Energy Saving Enhancements and Switching from Oil Furnace to High-Efficiency Heat Pump Cut CO_2 Emissions by 90%(-5,000 kg) Saving BC Homeowners Up to $19,500 Since 2004

Executive Summary

Energy related improvements we have undertaken have cut our home's annual carbon emissions by some 90% since 2000. Our 2019 annual energy costs have tumbled by 64% since 2000, mostly due to eliminating oil and despite the price of electricity increasing by 62% for Step 1 and 136% for Step 2 since 2000 and heating exclusively with electricity since 2010. Accumulated savings since 2004 total $17,465

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 requires 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 Mitsubishi 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 our sliding patio door with a swing Euro Door and replacing 2 of our 3 wooden doors with insulated steel doors with much improved seals which, along with the new windows, and patio door significantly 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 90%.

The heat pump has already paid for itself in 9 years. The financial payback, depending upon price assumptions and replacement options, ranged 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 British Columbians do this, the measures we take will reducing electricity demand by more than Site C's capacity, 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 creating 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)[1], 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[2] is the result. The scope has been expanded to include operating costs, lifecycle CO_2 emissions and a section making public policy recommendations. 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[3] 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

1 http://pics.uvic.ca

2 This paper updates the original and subsequent editions to Dec 31, 2019 and includes 20 years of data, 2000-2019. The author may be contacted at donaldscott@telus.net

3 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.

heat pump (Mr. SLIM) and its internal air handler[4], both of which are 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[5] =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.

Mitsubishi Mr. Slim 34,000 BTU, HSPF 9.4 & Internal Unit - Zuba Central ADP Air Handler 34,000 BTU

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[6]. That would still yield an annual savings of $900 to $1,250 compared to heating with oil at 2010 prices. Surprisingly, consumption has fallen significantly with savings much higher than anticipated.

4 Heat pump made in Japan. Air handler made in Grenada, Mississippi by Advanced Distributor Products. At 9 years, the only maintenance on our Zuba Central has been bi-annual inspections and air filter replacements.

5 Coefficient Of Performance (COP) – 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.

6 In 2019 with Tier 2 @ $0.1417 that would have been $425 - $625 annually.

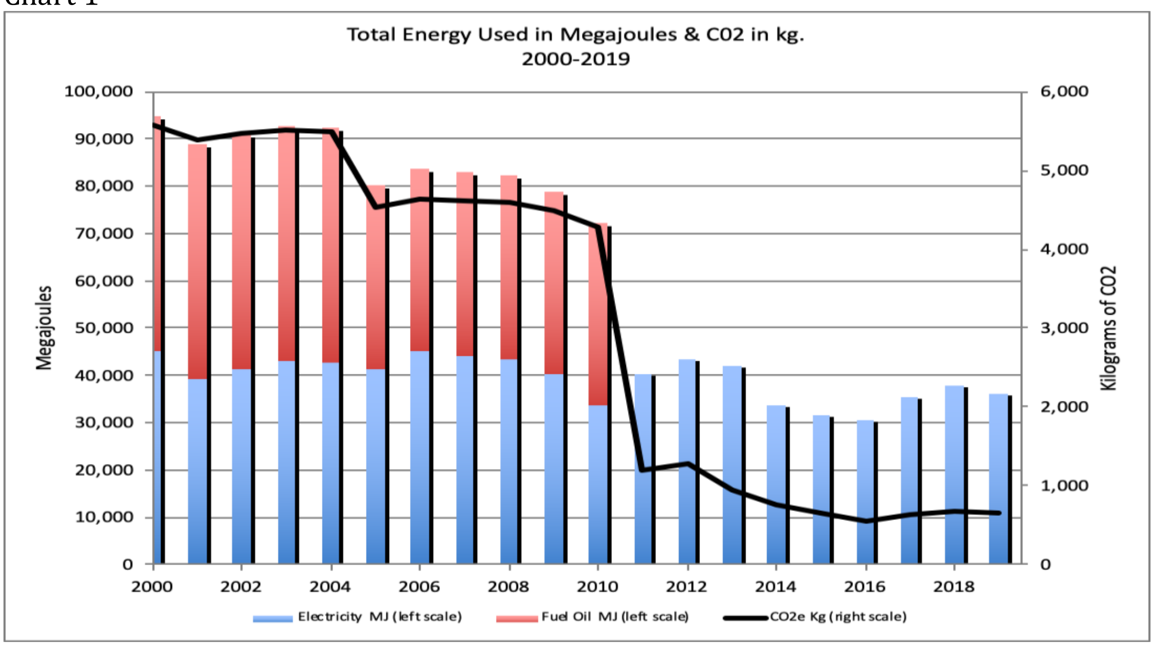
Energy Consumption Over Time

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, upgrading windows, 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 on 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



