The Economics of Electrifying Buildings

Medium-Size Commercial Retrofits

Report / September 2022

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About RMI

RMI is an independent nonprofit founded in 1982 that transforms global energy systems through market-driven solutions to align with a 1.5°C future and secure a clean, prosperous, zero-carbon future for all. We work in the world's most critical geographies and engage businesses, policymakers, communities, and NGOs to identify and scale energy system interventions that will cut greenhouse gas emissions at least 50 percent by 2030. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; and Beijing.

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Executive Summary

The growth of sustainable investing and climate regulations has created a pivotal moment for the US commercial real estate sector. Environmental, social, and governance (ESG) investment criteria are reaching new levels of importance: one major financial survey found that over half of a typical investor's portfolio is with ESG-focused companies and funds.[1] Tenant companies are demanding more concrete actions on sustainability from commercial asset managers and owners — with good reason. Economic and reputational risks are mounting for climate laggards; meanwhile, fossil fuel price volatility reached an all-time high during the pandemic.[2]

While there are far fewer commercial than residential buildings (approximately 5.6 million compared to 140 million), most of these properties are large: over 80% of commercial floor space in the US is in buildings larger than 10,000 square feet, whereas the average new single-family home in 2021 was 2,561 square feet according to NAHB analysis.[3] Commercial properties are more likely than residential buildings to be owned as part of a portfolio, providing more ability to replicate solutions. Therefore, changes to the comparatively small number of large commercial buildings can have an outsized impact on the overall buildings market.

One of the key changes necessary to address climate change is for all buildings to decarbonize their operations (i.e., stop burning fossil fuels on site). In the interest of scaling viable decarbonization solutions for the commercial sector, this report from RMI analyzes electrification conditions for a type of heating, ventilation, and air conditioning (HVAC) system that is ubiquitous in commercial buildings: the rooftop unit (RTU). Currently, heating in conventional RTUs is provided by combusting methane gas, commonly referred to by the fossil fuel industry as natural gas, hereafter referred to as gas. **Commercial electrification using 1:1 swap-outs of gas-fired RTUs for heat-pump RTUs is poised to electrify a vast pool of existing buildings that already use these systems, with limited upfront cost and technical complexity.**

RMI analyzed the technical, economic, and environmental implications of retrofitting fossil-gas-fired space heating and domestic hot water systems in a prototypical 50,000 square foot office building (considered medium sized). We compared a range of system decarbonization scenarios to a conventional gas-fired system replacement. Domestic hot water was electrified using a tanked heat pump water heater. For space heating, a range of scenarios were tested, including partially and fully electrified heat-pump RTUs. Finally, a combination of energy recovery ventilation (ERV), peak heating demand management, and on-site solar photovoltaics (PV) were analyzed in combination with an all-electric heat pump to understand the implications of streamlined, packaged decarbonization retrofits.

Our results show that regional climate conditions and gas utility rates are primary drivers of the economics of decarbonization retrofits in the commercial sector. **Medium-size commercial electrification retrofits can be cost-effective when paired with a suite of other energy retrofit measures and are likely to become more economical with increased policy changes across states and at the federal level.**

Additional findings include the following:

- A full decarbonization package — including efficiency, electrification, winter heating peak demand management, and solar PV — offers a neutral or positive 20-year net present value (NPV) in nearly all of the studied regions. The exception is Seattle, where a straightforward 1:1 equipment swap-out is most cost-efficient due to the temperate climate and limited solar availability. The economic value of a rooftop solar installation, in particular, should be leveraged to improve the economics of commercial building electrification. Through holistic system decarbonization packages, building owners can achieve robust, long-term carbon and cost savings, while streamlining capital investments and project delivery into a single intervention point.

- Building owners in cold-winter climates, such as Washington, D.C., and Chicago, can achieve a comparable or positive 20-year NPV, depending on electric utility rate design and gas tariffs, by packaging heat-pump RTU retrofits with ventilation efficiency, such as ERV, and peak heating demand management controls. **This package of measures will lower monthly utility costs and enhance power grid resiliency, especially at times when the grid is strained.** Policymakers should engage with utility providers to unlock incentive or rebate funding streams to enable these efficient electrification packages for commercial buildings.

- In temperate climates such as Seattle and Las Vegas, 1:1 swap-outs of gas-fired RTUs with fully electric heat-pump RTUs show comparable 20-year NPVs, between −$20,000 and $5,000 depending on gas rates. ERV and winter peak demand management do not improve the economics of electrification, although these remain valuable tools to enhance building performance and mitigate peak loads. For example, using peak demand management controls during rare extreme cold weather events will minimize strain on the grid, providing value to the electric utility. Policymakers and utilities can help building owners through utility rate pilots that are designed for all-electric customers. Utilities should further study grid capacity constraints to understand the implications of electrification at scale, especially if stand-alone electrification upgrades, without additional efficiency measures, are pursued by building owners.

- Policymakers can advance electrification retrofits of packaged rooftop systems in the commercial sector by supporting market development for these emerging systems. Economic development initiatives, including installer workforce training and supply chain support, can increase product access and choice for consumers. In addition, using public sector buildings to pilot these retrofits and conduct performance testing during the post-occupancy period will support market confidence in these technologies while stimulating demand for heat-pump RTUs.

Introduction

Commercial buildings, including business, educational, and retail facilities, generate 16% of energy-related CO_2 emissions in the United States, and about half of the total emissions from the building sector. The building sector accounts for 36% of total energy related CO_2 emissions in the United States, making it one of the highest emitting sectors. Direct fossil fuel combustion in commercial buildings alone accounts for 5% of total energy related CO_2 emissions in the country.[4] Eliminating fossil fuel systems from commercial buildings is key to unlocking a carbon-neutral building sector and achieving US climate targets. All-electric heating, ventilation, and air conditioning (HVAC), domestic hot water (DHW), and cooking systems enable higher-performing and carbon-free buildings as deployment of renewable energy generation resources accelerates and cleans up the electricity grid.

Leading commercial building developers, mechanical designers, and architects have demonstrated the viability of all-electric commercial buildings through a growing number of new construction projects over the past decade. These include the Adobe North Tower in San Jose, the JPMorgan headquarters project in New York City, and the One Boston Wharf Road project in Boston's Seaport District[5] — just a small sampling of buildings that have increased the confidence of policymakers to set a strong electrification agenda for new commercial construction.

All-electric building requirements are on the horizon in several states and municipalities. For example, New York City, America's largest city, passed a landmark bill in 2021 that requires new buildings to be free of fossil fuels, including natural gas (hereafter gas), starting in 2024. San Francisco's All-Electric New Construction Ordinance mandates electrification of all space heating and domestic hot water equipment in new buildings.[6] The State of Washington passed an update to the State Energy Code that will require efficient, all-electric space heating and domestic hot water for most new commercial and multifamily buildings taller than four stories;[7] many other state and local governments across the country are pursuing similar building electrification policies.

Another critical step is the electrification of heating equipment in existing commercial buildings. While residential electrification has gained momentum, the fragmented commercial market continues to grapple with fundamental questions of technical feasibility, cost, and value. Some building industry professionals perceive, inaccurately, that standardized electrification solutions are not an option for commercial buildings because each requires a custom design. However, the majority of commercial building HVAC and hot water systems fit one of a relatively small number of system types, and this presents a ripe opportunity for sector-wide decarbonization and improved building performance. The US Energy Information Administration collects data on common system types as part of the Commercial Building Energy Consumption Survey; its data supports this assertion.[8]

A packaged rooftop system is a type of HVAC system that contains all the necessary components in a single unit to provide conditioned air to a building. These packaged units are ubiquitous in small- to medium-sized commercial office buildings (10,000–100,000 square feet), which are prevalent in the commercial sector. Given their significant market share, these packaged systems offer a great opportunity to achieve robust and scalable commercial building electrification. Emerging packaged rooftop unit (RTU) heat-pump systems offer a replicable model for a 1:1 equipment swap-out that will electrify these buildings with limited upfront cost and technical complexity.

Our analysis investigates the technical (i.e., energy impacts), economic, and environmental (i.e., carbon emissions impacts) aspects of electrifying existing commercial space heating and domestic hot water systems in four US cities: Washington, D.C., Chicago, Seattle, and Las Vegas. These cities were selected based on their varying winter conditions — ranging from the harsh cold of Chicago to the milder conditions of Las Vegas — and the differences in their gas and electric utility rates.

An Opportunity to Decarbonize

The Commercial Building Sector

Electrification in the commercial sector presents a valuable decarbonization opportunity, as its substantial square footage and emissions footprint is distributed over fewer, larger individual buildings than the residential sector, 5.6 million compared to 140 million.[9] **Buildings exceeding 10,000 square feet account for 82% of the total commercial floor space in the United States, so targeting these buildings for electrification will have an outsized impact on reducing carbon emissions.**

The commercial sector contains a wide range of buildings with a diverse set of primary use types, including food service, storage, retail, religious worship, public assembly, education, and office work. The economic and technical conditions for electrifying these buildings vary considerably. The 2018 Commercial Building Energy Consumption Survey found that office space comprised 17% of US commercial floor space, warehouse and storage 18%, education 14%, and retail 11%.[10] Commercial office space was chosen as the focus of this study, because it is one of the largest building use categories and has complex space conditioning criteria. Warehouse and storage buildings, while large in total area, have simpler mechanical system configurations and should be studied separately.

