A Guide to Measurement and Verification of Heat Pump Retrofits in Multi-Unit Residential Buildings

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About The Atmospheric Fund

The Atmospheric Fund (TAF) is a regional climate agency that invests in low-carbon solutions in the Greater Toronto and Hamilton Area and helps scale them up for broad implementation. We are experienced leaders and collaborate with stakeholders in the private, public and non-profit sectors who have ideas and opportunities for reducing carbon emissions. Supported by endowment funds, we advance the most promising concepts by investing, providing grants, influencing policies and running programs. We're particularly interested in ideas that offer benefits beyond carbon reduction such as improving people's health, creating local green jobs, boosting urban resiliency, and contributing to a fair society.

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Content

Introduction

Space heating represents the largest energy end use in Ontario multifamily buildings at 54.6%[1]

Heat pumps can offer significant energy savings compared to traditional heating systems used in multi-unit residential buildings (MURB). However, upgrading to a heat pump represents a significant capital expenditure for building owners, property managers, and condo boards. Measurement and verification (M&V) allows for the tracking of a heat pump's performance to ensure your investment in a heat pump system is providing the expected energy savings.

Purpose of the Guide

The Atmospheric Fund (TAF) commissioned this guide to support their **Retrofit Accelerator** program, which aims to increase the pace, scale, and ambition of retrofits in the Greater Toronto and Hamilton Area (GTHA) and beyond. This guide is intended for building owners, condo board members, and property managers to ensure heat pump installations are generating the expected energy savings, thus increasing heat pump adoption and encouraging electrification across the multifamily sector.

We outline M&V procedures and recommendations for heat pump retrofits, focusing on space heating retrofits in electrically-heated MURBs. However, many of the principles can also be applied to heat pump retrofits in gas-heated buildings.

About the IPMVP

The Efficiency Valuation Organization's (EVO) International Performance Measurement and Verification Protocol (IPMVP) Core Concepts is an internationally recognized protocol for verifying the energy, demand and cost-savings of energy efficiency measures (EEM). The latest version of the IMPVP Core Concepts (2022 EVO 10000 – 1:2022) is available at evo-world.org. 2022 EVO 10000 – 1:2022 shall be referred to as "the IPMVP" hereafter in this guide.

The IPMVP provides four options for determining energy and demand savings. In brief, they are:

- **Option A:** Retrofit Isolation, Key Parameter(s) Measurement
- **Option B:** Retrofit Isolation, All Parameters Measurement
- **Option C:** Whole Facility
- **Option D:** Calibrated Simulation

How this Guide Uses the IPMVP

This guide adheres to the IPMVP and applies concepts and procedures originating from the IPMVP.

[1] Natural Resources Canada, National Energy Use Database, Comprehensive Energy Use Database, Residential Sector, Ontario, Table 39: Apartments Secondary Energy Use and GHG Emissions by End-Use

Introduction to Measurement and Verification

Energy and demand savings cannot be directly measured as they represent energy that was not consumed and demand that did not occur. Therefore, energy and demand savings must be calculated. Measurement and verification (M&V) is the process for determining energy and demand savings using a combination of measured data and calculations. Efficiency Valuation Organization (EVO) defines M&V as the process of planning, measuring, collecting and analyzing data to verify and report energy savings within a facility by implementing energy efficiency measures (EEM).

The IPMVP describes the following principles of M&V:

- **Accurate –** Reported M&V savings shall be as accurate as is reasonably possible, while balancing M&V rigour with total project costs.
- **Complete –** Reported energy savings should consider all aspects of the project.
- **Conservative –** All assumptions and judgment calls should be made such that the reported savings are under-stated instead of over-stated.
- **Consistent –** The reporting of energy savings should be consistent and comparable amongst energy professionals, project types, etc.
- **Relevant –** The determination of energy savings shall measure energy-influencing factors and verify the performance factors that are of concern related to the heat pump upgrade.
- **Transparent –** All M&V activities shall be clearly documented and presented in a manner that all parties, including third party reviewers, can follow and understand.

The general equation for determining avoided consumption energy savings, as outlined in the IPMVP, is:

Avoided Energy Savings = Baseline Period Energy – Reporting Period Energy ± Routine Adjustments to Baseline Conditions ± Non-Routine Adjustments to Baseline Conditions

In the context of a MURB heat pump retrofit, M&V involves comparing the measured energy usage of the baseline (e.g. existing) heating system with the heat pump's energy usage while adjusting for weather and any other key differences between the baseline and reporting periods.