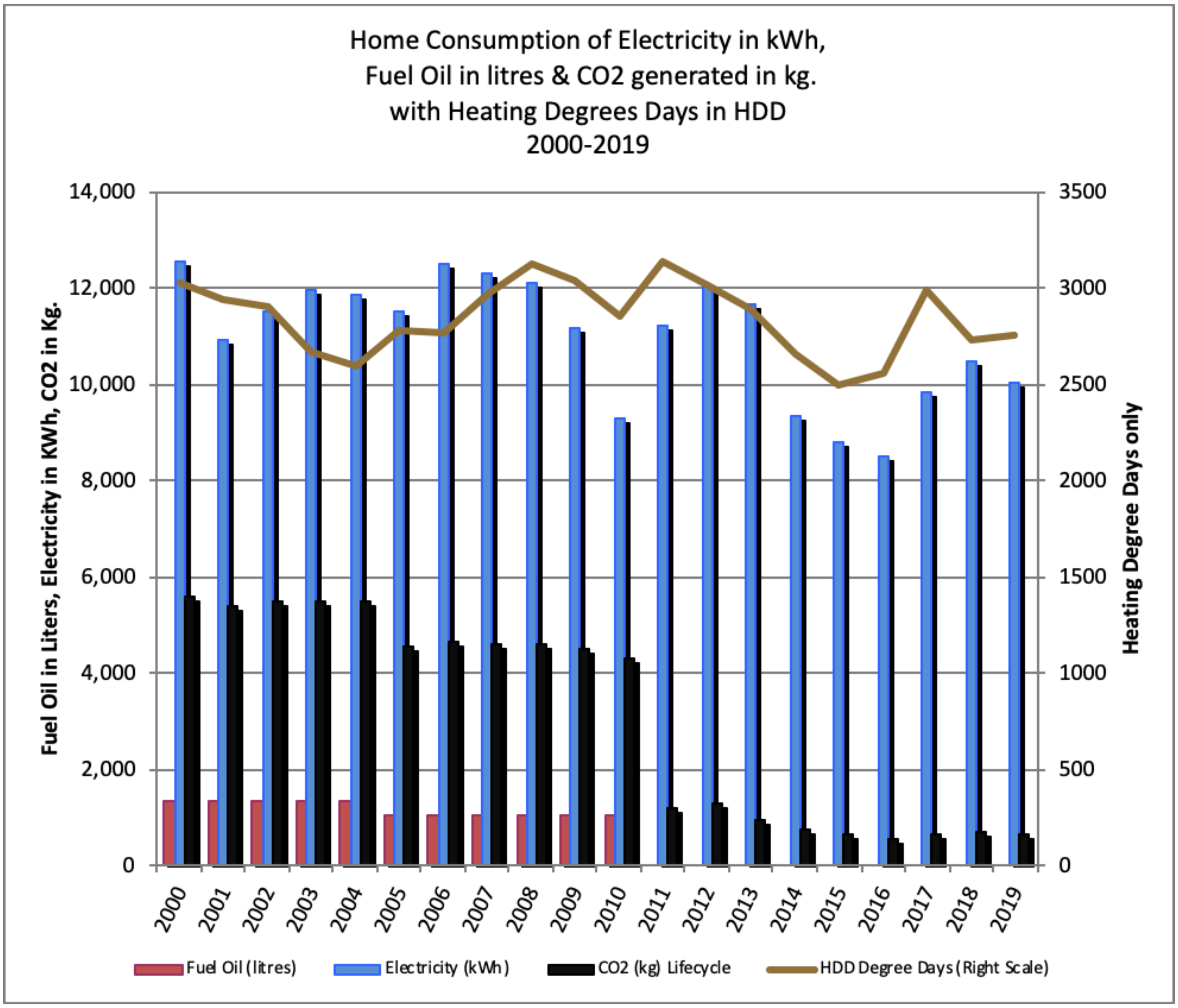
7 The **joule** (symbol: J) is a derived unit of energy in the International System of Units.[1] It is equal to the energy transferred to (or work done on) an object when a force of one newton acts on that object in the direction of its motion through a distance of one metre (1 newton metre or N·m). 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 (black), with Heating Degree Days (gold) 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 gold zigzagging line.

