# *Initial Economic Analysis of Electric Thermal Storage in the Yukon*

DRAFT

Submitted to the Energy Solutions Centre

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# Executive Summary

Home heating requirements in the Yukon climate form a high proportion of total residential energy use. The contribution of electric space heating to overall electricity demand is significant and increasing. Yukon electricity use is fast-approaching the capacity of the hydro-electric power generation system. Diesel generators are used on an increasingly regular basis to meet daily electricity demand peaks.

Utilities have long recognized the benefits of "shaving" peak electricity demand and shifting it to "fill valleys". In our Yukon situation, savings from reducing peak diesel use can be significant, both in terms of reducing operating costs and in reducing the need for building new capacity. One way to shift demand to off-peak times is to use Electric Thermal Storage (ETS) for space heating. ETS uses electricity to store heat in a high thermal capacity material, charging only during night time off-peak hours (11pm to 7am typical), then releasing the stored heat over the next 16 hours. ETS units can supply adequate heat for an individual room or an entire building. On the Yukon's electricity grid, ETS units could replace electric baseboards in many new and existing houses as primary space heating.

Experiences in Alaska, PEI and Nova Scotia show that suitable integration of ETS technology can eliminate the need for electric baseboards, reduce space heating costs (e.g. with Time of Use rates), reduce peak winter electricity demand and help make renewable energy (wind and solar) more useable and economic.

This report explores the potential for demand-side ETS use on the Yukon grid to reduce the need for adding electric generation capacity and achieve diesel fuel savings - by decreasing day-time demand and increasing use of available night-time hydro and other renewable energy sources.

The potential savings from shifting the electricity load to off-peak periods is substantial. Assuming a maximum of 9 MW of installed ETS, potential annual diesel savings for 1,440 dwellings (equivalent to 9 MW) converted from electric baseboards to ETS for the study period (2010 – 2012) is calculated at 2,470 MWh, or 31%. On a single winter day, using ETS to stabilize or level the load on the Yukon electric grid could shave 7.6 MW of needed diesel capacity by shifting electricity use from day-time peaks into night-time valleys, improving the ability of the Yukon's hydro system to meet peak requirements.

Our calculations indicate that 0.9 to 1.3 MW of new additional capacity will be required each year to meet the demand for electric heat in **new housing**. At an estimated cost of $1.5M per MW of installed capacity for new diesel, this translates to an estimated cost of $9,600 per new dwelling. Based on this, incentives to convert to ETS could include either a grant to cover the additional cost of ETS over electric baseboards, ranging from $6,324 to $8,370 (less than the per dwelling cost of adding capacity), or a per kWh incentive of $0.097 for 5 years. Over 20 years, the incentive drops to $0.04/kWh.

For **existing housing**, the $9,600 per dwelling cost of adding capacity is less than $12,730 purchase and installation cost for an ETS. However, if enough dwellings were converted to achieve the maximum shiftable load (7.6 MW, or 1200 homes), a rebate for the savings in diesel fuel would be $0.0281 per kWh. If all estimated existing electrically heated dwellings were converted to ETS, the rebate would be $0.0184 per kWh.

The use of solar PV in conjunction with ETS can also reduce diesel use. Of a total 1,075 MWh/year which would be generated by 1 MW of installed PV capacity, 324 MWh/year (or 30% of total annual PV generation) could directly displace diesel generation on the grid.

Based on recent information regarding higher capital costs for new capacity, anticipated increase in the cost of diesel fuel and the potential for reducing ETS capital and installation costs, the savings estimates in this report likely understate the benefits of ETS.

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# 1 Introduction

Canadian building heating accounts for approximately 18%[1] of total national annual energy consumption. Since the Yukon climate is particularly cold in winter, heating costs can be an even higher proportion of total energy use than in other parts of the country.

The contribution of electric space heating to overall electricity demand is significant. In the last few years, electrically heat has been installed in about 90% of new Yukon housing[2] with a current residential electric heating peak hour demand (or load) of approximately 9.6 MegaWatts (MW)[3]. The effects of this include increasing the demand for electrical energy and increasing the need for additional electricity generation capacity ("capacity") to meet the peak load.

Electricity use is fast-approaching the capacity of the Yukon's hydro-electric power generation system, so diesel generators are used on an increasingly regular basis to meet daily electricity demand peak loads in the morning and early evening.

To help manage loads, utilities have long recognized the benefits of "shaving" peak electricity demand, and instead, shifting it to "fill valleys". In our Yukon situation, savings from reducing peak diesel use can be significant, due to higher operating costs of diesel generation (mainly fuel cost) compared to hydro-electric generation.

Shifting electricity demand to lower electricity-use periods also increases the load factor[4] on the electrical grid, reducing the average cost per kiloWatt hour (kWh) of electricity generated. This also optimizes the overall performance of the electricity generation facilities.

One way to shift demand to off-peak times is to use Electric Thermal Storage (ETS) for space heating. ETS uses electricity to heat a high thermal capacity material which stores the heat, releasing it over a period of time. An ETS unit can supply space heating for an individual room or an entire building.

Using an ETS system does not reduce actual energy use; the total number of kWh used for space heating remains the same whether or not ETS is used. The main benefit of ETS is that it provides a way of shifting meaningful amounts of electricity use from high-cost (diesel ) or "peak" generating times of day to lower-cost (hydro, wind) or "off-peak" generating times of day.

This report explores the potential for residential ETS use on the Yukon grid to shave peak electricity demand, resulting in twofold savings to the utility. The utility saves by avoiding the need to add peak generating capacity (capital savings) and by using more lower-cost energy generating alternatives such as hydro and wind (O&M savings).

A parallel study incorporated in this report examines the use of ETS by other utilities and models the potential energy savings by using ETS.

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[1] Natural Resources Canada, Energy Use Data Handbook 1990 – 2009, Catalogue No. M141-11/2009E-PDF, ISSN 1910-4413, p. 4

[2] Personal communication, Hector Lang, Yukon Chief Electrical Inspector.

[3] Yukon Energy Corporation, 2012/2013 General Rate Application, page 1-7, lines 22 to 27, http://yukonutilitiesboard.yk.ca/pdf/1338_YEC%202012_2013%20GRA%20FINAL_2012%2004%2027%20Tabs%201-11.pdf, (Accessed October 25, 2012)

[4] Load factor: "The average power divided by the peak power over a period of time." Source: http://en.wikipedia.org/wiki/Load_factor

There are four main benefits to promoting widespread use of ETS systems in the Yukon and shifting the electric space-heating load to off-peak periods:

1. It could reduce the amount of diesel fuel used to meet peak daytime winter loads.
2. It could reduce the need to add capacity to the electrical generating system.
3. It offers a suitable use for wind-generated electricity when the wind is blowing.
4. Although it would not contribute directly to peak shaving, solar photovoltaic ("solar PV" or simply "PV") could make more effective use of hydro generated power.

ETS can also take better advantage of wind-generated electricity produced in off-peak periods by storing it as heat for later use. Projects in Alaska and Prince Edward Island are effectively using ETS in conjunction with hybrid systems that rely on both diesel-generated and wind-generated electricity.

Solar PV can also play a role in a Yukon ETS program to supplement existing hydro-electric generation. From January to May in Whitehorse, the electrical load is highest, water flow is lowest and the solar energy available is 48% of the annual total.[5] Since ETS would increase the use of hydro power at night-time (off-peak hours), using PV during the day would help offset this, thereby saving more of the valuable hydro resource for use in late winter and spring.

The objective of this study is to establish reasonable assumptions and use the assumptions to estimate preliminary figures for savings by using ETS to shave peak electricity demand. Three possible scenarios are examined:

- Shifting peak electric heating load to off-peak periods with peak load supplied by diesel
- Shifting peak electric heating to off-peak periods with off-peak load supplied by existing hydro
- Using solar PV to reduce the electric heating load supplied by diesel generators

It should be noted that an experiment in peak load shifting was completed in the Yukon. In 2000, the Energy Solutions Centre conducted a 50 household pilot project to assess the acceptance of load-shifting timers installed on DHW tanks ("Penguin Pilot Project, Results and Evaluation Report" is available at www.energy.gov.yk.ca/pdf/penguin_final_report.pdf).

On another related note, the Synthesis report from the January 2011 YEC/YECL Demand Side Management Plan Focus Group Session indicates that participants were interested in exploring Time-of-Use rates,[6] including comparisons with other measures such as load shifting from day to night.

[5] J. Maissan, 2009 research based on publically available information through NRCan
[6] http://www.yukonenergy.ca/media/site_documents/1005_DSM_focus_group_final_report_Feb2011%5B1%5D.pdf

# 2 Background on Electric Thermal Storage

## 2.1 ETS systems

Electric thermal storage or "ETS" refers to an electric space heater with a built-in heat sink (storage). Stand-alone ETS room units (about the same size as a room-unit oil heater) are suitable for building additions and replacing electric baseboards. ETS furnace units connect to a central heating system, either forced air or hydronic (hot water). ETS systems are sized to match heating requirements of the heated space during the coldest periods of the year.

An ETS unit consists of a well-insulated cabinet containing electric elements which nest along channels through high thermal capacity iron-ceramic bricks. A timer or other signalling mechanism in the unit can be used to control when the ETS draws electricity. The bricks absorb heat from the electric elements and store it for extended periods of time (up to 16 hours). When the thermostat calls for heat, the fan (or heat exchanger in the case of a hydronic system) in the ETS unit distributes stored heat to the building. The unit can charge and deliver heat at the same time when required.

The ETS can be programmed, through a variety of means, to turn on during times of lower electricity demand ("off-peak" periods, in the night-time). An ETS system specifically programmed for off-peak times of day reduces (or completely eliminates) the need to generate electricity for space-heating during these peak demand periods. During a Yukon winter, these peak periods frequently require the use of diesel-powered electricity generation ("diesel generation" or "diesel electricity").

There are several methods of controlling an ETS system which are described in more detail later in this section. In each case, the main objective is to manage the ETS unit so it draws electricity during low-demand periods when the cost of generating electricity is typically lower, and turns the ETS elements off during peak-demand periods when the cost of generating electricity is higher.

## 2.2 Experience in Other Jurisdictions (North America)

### 2.2.1 Summary

Utilities across North America are (and have been) developing and implementing ETS load-shifting programs for residential and commercial customers, some for many years. These are largely in areas where peak electricity is generated with fossil-fuels (coal and oil) as well as areas which have a component of wind generated electricity. The nature of benefits to the utilities vary, but in all cases the economics of electricity supply are favourable to load shifting using ETS and domestic hot water (DHW) tank controls.

Proponents of ETS programs include independent electric utilities, municipal or provincial electric utilities and electric cooperatives.

Some long-standing ETS programs in the US were established up to 25 years ago. In several cases (specifically noted in discussions about utilities in Kentucky and Pennsylvania), the recent (mid 2000's) introduction of ductless (or "mini-split") Air Source Heat Pumps (ASHP) has reduced the uptake of ETS systems. These systems reduce heating cost compared to older heat pumps and can also be used to provide cooling.

This change in focus is largely due to the climate and nature of the electric loads in these areas. The application of ASHP's in Yukon was evaluated previously in the report "Heat Pump Characterization Study" which is available at www.energy.gov.yk.ca/pdf/yukon_airsource_heatpump_mar_2010.pdf.

Ductless ASHP's use one outdoor condenser which can service several interior wall mounted units that supply heat to individual rooms. The mini-split AHSP system is even more energy efficient than a ducted system. In addition to providing space heat in the winter, the operation of an ASHP can be reversed in the summer months to provide air-conditioning as well. This makes them attractive in warmer locations where summer cooling is desirable.

Some electrical utilities offer lease or rental options for ETS systems, others offer up-front monetary rebates for the equipment and/or installation cost of ETS systems either as a fixed rebate, a percentage of the installed cost, or based on system size.

Fixed rebates range from $500 to $1500 for a room unit or $4500 per furnace. One utility offers a rebate of 75% of the total installed cost of the system to a maximum of $2,500. Rebates based on system size, some of which have a maximum amount, range from $16 per kW to $100 per kW.

Ongoing incentives include reduced rates, specifically referred to as Time of Use (TOU) or Time of Day (TOD) rates during off-peak use of electricity. One electrical cooperative in Kentucky offers a 40% rate discount for off-peak hours to households using an ETS system. The difference (savings to customer) between on-peak and off-peak rates ranges from $0.03/kWh (Montana-Dakota) to $0.11/kWh (Bedford Pennsylvania).

### *2.2.2 Specific Examples of ETS programs*

The Utilities spreadsheet (included as Appendix B) includes fifteen examples of ETS programs in Canada and the United States. The spreadsheet briefly describes each program and some of the features relating to rebates, rates, and control signals. The upper portion of the spreadsheet summarizes the nine programs that are described in greater detail below, and includes contact information.

The following detailed sections illustrate the range of rebates and rate discounts used and the wide variety of options available for controlling ETS system.

#### 2.2.2.1 PowerShift Atlantic (pilot research project)

This program, which began in 2010, is a four-year research collaboration between New Brunswick Power, Saint John Energy, Maritime Electric, Nova Scotia Power, New Brunswick System Operator, the University of New Brunswick, Natural Resources Canada and the provincial governments of New Brunswick and Prince Edward Island.

PowerShift Atlantic monitors more than 1,000 homes and businesses across the Maritimes, with the purpose of balancing customer load with variable wind energy supply. This is the first project in the world to use aggregated load to integrate wind power into the electrical system. The technology could also be applied to solar power.

The pilot project is utilizing Grid-interactive Electric Thermal Storage (GETS) technology to shift the times of day use of electricity to optimize wind generation without interrupting or disrupting electrical service to participating customers. The GETS system uses a solid state relay and a communications board at the customer end. (Steffes Corporation ("Steffes" – based in North Dakota) has developed new ETS units that include the GETS communication board.) GETS requires high-speed internet to send signals to control ETS room and furnace systems, domestic hot water (DHW) tanks, air conditioning, ventilation and refrigeration systems.

#### 2.2.2.2 Nova Scotia Power

In 1996, the Nova Scotia Utility Review Board mandated Nova Scotia Power (NSP) to implement Time-of-Use (TOU) rates. Electricity demand, mainly in the commercial/industrial sector, was increasing and they were hoping to avoid having to add new capacity. Electricity generation in Nova Scotia was primarily from coal and oil, with a small amount of hydro and an increasing amount of wind power.

Following a Request for Proposals process, a contract was issued to Steffes to supply ETS room heaters. NSP was in charge of distribution and installation. Installing an ETS room heater was the only way for residents to receive TOU rates.

*Rebates and Rate Incentives:* For a few years, NSP recruited and trained contractors and advertised the program heavily. Introductory rebates were provided (by Steffes and NSP) to meet just under 50% of the cost of each 9 kW ETS room unit (total rebate of $985). Installation was not covered.

Word-of-mouth promotion has played a huge role in increasing the uptake of ETS systems. Currently there is no up-front incentive offered through NSP. Steffes still provides a discount of about $150 per unit.

The TOU rate available to ETS customers is $0.07/kWh compared to standard rate of nearly $0.14/kWh and a winter peak rate of $0.18/kWh.

In the late 1990's, a research project in Nova Scotia was looking into using DHW to charge in-floor slab heating during off-peak hours. Steffes became involved with this successful research project and subsequently developed a central hydronic ETS system.

It was found to be too complex for NSP to be in charge of distribution and installation of central space-heating equipment, so the utility review board granted approval of TOU rates for independently supplied and installed ETS systems, provided they met three conditions:

1. they must be an electric-based heating system.
2. they must include thermal storage.
3. they must allow the utility to control the timing of electricity use.

*ETS System Control:* ETS system control was achieved using programmable (Alstom) time-of-day meters. Some 10,000 meters are now installed. About half of ETS units are installed in new construction, the other half as space heating retrofits in existing residences. Many of these are combined with ductless ASHP's, which NSP reports as effective to -25 C.

A gradual shift in the source of residential space heating has occurred over the past 20 years, from 80% oil to nearly 90% electric (ETS/ASHP). NSP is also participating in the PowerShift Atlantic program.

#### 2.2.2.3 New Brunswick Power

In an effort to shift demand away from peak hours and fossil fuel fired electricity generation plants and better integrate renewables like wind, NB Power announced on July 2, 2013 that they are soliciting participants for a new ETS pilot project. About 100 people, primarily NB Power employees, have signed up for the pilot project so far, and the utility wants more participants. Requirements for the pilot project include high-speed internet and electric baseboards as the primary heat source. The pilot program will use new ETS units, capable of delivering continuous heat for up to 16 hours.

The units themselves cost more than typical baseboards, but the program will evaluate the total installed cost and what kind of programs might help with the cost difference. Options include a discount, rental, or a lower rate for charging the units at night.

*Rebates and Rate Incentives:* There is no cost to participate in the pilot program. NB Power will provide and install up to three ETS room units per residence and provide free warranty and repair until 2023. If a customer opts out prior to that, NB Power will discontinue warranty and repair service, but the customer will retain ownership of the equipment.

*ETS System Control:* The program will use a wireless signal via high-speed internet through secure, two-way communication. This will allow the utility to control when the ETS room heater charges to coincide with changing wind speed patterns.

The pilot project will assess how customers respond to the program, work with the program, and evaluate the effectiveness of using wireless communication to send signals.

#### 2.2.2.4 City of Summerside, PEI

Electricity for the City of Summerside (a municipally-owned utility with about 7,000 electrical accounts) uses nearly 50% wind power (24% from local turbines, 25% from two wind farms). They initiated an ETS program because night-time electricity generation (from wind) exceeded demand and they were selling the excess to New Brunswick for only $0.03/kWh.

*Rebates and Rate Incentives:* The provincial government offers a 10% discount for installation. The City of Summerside offers three options for ETS systems, lease-to-own, rental or purchase.

The regular electricity rate is $0.12/kWh. Under the ETS program, customers are installing Steffes room or whole-house ETS systems, which are subject to an off-peak rate of $0.08/kWh for 8 months per year. (Note: Rheem Marathon domestic hot water systems benefit from the off-peak rate for 12 months per year.)

*ETS System Control:* ETS and DHW systems are controlled by time clocks and a smart meter, which is installed at the same time as the ETS system. To address health concerns about wireless signals, Steffes and a local company are working toward sending control signals over fibre optic cable.

Where fibre optic cable is not available, signals use the wireless function of the meter and use time clocks on the appliances. Where fibre optic cable is available, the smart meter uses a wired connection. As fibre optic cable is installed, the wireless communication function is dismantled and the signals are transmitted over the fibre optic cable using internet protocols and specially-developed software.

#### 2.2.2.5 Minnesota – Connexus Energy Cooperative & Great River Energy

Coal-generation provides baseload power for Minnesota with wind playing an increasing role due to the U.S. federal “25x’25” program. Under this program, states are required to generate 25% of their electricity supply from renewable sources by 2025. Great River Energy (GRE), an electrical wholesaler to 28 coops across Minnesota, has achieved 12% renewable electricity generation, primarily from incorporating wind energy. Due to the political commitment to renewable energy and the increase in available wind energy at night, the night-time cost of electricity has been steadily declining.

