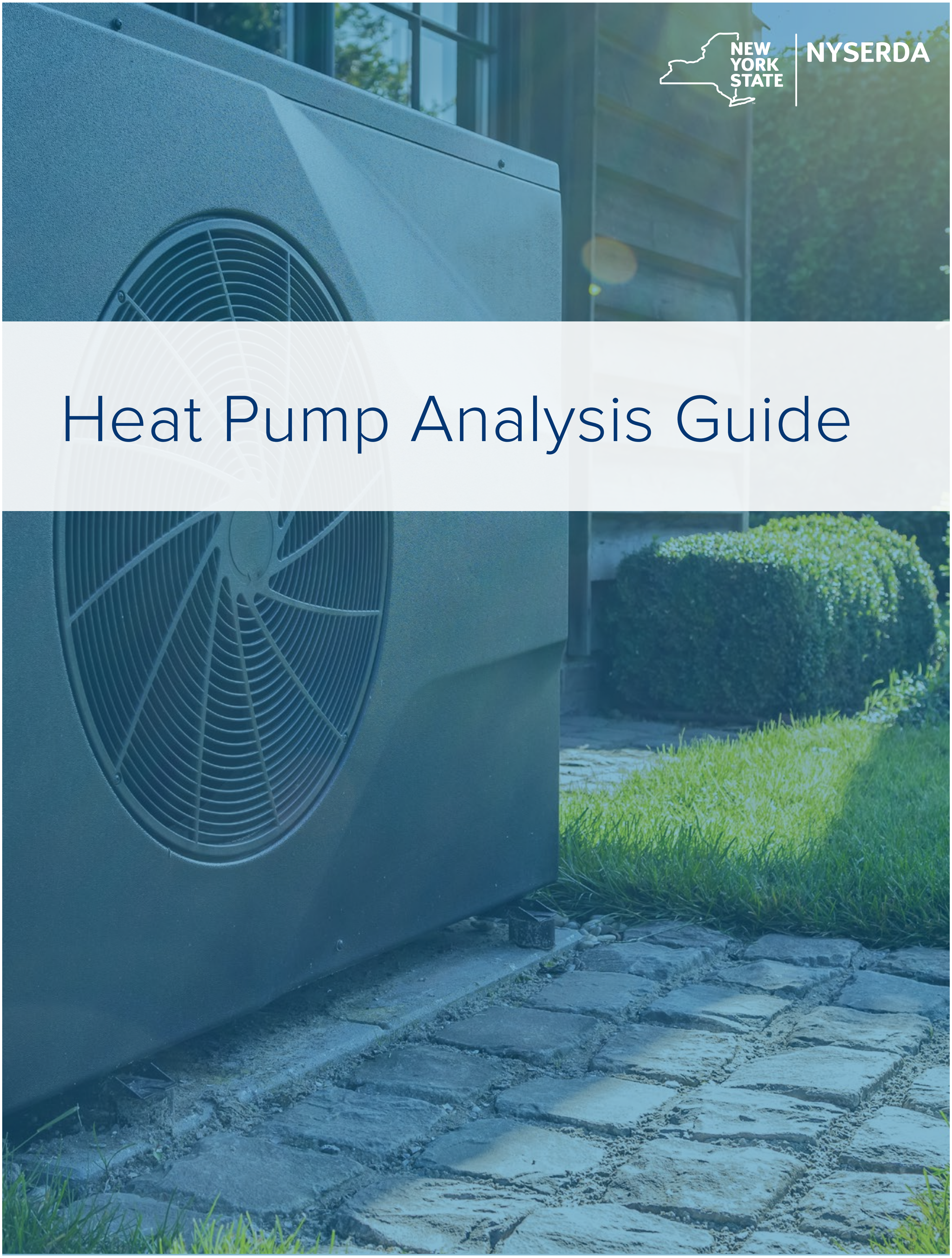
NEW YORK STATE | NYSERDA

# Heat Pump Analysis Guide



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As the drive for building electrification continues to accelerate to meet New York State's Climate Leadership and Community Protection Act (Climate Act) goal of achieving a carbon neutral economy by 2050, so does the need for sharing and promoting strategies for analyzing and presenting electrification opportunities.

