

Where to Target LMI Electrification Upgrades: Gaining Insights from New York Housing Data

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ABSTRACT

New York State's (NYS) 2019 Climate Leadership and Community Protection Act (CLCPA) targets an 85% reduction in economy-wide greenhouse gas emissions by 2050, requiring broad and energy-efficient electrification of space conditioning, water heating, and appliances in buildings. The most promising avenue to efficient electrification, heat pump technology lags significantly in existing building retrofits and must be rapidly scaled to meet emissions reduction targets. In residential buildings, low and moderate-income (LMI) housing stakeholders require careful consideration in state-sponsored electrification approaches due to the potential for burdening LMI households with additional monthly costs resulting from a heat pump retrofit. LMI households represent nearly half the state's population and occupy a similarly large portion of housing units (46% of residences, 33% of square footage, and 62% of multifamily units). Identifying priority segments of LMI housing and targeted strategies to overcome specific barriers to electrification is an urgent task for policymakers, program administrators, and market actors seeking to scale up building decarbonization in NYS.

A New York State Public Authority (New York State Energy Research and Development Authority, NYSEDA) commissioned a study to assist with prioritizing LMI segments best suited for electrification and identifying potential pilot program opportunities to accelerate market scale. The study:

- Built a comprehensive statewide Household and Residential Building Database, derived from 50+ sources, capturing information about NYS's LMI buildings, including physical characteristics, energy characteristics, occupancy, rental/ownership information, and public subsidy information. Where information was not available, predictive models based on known information (derived from building audits) were created to fill gaps in data. The accuracy of these values was enhanced further by using a hierarchical spatial renormalization algorithm.
- Identified specific electrification barriers facing LMI households and building owners, categorized as technical, knowledge/engagement, economic, and policy/institutional.
- Defined building typologies, sourced from database analyses, with characteristics supporting electrification. These typologies were overlaid with an economic analysis of fuel and electrification retrofit costs, to identify building typologies with the most favorable financial results for residents and building owners.
- Developed a set of near-term programmatic offerings and policy changes to advance electrification projects targeting heating and domestic hot water in LMI buildings.

Introduction

In 2019, New York State (NYS) passed the Climate Leadership and Community Protection Act (CLCPA), containing aggressive climate targets. To achieve the climate targets, and specifically, an 85% reduction in greenhouse gas (GHG) emissions by 2050, electrification of heating, domestic hot water (DHW), and appliances (cooking, clothes drying) will be required of all NYS's buildings.

Low and moderate-income (LMI) housing in NYS represents 46% of residential buildings, 33% of residential building square feet, and more than 62% of multifamily (MF) units.¹ Because LMI households represent nearly half the state's population, identifying priority segments and specific strategies to overcome the unique barriers to LMI housing electrification is an urgent task for policymakers, program administrators, and market actors. NYSEDA commissioned this study to prioritize building typologies best suited for electrification and design pilot programs to reach these buildings. To do so, the team performed the following activities (summarized in Figure 1):

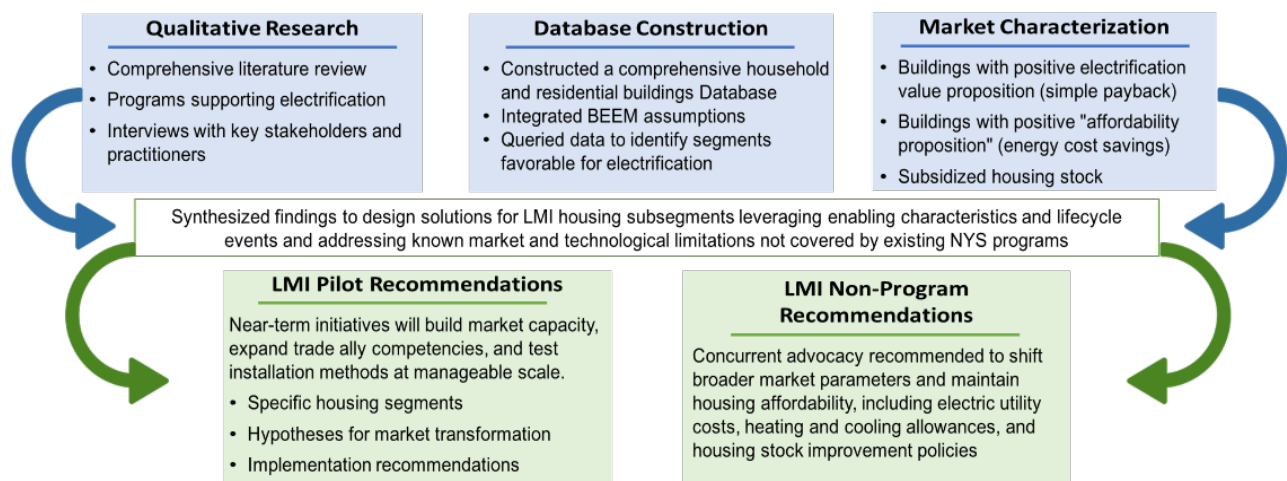


Figure 1. Schematic of research tasks performed. *Source:* Guidehouse.