Multi-Unit Heat Pump Retrofit Scenarios

Heat pump retrofits in Ontario MURBs can be broadly classified under the following scenarios:

1. Replacing or supplementing (e.g. in a hybrid system) an electric or gas heating system with a heat pump for heating and cooling.
2. Replacing or supplementing (e.g. in a hybrid system) an electric or gas heating system and replacing an existing electric cooling system with a heat pump for heating and cooling.
3. Replacing an existing natural gas space heating system with a heat pump system for space heating and cooling.
4. Replacing or supplementing (e.g. in a hybrid system) an existing electric or gas domestic hot water (DHW) system with a heat pump system.

This guide is designed for the measurement and verification of savings from upgrading electrically-heated MURBs to heat pumps. Presently, these are generally the most cost-effective heat pump retrofits in Ontario and therefore the most common. However, the content of this guide can be applied to all heat pump scenarios (e.g. replacing gas-heating, hybrid systems, etc.), with some modifications.

Types of Heat Pumps

This guide provides a high-level description of the types of heat pumps available on the market. More details are available in the TAF publication "**A Guide to Retrofitting Electrically-Heated Multi-Family Dwellings in Ontario with Heat Pumps**".

The term heat pump is somewhat of a misnomer, as heat pumps can provide both heating and cooling. Heat pumps can broadly be classified as either:

1. **Air-Source Heat Pumps**
2. **Ground-Source Heat Pumps**

Air-source heat pumps extract heat from outdoor air and move it indoors during the heating season. During the cooling season, this process is reversed, and heat is extracted from indoor spaces and moved outside.

Ground-source heat pumps move heat stored in the ground to the indoor space during the heating season. During the cooling season, ground-source heat pumps move heat from the indoor spaces to the ground. Ground-source heat pumps can also add or remove heat from a body of water. Ground-source heat pumps are sometimes called geothermal or geoexchange systems.

Heat pump systems can distribute heating and cooling throughout a MURB using:

- Air – through existing or new ducts
- Water – through existing or new hydronic distribution systems
- Refrigerant – through refrigerant lines in a variable refrigerant flow (VRF) or "ductless" system

Using IPMVP Option C to Determine Heat Pump Savings

IPMVP Option C (Whole Facility) is generally the recommended M&V option for whole-facility heat pump upgrades in MURBs. MURB energy usage patterns are typically well established and weather dependent. For heat pump retrofit projects, a MURB's energy usage history can be used to create energy regression models with very high confidence levels to represent the relationship between the building's energy use and weather. Comparing baseline regression models and post-retrofit utility data is a relatively simple process that results in energy savings values with a high degree of confidence using actual building metered data and local weather data.

Measurement Boundary

The measurement boundary is typically the building's main electrical meter from the Local Distribution Company (LDC). An illustration of this measurement boundary is shown below in Figure 1.