This guide compiles recommendations for conducting a thorough analysis and providing a deeper, contextualized understanding of space conditioning and domestic hot water (DHW) heat pump and heat pump-ready opportunities to commercial and multifamily building owners.

We highly encourage the FlexTech consultants and independent service providers participating in the FlexTech program to adopt the recommendations presented herein to support NYS in advancing to the forefront of restoring our climate stability.

### STEPS:

1. **Building Evaluation** – Gather a thorough understanding of the existing building systems, components, and operation.
2. **Measure Candidacy** – Identify preliminarily viable and desired heat pump opportunities.
3. **Analysis** – Incorporate key analysis approaches to produce realistic energy impacts, Non-Energy Impacts (NEIs) and project economics.
4. **Green House Gas (GHG) Economic Impact** – Incorporate GHG economic impacts to provide a holistic picture of the project.

# 1. Building Evaluation

## Systems, Components, Operation

A thorough building evaluation is fundamental to determining the candidacy of space conditioning and DHW electrification and electrification readiness opportunities and recommended measures.

This section presents the existing building components and data points that are fundamental to establish a solid foundation for the electrification analysis. Being as specific as possible with existing conditions will limit assumptions and provide the customer with accurate takeaways and next steps.

**Tariff:** A document that lists the rates, terms and conditions of a local distribution company's services that are subject to review and approval by the New York State Public Service Commission.

**Demand:** The amount of electricity that must be generated to meet the needs of all customers at a certain point in time.

### Utilities, Infrastructure and Thermal Sources

Space conditioning electrification measures may increase electric capacity, peak demand, and consumption charges. At a minimum, 24 months of utility data should be evaluated. Collect the following information to assess potential site barriers and utility impacts.

- ☐ **Electric Utility Tariffs** – Conduct a detailed investigation of the customer's electric utility tariffs to understand any potential rate impacts and their influence on a project's financial metrics.
- ☐ **Marginal Electric Rates** – Use marginal utility rates that decouple peak demand from off-peak rates to generate more accurate cost-savings projections.
- ☐ **Electric Infrastructure** – Document the existing electric infrastructure such as: transformers, electric service panels, subpanels and switchgear sizes and configurations. Document the building's existing electric service capacity, existing electrical loads, and available breaker space in existing panels and subpanels. Gather MEP drawings that include wiring layout.
- ☐ **Thermal Sources** – Identify access/proximity to thermal resources, such as land suitable for ground source applications, water sources, or waste heat to allow for consideration of all potential thermal sources and sinks that are available for use.

## Conditioned Building Square Footage

Conditioned square footage is fundamental to analyzing the building design heating and cooling loads for right sizing heat pumps and evaluating the impact of electrification measures. It is recommended to differentiate gross floor area from conditioned square footage.

- ❑ **Gross Floor Area** – Obtain square footage of the gross floor area, measured from the exterior faces of walls or from the centerline of walls separating buildings, but excluding covered walkways, open roofed-over areas, porches and similar spaces, pipe trenches, exterior terraces or steps, chimneys, roof overhangs, and similar features.

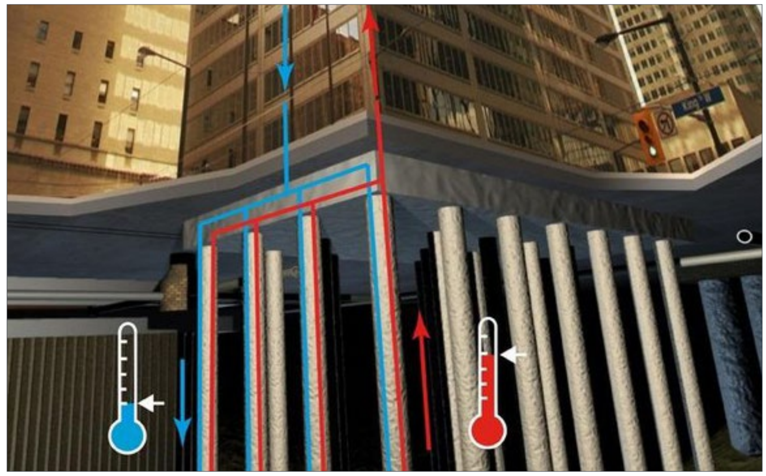

*Image courtesy of Egg Geo, LLC*

- ❑ **Conditioned Square Footage:** (By space area where applicable) – Obtain square footage of the conditioned space at an area-level when heat pumps only displace a portion of the load.