- Built a comprehensive statewide Household and Residential Building Database (the Database) detailing the LMI sector's building characteristics, including physical characteristics (such as height, size, number of apartments, geography), energy characteristics, (fuel type, heating system type, domestic hot water system type), and whether or not the building is rent-regulated or publicly owned or subsidized.
- Identified specific electrification barriers facing LMI households and building owners, categorized as technical, knowledge/engagement, economic, and policy/institutional.
- Defined building typologies, sourced from database analyses, with characteristics enabling electrification. These typologies were overlaid with an economic analysis of fuel and electrification retrofit costs, to identify building typologies with the most favorable financial results for residents and building owners.
- Proposed solutions mapped to the barriers, leveraging enabling characteristics identified above, with distinctions addressed by building life-cycle events and ownership

¹ As determined through Guidehouse analysis, 2021.

characteristics. Solutions were developed into a set of near-term programmatic offerings and policy changes to advance electrification projects targeting heating and domestic hot water in LMI buildings.

Definitions

- **Low income:** defined as less than or equal to 60% of state median income (SMI).
- **Moderate income:** defined as between 60% and 80% area median income (AMI) or SMI, whichever is higher.
- **Single-family homes:** one-to-four-unit residential buildings.
- **Multifamily buildings:** residential buildings with five or more units.
- **LMI Multifamily buildings:** At least 25% of units are occupied by or designated for income-qualified households. A building with more than 25% low-income units and more than 25% moderate-income units was classified as a low-income building.
- **Heat pumps:** This study considered all forms of heat pumps commonly used for space and/or water conditioning, including mini- and multi-split air-source heat pumps (ASHP), air-to-water heat pumps, and ground-source heat pumps (GSHP) with various distribution configurations including, ductless, ducted, and variable refrigerant flow (VRF).
- **Study team:** led by Guidehouse, in partnership with the Association for Energy Affordability, Taitem Engineering, and Urban Green Council.

Qualitative Research

Qualitative research was conducted to confirm barriers and propose solutions to LMI electrification. The study team compiled an extensive list of electrification barriers, including barriers that apply across the entire residential sector (including non-LMI housing), across the entire LMI sector, or that apply only to a smaller subset of buildings or equipment types. These barriers were extracted through a phased and methodical process to guarantee sufficient breadth, consideration, and relevance:

- **Literature Review.** The study team conducted a review of more than 25 publications to identify barriers impacting LMI electrification. Categorizing barriers helped the study team identify overlap, interrelation, and hierarchy among barriers such as which ones were symptoms of a broader challenge. This initial barrier research-informed stakeholder interview questions and provided context for the pilot recommendations.
- **Northeast Program Research.** To identify potential solutions to overcome identified barriers, the study team reviewed more than 60 Northeast energy efficiency (EE) programs that encourage electrification measures, that are currently active, and are generally publicly accessible. This research surfaced various program characteristics targeting a specific set of barriers to electrification but did not identify a single comprehensive stand-alone electrification initiative, for either LMI or market-rate customers.
- **Industry Stakeholder Interviews.** The study team conducted interviews with representatives of NY's public and private LMI housing entities involved in financing, property development, ownership, management, and environmental justice. The interviews were conducted with people who have first-hand experience with - or have

observed barriers to – successful deployment and use of heat pumps in LMI housing. The interviews built on the literature review’s initial inventory of barriers and provided insight into which should be prioritized for NYSERDA and its partners to address.

- **Team Subject Matter Experts.** The study team was comprised of individuals and their affiliated practices who hold substantial institutional knowledge in the realm of clean energy markets, engineering, program administration, and policy. Their collective input served to affirm, qualify, and enhance Qualitative Research phase results.

Qualitative research identified four categories of barriers with specific relevance to LMI electrification:

- **Technical.** Physical, technological, or engineering barriers to viable heat pump installations including, but not limited to, lack of appropriate technologies to serve specific building use cases, lack of existing electrical service capacity to support electrification, difficult to retrofit existing heating, ventilation, and air conditioning (HVAC) and distribution systems, physical space for heat pump equipment, housing stock quality and deferred maintenance.
- **Knowledge/Engagement.** Low levels of stakeholder awareness, understanding, or involvement in electrification efforts, including, but not limited to institutional inertia and familiarity with fossil-fuel technology, contractors with piping and sheet metal experience rather than heat pump experience, and general lack of awareness of heat pump (HP) technologies and their potential benefits.
- **Economic.** Cost barriers (both monetary and labor resources) associated with implementing HP technologies and/or full electrification, including but not limited to equipment purchase and installation costs, low natural gas prices (compared to electricity), lack of sufficient energy cost savings to offset investment, split incentive issues (where property owners are responsible for building investments, and tenants are responsible for energy costs), and ability to maintain housing affordability.
- **Policy/Institutional.** Policies, or absence of regulation/policy, which prohibit or constrain owners from investing in new heating equipment, including but not limited to utility allowance protocols, access to capital and financing, misaligned fiduciary responsibilities, and submetering.

