New York Building Electrification and Decarbonization Costs

June 2022

by:

Kenneth T. Rosen
David Bank
Max Hall
Irina Chernikova
Scott Reed

Rosen Consulting Group
1995 University Avenue
Suite 550
Berkeley, CA 94704
510 549-4510
510 849-1209 fax

www.rosenconsulting.com

DRAFT

Table of Contents

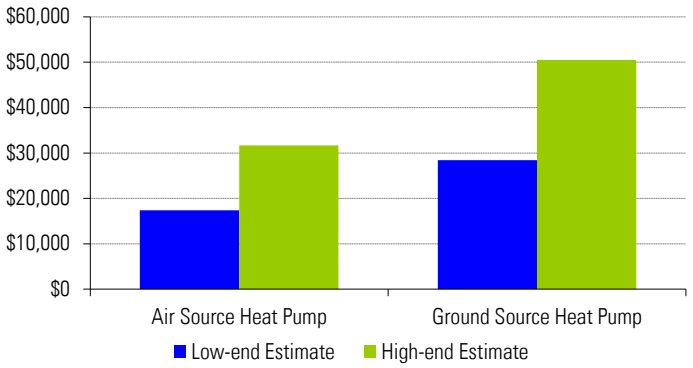
Executive Summary

On behalf of the New York State Association of REALTORS® (NYSAR), Rosen Consulting Group (RCG), conducted an extensive review of existing literature related to building electrification and decarbonization costs, nationally and across different states and markets around the country. Where possible, RCG highlights prior research most relevant to the differing climate zones for Upstate vs. Downstate New York. However, unless otherwise indicated, all RCG estimates should be interpreted as 2022 statewide figures, and do not reflect any rebates or credits, which can vary dramatically.

Upfront Construction and Retrofitting Cost Implications

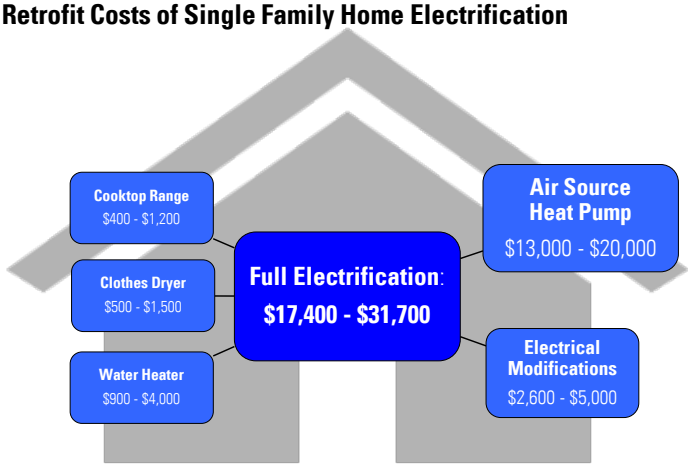
- The overall RCG estimate range for construction and retrofitting costs, based on a review of more than 25 studies, is designed to showcase two of the more distinct options for electrification scenarios, while removing some of the more extreme low-cost and high-cost outliers.
- The low-end range of the RCG estimates generally aligns with a base case, more affordable, or bare minimum level of equipment necessary for all-electric upgrades or new construction, whereas the high-end range generally aligns with higher quality or more energy efficient equipment upgrades.
- **Single Family Homes:** RCG estimates that overall costs to retrofit a typical, existing gas-powered single family home in New York ranges from $17,400 to $31,700, including an air source heat pump, water heater, cooktop range, clothes dryer and electrical modifications.
  - Overall costs to retrofit with a ground source heat pump in New York would be significantly more expensive, ranging from $28,400 to $50,500, including the full set of additional appliances.
  - For new construction, the total construction costs for electrification of new single family homes in New York are estimated to range from $12,000 to $23,000, accounting for an air source heat pump, full range of appliances, labor and infrastructure necessities. Notably, this range represents the full building costs rather than an incremental cost estimate. The incremental costs of electrification within a new construction scenario vs. the cost of gas equipment by NAHB ranged from $3,200 to $12,400 in 2021.
- **Multifamily:** RCG analyzed cost ranges for small, low-rise apartment buildings (small multifamily) with two to 19 units and large, mid- to high-rise apartment buildings (large multifamily) with more than 20 units, including a full set of electrical appliances.
  - For small multifamily buildings, overall costs to retrofit with an air or water source heat pump ranges from $13,000 to $30,100 per unit. Retrofit costs with a ground source heat pump ranges from $29,600 to $42,900 per unit.
  - For large multifamily buildings, generally most relevant for apartment and condominium buildings in Downstate New

RCG Estimate: Cost of Single Family Home Electrification Retrofit



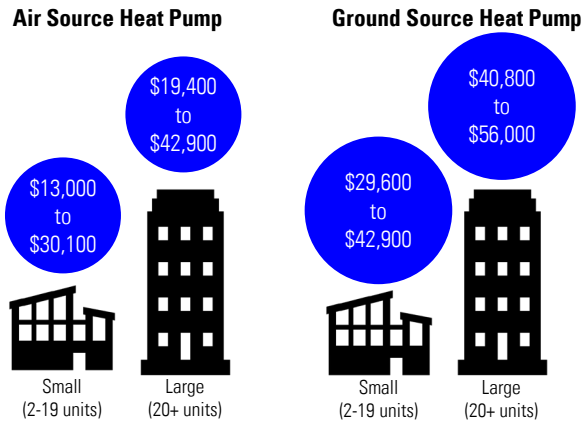
Note: Includes full set of appliances (HP/AC, water heater, clothes dryer, cooktop range) and electrical mod.
Sources: Various studies, RCG

Retrofit Costs of Single Family Home Electrification



Notes: RCG estimates include inflation-adjustment. Ground Source Heat Pump estimate: $24,000 - $38,800
Source: Various studies, RCG

Retrofit Costs of Multifamily Electrification (Per Unit)



Note: Includes full set of appliances (HP/AC, water heater, clothes dryer, cooktop range) and electrical mod.
Sources: Various studies, RCG

York, overall costs to retrofit range from $19,400 to $42,900 per unit with an air or water source heat pump, and from $40,800 to $56,000 per unit with a ground source heat pump.

- **Office:** RCG estimates that overall costs to retrofit a typical gas-powered office building ranges from $12 to $21 per square foot for buildings with air source heat pumps, including heat pump water heaters and necessary infrastructure and electrical upgrades.
  - The comparable overall costs to retrofit with a ground source heat pump would be significantly more expensive, ranging from $17 to $24 per square foot.

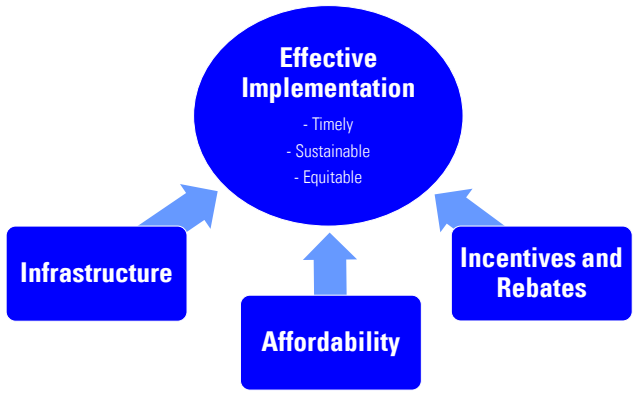
Ongoing Cost Implications

- **Single Family Homes:** For homes that implement relatively standard electrification upgrades with minimal additional efficiency upgrades, the annual energy bill could increase by between $450 and nearly $700, compared with existing gas costs, with an average increase of approximately $570 across the various studies focused on cold weather climates.
  - The increase in cost for homes that undergo more extensive building upgrades, such as equipment with greater efficiency ratings or building shell upgrades, could range from more than $300 to approximately $410 annually, with an average increase of nearly $380 across studies analyzed by RCG.
  - While research was limited, it is quite likely that electrification could generate significant savings for single family homes that use fuels other than gas, such as heating oil or propane.
- **Multifamily and Office:** Comprehensive research regarding the ongoing costs for multifamily and commercial office buildings following electrification was much more limited. According to NYSERDA:
  - A 7-story multifamily building in New York City could save between $500 and $900 per unit annually depending on the fuel currently used, with oil buildings expected to save significantly more than gas buildings.
  - Offices in Downstate New York could save $0.40 per square foot, after converting from gas to electric and making significant shell upgrades in compliance with the New York State Energy Conservation Construction Code.

Policy Considerations

- While there are numerous potential benefits associated with decarbonization, effective implementation will prove crucial to achieving these benefits in a timely, sustainable and equitable way.
- Factors relating to the infrastructure needed to reliably produce and distribute sufficient electricity to support large-scale building electrification, housing affordability and cost burdens, and the financial incentives, subsidies or rebates that may be required to support a transition, were recurring themes that warrant careful consideration. Financial incentives, such as rebates and tax credits, are likely to be key factors in terms of facilitating and expediting adoption of electrical heat pumps and other appliances.

Policy Considerations



Source: Various studies, RCG

Conclusion

While there are many valuable climate benefits that can be achieved through electrification, there are also a wide range of possible costs associated with the electrification of single family homes, multifamily units and commercial buildings. In practice, it is likely that upfront costs could prove very significant for many households and businesses without substantial subsidies. Notably, upfront costs are significantly greater, in many cases, to retrofit an existing home or building compared with the costs associated with new construction. In addition, ongoing energy costs following electrification are more likely to increase for homes currently using gas, but could decrease substantially relative to other fuel sources.

