Capstone Project: Decarbonization Through Electrification

A Business Case for Air-Source Heat Pumps

GLA 2000H Sustainability Capstone

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We acknowledge that this report was developed on the traditional territory of many nations including the Mississaugas of the Credit, the Anishnabeg, the Chippewa, the Haudenosaunee and the Wendat peoples, and is now home to many diverse First Nations, Inuit and Métis peoples. We also acknowledge that Toronto is covered by Treaty 13, signed with the Mississaugas of the Credit, and the Williams Treaties signed with multiple Anishinabek Nations. Toronto is also part of the 'Dish With One Spoon Territory'. The Dish With One Spoon is a wampum treaty between multiple Anishinabek and Haudenosaunee Nations that bound them to share the territory and protect the land covering much of the Great Lakes area. Subsequent Indigenous Nations, peoples, settlers and newcomers have been invited into this treaty in the spirit of peace, friendship and respect.

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Introduction

In completion of our capstone class GLA2000H, we conducted an external consultancy project for the City of Toronto, Public Energy Initiatives – Existing Buildings Environment & Energy Division.

Our role was to assess the feasibility of a financial incentivization program that prompts the retrofitting of building heating units from fossil fuel systems (i.e. natural gas furnaces and boilers) to electric heating technologies (i.e. air-sources heat pumps) for low rise commercial buildings in Toronto. This program would be a part of Toronto's Transform TO initiative, the city's climate action plan to reduce GHG emissions to net zero by 2050 or earlier.[1] The overarching challenge we faced with this project was balancing the requirement of improving building energy efficiency and in turn reducing carbon emissions without increasing energy costs for consumers. The focus of our program was to incentivize the upfront capital cost of switching from natural gas to heat pump technology, understanding that natural gas comes with an additional annual operation charge which is expected to make switching favourable for low-rise commercial units.

To assess the feasibility of such a program, we conducted a comparative analysis of electrification incentive programs in North America, as well as research on the different financial incentivization schemes to identify relevant best practices. We have also designed a financial model and ran various rebate scenarios with varying project implementation settings. This financial model facilitated the building of a business case which demonstrated that the adoption of electric heating systems (air-source heat pumps) is cost-effective for small commercial buildings in Toronto. Additionally, this report includes recommendations for a proposed program implementation strategy which includes suggestions for program funding, marketing, and on-the-ground implementation. These are the original research questions that guided our work throughout the semester:

- What is the capital cost of switching from a natural gas furnace to a heat pump?
- What type of heat pump would be most cost-effective for this program?
- How many small businesses are in Toronto and what systems are they currently using?
- What is the range of energy consumption amongst low-rise businesses?
- What level of incentive is required to see maximum market buy-in?
- What is the most effective way to market the program?

Analytical assumptions

The authors of this report would like to acknowledge that this research project does not provide a comprehensive study of all possible incentivization schemes for decarbonization through the electrification of heating systems. Rather, this research project has been framed based on a set of assumptions suggested or requested by the client. These assumptions include:

- A sole focus on air-source heat pumps (ASHPs) as the electric alternative to natural gas heating systems.
- That there will be no significant change in the price of electricity or gas in the upcoming years in Ontario. As such, the prices remain constant in our financial costing model.
- That some of the data used in our financial model was provided by the client as it is not available in the public domain and includes: any data on the number of, size of and gas consumption of commercial buildings targeted by this program and information on current heating systems used in these buildings.

[1] City of Toronto, Environment and Energy Division. 2018. *TransformTO: Climate Action for a Healthy, Equitable & Prosperous Toronto Implementation.*

- All ductless buildings would require the installation of 6 to 7 air handlers understanding that this may be overstated in some cases and understated in others given that we do not know building layouts. That said, this is a good average.
- That we do not include the operational cost of adding air conditioning to a building in our model because we do not have accurate data on usage.
- That we did not account for the difference in types of activities carried out in low-rise commercial buildings. For instance, we did not study the split of restaurants and buildings that may still need a gas connection as this data was not available to us, and other rebate programs that we reviewed did not segregate that data either.
- That we did not include hot water heaters in our financial costing model for the same reasons mentioned above.

Methodology

We adopted both quantitative and qualitative methodological approaches in our data collection and analysis. The quantitative approach pertained to our financial costing model, while the qualitative approach pertained to our review of existing literature on the topic of decarbonization through electrification and incentivization programs.

To answer our research questions, we collected data on low-rise commercial buildings in Toronto. More specifically, we gathered data on building sizes, the energy consumption, and existing heating equipment being used. We also gathered information on the capital costs of installing either fossil fuel heating systems (gas furnaces or boilers) and air-source heat pumps to better evaluate the capital costs landlords face should they consider a new heating system installation. We made sure to take into account the cold climate and unique peaks in energy use to inform our decisions. With regards to energy costs, as stated previously in our analytical assumptions section, we decided to use current energy costs for both gas and electricity and assumed that there would be no drastic changes to these prices in future projections.

We would also like to note that we selected heating systems that would best cover the needs of these buildings in terms of efficiency, capacity and durability. Moreover, the chosen prices and equipment take into consideration the worst-case scenarios in which consumers invested high amounts of resources in their past systems, as we believed that this assumption will help us offer incentives that would encourage consumers to update their equipment and switch to air source heat pumps. The specifications of the systems and the reasoning for our choices are explained in detail in the following section.

Once our data collection was complete, we then developed a financial costing model that incorporated various energy consumption rates for heating spaces based on building unit size. This financial model allowed us to generate various scenarios to best identify the range of consumption in which consumers might be willing to switch from natural gas to air-source heat pumps given varying rates of incentive (rebates).

Literature Review

To complete this literature review, we relied on research reports produced by private organizations and public entities working in the energy space, and academic articles and reviews tackling these topics.

a) Heating and carbon emissions of buildings in Toronto.