Chart 2



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

Average annual fuel oil consumption[9] dropped 23% after we replaced all our aluminum framed single-pane windows with high quality dual-pane vinyl windows and replaced the sliding patio door with dual-pane vinyl cladded Euro door 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, 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 Chart 2 & Table 1 on page 12), approximately 1,900 kWh more than in 2010 (when heating with oil), much less of an increase than the 3,000 – 4,000 kWh we anticipated with the heat pump. 2010[11] was also 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 the North and East exterior walls (the West wall was insulated to R22 in 2009 and the south 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 near 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 continued to fall, with both 2015 and 2016 well below 9,000 kWh. Our 2016 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!

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 1995-2004 (prior to windows) and 2005-2010 (post new windows but before replacing oil furnace with heat pump, basement insulation and 2 exterior doors).

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.

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.

In the fall of 2017, we purchased an electric car, a Nissan Leaf and charge it primarily at home using an exterior 15 AMP 120 V plug. The 2017 increase is mostly attributed to the increase in HDD, some 450 above 2016. The minor increase in kWh in 2018 and 2019 is mostly attributed to charging the EV as the HDD was stable. They are still our 6th and 7th lowest kWh levels since 2000.

Other factors that have contributed to reducing energy consumption have been replacing appliances [fridge (2004 & 2009 & 2019), freezer (2004 and 2012), Bosch dishwasher (1999), top-load washer and dryer with front-load units (2002)] and our household lights with LED or compact florescent lights. Each of these appliances/lights consumes much 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 20 years, our 2016 CO_2 emissions (514 kg.) were 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. In 2019, our emissions are less than 12% of 2000 emissions and only 21% of our pre heat pump 2005-2010 average emissions and we are now charging a car that we drive 10,000 km annually. The biggest factor by far, probably around 70%, was replacing the oil furnace with the Mitsubishi Zuba Central heat pump.

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 generating capacity. Burrard has been phased-out of operation since 2012 and mothballed in 2016. But Hydro also buys power from Independent Power Producers 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 natural 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 2016 onward. 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.

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.
14 www.bchydro.com/energy-in-bc/our_system/generation/our_facilities.html

Water-generated electricity is also not carbon free because carbon in released in the construction of the dams, the building of transmission lines and from methane rising from flooded reservoirs. 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. The manufacturing and transportation to the site of reinforcing steel produces CO_2 emissions as does construction. Earthen dams, common in some BC Hydro reservoirs for power generation stations involve a lot of heavy-duty equipment that emit greenhouse gases moving the earth. These emissions must 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. An expert in hydro generation facilities notes that for BC, 24 g/kWh was a reasonable estimate, so I have used 24 g/kWh in my calculations. Emissions during operations and maintenance of hydro plants are miniscule.

