Knowledge IS Power

Heat Pumps: Harnessing "Free" Heat for Long-term, Sustainable Heating and Cooling

May 16, 2023

This is another very long article but if you ‘ve been receiving my emails for a while, you know that I try to be thorough. After all, this my after-tax retirement money that I’m spending and my long-term income stream so I want to be sure I'm getting value for my money, especially with the looming 800% increase in carbon tax.

And "free" electricity (like solar panels) and some "free" heat (like heat pumps) is always compelling, especially with the unaffordability crisis of rental and purchase housing.

What Happened?
The blower motor for my gas furnace burned out in early April (2023). The cost to replace the motor was an extortionate $3,900 plus $400 for a blower fan plus labour versus buying a new natural gas furnace for $4,500 to $5,000.

I Re-Discovered Heat Pumps
While looking for a replacement furnace, I was given a Toronto Star Saturday double-page spread on heat pumps (2023 04 08, “Pump up the House”). Like many people, I thought heat pumps were generally not economically viable in northern climes like Toronto. The paragraph that resonated with me said, “… the latest natural gas furnaces are 96 to 98 per cent efficient [while] heat pumps are 250 to 550 per cent efficient.” The article launched me on another investigative quest for making my home and my rental investment properties more affordable to me and potentially my tenants.

My perception was grossly out of date. Heat pump technologies have evolved significantly despite their traditional reputation, including efficient compressors, low-resistance bearings, improved coil designs, super-efficient fans, better defrosting mechanisms, and ever-improving motors. Better quality heat pumps can operate as efficiently today as any fossil-fuelled furnace or boiler in temperatures as low as -30°C.

I didn’t realize that my “high-efficiency” two-stage gas furnace was actually 15 years old and my air conditioner was 30 years old (but still working fine). I learned after a few calls around to contractors that the government’s Greener Homes Grant program offered compelling rebates for eligible retrofits such as home insulation, windows and doors, heat pumps and renewable energy systems.

In my case, I’m eligible for $6,500 for the replaced heating and cooling system and $600 for the pre- and post-inspection.

Why a Heat Pump

After much research, I decided to buy a heat pump system. Here’s why.

A central furnace or boiler's efficiency is measured by Annual Fuel Utilization Efficiency (AFUE), which states how efficient the appliance is in converting energy from a fossil fuel to heat over the course of a year. AFUE is expressed as a ratio between the furnace or boiler’s annual heat output compared to the total annual fossil fuel energy it consumed. 90% AFUE means 90% of the consumed fuel energy becomes heat for the home while the other 10% is lost in the chimney or vent, and elsewhere. An all-electric furnace or boiler has no flue loss so they are usually more efficient but the disparity in cost between natural gas and electricity have traditionally made all-electric furnaces and boilers uneconomical.

The efficiency of heat pumps, refrigerators and air conditioners is defined by its COP rating. COP means “Coefficient Of Performance” and it’s the ratio of useful heating or cooling that is provided for the “work” or energy required. In practical terms, it defines the relationship between the power (kW) that is drawn out of the heat pump as cooling or heat, and the power (kW) that is supplied to the compressor.

To calculate the COP of a heat pump, the value of the heat output from the condenser (Q) is divided by the power supplied to the compressor (W). For example, a heat pump with a COP of 2 means 1 kW of power is used by the pump’s compressor to generate 2 kW of cooling power.

In layperson terms, you can think of 100% efficiency as one unit of energy input generates one unit of heating or cooling output. A higher COP values means higher efficiency and lower energy (power) consumption; therefore, lower operating costs.

Fossil-fueled (natural gas, propane, electricity, oil) furnaces and air conditioners can never achieve better than 100% efficiency. The theoretical “perfect” heat pump COP is arguably around 10 but in practice, it’s much lower. Generally, any heat pump with a COP above 3 has very high energy efficiency.

Fuel Efficiencies

Unlike fossil-fueled furnaces and air conditioners, heat pumps can achieve efficiencies of 250 to as much as (theoretically) 800%, that is, 2.5 to 8 times heating or cooling output for each unit of input.

