The Ravina Project

Household Heating Efficiency

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The Ravina Project - Goals

The Ravina Project consists of several projects all proceeding concurrently. If we were to rename our project today we probably would name it, “The Ravina Projects”.

Our project goals page allows our readers to understand the scope and depth of the various areas of inquiry focused totally on the household.

See the Project Goals page on our WEB site at:

www.theravinaproject.org/project_goals.htm

Household Heating Efficiency

Introduction and Abstract

Over the years we have incrementally upgraded our structure to be better insulated. Our previous papers on household thermodynamics have charted these upgrades and the results.

In this paper we will gather all data from 2004 until the present and produce a 'bottom line' on the savings realized from the years of upgrades.

As we will see the method seems to be straightforward but such is not the case. We discovered that a natural gas reseller we subscribed to made our cost per cubic meter invalid. Instead we calculate a standard cost per cubic meter of natural gas and use it as our cost metric. However, costing aside we discover that the savings in natural gas consumed is about 32% which corresponds well with our increase in heating efficiency.

Ultimately the goal is to reduce our carbon footprint. Note that here in Ontario, swapping out energy derived from natural gas and replacing it with grid electricity reduces carbon release by 440% for every kWh of energy used. This paper derives its efficiency numbers solely from natural gas usage. The efficiency gain is a CO2 loss. A future paper will examine the total energy used from all sources to calculate net CO2 loss.

Our Data

The data sources used are the natural gas utility monthly invoices we have kept and entered into our natural gas database each month. The first invoice in the system is dated April 22nd, 2004 and the last dated January 23rd 2018.

Our Method

Our method is based on the idea that the number of cubic meters of natural gas burned per heating degree day is the household's heating efficiency on a particular day. We know that not all natural gas consumed is for heating. We calculate the average summer daily amount of natural gas used for other things like cooking and hot water production. We reduce the heating season's daily amount of natural gas used. What is left over is the amount used specifically for heating.

Once we have the seasonal heating efficiency calculated in cubic meters of natural gas used for every heating degree day, we can calculate using the utility invoices the 'all up' cost per cubic meter of natural gas delivered to our house. From there we can calculate the cost of natural gas per heating degree day. If we take that cost and multiply it by the number of heating degree days in a season we get the total cost of heating for the season.

We then can compare the cost of heating for a season with a baseline season which is the 2004-05 heating season. Any difference will be saving directly based upon the increase in household heating efficiency.

Data Presentation

The calculations are available with the supporting data in Appendices 1 and 2. The main body of the paper consists of charts allowing the reader to better understand the data without getting into the 'weeds' as it were. Note that our database starts after an initial round of upgrades to the house. We will cover them in detail to give the reader a good idea of the starting point of this experiment.

Calculations used in the paper

Heating degree days (HDD)

Heating degree days (HDD) are only generated during the heating season at this location. The heating season starts in Toronto at the beginning of the day on October 1st and ends and the end of day May 31st of the following year. HDDs provided by the local weather office are the number of degrees the average daily 24-hour temperature is below 18 degrees Centigrade. Add all the daily HDDs up and that's the total for the season.

Calculating natural gas used for Heating

We use natural gas for many things other than heating. So how do we separate out the gas used for heating from the rest? We look at the non-heating season's gas usage when the furnace is turned OFF. We calculate the daily use of non-heating gas and use that to subtract on a daily basis from the daily gas usage during the heating season.

Calculating household efficiency

We have the seasonal totals for Heating Degrees Days and the net natural gas usage in cubic meters. We can calculate the number of cubic meters of natural gas burned for every heating degree day or **m^3/HDD**. That number is the household efficiency for that season.

Calculating natural gas cost per m^3

We total all the invoiced dollar amounts for a heating season plus the total usage in cubic meters. We divide the dollar amount by the number of cubic meters used to get the cost per cubic meter of natural gas delivered to our gas meter: **$$/m^3.**

Calculating the heating cost per heating degree day

We know the household efficiency in cubic meters of gas used per heating degree day: **m^3/HDD**. We also know the cost of one cubic meter of gas: **$$/m^3**. We multiply the efficiency by the cost and we get the cost of one heating degree day: **$$/HDD**.

Calculating the seasonal cost of heating

From above we know the cost per heating degree day: **$$/HDD**. From Environment Canada we know the total number of heating degree days in the season: **HDD**. We then find the total cost of heating for the season by multiplying the cost per HDD by the number of HDDs in the season: **$$/HDD times HDD equals $$**.

Calculating the standard cost of a cubic meter of natural gas

The standard cost per cubic meter is calculated as the average cost per cubic meter of natural gas over the heating seasons 2011-12 to 2017-18.

Calculating baseline efficiency

The baseline efficiency is the household efficiency calculated using the data from the heating season 2004-05. The household had no modifications for heating efficiency. All modifications relevant to our databases were done subsequent to that year. If we want to compare a subsequent year to the baseline year we use this efficiency value in our work.

Upgrades completed before project start

The house had several upgrades completed before 2004 and are not included in the databases this paper is based upon.

Basement Headers

Where the top of the basement walls meet the house structure, there is an opportunity for air to seep from the basement into the walls of the first story. The header area was sprayed with a hard foam that seals off any possible leakage. In this picture the foam is apparent. What you can't see is that the whole basement, all the walls have had the same treatment.

Boiler for heating and domestic hot water

The furnace and hot water heater were removed and in their places a natural gas fired boiler was installed. It provides hot water on demand and hot water for the radiators. It is 95% efficient.

This is what the boiler looks like with the sheet metal removed. The actual heat exchanger and fire box are quite small.

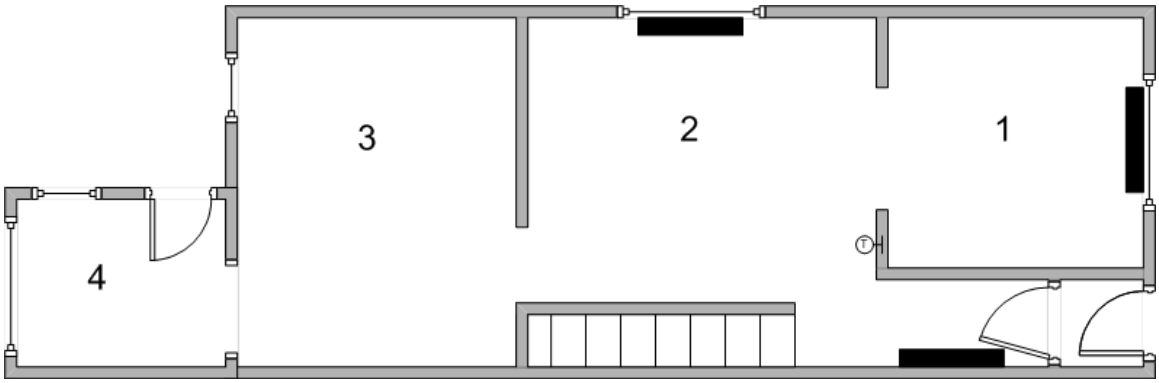
Replacement of the windows and doors.

The windows and doors were replaced. The neighbour's house has the type of window that were part of our house before replacement. Note the siding on the neighbour's house is shakes. Our house had the same siding. The vinyl siding in the picture was an upgrade captured by our data.

The attic under the roof peak was filled with insulation. This finished off the house upgrades completed before our experiment and database started.

House first floor plan

To better understand the heat flow in the house here is a diagram of the first floor..



Area 1 is the living room, area 2 is the dining room. Area 3 is the kitchen and area 4 is a very early addition to the house that can be seen in the above picture. We'll call it the plant room.

The interesting thing to note is that the living room, dining room and entrance hallway are heated by radiators … the black elongated rectangles in the diagram above. The kitchen and plant room are not heated.

Area 4 the plant room, a special case

The plant room contains all the plants that must be brought into the house during the cold weather. The optimum temperature for this room is about 10 C. Any heat that makes it to this area comes from the radiators in areas 1, 2, and the entrance hallway.

This is a perfect example of plants dictating the heat usage in a house and thereby affecting the house heating efficiency. If the plants were not in area 4, the obvious solution would be to put a door on the area and separate it from the kitchen.