The challenge with wind energy is to find a way to store it so it can be used when needed. GRE believes any form of ETS is the ideal solution. Starting in the early 1970s GRE began working with Steffes to develop ETS room heating units. GRE initiated an attractive rebate program to promote the use of ETS and help with their focus on load-shifting. Over the years the options for space heating ETS systems expanded to include hydronic, in-floor and forced air.

Their ongoing ETS space-heating program was initially highly successful, but subscription in the program has shrunk over the past few years due to two factors. Firstly, many residents are installing ducted air-conditioning systems, so the non-ducted ETS room heaters are not as popular. Secondly, there has been an increase in the availability of natural gas for space heating and natural gas space heating has a cheaper capital cost than ETS. Overall, there is low demand for electric heat except for use in building additions.

GRE has been refocusing their approach toward domestic hot water. Since virtually every house already has a domestic hot water tank, switching out the tank to a super-insulated high-volume unit is a more certain way to achieve load-shifting, albeit with a lower load per house. A few years ago, they implemented an ETS hot water program which involves installing large capacity (85 – 120 gallon) Rheem Marathon ETS water heaters programmed to turn on from 11 pm to 7 am every day. Nearly 100,000 tanks have been installed to date.

*Rebates and Rate Incentives:* Initial rebates for ETS space heating were substantial, in the order of $50.00 per installed kW to encourage as many installations as possible.

Over several years, the rebate was eliminated due to the success of the program and the need to focus on reducing summer peak demand caused by the growth in the use of central air conditioners. Today the ETS space heating rebates are in place once again at $25 per kW.

Additionally, customers pay TOU rates for electricity. Off-peak electricity rates are $0.05/kWh, compared to regular rate of $0.10/kWh.

For their DHW program, Marathon tanks are purchased and resold to customers at a discounted price. ETS water heating rebates are $300 per tank. Great River is also looking at lease or rental options to reduce up-front costs to customers.

*ETS System Control:* Initially, the use of simple time-clocks provided control for load-switching. Research showed, however, that over time, the clocks were not reliably registering the correct time, and therefore not fully achieving the desired load-shifting advantages for the utility.

They moved to a radio-frequency monitoring process which involves the utility sending a radio signal, using existing broadcasting towers, to a grey box attached to the meter socket on the home. The grey box contains a load management receiver. When it hears the signal it opens or closes a relay that controls time-of-use equipment including ETS, DHW and air-conditioning units.

The disadvantage to this one-way system is that there is no way for the utility to know if the signal is working properly. Now they are adding a feature which notifies the utility that the signal has been received.

More recently, Great River is also experimenting with the use of internet signals using the existing internet service at the home and a fibre-optic based controller on the DHW tank. These units look at electricity pricing every 5 minutes and signal ETS units to turn on or off to balance the load. The system is hard-wired, and so helps to alleviate some public concerns about wireless signals. GRE is working with Steffes to develop software for this Grid-Interactive monitoring for ETS equipment, called GETS. Over 1000 units that work through internet protocol are now installed.

Electricity use by the DHW tanks is not sub-metered. For billing purposes, their DHW program simply provides a 400 kWh credit per month for customers who have purchased a Marathon tank and are on the time-of-use load-management schedule.

#### 2.2.2.6 Concord Light

Concord Massachusetts is a well-to-do bedroom community of Boston. Concord Light is the municipally-owned utility. Its customers include a high percentage of engineers and other professionals from MIT and Harvard. Their fully mature ETS program has helped install 140 units (including forced-air and hydronic whole house systems and individual room units), giving the utility control of a total of 3,816 kW of connected ETS load. Trained and experienced contractors handle installation of the ETS systems.

*Rebates and Rate Incentives:* Concord Light offers the highest up-front equipment rebate encountered in this survey, providing $100/kW installed capacity. They also offer an off-peak rate of $0.06/kWh, compared to a peak load rate of $0.14/kWh.

Concord Light's original target was 100 ETS conversions, which they have now surpassed. They had considered eliminating the rebate, but the installation contractors have reported that the rebate allows customers to choose a switch to ETS over natural gas (from oil heat).

*ETS System Control:* When the ETS system is installed, a second meter is connected to the ETS circuits in the electrical panel. ETS units are often used in conjunction with Air Source Heat Pumps (ASHP) as backup for the coldest times of year when the ASHP isn't able to meet the heating load.

#### 2.2.2.7 Bedford Rural Electric Co-op

The Bedford Rural Electric Co-op serves approximately 9100 rural members across Bedford County and parts of two other counties in southern Pennsylvania. Though the ETS program is still in effect, uptake was mainly active in the 1980's and 1990's.

Most, if not all, of the ETS equipment was provided by Steffes. Since then, there is a growing interest in heat pumps, both air source and geothermal, due to their ability to provide air-conditioning during the summer months as well as heat during winter.

*Rebates and Rate Incentives:* The Co-op will still provide an up-front incentive of $75 per kW of installed ETS to a maximum of $750. This was based on a typical size of 10 kW for ETS systems. Off peak rates are $0.047/kWh compared to peak rates of roughly $0.11/kWh. The Co-op also provides, free of charge ($900 value) to all new residences, an 85-gallon well insulated Rheem Marathon hot water tank controlled to operate only in off peak hours. Since domestic hot water heating can be up to 25% of total heating costs, this helps maximize the value of load-shifting savings to the utility.

*ETS System Control:* ETS (and DHW tank) control signals are sent from smart meters (Advanced Metering Infrastructure or AMI) at the residence through the power lines to electrical substations, then a radio signal is used to take the signal to the billing office. A simplified software package developed by Eaton Cooper takes care of daily residential readings.

#### 2.2.2.8 South Kentucky Rural Electric Cooperative

This Co-op serves approximately 70,000 customers in south central Kentucky. Over 90% of their electricity is coal-generated. Conservation opportunities are welcomed to avoid investing in new capacity. They have had an ETS program for over 20 years, with some 3000-3500 ETS systems installed. Since many of their customers are rural and use wood heat, the houses do not have ventilation ducts, so the majority of ETS systems are room units rather than whole-house furnaces. Again, Steffes has provided the Co-op with solid technical support.

Over the past 2 years, the number of ETS installations have dropped dramatically. A large part of this is attributable to new ductless ASHPs (which also provide air conditioning) taking over the market.

*Rebates and Rate Incentives:* The Co-op offers a $500 rebate on ETS equipment, which has an installed cost of approximately $2500. Once the system is installed, the customer receives a 40% discount from the regular residential electricity rate for the off-peak kWh used. This is estimated based on the number and size of the ETS units installed and the number of off-peak hours in the billing period. This system of estimating the kWh eligible for the reduced rate enabled the utility to avoid having to deal with ETS through the rate application process. The discounted rate was locked in for a 10 year period.

*ETS System Control:* Initially the Co-op relied on TOU clock meters or Load Control switches (Load Control Transponder, LCT) which programmed the use of the ETS equipment for off-peak hours. More recently they have switched to AMI meters throughout the coop service area, for all customers including those with ETS systems.

### 2.3 Supply of ETS equipment

According to the utilities contacted as part of this study, in many jurisdictions across Canada and the US Steffes has become synonymous with ETS systems. They play a significant and greatly appreciated supply and support role in the implementation of ETS equipment and controls. They have worked closely with program personnel and local companies on the ground to provide technical support, local training and work collaboratively to develop appropriate control technologies for local situations.

From the research in this survey, Steffes and Dimplex are the only manufacturers and suppliers of ETS technology serving the North American market.

In discussion with Steffes about obtaining best results from ETS programs, they strongly recommend controlling electric DHW load at the same time as the ETS.

### 2.4 Controlling the operation of the ETS

Numerous configurations of equipment and communications are available to control the time of use of ETS systems. The choice of a controlling device ranges from extremely simple to extremely sophisticated and is determined by several factors including utility infrastructure, existing and planned electricity generation and consumption measuring equipment, availability of high-speed internet service or fibre optic cable internet networks, FM radio infrastructure, signal reliability and cost.

In some cases the utility takes a fairly cautious approach, installing advanced metering units only in conjunction with ETS equipment to allow for two-way communication. In other cases, advanced metering and TOU rates are already in place and the ETS program can take advantage of the existing technology and billing system.

#### 2.4.1.1 Individual ETS Timer

This involves a plug-in module installed on the ETS unit which is programmed to coincide with the desired on-off times according to peak loads. While the timer control will work indefinitely, it does not offer remote control so there is currently no guarantee for the utility that the load is off during peak periods. It is theoretically possible to synchronise clocks over the internet, but this feature is not currently offered and its effectiveness is not known.

#### 2.4.1.2 Time of Use (TOU) or Time of Day (TOD) rates

This refers to the electricity rates set by the utility to reflect a higher cost per kWh during “on-peak” high-demand hours and a reduced cost per kWh during “off-peak” low-demand times. A third “mid-peak” rate is often included as well. Implementing TOU/TOD pricing involves the installation of a **smart meter** (see below).

#### 2.4.1.3 Advanced Metering Infrastructure (AMI)

AMI is the technical name for a **smart meter** system which is installed by a utility to provide automated two-way communication between the meter and the utility company. The AMI provides the utility with real-time power consumption data, allows the utility to control time of use of specific appliances and allows customers to make informed choices about their energy use.

#### 2.4.1.4 Automatic Meter Reading (AMR)

AMR systems originally provided for one-way information flow for remote meter reading. However the newer more sophisticated AMI systems allow for two-way communication between the utility and the customers equipment.

#### 2.4.1.5 Internet

A household internet signal may be used to control ETS systems. This uses only a very small amount of the signal.

#### 2.4.1.6 GETS (Grid-Interactive Electric Thermal Storage)

PowerShift Atlantic is using a GETS system which controls specific appliances that store electricity as heat (heat sink). This system allows instant response to changes and fluctuations in electricity supply, so these appliances in the home can be turned on and off (without disrupting the occupants) to take advantage of variable energy supply sources such as wind or solar.

#### 2.4.1.7 Power line Communication (PLC)

Where power lines are available, sending control signals over the power-line is a “wired” option for communication between the utility and their customers. The power line signal goes from the customer to the substation and is then relayed to the utility office.

#### 2.4.1.8 FM Radio signal

A signal is initiated by the utility and carried through an existing network of FM transmitters and receivers to a controller near the ETS. A switch to open or close the ETS circuit is activated by the signal. The control box for this system costs approximately $100. In recent years, AMI is becoming a much more popular technology than using a radio signal for signalling ETS systems.

#### 2.4.1.9 Wi-fi

Wi-fi (WiSmart) is a platform that enables wireless communication for remote meter reading. This allows the meter reader to use a hand-held receiver outside the customer's yard, a time-saving method that also avoids contact with territorial dogs.

# 3 Peak Energy and Capacity Modelling

## *3.1 Introduction to the Energy Model*

The purpose of this modelling exercise is to provide an estimate of the electrical heating on the grid and to calculate the effectiveness of ETS with regards to avoiding diesel-electric generation on the Yukon grid for space heating.

Hourly generation data for the Yukon electrical grid for the period 2010 to 2012, presented in Figure 1 (described in following paragraphs), was obtained with permission from Yukon Energy Corporation. Hourly weather data (temperature and wind) was collected from the Whitehorse airport station. Solar data was provided by the Energy Solutions Centre. These data sets were integrated into a spreadsheet and used to model the effectiveness of the ETS for diverting heating load away from the daytime peak hours to the off-peak hours, typically between 11 pm and 7 am. For this study phase we also modelled the use of rooftop PV for direct electrical heating, which is presented in Section 3.4.

Figure 1 presents the hourly time series on the Yukon grid showing the total electric generation, the diesel-electric production within the total generation, and the total electrical heating load that is estimated to exist within the total generation. From this figure one may note that more diesel-electricity was generated in 2011 than the other years. It should be noted that in 2011 the Mayo-Dawson grid was connected to the main Yukon grid. The same year the Mayo dam was upgraded to include the new Mayo B portion, which was also integrated into the main Yukon grid.

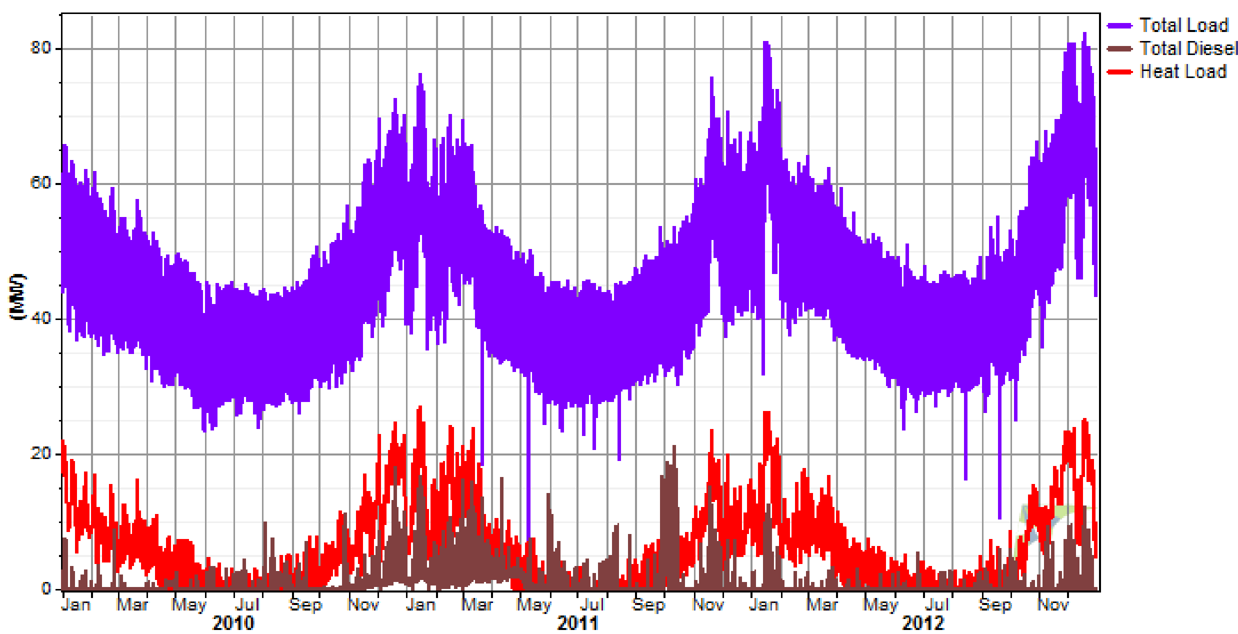


**Figure 1: Hourly total electric load, diesel generation, and electric heat load, January 2010-December 2012**

Table 1 shows the total grid generation, the diesel generation, and the estimated heat load for the three years 2010 to 2012. In 2011 there is a jump to almost 16 GigaWatt-hours (GWh) of diesel-electric generation which accounted for the Mayo hydro plant shutdown during grid connections. The diesel-electric generation for the three years average out to 8 GWh which the authors use for the analysis in this study.

Consideration was made to use only 2012 and 2013 data (which was only received near the deadline for this study), however the 2013 period shows that only 1.9 GWh of diesel-electricity was generated. For this first sweep at modelling ETS integration into the Yukon grid the authors use the whole 2010-2012 period to account for greater diesel-electric generation which is expected to be required in future years.

**Table 1 Generation, heat load and temperatures over the three-year study period.**

| | 2010 | 2011 | 2012 | Average | |
|---|---|---|---|---|---|
| Total generation | 380.8 | 401.8 | 425.7 | 402.7 | GWh |
| Diesel generation | 5.2 | 15.9 | 3.0 | 8.0 | GWh |
| Total heat load (est.) | 48.6 | 53.0 | 57.0 | 52.9 | GWh |
| Annual mean temperature | 0.98 | -0.20 | -1.04 | -0.09 | °C |

From the ICF Marbek report, in 2010 there were about 27 GWh of electricity used for space heating in the residential sector and 21.6 GWh for the commercial sector. The total annual electricity demand for space heating was 48.6 GWh. There are no official numbers on the space heating met by other sources such as oil and propane, but the total for those two fossil fuel sources is estimated to be 300 to 400 GWh/yr.[7]

Based on the 48.6 GWh (for 2010) of heating demand for residential and commercial sectors and the outdoor temperature data, the graph in Figure 1 shows the heating load on the grid compared to the total load on the grid. It should be noted as shown in Table 1 that the average annual outdoor temperature has dropped consistently over the three-year period and that the estimated heat load will have gone up as well. This model does not account for added new electric heating load from new construction. The approach used to estimate hourly load is explained in the following section. According to this analysis the total electrical heating demand represents about 13% of the total grid demand. The residential electric heating portion represents about 7% of the grid load.

## 3.2 Calculating Annual heating needs from a design heat load (DHL) for a dwelling

In order to calculate how much space heating is required by dwellings in Whitehorse we used the outside temperature data collected at the Whitehorse airport. The theory used in this study is that the home heating needs go up as the outside temperature goes down, or as the difference between the desired room temperature and the outside temperature increases. A number of assumptions are made with regard to this relationship:

- The relationship between heat load and outside temperature is linear
- The home design heating temperature for Whitehorse is -42°C
- The design heat load (DHL) is 7.7 kW
- The outside temperature at which a home no longer needs heat is 10°C. We assume that body heat, passive solar gain, and heat from electrical appliances provide the necessary heat for the home above this temperature
- The desired room temperature for the typical home is 18°C
- Wind chill factor (or “wind load”) is ignored.

[7] Source: calculated from 2011 census data and information in ICF Marbek, *Yukon Electrical Conservation and Demand Management Potential Review: Residential Sector Final Report*

The result is a linear relationship between the outdoor temperature and the heating load that is depicted in the graph of Figure 2. In this case the relationship is for a single detached home with a DHL of 7.7 kW at -42°C which would keep the dwelling at a room temperature of 18°C.