One common topic that emerged from the team’s qualitative research, and that spanned multiple-barrier categories above, concerns the ability of heat pumps to provide both cooling and heating. HP cooling services will provide physical comfort and health benefits for LMI households whose previous access to cooling was limited. But cooling also adds operational costs with complex implications in the LMI space:

- HP cooling benefits include increased tenant comfort, improved public health and safety during extreme heat events, higher efficiencies than conventional AC window units, and greater utility from less equipment (compared with conventional heating and cooling schemes, e.g., boilers and chillers).

- Heating is a utility required to be provided by NY landlords, while cooling is not.² In most multifamily LMI housing, landlords typically pay heating costs, especially for fuel-based heating (gas, oil), and incorporate these costs when setting rents. A heat pump conversion in such a building leads to difficult questions of cooling cost responsibilities and the overall HP value proposition.
 - There are no NYS policies dictating AC or cooling cost allocation among landlords and tenants
 - Owners providing tenant-controlled heating equipment that can also provide cooling (such as a mini-split heat pump) puts the owner at risk of bearing added operational costs that may jeopardize their business model
 - Currently, cooling costs are not incorporated in NYS Utility Allowance calculations for subsidized income-restricted housing
 - There is no single solution for how to meter heat pump equipment and charge for cooling services that preserve existing cost responsibilities between landlords and tenants

Database Construction

To perform its quantitative analysis of New York’s LMI housing stock, the team first had to create a unified comprehensive residential building Database to serve as the foundation, as no single data source existed covering the entire state. An extensive range of building data sources were sought out, with more than 105 sources ultimately identified, each having its own strengths and weaknesses with respect to data ownership/availability, breadth of coverage, depth of detail, accuracy, timeliness, and format. Sources included census data, agency databases, audit records, commercial databases, and government tax and property records. The Database was created by unifying these multiple sources, coupled with a process to correct and/or predict erroneous and missing data for individual households and buildings.

The construction of the Database was accomplished via the following three-phase process.

Phase 1 – Itemization, Extraction, Vetting, and Unification of Identified Data Sources

Unified data dictionaries were established for a Household Database and a Residential Building Database. Standard record attribute names, definitions, discrete choices, units, and formats were specified for each database. Each data dictionary was keyed by a comprehensive multi-field location definition that included address, building name/number, city, zip code, and county, that was demonstrated to produce, upon geocoding, the geocoordinates associated with the corresponding building geographic information system (GIS) footprint, thus creating an explicit one-to-one relationship between location key and building footprint. Any building unit number supplemented the location key to distinguish units in a multiunit building. Two specific building data sources were identified as primary sources for establishing location key values, as these were deemed most complete and reliable at the time of the analysis: New York City PAD

² If the outdoor temperature falls below 55°F between the hours of six a.m. and ten p.m., each apartment must be heated to a temperature of at least 68°F. If the outdoor temperature falls below 40°F between the hours of ten p.m. and six a.m., each apartment must be heated to a temperature of at least 55°F. NY MDL § 79; NY MRL § 173.

(Property Address Directory) data was used for New York City (NYC) buildings and New York State Tax and Finance data was used for non-NYC buildings.

Values from secondary sources were matched to the primary sources. Records were linked through the use of NYS or NYC standardized building identification (ID) numbers or an advanced fuzzy address matching algorithm and guided by the data dictionaries. These mappings entailed, in some cases, explicit transformations of the field values, such as discrete choice values, value unit conversion, etc., to match the primary data location key structure. Once the mappings and transformations were defined, data from the various data sources were transferred into new unified Household and Building databases. The following were key considerations concerning the data mapping and how these issues were dealt with:

- **Duplicates/Differences.** Values from individual data fields from each source were compared. Exact matches were detected, and duplicates were removed. All different values were retained and evaluated in terms of both “timing” and “distance from one another” – a methodology applicable to numerical and textual values. For timing, the latest value was retained. For distance, a determination was made to either select a single value from the remaining values or create a composite value via a weighted averaging (e.g., weights being tied to the distances).
- **Aggregations.** Records associated with aggregations were not tied to the location key. A unique ID referenced these for the aggregation’s partitions (e.g., census tract, zip code, county, etc.). Using geolocation analysis, each household and each residential building were assigned to each of the aggregation partitions it belongs to, resulting in a one-to-many linkage for each household and building. Set logic was then applied to partition memberships to define overlaps between the aggregations.

Phase 2 – Prediction of LMI Households Via Geospatially Enhanced Machine Learning

There were numerous instances where the required LMI status determination was unavailable in the source data or was of questionable accuracy. In these instances, the LMI status was predicted based on the degree to which a specific household matched/compared to other households designated as LMI by NYSERDA’s rules. This approach required the creation of a probabilistic predictive model that assigned an LMI status to a household with X% certainty. Having established a geocoded database for all NYS households, a machine learning-based model was developed to predict LMI households that were not flagged in the Household Database. The methodology relies on the tendency of LMI households to cluster. At a high level, the methodology is as follows (an example is depicted in Figure 2, a geospatial cluster analysis, where circled regions show predicted LMI regions):

1. The number of flagged LMI households per United States (US) census tract was compared to the census tract total to see what percent of LMI households were flagged for that tract.
2. This flagged household set was split into training and testing sets, with the training set configured to implement a k-fold cross validation mechanism for final model selection.³

³ In some cases, two models were built depending on population size and geography.