Our Cost of Energy since 2000

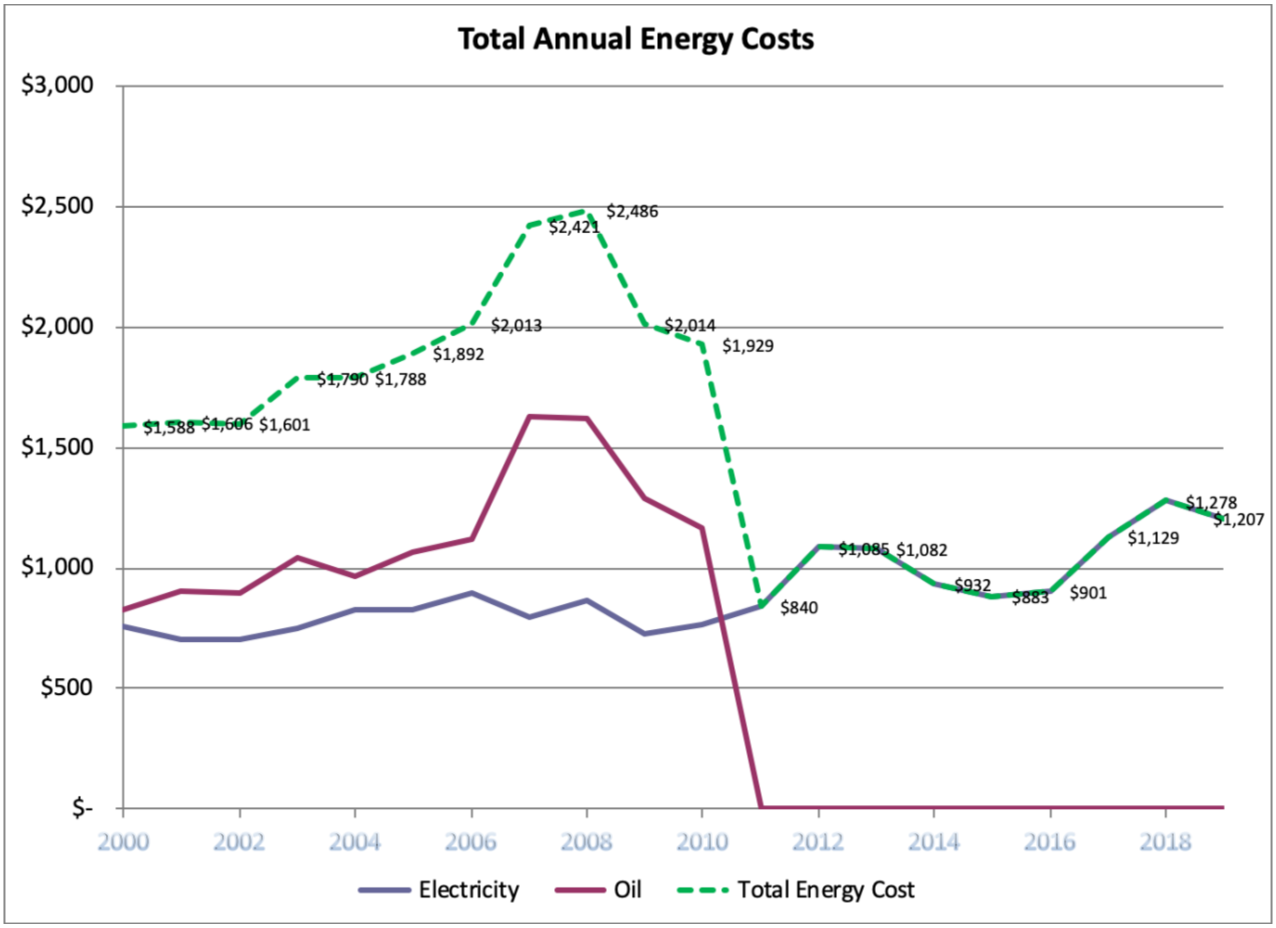
Previous editions of this home energy study focused on energy use (litres of oil and kWh of electricity) and CO_2 emissions. However, readers frequently asked about costs and how much we are paying for energy over time. So, Table 2[17] and Chart 3 illustrate annual costs since 2000 in this update.

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 price in the Fall of 2019 was about $1.75.

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 2019, Step 1 applied to the first 644 kWh/month and costs $0.0945 /kWh. Beyond 644kWh, Step 2's rate of $0.1417/kWh applies. So, BC Hydro's base rates have increased 62% since 2000 and Step 2 rates have increased 136% over the single base rate in 2000. With BC Hydro's escalating debt due to Hydro's past massive dividends to the province, the very expensive IPP contracts forced on BC Hydro, fuzzy accounting pre-booking future years revenues and debt related to Site C's $9+ billion cost, expect both rates to continue rising.

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 *Tables 2 & 3* illustrate, despite Hydro rates almost doubling, our total energy costs have fallen significantly. Our total energy costs were $1,588 in 2000, peaked at $2,486 in 2008 and in 2019 were only $1,207; down 51% or $1,280 from the peak and $308 less than in 2000.

