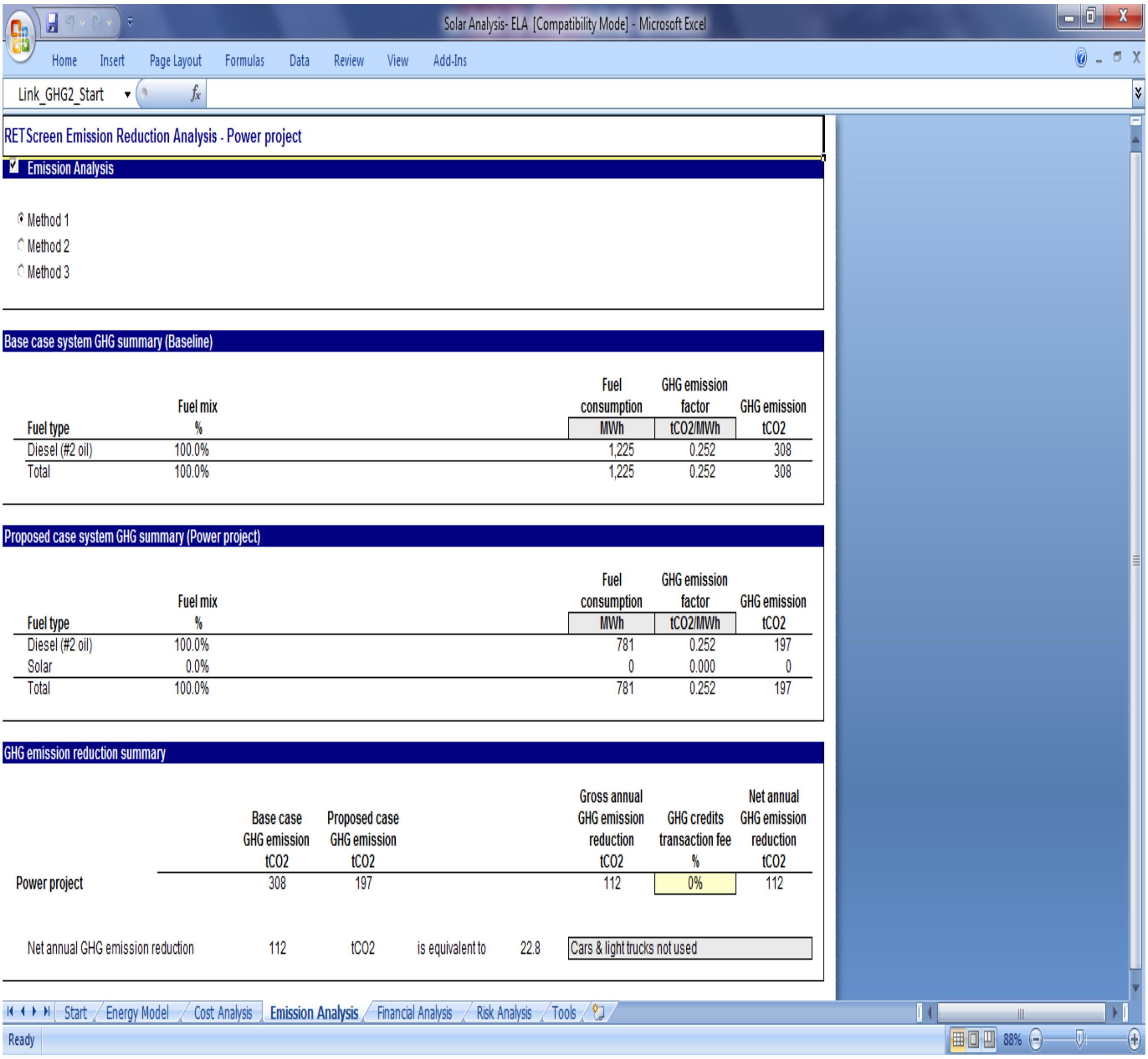
Annual costs (credits)	Unit	Quantity	Unit cost	Amount
O&M				
Parts & labour	project	16	$ 55	$ 880
User-defined	cost			$ -
Contingencies	%		$ 880	$ -
Sub-total:				$ 880
Fuel cost - proposed case				
Diesel (#2 oil)	L	73,225	$ 0.800	$ 58,580
Sub-total:				$ 58,580

Annual savings	Unit	Quantity	Unit cost	Amount
Fuel cost - base case				
Diesel (#2 oil)	L	114,867	$ 0.804	$ 92,354
Sub-total:				$ 92,354

Periodic costs (credits)	Unit	Year	Unit cost	Amount
User-defined	cost	12	$ 50,000	$ 50,000
				$ -
End of project life	cost			$ -

Go to Emission Analysis sheet

Emission Analysis:



RETScreen Emission Reduction Analysis - Power project

☑ Emission Analysis

● Method 1
○ Method 2
○ Method 3

Base case system GHG summary (Baseline)

Fuel type	Fuel mix %	Fuel consumption MWh	GHG emission factor tCO2/MWh	GHG emission tCO2
Diesel (#2 oil)	100.0%	1,225	0.252	308
Total	100.0%	1,225	0.252	308

Proposed case system GHG summary (Power project)

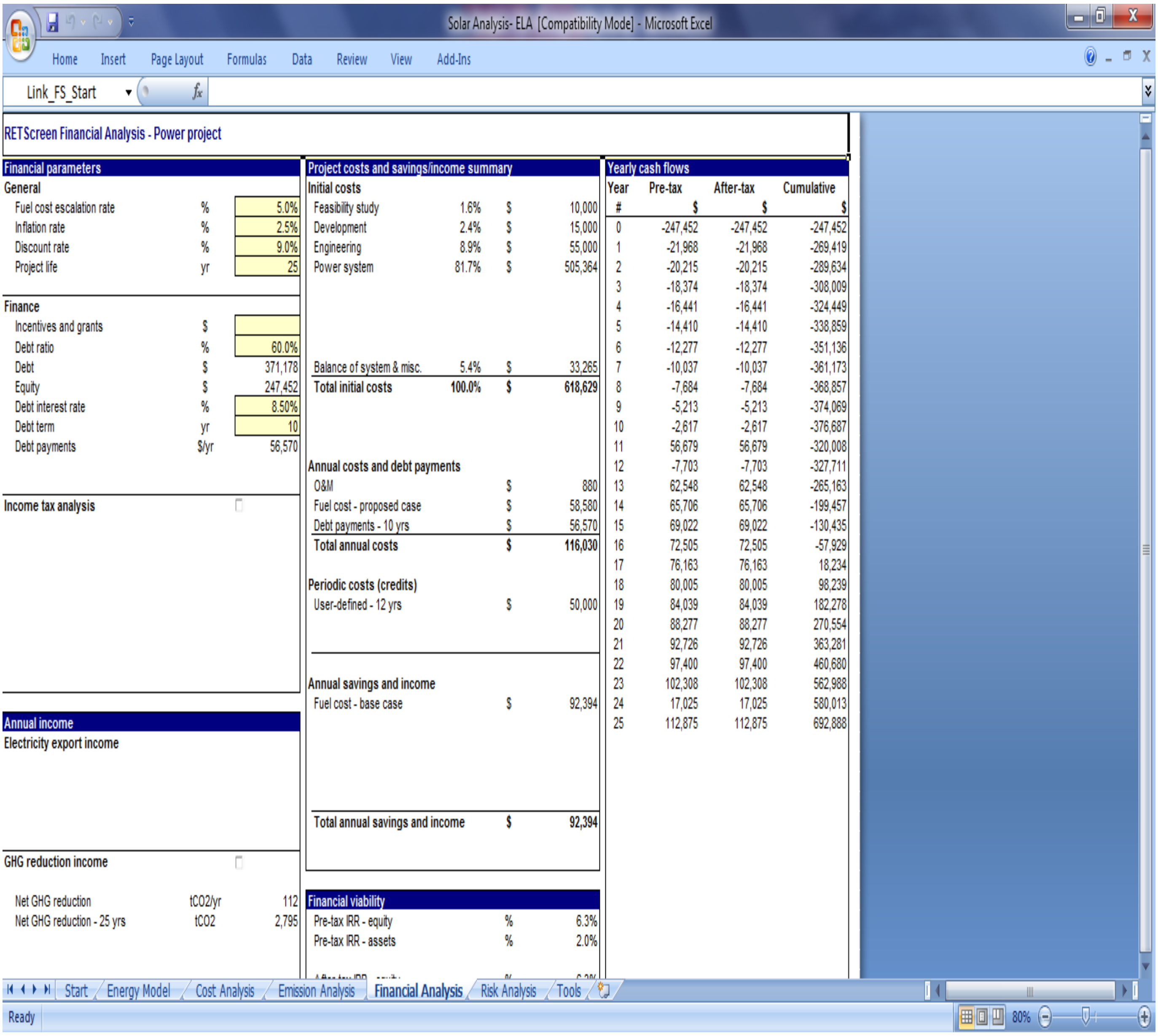
Fuel type	Fuel mix %	Fuel consumption MWh	GHG emission factor tCO2/MWh	GHG emission tCO2
Diesel (#2 oil)	100.0%	781	0.252	197
Solar	0.0%	0	0.000	0
Total	100.0%	781	0.252	197