In Toronto, buildings and homes are responsible for roughly 52% of the GHG emissions, primarily from natural gas used for heating indoor spaces and water.[2] Residential buildings are the largest contributors to emissions in this sector (51%), followed by our targeted market

[2] City of Toronto. 2019. *Toronto's 2017 Greenhouse Gas Emissions Inventory.*

commercial/institutional (36%), and industrial buildings (13%). According to forecasts from the Atmospheric Fund, these emissions would amount to roughly 9 million tonnes of eCO2 in 2020 annually.[3] Therefore, electrification of heating systems, which would decrease the emissions of commercial buildings, could provide a significant contribution to TransformTO's building emission reduction target.[4]

The electrification of heating systems has both economic and non-economic benefits for users. Electrification of space heating creates opportunities for many consumers to save money on their total energy bills, benefit from increased energy security, improved indoor and outdoor air quality, increased resilience and thermal comfort in extreme weather events, avoided weather damage costs, and increased property value.[5]

Figure 1. Toronto's Greenhouse Gas Emissions (2017)

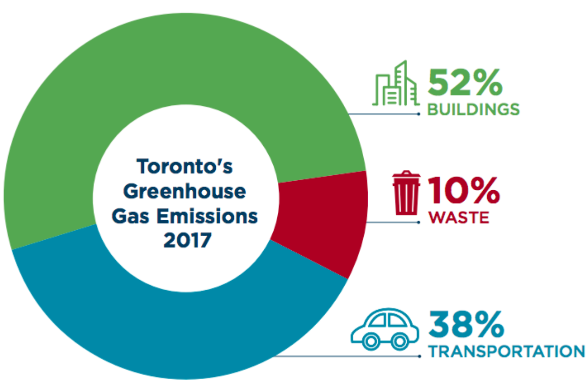
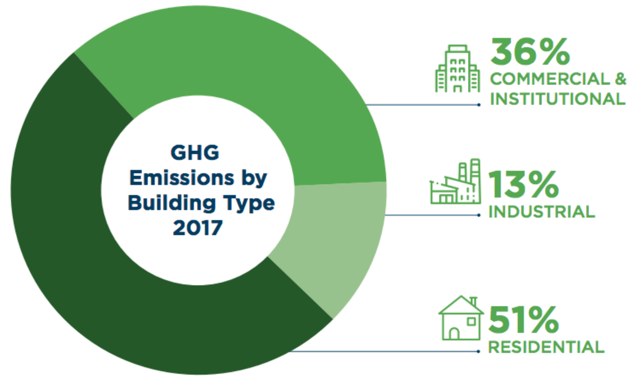


Figure 2. GHG Emissions by Building Type (2017)



b) On the importance of electrification in space heating

It is important to recognize that advances in electric technologies are improving quality of life through better air quality and more comfortable heating and cooling. Electric heating systems also represent a more economically viable option to fulfil energy needs of consumers worldwide in many contexts. Moreover, significant decreases in the electricity sector greenhouse gas emissions are making electricity a more sustainable source of energy.[6]

In the average Canadian household, the largest uses of energy are for space heating (62.4% of total end-use demand) and water heating (18.7% of total end-use demand).[7] In Ontario, buildings account for approximately one quarter of total greenhouse gas emissions. Therefore, the electrification of space heating can have a significant impact on the Canadian carbon footprint.

c) Decarbonizing space heating through heat pumps

Heat pumps offer a feasible option to lower GHG emissions by cutting typical energy use for heating by a factor of four or more.[8] According to the International Energy Agency, electricity's share in

[3] The Atmospheric Fund. 2019. 2016 *Greenhouse Gas Emissions Inventory.*

[4] City of Toronto, Environment and Energy Division. 2018. *TransformTO: Climate Action for a Healthy, Equitable & Prosperous Toronto Implementation.*

[5] Ibid.

[6] Environmental and Energy Study Institute. 2019. *Electrification.*

[7] Ibid.

[8] International Energy Agency. 2019. *The Critical Role of Buildings. Perspectives for the Clean Energy Transition.*

final energy will reach about 35% by 2050, this growth assumes the adoption of heat pumps in buildings and industry.[9]

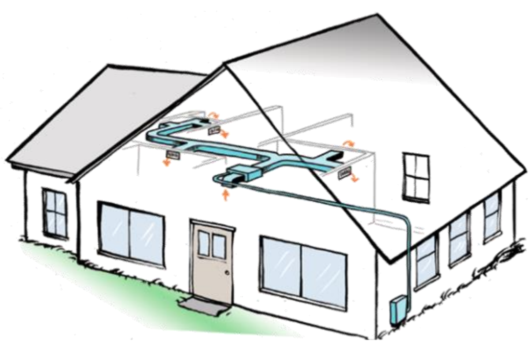
There are three types of heat pumps in the market: air-source, water-source, and geothermal. The most common type of heat pump is the air-source. As previously mentioned in our analytical assumptions, this project only considered the installation of air-source heat pumps as they are the most cost-effective option.

d) Air-source heat pumps.

During the cold season, air-source heat pumps use electricity to move heat from outdoors into an interior space; during the heat season, they move heat from indoors and reject it outside. We will later discuss more thoroughly the relevance of heat pumps to cold climates. There are two types of air-source heat pumps:

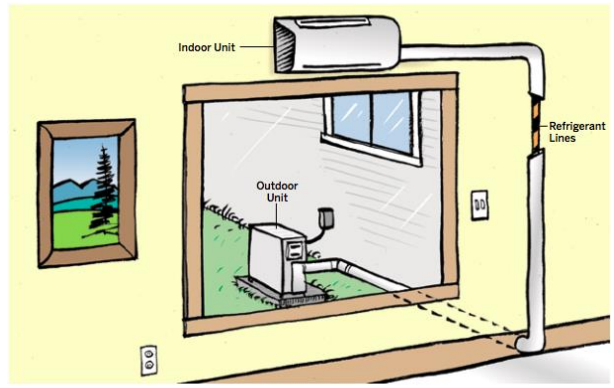
- Ducted heat pumps, which rely on ductwork to move air evenly around spaces (installed when there is pre-existing ductwork in the building).

Figure 3. Ducted heat pump system



- Ductless or mini-split-system heat pumps require minimal construction, making them good retrofit add-ons to houses and buildings with non-ducted heating systems. Ductless heat pumps require an outdoor condenser and several indoor air-handling units (depending on how many rooms require heating or cooling). The advantages of mini splits are their small size and flexibility, easy installation, and that they are usually quieter than their ducted system counterparts.[10]

Figure 4. Ductless Mini-Split Heat Pump



e) On the efficiency of heat pumps in cold climates

The efficiency of air-source heat pumps is measured by the seasonal energy ratio (SEER), the coefficient of performance (COP), and the heating seasonal performance factor (HSPF). The higher the units' rating, the more energy efficient it is. The coefficient of performance measures the amount of heat transferred for every kWh of electricity supplied to the heat pump. The heating season performance factor is the most important ratio to measure the efficiency of a heat pump. Consumers rely more on this measure when buying devices in cold climates. Every increase in HSPF indicates that the system uses 10% less energy, which translates to lower energy costs. Highly efficient heat pumps, which is what the client wanted us to focus our analysis on, have more than 8.5 HSPF.