## Heating and Cooling Systems

Collecting the following heating and cooling system data points will allow for understanding how the building operates, potential opportunities for upgrading, establishing the baseline for electrification measure impact evaluation, and accurately estimating energy impacts for many heat pump technologies. If information is unavailable, indicate any assumptions that have been made and provide details on how such assumptions were derived, including the sources of the assumptions used.

**Heating and Cooling Loads:**

- ❑ Design loads of the existing systems

**Existing Equipment Specifications:**

- ❑ Type/make/model
- ❑ Configuration
- ❑ Fuel type
- ❑ Input & output capacities

**Existing Operation:**

- ❑ Control type and configuration
- ❑ Control strategies, setpoints, and schedules
- ❑ Operating efficiency ratings
- ❑ Heating ratings: AFUE, Et, Ec, COP, HSPF
- ❑ Cooling ratings: CEER, SEER, IEER, EER, kW/Ton
- ❑ Tested operational efficiency
- ❑ Data logging for measured operational parameters
- ❑ BMS/EMS trend data, if available (minimum of 12 months at hourly intervals; ideally at 15- minute intervals)

**Existing Distribution System:**

- ❑ Type and configuration
- ❑ Specifications
- ❑ Energy-impacting components

**Existing Conditions:**

- ❑ Equipment age
- ❑ Condition of equipment, controls, distribution system
- ❑ Ability to perform as designed
- ❑ Sources and corresponding magnitude of inefficiency

**AFUE:** Annual Fuel Utilization Efficiency

**Et:** Thermal Efficiency

**Ec:** Combustion Efficiency

**COP:** Coefficient of Performance

**HSPF:** Heating Seasonal Performance Factor

**CEER:** Combined Energy Efficiency Ratio

**SEER:** Seasonal Energy Efficiency Ratio

**IEER:** Integrated Energy Efficiency Ratio

**EER:** Energy Efficiency Ratio

**kW/Ton:** Peak power draw/peak cooling consumption

## Ventilation and Exhaust

Ventilation and exhaust are crucial aspects in assessing building/space loads, HVAC sizing requirements, and the potential for system balancing and energy recovery strategies. Strategies for reducing ventilation and exhaust energy use should be investigated thoroughly due to the impact on thermal loads within a facility. Capture data related to whole-building ventilation and spot ventilation (bathrooms, kitchens, etc.).

**System Design Specifications:**

- ☐ Tested ventilation rates (CFM)
- ☐ Outdoor air percentage
- ☐ Make-up air requirements
- ☐ Reheat requirements

**Existing Equipment Specifications:**

- ☐ Type/make/model
- ☐ Configuration
- ☐ Sizing
- ☐ Presence of DOAS, ERVs or HRVs

**Existing Operation:**

- ☐ Control type and configuration
- ☐ Control strategies, setpoints, and schedules
- ☐ Operating ventilation rates (CFM)
- ☐ Operating outdoor air percentage

**Existing Distribution System:**

- ☐ Type and configuration
- ☐ Specifications
- ☐ Energy-impacting components
- ☐ Space types served

**Existing Conditions:**

- ☐ Equipment age
- ☐ Condition of equipment, controls, distribution system
- ☐ Ability to perform as designed
- ☐ Sources and corresponding magnitude of inefficiency

**CFM:** Cubic Feet/Minute

**DOAS:** Dedicated Outdoor Air System

**ERV:** Energy Recovery Ventilator

**HRV:** Heat Recovery Ventilator

## Envelope

Detailed envelope analysis is integral to the evaluation of HVAC system loads, right sizing electrification equipment and addressing comfort issues in a facility. Collect the following information to inform a thorough envelope analysis.