Heat Flow Management

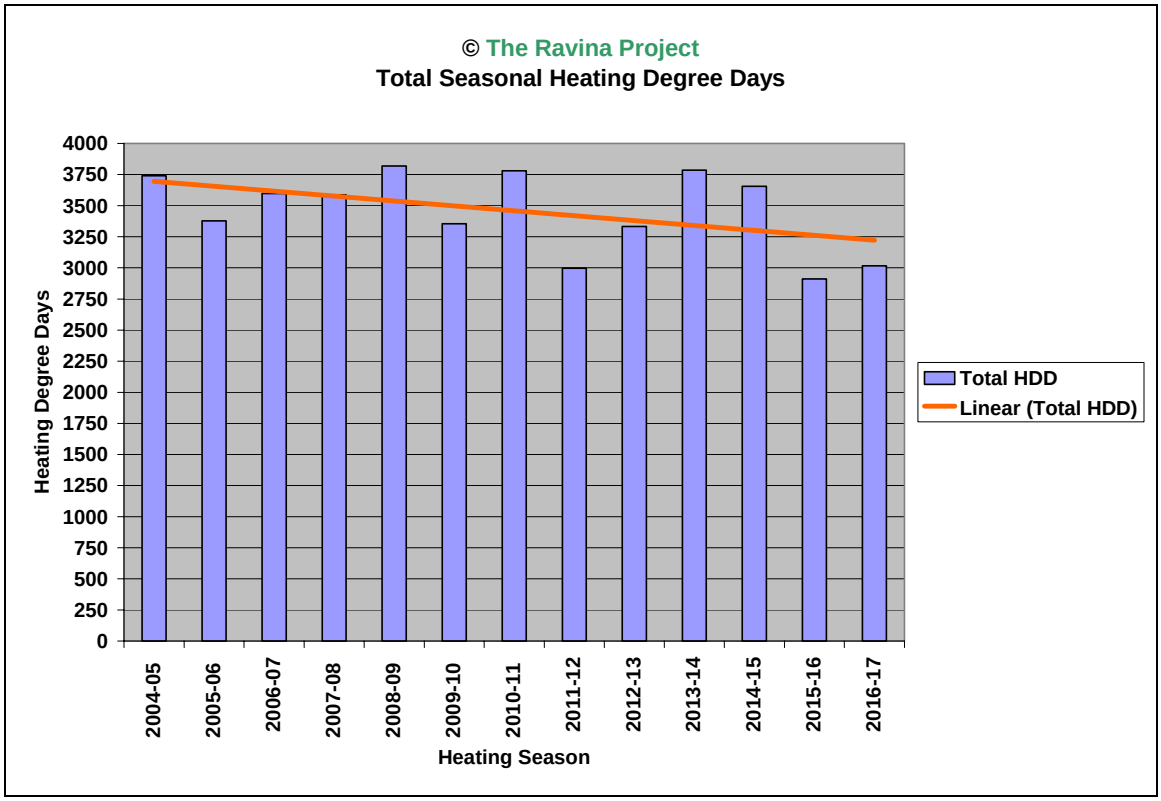
The role of heat flow and heat flow management is critical to our success in increasing the heating efficiency of our household. Over the course of the experiment starting in the heating season of 2004-05 we made small changes with the goal to improve our household heating efficiency. As each winter went by, we gathered the data and determined whether our efforts in heat flow management paid off by increasing our heating efficiency.

The rest of this paper is devoted to unpacking these changes and demonstrating the relative success of each change we made.

How cold was each heating season?

Since this paper focuses upon insulation plus internal heat flow management and their effects on wintertime energy use, the first data we should look at is the number of heating days in each season. They will tell us how cold each heating season was. The heating degree days values are all from Environment Canada's local weather office.

Consider the following chart:



We can conclude several things from this chart.

The first one is that our heating seasons except for three have been relatively consistent hovering around 3,500 heating degree days. The three outliers group themselves just below 3,000.

The heating season is trending warmer.

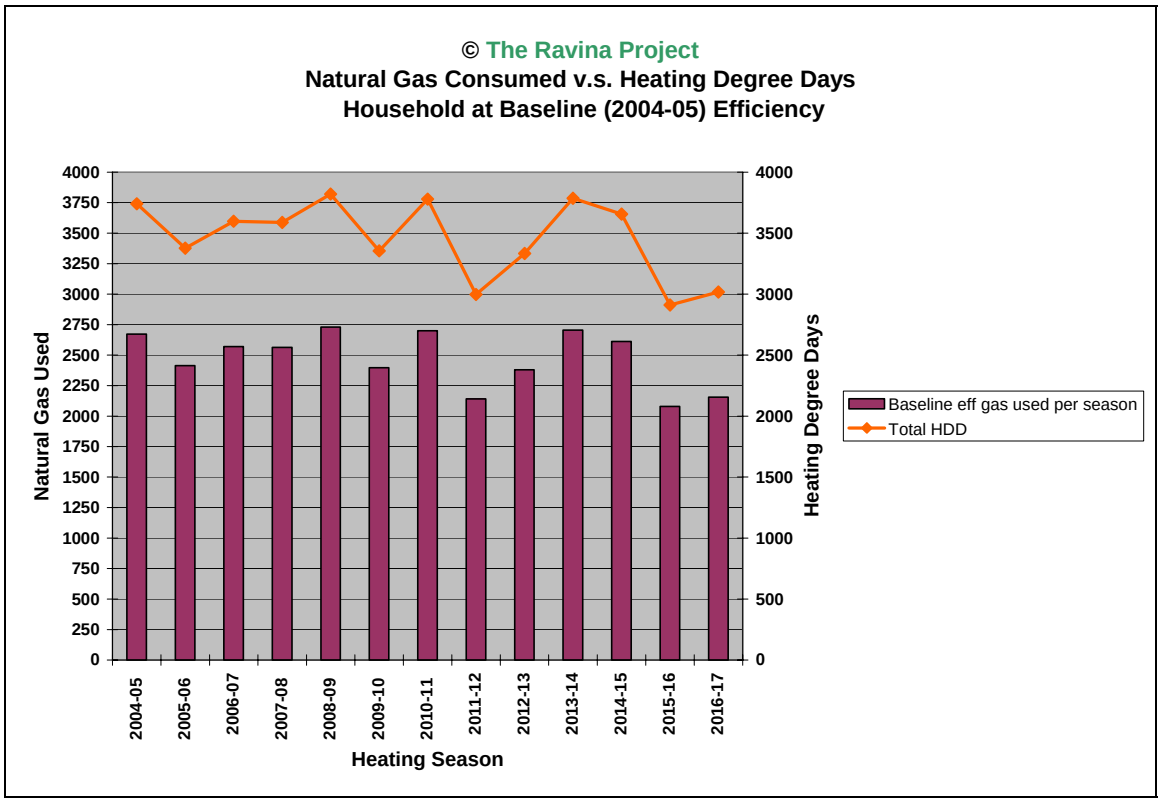
A house with no upgrades to its insulation or internal heat flow and no changes to the wintertime thermostat settings should track the number of HDD almost exactly over the course of this chart in its use of fuel to heat the house.

We can see this in the following chart.

Profile of an unmodified household

During the heating season of 2004-05 our house had a heating efficiency of 0.7144 cubic meters of natural gas used for every heating degree day.

Consider the following chart:



If our household did not upgrade in various ways the number of cubic meters of natural gas used would follow in proportion to the total heating degree days in each season.

The chart shows a usage profile of 32,115 cubic meters of natural gas used over 13 heating seasons.

Since we know the baseline efficiency to be 0.7144 m3/HDD, to calculate the natural gas usage for any season we multiply the efficiency by the number of heating degree days in the season. The result will be the total cubic meters of natural gas used in that season.

The key here is to show you, dear reader, that in an unmodified household the amount of energy required for heating will track exactly, more of less, the number of heating degree days in the season.

The goal of insulating and internal heat flow management is to break away from that ‘tracking’.

Note as well that the thermostat determines whether the furnace is turned ON or OFF. Warmer air around the thermostat means the furnace will be kept OFF for longer periods of time which means the household will burn less natural gas for heating. The goal ultimately is to keep the air surrounding the thermostat as warm as possible.

Efficiency Improvements

Each summer starting with the summer of 2005 we made improvements to the household in some way. These are detailed in our Household Thermodynamics papers on our WEB site.

Our biggest boost in efficiency came as a result of adding insulating under new siding placed upon the second floor of the house.