- Using the training set, a machine learning-based model was developed to predict the income eligibility of non-flagged households. The model included all available household attributes defined in the unified Household database, as appropriate.
- Once the models were created, the remaining error of the models was input to a geostatistical kriging algorithm to adjust for any spatial patterns in the error.⁴

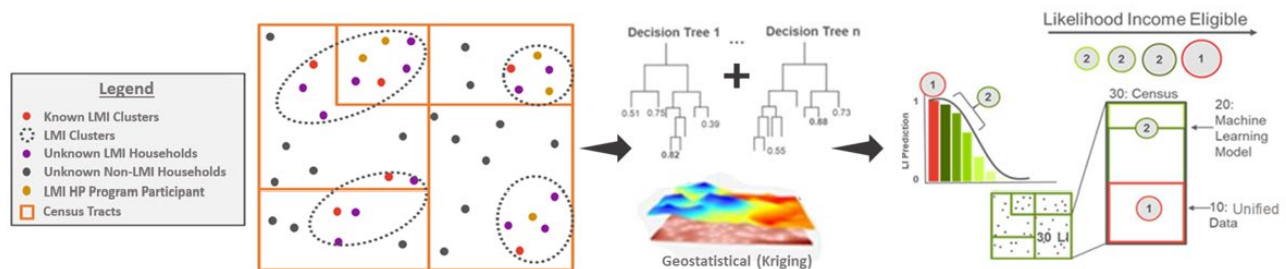


Figure 2. Economic Geospatial Correlations between Households and Low-Income Household Identification Process. Source: Guidehouse 2021.

Once the algorithm was validated with the test set, the model was employed to assign a probabilistic score to each unlabeled household in the unified database, indicating the likelihood that the household is an LMI household. Finally, the low-income flag was assigned to the households which had the highest probability, up until the point where the known-flagged and machine-learning-predicted number of households was equal to the number of LMI households recorded by the US census (per tract); the results were then calibrated using the US census tract data.

Phase 3 – Prediction of Building Type, Physical Characteristics, Ownership, and Economic Classification Via Geospatially Enhanced Machine Learning

A key challenge concerning data available on individual buildings was that most databases did not have information on heating system types, distribution system types, cooling system types, fuels, etc. which was critical to the underlying task of evaluating electrification potential. Audit data made available by both NYSEDA and study team members, in conjunction with data obtained from other sources, was used to drive the development of machine-learning models to predict missing values for key building physical characteristics that would impact building energy consumption and electrification potential. These models' outputs were also coupled with the hierarchical geospatial mosaic methodology. During this task, the team was mindful of the significant bias between NYC samples and non-NYC samples⁵, and the effect that bias would have on the performance of the predictive models. The fields that were prioritized for modeling and prediction are shown in Table 1. Area Under the Curve – Receiver Operating Characteristics (AUC-ROC) were used as model performance metrics.

⁴ Kriging is a statistical interpolation methodology that takes into account spatial covariances to fill in missing information, in this case about LMI housing characteristics.

⁵ NYC data being more complete because of local laws requiring audits.

Table 1. Fields enhanced by predictive models

Field	AUC – ROC	Field	AUC – ROC
Heating fuel type	0.79	Boiler installation date	0.71
Electric metering	0.88	Boiler age range	0.73
Gas metering	0.95	Estimated retirement year	0.73
Heating system type	0.85	Number of cooking appliances*	-
Heating distribution system type	0.94	Type of cooking appliances	0.70
DHW system connection to heating system	0.87	DHW system type	0.96
Boiler capacity (gross BTU)	0.81	Cooling system type	0.94

* There were too few data to build a model for this field, instead, type of appliance and number of units was used.
Source: Guidehouse analysis.

For each modeled field, independent models were developed to produce possible values for the field, along with the probabilities associated with each possible value. For example, for heating system type, the model would predict an 80% chance that the heating system was steam, a 10% chance it was electric, etc. In building the models, cross-validation folds were developed.⁶ This step resulted in 40 to 50 models being built per field. The model that performed the best was identified using the cross-validation folds.

Once predicted values were produced, the study team reviewed the results and assessed whether the resulting building characteristics distributions aligned with their experiences and existing data sources – including NYC LL87⁷ data and NYSEDA’s 2018 New York State Residential Building Stock Assessment. For four fields - (1) heating fuel type, (2) heating system type, (3) cooling system type, and (4) connection to water heating—an additional calibrated distribution was used to supplement the predictive models. The issue for these four fields was likely that the underlying data was biased toward one value or another in the source data, and the source data was a relatively small dataset, resulting in the predictive models exacerbating the biases. There were two steps in the calibration process. The first step was to develop target “distributions” for each field for each building type based on professional judgment using other data sources or expertise. The second step was to convert the target distributions to target counts. For example, if the multifamily building heating system distribution were 20% steam, that would equate to the number of buildings expected to have that system (20% times the total number of buildings in that category). This target was used to fill the buckets for this field until that count was reached.⁸

⁶ k-fold cross validation is a method used to evaluate machine learning models on a limited data sample. The sample is split into k parts and resampled in the model to determine how good the model is in predicting unseen data.