It is important to note that both the efficiency and capacity of air-source heat pumps decline as outdoor temperature decreases. Efficiencies of heat pumps vary depending on outdoor temperatures. For example, at +5°C, the coefficient of performance (COP) of a heat pump is roughly 3.5, it is common to reach a COP of 4 or 5 in relatively mild climates, whereas at -8°C, the COP drops to around 2.3. The

[9] International Energy Agency. 2019. *The Critical Role of Buildings. Perspectives for the Clean Energy Transition.*

[10] Ibid.

COP decreases with temperature because it is more difficult to extract heat from cooler air.[11] Nevertheless, in the last few years heat pumps efficiency in cold climates have improved drastically. Air-source heat pumps with the lowest levels of efficiency have a single-stage reciprocating compressor, but the newer higher efficiency units which are required in colder temperatures now use variable or two-stage systems, allowing heat pumps to operate close to the heating or cooling capacity needed at any season.[12] This new generation of air-source heat pumps have demonstrated improved heating performance under extreme temperatures, offering higher efficiency and a better prospect for our program given Toronto's climate zone.

f) Benchmark of successful rebate programs

The table in Appendix 1 provides a summary of several successful American rebate programs. Analysing similar programs was instructive in developing benchmarks and provided us a comprehensive understanding of the different options for financial incentivization of decarbonization through electrification in general, and specifically through the promotion of heat pumps. We dedicated additional attention to programs implemented in the North-eastern states of the United States as they have similar climates to that of Ontario.[13]

g) The split-incentive issue

The "split-incentive issue" or "landlord-tenant issue" has long been a hurdle for policymakers looking to incentivize investment in energy-saving retrofits. This issue exists because capital costs of energy-saving investments are incurred by landlords, while tenants are often the ones who would receive the operating-cost reductions from said capital. Thus, there is a split-incentive, and this hinders investment rates. The issue has been well documented, with most studies finding that it stymies adoption of energy efficiency installations.[14] [15]

One theme that emerges from the literature is that policy options which incorporate property tax tools can be effective if implemented properly. One such policy option has been used to tackle the split-incentive issue are Property Assessed Clean Energy programs—a form of financing where owners finance energy improvements on their property, paying for these improvements by entering into a voluntary agreement to place a tax assessment on their property. The assessment allows longer-term financing, and transferability of repayment obligations to subsequent property owners. The use of tax based incentivization is supported by much of the literature. For instance, one Australian study found that the split-incentive issue was not highly relevant in the region, but that this was only the case due to their tax code already sufficiently incentivizing such investments.[16] One hurdle PACE programs can face was highlighted by Milano & Cockrell, who found they can create challenges for mortgage lenders looking to sell these mortgages in secondary markets, thus they recommend implementing means to subordinate PACE liens into general mortgage loan liens.[17] A study conducted a study for the U.S. Department of Energy on PACE programs, found that PACE programs are effective

[11] Advanced Energy Centre, Mars Cleantech and Enbridge. 2018. *Future of Home Heating.* Ontario, Canada.

[12] Energy Saver. 2020. *Heat Pump Systems*.

[13] Nedel, Steven. 2018. *Energy Savings, Consumer Economics, and Greenhouse Gas Emissions Reductions from Replacing Oil and Propane Furnaces, Boilers, and Water Heaters with Air-Source Heat Pumps*. Report A1803.

[14] Melvin, Jesse. 2018. *The split incentives energy efficiency problem: Evidence of underinvestment by landlords.* Energy Policy 115.

[15] Gillingham, Kenneth, Matthew Harding, and David Rapson. 2012. *Split incentives in residential energy consumption*. The Energy Journal 33, no. 2.

[16] Wood, Gavin, Rachel Ong, and Clinton McMurray. 2012. *Housing tenure, energy consumption and the split-incentive issue in Australia*. International Journal of Housing Policy 12, no. 4.

[17] Milano, James and Peter Cockrell. 2019. *Recent Developments in PACE Financing*. The Business Lawyer 74, no. 2.

especially when processes are standardized.[18] They also recommend the implementation of "credit enhancement" mechanisms, in order to provide lower interest rates, a theme that is common among the main tools used to address the issue.

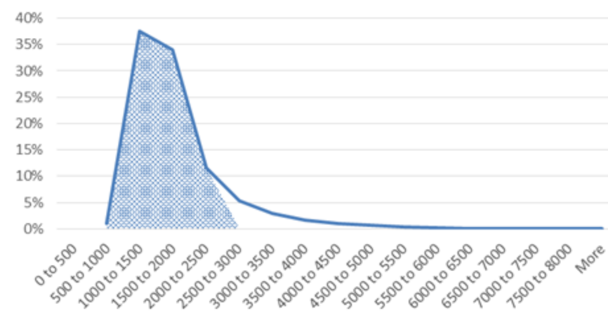
Given the high popularity and demonstrable success rates of PACE programs, it is unsurprising that Canada has already begun implementing similar programs with varying degrees of success. Several provinces have implemented PACE programs. The group PACECANADA advocates for its implementation, and for legislation requiring municipalities to be the source of PACE investment capital, and to have a government entity carry out assessments.[19] Toronto has its Home Energy Loan Program (HELP) which offers competitive interest rates for loans of up to $75,000 for home energy improvements and retrofits. HELP does apply to heat pumps specifically[20], however, only for homeowners.

Data Collection

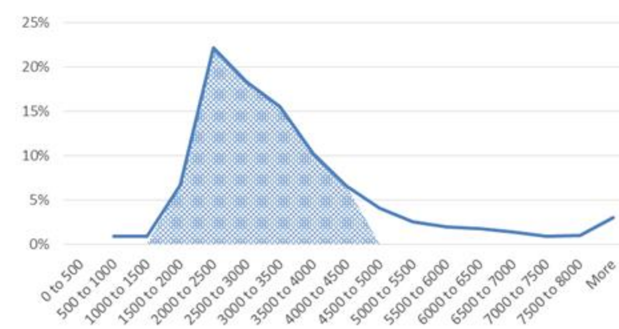
Low-rise commercial buildings in Toronto

As mentioned before, this report focuses on identifying incentivization schemes for landlords and tenants of low-rise commercial buildings in Toronto. To that end, we first identified the number of buildings of this category in the city, and the heating systems they are currently using. Based on information provided by the City of Toronto, there are approximately 11,000 low-rise commercial buildings in the city. About 88% of these buildings rely on gas for space heating, with 43% using forced air systems, and the rest using boilers. In addition, out of the 11,000 buildings, 20% have air conditioning. In terms of size, most buildings (83%) are between 1,000 to 2,500 sf. It is important to note that we are also considering buildings in which main floors have additional residential or commercial units above. In these cases, we will offer incentives not only for the main floor, but also to the entire building to switch to electric air-source heat pumps, as the additional units above may be using a shared heating system with the main commercial floor. Therefore, for whole buildings the size range is between 1,500 and 4,500 sf (see Appendix 2 for more detail about the building size distribution).