Further segmentation of the commercial office market is necessary to distinguish between large office buildings, where customized decarbonization solutions are needed, and small- to medium-sized buildings (<100,000 square feet), where packaged mechanical systems can be targeted for cost-effective all-electric equipment swap-outs. Of commercial office floor space, 48% is in buildings with an area of 10,000–100,000 square feet, making this a priority target for electrification.

Market Insights on Commercial Electrification

Before developing this analysis, RMI conducted interviews with policymakers and building industry stakeholders to gather key market insights on the current state of commercial building electrification. RMI's analysis of this input identified several perceived barriers to electrification:

- **A proof-of-concept demonstration of commercial building electrification is needed** to demonstrate the feasibility, value, and path to achieving efficient electrification in commercial buildings. Both policy and industry stakeholders expressed a need for such a "sales pitch."

- **There is a lack of clarity about how efficiency projects tie into electrification.** Policy and utility players did not have a clear strategy for communicating and demonstrating the link between these two efforts. Building owners think about efficiency projects on annual maintenance cycles, but they see electrification projects as major upfront investments during asset repositioning.

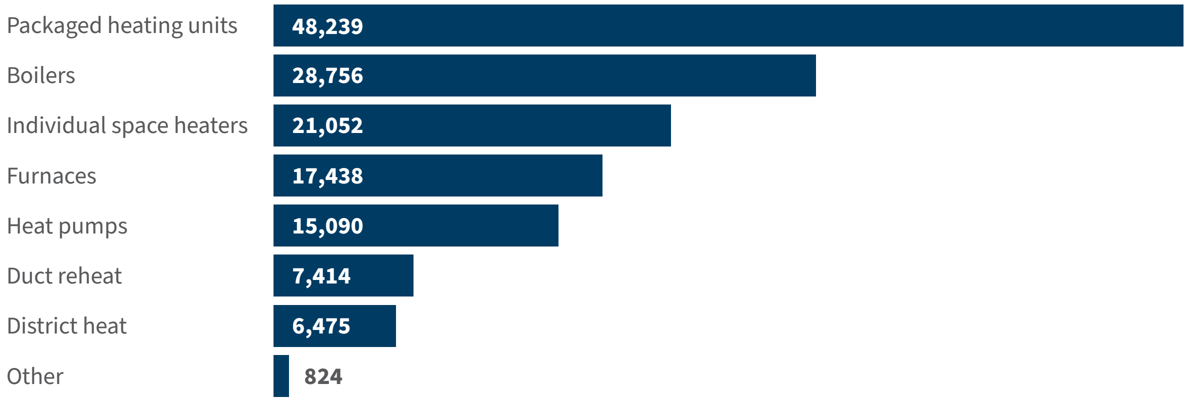
- **For electrification, policy mandates will drive action.** Policy and industry stakeholders expressed the view that a key factor driving owners to pursue electrification is the presence or expectation of local policy requirements that will leave portfolio owners with stranded assets unless they undertake electrification.

- **Policymakers have some consensus on electrification priorities.** A variety of public policy mechanisms to promote commercial building electrification were mentioned. However, there was some consensus that requiring carbon assessments and setting building performance standards (BPS) are key levers to nudge owners. Prescriptive criteria and tightened language around electrification will be required to avoid owners using offsets or cheaper investments to meet BPS on paper only.

- **Policymakers need resources to communicate with one another and with building owners.** They asked for a clear narrative and quantitative information to explain why they should push for commercial building electrification and what this means for building projects and the industry. Examples of such resources include a guide that can be delivered to building developers during planning meetings, and information on workforce training to offer during policy discussions with labor groups.

- **Stakeholder misconceptions regarding operational costs and return on investment (ROI) need to be corrected.** Both policy and building owner groups expressed the perception that in many cases commercial building electrification will lead to operational cost increases that must be mitigated through complementary efficiency and peak demand management technologies or new utility rate designs.

Exhibit 1 **Total US commercial floor space served by common heating systems (million square feet)**



Source: Commercial Building Energy Consumption Survey, 2018

A Prototypical Mechanical System in a Diverse Sector

US commercial buildings use a variety of space heating systems (Exhibit 1). The mechanical equipment for these falls into three broad categories:

- Packaged unitary systems that serve single zones or multiple small zones (around 20% of commercial floor space)
- Packaged rooftop systems that serve whole floors or small buildings, with a portion having zone-level duct reheat (around 50% of commercial floor space)
- Centralized systems in which equipment such as a boiler or central heat pump charges hot water, steam, or refrigerant for distribution to supporting terminal heat emitters (around 30% of commercial floor space)

Packaged rooftop systems are typically installed in small- to medium-sized commercial buildings. Given their market share, they should be a target for robust and scalable commercial building electrification. Emerging packaged RTU heat-pump systems offer a replicable model for 1:1 equipment swap-out that will electrify this building system typology with limited upfront cost and technical complexity.

Heat Pump Rooftop Units

Packaged RTUs are air-handling units (AHUs) that include both the heating and cooling components to produce conditioned air within one integrated cabinet. Unconditioned air passes through heating and/or cooling coils and is then delivered via ductwork to different thermal zones to meet the thermal comfort and ventilation requirements of interior spaces. Commercial buildings have minimum ventilation requirements, such as those specified by ASHRAE Standard 62.1.[11] As such, packaged central air systems are a common configuration across the commercial sector — in industrial and retail facilities, schools, and medium-sized office buildings.

Packaged RTUs offer an advantageous solution for many building owners because they contain all components in one unit, reducing space needs and maintenance complexity. They are, however, not typically used in large commercial buildings. In these buildings, it is more efficient for central thermal plants to produce hot and chilled water, which is then delivered to AHUs that contain heating and cooling coils.

In many buildings, the packaged RTU is paired with variable air volume (VAV) terminal units with electric resistance reheat, which provides zone-level thermal control. Packaged RTUs can also be paired with perimeter fan-coil units that provide in-room heating separately from mechanical ventilation. The current industry standard RTUs provide space heating by burning gas. Combustion efficiency is around 80% for these units,[12] though models are available that can achieve more than 90% efficiency. While most installed RTUs are conventional models, energy-savvy portfolio owners are increasingly adopting high-efficiency models and RTUs that are coupled with energy recovery ventilation (ERV), which recovers up to 70% of heat energy from the exhaust air stream.

Leading HVAC equipment manufacturers now offer electric heat-pump RTU models, which can minimize or eliminate the use of gas for space heating. These products use air-to-air heat pumps to condition outdoor air that enters the building. The selection of heat-pump RTUs is poised to grow significantly in coming years, as more vendors offer these products, more efficient cold-climate heat-pump RTUs enter the market, and demand increases.

Today, fully electric heat-pump RTUs are available on the market and ready for deployment. These systems have auxiliary heating sources (electric or gas) for extremely cold temperatures in which the air-to-air heat pump has reduced capacity and efficiency due to performance degradation at low temperatures.[i] For example, one model of heat-pump RTU has a capacity of 164 MBH (1 MBH = 1,000 British thermal units per hour) and a rated coefficient of performance of 3.64 at 47°F, which is reduced to 91 MBH with a coefficient of performance of 2.25 at 17°F.[13] Sizing appropriately for low-temperature capacity de-rating is an important consideration for specification of all-electric heat-pump RTUs. Larger equipment may be needed to meet heating demands without additional efficiency retrofits.

In all-electric units, the backup heating system is an electric resistance coil. Electric resistance heating has a coefficient of performance of 1.0, meaning that in very cold temperatures (below 0°F), the heat pump will operate less efficiently than during temperate periods. Co-installing all-electric heat-pump RTUs with ERV can mitigate significant oversizing of equipment due to capacity and efficiency de-rating concerns.

Manufacturers also offer partially electrified RTUs that meet typical heating loads through air-to-air heat pumps, with limited use of gas in the auxiliary heating coils during peak demand or reduced heat pump capacity. This report demonstrates economic and environmental conditions for all-electric and partially electric heat-pump RTUs.

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[i] In this context, *capacity* refers to the total heating load that can be served by a mechanical system, and *efficiency* measures units of heating output per unit of electrical input.

Energy Efficiency Packages

Commercial building owners have different decision-making frameworks for energy efficiency and decarbonization investments than residential owners. For many portfolio owners, ESG commitments and climate action goals create an impetus for strategic investment in operational energy and carbon reduction measures. In addition, commercial owners tend to focus on lifecycle cost implications rather than on upfront cost, valuing metrics such as return-on-investment (ROI) and net present value (NPV).

However, a major barrier to owners pursuing electrification projects in existing commercial buildings is the perception that these investments do not offer lifecycle savings. For instance, some stakeholders expressed concerns that electrification will result in increased operational costs, as electric utility rates can make electricity more expensive than gas. This is certainly a warranted concern, but one that should be studied on a case-by-case basis, since a generalized assumption that all electrification projects result in cost increases has been shown to be incorrect in many locations, including by prior RMI analyses.[14]

Commercial electrification retrofits should be considered part of a broader suite of energy upgrades, which can create financially viable decarbonization pathways. For commercial buildings, key energy improvements to consider in coordination with electrification include ventilation efficiency measures, envelope improvements, HVAC controls optimization, and rooftop solar. Combined efficiency and electrification packages were included in RMI's analysis to demonstrate the business case for decarbonization in the commercial sector.