Consider the following graphic and chart:

Heating Efficiency

Changes to heat flow & efficiency m^3/HDD

2004-05 - 0.71 no changes

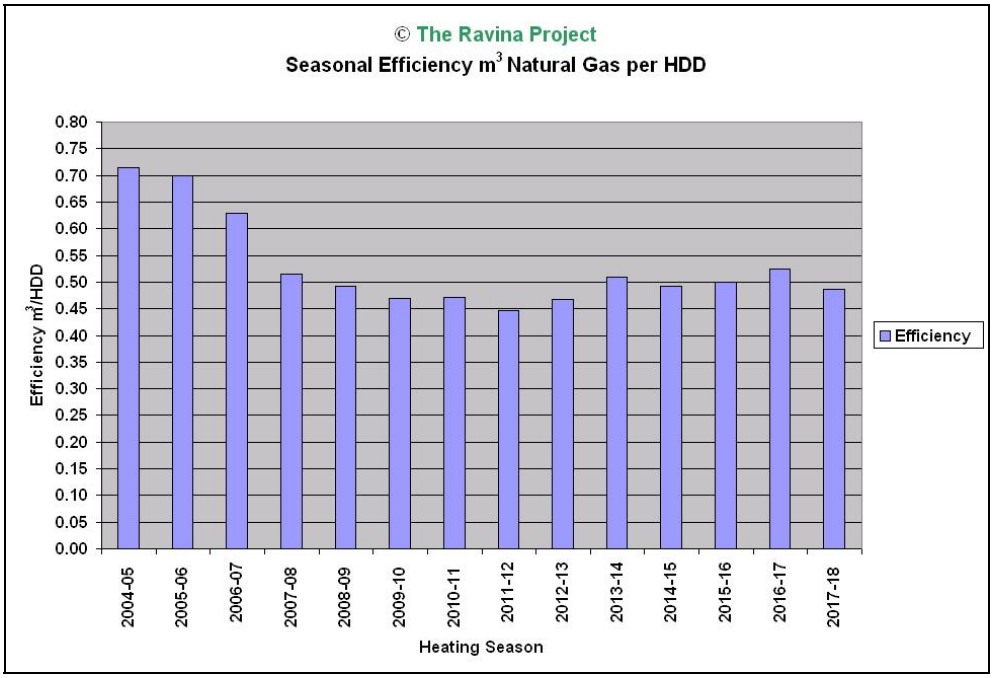
2005-06 - 0.70 heater in area 4 & heavy curtain between 3 & 4

2006-07 - 0.63 heater in area 3

2007-08 – 0.51 vinyl siding over R 2.81 foam on coldest 2nd floor wall

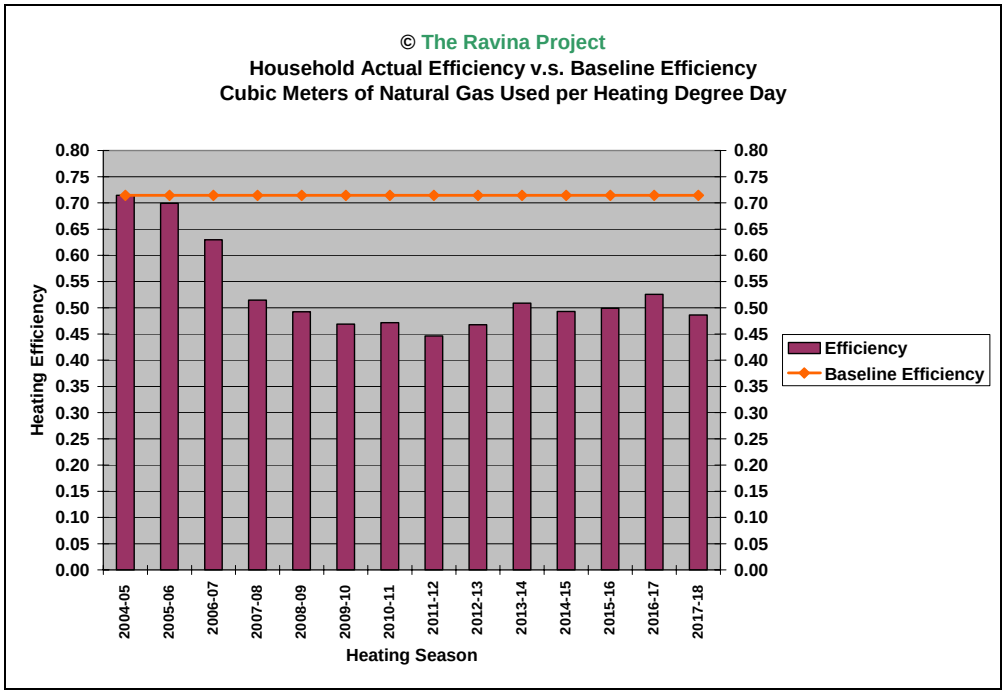
2008-10 – 0.49, 0.47 vinyl siding over R 2.81 foam on rest of second floor, new basement windows

2010-11 - 0.47 computerized thermostat, folding door between areas 3 & 4, curtain placed between areas 2 & 3



The graphic lists the year of the upgrade, the efficiency measured during the heating season and the changes/upgrades done in the previous summer or during the heating season. The chart plots the measured efficiencies. Note the change in efficiency from putting an extra heater in area 3, the kitchen and the larger change when the coldest second floor wall was covered by foam insulation and vinyl siding.

Consider the following chart:



The orange line represents the household efficiency if no insulation and heat management were put in place. It is a constant calculated using data from the baseline year of 2004-05.

The bars represent the actual measured seasonal household efficiency. The gap in efficiency translates into a yearly savings that never change, more or less.

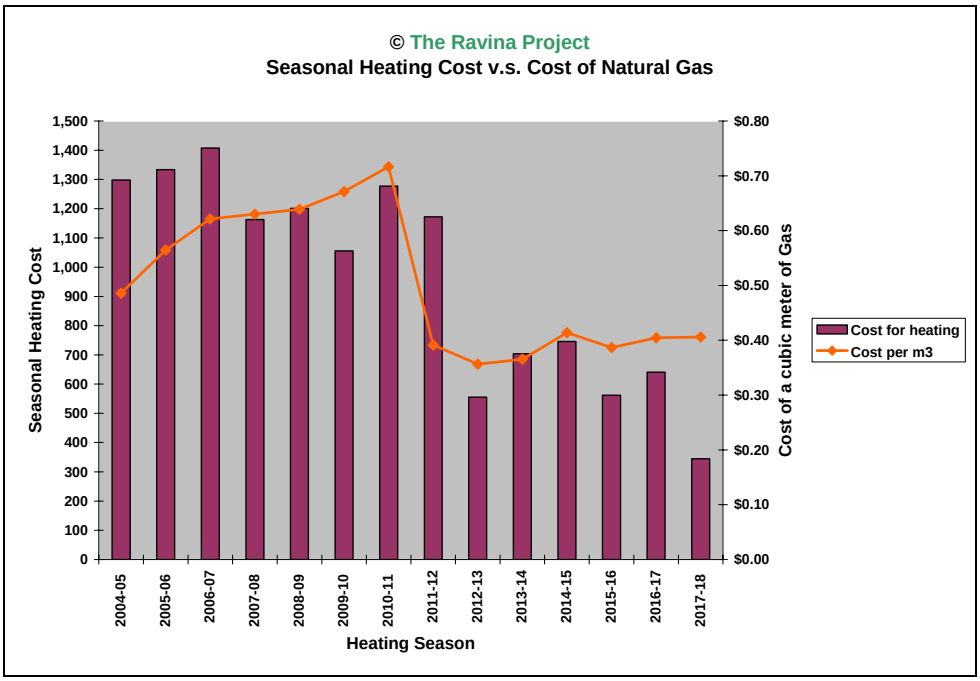
Efficiency and Return on Investment

How does the change in heating efficiency translate into real dollars?

An answer to this question of return on investment is actually more complex that it would seem. One would suspect that with each seasonal decrease in the use of natural gas the gas bill would decrease. And that assumption would be more or less correct except for one thing … it assumes that the cost per cubic meter of natural gas is constant over the time period. It wasn't.