New York Building Electrification and Decarbonization Costs

On behalf of the New York State Association of REALTORS® (NYSAR), Rosen Consulting Group (RCG), conducted an extensive review of existing literature related to building electrification and decarbonization costs, nationally and across different states and markets around the country. Additionally, RCG reviewed drafted proposals by the New York State Climate Action Council, the accompanying detailed integration analysis, as well as the Carbon Neutral Buildings Roadmap from the New York State Energy Research and Development Authority (NYSERDA). RCG identified the most relevant cost studies, with particular attention to appropriate cost estimates based on geographical and weather requirements in order to determine reasonable estimates of costs of electrification across properties types. Where possible, RCG highlights prior research most relevant to the differing climate zones for Upstate vs. Downstate New York. However, unless otherwise indicated, all RCG estimates should be interpreted as statewide figures as of 2022. Notably, estimates do not reflect any rebates or credits, which can vary dramatically by location, utility provider and household income, among other influencing factors.

Cost Methodology and Review of Existing Literature

This report evaluates existing studies, surveys and analyses focused on costs pertaining to electrification and decarbonization in the construction of new buildings and retrofitting of existing buildings. RCG reviewed more than 25 professional studies developed within the past five to ten years and compiled total upfront and ongoing cost breakdowns of the standard products, equipment and infrastructure upgrades needed to transition from existing fossil fuel sources to electrical equivalents. Of the more than 25 studies reviewed, 14 provided methodology sufficiently comparable to be utilized in determining approximate cost ranges for the State of New York as of 2022. Notably, each study had varying degrees of relevant, applicable information and covered different geographies, time frames, property types, types of appliances and options related to the electrification process. As a result, RCG attempted to take a holistic view in capturing reasonable homeowner and commercial costs in New York, rather than focus on any extreme low or high costs that could potentially exist, depending on the exact circumstances of any individual property undergoing the electrification process. In addition to the studies listed below used directly in the cost analysis, RCG incorporated background data and concepts from a range of state and federal government resources, including the U.S. Census (American Community Survey and American Housing Survey), the Bureau of Labor Statistics (Producer Price Index) and NYSERDA (Residential Building Stock Assessment).

Studies Used in This Report

- **Lawrence Berkeley National Laboratory (LBNL, 2018):** provided multifamily cost analysis results from the Sacramento Municipal Utility District (SMUD) within California.
- **MacArthur Foundation (2018):** analyzed multifamily energy costs and savings for four large electrified apartment buildings in Orlando, Florida (Climate Zone 2).
- **Navigant Consulting, Inc. (Navigant, 2018):** studied single family and multifamily new construction and electrification retrofit costs in California. Multifamily costs assumed a low-rise, two-story building with eight units.
- **Rocky Mountain Institute (RMI, 2018):** analyzed the economics and carbon impacts of the electrification of single family residential space, including costs for new construction and home retrofits for various electric rate structures in four locations: Oakland (Climate Zone 3), Houston (Climate Zone 2), Providence (Climate Zone 6) and Chicago (Climate Zone 5). For the purposes of this report, and to address colder climate cost ranges for heating, RCG focused primarily on figures associated with Providence, RI and, to a lesser extent, Chicago, IL.
- **Synapse Energy Economics, Inc. (Synapse, 2018):** estimated costs associated with multifamily electrification retrofit projects in California and policy recommendations to meet statewide goals for reducing greenhouse gas emissions.
- **Energy and Environmental Economics, Inc. (E3 - California, 2019):** analyzed upfront capital costs for electrification, energy bills by source and lifecycle savings between gas-fired and electric technologies for single family homes and low-rise multifamily buildings across six different climate zones in California. For the multifamily cost analysis, the study assumed low-rise buildings with two-to-four units.
- **Steven Winter Associates, Inc. (SWA, 2019):** estimated costs for multifamily building retrofit projects, examining the costs for different heating and cooling systems.

- **Group14 Engineering, PBC (Group14, 2020):** provided estimates of new construction and retrofitting costs for single family and office buildings in Colorado. Cost estimates are analyzed for a 3,077 square foot, two-story home for single family and a 28,000 square foot office.
- **American Council for an Energy-Efficient Economy, New Buildings Institutes (ACEEE, NBI, 2021):** examined utility cost savings and existing efficiency programs and policies for heat pump water heaters for a sample of multifamily units in the Mid-Atlantic and in New England.
- **City of Berkeley (Berkeley, 2021):** analyzed electrification costs related to standard appliance and utility packages, noting incremental capital costs, energy bill savings, and savings with existing financing and incentives in Berkeley, California (Climate Zone 3). Provided cost analyses for single family homes under 1,500 square feet, 1,500 to 3,500 square feet and over 3,500 square feet and multifamily units over and under 1,000 square feet.
- **National Association of Home Builders (NAHB, 2021):** evaluated the cost impact of electrification strategies on new and existing single-family homes, comparing all-electric houses to natural gas equipment and appliances. Single-family new construction and retrofitting was modeled for four locations: Houston (warm climate, Climate Zone 2), Baltimore (mixed climate, Climate Zone 4), Denver (cold climate, Climate Zone 5) and Minneapolis (cold climate, Climate Zone 6). For the purposes of this report, to provide a range of mixed climate and colder climate costs, RCG used figures associated with Baltimore, MD and Minneapolis, MN. From the perspective of climate requirements, cost analysis for Baltimore is most comparable to Downstate New York (Climate Zone 4), while cost analysis for Minneapolis is more comparable to Upstate New York (Climate Zones 5 and 6).
- **Energy and Environmental Economics, Inc. (E3 Integration Analysis, 2021):** summarized, reported and documented the findings, results and methodology of the Integration Analysis developed to support the Climate Action Council in its development of the Draft Scoping Plan pursuant to the Climate Act. Included estimates for single family, multifamily and commercial results in New York State, which varied depending on type of heat pump, as well as the size and exterior of building.
- **New York State Energy Research and Development Authority (NYSERDA, 2021):** Provided modeled scenarios, benefits and challenges for single family homes, multifamily, office, and higher education buildings in New York State, with cost analyses from RMI. Multifamily model based on seven-story building in Climate Zone 4A (Downstate). Single family model based on Climate Zone 6A (Upstate). Office model based on 500,000 square foot, 12-story building in Climate Zone 4A (Downstate). Results varied by type of appliances, exterior or building shells and retrofit or new construction.
- **New Buildings Institute (NBI, 2022):** provided upfront costs, life cycle costs and energy savings for office electrification in Climate Zone 5A.

The studies reviewed for this report utilize a range of methodologies to analyze costs related to electrification, typically using various, specific examples with exact building parameters and appliance specifications. Where appropriate, RCG listed generalized classifications for single family homes, multifamily units and office buildings in the above list of sources. While classifications might not be listed for studies with multiple specific examples, the primary examples and the associated costs are grouped together as ranges in RCG's cost analysis tables. The content of most studies generally included an overview of local electrification efforts at the time of the study, limited cost analyses on retrofitting costs and ongoing energy costs, more thorough analysis of greenhouse gas emissions, and policy recommendations to meet local decarbonization goals. Cost analysis in many studies was limited to a single example of costs for a specific home, multifamily unit or office building, with more exact types of appliance descriptions.

Studies generally concluded that electrification technology is likely to be more cost-effective: 1) in new buildings than in retrofitting existing buildings, 2) for upfront costs of comparable appliances in residential buildings as opposed to commercial buildings, 3) when a single electric heat pump can provide both heating and cooling, 4) where some gas infrastructure retrofit costs can be avoided, and 5) in locations with mild winters. Notably, there was significant concerns within different studies regarding the advanced needs related to infrastructure planning, electricity rate structures designed to encourage electrification, grid capacity improvements and flexibility, technological advancements for appliances and further studies or quantification of the impacts from electrification efforts.

Results for ongoing energy costs were mixed, typically by geography, associated Climate Zones and type of fuel comparison. While more expensive than natural gas alternatives, studies estimated that ongoing costs for electrical appliances were less than appliances fueled by propane or heating oil. Studies indicated greater annual energy bill differences in colder climates when compared with natural gas alternatives. In more mild weather (which would be less applicable in New York), while appliance electrification was generally more expensive than natural gas, some studies concluded that the cost difference would represent only a small percent of the local median

household income. In studies where ongoing energy costs with appliance electrification was less expensive than natural gas alternatives, the energy cost savings were generally considered too small to payback upfront costs over the expected lifetime of appliances.

Many studies recommended a variety of local efforts and policy development prior to large-scale measures to decarbonize buildings. Some studies indicated that electrification technologies would need further development for electrification retrofits to succeed at scale. Increased education of local contractors, prior to the roll-out of policies, as well as increased inventories of necessary systems for the retrofitting process, were encouraged to improve short term efforts. Additionally, development of local rebates, incentives and more targeted support of multifamily and lower-income residents were suggested to offset costs for the most vulnerable households. Lastly, while recognizing the climate benefits of decarbonization and the importance of electrification, some studies noted that such efforts would likely contribute to further weakening of housing affordability.

Cost Methodology

The standard costs for residential properties typically included equipment purchase costs and labor and installation fees for a standard: 1) heat pump, 2) air conditioner, 3) water heater, 4) cooktop range and 5) clothes dryer, as well as underlying electrical upgrades for infrastructure improvements, wiring, valves and other home modifications. The standard costs for commercial properties were limited to the office sector, which typically included more variations in the examined equipment by study, generally grouped as heat pumps or central heating and cooling systems, water heaters and underlying electrical upgrades, typically reported as a per square foot estimate. Each study used a separate methodology to analyze costs, in some cases providing an exact midpoint or average cost related to individual equipment, and in other cases providing ranges across varying options of equipment types or quality. The average cost or cumulative cost ranges for the different types of equipment or upgrades were used to determine the expected ranges for the total upfront costs of electrification used in this report. It is important to note that many households and buildings in New York may have existing electric appliances already installed or in place, particularly electric dryers in single family homes. To account for possible variations in electrification packages needed for retrofitting each home, unit or building, where possible, RCG provided a breakdown of costs associated with each individual appliance or improvement, which can be summed up separately for customized retrofitting. Furthermore, as an additional note, while most studies indicated similar cost ranges for upfront multifamily retrofitting costs, when compared with single family, RCG expects some reduced costs for multifamily units depending on in-house installation capabilities or agreements with local vendors and appliance suppliers, particularly for larger firms most likely to benefit from economies of scale.