Analysis: Retrofitting a Medium-Size Office Building

RMI analyzed the technical, economic, and environmental implications of retrofitting gas-fired space heating and domestic hot water systems in a prototypical 50,000 square feet office building.

Six Model Cases Applied to Four US Cities

The prototypical building uses conventional gas-fired packaged RTUs for space heating and cooling, along with a small, tanked gas-fired domestic hot water heater. Three packaged units serving 50,000 square feet and zone-level VAV reheat electric resistance coils are used to maintain thermal comfort and adjust for conditions in individual thermal zones. VAV reheat coils in buildings served by packaged systems typically use electric resistance, with hydronic reheat coils more common in larger buildings with central plants. The building envelope modeled in this study aligns with post-1980s construction. Opaque walls have moderate levels of insulation, and all glazing is basic performance double insulated glass units.

Exhibit 2 summarizes the electrification, efficiency, and renewable energy cases that were modeled in this study. First, partial (Case 2) and full (Case 3) electrification measures were applied to understand the implications of 1:1 equipment swap-outs. Only ERV (Case 4) and ERV with winter peak demand management (Case 5) were layered onto the electrification measures to support electric heat pump performance during peak winter conditions. The modeled peak heating demand management sequence was narrow in scope: on cold nights when minimum outdoor dry-bulb air temperatures are below 20°F, the heating thermostat setback is overridden to maintain consistent temperatures overnight and reduce peak startup heating loads in the morning; the setpoint is reset to 65°F instead of 60°F. Finally, a modestly sized PV system was included to complete the decarbonization package (Case 6).

Exhibit 2 **Modeled cases**

Case	Existing RTU replaced with:	Efficiency details	PV details
1. No electrification	Conventional gas RTU		
2. Partial electrification	Heat-pump RTU with gas backup		
3. Full electrification	Heat-pump RTU with electric resistance backup		
4. Efficient electrification	Heat-pump RTU with electric resistance backup + ERV + efficiency measures	10% fan power efficiency improvement	
5. Efficient electrification + demand management	Heat-pump RTU with electric resistance backup + ERV + demand management + efficiency measures	10% fan power efficiency improvement	
6. Efficient electrification + demand management + PV	Heat-pump RTU with electric resistance backup + ERV + demand management + PV + efficiency measures	10% fan power efficiency improvement	100 kW DC, azimuth 180°, flat panels, 25% of roof area

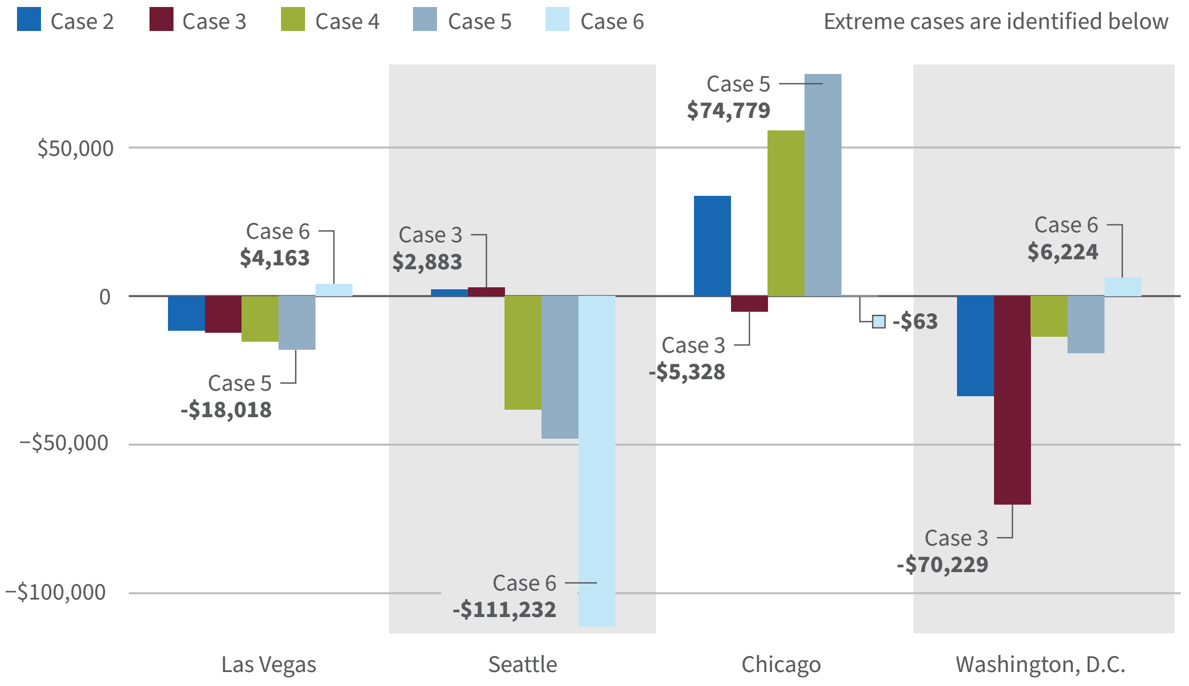
Building envelope enhancements were tested in early iterations of this analysis. However, these measures did not provide significant energy or cost savings given that the base building already included moderate levels of opaque insulation and insulated glazing.

These six cases were modeled for four US cities: Washington, D.C., Chicago, Seattle, and Las Vegas. Results for the four cities are discussed in detail in the sections that follow. The key takeaways are the following:

- In cities with cold winters, such as Washington, D.C., and Chicago, including ERV as part of a heat-pump RTU provided significant annual energy savings, improving the economics of electrification.
- Gas utility costs were a key factor in determining the economics of electrification. In Chicago, higher gas costs meant that electrification resulted in net positive savings over a 20-year lifecycle. In Washington, D.C., lower gas costs meant lower savings from electrification.
- In Seattle, installation of a heat-pump RTU had a positive NPV over 20 years, even with ERV. In Seattle's temperate climate, which is characterized by mild summer and winter temperatures, ERV, peak demand management, and solar PV did not reduce energy costs enough to provide an effective payback when coupled with a heat pump retrofit.
- In Las Vegas, the mild winter climate and low gas use in the baseline meant that electrification, even with ERV and demand management, did not pay back over 20 years. In order for electrification to be cost-effective here, solar PV should be grouped with electrification for a broader decarbonization package.

The broad economic viability of different options for each city is summarized in Exhibit 3.

Exhibit 3 **The 20-year net present value of each case by city**



Washington, D.C.

In Washington, D.C. (Exhibits 4–8), building owners who install heat-pump RTUs with ERV in combination with a rooftop solar PV system could achieve a positive 20-year NPV. The ERV system is key to mitigating peak electric loads during cold winter periods with an electric heat-pump system, while offering significant energy efficiency on an annual basis. Gas, per unit of energy, is less expensive than electricity; therefore, even the efficient, all-electric retrofit case does not pay back over 20 years under current gas rates here. An increase in the cost of gas would improve the economics of electrification alone. **For now, coupling the electrification retrofit with an on-site renewable energy installation will enable building owners to achieve a positive return.**

The following exhibits, which are repeated for the other cities, present the city's annual gas and electricity use, annual gas and electricity cost, electricity demand for two days that include case 1's peak demand day, the 20-year NPV of each electrification case, and annual greenhouse gas emissions for 2022 and 2050. These exhibits represent the current energy and operational cost of each case as well as economic and emissions behavior over time.

Exhibits 4 and 5 present annual gas and electricity use and cost for Washington, D.C. For case 1, gas accounts for 15% of total annual energy use; however, due to the rate structure, it only accounts for around 3.4% of total charges. Case 3 (full electrification) increases electricity use by 5%; however, it reduces total energy use by 11% compared to case 1. Overall, case 3 increases the annual utility charges by 3.9% compared to case 1.