Graph 1. Building Size – Commercial Unit Only



Graph 2. Building Size – Whole Building



Finally, in terms of energy consumption, if we assume an energy use intensity (EUI) of 215 kWh/m2 of gas, buildings in the first category will consume on average between 2,200 to 4,100 m^3 of natural gas, while buildings with additional residential or commercial units above will consume between 3,200 to 7,800 m^3. We will use these ranges to build the cost model and business case (see Appendix 2).

Cost of Heat Pumps

To compare prices, we used the highest efficient air-source heat pumps in the market (two-stage and

[18] Leventis, Greg, L. C. Schwartz, Chris Kramer, and Jeff Deason. 2018. *Lessons in Commercial PACE Leadership: The Path from Legislation to Launch.*

[19] Pace Financial. 2019. *PACE in Europe and Canada*.

[20] City of Toronto, Environment and Energy Division. 2018. *TransformTO: Climate Action for a Healthy, Equitable & Prosperous Toronto* Implementation.

variable systems). Appendix 4 shows the range of prices, with installation costs included, of the main brands of heat pumps available in Canada. All systems are ducted with the average HSPF required for the Toronto climate (Appendix 3). For comparison purposes, each unit includes a 3-ton outdoor condenser, a 1300-1400 cfm air handler and a programmable heat pump thermostat.[21] All the systems are Energy Star certified[22], as the project would require consumers to install the most efficient heat pumps to withstand cold temperatures.

Heat pump prices from the top certified brands range from 2,435 to 10,390 U.S. dollars. For the purpose of our business case, we will focus on the top five brands as they have higher efficiency ratios, more durability, and are built with high quality parts, requiring less maintenance throughout their useful life.

Additionally, we focused on ducted systems that have higher capacity. As mentioned before, 83% of low-rise commercial buildings in Toronto are between 1,000 and 2,500 sf, requiring a heat pump of 2 to 4-ton capacity. However, if we include buildings that also have residential units above the main floor, total building size ranges from 1,500 to 4,500 sf, which require heat pumps of 2.5 to 5-ton capacity. Moreover, different climatic zones require not only different efficiency ratios, but also different heat pump sizes to avoid shortcomings or energy waste. The more extreme weather changes are, the larger the units need to be. As mentioned before, Toronto is located in climatic zones 5 and 6, which require heat pumps of at least 3.5-ton capacity.[23] Finally, if we also consider that some buildings in Toronto have poor insulation, heating systems with lower efficiency and capacity will not be enough to evenly heat spaces during very low temperatures.

On the other hand, mini-split systems (ductless) are more cost-efficient because they require less construction, however, it is important to note that upfront costs may be higher as several air handlers are needed to heat larger spaces. The prices (Appendix 4) are based on installing a mini-split heat pump for a 1700-2200 sf property, including 2 outdoor units and 6-7 indoor wall mounted air handlers.[24] There are some buildings that will require more air handlers, especially those that have residential units above a commercial floor, in these cases we will consider that every extra indoor air handler will cost an additional 700 U.S. dollars.

Based on these criteria, we will incentivize the installation of ducted ASHP with 3.5, 4 and 5-ton capacities depending on building size, and ductless systems with 6-7 indoor air handlers. The average prices (in U.S. dollars) of heat pumps with these specifications range between 6,790 to 9,512 dollars (including a 1,000 to 2,000 U.S. dollar cost for installation).

Table 1. Cost of air-source heat pumps

ASHP	Average Price (USD)
Ducted 3.5 ton	$8,390
Ducted 4 ton	$8,591
Ducted 5 ton	$9,512
Ductless (6-7 air handlers)	$6,790
Extra air-handler for mini-split	$700

Gas Furnaces

For comparison purposes, we are assuming that our targeted buildings also have high efficiency gas furnaces installed. By choosing three top capacities similar to those of the heat pumps, we can offer

[21] Pick HVAC, Cooling and Heating Guide. 2020. *Top Brands of Heat Pumps.*

[22] Systems that have the Energy Star certification meet strict energy efficiency guidelines set by the United States Environmental Protection Agency.

[23] Pick HVAC, Cooling and Heating Guide. 2020. *What size heat pump do I need?*

[24] Pick HVAC, Cooling and Heating Guide. 2020. *Mini-Split AC/Heat Pump Reviews and Prices 2020*.

incentives even for consumers that have invested a higher amount of resources in their furnaces. We will consider the average prices of standard brands (15 to 20-year durability, two-stage gas valves and better temperature balances), with installation costs included (U.S. dollars).

Table 2. Cost of gas furnaces

Size (sf)	Price (USD)
1400-1800	$3,710
1800-2300	$4,245
2300-3000	$4,710

Central air conditioning

Our model also includes air conditioning costs. As mentioned before, more than 80% of low-rise commercial buildings currently lack central air conditioning, therefore, by offering the installation of air-source heat pumps, they are getting at the same time a cooling system, as this equipment works both ways depending on the season. Based on this, we are assuming that because consumers will be better off with a new heat pump that is also an air conditioner, we factored it in our model as an additional value for consumers.

As with the prices of gas furnaces, we are also considering high efficiency air conditioning prices to cover most of the worst-case scenarios in which consumers would invest large amounts of resources in heating and cooling. The following price list (in Canadian dollars) includes installation costs.

Table 3. Cost of air conditioning

Size (tons)	Price (CAD)
3.5	$5,500
4	$6,000
5	$7,000

Data Analysis

In this section, we present the outcomes of our financial costing model and explain our equations for calculating net present values. We also discuss the equity perspective when considering whole buildings scenarios to our financial model and provide an interpretation for the abated carbon emissions resulting from our scenarios.

a) Model Outcomes

Our model shows that smaller buildings (<1500 sf) have a logical business case for adopting a heat pump over a gas heating system, as the fixed cost savings incurred from not paying gas-delivery fees represent a relatively large portion of their overall expenses. As such, even without financial incentive, these smaller buildings stand to save money from investing in a high efficiency heat pump over another gas furnace or water boiler.