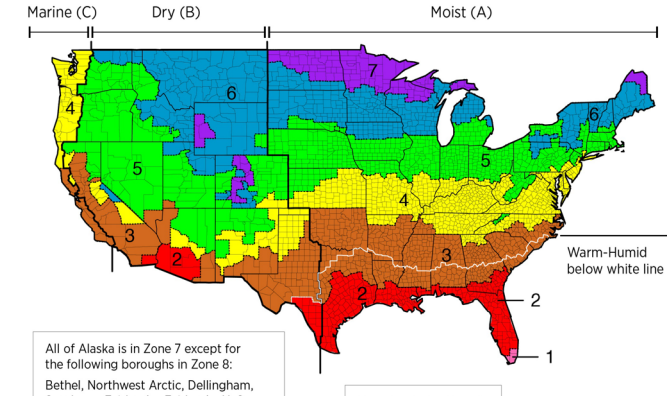
Given the wide range of studies completed at different time periods and focused on different geographies, it was necessary to incorporate some adjustments in order to ensure comparable figures across studies, and to translate the results of our review of existing literature to reasonable estimates for the overall upfront cost in New York, as of the current year. Specifically, RCG incorporated inflation adjustments where necessary, as well as a series of weights based on geographic relevance, in order to best align with the climate zones in New York. Note that adjustments were not made for ongoing costs owing to the limited availability of data and the ongoing (as opposed to point-in-time) nature of these estimates.

- To determine the ranges specific to each type of necessary equipment, RCG adjusted figures for inflation, using the producer price index (PPI) for intermediate demand of materials and components for construction. When not specifically available, RCG assumed the year of data used in the individual studies to be one year prior to the report publication date of the related studies, as contemporaneous cost data would likely be less readily available. To reduce the possibility of overestimating cumulative new construction and retrofit costs, as well as retrofit costs by type of appliance, cost figures for studies released during the current and previous year (within 2021 and 2022), were kept unadjusted.

RCG also utilized climate zones from the International Code Council (ICC) to identify comparable markets within available studies, as well as internal expertise on real estate and housing market conditions, to develop reasonable weights for the low and high cost ranges, considering expected price variations across different geographies and study methodologies. The State of New York is located within three primary climate zones, Climate Zone 4, which represents a mixed climate, and Climate Zones 5 and 6, which represent cold climates. For the purposes of this report, as well as weighting costs for different markets, Downstate New York is located within Climate Zone 4, while Upstate New York is located within Climate Zones 5 and 6.

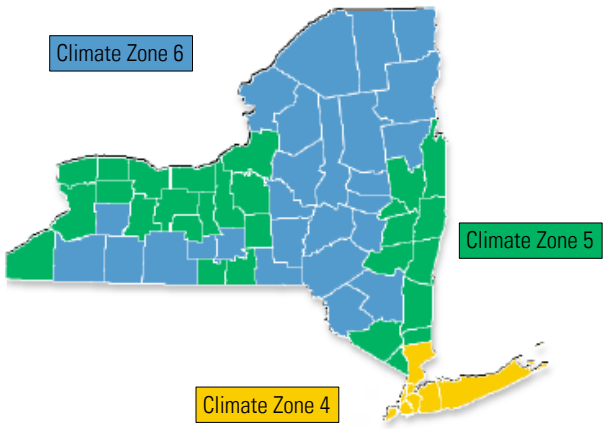
- In determining weights for the overall estimates, the more recent New York-focused studies were prioritized with larger weights. In particular, the E3 integration analysis released in conjunction with the New York State Climate Action Council Draft Scoping Plan, was generally provided the largest weight for cost breakdowns by equipment type, typically ranging from 25% to 50% of the overall estimate.

United States Climate Zone Map



Source: IECC

New York State Climate Zone Map



Source: Open Data NY

- Studies which analyzed geographies with climate zones most similar to New York, were then provided the second largest weight. For instance, within the single family cost analysis, a study by the NAHB provided costs for Baltimore (Climate Zone 4) and Minneapolis (Climate Zone 6), while a study by RMI provided costs for Providence (Climate Zone 6), and to a lesser extent Chicago (Climate Zone 5). While the costs associated with each geography were not one-to-one with New York, these figures helped to guide the expected ranges for New York as it relates to colder climates and pricing for the types of equipment necessary in freezing temperatures. Weights for studies with climate zones comparable to New York were typically weighted in the 15% to 45% range, depending largely on the number of studies reporting costs for each type of equipment needed to transition to all-electric buildings, as the level of detail varied considerably by study.
- The remaining smaller weights used in determining overall costs were generally for California studies, the primary focus for many recent studies, reflecting considerable recent local efforts in California to advance electrification. The smaller weights for individual California studies typically ranged from 5% to 15%.
- In cases where RCG's inflation-adjusted figures for a specific type of equipment exceeded what RCG believed would be appropriate to capture the bare minimum or low-end range of potential overall costs, RCG defaulted to the recent, unadjusted New York estimates from the E3 integration analysis or the NYSERDA study. The use of unadjusted figures for the expected low-range of the overall cost estimates was specifically intended to allow for the possibility of lower cost options and minimize the risk of overstating costs.
- Lastly, when examining the maximum or high-end range of potential overall costs, RCG incorporated moderate adjustments to take into account the rapid surge in construction costs and inflation. Notably, PPI growth for materials and components for construction was recorded at 20.8% through year-end 2021, reflective of significant supply chain disruptions and rising labor costs, energy prices and interest rates. However, as RCG used unadjusted figures for studies released in the past year, manual adjustments were made to the high-end range in instances where there were greater limitations on available data for specific costs, notably for new single family construction.

New York Energy Background

Energy Usage

- As of 2020, there were 7.4 million occupied housing units in New York, which includes all owner- and renter-occupied single family and multifamily housing in the state. Of those 12.5% (925,300) used electricity for house heating fuel, according to the U.S. Census. In comparison, nearly 60% of household used utility gas for home heating (4.4 million), and fuel oil/kerosene accounted for 19.6% of households (1.45 million).
- Reflecting the concentration in multifamily housing, renters in New York were much more likely to use electricity for home heating than homeowners (19.2% vs. 6.8%). However, natural gas utilization was more closely aligned (58.2% of renters vs. 60.3% of homeowners).
- Since 2010, the statewide share of households using electricity for home heating increased from 8.9% to 12.5%, the share using utility gas increased from 53.4% to 59.4%, and the share using oil/kerosene declined from 31.3% to 19.6%

Energy Costs

- As of 2019, the average monthly electricity bill in New York was approximately $110, with approximately 10% of households spending more than $200/month, according to the Census.
- In comparison, while heating costs fluctuate dramatically across the year, the statewide average monthly gas bill was approximately $82 as of 2019, with fewer than 6% of households spending more than $200/month.
- Fuel oil costs averaged $174/month, with 32% of users paying $200 or more per month.
- More broadly, the average annual energy bill in New York was $2,040 as of 2021, according to an analysis by WalletHub.

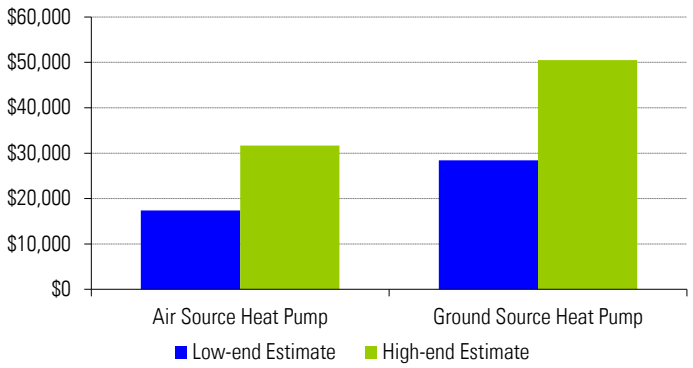
Retrofitting Cost Implications

Throughout this report, RCG uses a variety of ranges to emphasize the variations in options available to households and businesses for electrification purposes, depending on available income and affordability, or expenses able to be allocated to new construction and retrofitting. While individual ranges for heat pumps and other appliances indicate possible costs for numerous types of products, with different levels of efficiency and capabilities, the overall RCG estimate range is designed to showcase two of the more distinct electrification scenarios, while removing some of the extreme low-cost and high-cost outliers. The low-end range of the overall RCG estimate generally aligns with a base case, more affordable, or bare minimum level of equipment necessary for an all-electric upgrade, whereas the high-end range generally aligns with higher quality or more energy efficient equipment upgrades. The high-end range may provide a more comparable level of service and functionality of electrical equipment needed to match or exceed mid- to higher-end gas equipment, and/or to account for older homes that would need much more significant upgrades to accommodate electrical equipment.