GHG emission reduction summary

	Base case GHG emission tCO2	Proposed case GHG emission tCO2	Gross annual GHG emission reduction tCO2	GHG credits transaction fee %	Net annual GHG emission reduction tCO2
Power project	308	197	112	0%	112

Net annual GHG emission reduction 112 tCO2 is equivalent to 22.8 Cars & light trucks not used

Financial Analysis:



RETScreen Financial Analysis - Power project

Financial parameters

General		
Fuel cost escalation rate	%	5.0%
Inflation rate	%	2.5%
Discount rate	%	9.0%
Project life	yr	25
Finance		
Incentives and grants	$	
Debt ratio	%	60.0%
Debt	$	371,178
Equity	$	247,452
Debt interest rate	%	8.50%
Debt term	yr	10
Debt payments	$/yr	56,570
Income tax analysis ☐		

Annual income

Electricity export income

GHG reduction income ☐		
Net GHG reduction	tCO2/yr	112
Net GHG reduction - 25 yrs	tCO2	2,795

Project costs and savings/income summary

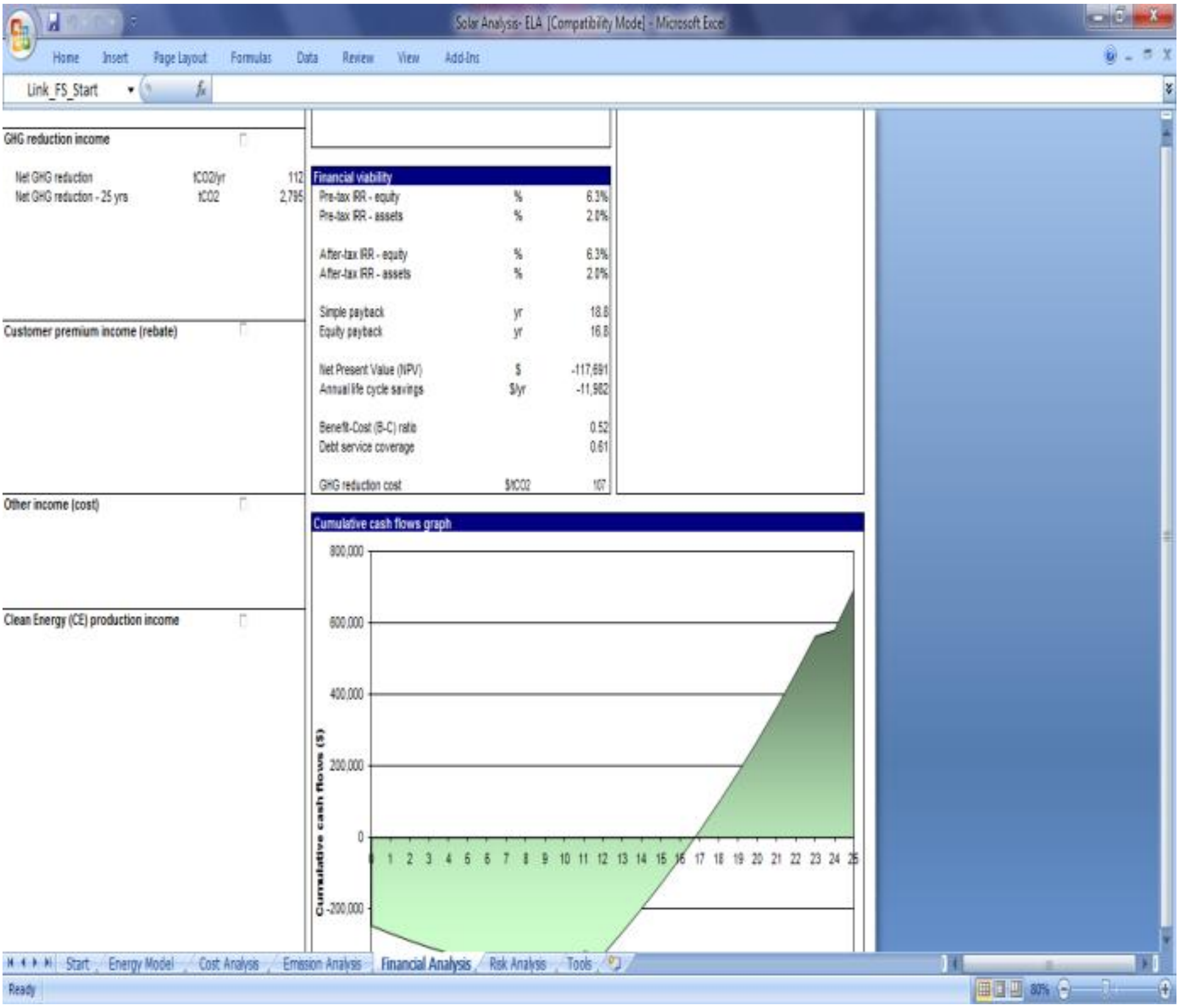
Initial costs			
Feasibility study	1.6%	$	10,000
Development	2.4%	$	15,000
Engineering	8.9%	$	55,000
Power system	81.7%	$	505,364
Balance of system & misc.	5.4%	$	33,265
Total initial costs	**100.0%**	**$**	**618,629**
Annual costs and debt payments			
O&M		$	880
Fuel cost - proposed case		$	58,580
Debt payments - 10 yrs		$	56,570
Total annual costs		**$**	**116,030**
Periodic costs (credits)			
User-defined - 12 yrs		$	50,000
Annual savings and income			
Fuel cost - base case		$	92,394
Total annual savings and income		**$**	**92,394**

Financial viability

Pre-tax IRR - equity	%	6.3%
Pre-tax IRR - assets	%	2.0%

Yearly cash flows

Year	Pre-tax	After-tax	Cumulative
#	$	$	$
0	-247,452	-247,452	-247,452
1	-21,968	-21,968	-269,419
2	-20,215	-20,215	-289,634
3	-18,374	-18,374	-308,009
4	-16,441	-16,441	-324,449
5	-14,410	-14,410	-338,859
6	-12,277	-12,277	-351,136
7	-10,037	-10,037	-361,173
8	-7,684	-7,684	-368,857
9	-5,213	-5,213	-374,069
10	-2,617	-2,617	-376,687
11	56,679	56,679	-320,008
12	-7,703	-7,703	-327,711
13	62,548	62,548	-265,163
14	65,706	65,706	-199,457
15	69,022	69,022	-130,435
16	72,505	72,505	-57,929
17	76,163	76,163	18,234
18	80,005	80,005	98,239
19	84,039	84,039	182,278
20	88,277	88,277	270,554
21	92,726	92,726	363,281
22	97,400	97,400	460,680
23	102,308	102,308	562,988
24	17,025	17,025	580,013
25	112,875	112,875	692,888



GHG reduction income

Net GHG reduction	tCO2/yr	112
Net GHG reduction - 25 yrs	tCO2	2,795

Customer premium income (rebate)

Other income (cost)

