Energy Enhancements and Switching from Oil Furnace to High Efficiency Heat Pump Cuts CO_2 Emissions by 90%(-5,015 kg) Saving BC Home Over $1,500 Annually

Executive Summary[1]

Energy related improvements we have undertaken have cut our home's annual carbon emissions by at least 90%. Our annual costs have tumbled 64%, despite the price of electricity increasing by about 50% since 2000.

Individual families can make dramatic reductions in their home's carbon emissions and easily save significant amounts of money now and into the future. This is not rocket science, but it does require addressing easily identified factors and solving them in a co-ordinated way.

Energy consumption is affected by a number of factors. The primary factors that contributed to our reduction of energy and CO_2 emissions were:

- Replacing our oil furnace with a high efficiency heat pump
- Reducing heat loss by replacing single pane windows with good quality double-pane windows, increasing our insulation levels in the basement and replacing 2 of our 3 wooden doors with insulated doors with much improved seals which, with the new windows, reduced air leakage.
- Gradually replacing our old electrical appliances and incandescent lights with much more efficient appliances and LED lighting.
- The number and age of people living in the house
- The length and depth of the cold seasons in Heating Degree Days (HDD's)

Together, these factors dramatically reduced our annual carbon emissions by at least 90%.

The heat pump's financial payback, depending upon price assumptions and replacement options, ranges from 5.7 years to 11 years. This implies a return on investment of between 6.5% and 13%, much better than one can get on most investments, and this return is virtually guaranteed.

By counting carbon as carefully as we count dollars, citizens make sounder investments, save lots of money, dramatically reduce our homes' carbon emissions and reduce electricity demand on BC Hydro. If enough of us do this, the measures we take will contribute to significantly reducing electricity demand by more than Site C's capacity, and freeing up enough electricity to electrify two thirds of BC's cars. More critically, we will reduce our own greenhouse gas (GHG) emissions that are forcing global temperatures rapidly upwards and presenting near impossible challenges for our children and future generations.

Background

While attending a forum on global warming and energy in 2012 hosted by the Pacific Institute for Climate Solutions (PICS)[2], I commented on the significant reduction energy consumption and CO_2 emissions we experienced at our home following the installation of a high-efficiency heat pump. Hearing this, then PICS Director Dr. Thomas Pedersen asked me to produce a short paper on our experience. This paper[3] is the result. The scope has been expanded to include operating costs,

---

[1] For Public Policy Recommendations, see page 7

[2] http://pics.uvic.ca

[3] This paper updates the original and subsequent editions to Dec 31, 2016 and includes 17 years of data, 2000-2016. The author may be contacted at donaldscott@telus.net

lifecycle CO_2 emissions and a section making public policy recommendations including a Hydro facilitated program to encourage more homeowners to replace oil and natural gas furnaces and electric baseboard heaters and furnaces with high efficiency heat pumps. Federal energy use researchers at NRCan have noted that it is rare to have this degree of actual household experience both prior to and after the installation of various energy related home improvements. I hope you find the study useful.

Our 1967 built home was heated with a forced-air oil furnace until 2010. We do not have a natural gas line to the house. Virtually all other energy consumed[4] is electricity, including our domestic hot water, which is heated in a 170-litre tank and is our second largest electricity consumer. On December 16, 2010, we replaced the oil furnace with the highest efficiency electric powered heat pump we could find that was compatible with the existing air ducts system used to distribute heated air throughout the house.

We looked at various systems by both North American and foreign manufacturers. Choosing a comparable wholly North American manufacturer would have cost more, meant a less efficient unit and required $3500 to upgrade our 100 AMP electrical panel to a 200 AMP panel. However, with low ampere demand of the Mitsubishi Zuba Central heat pump (Mr. SLIM) and its internal air handler[5], both 220-volt units with highly efficient variable speed DC fan motors, our existing 100 AMP panel was sufficient with the addition of new 220 lines to both units at a cost of $1200.

The Zuba Central's advanced technology allows it to work down to -30°C (COP[6] =1.2). Therefore it is still very efficient at coastal British Columbia's winter temperatures (COP = 3.4 @ +5° C, COP = 2.6 @ 0° C, COP = 2.1 @ -5°C, & COP = 1.8 @ -15° C), whereas most NA manufacturers' heat pumps don't function efficiently below 0° C, requiring a cold weather supplement (resistance coils [COP = 1.0] or gas/oil furnace [COP = .80 to.95] when outside temperatures dip below freezing. The one NA manufacturer's premier unit with DC motors would have cost about $1,000 more. I asked a couple of third party commercial technicians with extensive experience installing many brands of heat pumps to compare them. They told me there was no comparison. They said the Mitsubishi is way more efficient, much quieter, had superior reliability, less maintenance and worked at much lower temperatures. Only Mitsubishi approved trained technicians are allowed to install them.

We anticipated that converting to the heat pump would significantly increase our electricity consumption, probably in the vicinity of 3,000 – 4,000 kWh annually, which at 2010 Tier 2 electricity rates of $.0878/kWh, would cost between $265 and $350 annually. That would still yield an annual savings of $900 to $1,250 compared to heating with oil at 2010 prices.