The reason for this is that heat pumps don’t generate heat by burning something like a fossil fuel. They instead transfer the “free” heat that is “stored” all around us. Even when it’s -30°C, there is still an enormous amount of heat energy stored in the cold outside air. After all, the temperature of outer space, where there is almost no heat at all, is around −270°C.

Heat pumps traditionally have a reputation for not working in cold climates. However, as is often the case, technologies have advanced significantly faster than the changing of reputations and the updating of consumer knowledge.

What’s the Magic?

Traditional heat and cooling appliances generate heat by burning fossil fuels, typically converting and leaving behind some form of carbon residue. By contrast, a heat pump generally uses electricity to transfer heat from a colder environment to a warmer one, where the amount of heat transferred is notably greater than the energy source consumed to make the transfer.

In the winter time, a heat pump transfers heat from outside, even when its blistering cold, to the inside of a home, for example. In the summertime, it transfers heat from inside the home to the outside.

The heat transfer process in a heat pump is achieved by pumping a refrigerant within a closed system through a cycle of evaporation, compression, condensation and expansion.

Heat pump refrigerant has a very low boiling point, which is important because it allows the refrigerant to evaporate and absorb heat from the surrounding area, even at low weather temperatures. It also allows for use of smaller compressors and heat exchangers, which reduce the size and cost of heating and air conditioning systems.

Heat pump refrigerant boils at much lower temperatures than the lowest weather temperature in Toronto's recorded history. The coldest temperature in Toronto, Canada in the past twenty-two years (Jan. 2010 to 2022) was -25°C on February 15, 2015. The mildest was -13.1°C on February 12, 2021. The average coldest day over the 22-year period was -19.4°C. Toronto's coldest day in its recorded weather history was -32.8°C on January 10, 1859. A look at all of Toronto's coldest annual temperatures shows a steadily-increasing global warming trend over the many decades. Note that the "wind chill factor" only applies to living things, not mechanical equipment.

The boiling point of the previously-common R410A refrigerant is -48.5°C. The boiling point of the trending R454B refrigerant is -50.9°C.

When the refrigerant boils at its low temperature, it absorbs heat from the surrounding environment and evaporates into a gas. Even when its -25°C outside, it is still much warmer than -50.9°C so the refrigerant will always boil in GTA winter weather, even on the coldest Toronto days.

When a gas is compressed, its temperature increases and when it expands its temperature decreases (research Boyle's Law). The compression of the refrigerant gas is done with … a compressor (surprise). The heated refrigerant is pumped through a condenser, where the heat is released from the condensing gas to the surroundings, or more commonly, to a heat exchanger.