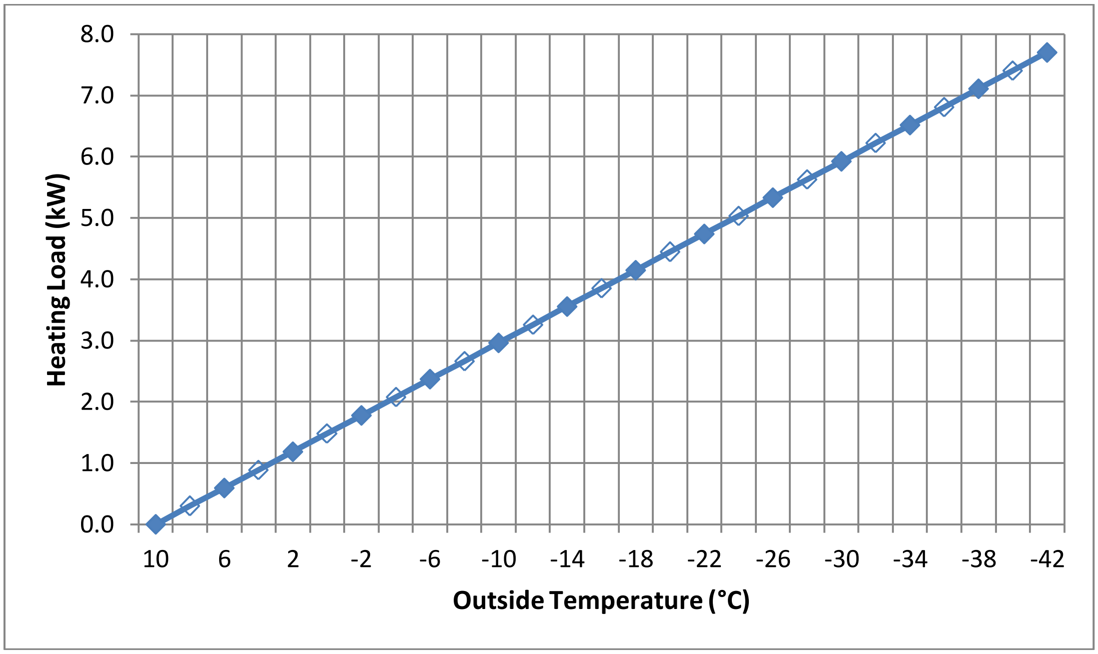


**Figure 2: Space heating load vs. outside temperature for a single detached house**

Using the assumptions from above we create a linear equation that converts the Whitehorse airport temperature into spacing heating load (power in kW) and can calculate the annual heating needs (energy kWh) of a home based on its design heating load. This formula was used to create the total electrical heating load shown in Figure 1 above (a 48.6 GW heating consumption for 2010 was matched with a total system DHL of 28 MW, at -42°C).

Table 2 presents the increases in peak load or capacity requirements resulting from the addition of one new dwelling unit obtained from the ICF Marbek report.[8] A new electrically-heated single detached house is assumed to increase the peak load capacity requirement by 0.0102 MW or 10.2 kW (0.0077 MW+0.0025 MW). A new single detached dwelling that is not electrically heated would only increase peak demand by 2.5 kilowatts (0.0025 MW).

[8] Source: Calculated from ICF Marbek, *Yukon Electrical Conservation and Demand Management Potential Review: Residential Sector Final Report,* Exhibit B 6

**Table 2 Peak load increase per new electrically-heated dwelling (ICF Marbek report)**

| | Increase in heating peak load | Increase in non-heating base peak load | Total increase in base peak load | Non heating load as % of total |
|---|---|---|---|---|
| Single detached | 0.0077 MW | 0.0025 MW | 0.0102 MW | 24.5% |
| Row/attached/mobile | 0.0050 MW | 0.0018 MW | 0.0068 MW | 26.5% |
| Apartment | 0.0033 MW | 0.0016 MW | 0.0049 MW | 32.6% |

Source: Calculated from ICF Marbek, *Yukon Electrical Conservation and Demand Management Potential Review: Residential Sector Final Report*, Exhibit B 6

From the ICF Marbek report we derived average design heat (power) loads and annual heating (energy) needs of three types of dwellings and we compare those to our modelled results as shown in Table 3:

**Table 3 Comparison between the ICF Marbek report results and the authors' model of heat energy needs versus the design heat load (DHL) of a dwelling type.**

| Dwelling type | Design heat load kW | Annual heating 2010 kWh/year *Marbek* | Annual heating 2010 kWh/year *Modelled* | Error |
|---|---|---|---|---|
| Single detached | 7.7 | 13,350 | 13,371 | 0% |
| Attached and mobile | 5.0 | 8,541 | 8,682 | -2% |
| Apartments | 3.6 | 6,544 | 6,251 | 4% |

Note in the Table 3 that these values were calculated for the year 2010. The total combined average DHL for a Whitehorse dwelling is 6.3 kW and the heating needs for 2010 was modelled as 10,940 kWh, averaged over 2010-2012 the modelled consumption is actually 12,000 kWh.

Based on that information and considering that 2010 had an exceptionally warm winter, Table 4 presents, by different housing types, our assumptions about energy use for heating and non-heating purposes. For example, an electrically heated new single detached house is assumed to consume 27,700 kWh annually while a new house that uses a non-electric heating system would use 13,500 kWh. [9]

**Table 4 Annual kWh energy use by new dwellings by type and for heating and non-heating loads (used in model)**

| | Annual heating kWh per new dwelling | Non-heating kWh energy use per new dwelling | Total kWh energy use per new dwelling |
|---|---|---|---|
| Single detached | 14,200 kWh | 13,500 kWh | 27,700 kWh |
| Row/attached/mobile | 9,400 kWh | 10,000 kWh | 19,400 kWh |
| Apartment | 4,000 kWh | 6,000 kWh | 10,000 kWh |

[9] Note that this information derived from the ICF Marbek report is not consistent with YECL's GRA information which indicated that the average Whitehorse residential use per customer was about 11,349 kWh per year in 2011. They were forecasting about 11,211 kWh per year going forward, but have since reduced their forecasts by about 420 kWh per year for all Yukon customers. These numbers include all uses – electric heat as well.

Table 5 summarizes average energy use assumptions for different types of dwellings. These assumptions are used in the economic analysis. The assumptions for existing dwellings are based on the ICF Marbek report data, while those for new dwellings were derived from the modelling exercise. We can assume that although they are more energy efficient, new dwellings are also much larger, resulting in a larger total heating energy need.

**Table 5 Average space heating and total energy use assumptions for new and existing dwellings**

| | Existing dwellings | | New dwellings | |
|---|---|---|---|---|
| | Heating | Total energy | Heating | Total energy |
| Single detached | 13,350 kWh | 24,856 kWh | 14,200 kWh | 27,700 kWh |
| Row/attached/mobile | 8,541 kWh | 17,096 kWh | 9,400 kWh | 19,400 kWh |
| Apartment | 7,274 kWh | 14,168 kWh | 4,000 kWh | 10,000 kWh |

## *3.3 Modelling shift to off peak hydro*

As stated earlier, the purpose of the ETS technology is to shift the electrical load in order to reduce the peak demand as well as diesel consumption on the Yukon electricity grid. The ideal situation is to shave the electricity load peaks and fill the valleys to attain an average load (orange line) that is more like the one depicted in Figure 3 below. That figure presents the hourly time series showing the total electrical load (Total Load), the hydro portion (Hydro) and the one day running average for the total load (Average Load 24h). The two-week period chosen was during the highest power peak in the 2010-2012 period. Note that in this figure the total load (black line) above the hydro load (blue line) is diesel load on the margin. Also note that on December 19 the second peak was 82.24 MW (5 pm) while the 24-hour average was at 74.68, a difference of 7.56 MW.

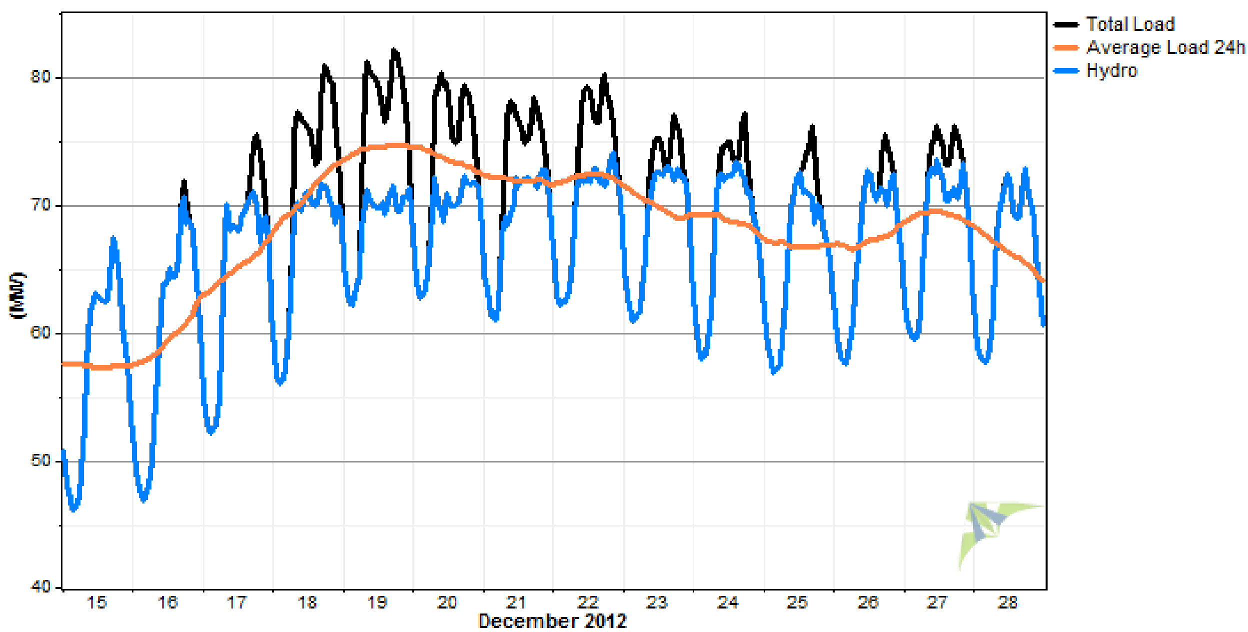


**Figure 3: Hourly total electrical load hydro portion and 24-hour running average total load, December 2012.**

The exercise in this part of the study is to theoretically replace electric baseboards with the ETS technology in a number of existing dwellings. We assume that we replace them in a mix of dwellings that include single detached, row houses, mobile homes and apartments whose mean DHL is 6.3 kW.

We ran the model in increments of 1 MW of total DHL representing approximately 160 dwellings each. This removes up to 1 MW of electric heating load (at -42°C) from the grid peak period (heating load is less when the outdoor temperature is higher). In the model we use a standard ETS unit with a heat (energy) storage capacity of 120 kWh and recharge power capacity of 19.2 kW. Depending on the dwelling type these specifications will change, but overall we are assuming that the above capacities per dwelling are the average for the conglomeration of dwellings.

In this model we also assume that the utility has full control over the ETS units on the demand side: that not all of the units will recharge at the same time so as to maintain a smoother grid load that follows the 24-hour average.

Applying the above 160 dwellings to the model we find that there is a saving of about 424 MWh/year (averaged over 2010-2012) in diesel consumption. This is about 2,649 kWh/yr per dwelling. Table 6 and Figure 4 show the diesel savings with each 1 MW incremental increase in total DHL.

In Table 6, it is not the number of homes which is significant, it is the 9 MW total DHL which becomes of interest as we look at how that affects the diesel savings. The 1,440 homes (each at an average of 6.3 kW DHL) just happens to be the number of homes converted to ETS which will achieve that 9 MW. We explore this concept further in Figure 4 and Figure 5.

**Table 6: Annual diesel saved versus the number of dwellings converted from electric baseboards to ETS**

| Number of Dwellings | Total Design Heat Load of Dwellings | Average Diesel saved | Average Diesel saved per MW | Average Diesel saved per Dwelling |
|---|---|---|---|---|
| 160 | 1 MW | 424 MWh | 424 MWh | 2,649 kWh |
| 320 | 2 MW | 845 MWh | 423 MWh | 2,641 kWh |
| 480 | 3 MW | 1,236 MWh | 412 MWh | 2,574 kWh |
| 640 | 4 MW | 1,563 MWh | 391 MWh | 2,442 kWh |
| 800 | 5 MW | 1,832 MWh | 366 MWh | 2,290 kWh |
| 960 | 6 MW | 2,051 MWh | 342 MWh | 2,137 kWh |
| 1120 | 7 MW | 2,229 MWh | 318 MWh | 1,990 kWh |
| 1280 | 8 MW | 2,365 MWh | 296 MWh | 1,848 kWh |
| **1440** | **9 MW** | **2,470 MWh** | **274 MWh** | **1,716 kWh** |
| 1600 | 10 MW | 2,553 MWh | 255 MWh | 1,596 kWh |
| 1920 | 12 MW | 2,664 MWh | 222 MWh | 1,388 kWh |
| 2240 | 14 MW | 2,737 MWh | 194 MWh | 1,222 kWh |
| 2560 | 16 MW | 2,787 MWh | 173 MWh | 1,089 kWh |
| 2880 | 18 MW | 2,826 MWh | 156 MWh | 981 kWh |
| 3200 | 20 MW | 2,856 MWh | 141 MWh | 892 kWh |
| 4445 | 28 MW | 2,920 MWh | 104 MWh | 657 kWh |

Figure 4 shows the incremental diesel saving with increase in number of dwellings converted from electric baseboards to ETS over the three-year study period (2010-12) up to 28 MW total or 4,445 dwellings. The upper row on the bottom axis is the total DHL (MW) for the number of homes in the lower row. With 1,440 dwellings (9 MW total DHL) switched from baseboards to ETS there is a potential diesel savings of 2,470 MWh/yr, 31%, or $0.79M/year at an avoided cost of $0.32/kWh. Of the 8 GWh of diesel that was consumed over the 3-year period of 2010 to 2012, up to 2.9 GWh or 36% of diesel could be saved by converting all of the electric baseboard space heating to ETS.

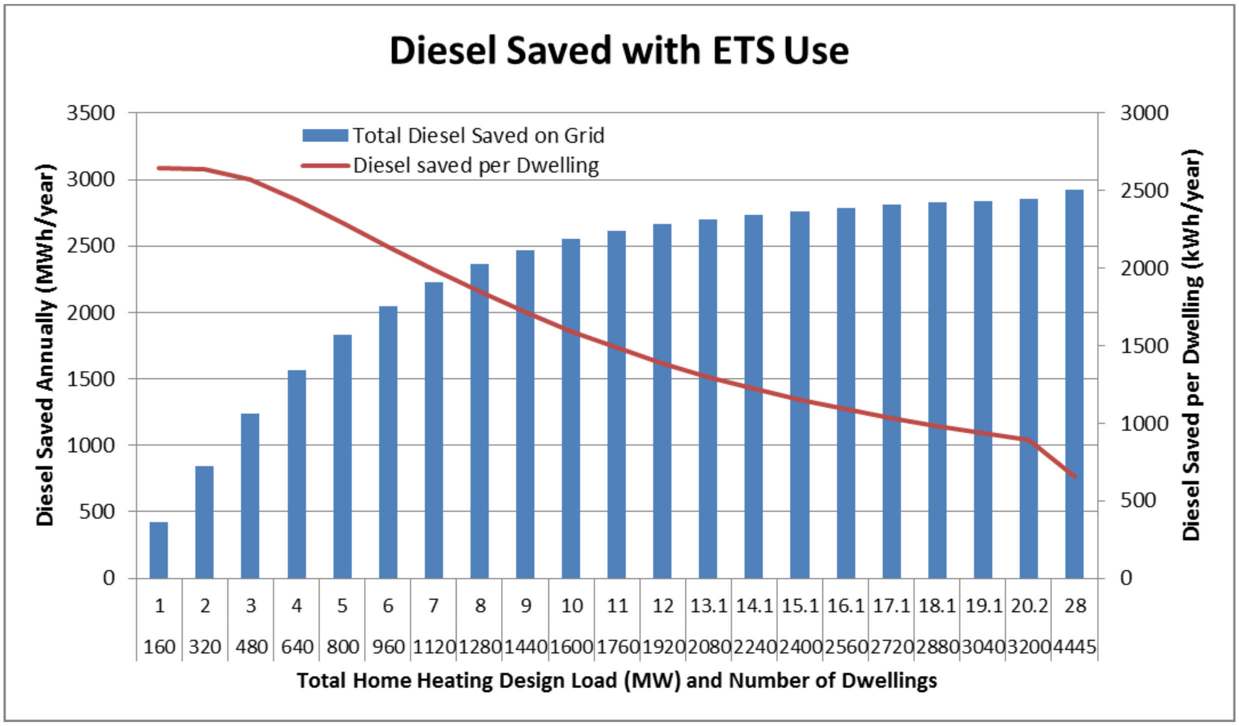


**Figure 4: Diesel saved versus incremental increase in dwellings converted from electric baseboards to ETS over 2010-2012**

Figure 5 shows an hourly data set of loads, generation and other data on the Yukon grid for a two-week period in December 2012 when the grid reached a peak load of 82 MW (suppertime December 19). The black line is the original total load on the grid. The light blue line is the hydro generation above which diesel is used when the total load exceeds the hydro. The brown line (Load-Heat) is the total load minus baseboard heating load from 1,440 homes. The orange line (Load&ETS) represents the new load with the ETS units in 1,440 homes. The darker blue line represents the diesel that is saved. The orange line labelled as "Load&ETS" is the modeled new grid load if 1,440 homes on electric baseboards (9 MW total DHL) were converted to ETS units.

Note that on December 19, the second peak of the brown line (load w/o heat) just meets the orange line (load with ETS). This meeting point was attained at 9 MW of total DHL being converted to ETS. This threshold is also the point at which converting more buildings to ETS would not reduce the peak demand on this coldest day. As shown in Table 6 however, converting more buildings will continue to save more diesel energy use on the grid.

The Load & ETS (orange) line mostly follows the 24-hour-average grid load line as noted in Figure 3, but it will sometimes peak above or dip below that line. The peaks above the average (e.g. suppertime

December 24) are loads not controlled by the ETS portion. The dips below the average (e.g. morning December 15) are the ETS units having completed their respective off-peak recharges.

The diesel savings (and use) are also shown by the darker blue line on the lower portion of the graph in Figure 5. Looking at December 19, 2012 the grid load swings from about 62 MW at 3 am to 82 MW at 6 pm. The ideal situation would be to have the load stabilized (or levelled) to the average of 75 MW or less for that day. We would then have shaved about 7.6 MW of needed diesel capacity.

With the load following the daily average on this day we would have saved 46 MWh (75 MWh saved during the day minus 29 MWh used during the night). This savings represent 31% of the 145 MWh of diesel generated electricity used that day. That same 46 MWh of saved diesel has been replaced by the hydro energy that was available during the night time lull (valley). This calculation was done using the hourly data for December 19, 2012.

Note that the diesel savings goes negative during some of the off peak hours such as on December 19. This will occur when the average grid load is greater than the hydro capacity which can be inferred from the light blue line (Hydro) to be about 70 to 72 MW, but overall there is substantial net diesel savings.