Energy Consumption Over Time

With energy consumption records kept since moving into our 1967-built split-level 1900 square foot (2400 ft^2 incl. heated basement, 2x4 walls with R7 insulation) home in 1994, one can observe changes to our fuel oil and electricity consumption over time. This allows us to measure the impact of upgrades such as replacing the oil furnace with our heat pump and upgrading windows,

---

[4] For complete disclosure, we have two fireplaces, one with an occasionally used high efficiency wood-insert stove, which was installed in Feb. 2007 for emergency use after a two-day winter power outage in 2006. The other fireplace is strictly decorative and blocked with insulation as it loses more inside warm air up the chimney than it produces in heat when used. We also use our propane BBQ occasionally, generally less than a tank (20 lbs.) per year.

[5] Heat pump made in Japan. Air Handler made in Grenada, Mississippi by Advanced Distributor Products. At 7 years, the only maintenance on our Zuba Central has been bi-annual inspections and air filter replacements.

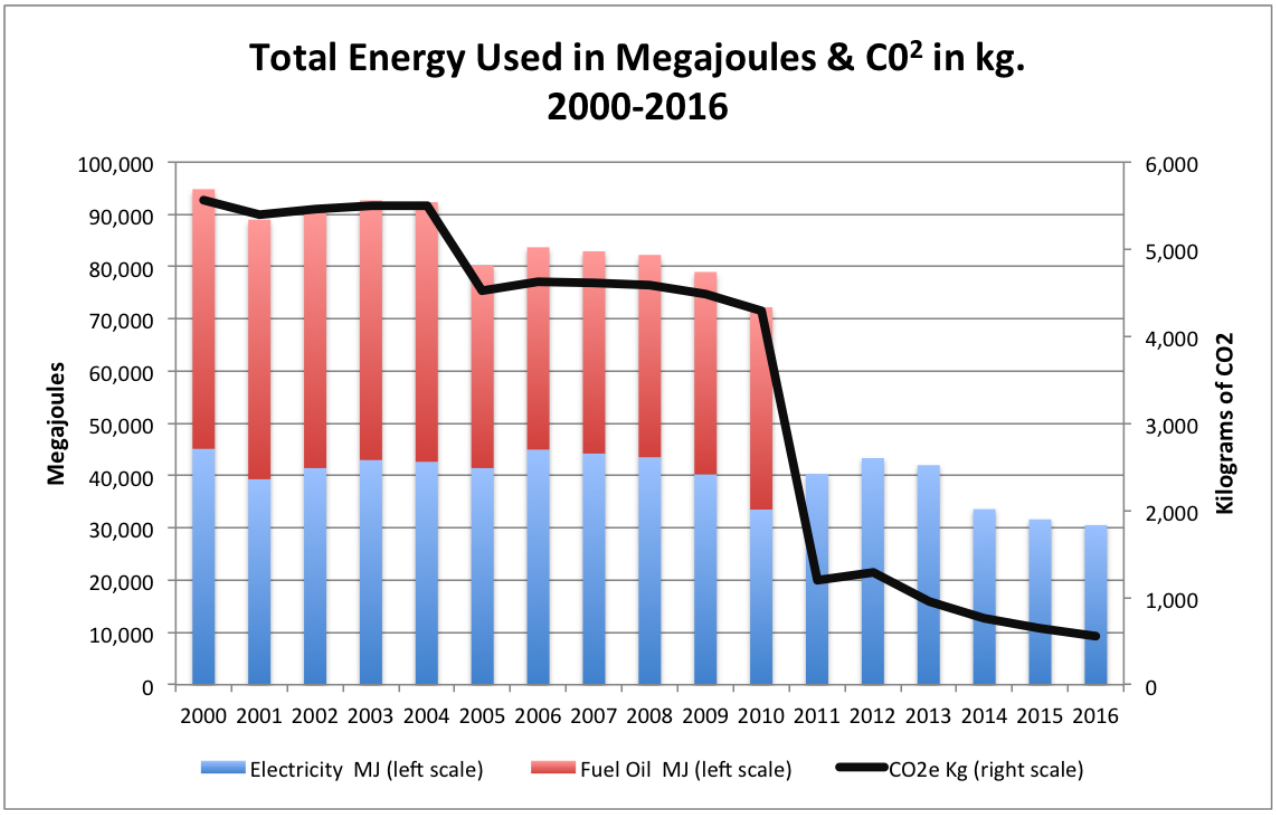
[6] Coefficient Of Performance – Ratio of heat output per unit of energy input. A COP of 3.5 provides 3.5 units of heat for each unit of energy consumed (i.e. 1 kWh consumed would provide 3.5 kWh equivalent heat output). For reference, a baseboard heater or electric furnace's COP is 1.0.

doors, basement insulation, appliances and lighting. From this energy consumption data, we can also calculate our CO_2 emissions annually and measure the impact the changes have had on reducing our carbon footprint.

Chart 1 depicts our home's energy consumption in megajoules (MJ)[7]. Using megajoules allows one to illustrate the energy consumed in both fuel oil and electricity in a common unit of measure. The vertical red columns represent the energy in the fuel oil consumed and the vertical blue columns represent the electrical energy consumed. The columns are stacked to illustrate total energy consumed each year. The MJ's consumed are depicted in the left hand scale.