Table 1 compares the oil (l) and electricity (kWh) consumed, Annual Heating Degree Days (HDD) and Carbon Emissions (kg) for our home from 2000 to 2019

Table 1	Fuel Oil (l) and Electrical Consumption (kWh), Heating Degree Days and CO2 emissions 2000-2019																			
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
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	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	9,848	10,484	10,033
HDD Degree Days	3023	2936	2900	2667	2587	2778	2771	2967	3128	3036	2848	3136	3,018	2,889	2655	2494	2561	2987	2731	2757
CO2 (kg) Lifecycle	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	643	685	655
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[18]. 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. For our home, 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 interior temperature is below 18 deg. C .

Table 2 compares the oil, electricity and total energy cost for our home from 2000 to 2019.

Table 2	Total Annual Energy Costs																			
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Electricity	$ 760	$ 705	$ 706	$ 747	$ 825	$ 828	$ 894	$ 796	$ 868	$ 727	$ 767	$ 840	$1,085	$1,082	$ 932	$ 883	$ 901	$1,129	$1,278	$1,207
Oil	$ 828	$ 901	$ 895	$ 1,043	$ 963	$1,064	$1,119	$1,625	$1,618	$1,287	$1,162	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
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	$1,129	$1,278	$1,207

Table 3 illustrates that we've saved $17,475 compared to what we would have spent on energy without the energy upgrades. By applying pre-upgrade average fuel oil consumption (1353 litres annually) to the actual cost of fuel oil in December/ January of each year (when our oil tank was usually filled). As noted, that electricity costs only increased modestly or fell until we bought an EV in 2017, despite heating exclusively with electricity since 2010 and the price of electricity increasing substantially. Specific electricity savings are not easy to identify by appliance due to central measurement and all the variables involved (e.g. number of people in house (i.e. hot water usage), electricity used by old oil burner, electricity used by heat pump, replacing appliances, LED lighting and charging EV).

Table 3	Energy Costs had we NOT replaced Windows, Insulated Basement and Replaced the Oil Furnace with the High Efficiency Mitsubishi Heat Pump and Resultant SAVINGS due to Improvements																				
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total Savings
Electricity	$ 760	$ 705	$ 706	$ 747	$ 825	$ 828	$ 894	$ 796	$ 868	$ 727	$ 767	$ 840	$ 1,085	$ 1,082	$ 932	$ 883	$ 901	$ 1,129	$ 1,278	$ 1,207	
Oil	$ 828	$ 901	$ 895	$ 1,043	$ 963	$ 1,299	$ 1,368	$ 1,898	$ 1,916	$ 1,544	$ 1,437	$ 1,799	$ 1,751	$ 1,824	$ 1,822	$ 1,477	$ 1,563	$ 1,781	$ 1,900	$ 1,960	
Total Energy Cost with No Improvements	$ 1,588	$ 1,606	$ 1,601	$ 1,790	$ 1,788	$ 2,127	$ 2,263	$ 2,694	$ 2,784	$ 2,270	$ 2,204	$ 2,639	$ 2,836	$ 2,905	$ 2,755	$ 2,360	$ 2,464	$ 2,910	$ 3,178	$ 3,168	
Actual Energy Cost with Improvements	$ 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	$ 1,129	$ 1,278	$ 1,207	
SAVINGS	$ -	$ -	$ -	$ -	$ -	$ (235)	$ (250)	$ (274)	$ (298)	$ (257)	$ (274)	$ (1,799)	$ (1,751)	$ (1,824)	$ (1,822)	$ (1,477)	$ (1,563)	$ (1,781)	$ (1,900)	$ (1,960)	$ (17,465)
Fuel Oil cost per litre				$ 0.78	$ 0.82	$ 0.98	$ 1.04	$ 1.14	$ 1.24	$ 1.07	$ 1.14	$ 1.33	$ 1.29	$ 1.35	$ 1.35	$ 1.09	$ 1.16	$ 1.32	$ 1.40	$ 1.45	$ 1.21

18 http://blueskymodel.org/kilowatt-hour

Summary of Operating Costs and Heat Pump Installation Costs

Annual Operating Costs and Savings:

Cost of heating with oil (at 2019 price of $1.75/ litre) 1,055 litres =	$ 1,850 / year
Cost of heating with Zuba Central Heat Pump (2019)	$ ~250 / yr.
Savings: @ $1.25/litre of fuel oil	$ 1,070 / year
Savings: @ $1.75/litre of fuel oil	$ 1,600 / year