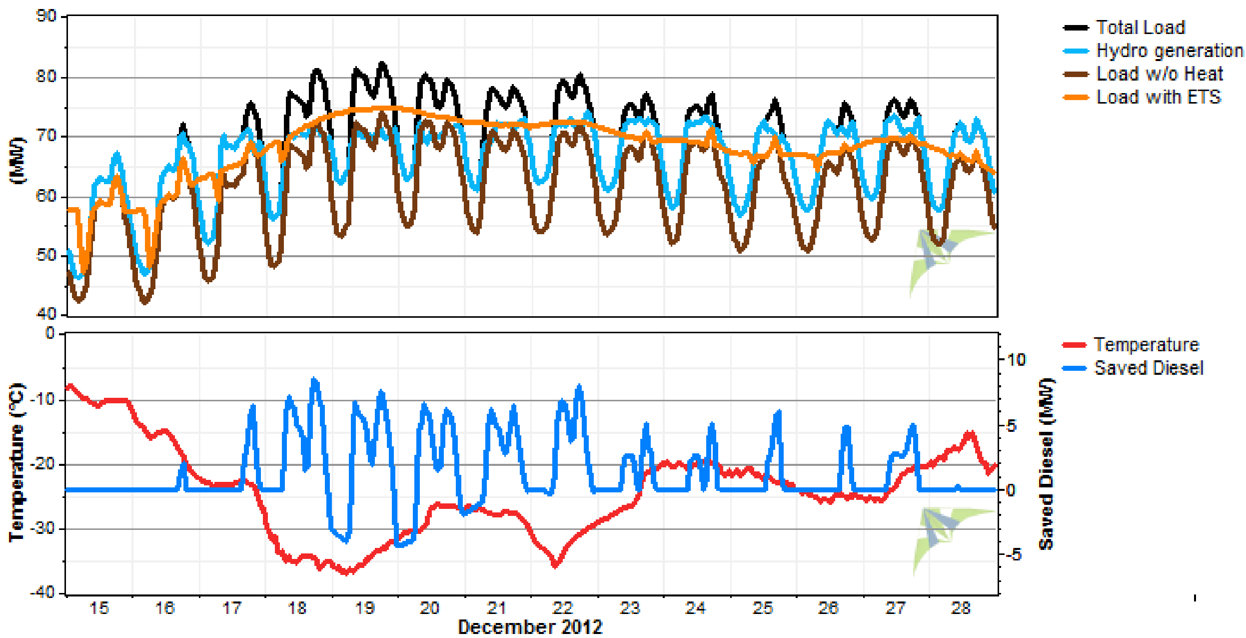


**Figure 5: Hourly load profile for converting 9 MW (1,440 houses) from electric baseboards to ETS, December 2012.**

## *3.4 PV Array to Heat Homes with ETS*

In this part of the study we model the use of solar PV for its potential displacement of diesel-electricity on the Yukon grid for direct heating of dwellings.

The PV energy output is based on actual production data from the 4.1 kW PV array on the roof of the Yukon Government administration building. The PV array produced an average of 4,410 kWh/year over three years (2010-2012). This is equivalent to 1,075 kWh per installed kW of capacity (or 1,075 MWh per installed MW). For the purpose of this study the PV array size is scaled according to desired system size (e.g. 1 or 6 kW) for a given dwelling and space heating requirement.

In modeling the impact that solar can have on reducing diesel use for electricity generation on the grid, we calculate how much solar energy (per given capacity) contributes to diesel savings when diesel is used to supplement electricity produced using hydro-electric turbines. Diesel powered generation supplements hydro-electricity when demand for electricity cannot be met using hydro alone and is referred to as "diesel generation on the margin."

Using the 2010-2012 grid generation data which includes diesel generation, the model calculates that up to 31% of the energy produced from solar can be used to displace diesel. This is consistent up to about 800 kW of total installed PV capacity on the grid. Above this limit there is a steady decline in usable solar energy that can be directed to diesel savings, as shown in Figure 6 which presents the portion of PV energy that could be directly attributed to saving diesel on the Yukon electricity grid compared to total installed PV capacity on the grid. If there is a total of 1 MW of installed PV capacity it would produce an average of 1,075 MWh/year and 324 MWh/year or 30% of that solar energy could displace diesel generation on the grid.

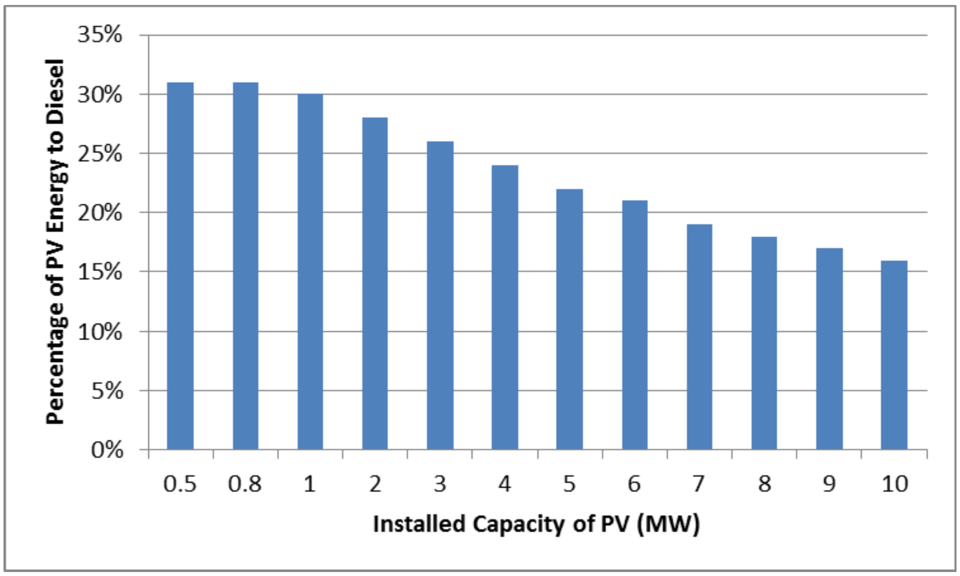


**Figure 6: Percentage of PV energy used to save diesel per MW of installed PV capacity**

In this exercise one single detached house is modelled and, as presented in Table 3 on page 19, the dwelling is assumed to have a 7.7 kW design heating load. It will have an ETS with 120 kWh and 19.2 kW of capacity. We will also model a SuperGreen home and a Passive House with an assumed DHL of 3.3 kW and 1.9 kW respectively.

Figure 7 shows the daily mean energy used from a 4 kW PV array on a new conventional dwelling with a DHL of 7.7 kW. The figure presents the time series showing the solar energy produced in average kW per day (red) and the portion of that solar that would be used directly for baseboard heating (blue) or for ETS (green). As is expected the home heating load (black line) is increased in the winter months when the PV solar energy production (red line) is reduced.

The blue line represents the electric baseboard scenario without ETS. Note that the baseboard heating coincides with the PV solar production from mid-October to mid-March. From the model we calculate that 31% of the total PV energy produced could go directly to space heating. Note that the rest of the solar electricity, however, is absorbed by the home's other electrical needs.

If the dwelling was equipped with an ETS (green line) more of PV solar is absorbed from March to June and in August and September. The model calculates that 47% of the PV energy could be used for heat with an ETS in the dwelling. Note that for a 4 kW PV system this represents 14% of the home's heating needs. Also note that in the months of June to August the heating provided by solar may not be used as most homes receive enough passive solar heat gain to not require heating.

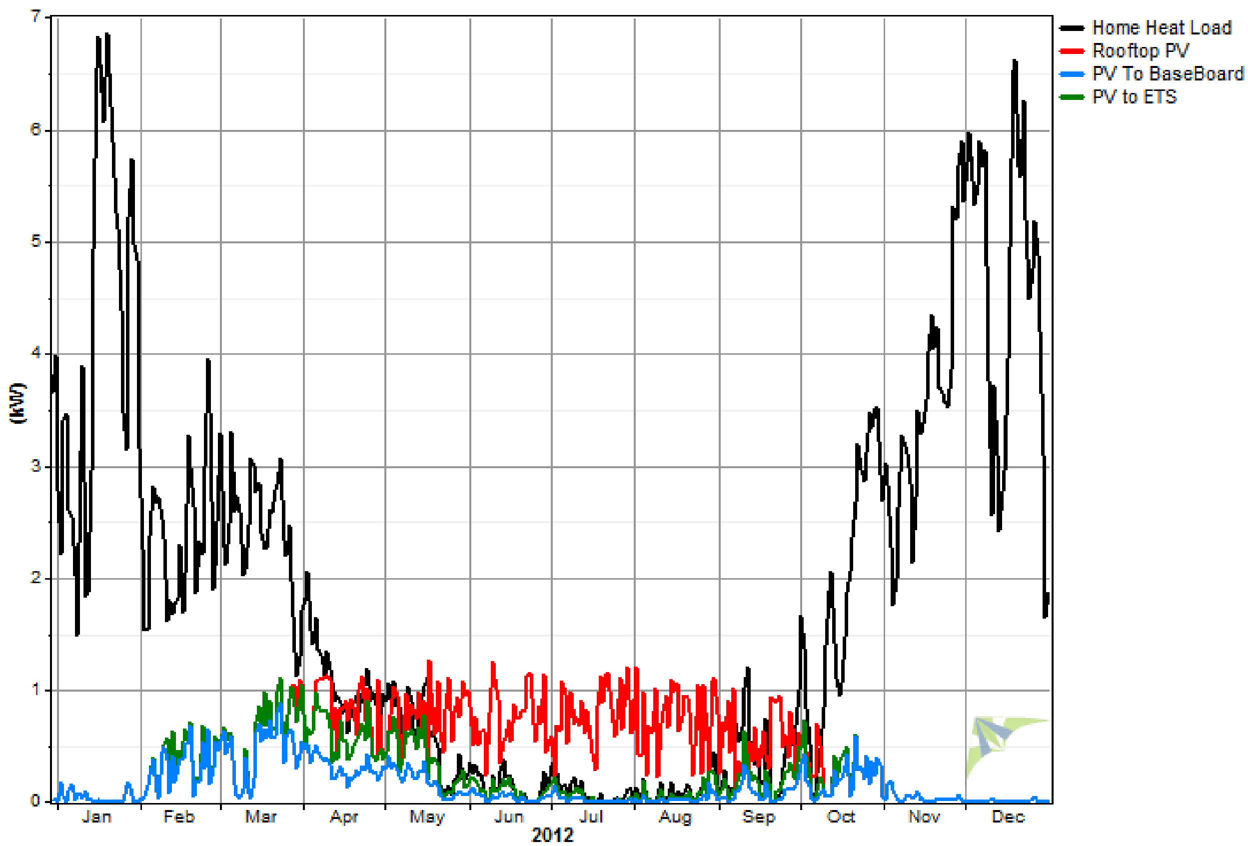


**Figure 7: Home heating load compared to rooftop PV generation for 2012**

**Different PV array sizes will have an impact on how much solar energy will be absorbed into space heating in a dwelling.**

Figure 8 shows how much solar energy could be used directly for just electric baseboard heating compared to storing into ETS. The graph shows that as the PV array size increases the ETS provides a better advantage for absorbing and storing more solar into heat for later use in the home.

Figure 9 shows how much energy per kW installed is estimated to be absorbed in dwellings of different insulation standards. With a 1 kW system, roughly half the solar energy could be absorbed by the ETS.

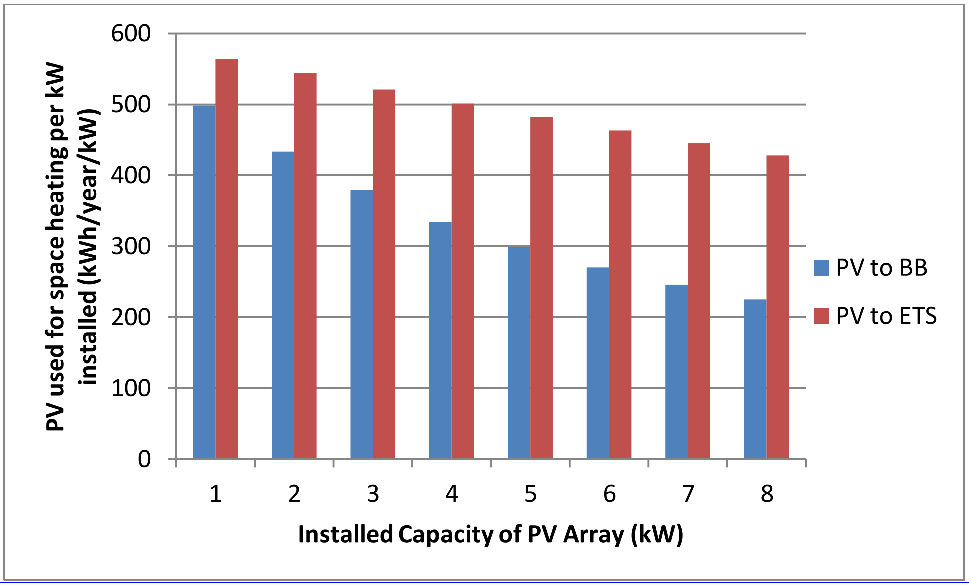


**Figure 8: For different array sizes this graph shows how much annual solar PV energy (in kWh per kW installed capacity) could be used for direct electric space heating (i.e. baseboard or "BB") and for the ETS technology.**

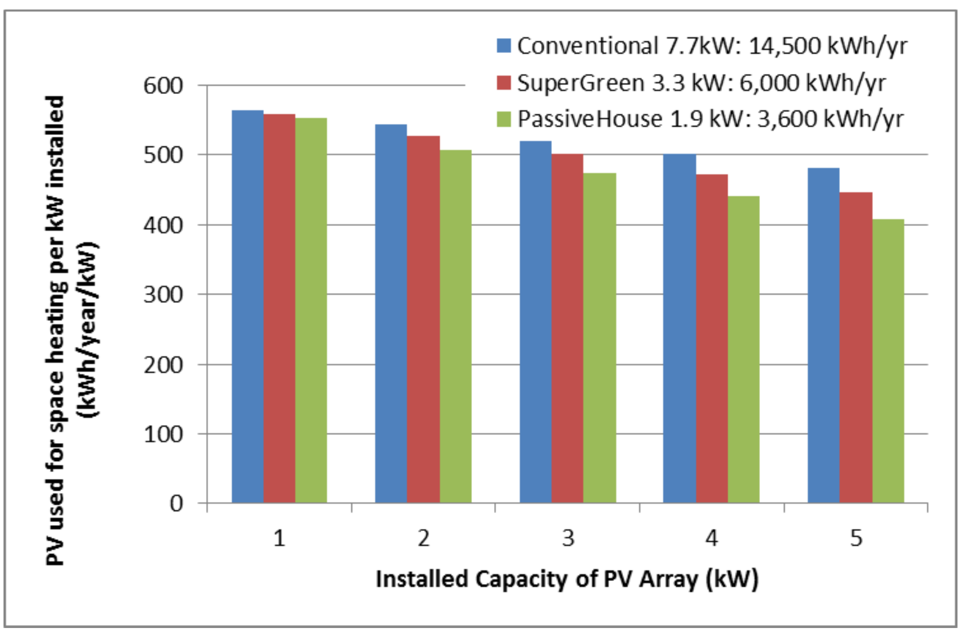


**Figure 9: A comparison of the absorption of solar energy into ETS heat storage for various PV array sizes and insulation standards of single detached dwellings.**

# 4 Economic analysis methodology

## *4.1 Overview*

Our methodology is essentially a life-cycle cost-benefit approach to savings from shifting peak demand from diesel generating capacity by using ETS. We developed a spreadsheet model that allows calculating the savings to the utility and the amount of revenue-neutral subsidies that could be offered to consumers.

Six scenarios or cases are possible:

**Case 1** Shifting peak electric heating load to off-peak periods with **peak load supplied by diesel**
Case 2 Shifting peak electric heating to off-peak periods with peak load supplied by new hydro
**Case 3** Shifting peak electric heating to off-peak periods with **off-peak** load supplied by **existing hydro**
**Case 4** Using **solar PV** to reduce the electric heating load supplied by diesel generators
Case 5 Using wind power to reduce the electric heating load supplied by diesel generators
Case 6 Using wind power and solar PV to reduce the electric heating load supplied by diesel generators

This report is concerned only with cases 1, 3 and 4, with the remaining cases to be completed as part of subsequent phases. Nevertheless, some of the work required for the other three scenarios has been done.

The analysis begins with a modeling exercise that estimates the peak capacity demand for electric heat for different housing types and the total energy use for electric heat and non-heating uses.

The model begins with an estimation of the number of current and forecast future dwelling units that use electric heat. A typical peak demand is applied to each type of dwelling (single detached, apartment and row/mobile), yielding the increase in peak load required as a result of the new construction. As well, typical annual energy use in kWh is applied to the number of dwellings.

The numbers on peak demand and energy use are then used in each of the scenarios. Based on cost per MW assumptions for additional capacity for each kind of generation, the total capital costs required are estimated. Where appropriate, the fuel savings are also estimated. This is translated into a per kWh cost savings.

Once the savings are known, we can calculate the maximum subsidy that could be offered to consumers. This subsidy could take any combination of forms including reduced kWh charges for energy use or some kind of grant.

The following were completed for each case:

1. Calculation of the maximum price of off-peak electricity for each option to be economically attractive to the consumer currently using electric heat or oil heat.
2. Recommendation on a range of off-peak electricity rates that would provide a net benefit to both the consumer and the utilities and show the net benefit.
3. Recommendation on a range of blended electricity rates that approximates the range of off-peak rates that provides a net benefit to both the consumer and the utilities.
4. For a range of grant amounts, calculation of the effect of offering an installation grant on raising the blended electricity rate that could be offered by the utility.
5. Completion of a cost-benefit analysis both from a consumer perspective and a utility perspective.
6. Completion of an analysis of the economic impacts for Yukon. Including information on other factors, such as reduced outages and frequency stabilization, reduced fossil fuel imports, reduction in greenhouse gas emissions and reduction in other pollutants.

It should be noted that TOU/TOD metering with lower charges for off peak usage is NOT required to make ETS work. So there is no need to calculate off-peak rates. Rather, we calculate the format which ETS subsidies could take - such as a reduction in the basic rate, an annual grant or an up-front grant.

### *4.1.1 Proportion of new dwellings using electric heat*

Our analysis assumes that 90% of new residential dwelling units built since 2011 use electric space heating. That 90% figure was arrived through discussions with construction industry sources as well as the chief electrical inspector. We do not expect it to change very much in the foreseeable future.

Currently, electric heat costs just a little more than fuel oil per kWh of heating for residential accounts. However, when the much lower capital costs of electric baseboards are taken into account, electric heat is much cheaper. Table 7 presents the per kWh costs of oil heat for different furnace/boiler efficiencies, based on the current price of $1.20 per litre for fuel oil and 10.84 kWh of energy per litre of oil. The cost per kWh at fuel oil costs of $1.00 and $1.40 per litre is presented for comparison. The kWh heating cost at $1.20 per litre compares favourably with the current electric prices of $0.1471/kWh (without subsidy) for the first monthly 1,000 kWh used and $0.1553/kWh for the next 1,500 kWh used.

**Table 7 Fuel oil cost per kWh of heat**

| Fuel Oil efficiency | $1.00/litre | $1.20/litre | $1.40/litre |
|---|---|---|---|
| 75% | $0.1230/kWh | $0.1476/kWh | $0.1722/kWh |
| 80% | $0.1153/kWh | $0.1384/kWh | $0.1615/kWh |
| 85% | $0.1085/kWh | $0.1302/kWh | $0.1520/kWh |

Given that most of the Yukon's electricity is generated from hydro and assuming that the price is essentially a blended rate, it would required a very large decline in fuel oil prices to reduce the cost advantage of electric space heating. So the situation where electric heat is most often chosen is likely to persist.