Single Family Homes

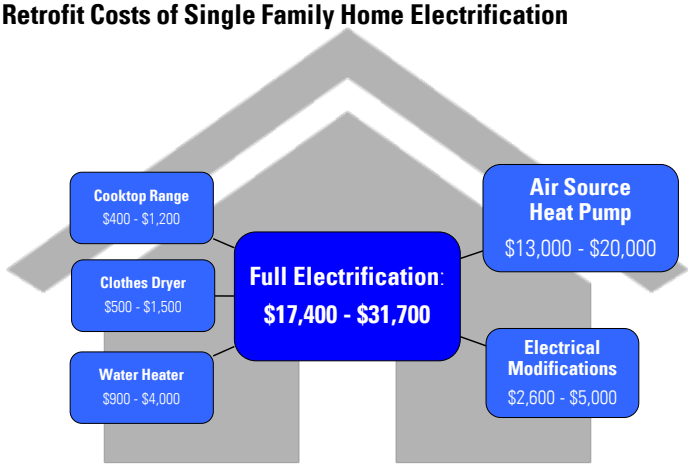
- The costs of retrofitting existing homes in New York to eliminate fossil fuel usage can vary dramatically, influenced by a range of factors including the: 1) existing fuel source; 2) type of heating equipment; 3) age, size and location of the home; and 4) building insulation/thermal envelope.
- In general, the largest components involved in retrofitting a home would be the costs of equipment and installation for replacing the existing heat source and water heater with a heat pump system. Additional costs would apply for households currently using gas for cooking and clothes drying.
- A full set of appliances, where listed throughout this report, consist of a heat pump and/or air conditioner, heat pump water heater, cooktop range and clothes dryer. All studies used in the cost analyses include a heat pump, while many also include an air conditioner. RCG estimates include a full set of appliances and the additional costs of electrical upgrades and modifications.
- RCG estimates that overall costs to retrofit a typical gas-powered single family home in New York ranges from $17,400 to $31,700, including an air source heat pump, water heater, cooktop range, clothes dryer and electrical modifications.

RCG Estimate: Cost of Single Family Home Electrification Retrofit



Note: Includes full set of appliances (HP/AC, water heater, clothes dryer, cooktop range) and electrical mod.
Sources: Various studies, RCG

Retrofit Costs of Single Family Home Electrification



Notes: RCG estimates include inflation-adjustment. Ground Source Heat Pump estimate: $24,000 - $38,800
Source: Various studies, RCG

Retrofit: Costs of Single Family Home Electrification (Total)

Study	Year	Geography	Heat Pump	Standard Range	Includes
Navigant	2018	California	Air Source	$19,000	Full set appliances, electrical mod.
RMI	2018	Providence	Air Source	$10,100 - $25,600	HP AC/WH, energy costs
E3 - California	2019	California	Air Source	$13,800 - $29,900	Full set appliances
Group14	2020	Colorado	Air Source	$20,400	HP AC/WH, electrical mod.
NAHB	2021	Baltimore, Minneapolis	Air Source	$25,000 - $27,100	Full set appliances, gas removal, electrical mod.
E3 Integration Analysis	2021	New York	Air Source	$15,900 - $23,900	Full set appliances
E3 Integration Analysis	2021	New York	Ground Source	$34,600 - $43,300	Full set appliances
NYSERDA	2021	New York	Air Source	$17,600 - $18,500	HP AC/WH only, comfort shell
NYSERDA	2021	New York	Air Source	$48,000	HP AC/WH only, code shell
NYSERDA	2021	New York	Ground Source	$24,000	HP AC/WH only, comfort shell
RCG Estimate (Air)	**2022**	**New York**	**Air Source**	**$17,400 - $31,700**	**Full set appliances, electrical mod.**
RCG Estimate (Ground)	**2022**	**New York**	**Ground Source**	**$28,400 - $50,500**	**Full set appliances, electrical mod.**

Notes: HP - Heat Pump, AC - Air Conditioner, WH - Water Heater; RCG estimates include inflation-adjustments; Full set appliances consists of HP and/or AC, HP WH, cooktop range and clothes dryer; Comfort shell refers to air sealing and attic insulation; Code shell refers to the New York State Energy Conservation Construction Code with more stringent compliance related to walls, roof, windows and air sealing; See additional notes in the Cost Methodology section

Source: RCG

- Overall costs to retrofit with a ground source heat pump in New York would be significantly more expensive, ranging from $28,400 to $50,500, including the full set of additional appliances. Despite the large initial investment, a ground source heat pump is typically more efficient than an air source heat pump, providing greater energy savings over time.
  - Breaking down the costs further, the estimated standard range of retrofit costs for heat pump air conditioners, which account for the largest share of retrofit costs, are estimated at $13,000 to $20,000 for air source heat pumps and $24,000 to $38,800 for ground source heat pumps.
  - The high-end of the range of retrofit costs for additional appliances is estimated at $4,000 for a water heater, $1,200 for a cooktop range and $1,500 for a clothes dryer. However, there are likely many less expensive options for each category. Retrofit costs for an electrical cooktop range, for instance, could cost approximately $400 for standard electric appliances, while a more expensive induction cooktop range, that more closely replicates the performance of a gas range, would be on the higher-end of the range.
- Of particular importance, many older homes would also require significant upgrades to electrical infrastructure in order to support the requirements of adding heat pumps.
  - Retrofit costs related to electrical infrastructure and modification, as well as the associated labor costs, would generally be expected to range from $2,600 to $5,000 for the typical existing gas-powered home. This does not include costs for labor, wiring and other expenses that are specific to individual appliances, which are included in the respective appliance costs highlighted above.
  - While not included in the overall retrofit cost estimates, many residential properties would require the additional installation of an electric vehicle charger circuit, amid the proposed ban on the sale of gas vehicles. Though limited in available research for the purposes of this analysis, the NAHB estimated a standard range of $600 to $2,100 for the addition of an electric vehicle charger circuit as of 2021.

Retrofit: Costs of Single Family Home Electrification (Heat Pump / Air Conditioning)

Study	Year	Geography	Heat Pump	Standard Range
Navigant	2018	California	Air Source	$8,600
RMI	2018	Providence	Air Source	$7,500
E3 - California	2019	California	Air Source	$7,000 - $20,000
Group14	2020	Colorado	Air Source	$15,000
NAHB	2021	Baltimore, Minneapolis	Air Source	$14,500 - $17,100
E3 Integration Analysis	2021	New York	Air Source	$14,100 - $19,400
E3 Integration Analysis	2021	New York	Ground Source	$32,800 - $38,800
RCG Estimate (Air)	**2022**	**New York**	**Air Source**	**$13,000 - $20,000**
RCG Estimate (Ground)	**2022**	**New York**	**Ground Source**	**$24,000 - $38,800**

Notes: RCG estimates include inflation-adjustments; See additional notes in the Cost Methodology section

Source: RCG

Retrofit: Costs of Single Family Home Electrification (Additional Appliances)

Study	Year	Geography	Water Heater	Cooktop Range	Clothes Dryer	Electrical Mod.
Navigant	2018	California	$4,500	$700	$500	$4,700
RMI	2018	Providence	$2,100	n/a	n/a	n/a
E3 - California	2019	California	$3,000 - $4,700	$1,700 - $2,300	$2,100 - $2,900	n/a
Group14	2020	Colorado	$3,300	n/a	n/a	$2,100
NAHB	2021	Baltimore, Minneapolis	$3,500	$700 - $1,100	$1,200	$1,300
E3 Integration Analysis	2021	New York	$900 - $3,300	$400	$500 - $800	n/a
RCG Estimate	**2022**	**New York**	**$900 - $4,000**	**$400 - $1,200**	**$500 - $1,500**	**$2,600 - $5,000**

Notes: RCG estimates include inflation-adjustments; See additional notes in the Cost Methodology section

Source: RCG

- Total retrofit costs in Minneapolis (Climate Zone 6), most similar to Upstate New York, is approximately 8.5% more costly than Baltimore (Climate Zone 4), most similar to Downstate New York, according to NAHB. Additionally, there is a greater incremental cost between climate zones when compared with the cost of retrofitting with gas appliances, with an additional $2,300 cost, on average, in Minneapolis compared with Baltimore, for electrification versus retrofitting with more energy efficient gas appliances.

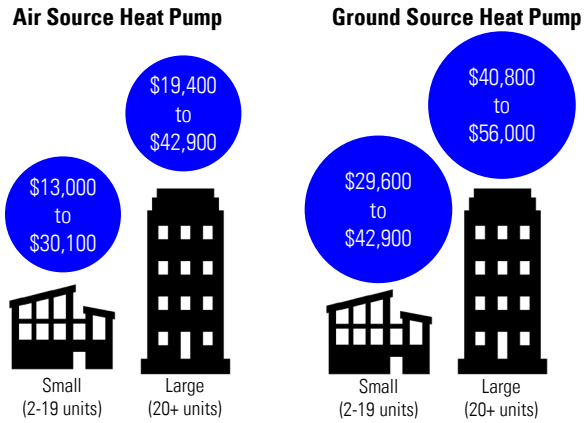
Other Maintenance Costs for Homeowners

- It is helpful to think about the costs of electrification relative to other housing maintenance costs that homeowners typically pay. As of 2019, New York homeowners spent an average of $1,204 in a typical year on routine maintenance costs, with only 12% of homeowners reporting spending more than $2,400, according to the Census.
- Among homeowners doing interior additions and replacements, the average expenditure on HVAC and electrical wiring/fuse boxes/breaker switches additions/replacements was $4,994 and $1,923, respectively, in 2019.

Multifamily

- The costs of retrofitting existing multifamily units in New York varies based on similar cost components as in the case of single family homes, with notable range differences for air and water source vs. ground source heat pumps, as well as by the size of the building or number of units retrofitted. In particular, consistent with the definitions in the most relevant existing studies, RCG analyzed cost ranges for small, low-rise apartment buildings (small multifamily) with two to 19 units and large, mid- to high-rise apartment buildings (large multifamily) with more than 20 units, which are generally most relevant for apartment and condominium buildings in Downstate New York.
- Small Multifamily Buildings:
  - Overall costs per unit to retrofit with an air or water source heat pump in New York ranges from $13,000 to $30,100 per unit. The standard range of retrofit costs for heat pump air conditioners in small buildings, which account for the largest share of retrofit costs, are estimated at $10,400 to $18,800 for air or water source heat pumps.
  - Overall costs per unit to retrofit with a ground source heat pump in New York ranges from $29,600 to $42,900 per unit. As part of these overall costs, the standard range for ground source heat pump air conditioners of small buildings are estimated at $27,000 to $31,600.