⁷ Local Law 87 (LL87) mandates that buildings over 50,000 gross square feet undergo periodic energy audit and retro-commissioning measures; for more information see [GBEE - Greener, Greater Buildings Plan - LL87: Energy Audits & Retro-commissioning \(nyc.gov\)](https://www.nyc.gov/about/gbep/greener-greater-buildings-plan-ll87-energy-audits-retro-commissioning).

⁸ Note that by applying distributions in this way, the actual heating system for the building in the database could be incorrect, but the overall distribution of heating systems across that building type would be correct.

Market Characterization and Analysis

Once the Database was constructed, the team employed several queries to pull counts of buildings, units, and floor areas for different permutations of building characteristics. The specific permutations chosen were informed by desirable market segmentation views and relevance to engineering and decarbonization analysis. These building characteristics and their associated values are described below:

- **Income-level.** Low, Moderate, Above, or Unknown
- **Region.** Values include NYC or Non-NYC; economic development regions; Downstate (NYC, Westchester, Nassau, and Suffolk County) or Upstate; NYC, Long Island, mid-Hudson Valley, and Upstate; as well as County and Town, more specifically
- **Subsidy Source/Type.** New York City Housing Authority (NYCHA), New York City Department of Housing Preservation and Development (HPD), New York State Homes and Community Renewal (HCR), Department of Housing and Urban Development (HUD), Mitchell-Lama, and/or Department of Finance (DOF). Many buildings may be subsidized by multiple sources.
- **Vintage.** Pre-1940, 1940-1978, 1979-2006, 2007-Present, or Unknown
- **Building Type.** Mobile Home, Single Family, 2-4 Family, Multifamily, or Condominium/Cooperative
- **Building Height.** 1-3 Stories, 4-7 Stories, or 8+ Stories
- **Heating Fuel Type.** Natural Gas, Electric, Oil, Propane/Unknown, or Other (Other includes Dual Fuel, Wood, Geothermal, Coal, or Solar)
- **Heating System Type.** Electric, Furnace, Hot Water, Steam, Heat Pump, or Unknown
- **Cooling System Type.** Central, Chilled, Window, or None
- **DHW Connection.** Yes – Year-Round, Yes – Heating Season Only, No, or Unknown
- **Cooking Type.** Gas, Electric, or Propane

For analysis views, the selection of building characteristics forms a “building typology.” A building typology is defined as a unique set of building characteristics. Table 2 provides an illustrative example of a building typology based on Region, Income Level, Building Type, Heating Fuel Type, Heating System Type, and Height. Each typology can be measured and compared to the rest of the housing stock based on building count, unit count, and/or total floor area. Additional fields and values may be overlaid on this typology, creating sub-permutations that can provide additional analytical insights with increased specificity.

Table 2. Building typology example

Region	Income level	Building type	Heating fuel	Heating system	Height type
NYC	Moderate	Single family	Oil	Hot water	1-3 stories

Source: Guidehouse 2021.

Different permutations of building typologies were leveraged to describe NYS’s residential building stock and characterize the LMI housing market. Figure 3 demonstrates the level of market segmentation granted by varying degrees of specificity and how multiple observations and key insights may be extracted from a strategically-crafted analysis. For example, from this

figure, it is clear that most LMI units are located in NYC, where multifamily is the predominant LMI building type and where natural gas is the predominant heating fuel. These types of simple observations formed the building blocks for later work to prioritize typologies and design programmatic solutions to advance electrification. In this example, the decision to query by unit count rather than building count is also relevant, given that capital investment decisions are typically made on a building level. In the market characterization exercise, queries were generated using both buildings and units as the basis of analysis.