Exhibit 4 **Annual gas and electricity use (MMBtu), Washington, D.C.**

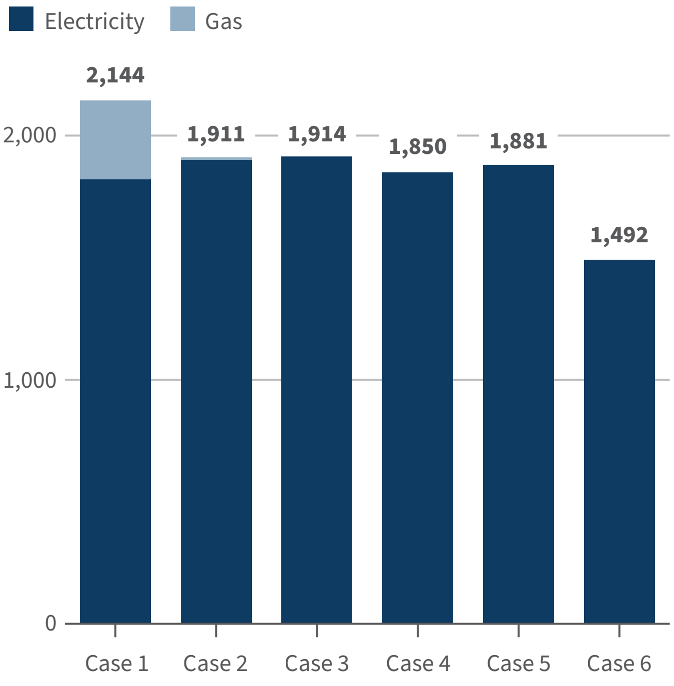
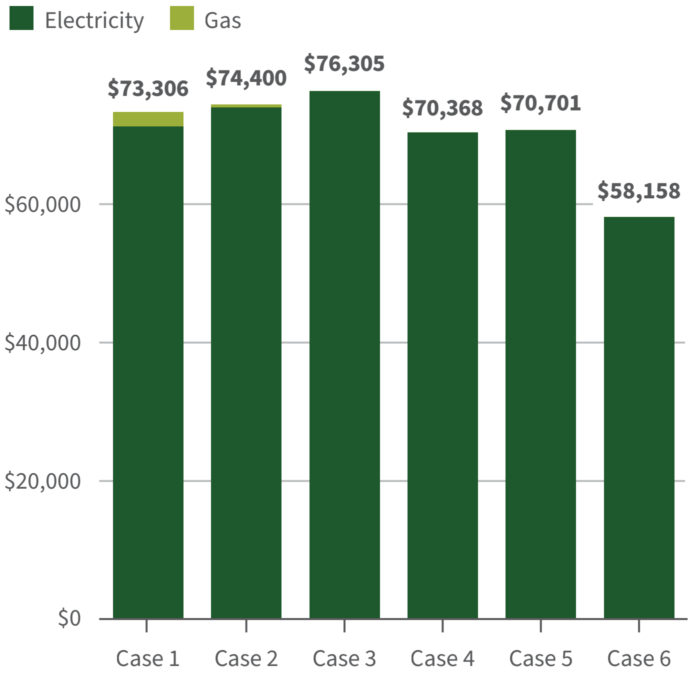


Exhibit 5 **Annual gas and electricity cost, Washington, D.C.**



Note: See Exhibit 2 on page 14 for case definitions. MMBtu = million British thermal units.

Exhibit 6 Electricity demand by case (kW) for two days in February 2019, Washington, D.C.

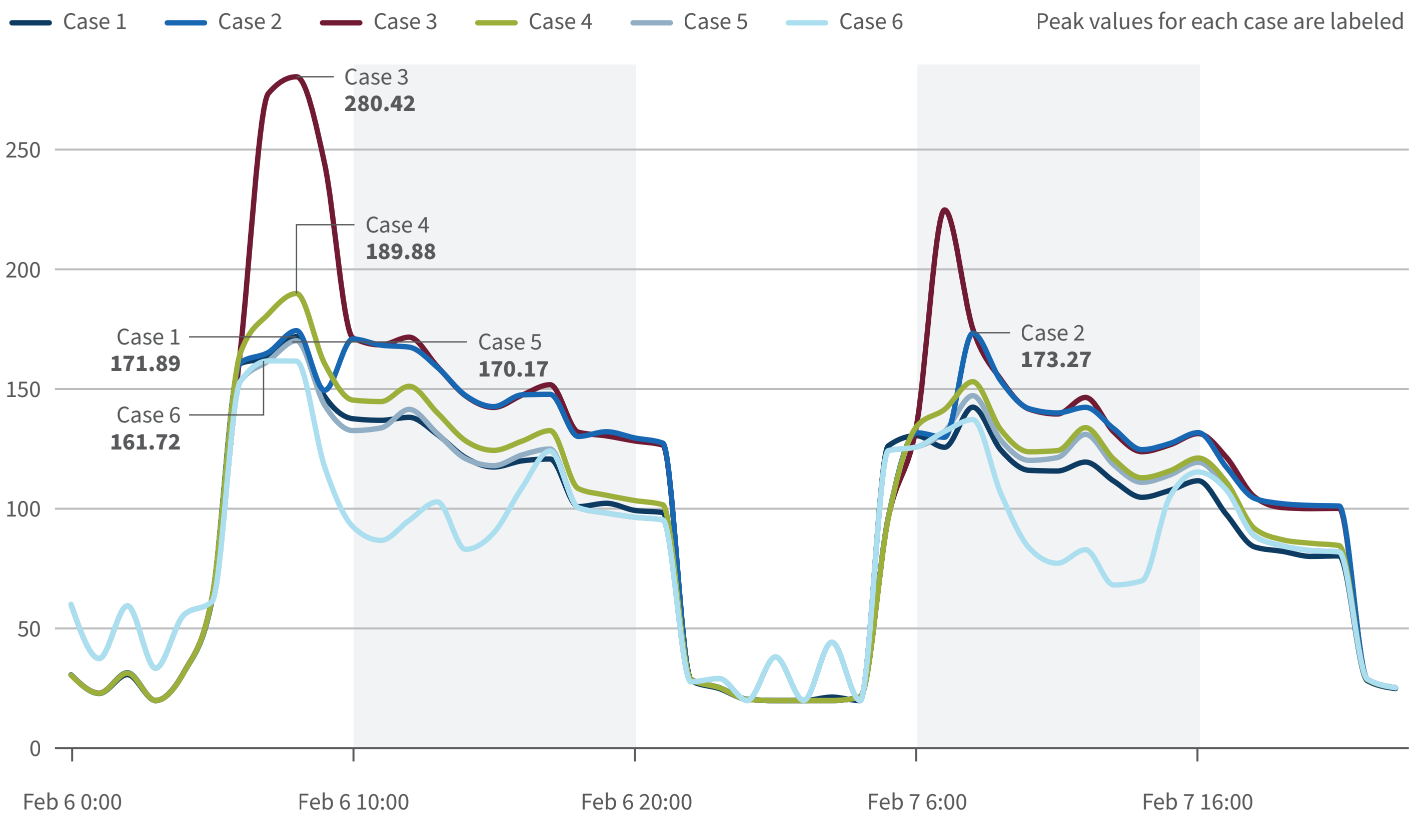


Exhibit 7 The 20-year net present value of each case for Washington, D.C., 2019 and 2021–22 rates

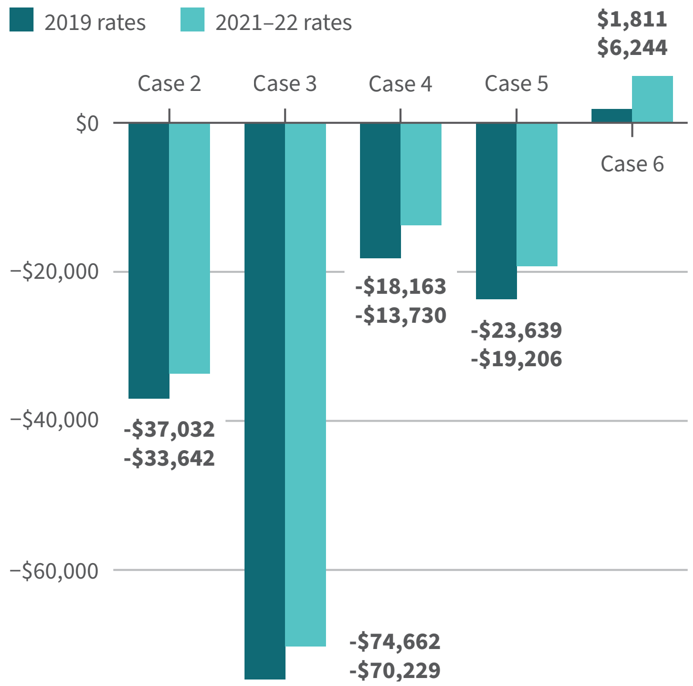
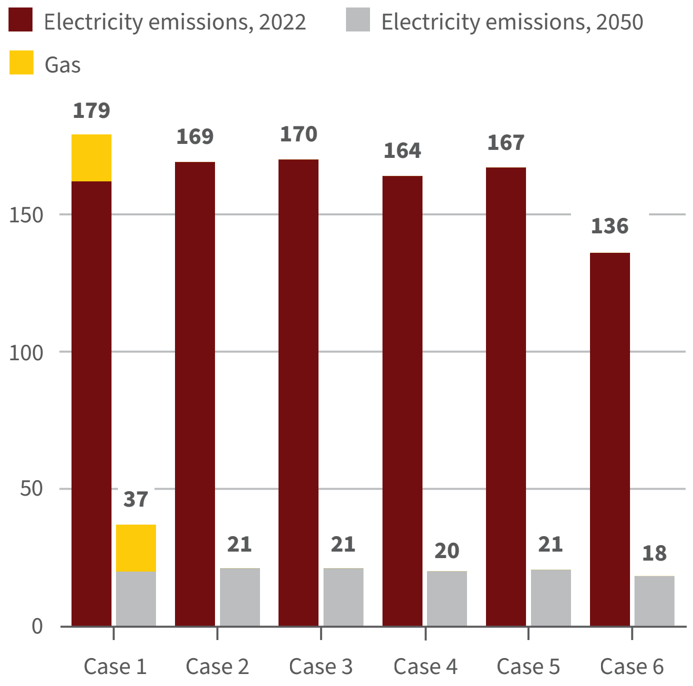


Exhibit 8 Annual greenhouse gas emissions (metric tons), 2022 and 2050, Washington, D.C.



Chicago

In Chicago (Exhibits 9–13), building owners who pursue installation of heat-pump RTUs with ERV and a winter peak demand management control sequence are likely to achieve a positive 20-year NPV. In Chicago's harsh winter climate, the ERV system and peak demand management sequence are critical energy efficiency and peak load reduction strategies that provide robust cost savings. Chicago also has a relatively high per unit cost of gas relative to other cities modeled in this study.