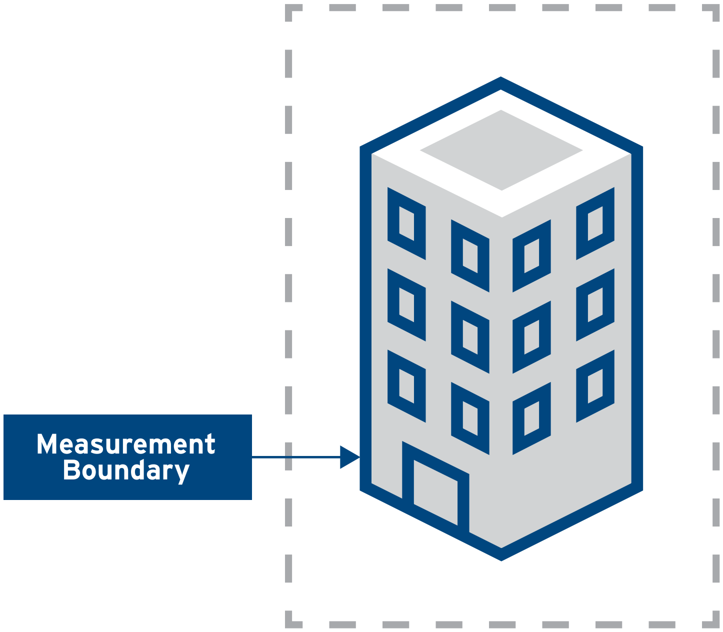


Figure 1: Measurement Boundary example: building's main electrical meter

Some MURBs will have multiple meters, including tenant sub-meters. For these scenarios, the measurement boundary shall be all meters that are impacted by the heat pump upgrade. If a sub-meter has no direct or indirect relationship to heating or cooling it can be excluded from the measurement boundary. Examples of sub-meters that may be excluded from the measurement boundary are rooftop cellular tower sub-meters, or an electric vehicle charger sub-meter.

Benefits of IPMVP Option C

Using IPMVP Option C M&V has several key advantages for heat pump retrofit projects:

- No additional meters are required.
- Savings are calculated using actual utility data for the building, appropriately adjusted for weather.
- The option is technology-agnostic and can be applied to all types of heat pump retrofit scenarios.
- Software tools are available to assist with the calculations, including Microsoft Excel and RETScreen® Expert.
- Once established, IPMVP Option C M&V can be used continuously to track the weather-adjusted energy performance of the heat pump upgrade over the heat pump's lifespan.

Calculating Energy Savings Using Option C

The general equation for determining avoided consumption energy savings, as outlined in the IPMVP Core Concepts, is:

Avoided Energy Savings = Baseline Period Energy – Reporting Period Energy ± Routine Adjustments to Baseline Conditions ± Non-Routine Adjustments to Baseline Conditions

When using Option C, the baseline period energy is determined using an established baseline model, adjusted to the reporting period's weather conditions (a routine adjustment).

The reporting period energy is the actual billed energy consumption for the facility, using the building's revenue-grade utility meter(s).

Non-routine adjustments, though uncommon, are made to account for any changes in the building's static factors, such as its size, significant changes to occupancy, envelope upgrades, etc.

Calculating Demand Savings Using Option C

Ontario facilities with a monthly demand >50 kW receive bills with demand-based (e.g. $/kW) charges and can therefore calculate summer and winter demand savings using utility data. Demand savings shall be calculated using the IESO's weather dependent definition of peak demand, as defined in the **IESO's Evaluation Measurement and Verification Protocols (Version 4)**.

Summer demand savings shall be calculated by:

Summer Demand Savings (kW) =

$$[0.3 \times (June_{Base} - June_{Post})] + [0.39 \times (July_{Base} - July_{Post})] + [0.31 \times (Aug_{Base} - Aug_{Post})]$$

Where:

- **$June_{Base}$, $July_{Base}$, Aug_{Base}** – represent the billed peak demand for the facility in the baseline period for the months of June, July, and August respectively.
- **$June_{Post}$, $July_{Post}$, Aug_{Post}** – represent the billed peak demand for the facility in the reporting period for the months of June, July, and August respectively.
- 0.3, 0.39 and 0.31 are weighting factors specified by the IESO.

Winter demand savings shall be calculated by:

Winter Demand Savings (kW) =

$$[0.65 \times (Dec_{Base} - Dec_{Post})] + [0.16 \times (Jan_{Base} - Jan_{Post})] + [0.19 \times (Feb_{Base} - Feb_{Post})]$$

Where:

- **Dec_{Base}, Jan_{Base}, Feb_{Base}** – represent the billed peak demand for the facility in the baseline period for the months of December, January and February respectively.
- **Dec_{Post}, Jan_{Post}, Feb_{Post}** – represent the billed peak demand for the facility in the reporting period for the months of December, January and February respectively.
- 0.65, 0.16 and 0.19 are weighting factors specified by the IESO that represent the relative impact on the electricity grid.

The above equation assumes that the billed peak demand represents the "design conditions" for the facility and occurs under similar conditions regardless of the year.

For buildings without central air conditioning, it is possible that a heat pump retrofit will result in a demand penalty (e.g. negative savings).

Baseline Model Development

A baseline regression model is required for IPMVP Option C. Regression models are mathematical equations that describe the relationship between one or more independent variables and a dependent variable.