The horizontal black line shows the dramatic reduction in CO_2 emissions due to the drop in energy usage with the scale on the right measuring the CO_2 emissions in kilograms.

Chart 1



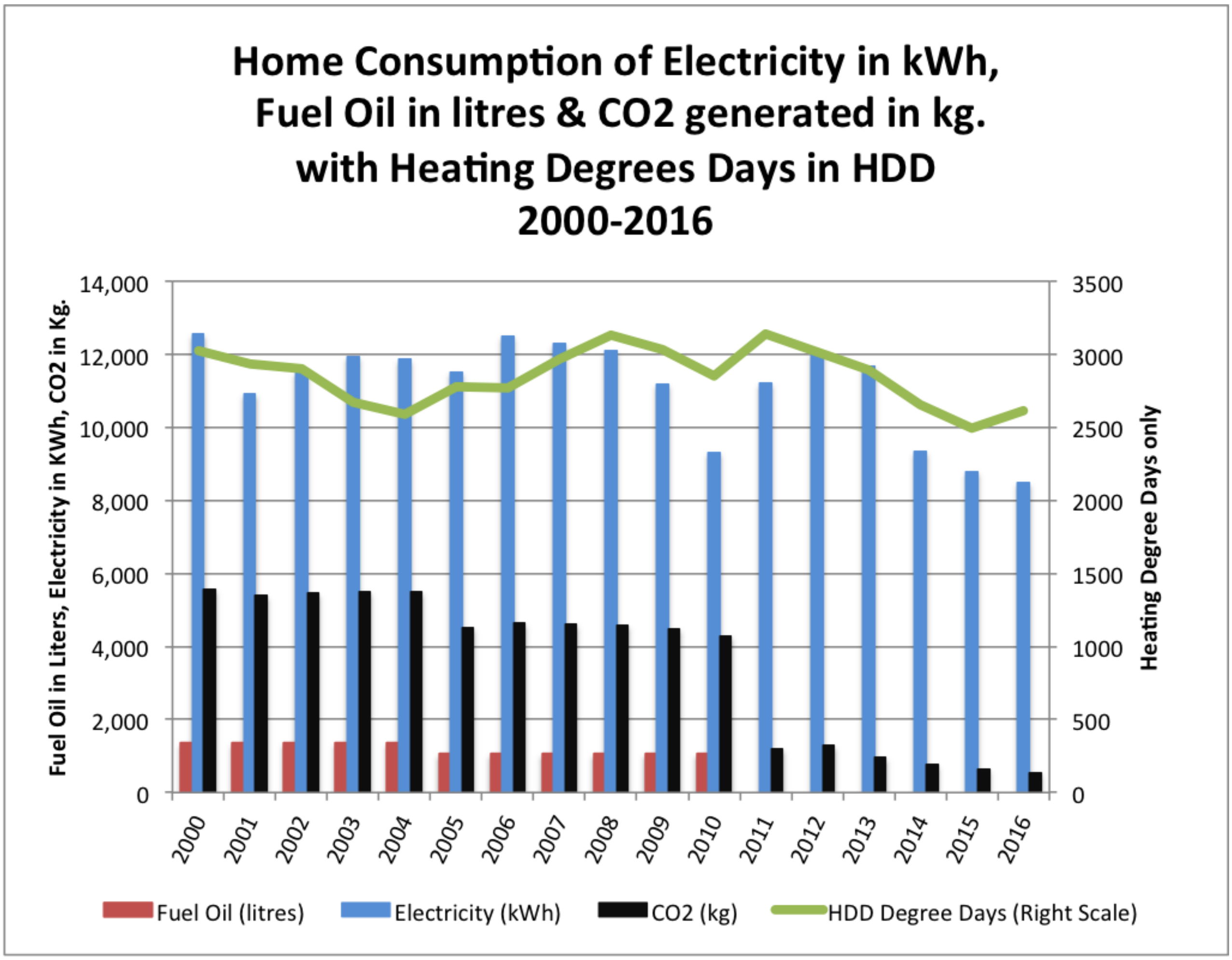
7 The **joule** (symbol: J) is a derived unit of energy in the International System of Units.[1] It is equal to the energy transferred to (or work done on) an object when a force of one newton acts on that object in the direction of its motion through a distance of one metre (1 newton metre or N· m). It is also the energy dissipated as heat when an electric current of one ampere passes through a resistance of one ohm for one second. A Mega Joule is 1,000,000 joules. For comparison, 1 GJ = 30 litres of gasoline or 2 standard BBQ propane tanks.

Chart 2 depicts our home's energy consumption & emissions in more familiar terms: fuel oil (red) in liters, electricity (blue) in kWh, CO_2 emissions in kg, with Heating Degree Days (green) in HDD[8] added to give year-to-year comparisons of the severity of each year's heating season.

The left hand scale measures quantities of electricity (in kWh), fuel oil (in litres) and CO_2 (in kg.)

The right hand scale applies only the Heating Degree Days horizontal green zigzaging line.