The prototypical building system used as the basis for this analysis, which uses electric resistance VAV reheat systems, is less common in Chicago than in the other three cities. As such, the results should not be applied to the broad swath of the commercial office market that uses gas-fired terminal units for supplemental, zone-level heating. Regional existing building system surveys should be used to identify buildings with legacy electric resistance reheat, which offer major opportunities for economical heat pump electrification retrofits in the Midwest.

Exhibits 9 and 10 present annual gas and electricity use and cost for Chicago. For case 1, gas usage accounts for 21% of total annual energy use; however, due to the rate structure it only accounts for around 10% of total charges. Case 3 (full electrification) increases electricity use by 10%; however, it reduces total energy use by 13% compared to case 1. Overall, case 3 increases annual utility charges by 1.6% compared to case 1.

Exhibit 9 **Annual gas and electricity use (MMBtu), Chicago**

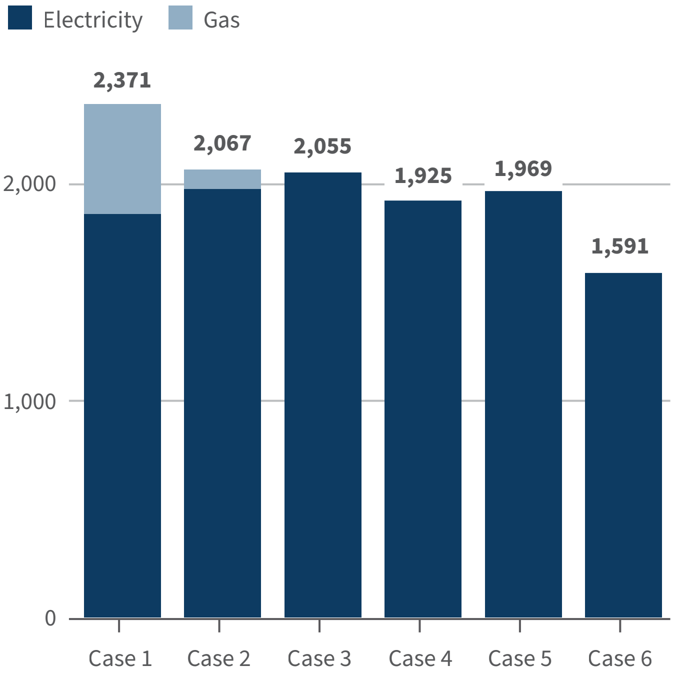
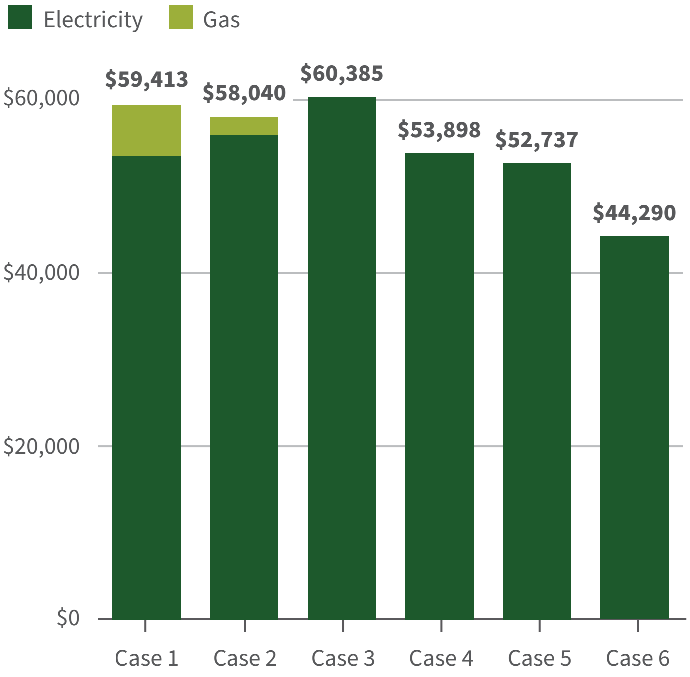


Exhibit 10 **Annual gas and electricity cost, Chicago**



Note: See Exhibit 2 on page 14 for case definitions. MMBtu = million British thermal units.

Exhibit 11 Electricity demand by case (kW) for two days in January 2019, Chicago

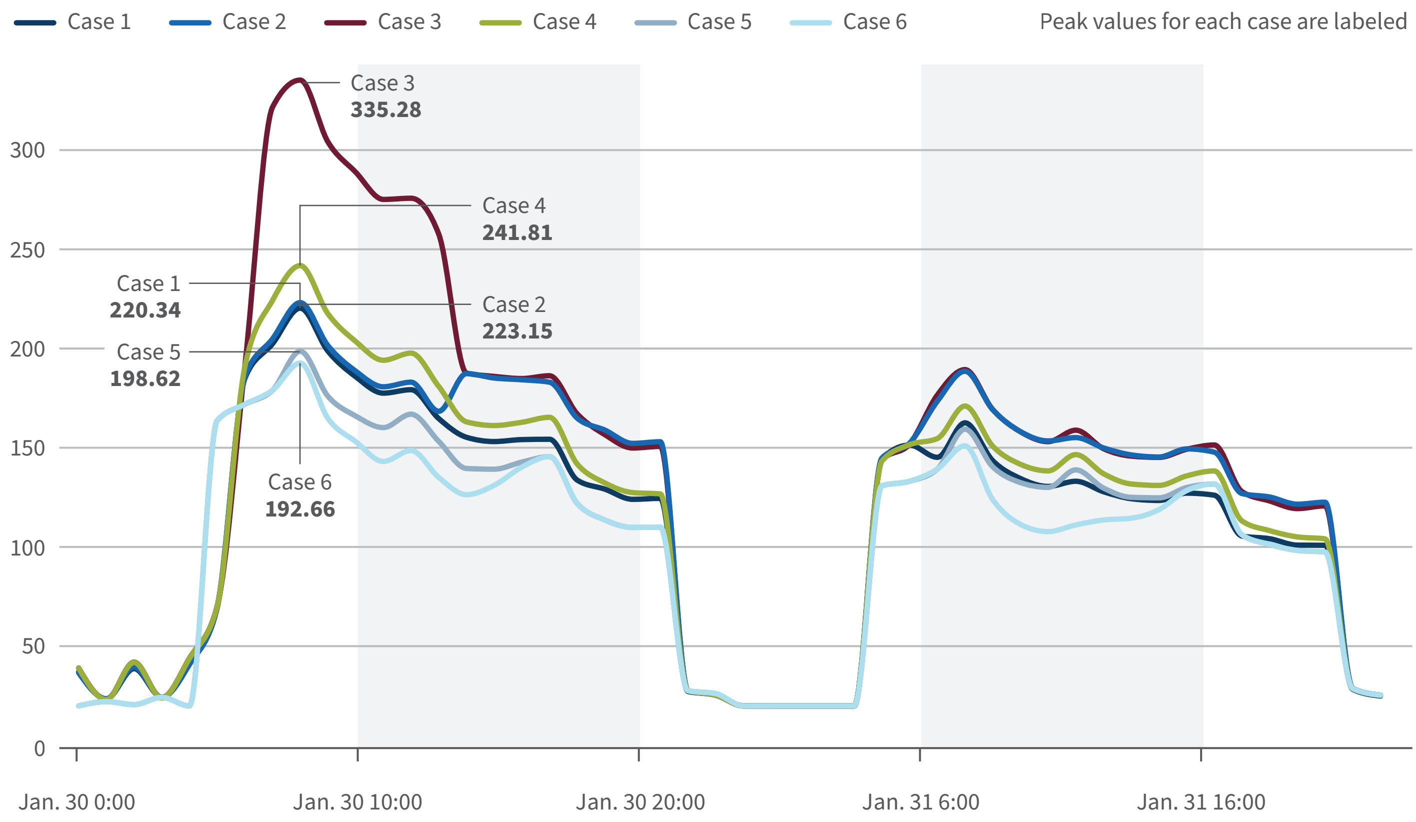


Exhibit 12 The 20-year net present value of each case for Chicago, 2019 and 2021–22 rates