Incentive levels were based on the price difference between buying a heat pump and its cheaper gas heating equivalent and are expressed as a percentage of that difference in cost. For ducted buildings in our mid-sized category (1500-2000 sf), we found that some incentive would be needed in order to make the investment attractive, such as a 25% incentive for an old heating system (> 15 years), and an incentive of roughly 50% for a mid-life system (10-15 years). In the case of the largest size range (2000-2500 sf), our model shows that an even higher level of incentive would be needed.

As for ductless buildings, based on our model less incentive would be required as positive NPVs are achieved even with no incentive provided for the first two building sizes with old and mid-life heating systems. Ultimately, this led us to the conclusion that the investment becomes a more attractive option for:

1. Smaller building sizes.
2. Older gas heating systems.

Despite the fact that smaller building ranges have positive Net Present Values (NPVs) for scenarios when no incentive is provided, we still assumed that some incentive would still be required. The reason behind this decision is that there is still a large price differential in initial capital cost between a heat pump and a gas heating system. Therefore, we did not produce scenarios that suggested no financial incentive be provided for these size ranges.

b) Whole-building scenarios: an equity perspective

We decided to include whole-building scenarios in order to assess the plausible implications of our program on the residents (tenants) of commercial buildings. Whole-building scenarios were, however, not our initial focus. The equity concern was that the program might lead to an increase in costs for the tenants of commercial buildings. The assumption was that commercial tenants or the landlord of the building would be paying for the entire unit's utilities (including above floors of residential tenants). This assumption was made in conjunction with the notion that a fragment of these above floor units would be using electric resistance heating systems. These electric-resistance heating systems are extremely costly to operate, costing up to 4 times as much as natural gas. Thus, the addition of a heat pump for the whole building would likely result in large utility savings for whoever is paying them.

c) Net Present Value calculations

To analyse the profitability of installations, we relied on an NPV calculation for the various scenarios. As such, it was an important value that fed our decision on incentivization level. It takes into account the unit cost of a heat pump, in addition to the depreciation of the furnace/boiler which was factored in as an additional cost. To do so, half the value of the AC system is subtracted from the user cost equation. We also subtracted the incentive from the user cost and assumed a 2% discount rate which aimed to be similar to the prime rate per our client's request.

We are however aware that the NPV is not a perfect measure because it has a long-term consideration of costing, whereas there isn't always willingness to pay the unit cost upfront.
The NPV calculation confirms the need for an incentive program. It identified the levels of incentive which provided positive NPVs for given building sizes. This would ensure that users switching from fossil fuel heating systems to heat pumps would not experience increases in their cost of living –because the overall expenses incurred by the building would decrease after the initial capital expenditure.

d) Carbon abatement

To calculate CO2e emission reductions, we assumed each m^3 of gas produces 1899g CO2e[25] in Ontario, and that each kWh of electricity produced in the province produces 31g CO2e.[26] The difference between these values was used in our model as the emission reduction value. The amount of gas that would be consumed by a given gas heating system at a specified building size was used to calculate the potential annual reduction in emissions from said system being replaced by a heat pump. This reduction was then expanded over the projected amount of buildings in that range that would adopt the program in each scenario. Once the emissions reductions of each range were calculated, they were combined for each scenario to yield that program's total carbon abatement, which was used in calculating each option's cost per tonne of abatement. We found that with a 5% adoption rate across the target building range, there would be roughly 2138 tonnes of CO2e emissions abated annually.

As a rough benchmark for carbon reductions costs, we were informed by our client that it would be instructive to look at New York City's recent implementation of a $268 USD[27] or roughly $378

[25] Ontario Ministry of the Environment and Climate Change. 2017. *Ontario Public Service Guidance Document for Quantifying Projected and Actual Greenhouse Gas Emissions Reductions.*

[26] The Atmospheric Fund. 2019. *A Clearer View on Ontario's Emissions.*

[27] Building Green. 2020. *New York City Mandates Carbon Limits for 50,000 Buildings*.

CAD fine on each tonne of carbon emissions surpassing a building's given limit. While this metric was by no means perfect, it was used to gauge if a given scenario was seen as having a high or low cost of abatement.

Recommendations and Scenarios

We recommend a tiered incentive program delivered through certified contractors which targets consumers with aging furnaces and boilers at the end of their lives delivered through certified contractors.

Scenario rationale

Our recommendation for program targets will be split into looking at commercial units, who we assume - based on conversations with that client - generally pay their own utilities either through individual units or through split metering, and the building as a whole. We know that some of the upper residential units use different systems than those outlined below but the intention of the program was to focus on natural gas use in the program. It is important to note that the total program cost shown in these scenarios does not include the training costs, marketing costs, or payment that may be provided to contractors for the program. The incentive level is split by building size and is the percent of the difference between the upfront cost of a heat pump and furnace that the program will provide. Some other notes:

- The program cost refers to the number of buildings in each size category times the incentive level assuming the program reaches 5% penetration.
- The number of buildings is how many buildings the program will reach at 5% penetration.
- Abated carbon refers to the total carbon abated based on the number of buildings in each category assumed to be reached.
- The cost of reduction is the program cost divided by the abated carbon.
- All prices are in Canadian dollars.

Main Commercial Unit

Table 4. Scenario 1: Target Commercial Units @ 5% Penetration

Size (sf)	<1500	1500-2000	2000-2500
No incentive	-	-	-
25% incentive	$209,243.13	-	-
50% incentive	-	$230,190.61	-
75% incentive	-	-	$192,571.96
100% incentive	-	-	-

Number of buildings	408
Program Cost	$632,005
Abated Carbon	2,138.96
Cost of Carbon Reduction	$295.47

Table 5. Scenario 2: Target Commercial Units @ 5% Penetration

Size (sf)	<1500	1500-2000	2000-2500
No incentive	-	-	-
25% incentive	$209,243.13	-	-
50% incentive	-	-	-
75% incentive	-	$557,507.68	-
100% incentive	-	-	$256,762.61

Number of buildings	408
Program Cost	$1,023,513.42
Abated Carbon	2,138.96
Cost of Carbon Reduction	$478.51

For the main commercial unit, please refer to Appendix 5 and 6, which are the NPVs considering both the ductless and ducted systems for older heating units, to see the rationale behind incentivization level. Here we looked to where the

NPV was positive, making a clear business case, however we know we likely need to incentivize above that level due to the significant upfront cost of a heat pump. As you can see in the first scenario, the cost per tonne of carbon reduction is much lower than in the second where we see a significant increase in the required incentive level for larger buildings. In scenario 2, we are hitting the million-dollar program mark we are aiming for. We realize that there is a much higher cost of reduction per tonne but believe that that is likely required to have us achieve 5% market penetration. Understanding that this may be too high of a cost for carbon reduction, we wanted to provide both options and the reasoning behind them.