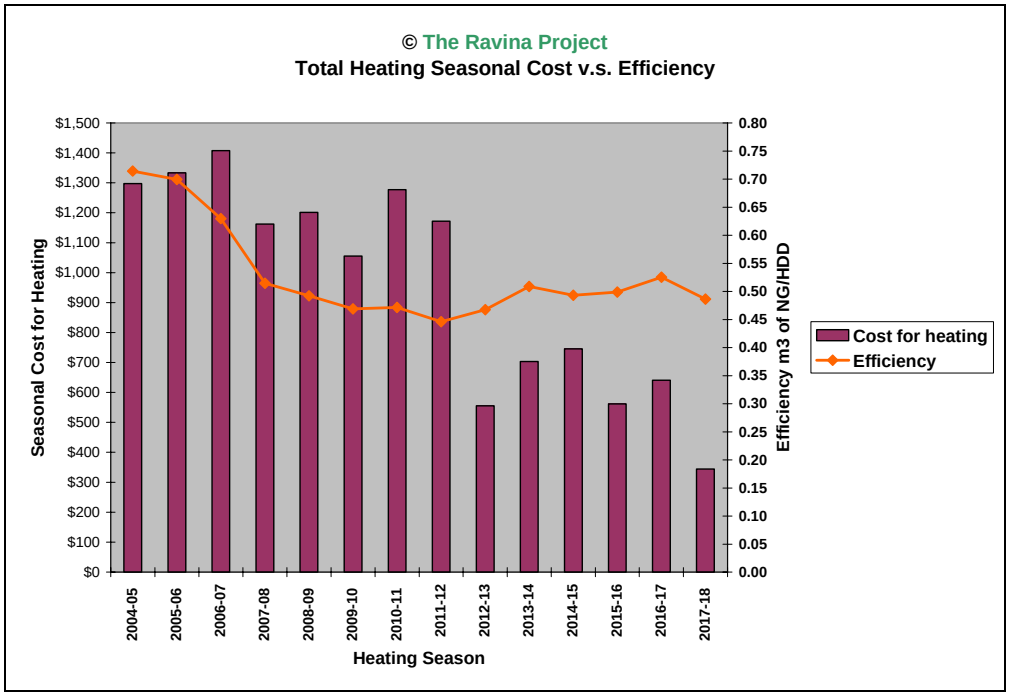
What happened? Early in The Ravina Project there was much made in the energy news press that there was a looming price spike in the cost of natural gas. This argument was prompted by wholesale conversions in the US energy industry from coal generation to natural gas. It was happening in Ontario as well. Many were talking about converting vehicles from petrol to natural gas. So to protect ourselves against an upside disaster we enrolled with a gas reseller that guaranteed us a gas price ceiling no matter what the 'real' cost of gas increased to.

In fact a few years into our contract the gas fracking boom started, the price of natural gas plummeted. We were stuck paying too much for our gas, that is, we paid more than households not enrolled in the program as we see in the following chart.



Even though our house was much more efficient to heat the cost of heating increased! You can see why. The price of natural gas was quite high as compared to the street price. You can see the drop at the end of the contract.

Consider the following chart:



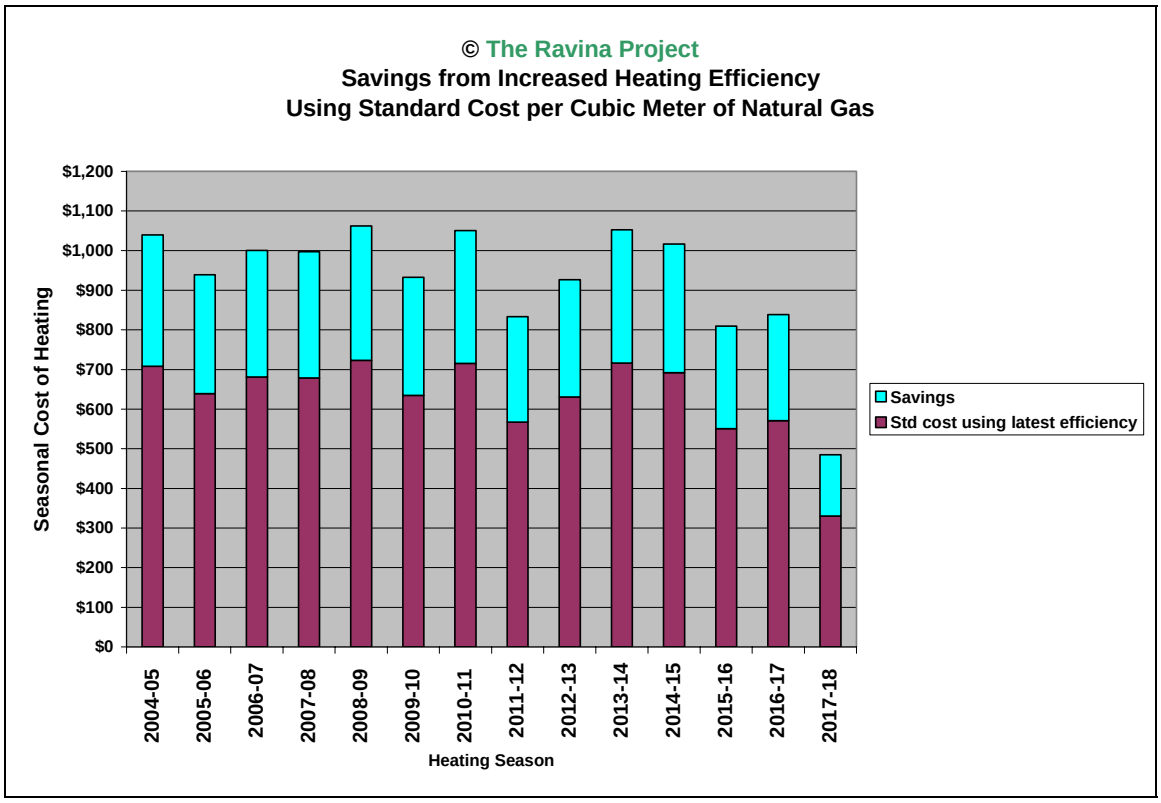
Here we graph the seasonal natural gas cost vs. our household efficiency. This is a brutal chart to look at. All the hard work and expense at making the household more efficient to heat and the seasonal cost of heating goes UP? Totally brutal!

This pricing anomaly means we will have to use a standard price for the cost of natural gas across all the years we are reporting upon.

So what standard pricing will we use? If you notice, the first chart on the page above shows the price of natural gas to be about constant over the last 7 years. We will use the average of these prices which is: $0.3892 / cubic meter of gas.

With this pricing in place we can get a handle on the savings we would get through our investment in insulation and internal heat management.

Consider the following chart:



This is the 'money' chart.

First a little deconstruction is in order. Using the standard cost per cubic meter of natural gas one can calculate the cost of heating for a season by multiplying it by the efficiency and then by the number of heating degree days for that heating season. The efficiency is measured by the number of cubic meters used per heating degree day. So the calculation without numbers is: the cost, **$/m^3** times the efficiency number of **m^3/HDD** times the actual number of **HDD** in the season. The HDD cancels out and so does the m^3 leaving just the $.

In the above chart the 'standard cost using latest efficiency' does just that: it calculates the dollar cost per heating season at a given efficiency and standard cost for energy.

What then is the 'savings' in the above chart? The savings calculation starts with identical inputs except the efficiency. The efficiency used is the baseline year's efficiency. Once that cost is calculated then the latest efficiency total is subtracted from it. The difference is the amount saved due to the increased efficiency … all else is equal.

Using a standard cost (which is very close to the price today) and baseline efficiency, the efficiency calculated using 2004-05 heating season numbers, the total heating invoices for all the years on the chart is **$12,498.31**. Keeping all else the same but using the latest efficiency calculated for 2017-18, the cost of heating falls to **$8,507.36**. Based upon the efficiency change, a savings of **$3,990.95** is achieved over 13 seasons for an average yearly savings of **$307.00** or **31.9%**.

Conclusion

We use the term 'internal heat management' several times in the paper. Internal heat is the heat generated in house in the wintertime to heat the house. Note that heat in this situation is typically carried by the air from one place to another and not by thermal radiation. Air density is very sensitive to its heat content so convection currents created by differences in air density can move air around the house in dramatic fashion. We know that the air is heated by radiators by thermal radiation and we also know that heat is transferred from hot air to colder air using thermal radiation. We also know that all heat generated in the house will eventually find its way to the outside in the winter time until thermal equilibrium between inside and outside temperatures is achieved. There is no stopping this migration. All we can do is to inhibit its flow. The best we can do then is to slow it down enough to keep the average air temperature surrounding the thermostat warmer.

Here in Ontario, Canada we have one of the cleanest electrical grids in the world with an average CO2 release per kiloWatt-hour generated of 43 grams. When we use electrical heaters to displace the use of natural gas the difference in CO2 release is 43 grams vs. 189 grams per kWh if energy used, a savings or about 440%. This calculation is based upon the fact that one cubic meter of natural gas releases 1,956 grams of CO2 when combusted. Since there are 10.35 kiloWatt-hours of energy in a cubic meter of natural gas, each kiloWatt-hour of natural gas releases 188.9 or a rounded amount of 189 grams of CO2.

Note the following points highlighted by our data and modifications:

1. There is no magic bullet to efficiency. Many things work together to attain the efficiency goals you desire.
2. A household consists of people, plants, pets and a structure. Each has a unique role to play in making the household more efficient.
3. Managing internal heat flow using curtains, doors and heaters affects household efficiency and carbon footprint.
4. Managing the house internal temperature using a computer controlled thermostat allows for consistently accurate time of day heat levels which adds to the efficiency.
5. Lifestyle changes including appropriate dress and house temperatures increase the winter time household efficiency.
6. Encapsulating and sealing up the house structure dramatically increases household efficiency.