Clean Energy (CE) production income

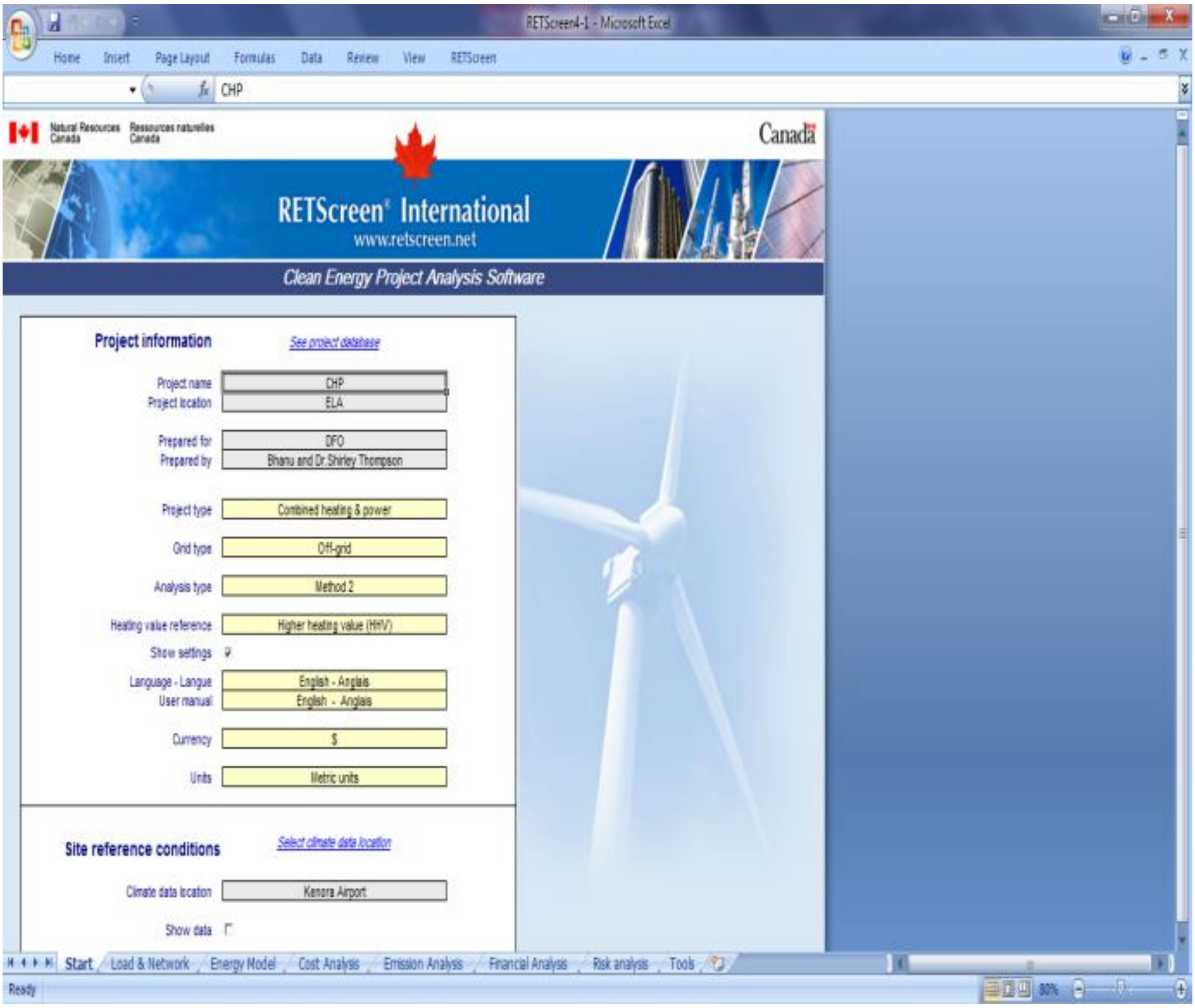
Financial viability

Pre-tax IRR - equity	%	6.3%
Pre-tax IRR - assets	%	2.0%
After-tax IRR - equity	%	6.3%
After-tax IRR - assets	%	2.0%
Simple payback	yr	18.8
Equity payback	yr	16.8
Net Present Value (NPV)	$	-117,691
Annual life cycle savings	$/yr	-11,982
Benefit-Cost (B-C) ratio		0.52
Debt service coverage		0.61
GHG reduction cost	$/tCO2	107

Cumulative cash flows graph

RETScreen 4.0: CHP Analysis

Project Information:



Project information

Project name: CHP
Project location: ELA

Prepared for: DFO
Prepared by: Bhanu and Dr.Shirley Thompson

Project type: Combined heating & power

Grid type: Off-grid

Analysis type: Method 2

Heating value reference: Higher heating value (HHV)
Show settings ☑

Language - Langue: English - Anglais
User manual: English - Anglais

Currency: $

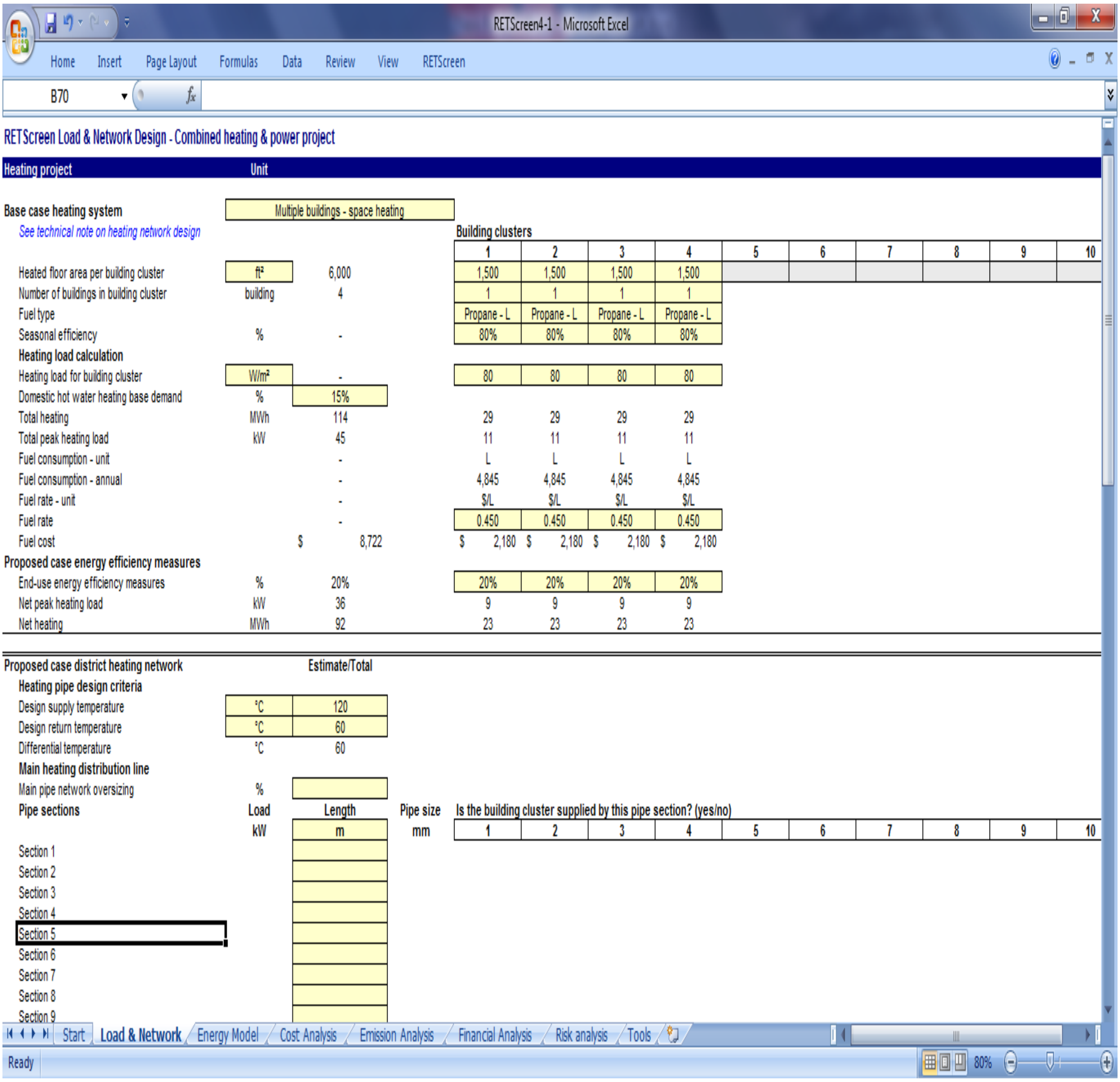
Units: Metric units

Site reference conditions

Climate data location: Kenora Airport

Show data ☐

Load and Network Design:

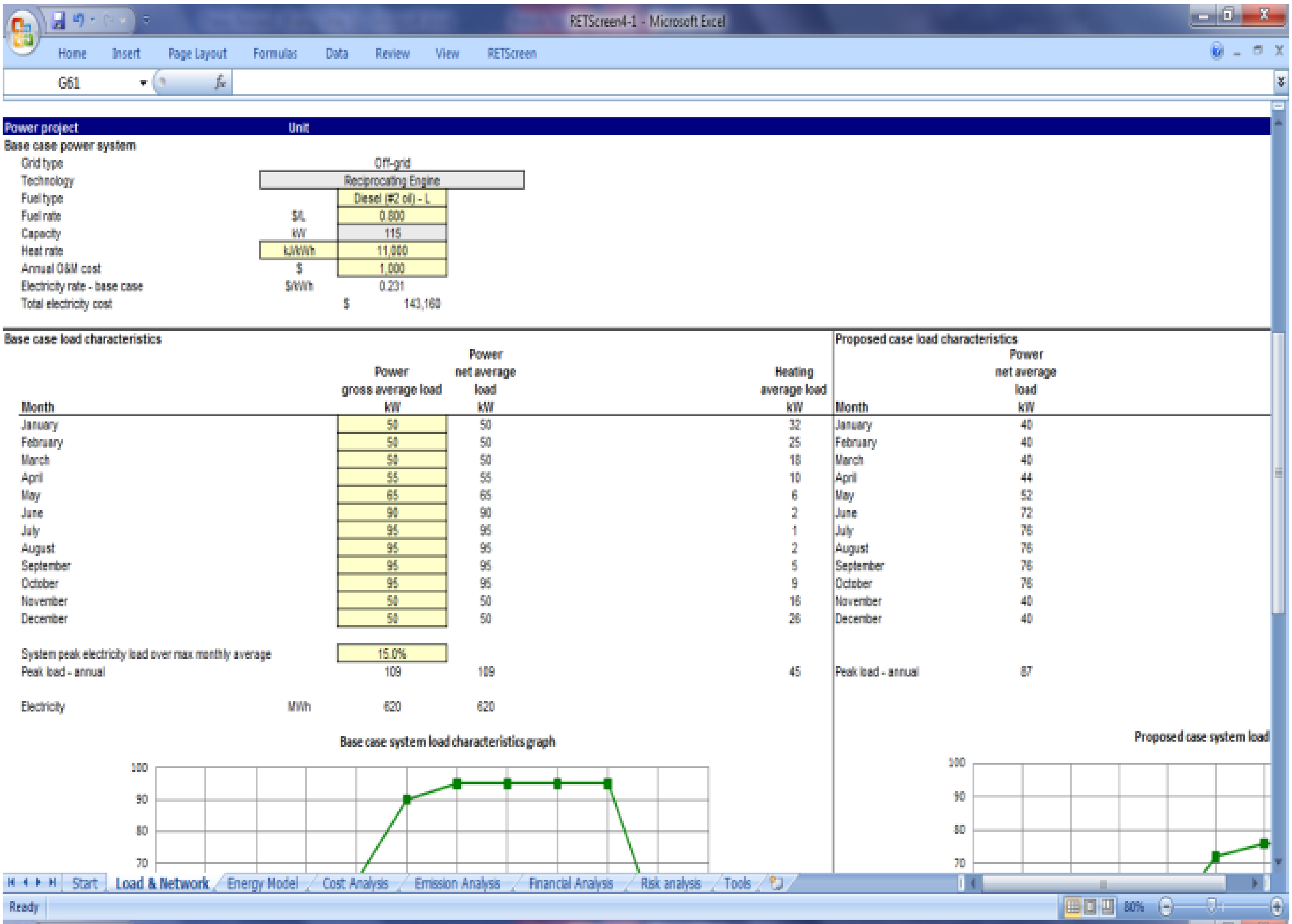


RETScreen Load & Network Design - Combined heating & power project

Heating project	Unit		1	2	3	4	5	6	7	8	9	10
Base case heating system	Multiple buildings - space heating											
See technical note on heating network design			Building clusters									
Heated floor area per building cluster	ft²	6,000	1,500	1,500	1,500	1,500						
Number of buildings in building cluster	building	4	1	1	1	1						
Fuel type			Propane - L	Propane - L	Propane - L	Propane - L						
Seasonal efficiency	%	-	80%	80%	80%	80%						
Heating load calculation												
Heating load for building cluster	W/m²	-	80	80	80	80						
Domestic hot water heating base demand	%	15%										
Total heating	MWh	114	29	29	29	29						
Total peak heating load	kW	45	11	11	11	11						
Fuel consumption - unit		-	L	L	L	L						
Fuel consumption - annual		-	4,845	4,845	4,845	4,845						
Fuel rate - unit		-	$/L	$/L	$/L	$/L						
Fuel rate		-	0.450	0.450	0.450	0.450						
Fuel cost	$	8,722	$ 2,180	$ 2,180	$ 2,180	$ 2,180						
Proposed case energy efficiency measures												
End-use energy efficiency measures	%	20%	20%	20%	20%	20%						
Net peak heating load	kW	36	9	9	9	9						
Net heating	MWh	92	23	23	23	23						

Proposed case district heating network		Estimate/Total											
Heating pipe design criteria													
Design supply temperature	°C	120											
Design return temperature	°C	60											
Differential temperature	°C	60											
Main heating distribution line													
Main pipe network oversizing	%												
Pipe sections	Load	Length	Pipe size	Is the building cluster supplied by this pipe section? (yes/no)									
	kW	m	mm	1	2	3	4	5	6	7	8	9	10
Section 1													
Section 2													
Section 3													
Section 4													
Section 5													
Section 6													
Section 7													
Section 8													
Section 9													

Power Project:



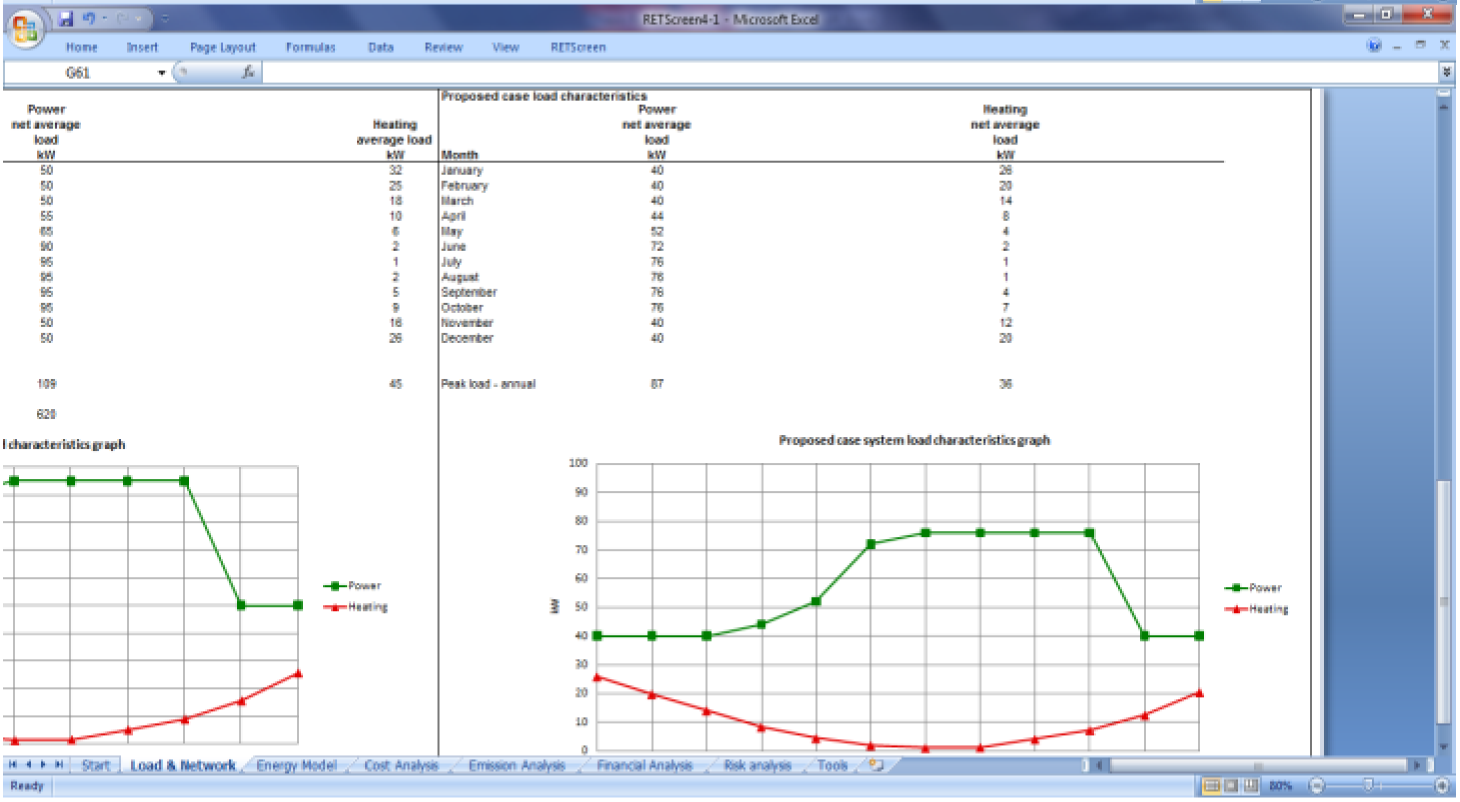
Power project	Unit	
Base case power system		
Grid type		Off-grid
Technology		Reciprocating Engine
Fuel type		Diesel (#2 oil) - L
Fuel rate	$/L	0.800
Capacity	kW	115
Heat rate	kJ/kWh	11,000
Annual O&M cost	$	1,000
Electricity rate - base case	$/kWh	0.231
Total electricity cost	$	143,160

Base case load characteristics

Month		Power gross average load kW	Power net average load kW	Heating average load kW
January		50	50	32
February		50	50	25
March		50	50	18
April		55	55	10
May		65	65	6
June		90	90	2
July		95	95	1
August		95	95	2
September		95	95	5
October		95	95	9
November		50	50	16
December		50	50	26
System peak electricity load over max monthly average		15.0%		
Peak load - annual		109	109	45
Electricity	MWh	620	620	

Proposed case load characteristics

Month	Power net average load kW
January	40
February	40
March	40
April	44
May	52
June	72
July	76
August	76
September	76
October	76
November	40
December	40
Peak load - annual	87