Capital cost of heat pump in 2010:

Preliminary Electrical[19] – adding 2x220V lines to 100AMP panel	$ 1,200
Zuba Central & Installation[20]	$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 oil remaining in tank	$ -200
Net Cost including electrical upgrade	$14,470

Payback

Straight line: net cost @ $1.25/ litre: $14,470/$1070	=	13.5 years
Straight line net costs @ $1.75 / litre: $14,470/$1600	=	9 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

Energy Ratings, Window, Insulation & Fireplace Upgrades

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 Pre-retrofit Air leakage: 5.46 ACH@50 Pa	= **EnerGuide**: **67**
2011	After Zuba Central, basement insulation upgrade to R22 & replacing two exterior wood doors with new insulated steel doors Post-retrofit Air leakage: 4.91 ACH@50 Pa	= **EnerGuide**: **82**

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

2005	New windows & patio door - vinyl framed double pane windows[21]	$10,335
2007	Vermont Castings small Winter Warm wood insert stove[22]	3,200
2009-11	Insulated basement walls to R-22 and 2 new insulated doors[23]	3,962
2011	EnerGuide Testing by City Green / ecoEnergy	168
Total		$18,765

19 Electrical by John & Chris Arnold of CanStar Electric
20 Installation by Foster Heating & Cooling
21 Vinyl Window Company
22 Majestic Mechanical Ltd.
23 Allegra Mgmt. - Harald Wolf, Roxul rock wool insulation

Public Policy Recommendations & Conclusion

Since the previous version (2017) of this study, BC has combined and greatly enhanced BC's various energy and GHG reduction programs under one umbrella, Clean BC[24]. A quick summary of the incentives offered for homes are as follows[25].

Home heating heat pumps – up to	$ 3000
Combined home and domestic Hot water Heat Pump	$ 4,000
Heat pumps in Indigenous communities – up to	$10,000
Heat pump hot water tank	$ 1,000
Insulation and upgrading windows - up to	$ 5,000
Electrical Services (panel) upgrade if needed for improvements	$ 1,000
Bonus benefit based on reduction in home EnerGuide rating up to	$ 2,000

Several municipalities such as Saanich are also offering automatic top-ups[26]:

Heat pump	$ 350
Heat pump hot water tank	$ 350
Electrical upgrade	$ 500

This is a very positive move and with more publicity should significantly increase the uptake across the province, but especially in the Lower Mainland, the Island, coastal regions and the Okanagan/Kootenays where most of the population and emissions occur.

Fortis BC is also a full participant in CLEAN BC and offers similar incentives where it is the main provider of gas and or electricity.

To maximize uptake[27], it would be very beneficial for BC to introduce an Energy Efficiency Upgrade Financing 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, has much of the base energy data, the collection capacity via its billing system and can borrow at extremely low interest rates. Fortis might be able to administer a similar program for their customers, possibly in collaboration with BC Hydro.

Participants would repay the loan by continuing to pay their current total energy costs (e.g. 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 necessarily be out of pocket. If they want or need to pay a supplementary amount, say $50 to $100 per month, the loan would be paid off that much faster. Once the loan is paid-off, the full

24 https://betterhomesbc.ca

25 https://betterhomesbc.ca/rebate-results/?buildingType=Renovating%20a%20home&location=Saanich&heatingType=Oil

26 Ibid.

27 As I update this study, we are in the midst of the COVID-19 Pandemic and gas and oil prices have collapsed, making it more difficult to encourage people to undertake significant energy upgrades, both due to economic uncertainty and unbelievably cheap natural gas, fuel oil and gasoline.

savings accrue to the homeowner in dramatically lower monthly energy payments. Homeowners could choose to pay up-front. Those using the Energy Efficiency Upgrade Financing Program should be able to make lump-sum payments without penalty thus lowering their principal and speeding up the loan repayment, so they realize their lower monthly energy payments sooner. Outstanding loans should be recovered on the sale of the subject house to reduce Hydro's exposure. An added benefit for homeowners is that heat pumps can reverse operations during summer months and provide air conditioning, which has been a welcome relief in recent summers.

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, Fortis BC's nor the homeowner's interest.

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. Upgrade exterior walls where it is cost effective or to increase comfort levels[28].