Based on current projections, it is unlikely that fuel oil will become cheaper relative to current electricity rates in the foreseeable future. Long term forecasts of the price of oil, at best, show only a slight decline of about 10% over the next 15 to 30 years down to about $90-$95 per barrel in real terms (i.e. after subtracting inflation, which means a higher price in terms of actual dollars). Most forecasts show it staying relatively steady or increasing in price. For example the OECD forecasts oil prices to increase by 7% per year to 2020[10], while the World Bank forecasts a small decline of less than 1% per year after the 2011-12 high.[11] Another "official" forecast is produced by the US Energy Information Administration that shows average annual price increases of 1.4% to 2.4%.[12] All these forecasts are in "real" terms, which means that the annual inflation percentage should be added to the base figure.

[10] Fournier, J., et al. (2013), "The Price of Oil – Will it Start Rising Again?", OECD Economics Department Working Papers, No. 1031, OECD Publishing. http://www.oecd-ilibrary.org/economics/the-price-of-oil-will-it-start-rising-again_5k49q186vxnp-en accessed 29/8/2013.

[11] Baffes, John, and Damir Ćosić (2013). *Global Economic Prospects: Commodity Markets Outlook*. World Bank, July 2013. http://go.worldbank.org/4ROCCIEQ50 accessed 29/8/2013

[12] US Energy Information Administration. *International energy Outlook 2013.* Report Number: DOE/EIA-0484(2013) http://www.eia.gov/forecasts/ieo/liquid_fuels.cfm accessed 29/8/2013

## 4.2 Estimated electric space heating: current demand

The 2010 ICF Marbek report provides fairly detailed estimates of space heating peak load and energy use estimates for electrically heated houses. Most of the detailed data in Appendix A is for energy use and Appendix B is for peak loads. However, that data is for 2010 and in the boom years of 2011 to 2013, over 800 new dwelling units have been built in Whitehorse, most of them electrically heated. Since 2010, the number of electrically heated dwellings has increased by more than 50%. Thus developing current estimates of demand for electric capacity and energy resulting from residential space heating has to take into account recently built housing.

### 4.2.1 Estimated number of dwelling units

The ICF Marbek report estimated the number of electrically and non-electrically heated residences as follows:

**Table 8 2010 number of dwellings by type and type of heating**

| Dwelling type | Electrically heated | Other heating | Total units |
|---|---|---|---|
| 1980 & newer single detached homes | 519 | 3,215 | 3,734 |
| Pre-1980 single detached homes | 439 | 2,724 | 3,163 |
| 1980 & newer attached/row housing | 69 | 426 | 495 |
| Pre-1980 attached/row housing | 59 | 360 | 419 |
| Apartment/condo units | 215 | 1,332 | 1,547 |
| Mobile/other | 129 | 805 | 934 |
| **Total dwellings** | **1,430** | **8,862** | **10,292** |
| Apartment/condo common areas | 24 | 147 | 171 |
| Seasonal dwellings, garages & sentinel lighting | | | 4,147 |
| Total accounts | **1,454** | **9,009** | **14,610** |

Source: ICF Marbek, *Yukon Electrical Conservation and Demand Management Potential Review: Residential Sector* Final Report, p.14

Based on CMHC building permits and housing completions figures from 2011 to 2013, Table 9 presents the estimated number of dwellings by type.

**Table 9 Estimated number of dwelling units by dwelling type, existing and new, 2010-13**

| | 2010 Existing | New units 2011 | New units 2012 | New units 2013 | 2013 estimated total |
|---|---|---|---|---|---|
| *All dwelling units* | | | | | |
| Single Detached | 6,897 | 112 | 104 | 75 | 7,188 |
| Attached/Mobile | 1,848 | 175 | 96 | 121 | 2,240 |
| Apartment | 1,547 | 16 | 36 | 86 | 1,685 |
| **Total** | 10,292 | 303 | 236 | 282 | 11,113 |
| *Electrical heat units* | | | | | |
| Single Detached | 958 | 101 | 94 | 68 | 1,221 |
| Attached/Mobile | 257 | 158 | 86 | 109 | 610 |
| Apartment | 215 | 14 | 32 | 77 | 338 |
| Total | 1,430 | 273 | 212 | 254 | 2,169 |

Source: 2010 data: calculated from ICF Marbek, *Yukon Electrical Conservation and Demand Management Potential Review: Residential* Sector Final Report, p.14; 2011-13 data: calculated from CMHC, *Building permits and dwelling completions*, Personal communication with Prairie & Territories Market Analysis

### 4.2.2 2013 generating capacity requirement for residential space heating

The ICF Marbek report presents the peak load capacity requirements for existing 2010 residential buildings in Appendix B of the residential report. To that should be added the new buildings to get at a more recent figure. The peak load per dwelling presented in Table 2 on page 19 are applied to the estimated number of dwelling units presented in Table 9 to yield the following peak load requirements for electrically heated and all residential units in 2013. The total estimated peak capacity residential requirements in 2013 are as follows:

**Table 10 Estimated residential peak loads, 2010-2013**

| | 2010 Existing | New units 2011 | New units 2012 | New units 2013 | 2013 Cumulative total |
|---|---|---|---|---|---|
| Space heating peak load | 9.7 MW | 1.6 MW | 1.3 MW | 1.3 MW | 13.9 MW |
| Other peak load | 24.8 MW | 0.6 MW | 0.5 MW | 0.5 MW | 26.5 MW |
| Total residential peak load | 34.5 MW | 2.2 MW | 1.8 MW | 1.9 MW | 40.4 MW |
| % space heating | 28% | 72% | 72% | 71% | 34% |

The portion of the residential peak load stemming from electric space heating is estimated to have increased from 28% in 2010 to 34% in 2013. Total peak demand from residential housing is estimated to have increased by almost 6 MW since 2010. Over 70% in the increase in residential peak load was due to electric heat in new housing. As part of this analysis, we assume that the peak load demand is currently being met.

### 4.2.3 2013 electrical energy demand for residential space heating

Based on the ICF Marbek report numbers for 2010 plus the estimated new dwelling numbers for 2011-2013 in Table 9 and average per dwelling energy use numbers presented in Table 4 on page 19, the following Table 11 presents estimated residential energy use to 2013:

**Table 11 Total energy use for residential space heating, 2010-2013**

| | 2010 Existing | New units 2011 | New units 2012 | New units 2013 | 2013 Cumulative total |
|---|---|---|---|---|---|
| Space heating energy | 27,740 MWh | 2,969 MWh | 2,271 MWh | 2,292 MWh | 35,272 MWh |
| Other energy | 118,260 MWh | 3,358 MWh | 2,580 MWh | 2,739 MWh | 126,937 MWh |
| Total electricity use | 146,000 MWh | 6,327 MWh | 4,851 MWh | 5,030 MWh | 162,209 MWh |

Total residential electrical energy use in 2013 is estimated at 162.2 GWh, assuming that 90% of new dwellings built since 2011 use electric space heating.

## 4.3 Electric space heating demand forecasts

The model uses forecasts or projections of the number of current and future dwelling units that use electric heat. The peak load and energy demand assumptions presented in Table 2 and Table 4 are applied to the housing projections to obtain the future peak loads and electricity demand.

### *4.3.1 Housing projections*

A number of recent housing forecasts are available, including CMHC's Population and Housing Demand model (PHD) and one done in early 2013 by Zanasi and Pomeroy for the Yukon Housing Corporation. The CMHC forecast has the advantage of breaking down the forecast by dwelling type, which is more useful for our purposes because different dwelling types have different heating requirements and consequent peak loads.

The following Table 12 presents CMHC's housing demand forecast for Whitehorse.

**Table 12 CMHC housing demand projections, Whitehorse, 2011-2036**

| | *Annual Increases in dwellings/households* | | | |
|---|---|---|---|---|
| | Total | Single-detached | Apartments | Other dwellings |
| High scenario | | | | |
| 2011-2016 | 200 | 120 | 20 | 40 |
| 2017-2021 | 160 | 100 | 40 | 20 |
| 2022-2026 | 160 | 80 | 20 | 40 |
| 2027-2031 | 120 | 80 | 40 | 20 |
| 2032-2036 | 120 | 60 | 20 | 40 |
| Low scenario | | | | |
| 2011-2016 | 120 | 80 | 20 | 20 |
| 2017-2021 | 140 | 80 | 20 | 40 |
| 2022-2026 | 120 | 60 | 40 | 20 |
| 2027-2031 | 100 | 60 | 20 | 20 |
| 2032-2036 | 100 | 60 | 20 | 20 |

Source: CMHC, PHD model, 2011-2036 forecasts

The Zanasi-Pomeroy forecasts for Whitehorse are quite different. Zanasi-Pomeroy had two scenarios: a zero migration scenario and one obtained from unpublished population forecasts developed by the Yukon Bureau of Statistics (YBS). The YBS based forecasts are much higher than the CMHC one as they assume the opening of a number of mines, which have now been delayed.

**Table 13 Zanasi-Pomeroy housing demand forecasts, Whitehorse, 2013-2032**

| | Zero Migration | YBS migration scenario |
|---|---|---|
| 2013-2017 | 132 | 305 |
| 2018-2022 | 28 | 273 |
| 2023-2027 | (46) | 263 |
| 2027-2032 | (131) | 248 |
| 2027-2032 | (131) | 244 |

Source: Luigi Zanasi and Stephen Pomeroy

Our analysis uses the low CMHC forecast as it seems to be between the two Zanasi Pomeroy scenarios.

### 4.3.2 Capacity requirements

To estimate the peak load resulting from the new dwellings, it is assumed that 90% of the new housing built will be electrically heated and that each new dwelling will increase the peak load by the amounts presented in Table 2 on page 19.

Multiplying the forecast number of dwelling units with the capacity requirement assumptions presented in Table 2 implies that 0.9 to 1.3 MW of new additional capacity will be required every year to meet the demand for electric heat in new housing. The following graph presents the forecast peak load over the net 25 years, highlighting the contribution of electric space heating as well as the total number dwellings and the number of electrically heated ones. Note that the total number of dwellings is not increasing very much in this projection.

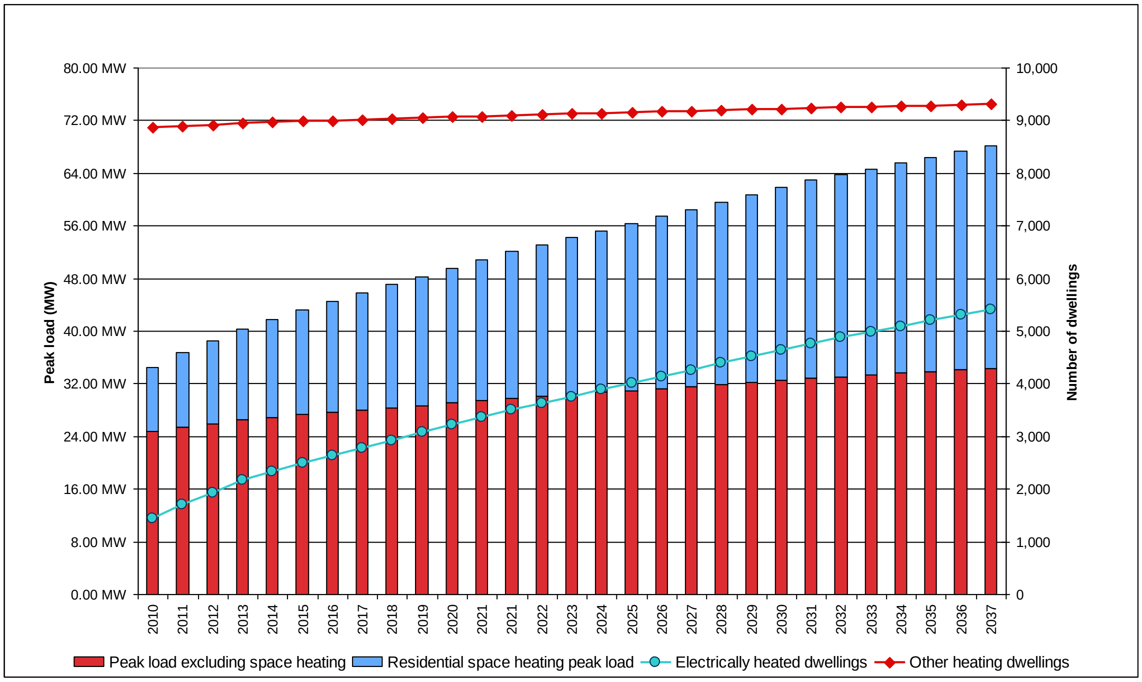


**Figure 10 Forecast residential peak load and number of housing units, 2010-2037**

## 4.4 Cost assumptions

Table 14 presents assumptions relating to new capacity (capital) costs per new installed MW for alternative forms of generation.

**Table 14 Generation capacity capital cost assumptions**

| | Electric capacity costs | Life |
|---|---|---|
| Hydro | $12,000,000/MW | 50 years |
| Diesel | $1,500,000/MW | 15 years |
| LNG | $1,500,000/MW | 15 years |
| Solar | $4,000,000/MW | 25 years |
| Wind | $3,600,000/MW | 20 years |

These assumptions are based mainly on Yukon Energy Corporation documents. It should be noted that the higher the generation capacity capital cost assumption, the higher the potential savings and the affordable subsidy. For the purposes of this analysis, lower capital cost assumptions are more prudent in that they will understate rather than overstate the benefits of ETS systems, giving reasonable numbers at the lower end of the range.

For hydro, low-end estimated costs are at about $10 million per MW plus an additional expense allowance of $2 million for transmission lines. It should be noted that winter maximum hydro generating capacity is generally lower than installed capacity because of lower winter water levels. These factors would increase savings, which would likely result in higher potential incentives.

In its latest Yukon Utilities Board (YUB) application, YEC quoted $2.5 million per MW for replacement of its Whitehorse diesel generators, including considerable ancillary work. Note that YECL is currently replacing a 1.5 MW diesel plant in Watson Lake for $1.474 million and plans to add a 2.0 MW standby generator in Carcross for $3 million in 2015. Therefore, we have used $1.5 million per MW of new diesel generation capacity, a reasonable assumption for the task at hand.

As a further comparison, the proposed new 13.1 LNG replacement is estimated to cost $38.8 million or $2.96 million per MW. This also includes a number of ancillary facilities. For incremental additions to the generating plant, $1.5 million—a figure similar to that for diesel capacity—seems reasonable, although YEC mentions $1.8 million per MW of LNG generating capacity in its Resource Plan Update.

Recently, large scale solar electric generation capacity was installed in Edmonton for $2.5 million per MW[13] and in Anchorage for $2.3-$2.5 million per MW plus owners costs, for a total of approximately $3.0 million per MW. So $4.0 million per MW for solar capacity seems reasonable for the purposes of this exercise. It should be noted that using a higher number is more appropriate for solar, as it will not replace peak capacity, but rather will have the effect of replacing daytime hydro and oil use. The lower the energy cost for non-solar generation, the more prudent the estimate.

The $3.6 million per MW for wind is from a major study of the potential for a Mount Sumanik wind farm.[14]

### *4.4.1 Generation/operating costs*

The operating costs considered in this analysis are the variable operating costs; fixed costs will remain the same whether electricity is generated or not. The numbers are fairly current based on Yukon Energy Corporation data. For diesel generation, the fuel cost of $0.30/kWh is based on $1.20 per litre for fuel and 10.84 kWh/litre at 37% efficiency. [15]

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[13] Personal communication with Gordon Howell of Howell-Mayhew Engineering

[14] Tecsult International, *Wind Assessment Feasibility Study*, 2009

[15] YEC's YESAB proposal "Whitehorse Diesel - Natural Gas Conversion Project YESAA Project Proposal - August 2013 Rev 1". Bases its $0.287 per kWh diesel fuel per kWh costs on a fuel purchase cost of $1.0513 per litre, the most recently Yukon Utilities Board approved fuel cost. For new higher efficiency diesel generators Yukon Energy calculates $0.246 per kWh (page 6-7 including footnotes). Yukon Energy's forecast fuel price for the first quarter of 2014 is $1.22 per litre. So using $0.30 per kWh fuel costs is a reasonable assumption.

**Table 15 Electricity generation variable operating costs per kWh**

| | Variable operating costs | Fuel costs |
|---|---|---|
| Hydro | $0.0100/kWh | $0.0000/kWh |
| Diesel | $0.0300/kWh | $0.3000/kWh |
| LNG | $0.0300/kWh | $0.1500/kWh |
| Solar | $0.0100/kWh | $0.0000/kWh |
| Wind | $0.0300/kWh | $0.0000/kWh |

For diesel and LNG, fixed costs can vary considerably depending on the size of the generating plant, from 3¢ to 10¢ per kWh. Variable costs essentially vary with fuel costs, which can be affected by the distance to the supply source and fuel transportation costs.

Large wind farms experience operating costs of 1-2¢/kWh, so 3¢/kWh is used in the interest of providing a reasonable yet cautious estimate.

### *4.4.2 ETS installation costs*

Table 16 presents the installation costs of ETS systems in different types of new and existing housing. These figures were obtained from discussions with Steffes and local electrical contractors, as well as the recent experience of installing ETS units in two Whitehorse residences. Note that these are incremental costs compared to electric baseboards. For example, there is no cost to upgrade to a 200 ampere service, since baseboards already require a 200 ampere service. Similarly, for new housing, there is little additional cost to install ducting as this is presumably available to meet the Heat Recovery Ventilation (HRV) requirements of the latest building codes.

The installation costs in new housing are assumed to be lower as little additional electrical work is required since the required circuits would have to be installed if electric heat is chosen. For new housing, the only incremental costs are the purchase price and freight costs of the ETS units. For existing housing, there would be additional costs of installing new circuits and ducting. The freight costs for single and row housing are based on actual freight costs paid for the two ETS installations in Whitehorse and amount to about $0.87 per lb. while the freight on apartment units is based on $1.00 per lb. According to the installation contractor, it should be possible to reduce the freight costs,[16] but for the purposes of our calculations we have used the actual costs described above.

**Table 16 Detailed ETS Purchase, Freight and Installation costs**

| **ETS installation** | ETS Purchase | Freight | **New housing** | Installation | **Existing housing** |
|---|---|---|---|---|---|
| Single detached | $6,840 | $1,890 | **$8,730** | $4,000 | **$12,730** |
| Row/attached/mobile | $6,840 | $1,890 | **$8,730** | $4,000 | **$12,730** |
| Apartment | $1,930 | $534 | **$6,324** | $1,000 | **$7,324** |

These installation costs are based on the assumptions for different housing types in Table 17.

[16] Personal communication, Milligan Sheet Metal, 2014/02/07.

**Table 17 Assumptions underlying ETS installation costs**

| Dwelling Type | Annual Heat (kWh) | Design Heat Load (kW) | ETS unit Types | ETS unit capacities | Reserve Capacity |
|---|---|---|---|---|---|
| Single detached | 14200 | 7.5 | 1 unit 4120 | 1x 24.8 kW:120 kWh | 16 hours at -42C |
| Row house | 9400 | 6.25 | 1 unit 4120 | 1x 24.8 kW:120 kWh | 19 hours at -42C |
| Apartment | 4000 | 2.1 | 3 units 2102 | 3x 2.4 kW:13.5 kWh | 19 hours at -42C |
| Apartment | | | 2 units 2103 | 2x 3.6 kW:20 kWh | 19 hours at -42C |

Purchase cost is assumed to be $6,840 for the 24.8 kW units, $1,930 for the 2.4 kW units, and $2,280 for the 3.6 kW units. (Note that the 3.6 kW unit is not used in our analyses.)