All the data that support this paper are presented in the appendices below. Appendix 1 contains the year by year data. Appendix 2 contains a summary table for all the years.

And finally, our world wide carbon pollution problem needs everyone participating in its solution. At the household level here at 43 Latitude our carbon footprint consists mostly of carbon release from household heating. We must use less to help in the overall effort.

We hope that this paper highlights some ideas that everyone can use to achieve their carbon reduction goals.

Appendix 1

Calculating the Baseline year 2004-05

The baseline year for this paper is the heating season of 2004-05. All data come from our utility invoices and Environment Canada's historical databases for Toronto from which we calculate the number of Heating Degree Days (HDD) for each season.

Our natural gas powered boiler system heats our hot water radiators which are original 1925 equipment, and produces hot water on demand. The specifications can be seen below.

http://www.theravinaproject.org/The%20Ravina%20Project%20-Trinity%20T150%20Boiler%2001.pdf

Calculating the average daily usage of natural gas for non-heating functions.

The calculated number of cubic meters of natural gas used during the heating season must be net of the number of cubic meters of gas used for cooking, hot water production, clothes washing and the like. We look specifically at the summertime before the heating season to calculate the non-heating gas usage. The method will be identical to every heating season's calculation.

The summer of 2004 will provide the non-heating usage for the baseline year.

Reading date	**Jun 23/04**	**Jul 23/04**	**Aug 24/04**	**Sep 23/04**
Number of days	29	30	32	30
M3 used	46	48	41	48
Total Bill	$29.90	$32.10	$29.64	$32.84

Note: here the heating season starts on October 1st and ends May 31st of the next year.

The total number of days is 121, the total usage is 183 cu. meters. The daily usage is therefore: **1.512 cubic meters** for non-heating purposes.

Calculating the 2004-05 heating season metrics

From our database we have the following:

Reading date	**Oct 25/04**	**Nov 19/04**	**Dec 21/04**	**Jan 25/05**
Number of days	32	25	32	35
M3 used	125	242	503	679
Total Bill	$76.50	$124.01	$242.45	$312.14

Reading date	**Feb 23/05**	**Mar 24/05**	**Apr 25/05**	**May 25/05**
Number of days	29	29	32	30
M3 used	559	518	266	149
Total Bill	$274.06	$254.93	$121.54	$71.56

The total number of billed days: 244.
Total gas usage is: 3,041 cubic meters
Total non-heating gas usage is 1.512 x 244 days = 369.0 cubic meters (m^3).
Total gas used for heating is: 3,041 – 369.0 = **2,672** m^3.

Calculating Household Efficiency in cubic meters (m^3) of gas used per heating degree day (HDD)

Using Environment Canada weather data:

Heating Degree Days (HDD) accumulated in 2004 from Oct 1st to Dec 31st : 1,248.8.
HDD in 2005 from Jan 1st to May 31st : 2,491.2.
Total HDD for heating season 2004-05 is: **3,740**.

Heating efficiency is: 2672 m^3/3740 HDD = **0.7144 m3 / HDD**.

Calculating the cost of natural gas heating 2004-05

Total cost of natural gas is the total dollars invoiced over the heating season: **$1,477.19.**
Cost of natural gas per cubic meter is: $1,477.19 / 3,041 m3 = **$0.4858/m3**.
Cost of natural gas for heating per HDD: 0.7144 m3/HDD x $0.4858 m3 = **$0.3470/HDD.**
From above, the number of heating degree days: 3,740.
Total cost for heating over 3,740 HDD: 3740 HDD x $0.3470/HDD = **$1,297.93**.

Baseline metric for this paper

The above calculations give us a baseline efficiency of: **0.7144 m3/HDD**.

Calculating the heating cost for heating season 2005-06

Calculating the average daily usage of natural gas for non-heating functions.

The summer of 2005 will provide the non-heating usage for heating season 2005-06.

Reading date	Jun 22/05	Jul 25/05	Aug 24/05	Sep 23/05
Number of days	28	33	30	30
M3 used	93	53	12	30
Total Bill	$49.42	$35.10	$17.43	$25.51

The total number of days is 121 with a total usage is 188 m3. The daily usage is therefore: **1.554 m3** for non-heating purposes.

Calculating the 2005-06 heating season metrics

From our database we have the following:

Reading date	Oct 24/05	Nov 23/05	Dec 22/05	Jan 25/06
Number of days	31	30	29	34
M3 used	151	268	493	504
Total Bill	$81.83	$136.00	$238.97	$279.36

Reading date	Feb 22/06	Mar 24/06	Apr 24/06	May 25/06
Number of days	28	30	31	31
M3 used	495	490	235	105
Total Bill	$305.14	$302.18	$137.86	$66.17

The total number of billed days: **244**.
Total gas usage is: **2,741** m3.
Total non-heating gas usage is 1.554 m3/day x 244 days = **379.1 m3**.
Total gas used for heating is: 2,741 m3 – 379.1 m3 = **2,361.9 m3**.

Calculating Household Efficiency in cubic meters of gas used per heating degree day

Using Environment Canada weather data:

HDD in 2005 from Oct 1st to Dec 31st: 1,273.9
HDD in 2006 from Jan 1st to May 31st : 2,102.9
Total HDD for heating season 2005-06 is: **3,376.8**

Heating efficiency is: 2361.9 m3 / 3376.8 HDD = **0.6994 m3 / HDD**.

Calculating the cost of natural gas heating 2005-06

Total cost of natural gas is the total invoiced over the heating season: **$1,547.51.**
Total cubic meters of NG consumed: **2,741.**
Cost of natural gas per cubic meter is: $1,547.51 / 2,741 m3 = **$0.5646/m3**.
Cost of natural gas for heating per HDD: 0.6994 m3 / HDD x $0.5646 / m3 = **$0.3949/HDD.**
Total cost for heating over 3,376.8 HDD: 3376.8 x $0.3949/HDD = **$1,333,47.**

Calculating the Heating cost for heating season 2006-07

Calculating the average daily usage of natural gas for non-heatring functions.

The summer of 2006 will provide the non-heating usage for heating season 2006-07.

Reading date	June 22/06	Jul 25/06	Aug 24/06	Sep 25/06
Number of days	28	33	30	32
M3 used	87	33	65	48
Total Bill	$63.44	$31.74	$50.70	$40.61

The total number of days is 123, the total natural gas usage is 233 m3. The daily usage is therefore: 1.894 m3 for non-heating purposes.

Calculating the 2006-07 heating season metrics

From our database we have the following:

Reading date	Oct 24/06	Nov 23/06	Dec 21/06	Jan 25/07
Number of days	29	30	28	35
M3 used	229	328	340	573
Total Bill	$146.92	$204.66	$211.67	$346.16

Reading date	Feb 22/07	Mar 23/07	Apr 24/07	May 25/07
Number of days	28	29	32	31
M3 used	440	417	300	97
Total Bill	$268.43	$255.09	$188.90	$71.02

The total number of billed days: **242**.
Total gas usage is: **2,724** m3.
Total non-heating gas usage is 1.894 x 242 days = **458.4 m3**.
Total gas used for heating is: 2,724 – 458.4 = **2,265.6 cubic meters**.

Calculating Household Efficiency in cubic meters of gas used per heating degree day

Using Environment Canada weather data:

HDD in 2006 from Oct 1st to Dec 31st : 1,171
HDD in 2007 from Jan 1st to May 31st : 2,426.7
Total HDD for heating season 2005-06 is: **3,597.7**

Heating efficiency is: 2265.6 m3 / 3597.7 HDD = **0.6297 m3 / HDD**.

Calculating the cost of natural gas heating 2006-07

Total cost of natural gas is the total invoiced over the heating season: **$1,692.85.**
Cost of natural gas per cubic meter is: $1,692.85 / 2,724 m3 = **$0.6215/m3**.
Cost of natural gas for heating per HDD: 0.6297 m3/HDD x $0.6215 = **$0.3913/HDD**
Total cost for heating over 3,597.7 HDD: 3597.7 HDD x $0.3913/HDD = **$1,407.96.**

Calculating the heating cost for heating season 2007-08

Calculating the average daily usage of natural gas for non-heating functions.

The summer of 2007 will provide the non-heating usage for heating season 2007-08.

Reading date	June 25/07	July 25/07	Aug 23/07	Sept 25/07
Number of days	31	30	29	33
M3 used	62	45	57	56
Total Bill	$49.68	$39.57	$46.69	$46.11

The total number of days is 123, the total usage is 220 m3. The daily usage is therefore: **1.789 m^3** for non-heating purposes.