Simple Linear Regression Models

Regression models can usually be developed for MURBs that establish a relationship between heating energy, the dependent variable, and weather, an independent variable. These regression models are linear (e.g. in the form of the equation of a line) and are expressed in the following format:

Energy in Period = (HDD in Period x M) + B

Where:

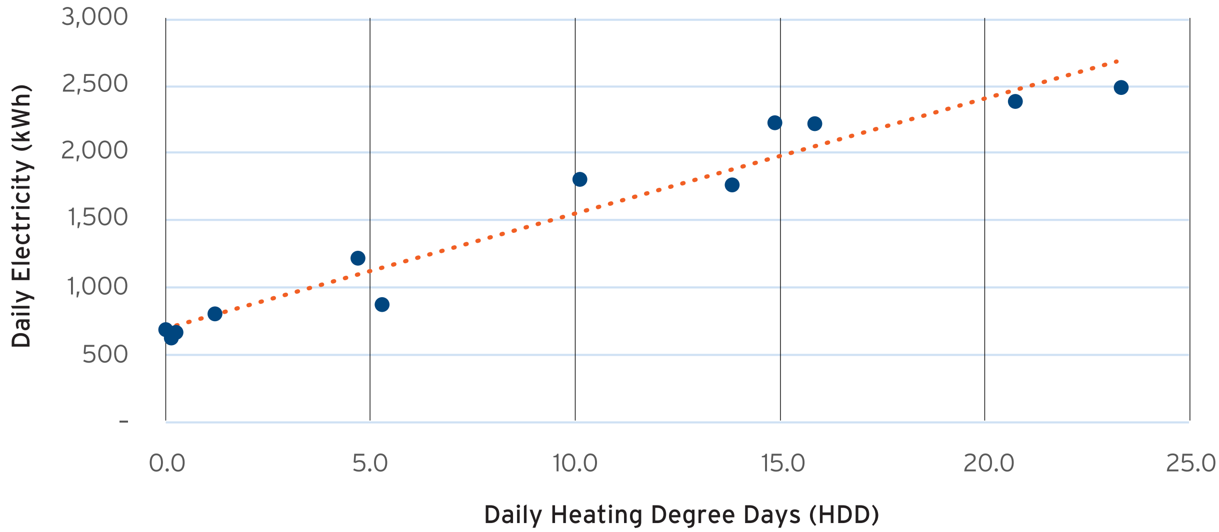
- **Period** = a specified time period, such as daily
- **HDD in Period** = heating degree days (HDD) in the period
- **M** = a constant coefficient representing the slope of the regression line
- **B** = the coefficient of the y-axis intercept of the regression graph, representing the baseload energy of the building during the period

The above equation can be used to predict baseline energy use within the period under different weather conditions. This can be used to estimate the heating energy your baseline (existing) system would have used under the same weather conditions as your new heat pump.

Since the above equation has a single independent variable (weather, in the form of heating degree days), it is called a simple regression model.

When developing a baseline model for natural gas, energy consumption in equivalent kWh (ekWh) can be determined by multiplying the natural gas consumption in cubic metres (m^3) by 10.33, as specified by **Natural Resources Canada**.

An example of a simple linear regression model is shown below in Figure 2:



Regression Equation:	y = 85.62x + 695.2 R^2 = 0.9474

Figure 2: Simple Linear Regression Model and Equation

Baseline Data Requirements

Actual utility meter data shall be used to develop the model. As per the IPMVP, utility meter data shall be considered 100% accurate. At a minimum, monthly data should be used to develop the model. Monthly data is usually sufficient for regression models used to calculate the energy savings of whole-building heat pump retrofits. When using monthly electricity billing data to develop a regression model, it is recommended to divide the electricity consumption by the number of days in the billing period to determine average daily energy use in the billing period. Developing a regression model using average daily energy use in the billing period ensures that the regression model properly accounts for differences in the number of days across different months and/or billing periods.

If available, more granular data can also be used (e.g. utility interval meter data) to develop the model. More granular data can produce more accurate models, though models developed using more granular data can also be more difficult to develop.

Independent Variable

MURBs typically use weather as the independent variable, in the form of heating degree days (HDD).

Degree Days

Degree days represent how hot or cold a day is and are therefore a measure of how much heating or cooling is needed to maintain the building at its desired temperature. Degree days are calculated against a reference or base temperature which represents a building's balance point. The balance point is the outdoor air temperature above which building cooling is required and below which building heating is required. For residential buildings (e.g. single family homes), degree days are calculated against a reference temperature of 18ºC.