**Existing Assembly: (at minimum & where applicable)**

- ☐ Roof/ceiling
  - ☐ Total roof area
  - ☐ Roof construction: deck, insulation type, membrane
  - ☐ Insulation thickness and R-value
  - ☐ Insulation location (attic floor vs. roof deck)
  - ☐ Attic ventilation approach (if applicable)
- ☐ Above- and below-grade exterior walls
  - ☐ Wall areas, by construction type
  - ☐ Wall construction
    - ☐ Framing, material, insulation type, façade
  - ☐ Insulation thickness and R-value
- ☐ Doors and windows
  - ☐ Door areas, by door type
  - ☐ Measurement of junction gaps
  - ☐ Framing
  - ☐ Door type (swinging/non-swinging)
  - ☐ Window type (fixed/operable)
  - ☐ Window glazing type
  - ☐ Window assembly U-value and solar heat gain coefficient (SHGC)
- ☐ Discuss the estimated load impacts due to excess air leakage

**Design Specifications:**

- ☐ Envelope assembly layers
- ☐ Insulation values (thickness, R-values, type)

**Existing Conditions:**

- ☐ Age and condition of assembly components
- ☐ Ability to perform as designed, sources and corresponding magnitude of inefficiency
- ☐ Floors
  - ☐ Floor area, by construction type and opposing surface
  - ☐ Floor construction
  - ☐ Material layers, framing, insulation type, opposing surfaces (ground, garage, open air, cawlspace, basement)
  - ☐ Insulation thickness, R-value

**Existing Operation/Infiltration Assessment:**

- ☐ High-level assessment (at minimum)
  - ☐ Leaky, average, tight
  - ☐ Visual inspection of envelope component junctions
- ☐ Quantitative assessment (ideally & where feasible)
  - ☐ Blower door testing
  - ☐ Thermal imaging

## Domestic Hot Water

In addition to contributing to full building electrification, incorporating DHW heat pumps could provide an opportunity to balance thermal loads. To explore this possibility, collect the following information about the existing DHW system.

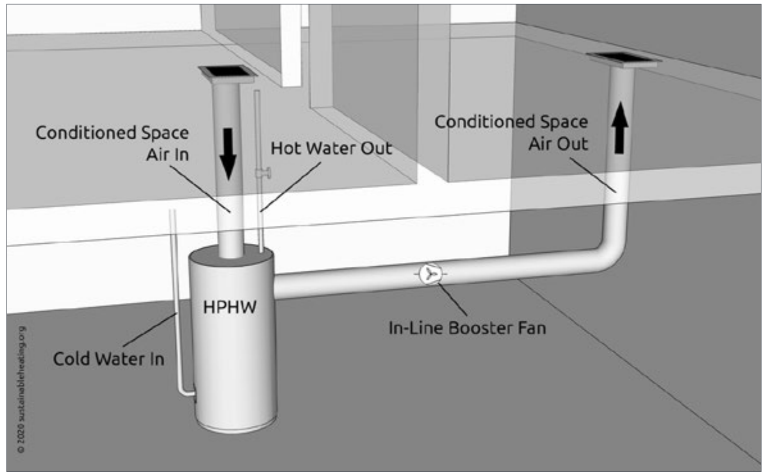


*Image courtesy of sustanableheating.org*

**System Specifications and Operating Parameters:**

- ☐ Loads per existing design
- ☐ Type, configuration, and location
- ☐ Fuel type
- ☐ Storage and input capacities
- ☐ Age and condition
- ☐ Ability to perform as designed
- ☐ Sources and corresponding magnitude of inefficiency

# 2. Measure Candidacy

Comprehensive evaluation of a building's space conditioning and DHW electrification potential is essential to presenting a range of upgrade opportunities to the building owner.

The factors discussed below should be considered throughout the life of the study. They will help guide what types of electrification measures should be analyzed in detail and considered as viable options for design.

Consult the building owner, owner's representative, or other authorized personnel before and after measures are identified. Outline the building owner's goals and document criteria that will impact their decision-making process. When the full range of opportunities are presented, you can work with the owner to establish the most strategic pathways for meeting their objectives.