Chart 2



Average annual fuel oil consumption[9] dropped 23% after we replaced all our aluminum framed single-pane widows with high quality dual pane vinyl windows in February 2005[10]. From 2005 to December 2010 average annual fuel oil consumption fell 300 litres from (1,353 to 1,054 litres) which reduced CO_2 emissions by an average of 963 kg. per year. At the 2008 price of $1.24/litre,

[8] Heating Degree Days - a measure of heating demand. I have set calculator for 18° C outside air temperature as below that requires home heating. E.g. a day at 10° C would be an 8 degree-day, a temp. of 0°C would be an 18 degree-day.) http://www.weatherdatadepot.com/?pi_ad_id=8426228665&gclid=CKfX9uOg-7QCFQ_hQgodG1MAdw

[9] Because the fuel oil tank was not filled in the same month each year, and not at all in 2010, I have averaged fuel consumption for the two periods 2000-2004 (actually average of 1995-2004) and 2005-2010.

[10] Windows made locally by The Vinyl Window Company of Saanichton, BC and installed by them. Vinyl windows on the local market differ substantially in quality.

replacing the windows saved us approximately $375 annually in fuel oil costs. Besides cost savings, the home became quieter, less draughty and much more comfortable. As with kitchen upgrades, cost recovery is not always one's sole consideration.

In 2011, our first full year with the heat pump, we consumed 11,207 kWh of electricity (see Table 1 on page 12), approximately 1,900 kWh more than in 2010 (when heating with oil). This was much less of an increase than the 3,000 – 4,000 kWh we anticipated with the heat pump. 2010[11] was a mild year with only 2,848 HDD compared to 3,036 HDD in 2009 and 3,136 HDD in 2011 which should have increased kWh usage more.

In March 2011 we raised the insulation level in the basement to R-26 from R-12 on two walls (one was insulated to R22 in 2009 - the fourth wall is not insulated as it abuts the on-slab two-story part of the house so is not an exterior wall). In 2011 we also replaced two of three exterior wood doors with insulated steel doors and new doorframes with much better seals to reduce heat loss.

In 2012, electricity consumption increased by 841 kWh to 12,048 kWh which was similar to 2008. The HDD of 3,018 was back at 2008 and 2009 levels and we had at least 2 college age daughters at home all year.

Since 2012, despite heating the home with electricity alone, we're using much less electricity than we did before installing the heat pump. In 2013 we became mostly empty nesters, but as we are now both retired, we keep the house warmer during the day than when we were away at work. 2014's electrical consumption matched the 2010 low with only 9,333 kWh hours. HDD was down near 2010 levels and we only had one daughter at home for 8 months and two for 3 months.

Our energy consumption continues to fall, with both 2015 and 2016 well below 9.000 kWh. In 2016 our electricity consumption hit a record low of 8,486 kWh. This is 4,015 kWh (-32%) less than 2006's 12,501 kWh – despite heating with electricity instead of oil!

Other factors that have contributed to reducing energy consumption have been replacing appliances [fridge (2004 & 2009), freezer (2004 and 2012), dishwasher (1999), top-load washer and dryer with front-load units (2002)] and our household lights with LED or florescent lights. Each of these appliances/lights consumes dramatically less energy than the units they replaced. Given our reduction in kWh, could it be possible that the heat pump is not using any more electricity than the oil burner motor and AC fan on the old oil furnace?

CO_2 Emissions Since 2000

Looking at CO_2 emissions for the past 15 years, our 2016 CO_2 emissions (514 kg.) are some 4930 kg. (-90%) below our 2000-2004 annual average (5,485 kg.) and 3,968 kg (-80%) less than the 2005-2010 average (4522 kg.) prior to installation of the heat pump but after upgrading windows. The biggest factor was replacing the oil furnace with the Mitsubishi Zuba Central heat pump.

The CO_2 calculations are based on our past fuel oil consumption and on the lifecycle carbon content of power supplied by BC Hydro[12]. The latter is very difficult to ascertain. BC Hydro has three natural gas fired generating stations[13]. Together they represented about 8% of Hydro's generation capacity till 2012 with the Burrard Gas Plant at 950 MW 89% of Hydro's fossil fuel

[11] In 2010, electrical consumption slid 1,876 kWh below 2009 due primarily to the reduction of 188 HDD, a long bare basement wall insulated to R22 in 2009 and our 3 daughters being away from home for half the year.

[12] CO_2 calculations are based on fuel oil at 3.128 kg/litre consumed, Fossil fuel generated electricity at 850 g/kWh and water generated electricity at 24 g/kWh. All are "lifecycle" based emissions.

[13] https://www.bchydro.com/energy-in-bc/our_system/generation/thermal_generation.html Burrard is now mothballed.

generating capacity. Burrard has been phased-out of operation since 2012 and mothballed in 2016. But Hydro also buys power from Independent Power Produces in BC (some from fossil fuels) and from Alberta and Washington State. Hydro imports cheap night-time surplus fossil fuel fired electricity generated in Alberta (coal and gas) and from the USA (primarily hydro and nuclear) to store more water in its reservoirs that is used to generate electricity sold back to Alberta and the USA during the day and summer at higher prices. Hydro states that 92% of its generation is water based[14], which is true, but generation is not quite the same as sales due to intermittent supply from various sources. To include the changing nature of BC Hydro's supply, I have calculated that 9% of BC Hydro's sold electricity was fossil fuel based until 2012, 7% in 2013 and 2014, 6% in 2015 and 5% in 2106. If one credits BC Hydro for the power exported reducing CO_2 emissions in Alberta and the NW USA, one could argue that Hydro's net CO_2 emissions are lower.