Retrofit Costs of Multifamily Electrification (Per Unit)



Note: Includes full set of appliances (HP/AC, water heater, clothes dryer, cooktop range) and electrical mod.
Sources: Various studies, RCG

- Larger Multifamily Buildings:
  - Overall costs per unit to retrofit an air or water source heat pump in New York ranges from $19,400 to $42,900 per unit. The standard range for air or water source heat pump air conditioners of large buildings are estimated at $16,800 to $31,600.
  - Overall costs per unit to retrofit a ground source heat pump in New York ranges from $40,800 to $56,000 per unit. The standard range for ground source heat pump air conditioners in large buildings are estimated at $38,200 to $44,700.

Retrofit: Costs of Multifamily Unit Electrification (Total)

Study	Year	Geography	Heat Pump	Building Size	Standard Range	Includes
LBNL	2018	California	Air Source	n/a	$10,700	Full set appliances, electrical mod.
Navigant	2018	California	Air Source	n/a	$18,800	Full set appliances, electrical mod.
Synapse	2018	California	Air Source	n/a	$8,000 - $10,500	HP AC/WH & Cooktop
E3 - California	2019	California	Air Source	n/a	$13,800 - $29,900	Full set appliances
SWA	2019	National	Air/Water Source	n/a	$6,800 - $16,800	HP AC/WH only
SWA	2019	National	Ground Source	n/a	$30,800	HP AC/WH only
Berkeley	2021	California	Air Source	n/a	$1,300 - $13,000	Full set appliances
E3 Integration Analysis	2021	New York	Air Source	2-19 units	$19,900 - $28,300	Full set appliances
E3 Integration Analysis	2021	New York	Air Source	20+ units	$32,700 - $41,500	Full set appliances
E3 Integration Analysis	2021	New York	Ground Source	2-19 units	$31,400 - $40,100	Full set appliances
E3 Integration Analysis	2021	New York	Ground Source	20+ units	$45,300 - $54,600	Full set appliances
NYSERDA	2021	New York	Air Source	n/a	$2,000 - $21,000	HP AC/WH only
RCG Estimate (Air/Small)	**2022**	**New York**	**Air Source**	**2-19 units**	**$13,000 - $30,100**	**Full set appliances, electrical mod.**
RCG Estimate (Air/Large)	**2022**	**New York**	**Air Source**	**20+ units**	**$19,400 - $42,900**	**Full set appliances, electrical mod.**
RCG Estimate (Ground/Small)	**2022**	**New York**	**Ground Source**	**2-19 units**	**$29,600 - $42,900**	**Full set appliances, electrical mod.**
RCG Estimate (Ground/Large)	**2022**	**New York**	**Ground Source**	**20+ units**	**$40,800 - $56,000**	**Full set appliances, electrical mod.**

Notes: HP - Heat Pump, AC - Air Conditioner, WH - Water Heater; Estimates provided for air source heat pumps; RCG estimates include inflation-adjustments; Full set appliances consists of HP and/or AC, HP WH, cooktop range and clothes dryer; See additional notes in the Cost Methodology section

Source: RCG

Retrofit: Costs of Multifamily Unit Electrification (Heat Pump / Air Conditioning)

Study	Year	Geography	Heat Pump	Building Size	Standard Range
LBNL	2018	California	Air Source	n/a	$5,300
Navigant	2018	California	Air Source	n/a	$8,600
Synapse	2018	California	Air Source	n/a	$3,600 - $6,100
E3 - California	2019	California	Air Source	n/a	$7,000 - $20,000
SWA	2019	National	Air/Water Source	n/a	$5,000 - $15,000
SWA	2019	National	Ground Source	n/a	$29,000
E3 Integration Analysis	2021	New York	Air Source	2-19 units	$13,100 - $18,400
E3 Integration Analysis	2021	New York	Air Source	20+ units	$25,900 - $31,600
E3 Integration Analysis	2021	New York	Ground Source	2-19 units	$24,600 - $30,200
E3 Integration Analysis	2021	New York	Ground Source	20+ units	$38,500 - $44,700
RCG Estimate (Air/Small)	**2022**	**New York**	**Air Source**	**2-19 units**	**$10,400 - $18,800**
RCG Estimate (Air/Large)	**2022**	**New York**	**Air Source**	**20+ units**	**$16,800 - $31,600**
RCG Estimate (Ground/Small)	**2022**	**New York**	**Ground Source**	**2-19 units**	**$27,000 - $31,600**
RCG Estimate (Ground/Large)	**2022**	**New York**	**Ground Source**	**20+ units**	**$38,200 - $44,700**

Notes: RCG estimates include inflation-adjustments; See additional notes in the Cost Methodology section

Source: RCG

- The list of appliances for multifamily buildings are the same as single family homes, with some minor variations in overall costs. The high-end of the range of retrofit costs per unit for additional appliances is estimated at $3,700 for a water heater, $1,200 for a cooktop range and $1,500 for a clothes dryer. However, there are likely many less expensive options for each category.
- Retrofit costs related to electrical infrastructure and modification, as well as the associated labor costs, would generally be expected to range from $800 to $4,900 for the typical existing gas-powered multifamily unit. This does not include costs for labor, wiring and other expenses that are specific to individual appliances, which are included in the respective appliance costs highlighted above.
- As mentioned previously, while most studies indicated similar cost ranges for upfront multifamily retrofitting costs, when compared with single family, RCG expects some reduced costs for multifamily units depending on in-house installation capabilities or agreements with local vendors and appliance suppliers, particularly for larger firms most likely to benefit from economies of scale.

Retrofit: Costs of Multifamily Unit Electrification (Additional Appliances)

Study	Year	Geography	Water Heater	Cooktop Range	Clothes Dryer	Electrical Mod.
LBNL	2018	California	$2,000	$2,000	$900	$600
Navigant	2018	California	$4,500	$700	$500	$4,400
Synapse	2018	California	$2,500	$2,000	n/a	n/a
E3 - California	2019	California	$3,000 - $4,700	$1,700 - $2,300	$2,100 - $2,900	n/a
SWA	2019	National	$1,800	n/a	n/a	n/a
E3 Integration Analysis	2021	New York	$900 - $3,300	$400	$500 - $800	n/a
RCG Estimate	**2022**	**New York**	**$900 - $3,700**	**$400 - $1,200**	**$500 - $1,500**	**$800 - $4,900**

Notes: RCG estimates include inflation-adjustments; See additional notes in the Cost Methodology section

Source: RCG

Retrofit: Costs per Square Foot of Office Building Electrification (Total)

Study	Year	Geography	Heat Pump	Standard Range	Includes
Group14	2020	Colorado	Air Source	$9	HP AC/WH & electrical mod.
E3 Integration Analysis	2021	New York	Air Source	$14 - $20	HP AC/WH, electrical mod.
E3 Integration Analysis	2021	New York	Ground Source	$17 - $23	HP AC/WH, electrical mod.
NYSERDA	2021	New York	Air Source	$9 - $14	HP AC/WH only
NBI	2022	Climate Zone 5A	Air Source	$3	HP AC/WH, electrical mod.
RCG Estimate (Air/Code)	**2022**	**New York**	**Air Source**	**$12 - $21**	**HP AC/WH, electrical mod.**
RCG Estimate (Ground/Code)	**2022**	**New York**	**Ground Source**	**$17 - $24**	**HP AC/WH, electrical mod.**

Notes: HP - Heat Pump, AC - Air Conditioner, WH - Water Heater; RCG estimates include inflation-adjustments; See additional notes in the Cost Methodology section

Source: RCG

Office

- Available information from the studies reviewed by RCG typically only provided retrofitting costs for existing office buildings. Costs for other real estate sectors, including industrial and retail, were generally considered to have too large of a cost range (influenced by a number of highly variable factors such as building size, business and facility type and location) to determine reliable high-level electrification cost estimates.
- With limited research available, RCG analyzed four studies with office-related costs, including data from Group14, the E3 New York Integration Analysis developed to support the Climate Action Council, NYSERDA and NBI. Retrofitting costs, measured as a per square foot cost, vary by air vs. ground source heat pump and by building exterior or shell. Notably, the building exterior was also analyzed in the E3 integration analysis for "reference", "basic" and "deep" shells. In comparison to the minimum, current "reference" exteriors, the amount of energy needed for space heating and cooling would generally decrease for buildings with "basic" and more significant, "deep" upgrades to the building shell.
- RCG estimates that overall costs to retrofit a typical gas-powered office building in New York ranges from $12 to $21 per square foot for buildings with air source heat pumps. The range includes costs for heat pump water heaters and infrastructure and electrical upgrades.
- Overall costs to retrofit with a ground source heat pump in New York would be significantly more expensive, ranging from $17 to $24 per square foot, including costs for heat pump water heater and infrastructure and electrical upgrades.