During our presentation, it came to our attention that there was interest in an additional scenario being added to our report. There was interest in adding a scenario where we only target the smallest building size, less than 1500 sf. Although we would only market the program to buildings in this range, we would still offer a similar incentive if larger building owners wanted to switch as well. The scenarios shown below assume 5 and 10% market penetration for smaller buildings and 0.5% for the other building sizes.

Table 6. Scenario 3: Target Smaller Buildings @ 5% Penetration

Size (sf)	<1500	1500-2000	2000-2500
No incentive	-	-	-
25% incentive	-	-	-
50% incentive	$418,486.25	$37,310.71	$12,595.21
75% incentive	-	-	-
100% incentive	-	-	-

Number of buildings	207
Program Cost	$468,392.16
Abated Carbon	896.26
Cost of Carbon Reduction	$522.61

Table 7. Scenario 4: Target Smaller Buildings @ 10% Penetration

Size (sf)	<1500	1500-2000	2000-2500
No incentive	-	-	-
25% incentive	-	-	-
50% incentive	$833,937.33	$37,310.71	$12,595.21
75% incentive	-	-	-
100% incentive	-	-	-

Number of buildings	391
Program Cost	$883,843.24
Abated Carbon	1,654.44
Cost of Carbon Reduction	$534.23

When we ran this scenario through the model, you can see that we assumed a 50% incentive would likely get us to the level of market penetration desired because here the NPV values are higher and we know these smaller units likely have the least cash to cover upfront costs. Although we understand the rationale behind this idea, it is worth noting that our cost of reduction is significantly higher if we choose this option, mainly because the smaller units are emitting less carbon in general, and their business case is strong because such a large portion of their bill is taken up by the fixed annual cost of operating on natural gas.

Whole-Building Scenarios

These scenarios will provide insight into what kind of incentives would be required for converting whole buildings to air-source heat pumps. In these scenarios, we assume that the residential units do not have their own meters and utilities are included in their rent payments. Although out of the scope of what we analysed, we know there are some instances where commercial tenants are using the same heating unit as their residential counterparts but have a split meter. If they are on the same unit, further investigation should be conducted to see if a rebate targeting the commercial tenant to ensure they are not unintentionally burdened by the transition. The incentive we discuss here is only to help with the upfront capital cost of unit conversion.

Table 8. Scenario 5: Target Whole Buildings @ 5% Penetration

Size (sf)	1500-2000	2000-2500	2500-3000
No incentive	-	-	-
25% incentive	$39,508.46	$116,174.58	-
50% incentive	-	-	$189,165.02
75% incentive	-	-	-
100% incentive	-	-	-

Size (sf)	3000-3500	3500-4000	4000-4500
No incentive	-	-	-
25% incentive	-	-	-
50% incentive	$168,317.63	-	-
75% incentive	-	$171,973.10	$120,432.24
100% incentive	-	-	-

Number of buildings	385
Program Cost	$805,571.03
Abated Carbon	3,627.37
Cost of Carbon Reduction	$222.08

Table 9. Scenario 6: Target Whole Buildings @ 5% Penetration

Size (sf)	1500-2000	2000-2500	2500-3000
No incentive	-	-	-
25% incentive	$39,508.46	-	-
50% incentive	-	$232,349.16	-
75% incentive	-	-	$283,747.53
100% incentive	-	-	-

Size (sf)	3000-3500	3500-4000	4000-4500
No incentive	-	-	-
25% incentive	-	-	-
50% incentive	-	-	-
75% incentive	$252,476.45	$171,973.10	$120,432.24
100% incentive	-	-	-

Number of buildings	385
Program Cost	$1,100,486.93
Abated Carbon	3,627.37
Cost of Carbon Reduction	$303.38

For the whole building scenarios, please refer to Appendix 7 and 8, which are the NPVs considering both the ductless and ducted systems for older heating units, to see the rationale behind incentivization level. We initially thought we could likely offer less incentive for the smaller buildings as landlords have longer ties to the property, making the positive NPV of the investment much more favourable. However, we quickly realized that many landlords are more interested in short term contracts and profitability, therefore they may still be deterred by the significant difference in upfront unit costs. As a result, we think that the incentives in Scenario 2 are more likely to hit the 5% adoption target. Both options are relatively close to the million-dollar program mark, however we believe Scenario 2 has a better chance of reaching the target. Additionally, we see less of a gap between the cost of carbon reduction per tonne in the whole building scenario.

Interesting to note here, although outside of the scope of our project which has focused on the conversion from natural gas, many upper units are likely heated through electric resistance, which is up to four times more costly than natural gas. This means we are potentially looking at a worst case in our whole-buildings scenario. This is because buildings with these electric resistance units would likely need a smaller incentive to prompt the switch, and thus the business case would be much more favourable than it already is. This is certainly a consideration that should be explored in the future.

Program Cost and Funding

For our budget, as previously mentioned in our scenarios, we had a target of roughly $1 million CAD. We estimate the cost of the training and educational programs for contractors to roughly $50,000 CAD. This training could be provided either on an online platform or in person and would lead to the contractors getting accreditation in heat pump installation and advisory by the program.

With regards to funding, we identified that the program would be eligible for funding from organizations such as the IESO[28] Grid Innovation Fund and the FCM[29] Green Municipal Fund. We hope that our project will facilitate applications to these programs for our client in the future, however we were unable to prepare the application given the timing of application opening being outside of our project timeline.

Recommendations for Program Implementation

We recommend the adoption of a midstream approach for the rebate program through a network of trained and approved contractors. The reason why recommend the adoption of a midstream approach through contractors, and not through a downstream program in which customers would have to apply for the rebate themselves, is that customers would automatically see the rebated price and would not have to file paperwork or go through an online procedure for mail-in rebates. Moreover, we wanted to avoid putting customers in a position where they would have to bear the cost of investment and then wait for the rebate, as we believed it might deter them from switching to heat pumps.

We recommend going through contractors for this program for two main reasons. The first reason is that contractors are often advising their clients and can influence their purchasing choices, essentially, they ultimately sell the program for the city. As such, involving them in the program could help increase market buy-in, as was the case for the NEEA (Northeast Energy Efficiency Alliance) in the United States.[30] Secondly, by making the sale of the rebate conditional to completion of training and certification, this program will create competition between contractors who are motivated to receive and pass along the incentive and ensure only trained contractors are part of the program. This practice has been adopted by many programs in the United States as previously mentioned in our literature review, and ultimately led to higher adoption rates (up to 13% adoption rate).