Water generated electricity is also not carbon free because carbon in released in the construction of the dams and the building of transmission lines. Manufacturing one tonne of Portland cement releases one tonne of CO_2[15]. Mining and transporting the gravel used in the making concrete also produces CO_2. Reinforcing steel produces CO_2 emissions in their manufacturing and transportation to the site and in construction. Earthen dams, common in some BC Hydro reservoirs for power generation stations involve a lot of heavy-duty equipment that emit greenhouse gases. These emissions must also be factored in and are amortized over the life of the plant in calculating CO_2 emissions. Reservoirs release methane from any vegetation and soils that are submerged so that must be considered. This is not an easy aspect to calculate so I have reviewed a IPCC[16] study that notes the range is generally 4-14 g/kWh but some reservoir outliers were as high as 150 g/kWh. I have also spoken with an expert in hydro generation facilities and he notes that for BC, 24 g/Kwh was a reasonable estimate; I have used 24 g/kWh in my calculations. Emissions during operations and maintenance of hydro plants are minimal.

Our Cost of Energy since 2000

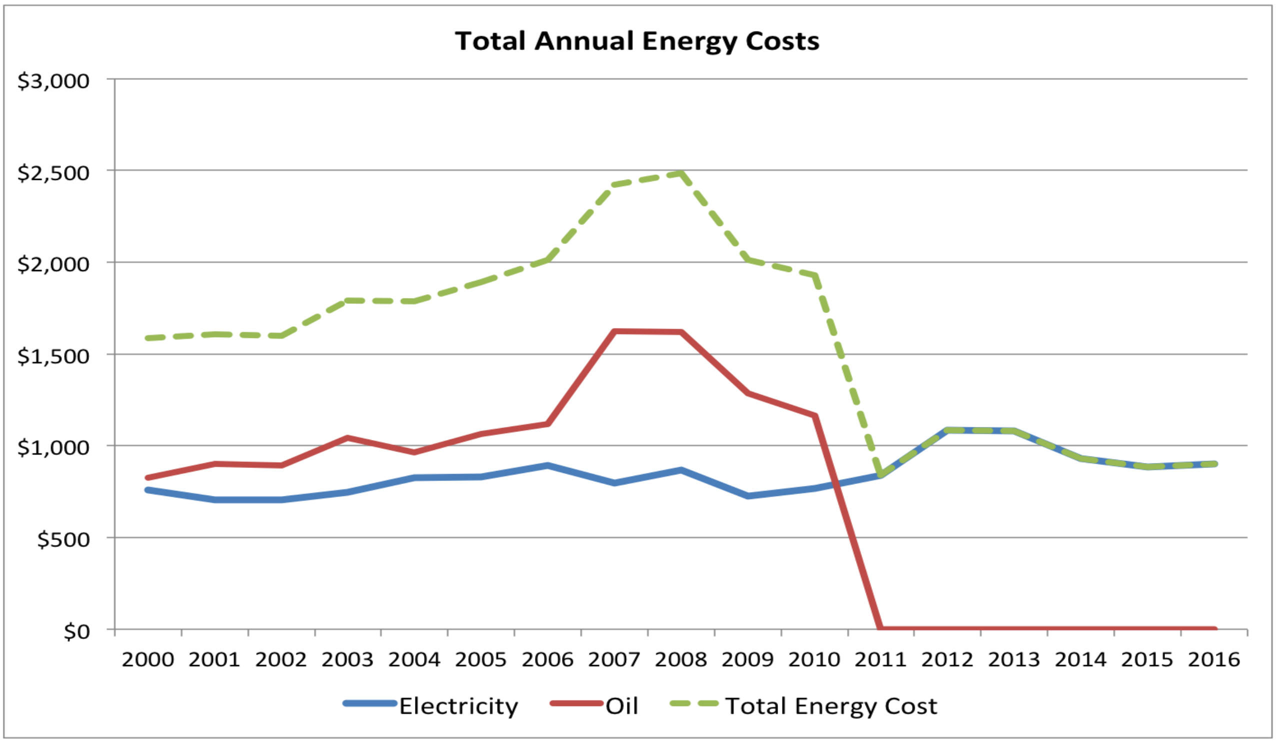
Previous editions of this home energy study have focused on energy use (litres of oil and kWh of electricity) and CO_2 emissions. This was intended to have people focus on counting CO_2 emissions as carefully as we count dollars. However, readers have frequently asked about costs and how much we are paying for energy over time. So I have added Table 2[17] and from that derived Chart 3 illustrating annual costs since 2000 in this update.

Cost is determined by quantity of energy used and the cost per unit of that energy. Both fuel oil and electricity have fluctuated over time: fuel oil was a low of $.57/litre in 2001 to $1.29/litre in 2008. The current price in August 2017 is $1.35.