Retrofit: Costs per Square Foot of Office Building Electrification (Appliances)

Study	Year	Geography	Heat Pump Type	Heat Pump	Water Heater	Electrical Mod.
Group14	2020	Colorado	Air Source	$8	$0.2	$0.1
E3 Integration Analysis	2021	New York	Air Source	$14 - $18	$0.3 - $2.0	n/a
E3 Integration Analysis	2021	New York	Ground Source	$17 - $21	$0.3 - $2.0	n/a
NBI	2022	Climate Zone 5A	Air Source	$2	$0.6	$0.4
RCG Estimate (Air)	**2022**	**New York**	**Air Source**	**$12 - $18**	**$0.3 - $2.0**	**$0.1 - $0.4**
RCG Estimate (Ground)	**2022**	**New York**	**Ground Source**	**$17 - $21**	**$0.3 - $2.0**	**$0.1 - $0.4**

Notes: RCG estimates include inflation-adjustments; See additional notes in the Cost Methodology section

Source: RCG

Retrofit: Costs per Square Foot of Office Building Electrification (Exterior)

Study	Year	Geography	Building Exterior	Costs per Sq. Ft.
E3 Integration Analysis	2021	New York	Reference	$4
E3 Integration Analysis	2021	New York	Basic Shell	$16
E3 Integration Analysis	2021	New York	Deep Shell	$28

Source: E3 Integration Analysis

- Breaking down the costs further, the high-end of the range of retrofit costs for a heat pump water heater is estimated at $2 per square foot, while infrastructure and electrical upgrades are estimated at $0.40 per square foot.
- Lastly, for building exterior, costs for reference, basic and deep shells are estimated at approximately $4, $16 and $28 per square foot, respectively, according to the E3 Integration Analysis.

New Construction Cost Implications

Single Family Homes

- Relative to the cost of retrofitting existing homes, the costs for electrifying new construction is typically more modest, in large part because homebuilders can plan to accommodate the need for electrical infrastructure from the initial building design rather than retrofitting based on existing, often outdated, systems.

Total Construction Cost

- Total construction costs for electrification of new single family homes in New York are estimated to range from $12,000 to $23,000, accounting for an air source heat pump, full range of appliances, labor and infrastructure necessities. However, RCG noted much less available research related to new construction pricing for electrification. Moreover, it is important to note that this range represents the full building costs of utilizing electric infrastructure and appliances in a new build rather than an incremental cost estimate.
- Electrification costs for single family homes, relative to the total construction costs for a new home, represent a relatively moderate share of costs. For example, electrification costs ranging from $12,000 to $23,000 for a new single family home, with an overall construction cost of $500,000, would represent approximately 2.5% to nearly 5.0% of total construction costs.
- For comparison, total construction costs for a standard efficiency gas-powered home was approximately $10,000, according to a recent study from NAHB. Total construction costs for a high efficiency gas-powered home, more comparable to the efficiency of electrical appliances, was approximately $13,000.

Incremental Construction Cost vs. Gas Equipment

- According to the study from NAHB, when compared with construction of a standard, new gas-powered home, the incremental costs of electrification in Minneapolis (Climate Zone 6), the most comparable market in terms of cold climate, ranged from $10,300 to $12,300 in 2021. Incremental costs of electrification in Baltimore (Climate Zone 4), ranged from $3,200 to $12,400 in 2021. This would translate to less than 2.5% of the total construction cost in the $500,000 example highlighted previously.

New Construction: Costs of Single Family Home Electrification

Study	Year	Geography	Standard Range	Includes
Navigant	2018	California	$9,200	Full set appliances, electrical mod.
RMI	2018	Providence	$6,500 - $14,300	HP AC/WH, energy costs
Group14	2020	Colorado	$16,600	HP AC/WH, electrical mod.
NAHB	2021	Baltimore, Minneapolis	$11,300 - $23,000	Full set appliances, electrical mod.
RCG Estimate	**2022**	**New York**	**$12,000 - $23,000**	**Full set appliances, electrical mod.**

Notes: HP - Heat Pump, AC - Air Conditioner, WH - Water Heater; Estimates provided for air source heat pumps; RCG estimates include inflation-adjustments; Full set appliances consists of HP and/or AC, HP WH, cooktop range and clothes dryer; NAHB range provides additional estimates for less costly, minimal efficiency equipment and more costly, high efficiency equipment not included in the incremental cost ranges; See additional notes in the Cost Methodology section

Source: RCG

- Incremental construction costs vs. comparable gas equipment vary further when examining different climate zones, in large part because of the equipment needed to accommodate the requirements of more extreme winter weather. While Baltimore (Climate Zone 4) and Minneapolis (Climate Zone 6) have similar high-end ranges for total and incremental construction costs, Baltimore's low-end range for incremental costs (the minimum necessary costs for a basic level of all-electric equipment) are significantly less than Minneapolis, despite similar construction costs for the gas baseline home.
    - The total low-end range for incremental construction costs in Minneapolis was 184% more costly than Baltimore ($10,900 versus $3,800), while the low-end range for incremental construction costs for heat pumps was 314% more costly than Baltimore ($7,900 versus $1,900), according to NAHB. This data highlights less expensive options for similarly efficient appliances in more mild climates. While these climate zones do, generally, align with the climate zone designations for Downstate vs. Upstate New York, it is notable that the variation in weather, and the likely corresponding cost differential, may be significantly smaller than in the Baltimore vs. Minneapolis example.
- While cost estimates provide a useful indicator of the potential expense for New York homeowners, it is important to recognize that the estimates represent a point in time. In particular, research studies conducted prior to the pandemic would not account for the rapid surge in construction costs, ongoing supply-chain challenges or major shortages of material and skilled labor.
- In fact, according to the Bureau of Labor Statistics, the cost of materials and components for construction (reported as part of the Produce Price Index), increased by 23.3% year-over-year as of March 2022, and was up by 36.6% since February 2020, prior to the pandemic shutdowns.

Ongoing Cost Implications

Single Family Homes

- While research on ongoing energy costs was less exhaustive than studies focused on upfront costs, it is likely that, after retrofitting homes to all-electric systems, energy bills would increase for many single family homes in New York currently using natural gas. The range of costs, however, depend heavily on the quality of equipment installed and whether or not homeowners have already undertaken or pursue other (additional) upgrades to the structure in order to increase the overall energy efficiency of the building.
    - For homes that implement relatively standard electrification upgrades with minimal additional efficiency upgrades, the annual energy bill could increase by between $450 and nearly $700, compared with existing gas costs, with an average increase of approximately $570 across the various studies focused on cold weather climates (Climate Zones 4-6).
    - The increase in cost for homes that undergo more extensive upgrades, such as heat pumps and water heaters with greater efficiency ratings or building shell upgrades, could range from more than $300 to approximately $410 annually, with an average increase of nearly $380 across the studies analyzed by RCG.
- These increases would be significant for single family homes. For example, a $620 increase for a Minnesota single family home would represent a 33% increase in total energy costs, according to NAHB.
    - While in a vastly different climate, analysis by the City of Berkeley (Berkeley, 2021) concluded that the average energy bill would also increase by nearly one-third as a result of basic electrification upgrades. However, the City of Berkeley also noted that with more substantial efficiency upgrades, housing units could save up to $130 annually.

Annual Increase in Energy Costs Due to Electrification for Single Family Homes Relative to Gas

Study	Year	Geography	Significant Upgrades	Minimal Upgrades	Includes
RMI	2018	Providence	$412	$453	HP AC/WH only, existing shell
RMI	2018	Chicago	n/a	$500	HP AC/WH only, existing shell
NYSERDA	2021	Upstate New York	$400	n/a	HP AC/WH only, comfort shell
NAHB	2021	Minneapolis	$322	$622	Full set appliances, existing shell
NBI	2022	Climate Zone 5A	n/a	$620	Full set appliances, existing shell
NAHB	2021	New York City	n/a	$689	Full set appliances, existing shell
Average Increase			**$378**	**$577**	

Notes: HP - Heat Pump, AC - Air Conditioner, WH - Water Heater; Full set appliances consists of HP and/or AC, HP WH, cooktop range and clothes dryer; Comfort shell refers to air sealing and attic insulation; All homes retrofitted from gas; Minimal upgrades includes lowest-efficiency options, often with no upgrades to the building shell; Significant upgrades include more efficient, and often more expensive, systems, as well as building shell upgrades

Source: RCG

- In New York, the average annual energy bill was $2,040 as of 2021, according to an analysis by WalletHub. An increase of 33% in this average energy bill would equate to an increase of approximately $670 annually, which is generally consistent with the incremental cost for homes in New York City, with minimal additional upgrades, according to NAHB.

- In general, prior research highlights that energy bill cost increases were more significant in regions with cold winters. By contrast, regions with warmer climates could attain more significant savings.
  - In particular, single family homes in Houston (Climate Zone 2) and Sacramento (Climate Zone 3) could save between $50 and $240 on utilities annually depending on the retrofit scenario, according to studies by NAHB and Navigant.

- Additionally, in relatively moderate climate regions, the change in annual energy costs could vary significantly. For example, in Baltimore, which is in Climate Zone 4, single family homes with minimal electrification upgrades would pay $240 more per year on energy costs, but homes that make more significant upgrades could achieve savings roughly equivalent to Houston. By comparison, however, at the time of the study, gas was 5% more expensive in New York City than in Baltimore, according to NAHB, and electricity cost 4.6 times as much as gas in New York City vs. only 3.4 times in Baltimore. As a result, the projected increase in energy bills for New York City (also Climate Zone 4) was much greater than in Baltimore.

- While research was limited, it is quite likely that electrification could generate significant savings for single family homes that use fuels other than gas, such as heating oil or propane.
  - An Upstate New York home currently using heating oil could save $1,900 annually on utilities through electrification, based on data collected by NYSERDA.

- It is notable, however, that existing studies do not consider the significant spike in natural gas costs in recent months, nor do these studies account for unknown future changes in electricity costs, especially shifts that could result from major investments in new technology and expanded production capacity. These factors could dramatically alter the above calculations on ongoing costs over time.

Multifamily & Office

- Comprehensive research regarding the ongoing costs for multifamily and commercial office buildings following electrification was much more limited.