## Sources and Sinks

Consider what sources and sinks are available for use:

**Earth-Coupled: This is not an exhaustive list**

- ☐ Vertical closed-loop
- ☐ Horizontal closed-loop
- ☐ Standing column
- ☐ Open loop (well water)
- ☐ Surface water (lake, river, etc.)
- ☐ Down-the-hole HX

**Air Source**

**Wastewater and Potable Water**

**Solar PV**

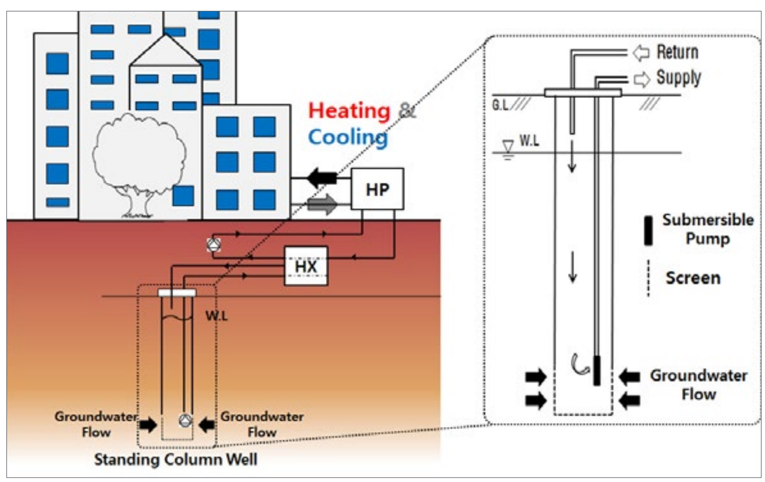


*Image courtesy of MDPI*

## Feasibility Considerations

**Physical:**

- [ ] Adequate space within the building and on roof tops, or on the property for heat pump equipment
- [ ] Adequate space and access for new refrigerant line sets
- [ ] Adequate space for electrical infrastructure
- [ ] Are geothermal wells practical given the building location Test boreholes are recommended when an adequate desk review is not possible.
- [ ] If a new, or upgraded distribution system is required/preferred, is there functional and sufficient space to install it
- [ ] Condensate drain planning required (if applicable)
- [ ] Tenant disruption

**Configuration:**

- [ ] What supply temperatures need to be met to feed the existing distribution system?
- [ ] Will the system be air to air, air to water, water to air, water to water, other?
- [ ] Will the preferred system provide both heating and cooling?
- [ ] If cooling, does the existing distribution method allow for cooling?

**Electrical:**

- [ ] Adequate power (electrical) capacity at the site? Think about the customer's future electrification needs, such as: EV charging, induction cooking, DHW, etc.
- [ ] If a service upgrade appears to be necessary, utility coordination early and often is recommended.
- [ ] Adequate free breaker space at the site?
- [ ] Current power supply (single or three-phase)?

**Regulatory:**

- [ ] Historical preservation regulations (can condensers be placed on the exterior of buildings, are façade alterations or retrofits acceptable, etc.)
- [ ] Noise ordinances and other restrictive regulatory considerations that may limit the use of certain equipment.
- [ ] Permitting considerations for geothermal drilling
- [ ] Greenhouse gas (GHG) and/or carbon reduction commitments/goals

**Economic:**

- [ ] Establish the customer's budget and determine Simple Payback (SP), Net Present Value (NPV), Internal Rate of Return (IRR) and Return on Investment (ROI) thresholds.
- [ ] Shifting utility cost burden from building owners to tenants and vice versa should be thoroughly investigated.

## Measure Evaluation

While not an exhaustive list, it is recommended that the following measures be evaluated as part of an electrification study. By striking measures from this list due to feasibility restrictions you can target the full range of heat pump and heat pump electrification opportunities that should be further analyzed for refined energy savings, financial analysis, and design. As measures are stricken, document the reason for the owner's benefit.