Hydro prices have been going in one direction, up. Back in 2001 electricity cost $0.06/kWh but in 2008 BC Hydro introduced graduated rates to promote conservation and increase revenues. When introduced, the Step 1 rate of $0.591/kWh applied to monthly residential consumption under 710 kWh and the Step 2 rate was $0.0827/kWh on consumption beyond 710 kWh. Over the years, both rates have risen while Step 2's threshold has lowered. In 2016, Step 1 applied to the first 644 kWh/month and costs $0.0829 /kWh. Beyond 644kWh, Step 2's rate of $0.1243/kWh applies. So BC Hydro's base rates have increased 38% since 2000 and Step 2 rates have increased 107% over the single base rate in 2000. With BC Hydro's escalating debt due to Hydro paying massive dividends to the province and Site C's $9 billion cost, both rates are scheduled to continue rising.

[14] www.bchydro.com/energy-in-bc/our_system/generation/our_facilities.html
[15] http://blogs.ei.columbia.edu/2012/05/09/emissions-from-the-cement-industry/
[16] http://www.ipcc-wg3.de/report/IPCC_SRREN_Ch05.pdf
[17] See Table 2 on page 12

Chart3



Yet, as Chart 3 and Table 2 illustrate, despite significantly increased Hydro rates, our total energy costs have fallen dramatically. Our total energy costs were $1,588 in 2000, peaked at $2,486 in 2008 and are currently only $901, down 64% from the peak.

Public Policy Recommendations & Conclusions

Introduce an energy efficiency home improvement program at low interest rates with possible provincial assistance for low-income households. It makes sense for BC Hydro to handle the financing and manage the program, as BC Hydro is a major benefactor of the program and has the base energy data, the collection capacity via its billing system and can borrow at extremely low interest rates.

Participants would repay the loan by continuing to pay their current total energy costs (electricity plus oil and/or natural gas used to heat the house) with the value of energy savings going to pay off their loan. Households would not be out of pocket. Once the loan is paid-off, the full savings accrue to the homeowner in dramatically lower monthly energy charges and payments. If homeowners choose, they could opt to pay up front or if they use the Energy Upgrade Financing, they could make lump-sum payments lowering their principal thus speeding up the loan repayment, without penalty, so they could realize their lower monthly energy charges sooner. Outstanding loans could be recovered on the sale of the subject house. An added benefit for homeowners is that heat pumps can reverse operations during summer months and provide air conditioning, which has been a welcome benefit in the summer of 2017.

The program must include heat loss reduction measures. It makes little sense to put an efficient heat pump in a leaky, poorly insulated home. That's not in Hydro's nor the homeowner's interest.

To achieve projected results, target improvements to reduce energy consumption by at least 60% (and CO_2 emissions by 85% for currently oil and gas heated homes). Include energy audits. Start by reducing heat leakage by replacing leaky windows and doors with EnerGuide approved double or triple-pane windows, insulated doors and hatches with good seals. Insulate attics to R50 and insulate basements and crawl spaces to at least R20. Ceilings are easy and inexpensive to insulate. Upgrade exterior walls where it is cost effective or to increase comfort levels. Target homes to achieve an EnerGuide Rating of 80. With this is achieved, address the heating units.

Oil furnace replacement segment

BC's Oil to Heat Pump program ($1,700 subsidy) is scheduled to expire in 2019 and has had a very low take up due to very little publicity and minimal promotion by the government and none by BC Hydro. Replacing oil furnaces with high efficiency heat pumps that meet the Heating Seasonal Performance Factor (HSPF) 9.0 or higher and function with a COP of at least 1.5 at minus 15 deg. C. SEER should be 15 to minimize air conditioning load.

Enerficinency's[18] study on home heating in BC estimated 4.4% of the energy used to heat homes in BC is fuel oil, consuming some 7.5 million GJ of energy. Replacing oil furnaces with high efficiency heat pumps could eliminate an estimated 210 million liters of fuel oil burned and 650,000 tonnes of CO_2 emissions in BC[19].

Replacing baseboard heaters and electric furnaces

Replacing baseboard heaters and electric furnaces with high efficiency heat pumps will reduce home heating related electrical consumption by 60% to 75%[20], a reduction in of over 5,500 GWh.

Natural Gas heated homes

Enerficiency's 2010 study estimated that natural gas comprises 46% of the energy used to heat BC's homes burning 82 million GJ of natural gas (10 times oil's 7.5 million GJ). At 56 kg/GJ of natural gas this produces 4.5 million tonnes of CO_2 annually. (Note, this is not "lifecycle" emissions, and the US DOE has noted that lifecycle natural gas emissions are dramatically higher due to large fugitive emissions at the wellhead, in processing and transmission. Other independent studies (Purdue[21]) show this to be true and with the new Canadian GHGSat's[22] Claire satellite in operation for the past year, monitoring fugitive emissions is now readily possible.)

Initially concentrate on older lower efficiency natural gas furnaces (75-80% efficiency), then move on to the higher efficiency units to get emissions down fastest.