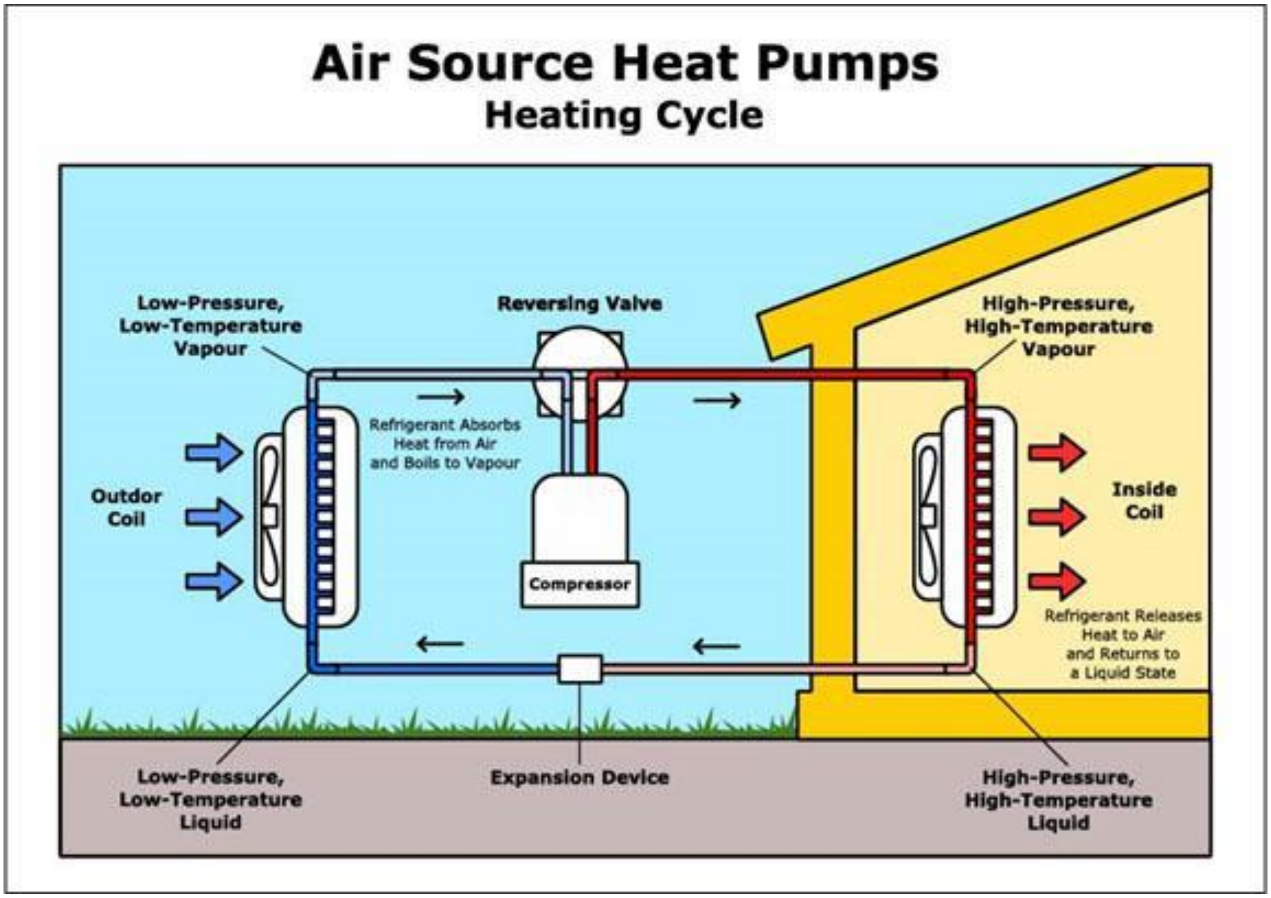
A heat exchanger transfers heat from one fluid to another fluid such that neither fluid will come into direct contact with the other using a heat-conducting material typically made of metal. The circulating fluid inside the heat exchanger absorbs the heat from the condensing gas and distributes the heat throughout the home's ductwork.

Most residential and small commercial heat exchangers have fins that are attached to the outside of the tubes. The fins increase the surface area available for heat transfer so a huge number of smaller fins has much more heat-transferring capability than a few larger fins. These fins work in the same way for car radiators, fridges, motorcycles and even computer CPUs and GPUs.

Unless you're my age or otherwise a car enthusiast, you may not know that the world-famous Volkswagen Beetle used an air-cooled engine with fins. Its engine was very light and economical on gasoline consumption because it had no radiator, water pump, thermostat, coolant or hoses.

Back to the refrigerant cycle—the pressurized condensing liquid refrigerant is then pumped through an expansion valve, which reduces the liquid refrigerant's temperature where it evaporates back into a gas. The refrigerant gas is pumped back outside where it again starts to absorb heat and boil to repeat the cycle, all in a matter of seconds or minutes, and for decades. The process of transferring heat from the colder medium to the warmer one requires energy input to drive the compressor and pump that circulates the refrigerant.

To cool an area, the cycle is literally reversed with a reversing valve that changes the direction of the refrigerant flow between the indoor and outdoor coils. During the cooling cycle, the reversing valve changes the direction of the refrigerant flow so that the indoor coil acts as the evaporator and absorbs heat from the inside air, while the outdoor coil acts as the condenser and releases heat to the outdoor air.



The reversing valve is controlled by a thermostat or a control board in the heat pump system. Heating or cooling is activated by temperature set points.

Ideally, to generate a constant and sustainable process of heating and cooling, a heat pump should be “fuelled” by a renewable energy source like solar panels with a battery storage system when the sun isn’t shining. In less ideal circumstances, a heat pump can still use a fossil fuel. *Moving* hot or cold air takes significantly less fuel than *generating* heated or cooled air.