**Envelope Improvements for Load Reduction:**

- [ ] Air sealing
- [ ] Attic/ceiling insulation
- [ ] Wall insulation or floor insulation
- [ ] Window upgrades/replacements (particularly important as the building age increases)

**Ventilation/Exhaust System Enhancements:**

- [ ] Airflow balancing
- [ ] Constant airflow regulators
- [ ] Demand control ventilation (DCV)
- [ ] Energy/heat recovery ventilation
- [ ] Variable speed/frequency control
- [ ] Building energy management systems (BEMS)
- [ ] HVAC controls optimization (e.g. ASHRAE Guideline 36 compliance)
- [ ] System retro-commissioning

**Integrating DHW and heat pumps for:**

- [ ] Energy recovery
- [ ] Thermal storage opportunities
- [ ] Thermal load balancing

**Low-Flow Fixtures to Reduce Hot Water Demand:**

- [ ] Faucet aerators
- [ ] Showerheads
- [ ] Pre-rinse spray valves in commercial kitchens
- [ ] Clothes washers
- [ ] Dishwashers
- [ ] Drain water heat recovery

**HVAC System and Controls Upgrades:**

- [ ] Building energy management systems (BEMS)
- [ ] HVAC controls optimization (e.g., ASHRAE Guideline 36 compliance)
- [ ] System retro-commissioning

**Staff and Occupant Training to Optimize Building/System Operation and Reduce Energy Waste.**

**Onsite Renewables and Energy Storage for the Purposes of Load Shifting and Peak Demand Reduction.**

# 3. Analysis

Detailed analysis of energy and non-energy impacts, and project economics is critical to understanding how electrification and thermal load reduction upgrades will affect buildings. This section will outline the preferred methods for determining those impacts.

## Energy

**Whole Building Simulation Software Modeling:**

To analyze the energy impacts of electrification measures it is recommended to use whole building energy modeling. This approach involves modeling the existing building by creating a pre-retrofit simulation using the existing building data collected in **Step 1: Existing Building Evaluation**, with a reputable whole building simulation software tool.

Whole building energy modeling allows building owners and designers to make informed decisions about the most energy effective measures to implement and shows those measures impact on overall building consumption and savings. It also helps to identify potential issues that may arise when implementing certain energy conservation measures (ECMs), for example:

- If a heat pump is installed, it may require an electric panel upgrade to account for the added electric load.
- Ensure that equipment is sized to meet the buildings' energy needs. Undersized equipment may not provide sufficient heating or cooling, while oversized equipment could lead to higher operational costs.

A whole building energy model often provides a more holistic analysis, but it also provides data for visual comparisons between the existing and proposed building energy consumptions, making it easier to communicate the impact of ECMs to stakeholders.

**When Establishing the Pre-Retrofit Simulation:**

- ☐ Review at a minimum the most recent 12-months of utility bills.
- ☐ Gather metered interval data if available.
- ☐ Develop 8,760 hourly utility use profiles with a minimum of hourly intervals or at more granular intervals if data is available.
- ☐ Develop energy use profiles using BMS/EMS trend data and data captured from loggers as specified in **Step 1: Existing Building Evaluation**.
- ☐ Inputs of the pre- and post-retrofit simulations should be the same unless the related component is specifically addressed by the proposed building improvement.
- ☐ The same operating condition assumptions should be used in both the pre-and post- retrofit simulations unless a change in operating conditions is specifically included as part of the measure.

**Energy Analysis Baseline, Post-Retrofit Simulation:**

Accurate pre-retrofit simulations are critical to providing practical recommendations to building owners.

- ☐ The pre-retrofit simulation should be adjusted using pre-retrofit parameters so that the projected annual energy consumption of each fuel is within an acceptable margin from the annual utility bills. Best practices recommend that the modeled existing energy consumption be within –10% to 0% of the weather normalized utility data. This means the whole-building energy model should not show a higher consumption than the weather-normalized utility data but can show up to 10% less energy consumption.
- ☐ Inputs of the pre-retrofit simulation should be based on information collected in **Step 1: Existing Building Evaluation**.
- ☐ If assumptions are used in the modeling, they should be stated clearly.
- ☐ Energy reduction measures should be evaluated by making changes to the appropriate parameters of the calibrated pre-retrofit simulation. Ideally the simulation software's energy reduction measure tools would be utilized for this (for example, eQuest the "Parametric Runs Tool" should be utilized).
- ☐ The model and savings calculations should be developed using a "stacked" approach, where energy savings begin with the existing components and are gradually transformed into the proposed design adding the energy reduction measures one-by-one. This allows for the analysis of measure interactivity, and the ability to determine each individual proposed measures impacts on the building energy consumption.