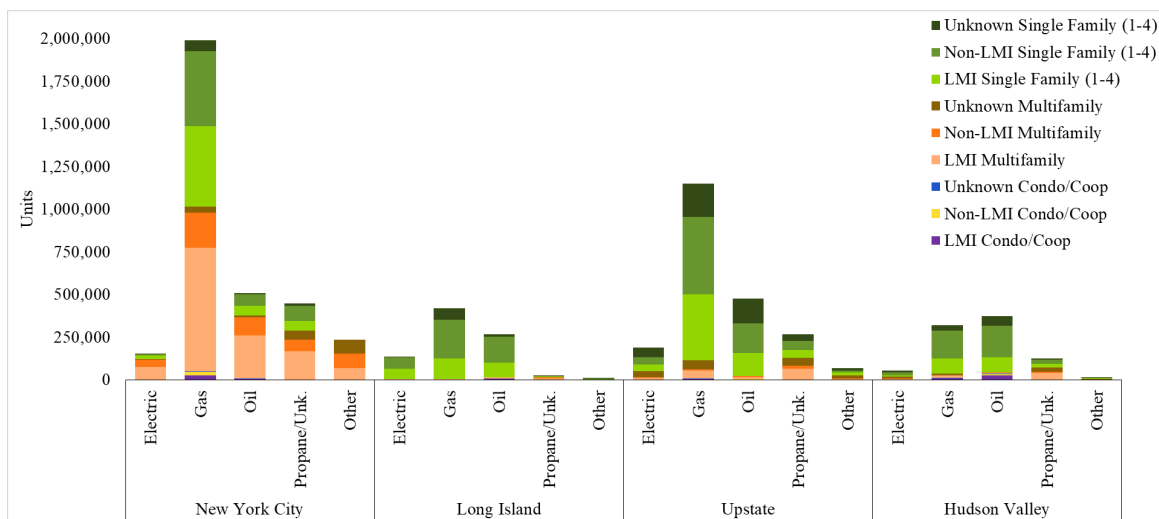


Figure 3. Primary heating fuel type for single family and multifamily buildings of different income types and geographic regions. Other includes dual fuel, wood, geothermal, coal, and solar. Single family includes mobile homes. Source: Guidehouse Database analysis.

Economic and energy use qualities, pulled from existing NYSERDA analyses, were layered onto Database query outputs to analyze, for example, the magnitude of incremental capital investment needed to electrify a specific typology at the point of equipment turnover. This same layering exercise also provided outputs estimating the resultant energy cost savings (positive or negative) resulting from such electrification retrofits.⁹

Table 3 provides a sample of this analysis, where incremental capital expenditure (CAPEX) is the net upfront cost of an air-source heat pump (ASHP) and basic envelope improvement measure, less the upfront cost of the most efficient conventional heating and cooling system available.^{10,11} In this sample, a histogram based on incremental per-unit CAPEX was created, and a cutoff point was set, above which all units would be discarded as outside the desirable range.

⁹ The basis of this analysis is NYSERDA's Building Efficiency and Electrification Model (BEEM) whose underlying data and assumptions are informed by real-world data about project costs and performance.

¹⁰ The upfront costs and energy savings associated with a basic envelope measure were informed by BEEM's Basic Shell package, a modest shell upgrade which includes air sealing, R-13 wall insulation, floor insulation, and R-49 ceiling insulation for pre-1980 buildings, and air sealing and R-49 ceiling insulation for post-1980 buildings.

¹¹ The upfront costs of the most efficient conventional heating and cooling system available was determined by the existing heating fuel type, heating system type, and cooling type present in the building typology.

Table 3. Incremental capital investment needed to weatherize and electrify the portion of NYS LMI building stock that provides energy savings from an ASHP under current market conditions

Region	Building type	Incremental CAPEX/unit cut-off (2021\$)	Units captured in cut-off	% of NYS LMI units captured in cut-off
Non-NYC	Single-family	\$12,250	294,723	9.0%
Non-NYC	Single-family (2-4)	\$8,200	38,828	1.2%
Non-NYC	Multifamily	\$21,900	56,795	1.7%
NYC	Single-family	\$13,150	75,126	2.3%
NYC	Single-family (2-4)	\$10,650	246,398	7.5%
NYC	Multifamily	\$21,950	557,017	17.0%

Non-NYC includes Nassau and Suffolk County, NYC includes all five boroughs. Incremental CAPEX/unit illustrated is the amount necessary to capture 50% of units within each Region-Building Type category that provide energy savings of at least \$20/unit per year. Increments of \$50 were used until representation meets or exceeds 50%. Source: Guidehouse analysis.

The outputs from these analytical processes were used to answer specific questions about key building segments and to prioritize building typologies, such as how many LMI units provide favorable savings at reasonable upfront costs, and what portion of these units are heated by oil versus gas. Prioritized building counts then were compared with the ambition required by NYS decarbonization targets, and segments were identified for pilot opportunities.

Key Findings

Creation of the Database enabled the study team to identify and prioritize electrification-specific aspects of the LMI market that were not previously well understood. The qualitative research, Database analysis, and building typology research were synthesized to develop findings and LMI electrification programmatic recommendations. A mix of program and non-program solutions are recommended to bring NYS's LMI electrification goals to scale.

Synthesis of Research and Analysis

The research and analysis of the Database and the views of the economic aspects of various typologies provide several key insights about how to effectively approach targeting electrification upgrades in LMI housing. Recommendations were formed with these insights:

- **Retrofits.** Energy-only retrofits solely to meet electrification goals are highly unlikely to be driven by energy cost savings under current market conditions. Currently, heat pump and envelope measure project life-cycle costs are favorable only for a small portion of NYS's LMI building stock. Care must be taken to prevent LMI households from experiencing increased energy costs.
- **Affordability.** Maintaining energy affordability for income-eligible households is the most pressing near-term challenge for electrification efforts, due to market installation and fuel costs (low natural gas prices compared to electricity).
 - Near term solutions should prioritize conversions from electric resistance, fuel oil, and propane, whose operational costs are higher than natural gas.