Installation costs are zero in new housing, as the same costs would be incurred if electric baseboards or furnaces were installed. In any case, we assume that the ducting installed for the HRV system would also be used for an electric furnace incorporating ETS. For existing dwellings, installation costs are estimated at $3,000 for single detached and row houses and $1,000 per apartment.

## *4.5 Revenue assumptions*

The revenue assumptions are the latest private residential kWh electricity rates approved by the Yukon Utilities Board to July 2013.

**Table 18 Residential Electricity rates**

| Electrical rates | 2011 base rate | Total July 2013 rate including 6.5% for YECL | Total rate 2014 on including YECL 1.5% requested increase |
|---|---|---|---|
| 0-1000 kWh | $0.1214/kWh | $0.1471/kWh | $0.1489/kWh |
| 1001-2500 kWh | $0.1282/kWh | $0.1553/kWh | $0.1572/kWh |
| 2501+ kWh | $0.1399/kWh | $0.1695/kWh | $0.1716/kWh |
| 2013 rate increase : 21.130% | | | |

Note that the rates for government residential accounts are higher, but we do not consider these here in the interest of prudent estimates. The total rate presented above includes the 11.01% increase allowed by the YUB to YEC in January 2013, the 3.62% increase allowed to YEC in July 2013 as well as the interim increase of 6.5%, pending YECL total proposed increase of 9.5% for 2013 plus 2014 (and a further 2.4% requested for 2015). The YEC 3.62% increase is temporary and will expire on June 30, 2014.

## *4.6 Consumer incentive requirements*

Incentives to consumers should be sufficient for a homeowner to switch from electric baseboards to ETS. These incentives depend on the cost of the ETS. The incentive should at least compensate for the additional cost of the ETS; and could be either in the form of a grant or in reduced kWh costs for heating, or a combination of both.

In the case of a grant, the amount should be at least the additional cost of buying and installing the ETS unit, as described in Table 16 on page 34. A per kWh incentive is more difficult to calculate. It should essentially be a series of subsidies or discounts whose present value is equal to the additional cost of the

ETS installation. Therefore, the subsidy depends on interest rates and the length of time the subsidy is to continue.

Figure 11 presents the minimum annual subsidy or discount required to compensate for the cost of the ETS installation from amortization periods between 5 and 25 years, based on 5.3% interest (the average 5-year mortgage interest rate for the second half of 2013).[17] Note that the figure for mobile homes, duplexes and row houses is the same as that for single detached houses as the installation costs are assumed to be the same, as presented in Table 16 on page 34.

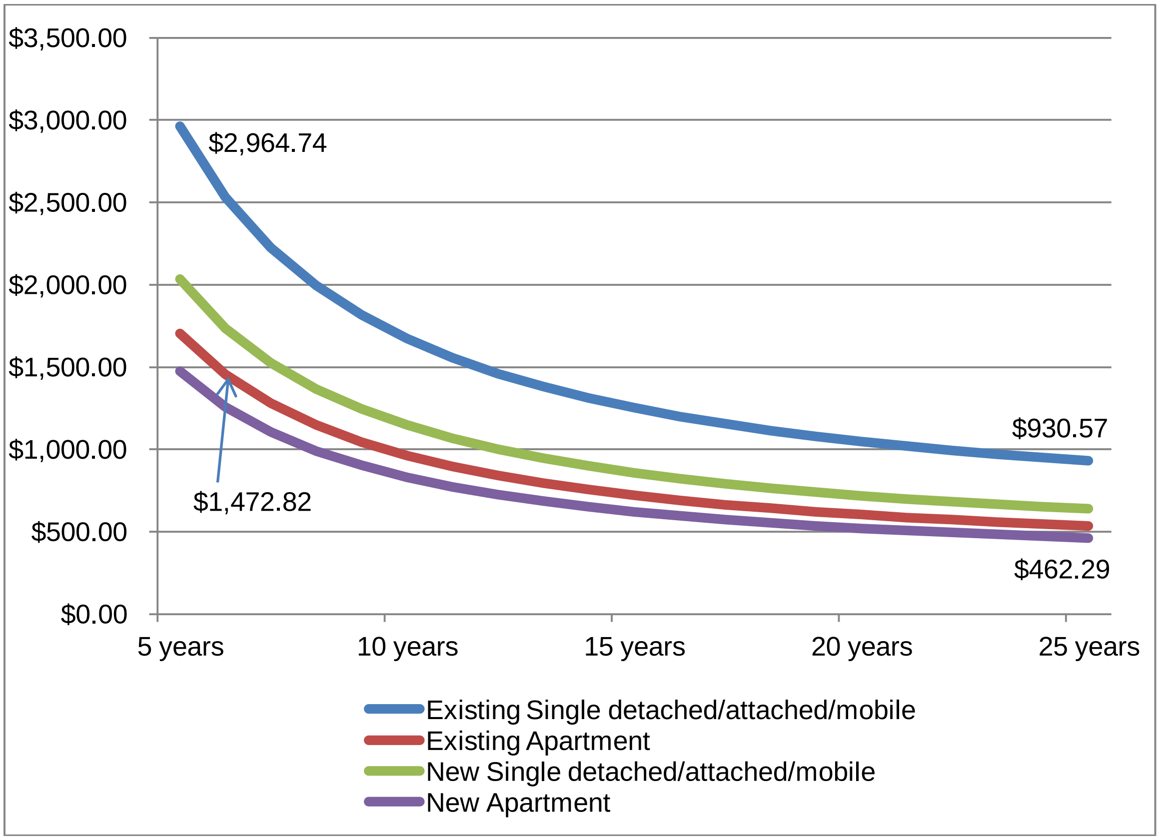


**Figure 11 Minimum break-even annual total dollar subsidy/discount for consumers**

Figure 12 and Figure 13 translate the total dollar subsidy into a per kilowatt-hour rebate or potential discount for, respectively, existing and new housing. The data presented in Figure **12** is based on the total kWh energy consumption presented in Table 5 on page 20.

[17] Calculated from data obtained from Bank of Canada, "Canadian interest rates and monetary policy variables: 10-year lookup", http://www.bankofcanada.ca/rates/interest-rates/canadian-interest-rates/

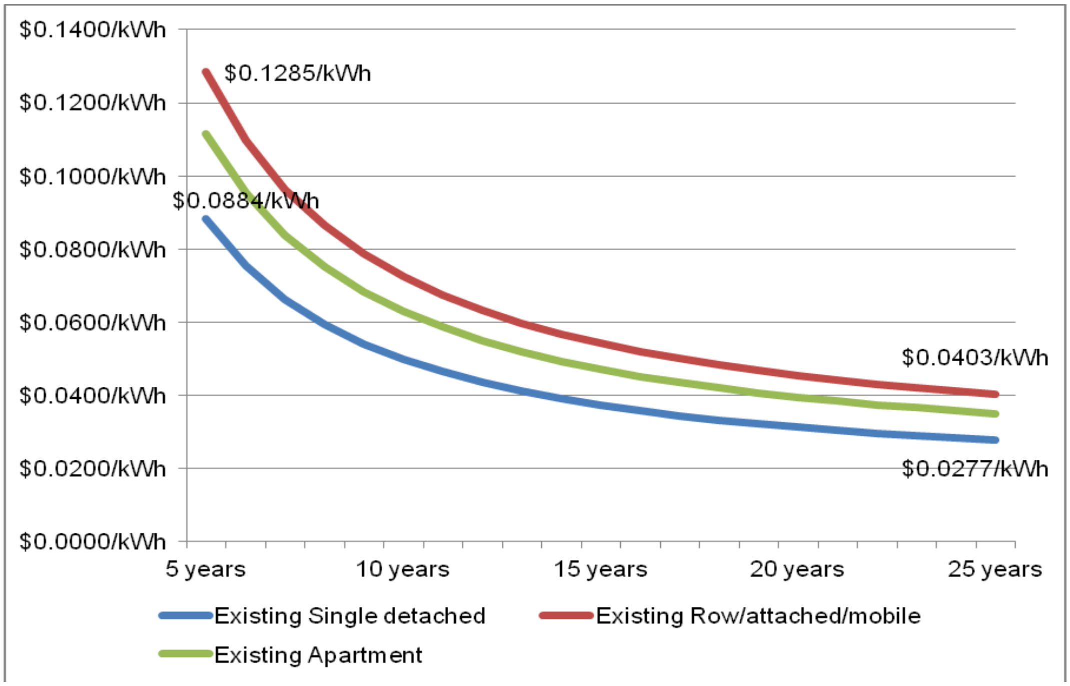


**Figure 12 Minimum $/kWh incentive required for existing housing**

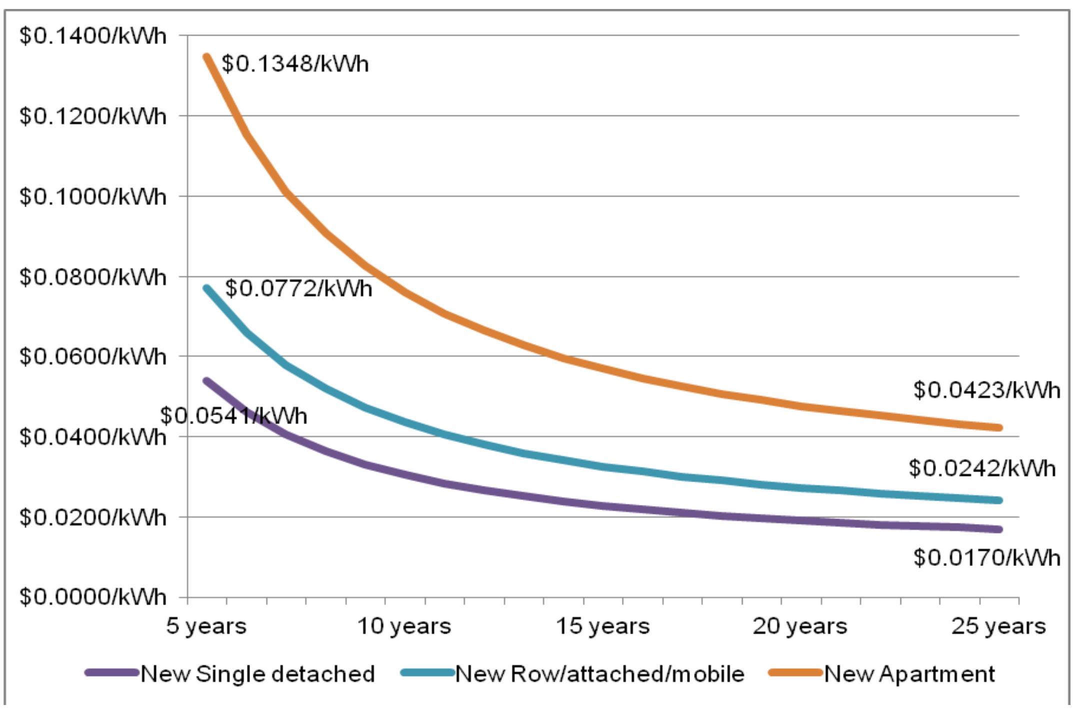


**Figure 13 Minimum $/kWh incentive required for new housing**

# 5 Case 1: Shifting peak electric heating load to off-peak periods with peak load supplied by diesel

For this case, the peak load would have to be supplied by diesel and assumes no surplus hydro is available. Consequently, unlike Case 2, there is no fuel or other operating cost savings; all heating energy would be supplied by diesel generators. Note that this case is very similar, if not identical, to the case where space heating electric energy was to be supplied by natural gas.

The savings in this case stem from avoiding adding additional generating capacity. By shifting the space heating peak load to night time, the utility will avoid adding additional diesel generating capacity.

The peak load shift could be either from future new housing installing ETS systems, or existing electrically heated houses retrofitting ETS units. Additional capacity will be required to service forecast new housing built in the near future as long as relative prices of electric heat and fuel oil remain similar to current ones, unless a ban is imposed on electric heat as is the case in communities which rely on diesel generated electricity.

To justify shifting the peak load for existing housing requires that additional demand for capacity materializes. This could be the case if there were a large increase in industrial (e.g. a mine) or commercial demand, or also could also be a response to increases in residential space heating demand for new housing. Also, Yukon Energy Corporation has a number of old generators that will have to be retired and replaced in the coming years so the need for new capacity will occur even without new load.

As presented in Figure 5 on page 23, there is about 7.6 MW of peak load that could be shifted, based on total design load of 9 MW.

We consider newly constructed and existing housing separately.

## 5.1 ETS incentives for new housing

As presented in Figure 10 on page 32, the forecast new housing would result in an increase of capacity required of between 0.9 to 2.0 MW per year just for space heating with a cost of $1.5 million per MW. By peak load shifting, the need for that additional peak capacity would not be required, resulting in savings in capital costs. These savings can be translated into a maximum grant, a maximum annual rebate, or a maximum per kWh subsidy.

Given the amount of load that could be shifted (7.6 MW), a program directed only at new housing could run from 2014 to 2018 or 2019. The total additional load required in those years for forecast new housing amounts to 6.73 MW in 2018 and 8.0 MW in 2019. As Figure 14 shows, after mid-2019, new capacity will be required as all peak load that could be shifted would have been.

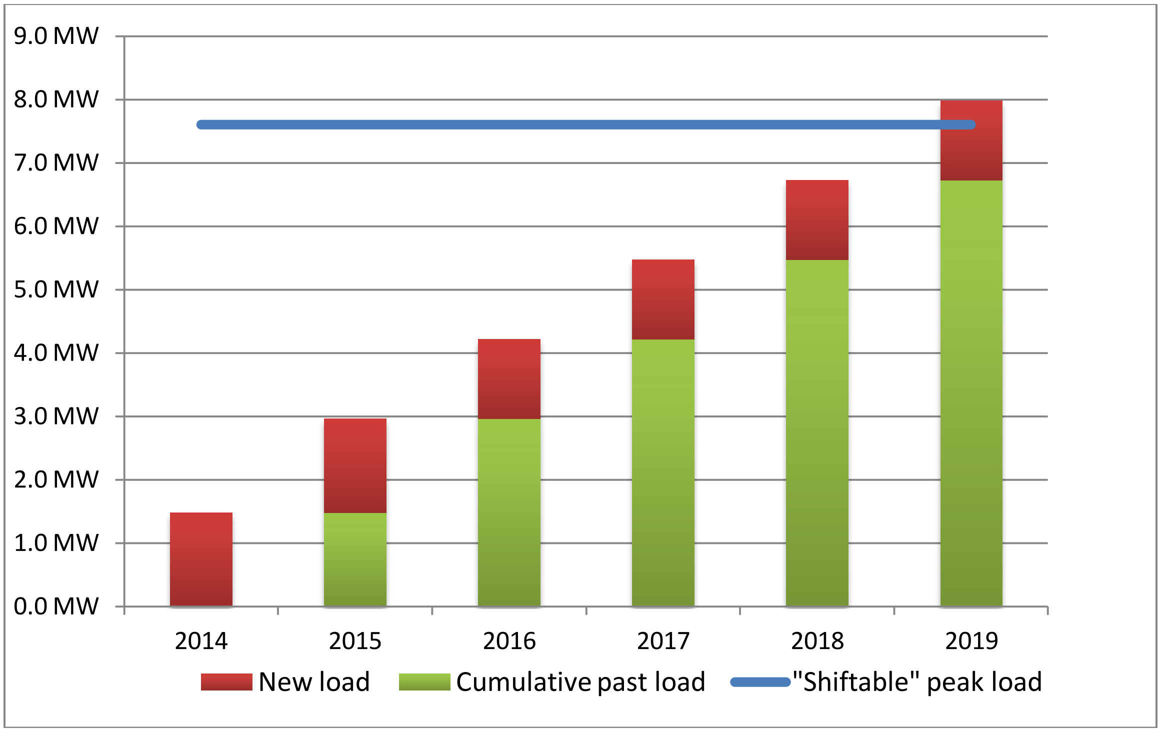


**Figure 14 Forecast peak load increases 2014-2019**

Based on the capital capacity cost of $1.5 million per MW described in section 4.4.1, the maximum subsidy could take form of a grant, a per kWh rebate, or a combination of both. In the case of a kWh rebate, the amount of the subsidy would depend on its duration. Therefore, the maximum rebate is calculated for 5, 10 or 15 years.

New peak capacity required to meet the new electrical heating need costs about $9,600 per new dwelling unit. This means that the utility could provide a grant of up to $9,600 per dwelling that installs ETS. This is above the cost of installing ETS in new housing, estimated to range from $6,324 for apartments to $8,730 for single detached and attached housing as presented in Table 16 on page 34. In the case of new housing, the utility could provide a grant for the full cost of installing an ETS system and still come out ahead.

Alternatively, the incentive could be provided as a lower blended kWh rate or kWh rebate or a combination grant and kWh rebate. The maximum kWh rebate will depend on how long it is offered. The shorter the period, the greater the kWh rebate. Figure 15 below shows the maximum kWh rebate that could be offered for 5, 10 and 15 years. Thus, the maximum rebate, were it to continue over 5 years, should not exceed 9.7¢ per kWh, while a rebate lasting 15 years would be much lower at 4¢ per kWh.

The maximum kWh rebate is estimated by first calculating the annual amount of subsidy available. This annual subsidy amount is the payment at the selected discount rate that would yield a present value equal to the maximum grant. That annual figure is then divided by the typical total kWh annual energy consumption to yield a rebate per kWh.

A blended rate would be calculated by simply subtracting the kWh rebate from the total rate. This, for example, with a 15¢ per kWh base rate and 4.0¢ per kWh rebate, the blended rate paid by the ETS user would be 11.0¢ per kWh.