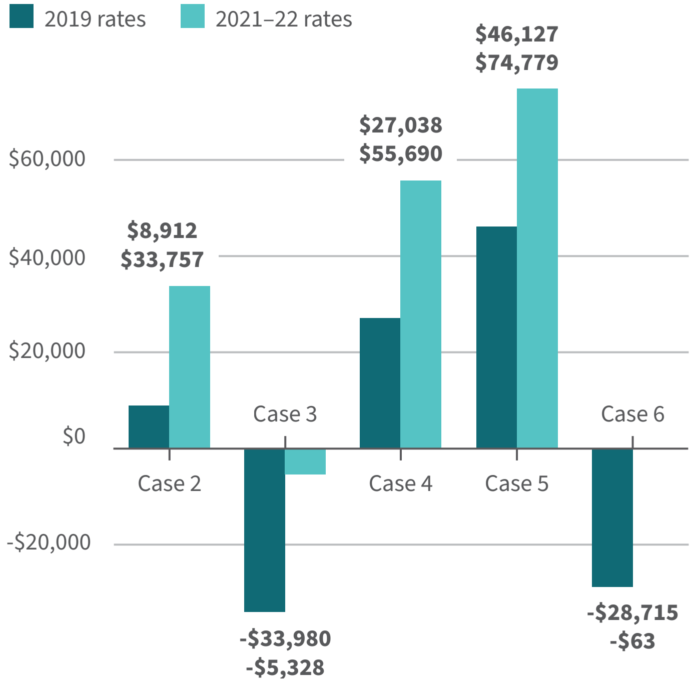
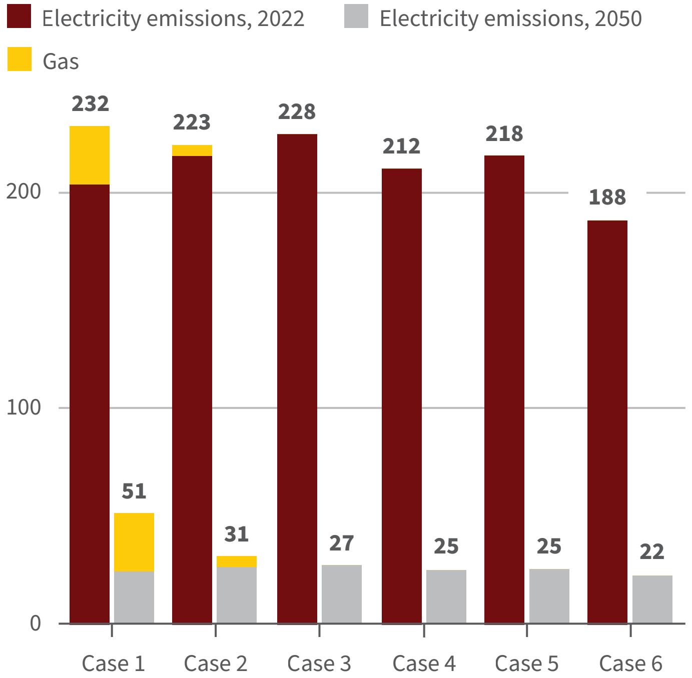


Exhibit 13 Annual greenhouse gas emissions (metric tons), 2022 and 2050, Chicago



Seattle

In Seattle (Exhibits 14–18), in the most economical electrification retrofit, building owners could achieve a neutral 20-year NPV by installing heat-pump RTUs without ERV, winter peak demand management, or rooftop PV. ERV and demand management sequencing would not provide significant energy savings in Seattle's temperate winters. However, these measures would provide significant benefits in mitigating peak electric demand, which has tremendous value. Utilities must study the impact of electrification at scale on grid capacity to ensure that there is sufficient infrastructure to support these loads.

The economic viability of the electrification case depends on gas utility rates. Under current (2021–2022) gas rates, an electrification retrofit has a positive return compared to no electrification over 20 years. As gas prices continue to rise, the economic conditions for electrification will continue to grow. Cost-efficient electrification retrofits of commercial office buildings are on the brink of viability in Seattle. Minor policy and program design changes, such as incentives or pilot rate designs, could improve the economics of electrification.

Exhibits 14 and 15 present annual gas and electricity use and cost for Seattle. For case 1, gas usage accounts for 16% of total annual energy use and around 7.4% of total charges. Case 3 (full electrification) increases electricity use by 5%; however, it reduces total energy use by 12% compared to case 1. Overall, case 3 decreases annual utility charges by 2.9% compared to case 1.

Exhibit 14 **Annual gas and electricity use (MMBtu), Seattle**

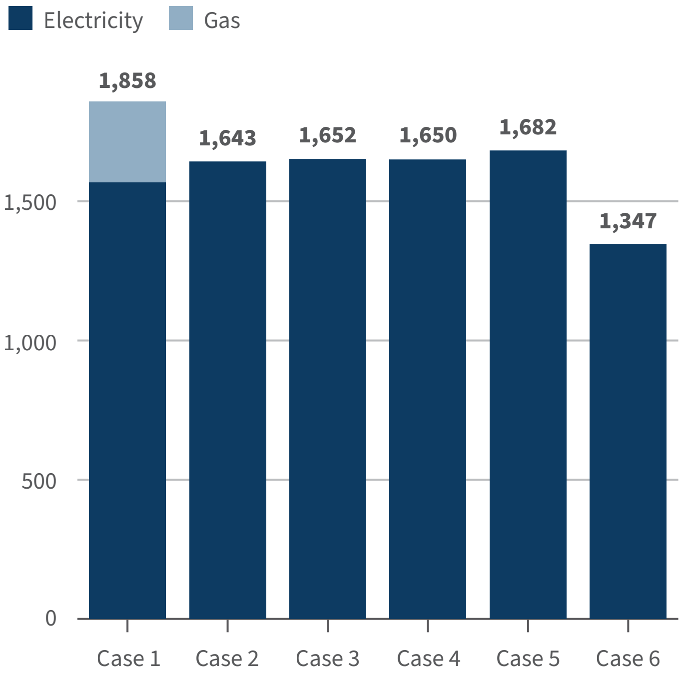
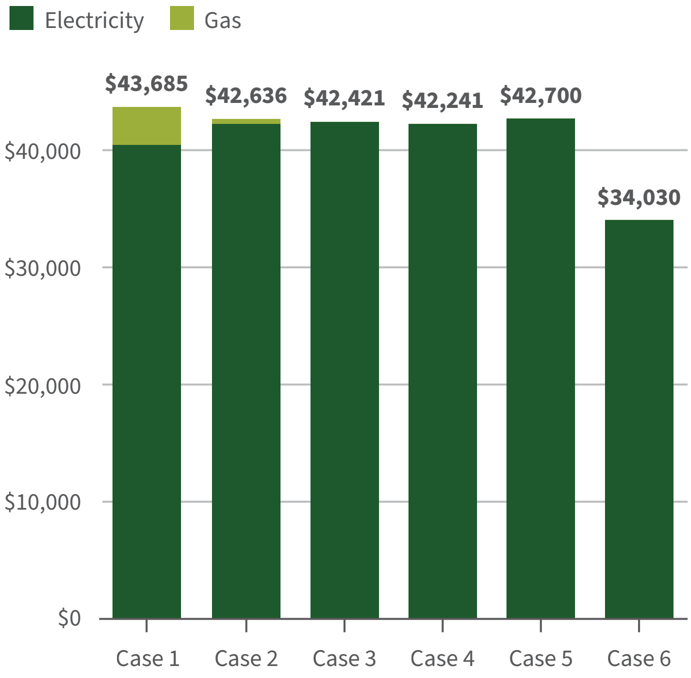


Exhibit 15 **Annual gas and electricity cost, Seattle**



Note: See Exhibit 2 on page 14 for case definitions. MMBtu = million British thermal units.

Exhibit 16 Electricity demand by case (kW) for two days in August 2019, Seattle

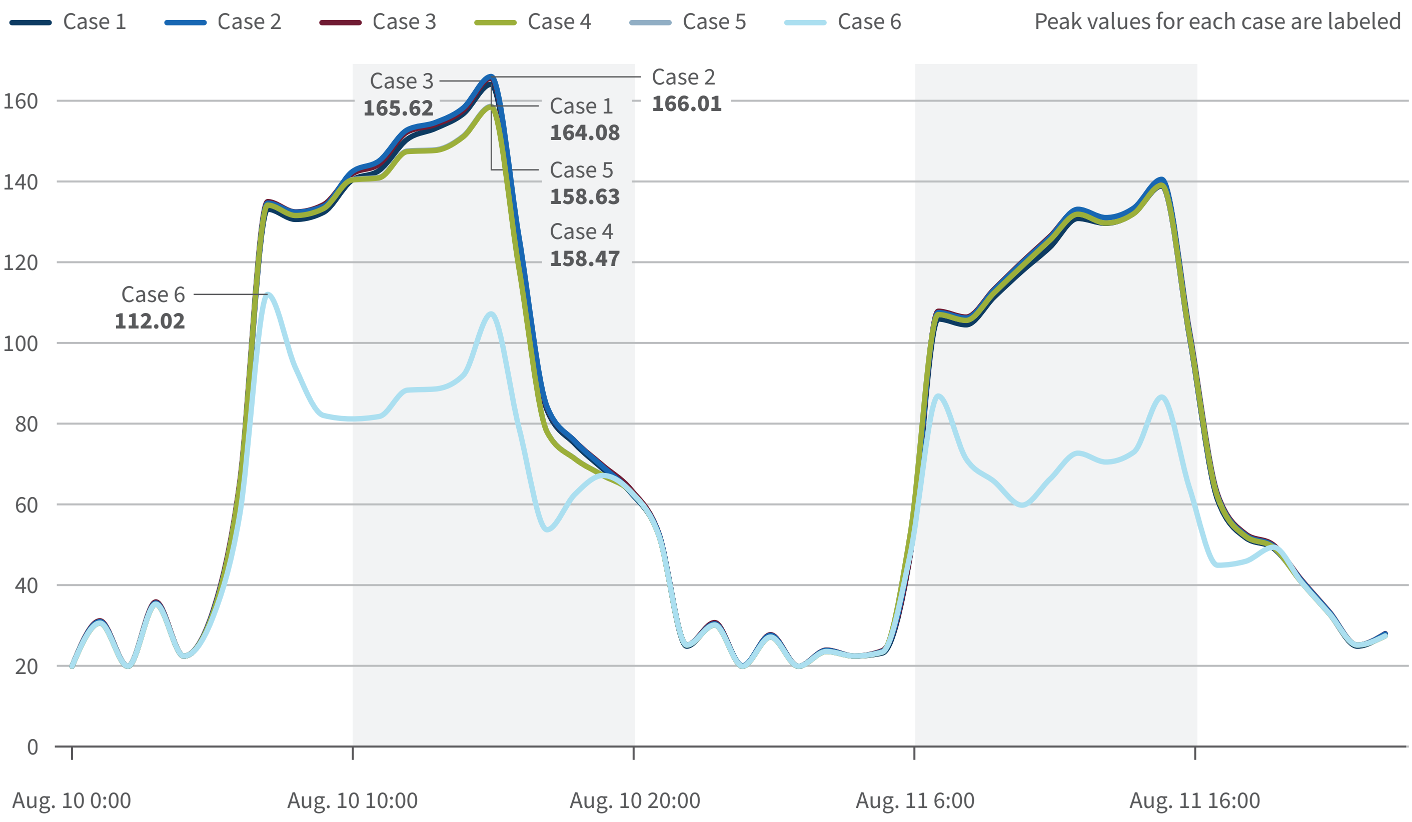


Exhibit 17 The 20-year net present value of each case for Seattle, 2019 and 2021–22 rates