Daily heating degree days (HDD) are the number of degrees that the daily average temperature is below the reference temperature. For example, if the daily average temperature is 0ºC and the reference temperature is 18ºC, there are 18 HDD that day. Note that daily HDD must be ≥0.

Daily cooling degree days (CDD) are the number of degrees that the daily average temperature is above the reference temperature. For example, if the daily average temperature is 30ºC and the reference temperature is 18ºC, there are 12 CDD that day. Like HDD, daily CDD must be ≥0.

Historical degree day data, calculated against a reference temperature of 18ºC, is available for a number of Canadian locations from **Environment Canada**. Worldwide degree day data for multiple reference temperatures is available from **BizEE Sofware**. Another source of degree day data is NASA weather data is also available in RETScreen Expert software.

Multivariable Regression Models

MURB buildings typically produce strong regression models when using HDD as an independent variable. In some cases, the regression model can be further improved by using more than one independent variable. Another common independent variable for MURBs is cooling degree days (CDD). A multivariable regression model with both HDD and CDD as independent variables is expressed in the following format:

Energy in Period = (HDD in Period x M) + (CDD in Period x N) + B

Where:

- **Period** = a specified time period, such as daily
- **HDD in Period** = heating degree days (HDD) in the period
- **CDD in Period** = cooling degree days (CDD) in the period
- **M** = a constant coefficient for heating
- **N** = a constant coefficient for cooling
- **B** = the coefficient of the y-axis intercept of the regression graph, representing the baseload energy of the building in the period

For buildings with air conditioning, it is recommended that a multivariable regression model be attempted when developing the baseline model. Information on validating a baseline model, including which independent variables should be included, can be found in the "Baseline Model Validation" section of this guide.

Baseline Model Validation

For a baseline regression model to be acceptable, it must demonstrate an acceptable goodness-of-fit. In order for a regression model to be used, it should aim to meet the following requirements, as originally outlined in the **IESO's Energy Performance Program Schedule "E" M&V Procedures (Version 1.3)**, summarized below.

Statistical Term	Equation	Recommended Value and Purpose
Number of data points	N	The total number of data points used to develop the regression model. A minimum of 12 should be used for monthly models.
Coefficient of Determination (R^2)	$1 - \frac{\sum_i (y_{act} - y_{calc})^2}{\sum_i (y_{act} - y_{avg})^2}$	The R^2 value indicates how well variation in the independent variable (weather) explain variation in the dependent variable (energy). R^2 ranges from 0 to 1. The higher the value, the stronger the association between variation in the dependent and independent variables. As a rule of thumb, a regression model should have a R^2 value above 0.75. While models with lower R^2 values may still be acceptable, this is typically not an issue for MURBs, which tend to have R^2 values above 0.75.
Coefficient of Variation of Root Mean Squared Error (CV(RMSE))	$\frac{\sqrt{\frac{\sum_i (y_{act} - y_{calc})^2}{(n-p)}}}{y_{avg}}$ Note: p = 2 for simple linear regression models	CV(RMSE) is the standard deviation of errors of prediction about the regression line normalized by the average energy value. It is recommended that CV(RMSE) be below 15%.
Net Determination Bias Error (NDBE)	$\frac{\sum_i (y_{act} - y_{calc})}{\sum_i y_{act}}$	NDBE is the sum of the errors divided by the actual energy. It is recommended that NDBE be less than +/- 0.005%.
T-Statistic (T_{stat} or T_{ratio})	$t_{\hat{\beta}} = \frac{\hat{\beta} - \beta_0}{s.e.(\hat{\beta})}$	The t-statistic represents how statistically significant a coefficient is. The higher the t-statistic, the more significant it is. A minimum value of 2 is required for all coefficients, including the coefficient for the baseload and the independent variable(s).

Note: the equations in the table above are presented for reference purposes only. It is expected that these values will be calculated using software tools, not manually.

Software Tools

While regression calculations can be performed manually, it is strongly recommended that software be used to develop the regression model. **Microsoft Excel** has built-in functions for regression analysis, as well a regression analysis feature as part of its **Analysis Toolpak**. RETScreen Expert software also has a powerful regression analysis feature.