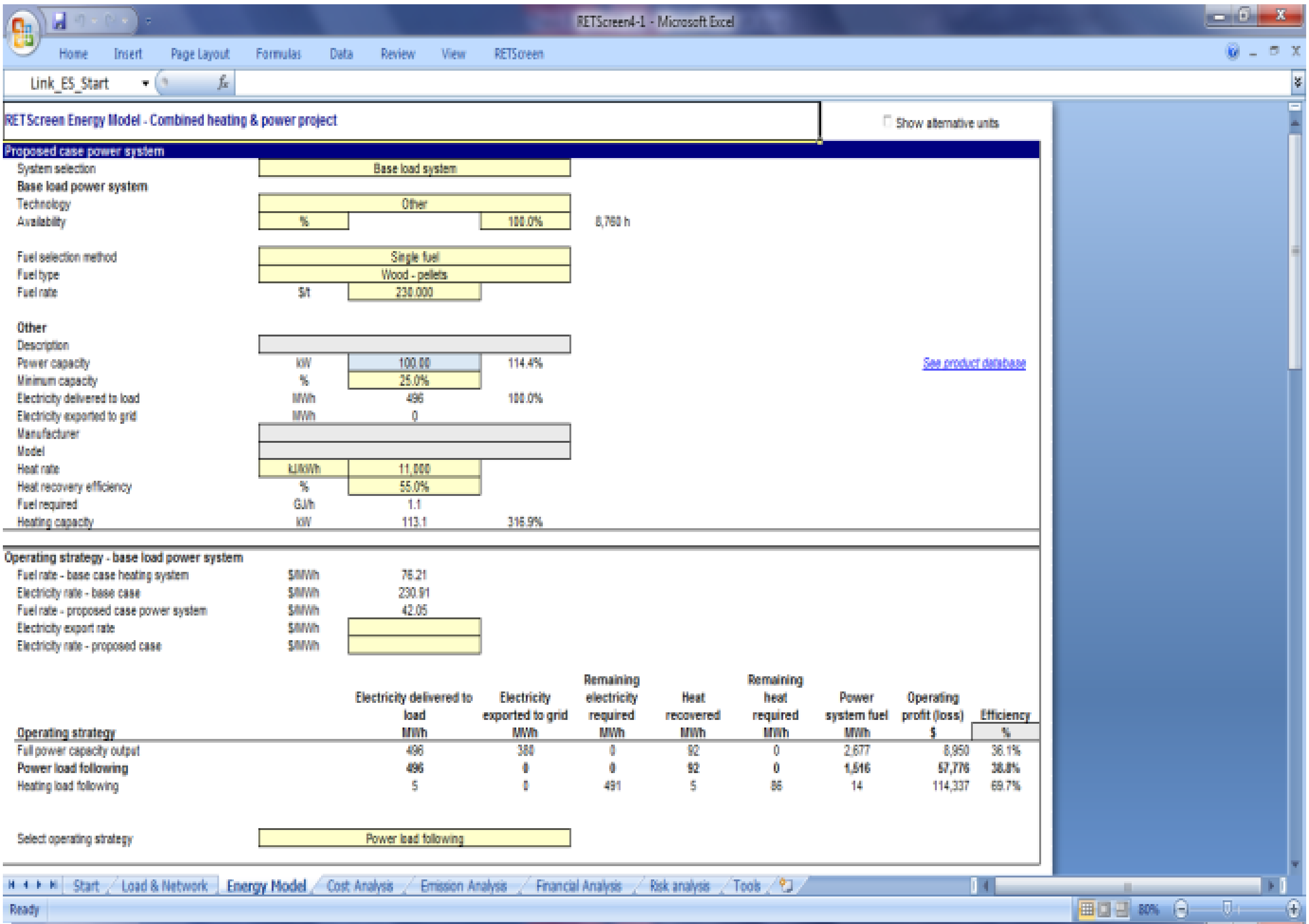


Power net average load kW	Heating average load kW
50	32
50	25
50	18
55	10
65	6
90	2
95	1
95	2
95	5
95	9
50	16
50	26
109	45
620	

Proposed case load characteristics

Month	Power net average load kW	Heating net average load kW
January	40	26
February	40	20
March	40	14
April	44	8
May	52	4
June	72	2
July	76	1
August	76	1
September	76	4
October	76	7
November	40	12
December	40	20
Peak load - annual	87	36

Energy Model:



RETScreen Energy Model - Combined heating & power project

Proposed case power system

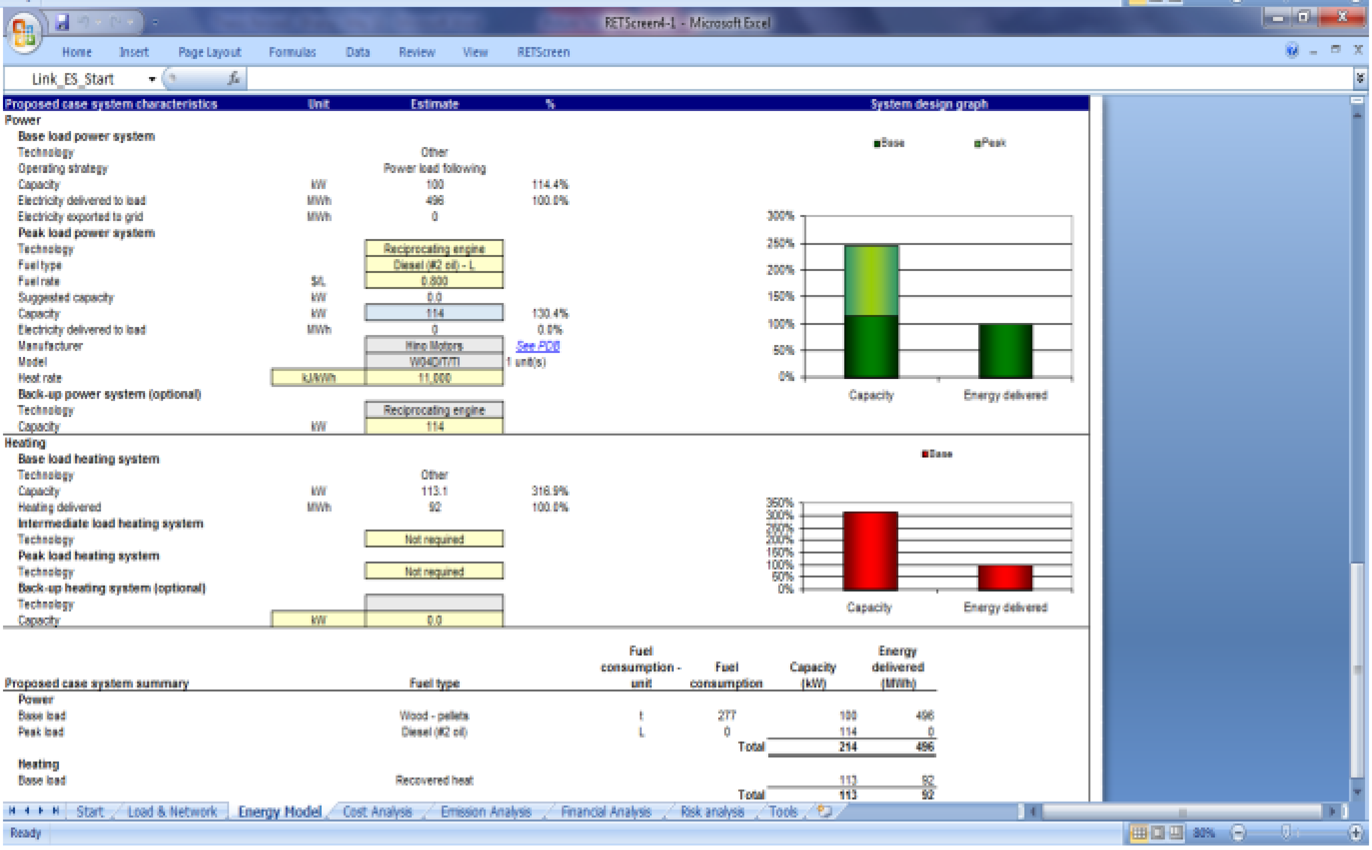
System selection		Base load system		
Base load power system				
Technology		Other		
Availability	%		100.0%	8,760 h
Fuel selection method		Single fuel		
Fuel type		Wood - pellets		
Fuel rate	$/t	230.000		
Other				
Description				
Power capacity	kW	100.00	114.4%	
Minimum capacity	%	25.0%		
Electricity delivered to load	MWh	496	100.0%	
Electricity exported to grid	MWh	0		
Manufacturer				
Model				
Heat rate	kJ/kWh	11,000		
Heat recovery efficiency	%	55.0%		
Fuel required	GJ/h	1.1		
Heating capacity	kW	113.1	316.9%	

Operating strategy - base load power system

Fuel rate - base case heating system	$/MWh	76.21
Electricity rate - base case	$/MWh	230.91
Fuel rate - proposed case power system	$/MWh	42.05
Electricity export rate	$/MWh	
Electricity rate - proposed case	$/MWh	

Operating strategy	Electricity delivered to load MWh	Electricity exported to grid MWh	Remaining electricity required MWh	Heat recovered MWh	Remaining heat required MWh	Power system fuel MWh	Operating profit (loss) $	Efficiency %
Full power capacity output	496	380	0	92	0	2,677	8,950	36.1%
Power load following	**496**	**0**	**0**	**92**	**0**	**1,616**	**57,776**	**38.8%**
Heating load following	5	0	491	5	86	14	114,337	69.7%