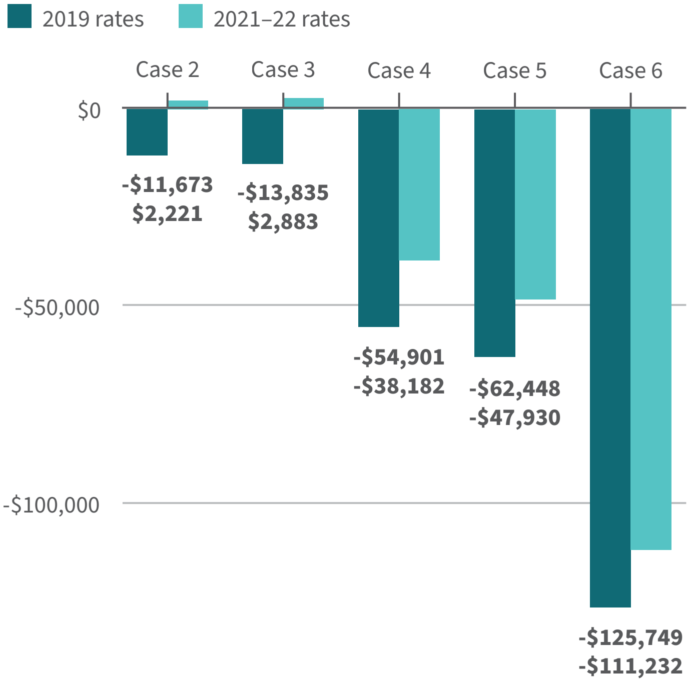
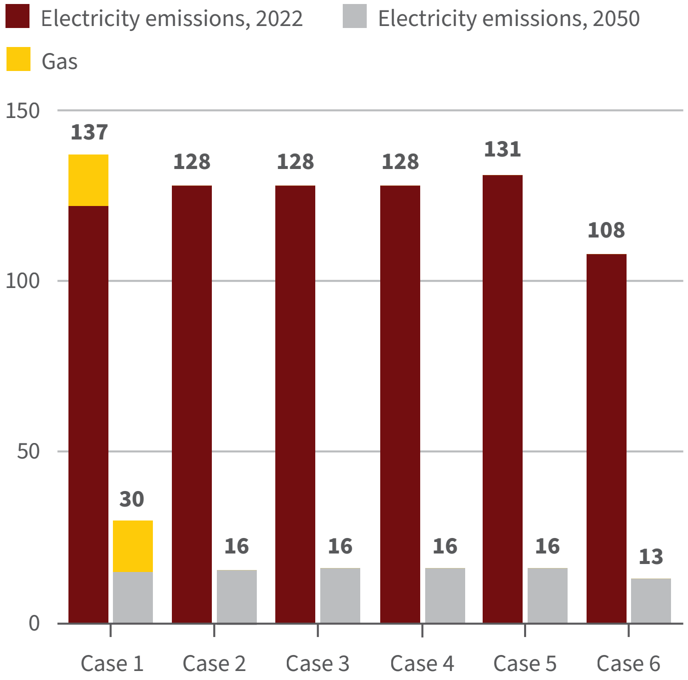


Exhibit 18 Annual greenhouse gas emissions (metric tons), 2022 and 2050, Seattle



Las Vegas

Given the temperate winters in Las Vegas (Exhibits 19–23), electrification would provide only a marginal change in the energy use profile of a commercial office building. To achieve a positive 20-year NPV, building owners should pursue a holistic decarbonization package of efficient electrification and on-site solar PV.

ERV does improve energy efficiency and peak load reduction during Las Vegas's hot summers, making this an important system to install as part of an electrification retrofit. An efficient heat-pump RTU retrofit in Las Vegas would nearly pay back over 20 years, with an NPV of −$20,000. The economics can be improved through incentives or pilot utility rate designs that reward customers for investing in building decarbonization.

Exhibits 19 and 20 present annual gas and electricity use and cost for Las Vegas. For case 1, gas usage accounts for 8% of total annual energy use and around 2.9% of total charges. Case 3 (full electrification) increases electricity use by 2%; however, it reduces total energy use by 6% compared to case 1. Overall, case 3 decreases annual utility charges by 1% compared to case 1.

Exhibit 19 **Annual gas and electricity use (MMBtu), Las Vegas**

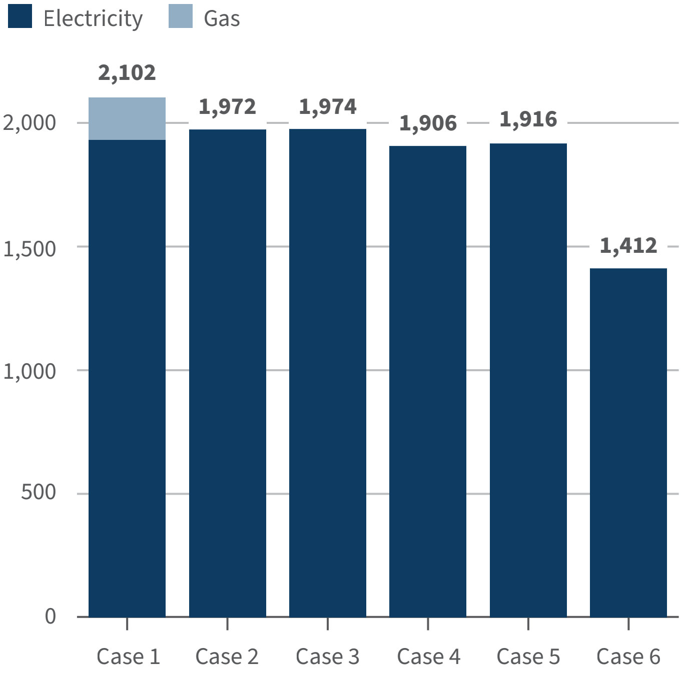
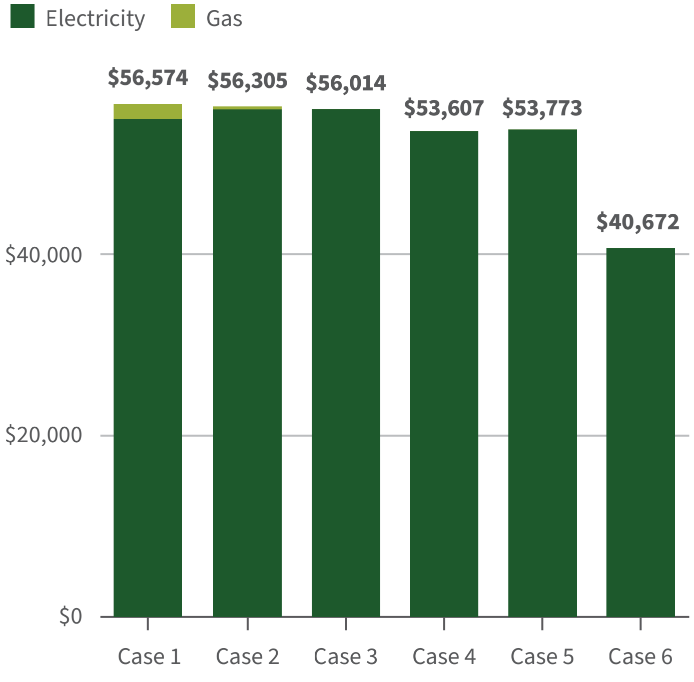


Exhibit 20 **Annual gas and electricity cost, Las Vegas**



Note: See Exhibit 2 on page 14 for case definitions. MMBtu = million British thermal units.