Which Heat Pump did I Choose?
I chose the Mitsubishi Zuba Central model PUZ-HA36NKA “hyper-heat” cold climate 36,000 BTU heat pump for several reasons. This article is already very long so I’ll just say the pivotal reasons were the 10-year warranty on parts *and labour*, and that it still works on Toronto’s coldest days. When the outdoor temperature is 18°C, its COP is a minimum of 3.5 and maximum of 5.46, depending on multiple operating conditions. Perhaps more importantly, at -25°C, the COP is between 1.4 and 1.9. That means it’s still more efficient on its worst day than a 98% efficient furnace is on its best day.

Also, unlike conventional units which only cycle between on and off, Zuba adjusts its capacity to continuously match the exact heating and cooling needs of your home, so you only pay for the energy you actually use. And it’s quiet. The outdoor unit is about 47 dB. A chirping bird is 44 dB and a normal conversation is 60 dB.

Gas Backup Heat
In the extremely rare (or even unlikely) event that the temperature drops below the point where the heat pump can function, you can still have an auxiliary unit built into the heat pump enclosure. It can be a gas-fired burner like a conventional furnace or it can be an electric resistive heating element similar to the common space heater. I chose the latter, an 8 kW heating element, for two reasons.I have excess electricity capacity from my solar panel system, and I want to be completely natural gas-free.

Having a gas backup means using less gas than a traditional gas furnace but you still have to pay a fixed monthly fee to be connected to the gas service, even if you don't use it.

In my April 2023 Enbridge Gas bill, the "Gas Supply Charge," which is only the cost of the actual gas I used, was about 18.7% of my total bill, ublike my electricity bill where 40% or more is the "connection" charge. The other 81.3% of my gas bill was getting the gas from the field or mine to me plus HST, cost adjustments, "customer charge," and the highly-contentious federal carbon tax (CT).

Brutal Carbon Tax

Currently, the CT averages about 14.8% of my monthly gas bill. Each April 1st, the tax is automatically increased by a predetermined amount. The CT increase schedule is:

Year	cents/m^3
2019	3.91
2020	5.87
2021	7.83
2022	9.79
2023	12.39
2024	15.25
2025	18.11
2026	20.97
2027	23.83
2028	26.69
2029	29.54
2030	32.40

For 2023, the CT went up 21%, from 9.79¢/m^3 to 12.39¢/m^3. From 2019 when the CT was introduced until 2030 (seven years from now), the carbon tax will have increased 829% !! The carbon tax may represent more than half of your total gas bill by then.

I don't often give credit to government and strategies but sometimes government does do clever things. While the CT may appear to be a cash grab, I suspect that the rapid increase in the tax is intended to create an economic business case to compel … well, everyone … to replace their gas appliances with environment-friendly and more energy-conserving alternatives. It may hurt everyone in the short-term financially but it's a good long-term plan for the good health and well-being of our children and their children, etc.

Natural Gas is a Sunset Industry

In 2019, the city of Berkeley, California became the first in the U.S.A. to ban natural gas hookups in new buildings. New York is the first U.S. state to pass legislation banning the use of fossil fuels in most new buildings, including gas stoves and furnaces, starting in 2026 for new buildings of seven stories or less.

Gas appliances and services in residential and commercial businesses is a "sunset" industry, heading the way of gas streetlights and lamps, typewriters, slide rules, compact disks, steam locomotives and many other obsolete technologies.

Electric Backup Heat

Electric heat is still more expensive than natural gas but the heat pump's backup heating element in my heat pump would only turn on with the most extreme low temperature, and then only for only one to five days per winter season.

If you have a net-metered solar panel system with surplus capacity as I previously reported in my solar panel pilot project, then the heating element is drawing from that surplus electricity account. I may not make as much of a profit selling electricity to the grid ("net metering") but I'm not paying out of pocket for the temporary electricity draw I require for those rare, extreme cold winter days.