- However, it is notable that some available research (most notably research from NYSERDA) suggests potential energy cost savings following significant upfront costs.
  - For example, a 7-story multifamily building in New York City could save between $500 and $900 per unit annually depending on the fuel currently used, with oil buildings expected to save significantly more than gas buildings.
  - While in a much warmer region (Climate Zone 2), electrified multifamily units in Orlando, which also underwent efficiency and shell upgrades, could save between $250 and $500 annually on energy costs as a result of electrification, according to the MacArthur Foundation. These savings represented between 18% and 29% of the total bill. While buildings in warmer climates are generally expected to have larger savings, units in this study were upgraded on a per unit basis, compared with upgrading an entire building, which would typically provide additional efficiency benefits and potential savings beyond upgrading single units.
  - Although, other studies identified more modest savings. For multifamily units in Sacramento, Navigant identified a savings of only $38 per unit in a 7,000 square foot building. The ACEEE, which only examined savings stemming from heat pump water heaters among a sample of units, identified a per-unit savings ranging from $12 in the Mid-Atlantic (which includes New York) to $55 in New England.

NYSERDA: Annual Decrease (Savings) in Energy Cost from Electrification (2021)

Property Type	Savings per unit/sqft.
New York City 7-Story Multifamily	
Gas (per unit)	$500
Oil (per unit)	$900
Downstate 500,000 Sqft. Office	
Code shell (per sqft.)	$0.40
Passive House shell (per sqft.)	$0.50

Notes: Code shell refers to the New York State Energy Conservation Construction Code with stringent compliance related to walls, roof, windows and air sealing; Passive House is a comprehensive standard based on airtightness, ventilation, waterproofing, heating, cooling and electric loads

Sources: NYSERDA, RCG

Annual Decrease (Savings) in Energy Cost Due to Electrification for Multifamily Units Relative to Gas

Study	Year	Geography	Minimal Upgrades	Significant Upgrades	Includes
ACEEE/NBI	2021	Middle Atlantic	$12	n/a	HP WH only, existing shell (full-building)
ACEEE/NBI	2021	New England	$55	n/a	HP WH only, existing shell (full-building)
Navigant	2018	Sacramento	$38	n/a	Full set appliances, existing shell (full-building)
MacArthur Foundation	2017	Orlando	$221	$495	Full set appliances, upgraded shell (single-unit)

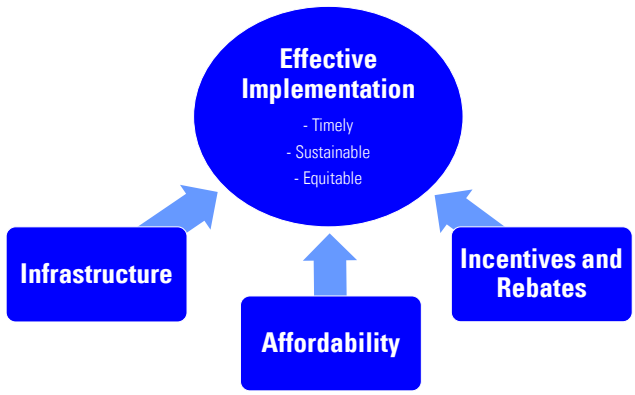
Notes: New York is included in Middle Atlantic. HP - Heat Pump, WH - Water Heater; Full set appliances consists of HP and/or AC, HP WH, cooktop range and clothes dryer; Comfort shell refers to air sealing and attic insulation; All homes retrofitted from gas; Minimal upgrades includes lowest-efficiency options, often with no upgrades to the building shell; Significant upgrades include more efficient, and often more expensive, systems, as well as building shell upgrades
Source: RCG

- The greater financial savings for electrification for multifamily buildings, relative to single family, is not necessarily surprising considering that a much greater share of rental units in the state already use electricity for home heating when compared with homeowners (19.2% vs. 6.8%), a trend that likely reflects the more favorable financial trade-off for ongoing costs, as well as the fact that costs are often passed on to tenants.
- Generally, ongoing energy cost savings could also be significant for retrofitted office buildings.
  - For example, offices in Downstate New York could save $0.40 per square foot, after converting from gas to electric, and making significant shell upgrades in compliance with the New York State Energy Conservation Construction Code according to NYSERDA.
  - Buildings that further increase efficiency using the "Passive House" standard for shell design, could instead save $0.50 per square foot. Passive House is a standard based on stringent airtightness, ventilation, waterproofing, heating, cooling and electric load requirements.
- As with multifamily buildings, significant energy bill savings for office buildings relative to gas are not entirely surprising. Various intrinsic characteristics of office buildings provide benefits for electrification, such as economies of scale for larger and more efficient equipment, and the greater thermal mass of large buildings, which supports load-flattening. Load-flattening involves increasing the energy efficiency of building, reducing energy use for heating and cooling throughout the day (i.e. a surge of heating in the morning; surge in cooling in the middle of the day), which "flattens" the energy load of a building.

Policy Considerations

While there are numerous potential benefits associated with decarbonization, effective implementation will prove crucial to achieving these benefits in a timely, sustainable and equitable way. Beyond the direct costs of electrification for new and existing real estate, many of the studies reviewed as part of the research for this report highlighted additional policy considerations that could prove particularly important in terms of the implementation of building electrification. Of particular note, factors relating to the infrastructure needed to reliably produce and distribute sufficient electricity to support large-scale building electrification, housing affordability and cost burdens, and the financial incentives, subsidies or rebates that may be required to support a transition, were recurring themes that warrant careful consideration.

Policy Considerations



Source: Various studies, RCG

Infrastructure

Prior research studies highlight a number of factors related to electricity infrastructure that are likely to prove critical in order to support building electrification efforts, including challenges related to energy generation capacity, distribution, transmission, storage, reliability and resiliency.

Generation, Distribution and Transmission

- Research from LBNL explains that, "a serious electrification push will impact electricity demand and modify hourly and seasonal load factors…requiring additional generation, transmission and distribution infrastructure, as well as a redesign of programs and incentives for demand-side management."
- Similarly, RMI concluded that, "widespread electrification will add substantial new load to the electricity system, and if not well managed could eventually impose large costs on the electricity system at both the bulk and local levels."
- The City of Berkeley study highlighted the "need to better understand grid impacts, including how future winter and summer peaks compare, load management, amp budgets, solar and storage," as well as preemptively ensuring "that homeowners have sufficient electric panel capacity and available circuitry for appliance fuel switching projects."
- According to Navigant, "research should examine the impacts that appliance electrification initiatives could have on local and statewide electrical grids, residential electric rates, and utility line extension and development costs for builders and the resulting impact on consumers." Additionally, research should be conducted on the interactive effect of a considerable increase in electric vehicle-charging stations in both new and existing neighborhoods.
- According to NYSERDA, while "each pathway results in trade-offs on costs, co-benefits and grid impacts," certain commercial buildings, particularly in multifamily electrification, could provide "significant grid benefits due to higher levels of efficiency and smaller HVAC equipment."

Reliability and Resiliency

- According to LBNL, "in the residential sector, as electric storage becomes increasingly affordable, the combination of electrified heating, solar, and electric storage can offer a long-term hedge against rising fossil fuel prices as well as greater resilience to power outages. Conversely, increased reliance on the electricity grid without an increase in distributed generation sources and/or microgrids could leave customers solely reliant on the electricity grid more vulnerable to power outages."
- As climate change may lead to more extreme weather conditions and blackouts or power shutoffs, the City of Berkeley study highlighted a concern among residents of reliable energy assurance. Many residents questioned in a survey, "felt that having natural gas provided redundancy, even though many natural gas appliances would not work during an electrical outage."

Implementation

- According to RMI, bundling insulation and sealing measures for relatively inefficient homes, especially in colder climates, "will be particularly important to reduce energy from space heating and mitigate the need for costly upgrades to the electric grid to meet increased peak demand."
- Where possible, RCG cost estimates highlighted in this report include both low-end and higher-end cost estimates for the full set of appliances needed to transition to all-electric buildings in order to help capture the range of quality and energy efficiency options available to building owners. However, it is important to consider the trade-offs and infrastructure implications involved in these upfront cost decisions. Research from the City of Berkeley concluded that lower-efficiency appliances, more typical for lower cost retrofit projects, could "minimize upfront costs but have the potential to dramatically increase grid impacts and homeowners' utility bills." In contrast, more costly "higher-performance products can minimize future investments in transmission and distribution infrastructure and mitigate grid load management challenges associated with building electrification."

Affordability

Considering the large upfront costs of electrification, particularly for retrofitting existing single family homes, as well as the potential for increased ongoing electricity costs relative to natural gas, prior research highlights the importance of understanding and mitigating the impacts on housing affordability, equity and the risk of displacement.

Upfront & Ongoing Costs

- As part of the conclusions from a study by Group14, building electrification policies were deemed "most applicable to new construction" of residential and commercial buildings. More significant renovation requirements were considered most applicable to commercial buildings, while "homeowners may not be able to afford the higher first cost or operating costs of heat pump equipment."
- According to the RMI study in 2018, "replacing natural gas furnaces and water heaters with electric heat pump devices is often not cost-effective at today's costs." For most homes using gas, changes to costs would be required for widespread electrification to be a low-cost option.
- RMI further indicated that, "widespread electrification will require some combination of additional cost reductions or increased value propositions to customers," such as a reduction in the price of heat pumps, reduction in contractor price for heat pump installation, improvement in electricity grid demand flexibility or applications of carbon pricing

Low-Income Households and Communities

- According to NYSERDA, "any policy requiring retrofits in low-income households and disadvantaged communities must also mitigate costs and threats to affordability."
- "When developing programs or policies around building electrification," Group 14 noted the importance of considering "equity and the impacts on low-income communities." "The majority of low-income communities are renters and may not have the opportunity to make the conversion to electric space and water heating equipment."
- "Existing low-income housing tends to be older and less energy efficient," according to a study from the City of Berkeley, "placing an unequal energy cost burden on low-income households and households of color who spend larger shares of their income on energy bills." Moreover, "affluent consumers have a greater ability to access existing programs and incentives, which require extra effort, knowledge and access."
- The study from the City of Berkeley further noted that "without adequate time for planning the transition to all-electric buildings, the risk increases for a further divide between those who can afford to electrify and those who cannot, and inadvertent displacement and other negative impacts to the communities that stand to be helped the most through electrification."
- Lastly, the City of Berkeley study also discussed the "need to address the split incentive between landlords, who would have to pay for the upgrades, and tenants, who would benefit from the upgrades but could be pushed out in order for the landlord to recoup costs and increase rents."