Finally, in the context of Toronto, we suggest that contractors promote the Home Energy Loan Program (HELP) to cover the portion of the costs which are not covered by rebates, as we found through our research that this can be an effective way to incentivize landlords and help negate the negative connotations of upfront financing.

On the HELP Program

We recommend that Toronto's Home Energy Loan Program (HELP) should be expanded to include commercial buildings, and that the incentive program be coupled with the promotion of HELP in order to further incentivize consumers. The literature surrounding PACE financing programs supports this recommendation, as it can address high up-front capital costs without the long-term personal commitments of a traditional loan. The fact that payments become tied to the property also appeals to landlords and commercial tenants who

[28] Independent Electricity System Operator (IESO).
[29] Federation of Canadian Municipalities (FCM).
[30] Nedel, Steven. 2018. *Energy Savings, Consumer Economics, and Greenhouse Gas Emissions Reductions from Replacing Oil and Propane Furnaces, Boilers, and Water Heaters with Air-Source Heat Pumps*. Report A1803.

may be prone to short term decision-making, as if they sell the property, they are no longer liable for financing costs.

Training and education programs for contractors

Our comparative study of other incentivization programs has shown that providing contractors with training can contribute to program success.[31] The benefit of these training programs is twofold: it helps build a network of contractors willing to be part of the rebate program, and it ensures that installers properly size and position heat pump units so that no parts of the home are under heated; otherwise, residents may return to using their fossil fuels heating systems. The contractors would also be trained to provide end users with advice on how to best use their thermostats to optimally heat their buildings. These training sessions could be provided either in-person or online and would grant the contractors with a certification.

Conclusion

The overarching challenge of this project was coming up with a program that would meet the requirements of improving building energy efficiency - and in turn reduce carbon emissions as to help meet TransformTO's emission reduction target - without increasing energy costs for consumers.

This report has shown that smaller buildings are the ideal target for the incentive program in terms of user financial savings, specifically due to the upfront cost of the unit and the annual operational payment. That being said, larger buildings account for more carbon emissions so it is important that they are also targeted. The older gas units provide a better business case for switching, as people are already preparing for investment in a new unit. Finally, delivering incentive programs through contractors has been proven to have success in other districts. As such, we recommend it as Toronto's method of program delivery.

We believe that this report provided insights that can guide decision-makers in building an innovative incentivization program directed at low-rise commercial buildings that could prompt their switching from fossil fuel heating systems to air-source heat pumps. Such a program would be in line with the city's climate action policies and the city's commitment to develop innovative financing mechanisms to incentivize and advance climate action work.

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Appendix

Appendix 1. Successful rebate programs.

City / State	Name of the program	Type of financial incentive (rebate, tax)	Value of rebate (USD)	Level of rebate (upstream, midstream, downstream)	Adoption rate / Market buy-in	Certification for contractors
Maine	Efficiency Maine	Rebate of installing ductless heat pumps	Commercial customers can get up to $1,250 in rebates for multiple units	Downstream	High Since 2011, more than 25,000 units have been installed	No
Massachusetts	Mass Save	Rebate for installing DHPs o central ducted heat pumps	Ranges from $100-$500 depending on building size	Midstream (through certified contractors)	High Incentivized 9,000 in 2016 only	Yes
	Clean Heating and Cooling Program (MassCEC)	Rebate for installing air-source or ground-source heat pumps	$625 rebate. Low-income customers are eligible for larger incentive (up to $1,500 per heat pump)	Downstream Participants must receive an energy audit to qualify for the rebate.	High Incentivized more than 9,000 units since 2015	Yes
Vermont	Electric Energy Efficiency Initiative (EVT)	Rebate for installing DHPs Has a DHP renting program (for 15 years)	$600 - 800 per unit Monthly cost of $41.99 to $54.99	Midstream (through distributors) Distributors are required to pass savings to customers through discount.	Very high adoption rate (highest in the US) EVT has incentivized more than 8,200 heat pumps.	N/A
The Northwest (Oregon, Washington, Idaho, Montana) Northwest Energy Efficiency Alliance (NEEA)	The Ductless Heat Pump Initiative (DHP)	Rebate for installing DHPs	Rebate from electric utilities: Local electric utility may offer rebates of up to $1,500 for installing a ductless HP.	Upstream and Midstream (worked with utilities)	DHP market penetration increased from 0% to 13% in the four states.	Yes
New York	NYSERDA	Rebate for contractors: Enrolled contractors who meet quality assurance and control requirements	$500 for each DHP or ducted air-source heat pump installed	Midstream But contractors were not required to pass on the rebate to their customers	Began in 2017, expected to install 21,000 heat pumps by December 2020 As of 2018, 150 contractors had enrolled, and 2,200 incentives distributed	No

Appendix 2. Low-rise commercial buildings' size and energy consumption.

Main Floor Area Range	% of buildings	Average gas consumption (m^3)
1000 – 1500	38	2,291.5
1500 – 2000	34	3,208
2000 – 2500	12	4,124.5
2500 – 3000	5	5,041
>3000	11	-

Whole Building	% of buildings	Average gas consumption (m^3)
1500 – 2000	7	3,208
2000 – 2500	22	4,124.5
2500 – 3000	18	5,041
3000 – 3500	15	5,957.5
3500 - 4000	10	6,874.5
4000 - 4500	7	7,791
>4500	21	-

Appendix 3. Climate Zones in Toronto

The temperature variations of the Greater Toronto Area places it between climatic zones 5 (cool) and 6 (cold). In these zones, systems around 9 HSPF and higher (16 SEER), or 3.6 COP, are the recommended options for optimal heating efficiency.