Calculating the 2007-08 heating season metrics

From our invoice data we have the following:

Reading date	Oct 24/07	Nov 23/07	Dec 21/07	Jan 25/08
Number of days	29	30	28	35
M3 used	78	285	302	503
Total Bill	$103.63	$135.74	$191.86	$305.69

Reading date	Feb 25/08	Mar 27/08	Apr 23/08	May 26/08
Number of days	31	31	27	33
M3 used	401	419	161	133
Total Bill	$245.96	$256.38	$107.38	$91.13

The total number of billed days: **244**.
Total gas usage is: **2,282 m3.**
Total non-heating gas usage is 1.789 x 244 days = **436.4 m3**.
Total gas used for heating is: 2,282 – 436.4 = **1,845.6 m3**.

Calculating Household Efficiency in cubic meters of gas used per heating degree day

Using Environment Canada weather data:

HDD in 2007 from Oct 1st to Dec 31st: 1,230.9
HDD in 2008 from Jan 1st to May 31st : 2,355.8
Total HDD for heating season 2007-08 is: **3,586.7**

Heating efficiency is: 1,845.6 m3 / 3586.7 HDD = **0.5146 m3 / HDD**.

Calculating the cost of natural gas heating 2007-08

Total cost of natural gas is the total invoiced over the heating season: **$1,437.77.**
Total cubic meters of NG consumed: **2,282**
Cost of natural gas per cubic meter is: $1,437.77 / 2,282 m3 = **$0.6300/m3**.
Cost of natural gas for heating per HDD: 0.5146 cubic meters/HDD x $0.6300 = **$0.3242/HDD**
Total cost for heating over 3,586.7 HDD: 3586.7 HDD x $0.3242 / HDD = **$1,162.80.**

Calculating the Heating cost for heating season 2008-09

Calculating the average daily usage of natural gas for non-heating functions.

The summer of 2008 will provide the non-heating usage for heating season 2008-09.

Reading date	Jun 23/08	July 24/08	Aug 23/08	Sept 24/08
Number of days	28	31	30	32
M3 used	66	53	56	54
Total Bill	$51.77	$48.69	$52.22	$46.95

The total number of days is 121, the total usage is 229 cu. meters. The daily usage is therefore: **1.893 m3** cubic meters for non-heating purposes.

Calculating the 2008-09 heating season metrics

From our database we have the following:

Reading date	Oct 23/08	Nov 24/08	Dec 23/08	Jan 26/09
Number of days	29	32	29	34
M3 used	117	280	393	535
Total Bill	$84.34	$180.14	$246.40	$329.18

Reading date	Feb 24/09	Mar 26/09	Apr 24/09	May 27/09
Number of days	29	30	29	33
M3 used	385	329	205	100
Total Bill	$241.26	$208.48	$133.55	$74.51

The total number of billed days: **245**.
Total gas usage is: **2,344** cubic meters
Total non-heating gas usage is 1.893 x 245 days = **463.7 m3**.
Total gas used for heating is: 2,344 – 463.7 = **1,880.3 cubic meters**.

Calculating Household Efficiency in cubic meters of gas used per heating degree day

Using Environment Canada weather data:

HDD in 2008 from Oct 1st to Dec 31st : 1,384.8
HDD in 2009 from Jan 1st to May 31st : 2,435
Total HDD for heating season 2008-09 is: **3,819.8**

Heating efficiency is: 1,866.3 m3 / 3,819.8 = **0.4923 m3 / HDD**.

Calculating the cost of natural gas heating 2008-09

Total cost of natural gas is the total invoiced over the heating season: **$1,497.86.**
Total cubic meters of NG consumed: **2,344.**
Cost of natural gas per cubic meter is: $1,497.86 / 2,344 m3 = **$0.6390/m3**.
Cost of natural gas for heating per HDD: 0.4923 cubic meters/HDD x $0.6390/m3 = **$0.3146.**
Total cost for heating over 3,819.8 HDD: 3819.8 x 0.3146 = **$1,201.56.**

Calculating the Heating cost for heating season 2009-10

Calculating the average daily usage of natural gas for non-heating functions.

The summer of 2009 will provide the non-heating usage for heating season 2008-09.

Reading date	Jun 24/09	July 27/09	Aug 26/09	Sept 25/09
Number of days	28	33	30	30
M3 used	57	56	61	65
Total Bill	$49.95	$49.21	$52.05	$57.00

The total number of days is 121, the total usage is 239 cu. meters. The daily usage is therefore: **1.975 m3** for non-heating purposes.

Calculating the 2009-10 heating season metrics

From our database we have the following:

Reading date	Oct 27/09	Nov 24/09	Dec 21/09	Jan 22/10
Number of days	32	28	27	32
M3 used	150	220	272	450
Total Bill	$106.73	$147.34	$177.47	$280.55

Reading date	Feb 22/10	Mar 23/10	Apr 21/10	May 21/10
Number of days	31	29	29	30
M3 used	434	260	128	129
Total Bill	$277.22	$175.58	$102.71	$103.35

The total number of billed days: **238**
Total gas usage is: **2,043** cubic meters
Total non-heating gas usage is 2,043 x 238 days = **470.1 m3**.
Total gas used for heating is: 2,043 – 470.1 = **1,572.9 cubic meters**.

Calculating Household Efficiency in cubic meters of gas used per heating degree day

Using Environment Canada weather data:

HDD in 2009 from Oct 1st to Dec 31st: 1,280.3
HDD in 2010 from Jan 1st to May 31st : 2,074.1
Total HDD for heating season 2009-10 is: **3,354.4**

Heating efficiency is: 1,574.9/3,354.4 = **0.4689 cubic meters / HDD**.

Calculating the cost of natural gas heating 2009-10

Total cost of natural gas is the total invoiced over the heating season: **$1,370.95**
Total cubic meters of NG consumed: **2,043**
Cost of natural gas per cubic meter is: $1,370.95 / 2,043 cubic meters = **$0.6710/m3**.
Cost of natural gas for heating per HDD: 0.4689 m3/HDD x $0.6710/m3 = **$0.3147/HDD**
Total cost for heating over 3,354.4 HDD: 3354.4 HDD x $0.3147/HDD = **$1,055.49.**

Calculating the Heating cost for heating season 2010-11

Calculating the average daily usage of natural gas for non-heating functions.

The summer of 2010 will provide the non-heating usage for heating season 2010-11.

Reading date	June 21/10	July 22/10	Aug 23/10	Sept 22/10
Number of days	31	31	32	30
M3 used	76	58	84	65
Total Bill	$66.30	$58.61	$76.50	$64.31

The total number of days is 124, the total usage is 283 cu. meters. The daily usage is therefore: 2.282 m3 for non-heating purposes. Note: we had an extra person in the household.

Calculating the 2010-11 heating season metrics

From our database we have the following:

Reading date	Oct 21/10	Nov 22/10	Dec 21/10	Jan 25/11
Number of days	29	32	29	35
M3 used	105	238	324	518
Total Bill	$90.49	$175.01	$229.63	$351.92

Reading date	Feb 22/11	Mar 23/11	Apr 20/11	May 25/11
Number of days	28	29	28	35
M3 used	431	266	304	155
Total Bill	$297.13	$192.95	$218.82	$121.85

The total number of billed days: **245**
Total gas usage is: **2,341 m3**.
Total non-heating gas usage is 2.282 x 245 days = **559.2 m3**.
Total gas used for heating is: 2,341 m3 – 559.2 m3 = **1,781.8 m3**.

Calculating Household Efficiency in cubic meters of gas used per heating degree day

Using Pearson weather data:

HDD in 2010 from Oct 1st to Dec 31st : 1,323.1
HDD in 2011 from Jan 1st to May 31st : 2,456.1
Total HDD for heating season 2010-11 is: **3,779.2**

Heating efficiency is: 1,781.8 m3 / 3,779.2 HDD = **0.4715 m3 / HDD**.

Calculating the cost of natural gas heating 2010-11

Total cost of natural gas is the total invoiced over the heating season: **$1,677.80.**
Cost of natural gas per cubic meter is: $1,677.80 / 2,341 m3 = **$0.7167/m3**.
Cost of natural gas for heating per HDD: 0.4715 m3/HDD x $0.7167/m3 = **$0.3379/HDD**
Total cost for heating over 3,779.2 HDD: 3779.2 HDD x $0.3379/HDD = **$1,277.05.**

Calculating the Heating cost for heating season 2011-12

Calculating the average daily usage of natural gas for non-heating functions.

The summer of 2011 will provide the non-heating usage for heating season 2011-12.

Reading date	Jun 22/11	July 25/11	Aug 23/11	Sep 23/11
Number of days	28	33	29	31
M3 used	78	60	65	78
Total Bill	$66.47	$54.88	$57.44	$64.07

The total number of days is 121, the total usage is 281 cu. meters. The daily usage is therefore: 2.322 m3 for non-heating purposes.