Once home heating has been tackled, consider electric domestic hot water heating as air-to-air heat pumps are emerging that may be able to handle that high demand appliance as well. Solar panels can also contribute to hot water heating and reducing system load.

Enhancing BC Hydro's capacity by eliminating inefficiency

Enerficiency's 2010 study[23] estimated that 68 million GJ of electricity is used in residences in BC. Baseboard heaters, electric furnaces and hot water heating (DHW) will consume most of this. BC

---

[18] http://www2.gov.bc.ca/assets/gov/environment/climate-change/stakeholder-support/ceei/resources/residential_heat_estimates.pdf , page 6

[19] Mike Wilson of Enerficiency (Residential Heating Oil, Propane, and Wood Heat Estimates for BC Communities) estimated 7.5 Million GJ of heating fuel is used for domestic heating. This converts to 210 million liters of fuel oil and 650,000 tonnes of CO_2

[20] COP = 1 for a baseboard heater or electric furnace. Moving to a high efficiency heat pump increases COP to 2.5 - 3.5 at winter temperatures in Coastal BC, Vancouver Island and the Lower Mainland and for a 55% to 75% saving.

[21] https://www.desmogblog.com/2017/03/20/natural-gas-power-plants-fracking-methane

[22] http://www.ghgsat.com/ https://www.utias-sfl.net/?page_id=1254

[23] http://www2.gov.bc.ca/assets/gov/environment/climate-change/stakeholder-support/ceei/resources/residential_heat_estimates.pdf

Hydro's Power Smart Conservation Potential Review – Residential Sector (2007) claimed single family and duplex homes in the Lower Mainland with electric heat used 3,276 kWh for DHW, 9,174 kWh for heating which represented 44% of their total annual usage of 20,970 kWh (note this is over twice our home's kWh consumption.)

At 44% of total electricity consumed being used to heat the house, this equals 30 million GJ across BC. Using an average 67% savings in converting baseboard heaters and electric furnaces to high efficiency heat pumps means a savings of some 20 million GJ of electricity annually. Twenty million GJ converts into 5,550 GWh of electricity[24].

Equivalent to Site C Dam

This is 109% of Site C Dam's projected 5,100 GWh[25] or 70% of the Revelstoke Dam's 7,817 GWh production. Efficiency gains are guaranteed supply, as availability is not dependent upon dam or generator maintenance or low water shutdowns. Once freed up by eliminating inefficient consumption, saved electricity is available forever.

So an aggressive program to convert existing baseboard heaters and electric furnaces starting with single family and duplex residences alone will "free up" more electricity than the controversial, costly and destructive Site C Dam will produce. And this will not cost BC Hydro a dime. Homeowners will pay for it out of their energy cost savings over 7 to 20 years depending on how much energy efficiency upgrading is required. Site C will cost $9 billion plus the costly burden of very long-term debt.

In terms of jobs, many times more jobs will be generated over the life of this initiative than with Site C and these jobs will be created where most people already live, in their home communities. No expensive remote construction camps are required.

Freeing up electricity for electric cars

The 5,550 GWh in energy savings would allow for the replacement of 67% of BC's 2.86 million registered passenger vehicles. An average electric car consumes 19 kWh per 100 km. Canadians, on average drive some 15,336 km per year.

Driving two thirds of BC registered passenger vehicles (1.902 million vehicles) driven the 15,336 km. Canadian average annually at 19 kWh per 100 km would require 2,914 kWh per car and 5,578 GWh collectively. This matches the energy savings generated by converting just single-family homes and duplexes with baseboard heaters or electric furnaces in BC to high efficiency heat pumps in the recommended program. Add townhouses, apartments and condos to the program and it might electrify 100% of BC's passenger vehicles.

Dramatically Reducing BC's GHG emissions is not only possible, it is relatively easy

Government estimates that BC emits about 64.5 mega tonnes of CO_{2e} annually. Replacing residential oil and natural gas furnaces with high efficiency heat pumps can reduce those emissions by 5.15 MT or 8%. Converting electric furnaces and baseboard heaters with high efficiency heat pumps will free up over 5,500 GJ of electricity, which can be used to heat homes with the oil and natural gas conversions plus allow for the electrification of most of the cars in BC reducing CO_2 emissions by another 4 MT and light trucks by another 5 MT[26]. Combined, this would reduce BC's GHG's by 14.5 MT of CO_{2e} or 22% of BC's reported emissions.

---

[24] http://www.translatorscafe.com/unit-converter/en/energy/2-14/#33

[25] https://www.bchydro.com/energy-in-bc/projects/site_c.html

[26] https://catalogue.data.gov.bc.ca/dataset/british-columbia-greenhouse-gas-emissions/resource/11b1da01-fabc-406c-8b13-91e87f126dec

Summary of Operating and Installation costs

Operating Costs:

Cost of heating with oil (at 2017 price of $1.25/ litre) 1,055 litres =	$ 1,320 / year
Cost of heating with Zuba Central Heat Pump (2017)	$ ~ 200 / yr.
Savings: @ $1.25/litre of fuel oil	$ 1,120 / year
Savings: @ $1.75/litre of fuel oil	$ 1,450 / year

Capital cost of heat pump in 2010:

Preliminary Electrical[27] – adding 2x220V lines to 100AMP panel	$ 1,200
Zuba Central & Installation[28]	$12,277
Relocating Air handler to increase air flow efficiency	$ 1,000
HST	$ 1,593
Government (Canada and BC) Energy efficiency rebates	$ -1,400
Sale of unused biofuel still in tank	$ -200
Net Cost with electrical upgrade	$14,470

Payback

Straight line: net cost @ $1.25/ litre: $14,470/$1320 =	11.0 years
Straight line net costs @ $1.75 / litre: $14,470/$1845 =	7.8 years
Cost of Zuba over installing a high efficiency gas furnace	$4,000
Payback over natural gas furnace ($4000/ est. $700 ann. saving)	5.7 years

Subject Home in Victoria BC

Energy Guide Efficiency Ratings – Energy Audits by City Green Solutions

2005 Before new windows = **EnerGuide**: **61**

2005 After windows = **EnerGuide 75**

2011 Before Zuba, basement insulation and 2 new exterior doors **EnerGuide**: **67**
Pre-retrofit Air leakage: 5.46 ACH@50 Pa

2011 After Zuba Central, basement insulation upgrade to R22 & replacing two exterior Wood doors with new insulated steel doors **EnerGuide**: **82**
Post-retrofit Air leakage: 4.91 ACH@50 Pa

Home Energy Efficiency Upgrades – Insulation, Air Tightness & Wood Insert

2005	Replaced all windows with vinyl framed double pane windows[29]	$10, 335
2007	Vermont Castings small Winter Warm wood insert stove[30]	3,200
2009-11	Insulated basement walls to R-22 and 2 new insulated doors[31]	3,962
2011	EnerGuide Testing by City Green / ecoEnergy	168
		$18,765

---

[27] Electrical by John & Chris Arnold of CanStar Electric
[28] Installation by Foster Heating & Cooling
[29] Vinyl Window Company
[30] Majestic Mechanical Ltd.
[31] Allegra Mgmt. - Harald Wolf, Roxul rock wool insulation

Subject House

Internal Unit - Zuba Central ADP Air Handler 34,000 BTU

Exterior Zuba Central Unit - Mr Slim 34,000 BTU, HSPF

Table 1 — **Fuel Oil (l) and Electrical Consumption (kWh), Heating Degree Days and CO2 emissions 2000-2016**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Fuel Oil (litres)	1,353	1,353	1,353	1,353	1,353	1,054	1,054	1,054	1,054	1,054	1,054	0	0	0	0	0	0
Electricity (kWh)	12,540	10,922	11,515	11,945	11,852	11,515	12,501	12,287	12,094	11,186	9,310	11,207	12,048	11,670	9,333	8,791	8,486
HDD Degree Days	3023	2936	2900	2667	2587	2778	2771	2967	3128	3036	2848	3136	3,018	2,889	2655	2494	2614
CO2 (kg)	5,569	5,397	5,460	5,506	5,496	4,525	4,630	4,607	4,587	4,490	4,290	1,195	1,284	955	764	647	554
HDD source	http://www.weatherdatadepot.com/?pi_ad_id=8426228665&gclid=CKfX9uOg-7QCFQ_hQgodG1MAdw																

All CO_2 calculations use "lifecycle" emissions. Fuel oil produces 3.128 kg. of CO_2 (lifecycle) per litre burned. Coal generated electricity produces 0.909 kg. of CO_2 per kWh generated[32]. Blue Sky's estimate for Natural Gas CO_2 emissions are 0.465 kg. /kWh, but emerging academic (Purdue U.) and US EPA and DOE estimates of actual GHG's emitted by fracked Natural Gas production's fugitive methane leaks and transportation are at least doubling the CO_2 equivalent of Natural Gas so it virtually equals coal. Water generated (hydro) electricity's lifecycle costs are estimated at 24 g/kWh. Estimates vary depending on the type of dam, climate and the substrate flooded. An IPCC study estimates most hydro at 4 to 14 g/kwh with some as high as 150 g/kWh. E.g. If our electricity consumed is 9% generated by fossil fuels, multiply the total kWh sold by 0.09 and then multiply that result by 850 g (.85 kg, a value recommended between coal and gas) to produce the total CO_2 embedded in the electricity consumed. Adding the CO_2 produced by the fuel oil to the CO_2 embedded in the electricity consumed produces total CO_2 in kilograms.

HDD is determined by setting the calculator at 18 degrees C as we set the thermostat to heat the house when the temperature is 18 deg. C or below.

Table 2 — **Total Annual Energy Costs**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Electricity	$760	$705	$706	$747	$825	$828	$894	$796	$868	$727	$767	$840	$1,085	$1,082	$932	$ 882.53	$ 901.33
Oil	$828	$901	$895	$1,043	$963	$1,064	$1,119	$1,625	$1,618	$1,287	$1,162	$0	$0	$0	$0	$0	$0
Total Energy Cost	$1,588	$1,606	$1,601	$1,790	$1,788	$1,892	$2,013	$2,421	$2,486	$2,014	$1,929	$840	$1,085	$1,082	$932	$883	$901

[32] http://blueskymodel.org/kilowatt-hour