Exhibit 21 Electricity demand by case (kW) for two days in July 2019, Las Vegas

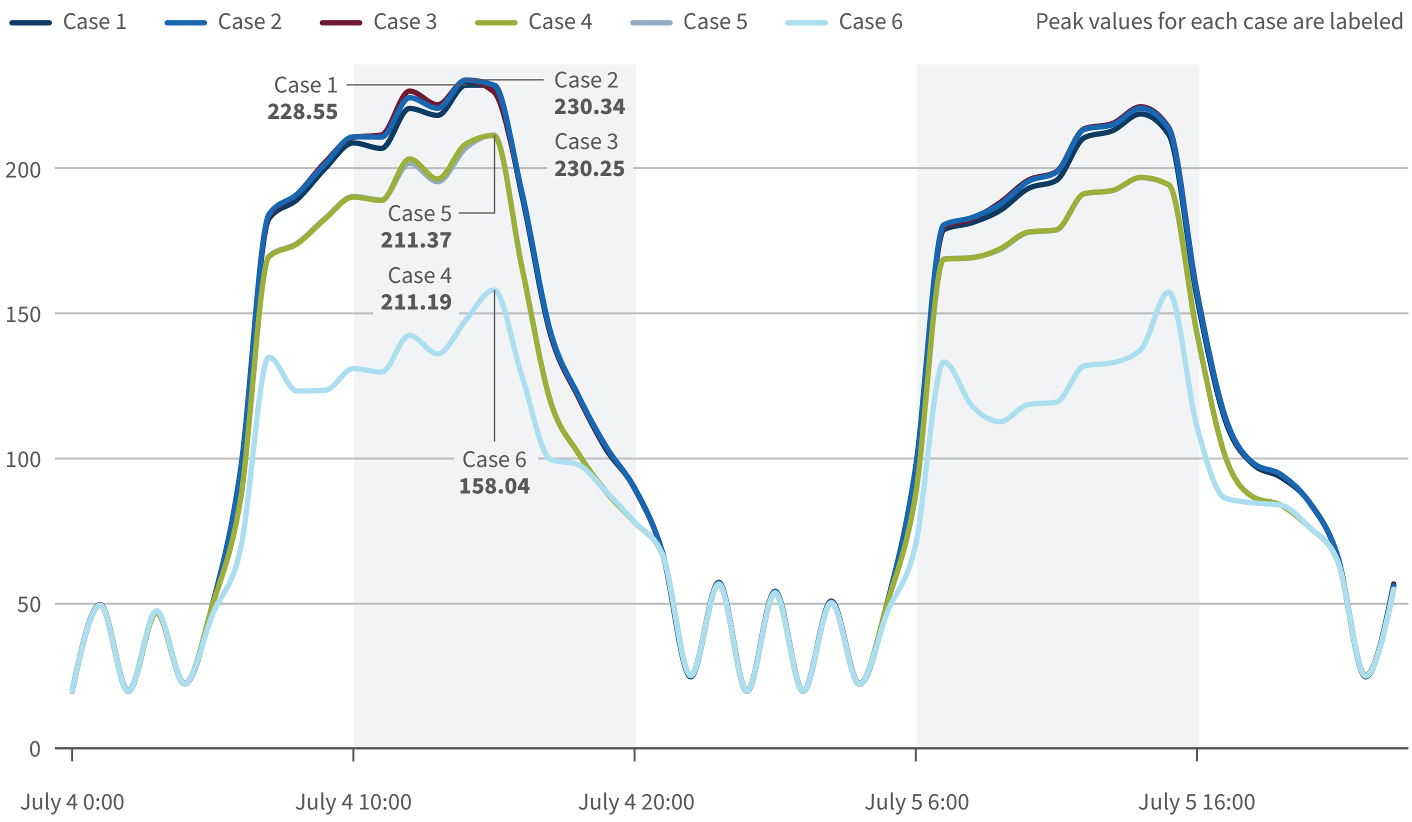


Exhibit 22 The 20-year net present value of each case for Las Vegas, 2019 and 2021–22 rates

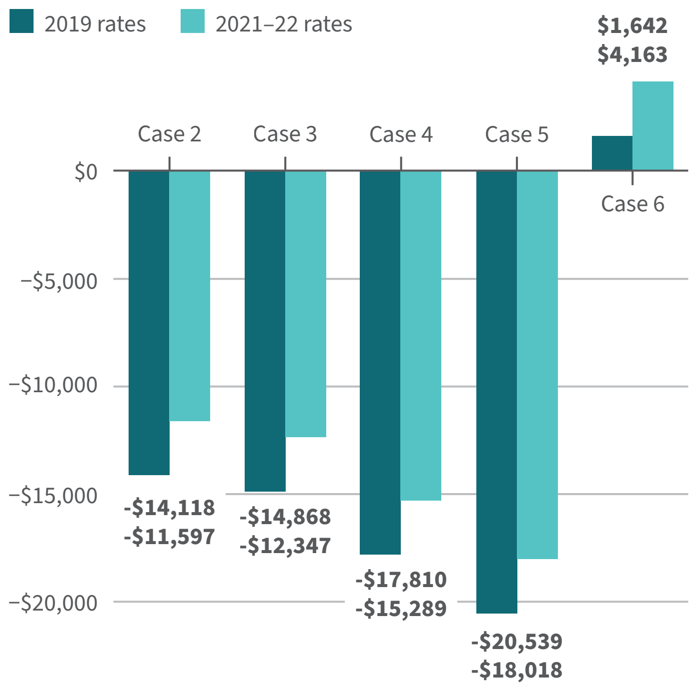
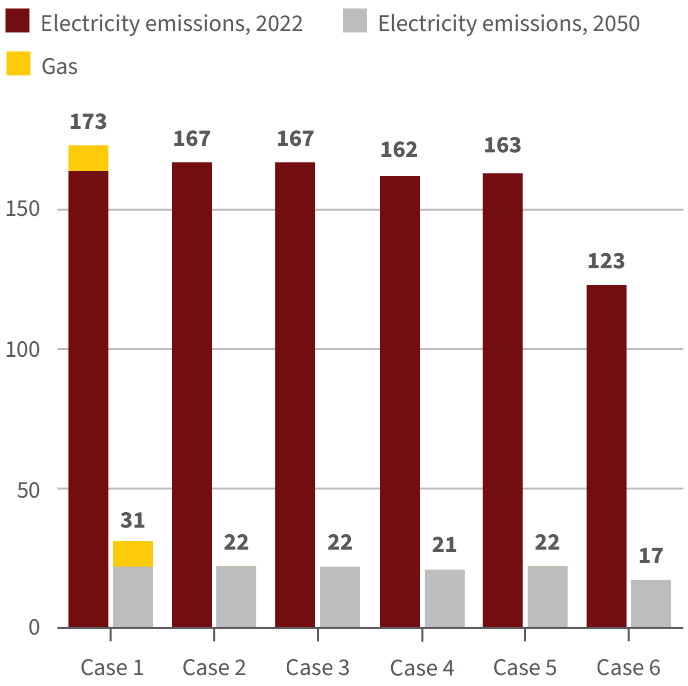


Exhibit 23 Annual greenhouse gas emissions (metric tons), 2022 and 2050, Las Vegas



How State and Local Governments Can Support Decarbonization

State and local governments have a critical role in accelerating decarbonization of existing commercial buildings through packaged heat-pump RTU retrofits. The following policy interventions will create an improved environment for the technologies modeled in this study.

Market Development

While cold-climate heat-pump RTUs are available in the US today, the installer market and supply chain for these products need to be fostered to increase product access and choice for consumers. Market development is a key strategy to bring down the upfront costs of all-electric units. Governments can play a role in market development in these ways:

- Stimulate demand for heat-pump RTUs through demonstration installations and procurement commitments in public portfolios.
- Establish workforce development programs to train installers of this technology.
- Contribute to performance testing and standard-setting efforts to increase consumer confidence in heat-pump RTUs. These efforts should be part of a collaborative effort across local, state, and federal government.

Utility Coordination

The economics of electrification are defined by operational energy costs as much as they are by upfront equipment and installation costs. Local and state governments can work with regional utilities to improve the economics of electrification in these ways:

- Develop pilot rate structures that encourage electrification by improving the economics of electrification. These pilot rate structures could also act as a proof-of-concept demonstration of the economic benefits of electrification.
- Adjust utility efficiency rebate/incentive programs to include equipment fuel-switching strategies. Efficiency programs can also be used to create streamlined packages of electrification and efficiency measures that provide end users the best environmental and economic result.

Building Performance Standards

- Establish building performance standards to advance decarbonization of existing buildings. New York City's pioneering Local Law 97, for example, sets carbon performance targets for buildings in the city. Commercial building electrification through 1:1 swap-outs of gas-fired packaged RTUs for their electric equivalents can be a straightforward, cost-effective decarbonization retrofit. Commercial buildings that can accommodate this type of electrification retrofit should be prioritized in building performance standards and guidance.

Conclusion

Our analysis predicts that the 20-year NPV will be positive or neutral for commercial building electrification using cold-climate heat-pump RTU equipment. These retrofits can be conducted as 1:1 equipment swap-outs with limited system reconfiguration, reducing upfront costs. Regional climate conditions and gas utility rates are primary drivers of the economics of decarbonization retrofits. However, even though these factors varied across the studied cities, an economically viable package of energy and electrification retrofits is still possible in all of them. Electrification in commercial buildings can be paired with a suite of other energy retrofit measures, particularly ERV, peak heating load management, and on-site solar PV, to improve cost-effectiveness and reduce grid impacts. Increased availability and improved performance of cold-climate heat pump RTU equipment will make it easier and more beneficial to implement these retrofits. Costs are likely to decrease over time with advancements in the heat pump product market and policy changes across states and at the federal level.

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