Calculating the 2011-12 heating season metrics

From our database we have the following:

Reading date	Oct 21/11	Nov 22/11	Dec 20/11	Jan 24/12
Number of days	28	32	28	35
M3 used	99	210	259	450
Total Bill	$78.26	$94.06	$95.84	$148.46

Reading date	Feb 22/12	Mar 23/12	Apr 24/12	May 25/12
Number of days	29	30	32	31
M3 used	321	240	201	126
Total Bill	$112.25	$89.88	$73.45	$53.31

The total number of billed days: **245.**
Total gas usage is: **1,906 m3** .
Total non-heating gas usage is 2.322 x 245 days = **569.0 m3**.
Total gas used for heating is: 2,322 – 569.0 = **1,337.0 m3**.

Calculating Household Efficiency in cubic meters of gas used per heating degree day

Using Pearson weather data:

HDD in 2011 from Oct 1st to Dec 31st : 1,101.6
HDD in 2012 from Jan 1st to May 31st : 1,895.2
Total HDD for heating season 2011-12 is: **2,996.8**

Heating efficiency is: 1,337 m3 / 2,996.8 HDD = **0.4462 cubic meters / HDD**.

Calculating the cost of natural gas heating 2011-12

Total cost of natural gas is the total invoiced over the heating season: **$745.51.**
Cost of natural gas per cubic meter is: $745.51 / 1,906 m3 = **$0.3911/m3**.
Cost of natural gas for heating per HDD: 0.4462 cubic meters/HDD x $0.3911/m3 = **$0.1745/HDD**
Total cost for heating over 2,996.8 HDD: 2,996.8 HDD x $0.1745/HDD = **$1,172.16.**

Calculating the Heating cost for heating season 2012-13

Calculating the average daily usage of natural gas for non-heating functions.

The summer of 2012 will provide the non-heating usage for heating season 2012-13.

Reading date	Jun 25/12	Jul 25/12	Aug 23/12	Sept 24/12
Number of days	31	30	29	32
M3 used	29	60	14	86
Total Bill	$29.82	$37.55	$26.12	$43.99

The total number of days is 122, the total usage is 189 cu. meters. The daily usage is therefore: **1.549 m3** for non-heating purposes.

Calculating the 2012-13 heating season metrics

From our database we have the following:

Reading date	Oct 23/12	Nov 22/12	Dec 19/12	Jan 23/13
Number of days	29	30	27	35
M3 used	56	246	178	440
Total Bill	$38.87	$83.26	$66.77	$137.22

Reading date	Feb 22/13	Mar 22/13	Apr 22/13	May 23/13
Number of days	30	28	31	31
M3 used	365	288	250	108
Total Bill	$120.85	$100.32	$89.27	$51.85

The total number of billed days: **241**
Total gas usage is: **1,931** m3
Total non-heating gas usage is 1.549 x 241 days = **373.4** m3.
Total gas used for heating is: 1,931 – 373.4 = **1,557.6 m3**.

Calculating Household Efficiency in cubic meters of gas used per heating degree day

Using Environment Canada weather data:

HDD in 2012 from Oct 1st to Dec 31st: 1,210
HDD in 2013 from Jan 1st to May 31st : 2,122.3
Total HDD for heating season 2012-13 is: **3,332.3**

Heating efficiency is: 1,557.6 m3/3,332.3 HDD = **0.4674 m3 / HDD**.

Calculating the cost of natural gas heating 2012-13

Total cost of natural gas is the total invoiced over the heating season: **$688.41**
Cost of natural gas per cubic meter is: $688.41 / 1,931 m3 = **$0.3565/m3**.
Cost of natural gas for heating per HDD: 0.4674 m3/HDD x $0.3565/m3 = **$0.1666/HDD**
Total cost for heating over 3,332.3 HDD: 3,332.3 HDD x $0.1666/HDD = **$555.31**

Calculating the Heating cost for heating season 2013-14

Calculating the average daily usage of natural gas for non-heatring functions.

The summer of 2013 will provide the non-heating usage for heating season 2013-14.

Reading date	Jun 20/13	Jul 24/13	Aug 22/13	Sept 24/13
Number of days	28	34	29	33
M3 used	49	43	38	70
Total Bill	$35.97	$35.36	$34.23	$43.87

The total number of days is 124, the total usage is 200 cu. meters. The daily usage is therefore: **1.613 m3** for non-heating purposes.

Calculating the 2013-14 heating season metrics

From our database we have the following:

Reading date	Oct 24/13	Nov 22/13	Dec 19/13	Jan 23/14
Number of days	30	29	27	35
M3 used	54	203	345	494
Total Bill	$37.66	$77.26	$114.74	$156.29

Reading date	Feb 20/14	Mar 24/14	Apr 23/14	May 23/14
Number of days	28	32	30	30
M3 used	437	409	240	132
Total Bill	$141.87	$134.30	$104.80	$78.66

The total number of billed days: **241**
Total gas usage is: **2,314 m3**
Total non-heating gas usage is 1.613 x 241 days = **388.7 m3**.
Total gas used for heating is: 2,314 – 388.7 = **1,925.3 m3**.

Calculating Household Efficiency in cubic meters of gas used per heating degree day

Using Environment Canada weather data:

HDD in 2013 from Oct 1st to Dec 31st: 1,246.6.
HDD in 2014 from Jan 1st to May 31st : 2,538.3.
Total HDD for heating season 2013-14 is: **3,784.9.**

Heating efficiency is: 1,925.3 m3 / 3,784.9 HDD = **0.5087 m3 / HDD**.

Calculating the cost of natural gas heating 2013-14

Total cost of natural gas is the total invoiced over the heating season: **$845.58.**
Cost of natural gas per cubic meter is: $845.58 / 2,314 m3 = **$0.3654/m3**.
Cost of natural gas for heating per HDD: 0.5087 m3/HDD x $0.3654/m3 = **$0.1859/HDD**
Total cost for heating over 3,784.9 HDD: 3,784.9 HDD x 0.1859 = **$703.54.**

Calculating the Heating cost for heating season 2014-15

Calculating the average daily usage of natural gas for non-heating functions.

The summer of 2014 will provide the non-heating usage for heating season 2014-15.

Reading date	Jun 21/14	Jul 24/14	Aug 23/14	Sept 23/14
Number of days	29	33	30	31
M3 used	46	44	58	63
Total Bill	$42.31	$39.69	$44.32	$46.19

The total number of days is 123, the total usage is 211 cu. meters. The daily usage is therefore: **1.715 m3** for non-heating purposes.

Calculating the 2014-15 heating season metrics

From our database we have the following:

Reading date	Oct 23/14	Nov 21/14	Dec 22/14	Jan 23/15
Number of days	30	29	31	32
M3 used	91	243	291	431
Total Bill	$50.00	$92.60	$106.25	$157.54

Reading date	Feb 20/15	Mar 24/15	Apr 22/15	May 22/15
Number of days	28	32	29	30
M3 used	422	395	224	119
Total Bill	$179.65	$169.67	$99.63	$61.83

The total number of billed days: **241.**
Total gas usage is: **2,216 m3**.
Total non-heating gas usage is 1.715 x 241 days = **413.4 m3**.
Total gas used for heating is: 2,216 – 413.4 = **1,802.6 m3**.

Calculating Household Efficiency in cubic meters of gas used per heating degree day

Using Environment Canada weather data:

HDD in 2014 from Oct 1st to Dec 31st : 1,157
HDD in 2015 from Jan 1st to May 31st : 2,499.1
Total HDD for heating season 2014-15 is: **3,656.1**

Heating efficiency is: 1,802.6 m3 / 3,656.1 HDD = **0.4930 m3 / HDD**.

Calculating the cost of natural gas heating 2014-15

Total cost of natural gas is the total invoiced over the heating season: **$917.17**.
Cost of natural gas per cubic meter is: $917.17 / 2,216 m3 = **$0.4139/m3**.
Cost of natural gas for heating per HDD: 0.4930 m3/HDD x $0.4139/m3 = **$0.2041/HDD.**
Total cost for heating over 3,656.1 HDD: 3,656.1 HDD x $0.2041/HDD = **$746.06.**

Calculating the Heating cost for heating season 2015-16

Calculating the average daily usage of natural gas for non-heating functions.

The summer of 2015 will provide the non-heating usage for heating season 2015-16.

Reading date	Jun 19/15	July 24/15	Aug 22/15	Sept 23/15
Number of days	28	35	29	31
M3 used	57	60	37	61
Total Bill	$41.54	$45.14	$37.37	$46.83

The total number of days is 123, the total usage is 215 cu. meters. The daily usage is therefore: **1.748 m3** for non-heating purposes.