Target homes to achieve an audited EnerGuide Rating of 80. This should reduce energy consumption by at least 60% (and CO_2 emissions by 85%+ for currently oil and gas heated homes).

Oil Furnace Replacement Segment – The Biggest Contributor To Reducing GHG's

Enerficiency's[29] 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[30].

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%[31], 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

28 While much progress is being made in building ultra-low energy homes and net zero homes, there is little progress in developing cost-effective ways to upgrade the envelope / exterior walls of existing home. More research needs to be done in this area, so builders have more proven options to choose from with confidence.

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

30 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

31 COP = 1 for a baseboard heater or electric furnace. Moving to a high efficiency heat pump increases COP to 2.5 - 3.7 at winter temperatures in Coastal BC, Vancouver Island and the Lower Mainland for a 55% to 75% saving.

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. In fact, they estimate lifecycle natural gas emissions can be as high as coal. Other independent studies (Purdue[32]) confirm this. With the Canadian firm GHGSat's[33] Claire, Iris and soon Hugo satellites in operation, monitoring fugitive emissions is now readily available.)

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.

Heating Domestic Hot Water Segment

Tackle electric domestic hot water heating with heat pump hot water tanks. Hot water tanks are usually the second largest consumer of energy in the home, second only to heating. As noted below, electric hot water tanks are responsible for about 15% of a home's total electricity use. Heat-pump hot water tanks can reduce that to about 5%. Solar panels can also contribute to hot water heating and reducing system load.

Enhancing BC Hydro's Capacity by Eliminating Inefficient Use of Electricity

Enerficiency's 2010 study[34] estimated that 68 million GJ of electricity is used in residences in BC. Baseboard heaters, electric furnaces and domestic hot water heating will consume most of this. BC 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 domestic hot water, 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[35]. Adding heat-pump hot water heaters will add significant negawatt capacity, perhaps 35% of what space heating does. That would be an additional 2000 GWh of freed up capacity or some 7,500 GWh.

Equivalent to Site C Dam

This is 147% of Site C Dam's projected 5,100 GWh[36] or 96% 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.

32 https://www.desmogblog.com/2017/03/20/natural-gas-power-plants-fracking-methane
33 http://www.ghgsat.com/ https://www.utias-sfl.net/?page_id=1254
34 http://www2.gov.bc.ca/assets/gov/environment/climate-change/stakeholder-support/ceei/resources/residential_heat_estimates.pdf
35 http://www.translatorscafe.com/unit-converter/en/energy/2-14/#33
36 https://www.bchydro.com/energy-in-bc/projects/site_c.html

An aggressive program to convert existing baseboard heaters and electric furnaces starting with single family and duplex residences alone will “free up” more electricity or “negawatts” than the controversial, costly and destructive Site C Dam will produce. Add in heat-pump hot-water heaters and you’re at 1.5 Site C’s

What’s best is that this will not cost BC Hydro a dime! Homeowners will pay for it out of their energy cost savings and perhaps a little more over 7 to 20 years depending on how much energy efficiency upgrading is required. Compare that with Site C’s $9 billion cost plus the interest burden of very long-term debt, often financed over 40 to 50 years.

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. We might be challenged to find enough electricians, technicians, carpenters, renovators, plumbers, etc. to meet the demand. 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) 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 hot water tanks, townhouses, apartments and condos to the program and it might electrify 100% of BC’s passenger vehicles and light trucks.

CONCLUSION

SIGNIFICANTLY REDUCING BC’S GHG EMISSIONS IS NOT ONLY POSSIBLE, IT IS RELATIVELY EASY AND WILL SAVE YOU SIGNIFICANT AMOUNTS OF MONEY OVER ALL TIME FRAMES

Government estimates that BC emits about 64.5 megatons 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 baseboard heaters and electric furnaces with high-efficiency heat pumps will free up over 5,500 GJ of electricity, heat-pump hot water heaters another 1.5 to 2 GJ. These “negawatts” can be used to not only heat homes that convert from oil and natural gas to heat pumps but also electrify virtually all the cars and light trucks in BC; reducing CO_2 emissions by another 4 MT for cars and other 5 MT[37] with light trucks. Combined, these conversions would reduce BC’s GHG’s by 15.5 MT of CO_{2e} or 25% of BC’s reported emissions allowing BC to meet our stated GHG reduction targets.

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