Between 35% and 40% of my monthly electricity bill—before solar panels—was for delivery and regulatory charges. On days where I generate more electricity than I use and sell it to the grid, I still have delivery and regulatory charges ranging from $20 to $26 per month. On days where I use more grid electricity than I generate (e.g. winter time) delivery and regulatory charges are $45 to $52 (42% to 48%, almost half) of my total bill.

My goal is for the grid to become my backup energy source rather than my primary provider. Ultimately, I'd like to be entirely off the grid and save the 50% of my electricity bill that is caused by:

- Connection charge even if I never use any electricity
- HST (Ontario is Canada's only province that charges HST on electricity)
- Debt retirement charges, especially for the nuclear plants
- Gross operational inefficiencies of monopolistic utility companies that pass on exorbitant "corporate fat" expenses to its consumers

System Cost
The heat pump system I purchased cost $18,500.00 before tax, comprising:

- Mitsubishi PUZ-HA36NKA - P-Series Hyper Heat (H2i) Outdoor Heat Pump PSeries, 19,000 to 42,000 BTU/h cooling and 21,000 to 54,000 BTU/h heating
- 36K BTU, R410A refrigerant
- "Hot Start" process means warm air flows immediately, and rapidly warms the area
- Automatic switching between cooling and heating processes
- Multiple fan speeds
- Automatic restart in the event of power outage
- Mitsubishi PAR-40MAAU deluxe MA remote controller with large backlit LCD display for full and basic modes. Supports P-Series rotation, 3D i-See sensor functions
- Mitsubishi EH08-SVZ-M - 8 kW electric resistive heat element backup
- All installation plus removal of existing furnace and air conditioner
- Mitsubishi 10 years parts and labour warranty.

- Even if your contractor is out of business, you can choose any approved Mitsubishi dealer and Mitsubishi will honour the warranty.
- Pre- and post-inspection is $700 plus tax is extra from a separate contractor

Electrical Panel Upgrade
The heat pump system requires a 40 A circuit and breaker for the air collector and a 60A circuit and breaker for the heat pump. I had to upgrade my 100A panel to 200 A at a cost of $3,200 plus tax. I received quotes of up to $5,000.

However, if I had known before I made the upgrade commitment, I might perhaps have considered purchasing a "smart panel" so that I wouldn't have to upgrade my existing panel to 200 A. There are two basic categories.

One type switches loads on and off. For example, you could have your electric HWT and electric stove on the same 40A circuit. If both were on at the same time it would trip the breaker. The smart panel can be set so that the HWT turns off whenever the stove is on. You require less dedicated circuits and less circuit breakers, and you might not have to upgrade your 100A panel.

The second type is more sophisticated and balances the loads. In the above example, the stove may only pull 25 A on average so the panel would reduce the HWT tank draw rather than turning it off.

In both cases however, the savings discussed above must be compared to the cost of these smart panels.

Government Incentives
The Greener Homes Program is currently offering a rebate of $600 for pre- and post-inspections (typically $700 total cost) and up to $6,500 for a newly-installed heat pump that replaces inefficient furnaces and air conditioners.

Net Cost of Acquisition
Subtract the expected $7,100 rebate from my acquisition cost of $18,500 + 700 = $19,200 - $7,100 = $12,100 (before HST).

A new 60,000 BTU, 98% efficient "better quality" gas furnace is perhaps $5,000. A new 3-ton air conditioner is perhaps $4,000 for a total of $9,000, leaving an arguable difference of $3,100. The government rebate may or may not apply. I assumed it didn't.

With rapidly increasing natural gas prices and carbon tax, ever-*in*efficient public utility "fat management," and legislation threatening to ban gas appliances, there's no doubt in my mind that I'll come out way ahead of my peers economically within five years.

Cost of Ownership (Ongoing Operation)
In my case, my efficiency report showed that my current heating and cooling system consumed an estimated 120 Gigajoules (GJ) per year. A typical new house uses perhaps 87 JG/year. My heat pump system would reduce energy consumption to an estimated 58 GJ/year, literally half of what I use now. That does not include savings from the solar panel system.