Calculating the 2015-16 heating season metrics

From our database we have the following:

Reading date	Oct 22/15	Nov 23/15	Dec 21/15	Jan 25/16
Number of days	29	32	28	35
M3 used	86	201	189	397
Total Bill	$50.23	$83.46	$79.89	$135.44

Reading date	Feb 22/16	Mar 23/16	Apr 21/16	May 24/16
Number of days	28	29	29	33
M3 used	327	282	231	164
Total Bill	$114.27	$101.82	$89.52	$70.90

The total number of billed days: **243.**
Total gas usage is: **1,877 m3**.
Total non-heating gas usage is 1.748 x 243 days = **424.8 m3.**
Total gas used for heating is: 1,877 – 424.8 = **1,452.2 m3**.

Calculating Household Efficiency in cubic meters of gas used per heating degree day

Using Environment Canada weather data:

HDD in 2015 from Oct 1st to Dec 31st : 900.8.
HDD in 2016 from Jan 1st to May 31st : 2,010.3.
Total HDD for heating season 2015-16 is: **2,911.1**

Heating efficiency is: 1,452 m3 / 2,911.1 HDD = **0.4989 cubic meters / HDD**.

Calculating the cost of natural gas heating 2015-16

Total cost of natural gas is the total invoiced over the heating season: **$725.90**
Cost of natural gas per cubic meter is: $725.90 / 1,877 m3 = **$0.3867/m3**.
Cost of natural gas for heating per HDD: 0.4989 m3/HDD x $0.3867 = **$0.1929/HDD.**
Total cost for heating over 2,911.1 HDD: 2,911.1 HDD x $0.1929/HDD = **$561.63.**

Calculating the Heating cost for heating season 2016-17

Calculating the average daily usage of natural gas for non-heating functions.

The summer of 2016 will provide the non-heating usage for heating season 2016-17.

Reading date	Jun 21/16	July 22/16	Aug 22/16	Sept 22/16
Number of days	28	31	31	30
M3 used	35	47	40	48
Total Bill	$33.13	$36.36	$34.28	$36.56

The total number of days is 120, the total usage is 170 cu. meters. The daily usage is therefore: **1.417 m3** for non-heating purposes.

Calculating the 2016-17 heating season metrics

From our database we have the following:

Reading date	Oct 24/16	Nov 23/16	Dec 20/16	Jan 23/17
Number of days	32	30	27	34
M3 used	72	188	285	372
Total Bill	$54.21	$86.09	$100.62	$133.44

Reading date	Feb 21/17	Mar 23/17	Apr 21/17	May 24/17
Number of days	29	29	28	32
M3 used	341	314	207	147
Total Bill	$128.05	$119.82	$87.60	$69.23

The total number of billed days: **241.**
Total gas usage is: **1,926 cubic meters**
Total non-heating gas usage is 1.417 x 241 days = **341.4 m3**.
Total gas used for heating is: 1,926 – 341.4 = **1,584.6 cubic meters**.

Calculating Household Efficiency in cubic meters of gas used per heating degree day

Using Environment Canada weather data:

HDD in 2016 from Oct 1st to Dec 31st : 1025.2
HDD in 2017 from Jan 1st to May 31st : 1,991.5
Total HDD for heating season 2016-17 is: **3,016.7**

Heating efficiency is: 1,584.6 m3 / 3,016.7 HDD = **0.5253 m3 / HDD**.

Calculating the cost of natural gas heating 2016-17

Total cost of natural gas is the total invoiced over the heating season: **$779.06**
Cost of natural gas per cubic meter is: $779.06 / 1,926 m3 = **$0.4045/cubic meter**.
Cost of natural gas for heating per HDD: 0.5253 m3 / HDD x $0.4045 / m3 = **$0.2125/HDD**
Total cost for heating over 3,016.7 HDD: 3,016.7 HDD x $0.2125 / HDD= **$640.96**

Calculating the Heating cost for heating season 2017-18

Calculating the average daily usage of natural gas for non-heating functions.

The summer of 2017 will provide the non-heating usage for heating season 2017-18.

Reading date	Jun 21/17	Jul 24/17	Aug 23/17	Sept 23/17
Number of days	27	32	29	30
M3 used	69	49	53	62
Total Bill	$44.72	$38.93	$40.53	$43.54

The total number of days is 118, the total usage is 233 cu. meters. The daily usage is therefore: 1.975 cubic meters for non-heating purposes.

Calculating the 2017-18 heating season metrics

From our database we have the following:

Reading date	Oct 23/17	Nov 22/17	Dec 20/17	Jan 23/18
Number of days	29	29	27	33
M3 used	62	230	296	493
Total Bill	$46.91	$97.20	$113.31	$181.46

The total number of billed days: **118**
Total gas usage is: **1081 m3**.
Total non-heating gas usage is 1.975 x 118 days = **233 m3**.
Total gas used for heating is: 1081 – 233 = **848 cubic meters**.

Calculating Household Efficiency in cubic meters of gas used per heating degree day

Using Environment Canada weather data:

HDD in 2017 from Oct 1st to Dec 31st : 1212.9
HDD in 2018 from Jan 1st to May 31st : 530.8
Total HDD for heating season 2017-18 is: **1743.7**

Heating efficiency is: 848 m3 / 1,743.7 HDD = **0.4863 m3 / HDD**.

Calculating the cost of natural gas heating 2017-18

Total cost of natural gas is the total invoiced over the heating season: **$438.88.**
Cost of natural gas per cubic meter is: $438.88 / 1081 m3 = **$0.4060/m3**.
Cost of natural gas for heating per HDD: $0.4863 m3 /HDD x $0.4060 / m3 = **$0.1974/HDD**
Total cost for heating over 1,743.7 HDD: 1743.7 HDD x $0.1974 / HDD = **$344.28.**

Appendix 2

Aggregated Totals

Heating Season	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
NG used for heating	2672.0	2361.9	2265.6	1845.6	1880.3	1572.9	1781.8	1337.0
Total HDD	3740.0	3376.8	3597.7	3586.7	3819.8	3354.4	3779.2	2996.8
Efficiency	0.7144	0.6994	0.6297	0.5146	0.4923	0.4689	0.4715	0.4462
Total Invoiced	$1,477.19	$1,547.51	$1,692.85	$1,437.77	$1,497.86	$1,370.95	$1,677.80	$745.51
Cost per m3	$0.4858	$0.5646	$0.6215	$0.6300	$0.6390	$0.6710	$0.7167	$0.3911
Cost per HDD	$0.3470	$0.3949	$0.3913	$0.3242	$0.3146	$0.3147	$0.3379	$0.1745
Cost for heating	$1,297.93	$1,333.47	$1,407.96	$1,162.80	$1,201.56	$1,055.49	$1,277.05	$1,172.16
Baseline eff gas used per season	2672	2412	2570	2562	2729	2396	2700	2141
Std cost of heating/HDD	0.2780	0.2722	0.2451	0.2003	0.1916	0.1825	0.1835	0.1736
Std cost with baseline efficiency	$1,039.85	$938.86	$1,000.28	$997.22	$1,062.03	$932.64	$1,050.74	$833.21
Std cost using latest efficiency	$707.80	$639.07	$680.87	$678.79	$722.91	$634.83	$715.22	$567.15
Savings	$332.04	$299.80	$319.41	$318.43	$339.13	$297.81	$335.52	$266.06

Heating Season	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
NG used for heating	1557.6	1925.3	1802.6	1452.2	1584.6	848.0
Total HDD	3332.3	3784.9	3656.1	2911.1	3016.7	1743.7
Efficiency	0.4674	0.5087	0.4930	0.4989	0.5253	0.4863
Total Invoiced	$688.41	$845.58	$917.17	$725.90	$779.06	$438.88
Cost per m3	$0.3565	$0.3654	$0.4139	$0.3867	$0.4045	$0.4060
Cost per HDD	$0.1666	$0.1859	$0.2041	$0.1929	$0.2125	$0.1974
Cost for heating	$555.31	$703.54	$746.06	$561.63	$640.96	$344.28
Baseline eff gas used per season	2381	2704	2612	2080	2155	1246
Std cost of heating/HDD	0.1819	0.1980	0.1919	0.1941	0.2044	0.1893
Std cost with baseline efficiency	$926.49	$1,052.33	$1,016.52	$809.38	$838.74	$484.81
Std cost using latest efficiency	$630.64	$716.30	$691.92	$550.93	$570.92	$330.00
Savings	$295.85	$336.03	$324.59	$258.45	$267.83	$154.81

"If we knew what we were doing, it would not be called research."
- A. Einstein

Project Directors

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