Potential Issues and Adjustments

Missing data or known outliers should be excluded from the baseline model.

The model should also be adjusted for any changes to the building during the baseline period that impact the building's electricity consumption. These are known as non-routine adjustments (NRA). Examples of this include:

- Other energy efficiency upgrades (e.g. lighting upgrade).
- Building addition or expansion.
- Major renovation.

NRA may also be required in the reporting period.

NRA should be made in accordance with the IPMVP Application Guide on Non-Routine Events & Adjustments, October 2020, EVO 10400 – 1:2020

Tips

18ºC is typically the degree day reference temperature and balance point for single family homes. MURBs however often produce stronger regression models with HDD values with different reference temperatures. RETScreen Expert software can be used to optimize the HDD reference temperature to produce a model that results in the highest coefficient of determination (R^2 value). **BizEE Software** also has a free online tool that can perform a sensitivity analysis to determine an appropriate balance point temperature.

Estimating Pre-Project Savings

Estimating the pre-project energy and demand savings from a heat pump upgrade is an important part of the M&V process, and a first step to determine if a building should proceed with the upgrade.

Heating Energy Savings

Heating energy savings are responsible for the majority of the total energy savings from a heat pump upgrade. Using your baseline simple linear regression model, annual heating energy requirements can be calculated by:

Annual Baseline Heating Energy (kWh) = Annual HDD x M

Where:

- **Annual HDD** = HDD in the baseline year
- **M** = a constant coefficient representing the slope of the regression line

For buildings using electric resistance heating, heating electricity consumption in kWh is equal to heating output in kWh. Therefore, the heat pump's annual heating energy can then be calculated by:

Annual Heat Pump Heating Energy (kWh) = Annual Baseline Heating Energy / $SCOP_h$

Where:

- **$SCOP_h$** = the average seasonal coefficient of performance (SCOP) of the heat pump over a heating season. The $SCOP_h$ is a ratio of the heating energy provided by the heat pump, divided by the input electrical energy to the heat pump. The $SCOP_h$ is dimensionless, as it uses the same units for heating and electrical energy.
  - SCOP can be calculated by multiplying the heating seasonal performance factor **(HSPF) by 0.293**.
  - HSPF values for **single package** air source heat pumps and **split** air source heat pumps available in Canada can be obtained from Natural Resources Canada.
  - When calculating SCOPh, ensure that HSPF values for Region 5 are used.

Therefore, pre-project heating energy savings can be estimated by:

Pre-Project Heating Energy Savings Estimate (kWh) =

Annual Baseline Heating Energy – Annual Heat Pump Heating Energy

Cooling Energy Savings

Estimating cooling energy savings can be more challenging, as few MURBs have central air conditioning (AC). Additionally, cooling is a much smaller energy end-use than heating.

Buildings without central air conditioning often have tenant-owned window units for space cooling. These units are discretely controlled and are of varying sizes and vintages. While heat pumps are on average more energy efficient than individual window AC units, it is possible that adding heat pump cooling to all tenants will result in a slight increase in cooling energy and demand compared to the baseline demand from the tenant-owned window AC units.

For buildings with central air conditioning, heat pumps typically offer both heating and cooling energy savings, with the cooling savings being achieved through improved efficiency.

Buildings with Multivariable Regression Models

If a multivariable regression model was developed using CDD, annual cooling energy requirements can be calculated by:

Annual Baseline Cooling Energy (kWh) = Annual CDD x N

Where:

- **Annual HDD** = CDD in the baseline year
- **N** = a regression model coefficient for cooling

The building's annual cooling load can then be calculated by:

Annual Cooling Load (Btu) =

Annual Baseline Cooling Energy (kWh) x [1000 Wh/kWh] x $SEER_{Baseline}$

Where:

- **$SEER_{Baseline}$** = The seasonal energy efficiency ratio (SEER) of the existing air conditioning system. The SEER is a ratio of the British thermal units (Btu) of heat removed from the building to the electricity consumption of the air conditioner in watt-hours (Wh), across an entire cooling season.

The heat pump's annual cooling energy can then be calculated by:

$$\textbf{Annual Heat Pump Cooling Energy (kWh)} = \frac{\text{Annual Cooling Load (Btu)}}{SEER_{HeatPump} \text{ x [1 kWh/1000 Wh]}}$$

Where:

- **$SEER_{HeatPump}$** = The seasonal energy efficiency ratio (SEER) of the heat pump system.