State and Local Incentives and Rebates

Consistent with the challenges of affordability related to both the upfront and ongoing costs on electrification, financial incentives, such as rebates and tax credits, are likely to be key factors in terms of facilitating and expediting adoption of electrical heat pumps and other appliances.

Current Incentives

- As of 2022, most rebate programs related to heat pumps in New York were offered through local utilities. This method of rebate distribution is common across the country. NYSERDA also provides a limited number of rebates for other efficiency and shell upgrades for homeowners who meet designated income or geographic criteria.
- The Federal government, also provides a tax credit specifically for ground source heat pumps. This credit is worth 26% of the cost of the device, as well as installation costs, for units put in services between 2019 and year-end 2022, and 22% for units put in service from 2023 through year-end 2024, when the program is set to expire.
- Beyond these programs utilities offer a range of rebates to consumers and contractors, through the NYS Clean Heat program. In most cases, utilities require that a certified contractor installs the system. Rebates can vary significantly depending on the specific house requirements and types of installation, among other qualifying factors.

- In other states, rebate policy regimes, which vary widely, can often be equally segmented between various jurisdictions and offering parties. For instance, various states in the Northeast, such as Massachusetts, Rhode Island and New Hampshire utilize a per ton heating capacity measure (12,000 BTUh = 1 ton), making it difficult to compare rebates. Others states solely offer a per project rebate.
- According to the study by LBNL, "most incentives for heat pump adoption do not specifically encourage the replacement of non-electric units. Rather, they either apply regardless of the technology replaced, or apply only if replacing a unit with a new unit using the same source of fuel. This latter case creates a barrier to electrification." While some utilities in New York State do offer further incentives for replacing old systems, this specific structure of incentives will prove an important implementation factor.
- Overall, while significant rebates may be available for some single family homeowners, it may be difficult to determine exactly what rebates could be achieved without contacting a certified contractor and creating a heat pump retrofit plan. Additionally, many resources for heat pump rebates through the state and various utilities required some level of technical knowledge of heat pump systems and varied significantly in estimates of the potential savings based on inputs, which may prove challenging for customers to estimate accurately.
- For multifamily and office buildings, use cases can vary so dramatically that utilities and the state offer inspection services to assess the appropriate system and potential rebates available to owners. Additionally, rebates figures can differ significantly depending on the utility. Given the range of potential situations, in practice, many businesses may need to hire a consultant to help navigate the potential financial incentives available.

Implementation

- The Draft Scoping Plan published by the New York State Climate Action Council indicates that, "for many customers now heating with low-cost gas… bill savings do not currently offer a clear economic return on investment for adopting a whole-home heat pump." As such, the scoping plan recommends that, "financial incentive programs will need to scale up dramatically to motivate millions of homeowners and building owners to install high efficiency electric heat pumps and make energy efficiency improvements."
- The plan further notes that for low- and moderate income households, "grant funding will need to cover most or all the near-term cost premium for building electrification and efficiency upgrades."
- Research from RMI recommends that policies seek to, "make electrification easier for customers by promoting it through utility marketing, developing a qualified contractor network for simple installation experience, providing standard financing offers, and structuring rebates so customers receive them at point of sale."
- The Draft Scoping Plan also puts forward recommendations to implement a rebate for ground source heat pumps similar in design to the New York Solar Energy System Equipment Credit, which provides a credit of 25% of the cost of the system, or $5,000, whichever is less for primary residences.
- The plan also proposed a "feebate" on fossil fuel heating systems, which would presumably charge a fee on existing fossil fuel systems, and generate revenue to fund a rebate for electrification and heat pumps.

Conclusion

While there are many valuable climate benefits that can be achieved through electrification, there are also a wide range of possible costs associated with the electrification of single family homes, multifamily units and commercial buildings. In practice, it is likely that upfront costs could prove very significant for many households and businesses without substantial subsidies, rebates or other incentives. Additionally, there are a variety of options and other factors, including the type of heat pump, efficiency of devices used, size and age of home or building, existing fuel sources, building exterior and infrastructure required that can translate to large differences in the range of costs for electrification. Notably, upfront costs are significantly greater, in many cases, to retrofit an existing home or building compared with the costs associated with new construction. In addition, ongoing energy costs following electrification are more likely to increase for homes currently using gas, but could decrease substantially relative to other fuel sources. Ongoing costs may also be more likely to generate savings for multifamily and office buildings. Finally, it is important to note that for the purposes of this analysis, estimated costs do not include any rebates or tax credits, which could dramatically reduce the costs for end-users, but can vary significantly by location, utility provider and household income, and are heavily dependent on federal, state and local policies, incentives and future funding.

Sources

Sources Used in the Cost Analysis

- Lawrence Berkeley National Laboratory (LBNL, 2018). "Electrifications of buildings and industry in the United States: Drivers, barriers, prospects and policy approaches."
- MacArthur Foundation (2018). "Cost Savings from Energy Retrofits in Multifamily Buildings."
- Navigant Consulting, Inc. (2018). "Impacts of Residential Appliance Electrification."
- Rocky Mountain Institute (RMI, 2018). "The Economics of Electrifying Buildings: How electric space and water heating supports decarbonization of residential buildings."
- Synapse Energy Economics, Inc. (2018). "Decarbonization of Heating Energy Use in California Buildings: Technology, Markets, Impacts and Policy Solutions."
- Energy and Environmental Economics, Inc. (E3, 2019). "Residential Building Electrification in California: Consumer economics, greenhouse gases and grid impacts."
- Steven Winter Associates, Inc. (SWA, 2019). "Heat Pump Retrofit Strategies for Multifamily Buildings."
- Group14 Engineering, PBC (2020). "Electrification of Commercial and Residential Buildings: An evaluation of the system options, economics, and strategies to achieve electrification of buildings."
- American Council for an Energy-Efficient Economy, New Buildings Institutes (ACEEE, NBI, 2021). "Increasing Sustainability of Multifamily Buildings with Heat Pump Water Heaters."
- City of Berkeley (2021). "Existing Buildings Electrification Strategy."
- National Association of Home Builders (NAHB, 2021). "Cost and Other Implications of Electrification Policies on Residential Construction."
- Energy and Environmental Economics, Inc. (E3, 2021). "New York State Climate Action Council Draft Scoping Plan – Integration Analysis Technical Supplement, Section I, Annex 1: Inputs and Assumptions."
- New York State Energy Research and Development Authority (NYSERDA, 2021). "Carbon Neutral Buildings Roadmap: Achieving a carbon neutral building stock in New York State by 2050."
- New Buildings Institute (NBI, 2022). "Cost Study of the Building Decarbonization Code: An analysis of the incremental first cost and life cycle cost of two common building types."

Additional Sources

- National Renewable Energy Laboratory (NREL, 2017). "Electrification Futures Study: End-Use Electric Technology Cost and Performance Projections through 2050."
- Point Energy Innovations (2017). "UC Carbon Neutral Buildings Cost Study."
- The Cadmus Group LLC (2018). "The Building Electrification Primer for City-Utility Coordination."
- Diversified Energy Specialists (DES, 2019). "Case Study: Massachusetts Air-Source Heat Pump Installations 2014-2019."
- The Brattle Group (2019). "Assessing the Economics of Electrification: Principles and Case Studies."
- City of Palo Alto (2020). "Utilities Advisory Commission Staff Report – Electrification Impact Study: Discussion of Electrification Cost and Staffing Impacts on the City of Palo Alto's Electric and Gas Distribution Systems."
- T2 and Associates (2020). "Cost of Electrification: A State-by-State Analysis and Results."
- Association for Energy Affordability (AEA, 2021). "Accelerating Electrification of California's Multifamily Buildings: Policy Considerations and Technical Guidelines."

- Building Electrification Institute (BEI, 2021). "City Playbooks for the Equitable Electrification of Multifamily Buildings – Playbook 1: Multifamily Electrification Background and Recommendations."
- City and County of San Francisco Board of Supervisors, Budget and Legislative Analyst (2021). "Policy Analysis Report – Re: Decarbonization Residential Buildings by Eliminating Natural Gas Usage."
- Consumer Energy Alliance (CEA, 2021). "Household Impacts of a Natural Gas Ban in New York."
- Energy Innovation: Policy and Technology LLC (2021). "Making Buildings Better: Building Provisions in the Build Back Better Act (House Version)."
- Fresh Energy and Midwest Energy Efficiency Alliance (Fresh Energy, MEEA, 2021). "Electrification of Multifamily Housing in Minnesota: Ensuring an Equitable Approach."
- Master of Public Policy Candidates at the Goldman School of Public Policy (2021). "Electrifying Existing Residential Buildings in Alameda."
- National Bureau of Economic Research (NBER, 2021). "What Matters for Electrification? Evidence from 70 Years of U.S. Home Heating Choices."
- New Buildings Institute (NBI, 2021). "The Building Electrification Technology Roadmap (BETR)."
- Redwood Energy (2021). "A Pocket Guide to All-Electric Retrofits of Single-Family Homes."
- Stanford Woods Institute for the Environment (2021). "The Costs of Building Decarbonization Policy Proposals for California Natural Gas Ratepayers: Identifying Cost-Effective Paths to a Zero Carbon Building Fleet."