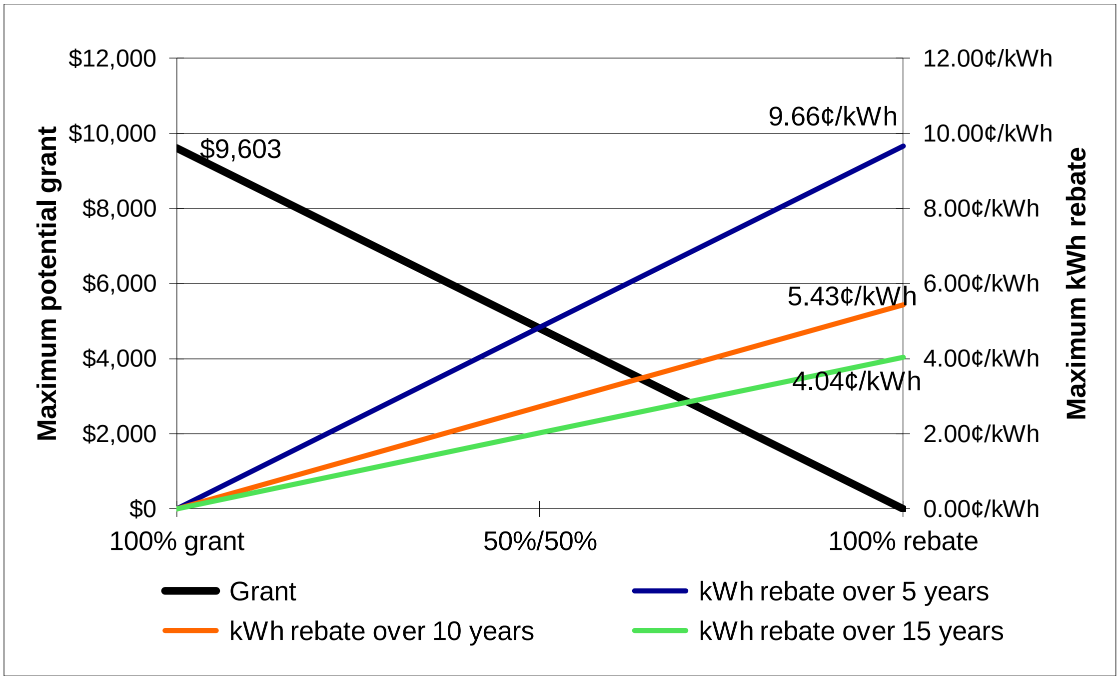


**Figure 15 Maximum grant vs kWh rebates from capacity saving resulting from peak switching, new housing, 5-15 years**

## *5.2 ETS Incentives for existing housing*

For existing housing there are no savings related to shifting from peak hours to off-peak hours, unless new capacity is required for other loads. Otherwise, no additional capacity would be required as it is presumably already in place. The total energy used (kWh) would be the same, however, existing aging diesel plants will need to be replaced in the near future.

As well, shifting the peak load for existing housing could be effectively used to avoid installing new capacity for non-residential customers. New capacity will be required for new housing, most of which is likely to be electrically heated, barring large declines in the cost of fuel oil. Also, large increases in commercial, or especially, industrial demand (e.g. from a new mine) could result in additional capacity requirements. In such a case, it would make sense to reduce peak load even if no new electrically-heated housing is being built.

The calculations and viability of a subsidy are different for existing housing. First, installing an ETS system in existing housing would be more expensive than in a new house as was detailed in Section 4.4.2 ETS installation costs and Table 16 on page 34. For existing single and attached housing, installation costs are estimated at $12,730 while the cost per apartment is $7,324.

**Table 19 ETS installation costs**

| ETS installation | Existing housing | New housing |
|---|---|---|
| Single detached | $12,730 | $8,730 |
| Row/attached/mobile | $12,730 | $8,730 |
| Apartment | $7,324 | $6,324 |

As with new housing, the incentive could take the form of a grant or a kWh rebate, or a combination of both. As the take-up rate for different dwelling types is not known, the subsidy should depend on dwelling type. Table 20 presents maximum grants and kWh hour rebates for the different housing types. Note that the two should not be added: either a grant or a kWh rebate could be offered. If a combination is desired, then, for example, the grant could be cut in half as would the rebate. A blended kWh rate could be offered, where the rebate is subtracted from the base kWh rate.

**Table 20 Maximum grant or kWh rebate for different dwelling types, existing housing**

| | **Single Detached** | **Attached/mobile** | **Apartment** |
|---|---|---|---|
| Maximum grant | $11,550 | $7,500 | $6,000 |
| kWh rebate over 5 years | 9.60¢/kWh | 8.91¢/kWh | 13.82¢/kWh |
| kWh rebate over 10 years | 5.37¢/kWh | 4.98¢/kWh | 7.73¢/kWh |
| kWh rebate over 15 years | 3.99¢/kWh | 3.70¢/kWh | 5.74¢/kWh |
| kWh rebate over 20 years | 3.32¢/kWh | 3.08¢/kWh | 4.77¢/kWh |

Comparing the figures presented in Table 19 and Table 20, the maximum potential grant is slightly lower than the ETS installation costs. In theory, it would not be enough to induce a rational homeowner to install an ETS system. However, as discussed in Section 7.1.2, with a rebate based on diesel fuel savings, an ETS system does become economic.

Given that a maximum of 7.6 MW could be shifted, a number of take-up or market penetration scenarios for different housing types are possible. Estimate of electrically heated housing units in 2013 amounted to 2,169 as provided in Table 9 on page 29 (comprised of 1,220 single detached houses; 610 duplex, attached and mobile homes; and 339 apartment units). Based on the design peak loads per dwelling units provided in Table 2 on page 19 presents examples of different scenarios for take-up or market penetration.

The first bar assumes the program is limited to single detached houses. Converting 81% or 990 of the estimated 1,220 single detached houses would "use up" the 7.6 MW peak load capacity saved by ETS. If the program excluded apartments, the maximum economic take up would be about 61% of detached and attached houses (including duplex, row houses and mobile homes). The last bar in the graph shows a situation where all attached and apartment units convert to ETS. This kind of program would still need some penetration in the single detached housing to reach the maximum 7.6 MW saved peak load capacity.

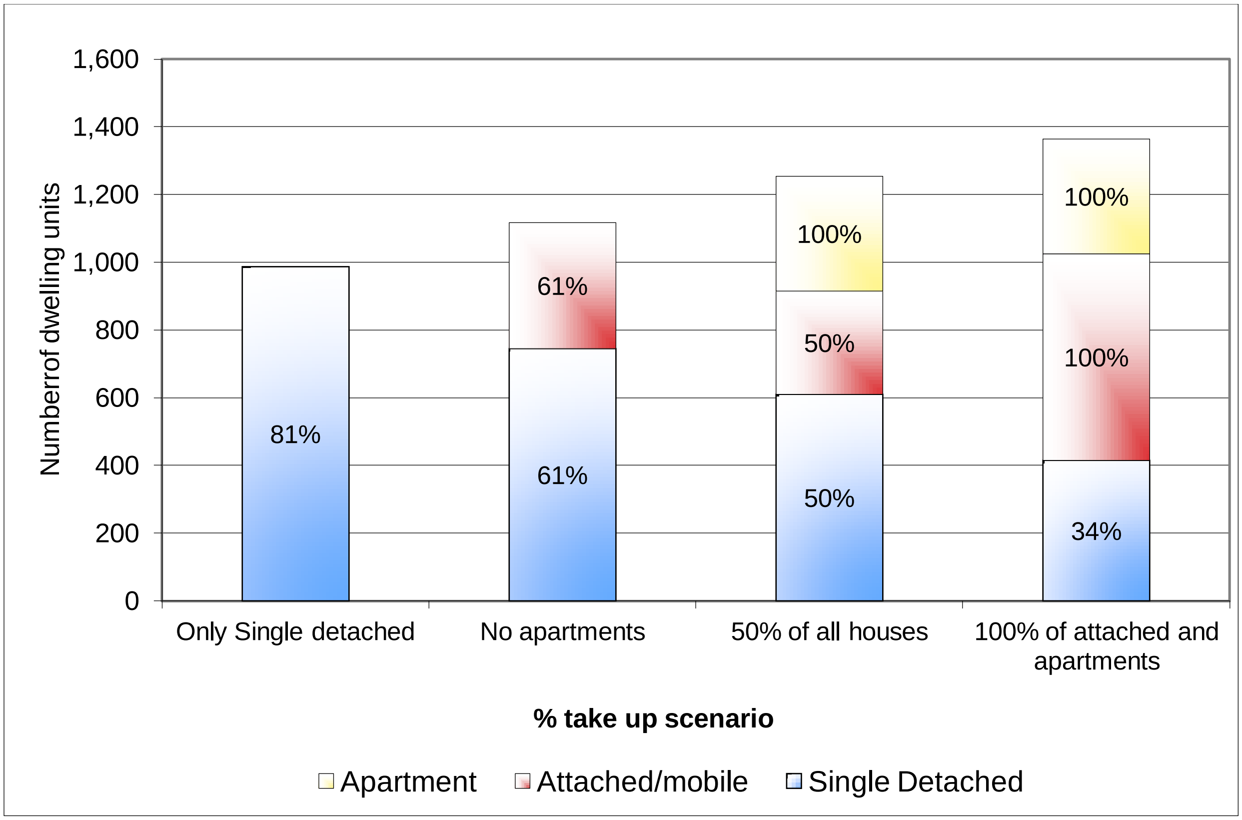


**Figure 16 ETS Market penetration or take-up scenarios for 7.6 MW peak load capacity savings, 2013 existing housing.**

# 6 Case 2: Shifting peak electric heating to off-peak periods with peak load supplied by new hydro

If hydro-electric capacity is built for winter peaking, the savings would be greater than shown in Case 1, due to the higher cost of hydro-electric generation equipment, which can range from about $2 million/MW (as in the case of the Aishihik third turbine which was an addition to an existing plant) to $16 million/MW (as in the case of Mayo B which was almost an entire new hydro-electric facility).

Examination of this case will form part of Phase II of this project.

# 7 Case 3: Shifting peak electric heating to off-peak periods with off-peak load supplied by existing hydro

This scenario examines the economics of shifting space heating peak load from diesel generation to existing off-peak hydro power. This is based on the assumption that the diesel capacity to meet the current (2013) space heating demand is not used in off-peak periods as hydro-electricity is available.

If additional diesel is used for peaking and existing hydro-electricity is used for off-peak periods, the savings would include the diesel fuel saving as well as the capital cost saving from avoiding building additional capacity, resulting in greater savings than shown in the Case 1.

The modelling exercise presented in *Section 3.3 Modelling shift to off peak hydro* showed that the potential savings in diesel generation depended on the number of houses converted to ETS. The average savings per dwelling declines as the number of houses using ETS increases. This assumes that sufficient water is available in the spring to generate the electricity.

There is 7.6 MW of peak load that could be shifted, as shown in Figure 5. However, unlike Case 1, shifting peak load from diesel to existing hydro (up to the maximum) can be justified without additional demand as the generating capacity presumably already exists. However, new diesel-fuelled capacity will be required as retiring capacity will need to be replaced in the near future.

The savings from avoiding burning diesel are 32¢ per kWh, assuming avoided costs of 30¢ per kWh for the fuel, 3¢/kWh operating costs, offset by 1¢ per kWh operating costs for hydro generation. Given those savings and based on the results of the modeling presented in Table 6 on page 21, we use the assumption that a switch to diesel saves an average of $422.08 per dwelling per year, which represents the maximum savings possible as shown in Table 21. As with Case 1, we consider existing housing and newly-constructed housing separately.

**Table 21 Potential annual diesel cost savings by switching to hydro**

| # of Dwellings converted to ETS | Diesel Saved | Total annual savings by utility @ 32¢/kWh | Diesel saved per dwelling | Net Diesel $ saved per dwelling @ 32¢/kWh |
|---|---|---|---|---|
| 160 | 424 MWh | $135,680 | 2,649 kWh | $847.68 |
| 320 | 845 MWh | $270,400 | 2,641 kWh | $845.12 |
| 480 | 1,236 MWh | $395,520 | 2,574 kWh | $823.68 |
| 640 | 1,563 MWh | $500,160 | 2,442 kWh | $781.44 |
| 800 | 1,832 MWh | $586,240 | 2,290 kWh | $732.80 |
| 960 | 2,051 MWh | $656,320 | 2,137 kWh | $683.84 |
| 1,120 | 2,229 MWh | $713,280 | 1,990 kWh | $636.80 |
| **1,200** | **2,297 MWh** | **$735,040** | **1,919 kWh** | **$614.08** |
| 1,280 | 2,365 MWh | $756,800 | 1,848 kWh | $591.36 |
| 1,600 | 2,553 MWh | $816,960 | 1,596 kWh | $510.72 |
| 1,920 | 2,664 MWh | $852,480 | 1,388 kWh | $444.16 |
| 2,240 | 2,737 MWh | $875,840 | 1,222 kWh | $391.04 |
| 2,560 | 2,787 MWh | $891,840 | 1,089 kWh | $348.48 |
| 2,880 | 2,826 MWh | $904,320 | 981 kWh | $313.92 |
| 3,200 | 2,856 MWh | $913,920 | 892 kWh | $285.44 |

## 7.1 ETS incentives for existing housing

For existing housing, it could be argued that there are no savings from avoiding additional capacity, as presumably, the capacity already exists. We first examine what the potential incentives could be if no additional capacity is needed, i.e. determine the value of the diesel saved with no consideration of generating capacity savings. However, as has been pointed out above, new generating capacity will be needed to replace existing aging generators, and additional capacity will be required for new housing and also potentially for industrial or commercial users. Therefore, including the savings resulting from avoiding increased capacity needs to be considered.

### 7.1.1 Diesel fuel savings only

The annual savings per dwelling unit presented in Table 21 can be converted to kWh rebates by dividing by total annual kWh consumption. The rebate will vary depending on how many houses are converted. The 7.6 MW maximum load that could be shifted would account for about 1,200 dwellings (bold in Table 22), presenting the maximum potential kWh rebate for different numbers of electrically-heated houses converted to ETS. The maximum rebate for diesel fuel savings resulting from ETS is about 2.81¢ per kWh. The other bolded line, for 2,169 dwellings, is the estimated total number of electrically heated dwelling units in 2013 (see Table 9 on page 29).

**Table 22 Maximum potential kWh rebate resulting from diesel fuel savings for different numbers of existing dwellings converted to ETS**

| Number of Dwellings converted to ETS | Maximum potential kWh rebate |
|---|---|
| 160 | $0.0388/kWh |
| 320 | $0.0387/kWh |
| 480 | $0.0377/kWh |
| 640 | $0.0358/kWh |
| 800 | $0.0335/kWh |
| 960 | $0.0313/kWh |
| 1,120 | $0.0291/kWh |
| **1,200** | **$0.0281/kWh** |
| 1,280 | $0.0271/kWh |
| 1,600 | $0.0234/kWh |
| 1,920 | $0.0203/kWh |
| **2,169** | **$0.0184/kWh** |
| 2,240 | $0.0179/kWh |
| 2,560 | $0.0159/kWh |
| 2,880 | $0.0144/kWh |
| 3,200 | $0.0131/kWh |

Another way of viewing this is taking the present value of the annual savings over a different period and comparing it to the cost of installing ETS as presented in Table 16 on page 34.

The following Figure 17 presents the present value of the diesel fuel savings over different time periods and compares it with ETS installation costs. It is clear that the diesel savings on their own are not sufficient to compensate for the cost of ETS installation. Note that these data implicitly assume no increase in the price of fuel, or alternatively that the 7% discount rate is a "real" discount rate where inflationary increases are already taken into account.

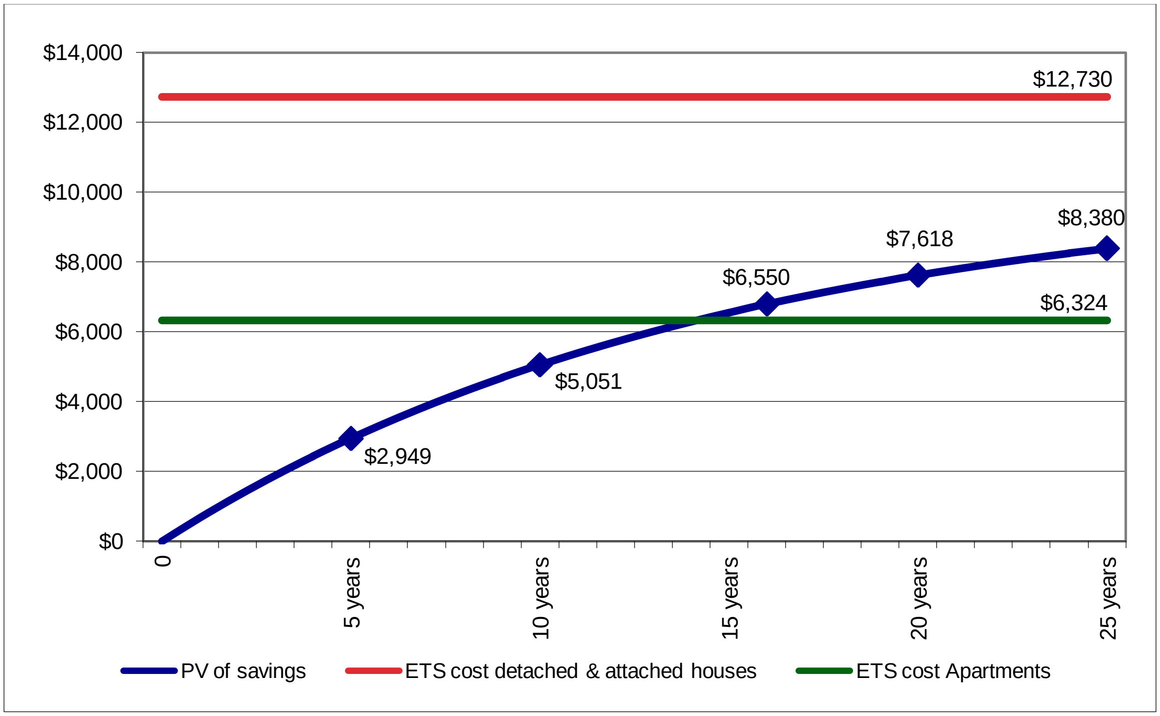


**Figure 17 Present value of potential diesel savings compared to ETS installation costs for existing housing**

### *7.1.2 Diesel fuel savings and avoided capacity increases*

If additional capacity is required for other reasons such as new industrial/commercial users, new electrically-heated dwellings, or just as replacement for end-of-life diesel generators, the cost of the additional capacity should also be considered. In that case, the maximum subsidy or rebate becomes economic for the dwelling owner. So the total maximum incentive will be the sum of the additional capacity savings described in 5.2 ETS Incentives for existing housing and of the kWh potential rebate described above.

If the two types of savings are added up together, potential ETS rebates or subsidies become economic after two years as Figure 18 below shows. After two years, the present value of the diesel fuel savings and the avoided capacity expenses exceed the cost of installing ETS in existing housing.