- Long-term affordability solutions will likely require policy and regulatory changes.
- The potential for added upfront and operational costs poses a challenge for affordable housing agencies required to meet specific housing production and preservation targets. Ongoing coordination and innovative approaches will be needed to enable these entities to embrace electrification.
- **Market Opportunity.** Given the economic challenges noted above, strategies are urgently needed that can deliver electrification solutions when a building's existing systems reach the end of useful life, leveraging pre-existing capital plans or unavoidable household investment decision points. Where LMI housing portfolios are overseen by a large corporate or government investor, clean energy programs should seek to understand and leverage those investors' replacement schedules and budgets between now and 2050. For single-family homes and smaller multifamily building owners, program administrators should prepare contractors and solution providers to deliver electrification services at the point of equipment failure.
- **Incentives.** Program designs should assume significant subsidy: LMI property owners and residents will be challenged to fund project costs, and the resulting energy cost savings may not be sufficient to leverage the private financing products currently available in the market.
- **Pilot Opportunities.** Segmentation approaches can serve as the basis for near-term pilot initiatives intended to capture the most cost-effective electrification opportunities that preserve or improve energy affordability for LMI households under today's market conditions. Segmentation-based pilots will also have to address broader barriers to heat pump deployment such as limited market capacity and trade ally competencies. Pilots can help test methods that push beyond these limitations at a manageable scale.
- **Database.** The analytical work made possible by the Database is a valuable tool for program administrators and policymakers, now and in the future. Much additional analysis could be performed beyond what was covered in this project's scope. Maintain and update the Database of NYS residential buildings to provide a strong tool for further identification of electrification opportunities based on market segments and enabling characteristics.

LMI Programmatic Recommendations

To build the foundation for electrification at scale, specific approaches are designed to reach, influence, and electrify single-family homes, mobile homes, and multi-family buildings, both for HVAC and domestic hot water end uses. Recommendations considered quantitative and qualitative insights to deliver a set of solutions for LMI housing subsegments that:

- Prioritize maintaining LMI housing affordability and ensure customers experience net energy cost benefits
- Incorporate the importance of building life-cycle events, prioritizing market opportunities to improve the customer value proposition.
- Leverage enabling characteristics of building typologies and quantitative understanding of market segments
- Overcome LMI electrification barriers and build market capacity

The pilot opportunities illustrated in Table 4 are designed to leverage market opportunities – the time when existing HVAC or water heating equipment has reached the end of its useful life. While these projects will likely still require significant implementation incentives, this approach leverages the fact that building owners will have to make a capital expenditure at this point, regardless of electrification goals. To that end, the study team recommends:

- Developing trade ally support to identify and refer failed fossil fuel and conventional electric resistance heating and domestic water heating systems for heat pump conversions.
- Collaborating with weatherization providers to identify and refer failing fossil fuel and conventional electric resistance heating and domestic water heating systems at the time of weatherization projects.
- Developing account management relationships with subsidized and non-subsidized affordable housing providers and portfolio owners to:
 - Understand subsidy nuances for each agency, develop and maintain a major renovation database, influence project financial / capital planning, facilitate electrification project risk assessments, and influence capital needs assessments
 - Refer projects to existing electrification programs primarily through planned replacement of end-of-life mechanical systems

Table 4. NYS electrification pilot program opportunities

Pilot Opportunities	LMI housing segment (baseline)	% of LMI units	Notes*
Rapid-Response SF Home ASHP Conversions	Upstate (Oil, Propane, Electricity)	6.1%	• Initial offering with propane forced-air; expand baseline fuel eligibility • Sufficient market size to build market capacity, higher upstate concentration • Preliminary pilot propane focus ensures participants receive substantive tangible fuel cost benefits • Pilot program installation costs are manageable (retrofitting fan coil into existing ductwork systems)
Rapid-Response Mobile Home ASHP Conversions	Upstate (Propane)	0.8%	• Preliminary focus: upstate single-family propane heated mobile homes, with hot air furnace / ductwork heating systems • Sufficient market size to build market capacity, higher upstate concentration • Ensures participants receive tangible fuel cost benefits • Pilot program installation costs are manageable (retrofitting fan coil into existing ductwork systems)
MF Gas Conversion Prevention	Un-subsidized non-NYC	3.8%	• Preliminary focus: non-NYC low- and mid-rise MF buildings with electric, propane, or fuel oil heating systems (higher concentration upstate)

	(Oil, Propane, Electricity)		• Sufficient market size to build market capacity • Ensures participants receive tangible fuel cost benefits • Prioritize MF buildings with end-of-life mechanical systems poised for natural gas conversion • Prioritize low- and mid-rise to reflect equipment availability
Account Managers to Identify, Prioritize, and Refer Subsidized MF Housing	Subsidized MF (Oil, Propane, Electricity)	3.9%	• Preliminary focus: subsidized MF housing with non-natural gas-fired heating systems • Account Manager collaboration with subsidized affordable housing providers to identify HP conversion opportunities and influence capital planning decisions • Ensures participants receive tangible fuel cost benefits • Prioritize MF buildings with end-of-life mechanical systems poised for natural gas conversion
LMI Home HPWH Rapid-Response Conversion	Statewide SF (All fuels)	51.0%	• Prioritize homes with existing systems located in basements to manage noise and impacts of winter cooling • Sufficient market size to build market capacity. • Ensures participants receive tangible fuel cost benefits
LMI Low- to Mid-Rise Home HPWH Conversion	Statewide MF (Gas, Oil, Propane, Electricity)	34.0%	• Prioritize buildings with existing systems located in basements to manage noise and impacts of winter cooling • Sufficient market size to test hypothesis • Ensures participants receive tangible fuel cost benefits • Subsidized or unsubsidized housing
LMI high-rise HPWH conversion	Statewide MF (Gas, Oil, Propane, Electricity)	9.2%	• Prioritize buildings with favorable locations for the compressor (penthouse, mechanical rooms, etc.) • Sufficient market size to test hypothesis • Ensures participants receive tangible fuel cost benefits • Subsidized or unsubsidized housing

* Key: Upstate = Non-NYC & Non-Long Island; ASHP = air source heat pump; HPWH = heat pump water heater; SF = single-family; MF = multifamily. *Source:* Guidehouse analysis.