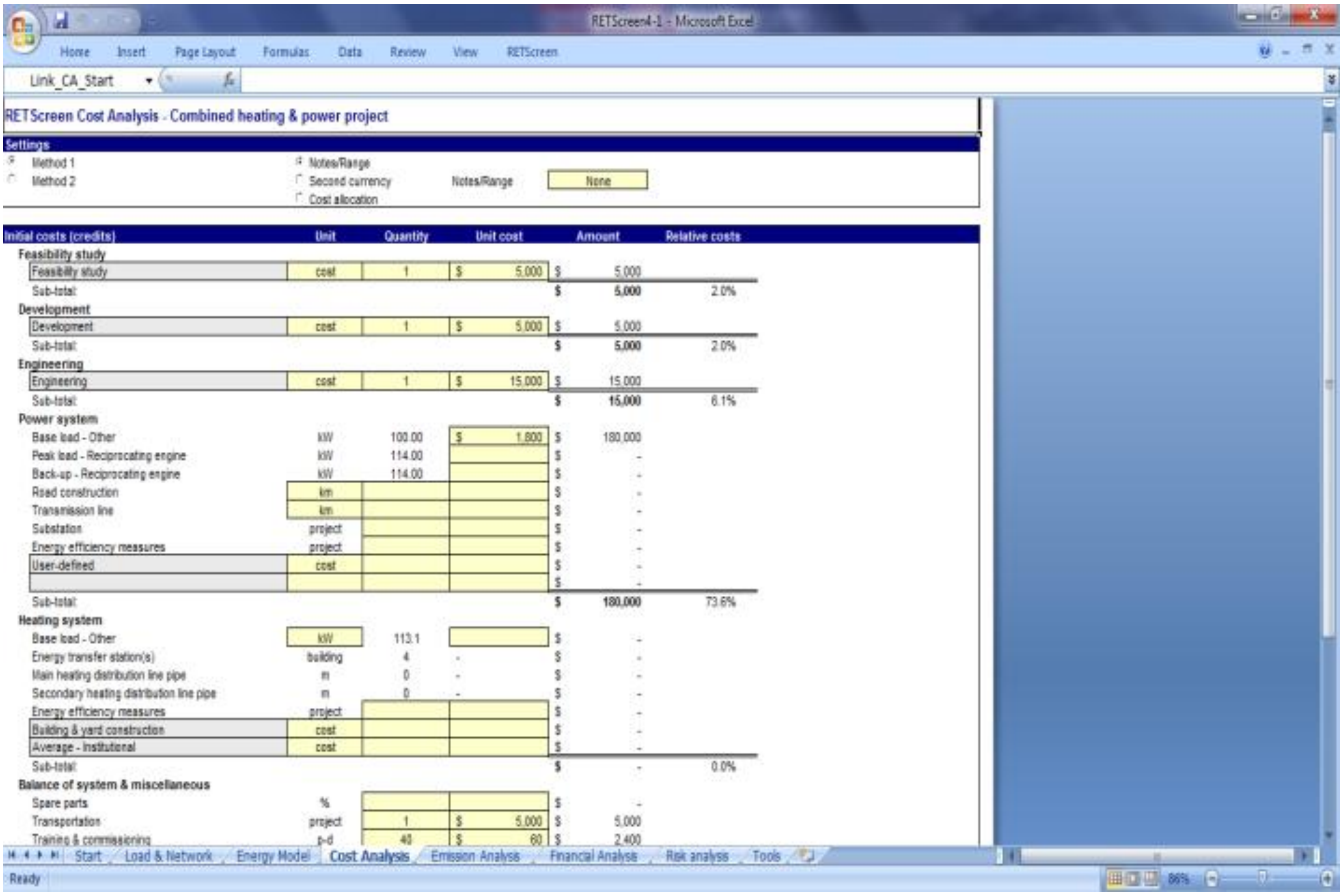
Select operating strategy: Power load following



Proposed case system characteristics	Unit	Estimate	%
Power			
Base load power system			
Technology		Other	
Operating strategy		Power load following	
Capacity	kW	100	114.4%
Electricity delivered to load	MWh	496	100.0%
Electricity exported to grid	MWh	0	
Peak load power system			
Technology		Reciprocating engine	
Fuel type		Diesel (#2 oil) - L	
Fuel rate	$/L	0.800	
Suggested capacity	kW	0.0	
Capacity	kW	114	130.4%
Electricity delivered to load	MWh	0	0.0%
Manufacturer		Hino Motors	See PDB
Model		W04D/T/TI	1 unit(s)
Heat rate	kJ/kWh	11,000	
Back-up power system (optional)			
Technology		Reciprocating engine	
Capacity	kW	114	
Heating			
Base load heating system			
Technology		Other	
Capacity	kW	113.1	316.9%
Heating delivered	MWh	92	100.0%
Intermediate load heating system			
Technology		Not required	
Peak load heating system			
Technology		Not required	
Back-up heating system (optional)			
Technology			
Capacity	kW	0.0	

Proposed case system summary	Fuel type	Fuel consumption - unit	Fuel consumption	Capacity (kW)	Energy delivered (MWh)
Power					
Base load	Wood - pellets	t	277	100	496
Peak load	Diesel (#2 oil)	L	0	114	0
			Total	214	496
Heating					
Base load	Recovered heat			113	92
			Total	113	92

Cost Analysis:



RETScreen Cost Analysis - Combined heating & power project

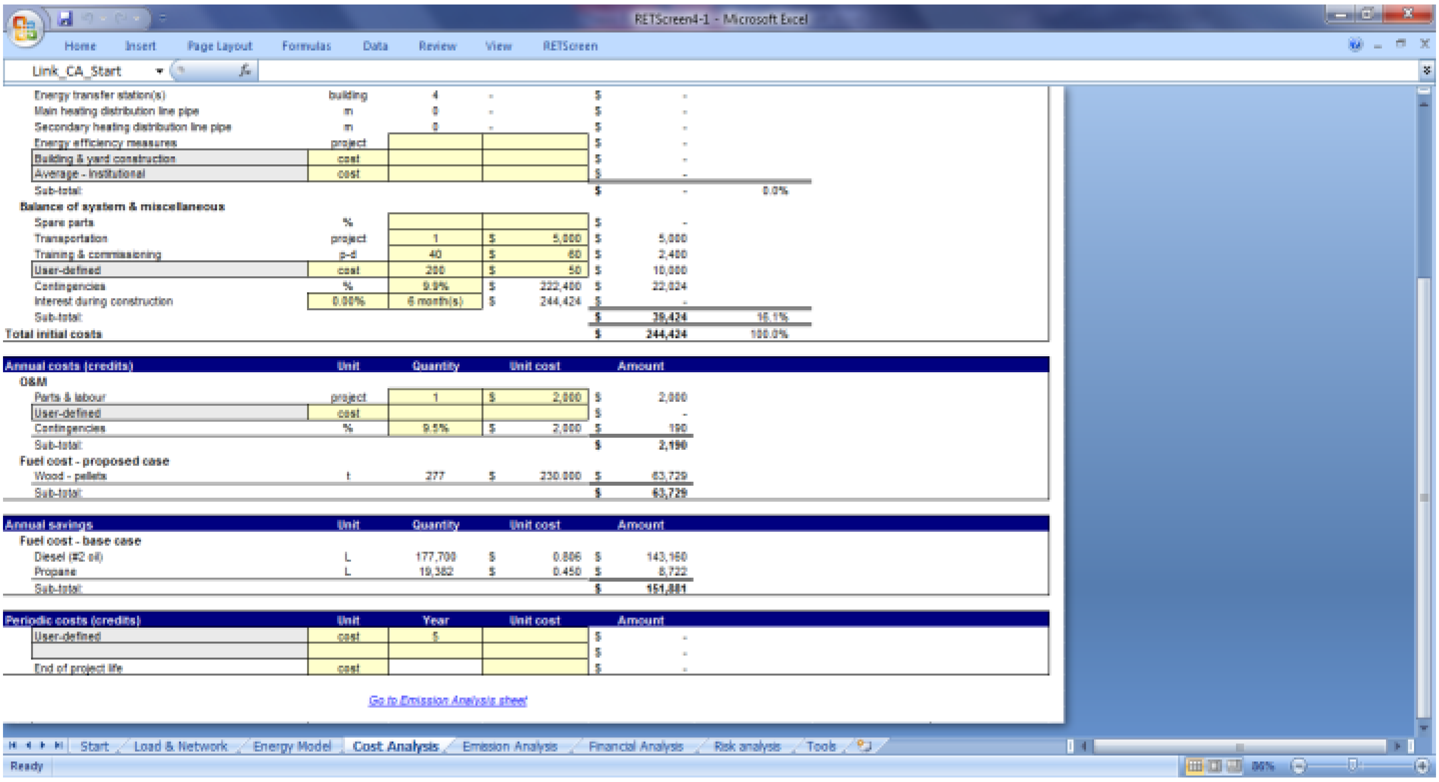
Settings

● Method 1
○ Method 2

● Notes/Range
○ Second currency
○ Cost allocation

Notes/Range: None

Initial costs (credits)	Unit	Quantity	Unit cost	Amount	Relative costs
Feasibility study					
Feasibility study	cost	1	$ 5,000	$ 5,000	
Sub-total:				**$ 5,000**	2.0%
Development					
Development	cost	1	$ 5,000	$ 5,000	
Sub-total:				**$ 5,000**	2.0%
Engineering					
Engineering	cost	1	$ 15,000	$ 15,000	
Sub-total:				**$ 15,000**	6.1%
Power system					
Base load - Other	kW	100.00	$ 1,800	$ 180,000	
Peak load - Reciprocating engine	kW	114.00		$ -	
Back-up - Reciprocating engine	kW	114.00		$ -	
Road construction	km			$ -	
Transmission line	km			$ -	
Substation	project			$ -	
Energy efficiency measures	project			$ -	
User-defined	cost			$ -	
				$ -	
Sub-total:				**$ 180,000**	73.6%
Heating system					
Base load - Other	kW	113.1		$ -	
Energy transfer station(s)	building	4	-	$ -	
Main heating distribution line pipe	m	0	-	$ -	
Secondary heating distribution line pipe	m	0	-	$ -	
Energy efficiency measures	project			$ -	
Building & yard construction	cost			$ -	
Average - Institutional	cost			$ -	
Sub-total:				$ -	0.0%
Balance of system & miscellaneous					
Spare parts	%			$ -	
Transportation	project	1	$ 5,000	$ 5,000	
Training & commissioning	p-d	40	$ 60	$ 2,400	



	Unit	Quantity	Unit cost	Amount	
Energy transfer station(s)	building	4	-	$ -	
Main heating distribution line pipe	m	0	-	$ -	
Secondary heating distribution line pipe	m	0	-	$ -	
Energy efficiency measures	project			$ -	
Building & yard construction	cost			$ -	
Average - Institutional	cost			$ -	
Sub-total:				$ -	0.0%
Balance of system & miscellaneous					
Spare parts	%			$ -	
Transportation	project	1	$ 5,000	$ 5,000	
Training & commissioning	p-d	40	$ 60	$ 2,400	
User-defined	cost	200	$ 50	$ 10,000	
Contingencies	%	9.9%	$ 222,400	$ 22,024	
Interest during construction	0.00%	6 month(s)	$ 244,424	$ -	
Sub-total:				**$ 39,424**	16.1%
Total initial costs				**$ 244,424**	100.0%

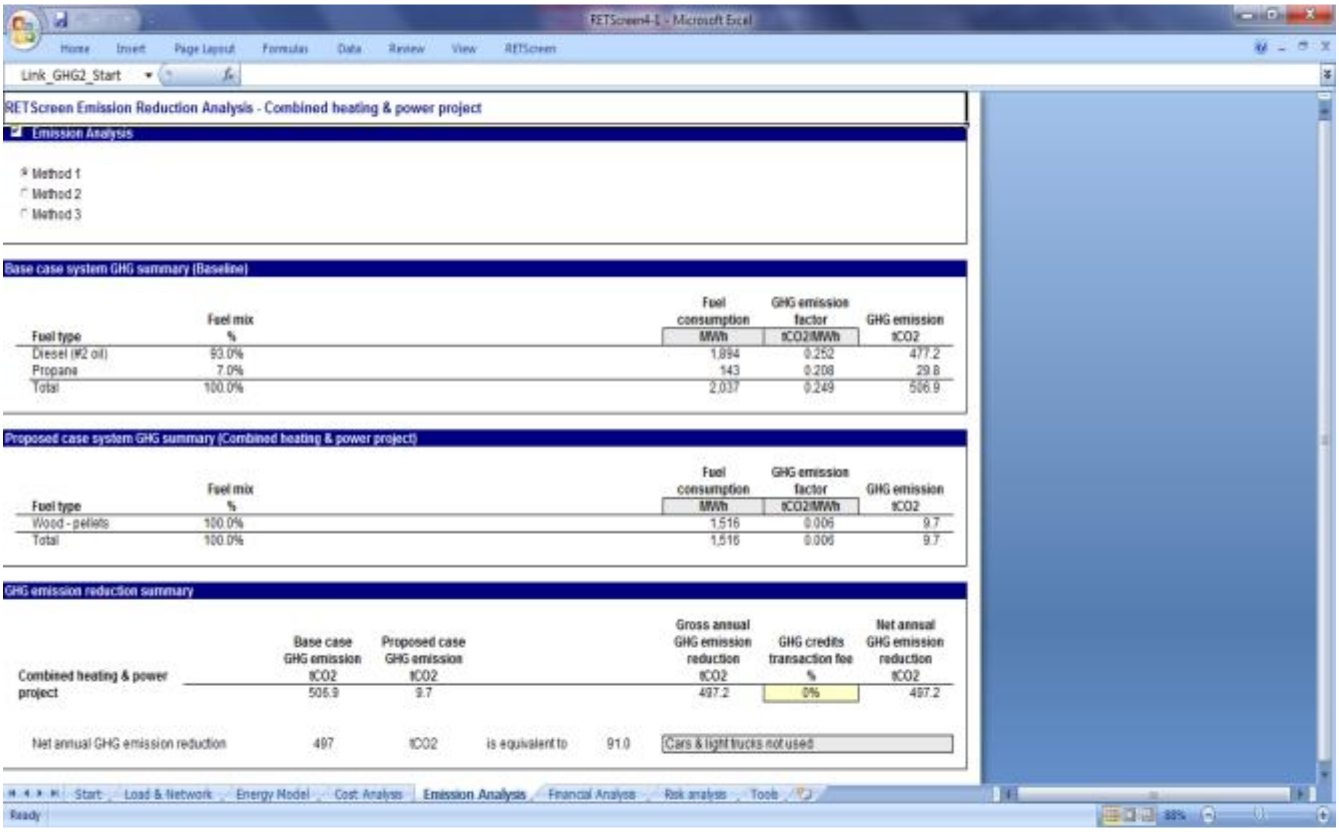
Annual costs (credits)	Unit	Quantity	Unit cost	Amount
O&M				
Parts & labour	project	1	$ 2,000	$ 2,000
User-defined	cost			$ -
Contingencies	%	9.5%	$ 2,000	$ 190
Sub-total:				**$ 2,190**
Fuel cost - proposed case				
Wood - pellets	t	277	$ 230.000	$ 63,729
Sub-total:				**$ 63,729**

Annual savings	Unit	Quantity	Unit cost	Amount
Fuel cost - base case				
Diesel (#2 oil)	L	177,700	$ 0.806	$ 143,160
Propane	L	19,382	$ 0.450	$ 8,722
Sub-total:				**$ 151,881**

Periodic costs (credits)	Unit	Year	Unit cost	Amount
User-defined	cost	5		$ -
				$ -
End of project life	cost			$ -

Go to Emission Analysis sheet

Emission Analysis:



RETScreen Emission Reduction Analysis - Combined heating & power project

☑ Emission Analysis

● Method 1
○ Method 2
○ Method 3

Base case system GHG summary (Baseline)

Fuel type	Fuel mix %	Fuel consumption MWh	GHG emission factor tCO2/MWh	GHG emission tCO2
Diesel (#2 oil)	93.0%	1,894	0.252	477.2
Propane	7.0%	143	0.208	29.8
Total	100.0%	2,037	0.249	506.9

Proposed case system GHG summary (Combined heating & power project)