Zone	Suggested SEER and HSPF	COP
Zone 1 & 2 (hot)	18-19 SEER / 9.5-10 HSPF	~4.0
Zone 3 & 4 (moderate)	14-15 SEER / 8.5 HSPF	~3.5
Zone 5 (cool)	15-17 SEER / 8.5-9.5 HSPF	~3.7
Zone 6 (cold)	18 SEER / 9.5 HSPF	~4.0
Zone 7 (very cold)	18 SEER / 9.5 HSPF	~4.0

Appendix 4. Ducted and Ductless AHSP Prices by Brand and Size (U.S. dollars)

	Ducted Heat Pump Size (Home Size)							Efficiency
Brand	**1.5 ton** (600-1000 sf)	**2 ton** (1001-1300 sf)	**2.5 ton** (1301-1600 sf)	**3 ton** (1601-1900 sf)	**3.5 ton** (1901-2200 sf)	**4 ton** (2201-2600 sf)	**5 ton** (2601 - 3200 sf)	SEER / HSPF
Trane	$6,800	$7,450	$7,970	$8,350	$8,590	$8,970	$10,390	16 / 9.5
Carrier	$6,400	$7,050	$7,570	$8,150	$8,690	$8,070	$9,390	16 / 9
Bryant	$6,560	$7,250	$7,660	$7,955	$8,290	$8,675	$9,090	16 / 9
American Standard	$6,500	$7,050	$7,470	$7,750	$8,090	$8,470	$9,390	16 / 9
Lennox	$6,650	$7,250	$7,530	$8,150	$8,290	$8,770	$9,300	16.5 / 9.5
Amana/Daikin	$2,425	$3,100	$3,780	$4,460	$5,140	$5,815	$6,495	16 / 9.7
Goodman	$4,100	$4,450	$4,970	$5,450	$5,790	$6,070	$6,990	16 / 9.5
York	$4,150	$4,550	$4,870	$5,150	$5,495	$5,770	$6,595	16 / 9
Maytag	$4,100	$4,450	$4,970	$5,450	$5,790	$6,070	$6,990	15 / 8.5
Armstrong Air	N/A	$4,750	$5,420	$6,090	N/A	$6,755	$7,425	16 / 8.5

Ductless ASHP Prices by Brand			
Brands	**Price (System Only)**	**Price (with Installation)**	**SEER / HSPF**
Fujitsu	$6,040	$7,180	20 / 11
LG	$5,145	$6,200	20 / 11
Mitsubishi	$7,450	$8,570	20 / 11
Daikin	$5,690	$6,950	20 / 11
Samsung	$5,290	$6,350	20 / 11
Pioneer	$5,490	$6,550	20 / 11
Gree	$4,390	$5,730	20 / 11

Appendix 5. Commercial Floor NPV Chart – Older Forced Air Unit

Commercial Floor NPV Chart (Older Forced Air Unit)			
Size	1000-1500	1500-2000	2000-2500
No Incentive	$2,497.18	$(529.81)	$(2,897.00)
25% Incentive	$4,090.32	$1,063.32	$(1,416.61)
50% Incentive	$5,683.46	$2,656.46	$63.78
75% Incentive	$7,276.59	$4,249.60	$1,544.17
100% Incentive	$8,869.73	$5,842.74	$3,024.57

Appendix 6. Commercial Floor NPV Chart – Older Ductless Unit

Commercial Floor NPV Chart (Older Ductless Unit)			
Size	1000-1500	1500-2000	2000-2500
No Incentive	$3,201.10	$174.11	$(2,852.89)
25% Incentive	$3,948.65	$921.66	$(2,105.34)
50% Incentive	$4,696.20	$1,669.21	$(1,357.79)
75% Incentive	$5,443.75	$2,416.76	$(610.24)
100% Incentive	$6,191.30	$3,164.30	$137.31

Appendix 7. Whole Building NPV Chart – Older Forced Air Unit

Whole Building NPV Chart (Older Forced Air Unit)						
Size	1500-2000	2000-2500	2500-3000	3000-3500	3500-4000	4000-4500
No Incentive	$3,115.00	$88.00	$(2,938.00)	$(5,965.00)	$(8,994.00)	$(12,021.00)
25% Incentive	$3,862.00	$835.00	$(2,191.00)	$(5,218.00)	$(8,246.00)	$(11,273.00)
50% Incentive	$4,610.00	$1,583.00	$(1,443.00)	$(4,470.00)	$(7,499.00)	$(10,526.00)
75% Incentive	$5,357.00	$2,330.00	$(696.00)	$(3,723.00)	$(6,751.00)	$(9,778.00)
100% Incentive	$6,105.00	$3,078.00	$51.00	$(2,975.00)	$(6,004.00)	$(9,031.00)

Appendix 8. Whole Building NPV Chart – Older Ductless Unit

Whole Building NPV Chart (Older Ductless Unit)						
Size	1500-2000	2000-2500	2500-3000	3000-3500	3500-4000	4000-4500
No Incentive	$3,115.00	$578.00	$(2,448.00)	$(5,475.00)	$(8,504.00)	$(11,531.00)
25% Incentive	$3,862.00	$1,326.00	$(1,700.00)	$(4,727.00)	$(7,756.00)	$(10,783.00)
50% Incentive	$4,610.00	$2,073.00	$(953.00)	$(3,980.00)	$(7,009.00)	$(10,036.00)
75% Incentive	$5,357.00	$2,821.00	$(205.00)	$(3,232.00)	$(6,261.00)	$(9,288.00)
100% Incentive	$6,105.00	$3,568.00	$541.00	$(2,475.00)	$(5,513.00)	$(8,540.00)

Appendix 9. Commercial Floor NPV Chart – Older Forced Air Unit (No additional value in getting AC)

Commercial Floor NPV Chart (Older Forced Air Unit)			
Size	1000-1500	1500-2000	2000-2500
No Incentive	$(198.90)	$(3,225.89)	$(5,838.18)
25% Incentive	$1,394.24	$(1,632.75)	$(4,357.79)
50% Incentive	$2,987.38	$(39.62)	$(2,877.40)
75% Incentive	$4,580.51	$1,553.52	$(1,397.00)
100% Incentive	$6,173.65	$3,146.66	$83.39

Appendix 10. Whole Building NPV Chart – Older Forced Air Unit (No additional value in getting AC)

Whole Building NPV Chart (Older Forced Air Unit)						
Size	1500-2000	2000-2500	2500-3000	3000-3500	3500-4000	4000-4500
No Incentive	$174.00	$(2,852.00)	$(5,879.00)	$(8,906.00)	$(11,935.00)	$(14,962.00)
25% Incentive	$921.00	$(2,105.00)	$(5,132.00)	$(8,159.00)	$(11,187.00)	$(14,214.00)
50% Incentive	$1,669.00	$(1,357.00)	$(4,384.00)	$(7,411.00)	$(10,440.00)	$(13,467.00)
75% Incentive	$2,416.00	$(610.00)	$(3,637.00)	$(6,664.00)	$(9,692.00)	$(12,819.00)
100% Incentive	$2,164.00	$137.00	$(2,889.00)	$(5,916.00)	$(8,945.00)	$(11,972.00)