LMI Non-Program Recommendations

The study also identified and confirmed key non-programmatic recommendations to build the foundation required to expand NYS's electrification initiatives. These include:

- **Upstate Data Collection.** Institute upstate building energy use benchmarking and data collection (akin to LL84¹²) to capture more information and enhance quantitative data analysis and programmatic recommendations.

¹² Local Law 84 of NYC (LL84) requires annual benchmarking data to be submitted by owners of buildings with more than 50,000 square feet for public disclosure by May 1, 2022; for more information, see https://www1.nyc.gov/html/gbee/html/plan/ll84_about.shtml.

- **Value Proposition.** Improve value proposition by considering fuel pricing and utility rate signals to align with NYS climate goals. Maintain affordability through the development of favorable LMI high-efficiency heating electric utility rates.
- **Workforce Development.** Provide robust training and knowledge resources to HVAC professionals to: (1) deliver consistent electrification messaging to end-use customers and project residents, (2) identify and refer end-of-life electrification project opportunities, and (3) recommend, design, install and repair electrification technologies.
- **Heat Pump Utility Allowances and Home Energy Assistance Program (HEAP) Benefits.** Design a model approach to heat pump utility allowances for occupants of income-qualified subsidized housing, and work with the state’s HEAP administrators to develop a heat pump benefit tier, to prioritize maintaining LMI housing affordability. Support regional HUD utility cost allowances for LMI cooling, and an HP-based electric heating allowance (compared to the current resistance heat allowance). Test in various building types and fuel cost responsibility configurations.
- **Advocate for Cooling Requirements.** Require landlords to provide cooling systems in LMI buildings, and assist agencies and utilities in incorporating support for cooling costs into existing affordability program rules and structures.
- **Consider Funding Guarantees to Prove Value Proposition.** Guarantee basic value proposition for tenants (no increased housing/energy costs) and property owners (reasonable ROI – return on investment).
- **Housing Stock Quality.** Develop/align program funding sources to support LMI home and building owners who need to make health and safety improvements before electrification is appropriate.
- **Utility Coordination.** Advocate for electric utilities to offer stand-alone electrification services (building service upgrades) to set customer schedule and cost expectations and streamline project timelines and implementation.

Database Construction: Lessons Learned

Based on the experiences gained through the execution of this study, the study team believes a successful, complex data analysis project should include:

- Identifying all existing datasets that are worth considering
- Analyzing and assessing each dataset to determine its relevance, usability, and limitations
- Determining any data gaps and how to address these

For this study, the team found that each of these steps can involve an iterative process, either within or across the steps. Thus, the amount of time and/or effort to produce a viable comprehensive buildings database may require recalibration(s) as the work unfolds.

Future Work to Improve Data Collection and Refinement

Through the course of the study, a number of areas were identified where the data was insufficient or inadequate, which limited the robustness of the analysis. Some of the more prominent areas are listed below. NYS should address these issues with further data enhancements and research projects to position NYSERDA for updating the analysis and programmatic scaling, including:

- Continue inter-agency coordination to true-up housing and building data collection. Inconsistency in subsidy data tracking and recording, and the absence of some subsidized housing from NY Tax and Finance Data limited the team’s ability to articulate strategies for specific state and city agencies.
- Address scarcity of audit data from non-NYC areas of the state, to improve the accuracy of the Database machine learning techniques.
- Enhance Database and predictive models for various fields by enabling access to more audit data from utilities, and increased benchmarking requirements. Collect:
 - Electrical service capacity and configuration (master / individual meter)
 - Fuel type specificity (e.g., natural gas vs. propane fuel)
 - Single-family home specificity: mobile, manufactured, co-op, condo
- Improve ability to parse “Other” fuel type category into its subcomponents, including oil and kerosene, to unlock additional fuel-specific initiatives.

Solution-Focused Research

- Develop method for approximating lot area versus building floor area for ground source heat pump (GSHP) viability
- Determine methods for integrating real-world data granularity to recommend best-fit technology solutions on an individual building basis (e.g., master vs. individual metered, size of existing electrical service and need for electrical panel changeout, roof space, ground area, etc.)
- Plan for medium-term and long-term approaches for electrification through research of the following questions
 - What lenses to use for LMI segment prioritization?
 - How much funding is available and from what sources?
 - At what point will local electric grid impacts need to be addressed?

References

Guidehouse, 2021, unpublished. *Low and Moderate Income (LMI) Electrification Study and Residential Housing Stock Database*. Produced by Guidehouse for NYSERDA.