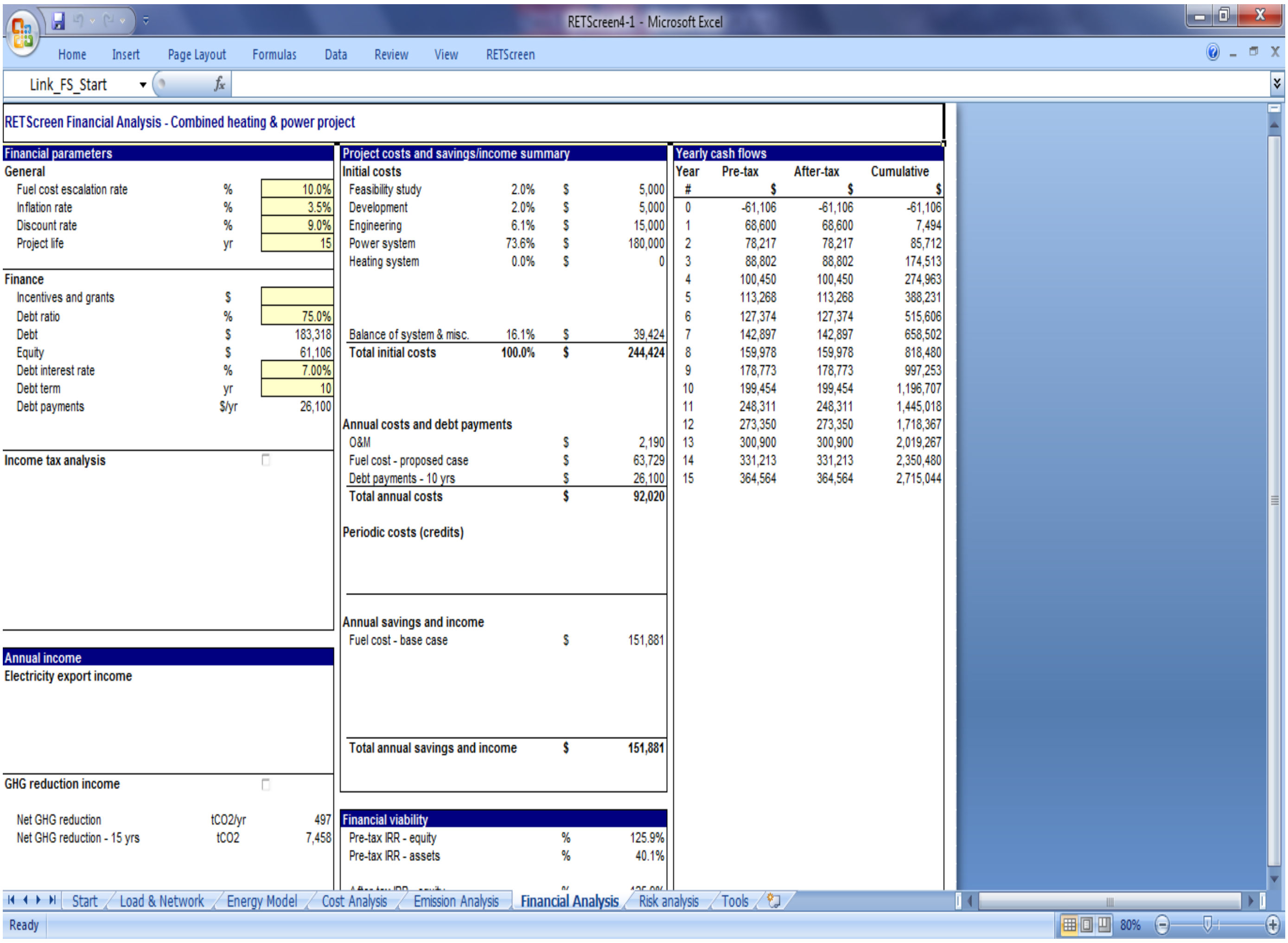
Fuel type	Fuel mix %	Fuel consumption MWh	GHG emission factor tCO2/MWh	GHG emission tCO2
Wood - pellets	100.0%	1,516	0.006	9.7
Total	100.0%	1,516	0.006	9.7

GHG emission reduction summary

	Base case GHG emission tCO2	Proposed case GHG emission tCO2	Gross annual GHG emission reduction tCO2	GHG credits transaction fee %	Net annual GHG emission reduction tCO2
Combined heating & power project	506.9	9.7	497.2	0%	497.2

Net annual GHG emission reduction 497 tCO2 is equivalent to 91.0 Cars & light trucks not used

Financial Analysis:



RETScreen Financial Analysis - Combined heating & power project

Financial parameters

General		
Fuel cost escalation rate	%	10.0%
Inflation rate	%	3.5%
Discount rate	%	9.0%
Project life	yr	15
Finance		
Incentives and grants	$	
Debt ratio	%	75.0%
Debt	$	183,318
Equity	$	61,106
Debt interest rate	%	7.00%
Debt term	yr	10
Debt payments	$/yr	26,100

Income tax analysis ☐

Annual income

Electricity export income

GHG reduction income ☐

Net GHG reduction	tCO2/yr	497
Net GHG reduction - 15 yrs	tCO2	7,458

Project costs and savings/income summary

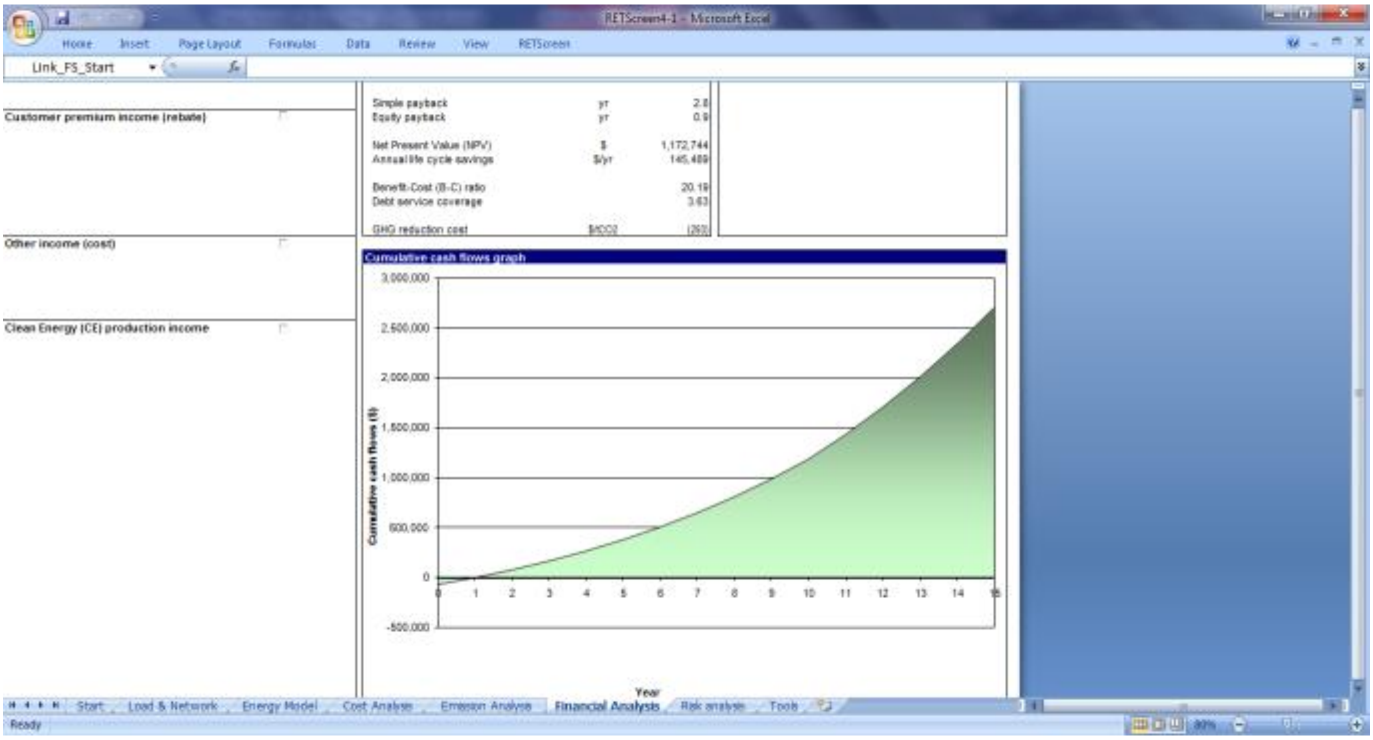
Initial costs			
Feasibility study	2.0%	$	5,000
Development	2.0%	$	5,000
Engineering	6.1%	$	15,000
Power system	73.6%	$	180,000
Heating system	0.0%	$	0
Balance of system & misc.	16.1%	$	39,424
Total initial costs	**100.0%**	**$**	**244,424**
Annual costs and debt payments			
O&M		$	2,190
Fuel cost - proposed case		$	63,729
Debt payments - 10 yrs		$	26,100
Total annual costs		**$**	**92,020**
Periodic costs (credits)			
Annual savings and income			
Fuel cost - base case		$	151,881
Total annual savings and income		**$**	**151,881**

Financial viability

Pre-tax IRR - equity	%	125.9%
Pre-tax IRR - assets	%	40.1%

Yearly cash flows

Year	Pre-tax	After-tax	Cumulative
#	$	$	$
0	-61,106	-61,106	-61,106
1	68,600	68,600	7,494
2	78,217	78,217	85,712
3	88,802	88,802	174,513
4	100,450	100,450	274,963
5	113,268	113,268	388,231
6	127,374	127,374	515,606
7	142,897	142,897	658,502
8	159,978	159,978	818,480
9	178,773	178,773	997,253
10	199,454	199,454	1,196,707
11	248,311	248,311	1,445,018
12	273,350	273,350	1,718,367
13	300,900	300,900	2,019,267
14	331,213	331,213	2,350,480
15	364,564	364,564	2,715,044



Customer premium income (rebate) ☐

Other income (cost) ☐

Clean Energy (CE) production income ☐

Simple payback	yr	2.8
Equity payback	yr	0.9
Net Present Value (NPV)	$	1,172,744
Annual life cycle savings	$/yr	145,489
Benefit-Cost (B-C) ratio		20.19
Debt service coverage		3.63
GHG reduction cost	$/tCO2	(263)