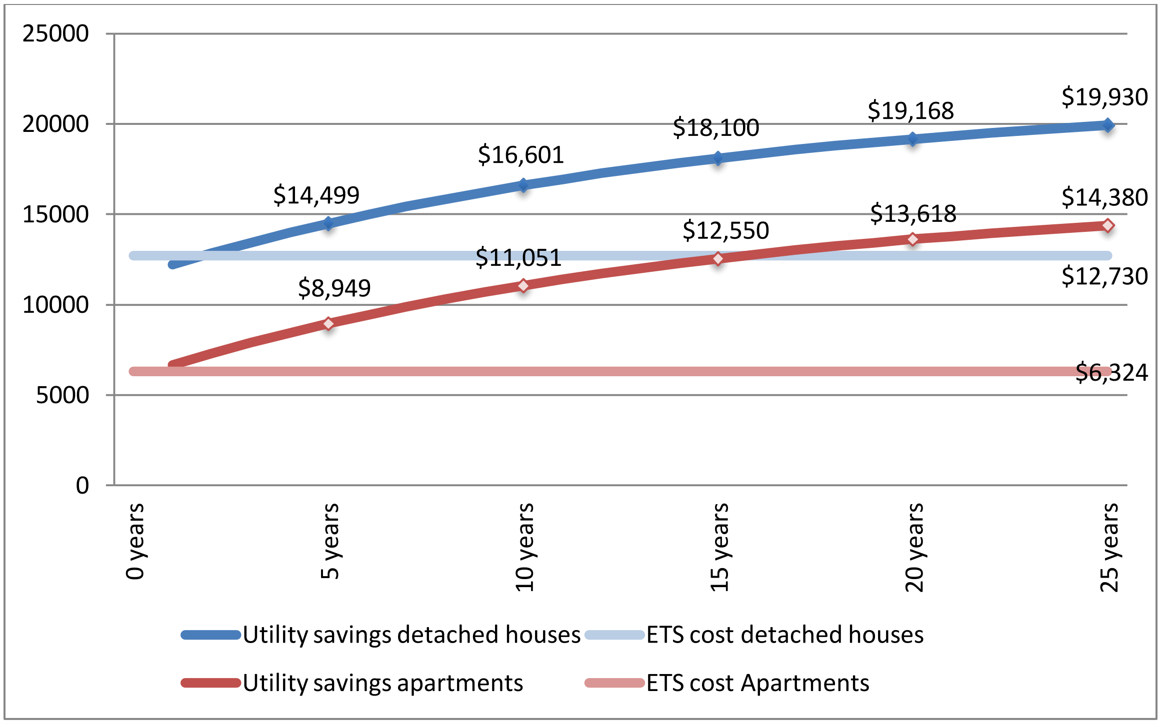


**Figure 18 Present value of potential diesel fuel and capacity savings compared to ETS installation costs for existing housing**

## 7.2 ETS incentives for new housing and/or increased capacity demand

The rebate for new housing or increased capacity demand could have two components: one for avoiding additional capacity (similar to the one described in Case 1 above) and another for savings in diesel fuel. The potential grant or rebate would be the sum of the capacity component described in section 5.1 (ETS incentives for new housing) and of the savings on diesel-only, described in the preceding section. Given that the maximum rebates calculated in Case 1 above were attractive for new house owners, the additional amount from diesel savings would make it even more so.

As was presented in Figure 10 on page 32, the forecast new housing would result in an increase of capacity required of between 0.9 to 2.0 MW per year just for space heating with a cost of $1.5 million per MW. By peak load shifting, the need for that additional peak capacity would not be required, resulting in savings in capital costs. These savings can be translated into a maximum grant, a maximum annual rebate or a maximum per kWh rebate.

The amount of the grant and of the rebate is dependent on the period during which it is offered. Figure 15 on page 40 showed the maximum grant or kWh rebate for different time periods and different dwelling types. For diesel savings, the longer the ETS is in place the greater the savings; the approximate $614.00 estimated savings (per dwelling for 1,200 dwellings as interpolated from the data presented in Table 21) is an ongoing annual saving.

Figure 19 presents the relationship between the maximum grant and the maximum kWh rebate if both peak capacity and diesel fuel savings are taken into account. The amounts depend on how long the subsidies continue. Over 5 years, the maximum up-front grant should be no more than $16,182 or the rebate at $0.0581 per kWh. At the other end, should the subsidies continue for only 5 years, the initial grant should not exceed $12,341 and the rebate could go as high as $0.1204 per kWh.

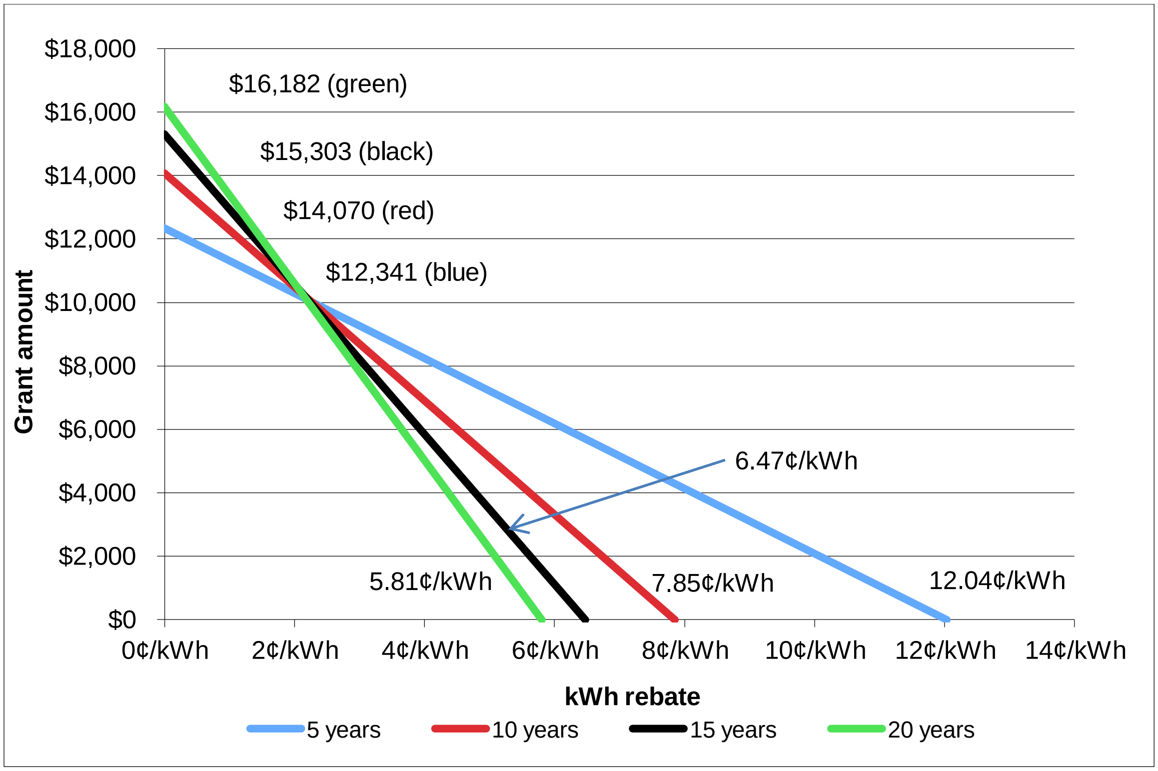


**Figure 19 Maximum potential grant vs maximum kWh rebate based on diesel and peak capacity savings, new housing, 5-20 years**

# 8 Case 4: Using solar PV to reduce the electric heating load supplied by diesel generators

Using solar PV in combination with ETS to supply and store electric heat during the day would reduce the amount of electricity supplied using diesel generators or hydro-electricity. As the peak demand occurs before sunrise and after sunset in December, PV cannot be used to shift the peak load. However, it could be used to reduce dependence on diesel.

PV would mainly displace daytime use of hydro-electricity, at least 59% of the PV-generated energy, according to the modelling exercise presented above in Section 3.4. However, it would also result in reduced diesel usage. Table 23 presents potential savings in diesel for different PV capacity installations.

**Table 23 Diesel savings in MWh from different sized PV installations**

| PV Capacity (MW) | PV annual Energy (MWh) | Diesel displaced (MWh) | Portion of PV to Diesel |
|---|---|---|---|
| 0.5 | 538 | 166 | 31% |
| 0.8 | 861 | 263 | 31% |
| 1.0 | 1,076 | 325 | 30% |
| 2.0 | 2,151 | 602 | 28% |
| 3.0 | 3,227 | 840 | 26% |
| 4.0 | 4,303 | 1,039 | 24% |
| 5.0 | 5,378 | 1,201 | 22% |
| 6.0 | 6,454 | 1,340 | 21% |
| 7.0 | 7,529 | 1,460 | 19% |
| 8.0 | 8,605 | 1,563 | 18% |
| 9.0 | 9,681 | 1,652 | 17% |
| 10.0 | 10,756 | 1,730 | 16% |
| 15.0 | 16,134 | 2,020 | 13% |
| 20.0 | 21,513 | 2,210 | 10% |

The numbers above are based on actual production data from the 4.1 kW PV system on the Yukon Legislature. The PV data is scaled to match the capacities shown above. The PV production data covers the three year period 2010 to 2012. The average diesel consumed during this period was 8045 MWh/yr. Note that the diesel plants produced 5175, 15926, 3024 MWh for the years 2010, 2011, and 2012 respectively. In 2011 the Mayo B plant was being connected to the grid, so the diesel plant ran more frequently during change over.

There might be some dollar savings here, depending on the relative costs of diesel vs. hydro-electric generation, but it would also "conserve" water to use late in the spring before the freshet occurs or in years of drought. Based on variable operating costs of 33¢/kWh for diesel generation and 1¢/kWh for hydro-electric generation, the savings for 1 MW installed PV would amount to about 10.7¢/kWh.

In the case of homeowner-installed ETS systems, the utility savings would be offset by foregone revenue amounting to 15.72¢/kWh assuming that the heating energy would fall in the second rate tranche of 1001-2500 kWh per month. So from the utility's perspective, the revenue losses from homeowner-owned PV systems could result in a net revenue loss. To break even, the utility would require diesel costs at a minimum of just under 50¢/kWh.

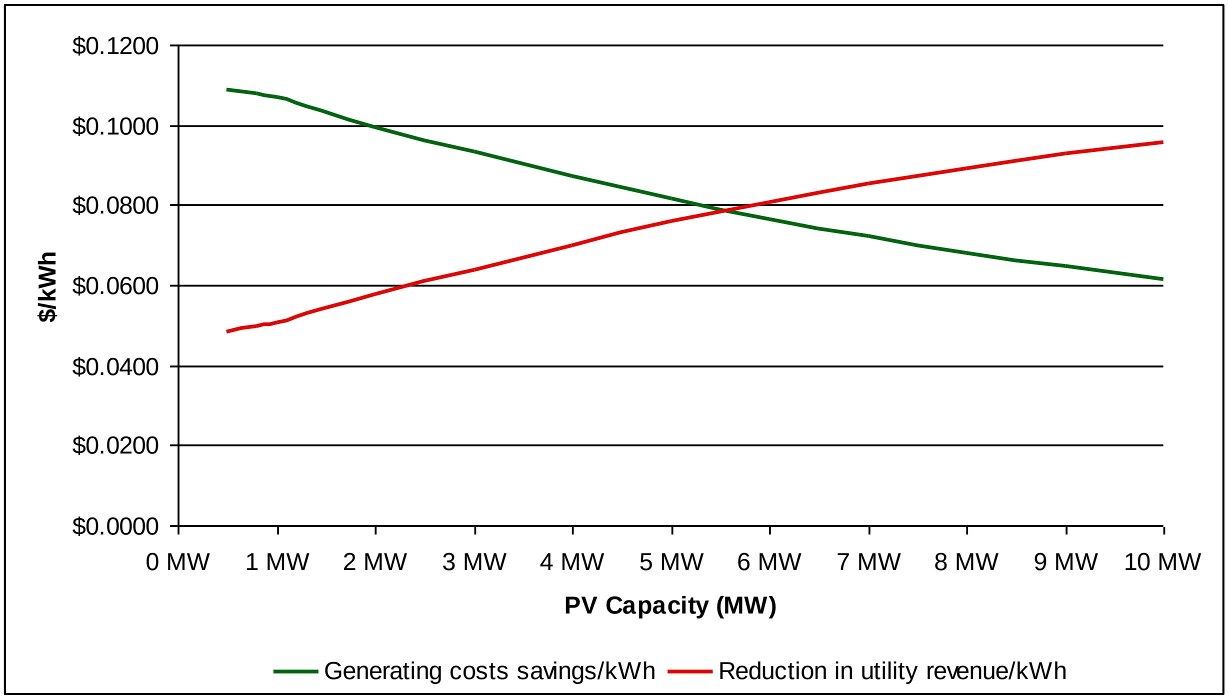


**Figure 20 Generating costs savings and effect on utility revenue per kWh of PV capacity**

ETS improves the economics of PV for homeowners, as heat can be stored during the day for release at other times. About 47% of the energy generated by the PV system could be used for heating with an ETS in place.

To compare the cost of PV electricity with that of diesel generated power involves calculating and comparing the levelized cost of energy (LCOE) of the two options. The LCOE calculation essentially involves estimating the present value of capital and operating costs and dividing by the "discounted" total energy produced by each of the options. Based on the capital and operating cost assumptions presented in Table 14 on page 32 for diesel and utility level PV generation, as well as the experience with installing a 4.7 kW system in Burwash Landing - to represent a smaller scale PV system ($26,000), Table 24 presents the LCOE for two configurations of PV systems and for diesel generation.

It should be noted that the estimates in Table 24 assume no increase in the cost of diesel fuel and no degradation of the PV system over its life. Also, it does not calculate recapitalization of the diesel system at the end of the 15 years, which would make diesel look worse. We also assume that the diesel generators have an availability of 100%. However, new diesel generators do not typically have an availability of more than 90% due to servicing requirements, so actual annual production would be (at best) 90% of 8,766 or 7,889 MWh per year per MW of capacity.

At the usual 7% discount rate, diesel is cheaper on a levelized cost basis but the LCOE is extremely sensitive to the discount rate. The discount rates where the LCOE of PV is the same as diesel are not very much lower: 5.95% for a utility scale system and 4.47% for a smaller scale PV system. Another interpretation of these figures is that the savings in fuel costs from a PV system yield a return of, respectively, 5.95% and 4.47% per year on the additional initial cost of a PV system

**Table 24 Comparison of Levelized Cost of Energy, PV & diesel generation**

| | ***PV Utility*** | ***PV Personal*** | ***Diesel*** |
|---|---|---|---|
| Annual energy produced per MW capacity | 922 MWh | 1,100 MWh | 8,766 MWh |
| Cost per MW | $4,000,000 | $5,500,000 | $1,500,000 |
| Life | 25 | 25 | 15 |
| Operating costs/kWh | $0.010/kWh | $0.010/kWh | $0.330/kWh |
| Annual operating costs | $9,220 | $11,000 | $2,892,780 |
| NPV of costs @ 7% discount rate | $4,107,446 | $5,628,189 | $35,211,252 |
| Total energy produced over life | 23,050 MWh | 27,500 MWh | 131,490 MWh |
| "Discounted" energy produced over life of investment | 10,745 MWh | 12,819 MWh | 79,840 MWh |
| Levelized Cost of Energy (LCOE) @ 7% discount rate | $0.382/kWh | $0.349/kWh | $0.349/kWh |
| Break-even discount rate | 5.95% | 4.47% | |
| Break-even cost per MW | $3,640,000 | $4,343,000 | |

# 9 Case 5: Using wind power to reduce the electric heating load supplied by diesel generators

This case will determine whether wind power can be economic at current energy prices if electric thermal storage is available to store the electricity generated during both on and off-peak periods in the Yukon. This case is similar to cases that were analyzed in Prince Edward Island and Alaska.

We believe this is one of the most promising areas of investigation, as ETS is eminently suited to intermittent forms of generation.

Examination of this case will be part of Phase II of this project.

# 10 Case 6: Using wind power and solar PV to reduce the electric heating load supplied by diesel generators

If solar PV and wind are used in combination with ETS to supply and store electric heat during the day, then the amount of electricity supplied using diesel generators or hydro-electricity could be reduced. In this case, PV and wind would replace alternatives when there is an economic advantage to doing so (e.g., to save water for electricity generation at a future time, such as in the spring, or during periods of drought).

This case will be evaluated to determine if solar electricity and wind in combination with ETS makes sense at current prices, for a house that meets the Passive House standard (e.g., 3,600 kWh and 1.5 kW heat load peak, plus 0.8 kW for HRV load), for a SuperGreen house (12,000 kWh annual heating load) and for conventional house construction (30,000 kWh annual heating load). With the new Whitehorse building standards the annual heating requirements for an average detached home would be 15,000 kWh per year. Another purpose is to evaluate at what price for solar PV systems and wind generation systems would wind and solar electricity combined with electric thermal storage make economic sense.

Examination of this case will be part of Phase II of this project.

# 11 Conclusion and Recommendations

## *11.1 Conclusion*

As part of a parallel study (also reproduced in this report), the use of ETS was documented in a fair number of utilities across northern North America to shift peak loads. It was established that time-of-use metering was not essential for the program to work: there are a number of other methods of controlling when ETS uses electricity.

In the modelling exercise done as part of the parallel study, it was established that about 7.6 MW of capacity could be shifted away from peak daytime diesel powered electric generation. Installing ETS systems in about 990 (single detached) dwelling units could shift that peak capacity. Forecasts of Yukon housing demand points to an increase in capacity requirement of about one MW per year for the foreseeable future as long as the current trend that 90% of new housing is electrically heated.

Given recently experienced costs of installing ETS, it would be economic for the utility to compensate new housing for the full cost of installing ETS units, either through a direct grant or through an on-going kWh rebate.

The situation is different for existing housing because of the higher costs of installation. Assuming a $1.5 million per MW installation cost for new diesel capacity, the avoided costs of installation resulting from peak shifting are not sufficient to compensate for the cost of ETS installation. However, if the diesel fuel savings are brought in, ETS does become economic.

Solar is less available during the winter, and therefore can not be used for peak shifting. During the shoulder seasons (spring and fall) however, solar is more available during the daytime peaking hours. Currently, the levelized cost of solar PV is only marginally more expensive than diesel generation. As the cost of PV continues to fall, there might eventually be room to displace diesel generation with PV for heating during the day.

## *11.2 Recommendations*

Refine estimates of potential savings by:

- Developing up-to-date diesel replacement cost estimates and rerunning the economic analysis (the $1.5 million per MW estimate used in this report appears low for grid back-up and peaking purposes);
- Obtaining a better estimate of the number electrically heated dwellings using detailed building permits & property assessment data;
- Getting better estimate of energy consumption by residences using actual data rather than modelling (select sample & monitor usage);
- Including analyses of using DHW tanks for electricity storage (in addition to ETS);
- Determining total surplus hydro capacity and energy on a seasonal and diurnal basis and refining diesel savings estimates accordingly. Our model assumes that there is available hydro capacity and energy at night on a year-round basis;

- Looking at scenarios with higher loads and varying loads. If the installation of electric baseboards continues at 90% for new houses, load growth scenarios will need to be adjusted accordingly;

- Obtaining daily load models from YEC to account for seasonal diurnal wind patterns – principally during the summer;

- Accounting for increased winter loads relative to summer loads as a result of increased electric heating load;

- Refining diesel savings analyses to include more years of data than the 2010-12 actual (used in our modeling) when hydro generation was above long-term average, so potentially underestimating ETS benefits in this report; and

- Considering the advantages of secondary sales opportunities.

We also recommend following up with other utilities to obtain more detail about their ETS programs, specifically:

- Sudbury Ontario ETS program;
- the difference between the use of Wifi and internet signals;
- the use of cellular signals (contact Steffes);
- New Brunswick Power - how their wireless signal works, where the modem is located, what address they use and how the ETS is connected to internet (IP? Email?) via high-speed internet through secure, two-way communication;
- City of Summerside, PEI - how are lease and rental payments calculated, what are the monthly customer payments; and
- Concord Light - how does the second meter at the electrical panel function for controlling the ETS circuits in the electrical panel.