**Implementing multiple ECMs in a building retrofit can have several interactive benefits. Some examples below:**

- When improving a buildings envelope (increasing insulation, sealing air leaks, new windows etc.), the need for heating and cooling can be reduced. This would allow for the installation of smaller and more efficient HVAC systems, which could then save on energy costs.
- Window and envelope retrofits reduce air infiltration, so best practices suggest installing a balanced ventilation system after envelope updates to ensure the tighter envelope does not pose indoor air quality concerns (with less airflow due to infiltration).
- Implementing water conservation measures, such as low flow fixtures, can reduce the water usage therefore reducing domestic hot water loads.

**Whole building modeling will show the customer comprehensive impacts of installed measures, including those that may be seen as negative impacts, for example:**

- Heat pumps may add electric loads to buildings.
- LEDs omit less heat so heating loads may increase.
- ENERGY STAR® appliances typically show heating penalties and cooling savings.
- Adding PV on the roof can lower the electric loads but can also increase the structural load on the roof.

## Non-Energy Impacts (NEI) and Economics

Electrification projects are becoming increasingly viable as state and federal incentives increase. When incentives are coupled with quantified benefits of avoided GHG emissions and other non-energy impacts, the case for electrification over business-as-usual becomes even more compelling.

**NEI Evaluation:**

At a minimum and where feasible, the following non-energy impacts should be quantified and/or discussed.

- [ ] Reduced operation & maintenance costs
- [ ] Reduced environmental impacts (avoided GHG emissions)
- [ ] Enhanced occupant comfort
- [ ] Occupant health & safety related to opportunities for increased indoor air quality and no on-site storage and/or combustion of fuels.

**Life Cycle Cost-Benefit Analysis (LCCBA):**

It is recommended when evaluating electrification options that a full LCCBA be conducted. The LCCBA provides a more holistic picture of the electrification project over its lifetime and should include:

- [ ] ROI
- [ ] IRR
- [ ] NPV
- [ ] Consideration of all cost components and adjustments (e.g., incremental costs and estimated incentives) and valuated benefits to provide accurate comparative metrics for evaluating competing ECM alternatives.
- [ ] The societal value of avoided GHG emissions derived from the project.
- [ ] Utility rate escalations/forecasting

**Avoided GHG Emissions:**

When conducting FlexTech building electrification analysis, it is recommended that avoided GHG emissions be quantified and included in the LCCBA. The following emissions factor sources are recommended for electricity and fossil fuels.

**Electric Emissions Factors:**

- ☐ NYSERDA's Projected Emissions Factors for New York Grid Electricity white paper is the recommended source for electricity emissions factors:
  - Section 5 of the publication describes the appropriate recommended use cases. Per Section 5, when evaluating buildings, it is recommended that the Average Emissions factor type be used.
- ☐ The annexed spreadsheet can be used to identify the average emission factor for the region, by year.

**Fossil Fuel Emissions Factors:**

- ☐ NYSERDA's Fossil and Biogenic Fuel Greenhouse Gas Emission Factors white paper is the recommended source for fossil fuel emissions factors

Building owners subject to New York City Local Law 97 should refer to RCNY §103-14 CHAPTER 100 Subchapter C Maintenance of Buildings when calculating emissions.

# 4. Green House Gas (GHG) Economic Impact

After quantifying avoided GHG emissions, it is also recommended to quantify the economic impact of the avoided GHG emissions using the damages-based approach specified in The New York State Department of Environmental Conservation (NYS DEC) Estimating a Value of Carbon guide: https://dec.ny.gov/regulatory/guidance-and-policy-documents/climate-change-guidance-documents.

To learn more about applying value to avoided GHGs, see NYSERDA's Fossil and Biogenic Fuel Greenhouse Gas Emission Factors white paper, Section 4: https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Publications/Energy-Analysis/22-23-Fossil-and-Biogenic-Fuel-Greenhouse-GasEmission-Factors.pdf.