Therefore, pre-project cooling energy savings can be estimated by:

Pre-Project Cooling Energy Savings Estimate (kWh) =
Annual Baseline Cooling Energy – Annual Heat Pump Cooling Energy

Buildings without Multivariable Regression Models

For buildings without a multivariable regression model that includes CDD, cooling energy savings can be estimated by:

Pre-Project Cooling Energy Savings Estimate (kWh) =

$$(CC \times 12) \times \left[\left(\frac{1}{EER_{Baseline}}\right) - \left(\frac{1}{EER_{HeatPump}}\right)\right] \times LF \times EFLH$$

Where:

- **CC** = The total cooling capacity of the cooling system in tons.
- **EERBaseline** = The energy efficiency ratio of the baseline system in units of Btu/Wh.
- **EERHeatPump** = The energy efficiency ratio of the heat pump system in units of Btu/Wh.
- **LF** = A loading factor to account for the fact that it is unlikely that 100% of the installed cooling capacity will be provided simultaneously (e.g., 0.8).
- **EFLH** = Equivalent full load hours, typically 200 as defined by the **IESO's Measures and Assumptions List** (for Room Air Conditioners).

Using Other IPMVP Options

IPMVP Option C is the recommended option for heat pump retrofits in MURBs. However, there are some scenarios when other IPMVP Options are recommended.

Option A and B

Option A – Retrofit Isolation: Key Parameters Measurement and **Option B** – Retrofit Isolation: All Parameter Measurements are generally not recommended for whole building heat pump retrofits in MURBs with established operating histories and utility profiles, as Option C is typically less expensive and less complex to implement.

However, Option A is recommended for the following scenarios:

- Partial building heat pump retrofits (e.g., replacing baseboard electric heating with ductless mini split heat pumps in two units out of 100 units).

When following Option A, additional metering must be purchased or rented. Additionally, as heat pump energy consumption and efficiency vary considerably depending on outdoor air conditions, measurements must be taken across a wide range of outdoor air temperatures to allow for annual energy savings calculations. Baseline and heat pump input power (kW) should be measured at different load levels spanning the system's total design loads. Annual energy use can be calculated by multiplying the measured performance at each load level by stipulated annual operating hours for said load level. One method for this would be to perform a "bin" analysis, where the annual weather data is sorted into various temperature bins (e.g. 0-5ºC, 5-10ºC, etc.). The average measured input power in a given temperature bin is then multiplied by the total number of hours for the bin.

Option B is more expensive than Option A, as all parameters must be measured. Option B is recommended for the following scenarios:

- Pilot studies where the building owner or manager is looking to gain insights into heat pump operations that can be applied across a portfolio of buildings.

A full description of the requirements and nuances for IPMVP-adherent Option A and B M&V is beyond the scope of this document. For further information please review the IPMVP.

Option D

Option D – Calibrated Simulation is often expensive, requiring the use of a third-party energy modeling consultant. ASHRAE 140-compliant software should be used for all Option D simulations. However, Option D is recommended for the following scenarios:

- Buildings undergoing major renovations where the baseline utility data will not be representative of the post-renovation building.
- Buildings being renovated from another function (e.g. former manufacturing) to multi-unit residential where no baseline data is available.
- Buildings with Canada Mortgage and Housing Corporation (CMHC) that wish to apply to CMHC's MLI Select incentive program.

A full description of the requirements and nuances for IPMVP-adherent Option D M&V is beyond the scope of this document. For further information please review the IPMVP.

References

These sources are referenced in this document and recommended for further reading:

1. IESO, Evaluation Measurement and Verification Protocols (Version 4),
2. IESO, Energy Performance Program Schedule "E" M&V Procedures (Version 1.3), June 2022
3. IPMVP Application Guide on Non- Routine Events & Adjustments, October 2020, EVO 10400 – 1:2020
4. IMPVP Core Concepts, 2022, EVO 10000 – 1:2022
5. TAF, A Clearer View of Ontario's Emissions Updated Electricity Factors and Guidelines, 2021
6. TAF, Harvesting Heat with Heat Pumps a Guide to Retrofitting Electrically-Heated Multi-Family Dwellings in Ontario with Heat Pumps, 2018