My 2022 home gas bill was about $1,835 comprising 2,702 cubic meters (m^3) of consumed gas. All things being equal, including that my new 98% efficiency gas furnace would have operated close to the same level as my previous one, then it is theoretically costing me $3,100 between purchasing a new gas furnace and the new heat pump … in order to save, say:

- 75% of my gas consumption (25% for HWT). Therefore, 75% of 18.7% of my gas bill (actual gas cost) = 14.0% on gas consumption savings
- 75% of my carbon tax bill. Assuming the same consistent 2,703 m^3 volume of gas used each year, my annual carbon tax bill would be $875/year by 2030
- I estimate that my total gas bill will increase by 50% over the next 7 years. If I had bought a new gas furnace then my 2030 gas bill might be $1,835 (2023 actual) x 1.5 = about $2,750.
- Out of that 2030 annual bill, carbon tax would be $875 or about 32% of my gas bill.
- So, saving 14% of my 2030 bill gas consumption = $385
- Plus 75% of carbon tax = $656
- Total savings in 2030 = $1,040 or about 38%

Averaging the cost increase from 2022 of $1,835 to 2030 cost of $2,750, yields an annual savings as per this table:

Year	cents/m³	$ Yrly	$ Mthly				
2019	3.91	105.65	8.80				
2020	5.87	158.61	13.22	**SAVINGS ANALYSIS**			
2021	7.83	211.57	17.63	Annual Bill	38%		
2022	9.79	264.53	22.04	$1,835	Savings	Cumulative	Year
2023	12.39	334.78	27.90	$1,949	741	Breakeven	
2024	15.25	412.06	34.34	$2,064	784	1,525	1
2025	18.11	489.33	40.78	$2,178	828	2,353	2
2026	20.97	566.61	47.22	$2,293	871	3,224	3
2027	23.83	643.89	53.66	$2,407	915	4,138	4
2028	26.69	721.16	60.10	$2,521	958	5,097	5
2029	29.54	798.17	66.51	$2,636	1,002	6,098	6
2030	32.4	875.45	72.95	$2,750	1,045	7,143	7

From the savings computed above, I expect that **I would recover the extra $3,100 investment** to buy a heat pump heating and cooling system instead of a traditional air conditioner and furnace **by the end of the third year.**

If I add in the $3,200 panel upgrade, which I probably would not have needed for the traditional furnace and air conditioner replacement, then the payback period (return *of* investment) should be about six years. However, I personally was long overdue for a panel upgrade anyway because I use far more electricity than my neighbours, and the extent and variety of electrical devices and appliances available today was already taxing my existing panel.

The above numbers are very rough and rely on educated speculation (a “guesstimate”). I believe though that these numbers are conservative and the actual savings may be more significant.

The more relevant fact though is that I’ll probably save 40% per year on the cost of gas versus my traditional fossil fuel-burning neighbours. **Over seven years** that may be about $7,000 or **$1,000 more in my pocket each year.**

By 2030 that’ll be enough for a preferred seating space assignment on an airplane, or maybe dinner for four at The Keg, or maybe the cost of gasoline for a round trip drive from Toronto to Montreal (but I’ll have an electric car by then).

Housing Affordability

Heat pump technology combined with solar panels and storage batteries have a compelling business case that not only makes your investment property values soar, it also adds cash flow into your pockets, creates an additional income stream for your property, AND will save tenants on living costs.

For example, even though the Ontario Energy Board requires all contractors to charge the same price for electricity consumption, theoretically, there would be no regulatory and delivery charges (except perhaps a limited time recovery of the initial capital expense), and possibly no taxes.

Unhappily, Oshawa Power has not replied to any of my expressions of interest to do a pilot or simply to implement a solar panel system. Brantford and Oshawa both demanded huge payments for a variety of “studies” and grid connection upgrades that are financially untenable.

But I'll keep trying. One day the (turbine) winds of change may blow in a favourable direction.

Next
I'm already committed to making my next purchase a heat pump clothes dryer. I've done the research and I'll write about it in a separate article.

Getting rid of my gas hot water tank (HWT would eliminate my gas bill (yaayy!). However, there are issues with a heat pump HWT that to I'll discuss in a future article.

An electric dual-way charging vehicle may also be in the cards.

Once I've run my heat pump system for a year, I'll do an analysis of the costs and send it out.

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