Decarbonization Retrofits for Affordable Housing: A Chicago Case Study

Abby Francisco PhD, Bill Lyons, Louise Sharrow, and Margaret Garascia[1], Elevate
Michael Burton, Bickerdike Redevelopment Corp
Stephen La Barge and Mark Milby, ComEd
Allie Cardiel PhD, Dan Cautley, and Scott Pigg, Slipstream

ABSTRACT

Reducing carbon emissions in existing buildings presents a wide set of challenges, even more so in affordable housing. Elevate and its community partners are overcoming these challenges to bring decarbonization retrofits to the tenants and owners of existing multi-family buildings. In this paper, Elevate, Bickerdike Redevelopment Corp, ComEd, and Slipstream present findings thus far from a retrofit of La Paz Place, a 44-unit affordable housing property in Chicago. Construction began in November 2021 and is expected to conclude Summer 2022 across the three buildings at the property, where natural gas equipment for heating, cooking, hot water, and laundry was converted to all-electric heat pumps, smart thermostats, electric stoves, and electric dryers. Rooftop solar will be added after electrification is complete. The project is projected to reduce energy consumption by 65% and carbon emissions by 44%, without increasing utility costs for the tenants or owner. Project partners are conducting pre- and post-retrofit monitoring and evaluation on a subset of units, including power metering and indoor air quality monitoring. Our lessons learned through the construction phase of the project focus on how to scale whole-building decarbonization retrofits for communities most in need.

Introduction

Illinois is pushing towards substantial reductions in carbon emissions in the power sector, with recent mandates for eliminating carbon emissions in the power sector by 2045 (State of Illinois 2021). Building decarbonization is a critical piece for further reduction in carbon emissions and avoiding the worst possible effects of climate change. Meeting this urgent obligation in the built environment means converting space heating, hot water, clothes dryer, and other end uses from burning fossil fuels such as natural gas, oil, or propane, to carbon-free electricity. Existing buildings will require substantial investments to make them significantly more energy efficient and to decarbonize space and water heating, which compose the majority of energy consumption in cold climates. Affordable multi-family housing represents a significant portion of the existing building stock, and therefore a large opportunity for scaling building decarbonization while improving affordable housing quality and resident comfort. However,

---

[1] Margaret Garascia is now at Climate Imperative continuing work on building decarbonization, at the time of this paper submission she was working at Elevate and spearheaded the Building Electrification Program.

affordable housing in cold climates also faces a specific set of challenges that must be directly addressed to achieve this potential and provide positive impacts to owners and residents.

The affordable housing sector typically has less access to reserves and capital financing and higher utility costs than market rate housing. These concerns have only been exacerbated by the COVID-19 pandemic, which saw increases in energy burdens, decreased income for renters and decreased rent collections for owners, and many staffing and vacancy challenges (JCHS 2021). As natural gas customer bases shrink from increased electrification, a key piece of decarbonization programs, homes remaining reliant on fossil fuels are expected to pay higher fixed costs to maintain gas infrastructure (Davis and Hausman 2022). Communities with lower incomes are at risk of bearing this burden of maintaining legacy infrastructure systems if electrification programs are not accessible to these communities. Rental housing also faces the additional barrier of split incentives, where owners who do not pay for utilities lack the financial incentives to invest in related energy efficiency retrofits.

Historically, the inability of air-source heat pumps (ASHPs) to provide adequate heat in extreme cold conditions limited uptake of ASHPs in colder climates. Heat pump technology advancements in recent decades have made electrifying heating systems in cold climates viable (CEE 2017), although uptake has not yet increased at the same rate. Technology skepticism, lack of contractors and resources, and relatively small incentives are all factors that have played a role in this trend. More wide-scale adoption of heat pump technologies in colder climates is necessary for electrification strategies.

There are relatively few examples of electrification and/or decarbonization efforts in the affordable housing building stock (ACEEE 2022). A 2021 study examined the energy and indoor air quality performance of two affordable six-unit multi-family buildings in Chicago, one of which used heat pumps for space heating (Slipstream 2021); however, both properties were new construction and faced different barriers compared to retrofitting an existing affordable housing building. Programs across the US have targeted electrification of existing low-income single- and multi-family properties, including utility programs in Sacramento (Gerdes 2019), DC (ACEEE 2022), and Utah (Brant 2020). While learnings from these case studies and programs can be immensely helpful for informing the design of other low-income electrification programs, examples of electrification in cold climates for affordable housing is still lacking. It is important for projects in this market to share successes and document challenges for other buildings to learn from and to inform decarbonization programs and policies in cold climates.

In this paper, a case study featuring decarbonization of an affordable, 44-unit multi-family property in Chicago is presented. The comprehensive retrofit approach, evaluation methodology, and lessons learned through the construction phase of the project document an example of a future pathway for decarbonizing this housing stock in a way that will not increase cost burdens for those who can least afford it.

Project Background

The case study presented in this paper is a project that is a part of Elevate's Building Electrification Program (BEP), launched in the fall of 2020. BEP offers grant support and a turnkey service delivery model to affordable housing developers and owners to implement electrification retrofits. The program, focused in Illinois, Wisconsin, and Michigan, is designed to: (a) help remove and replace on-site combustion of fossil fuels for space heating, hot water, stoves, and clothes drying with clean energy technologies, (b) create a healthier living environment for tenants, and (c) generate energy and carbon savings. The program provides dedicated grant funding to offset the overall cost of building electrification in affordable housing. A description of key stakeholders involved in this case study is as follows:

- **Elevate – Project Lead.** Elevate is a nonprofit headquartered in Chicago and working nationally. We design and implement programs that reduce utility bill costs, protect people and the environment, and ensure the benefits of clean and efficient energy use reach those who need them most. Making the benefits and services of the clean energy economy accessible to everyone is how we fight climate change while supporting equity. Elevate runs the Building Electrification Program and handles overall program management.
- **Bickerdike Redevelopment Corporation (BRC) – Building Owner.** Bickerdike is a member-based, nonprofit community development corporation working for the development of communities on the north side of Chicago, by and for the low and moderate-income people who live in these areas. Bickerdike serves 3,200 residents, 97% of whom identify as BIPOC. Bickerdike owns and operates La Paz Place, the building highlighted in this paper. Bickerdike led and facilitated tenant engagement as well as partnering on construction management and making all final building decisions.
- **ComEd – Utility Partner.** Commonwealth Edison Company (ComEd) provides electric service to more than 4 million customers across northern Illinois, or 70% of the state's population. For this project, ComEd's Energy Efficiency Research & Development (EE R&D) group provided funding support for hot water heater replacement and monitoring.
- **Slipstream – Monitoring Lead.** Slipstream is a mission-driven nonprofit that inspires new solutions to big energy challenges by empowering more people to adopt new practices and technologies. Slipstream designed and led the monitoring effort, including installations and data analysis.

Under BEP, Elevate assessed buildings for electrification feasibility and identified several properties as ideal candidates, including BRC's La Paz Place. After selecting La Paz Place as a candidate, Elevate developed a retrofit scope with dbHMS, a local engineering firm. Additionally, Elevate identified key evaluation goals which included cost and savings analyses as well as understanding of electric equipment performance and indoor air quality impacts. These latter goals required monitoring, which was implemented in partnership with Slipstream and ComEd EE R&D.

La Paz Place Overview

La Paz Place is a three-building property totaling 44 units in the Humboldt Park/Logan Square neighborhood of Chicago. BRC acquired and rehabbed La Paz Place in 1999 and the mechanical systems are currently approaching end of life. Of the 44 units at La Paz Place, 31 are affordable to families at 50% Area Median Income (AMI) or $44,550 for a family of 4, and 13 are affordable at 30% AMI ($26,730). BRC provides housing development and preservation, economic empowerment, leadership development, and tenant organizing, including employing one La Paz Place tenant as a tenant organizer.

Building structure. The three buildings are masonry construction with courtyards and flat roofs, which is typical of the pre-war vintage in Chicago. This type of pre-war low-rise building with five or more units represents 10% of Chicago's overall housing stock (Elevate 2017). Successful electrification demonstration at this property can set the stage for increased uptake across this segment. The units at La Paz Place range from one-bedroom to four-bedroom units (Table 1).

Table 1. Building Overview for La Paz Place Property

Building Address	1-Bed Units	2-Bed Units	3-Bed Units	4-Bed Units	Total
3535-37 W Dickens Ave	3	11	3	0	17
3600-02 W Shakespeare Ave	3	3	4	3	13
3604-08 W Shakespeare Ave	1	7	6	0	14

Prior to retrofitting La Paz Place, the end uses fueled by natural gas across all buildings included: in-unit gas stoves and furnaces, common area hot water heaters, and common area gas dryers. Central air conditioning was not provided; tenants could opt to install their own window air-conditioner for cooling. In 2013 all three buildings were upgraded with air sealing and added insulation in the roof cavities. As of 2019, all three buildings at the property had energy intensities relatively close to the national median multi-family property (Figure 1).

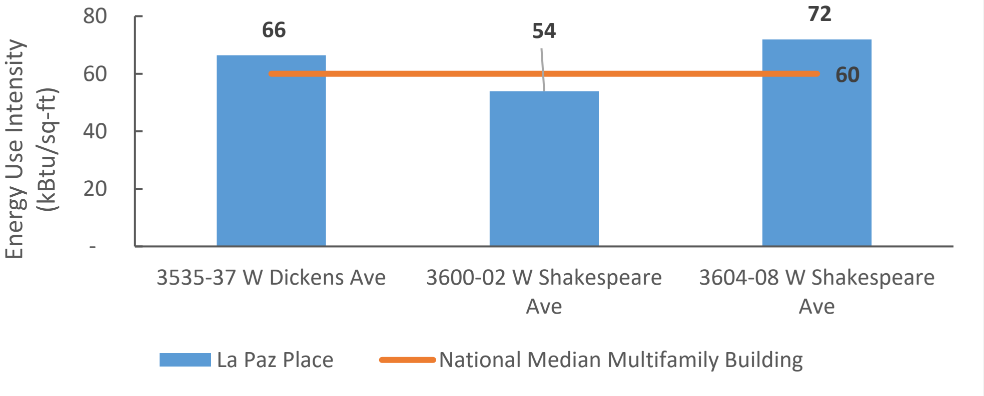

Figure 1. La Paz Place site energy use intensity in 2019

Billing structure. Utility bill payments at the property are divided between the owner and the tenants. The owner pays for electric use outside of the dwelling units and gas use from the central gas water heaters, gas dryers, and furnaces serving the common areas (i.e., laundry rooms and basements). Tenants are responsible for in-unit electric use and in-unit gas use (i.e., stoves and furnace). At least half of the tenants at La Paz Place report participating in utility bill payment assistance programs in the last year – this likely includes the Low-Income Home Energy Assistance Program (LIHEAP) and other types of assistance. Tenants qualifying for LIHEAP re-apply for each utility separately each year and the amount of financial assistance is dependent on several factors, including the heating system fuel. Pre-retrofit, tenants using LIHEAP reported gas as their primary heating fuel.

Feasibility and fit. The project team determined La Paz Place to be a good candidate for electrification based on several factors:

- **Owner Engagement:** First and foremost, the property owner BRC is heavily engaged, invests in properties for the long-term, and is interested in improving the quality of housing through efficiency and electrification. This was especially important for a pilot program for electrification in the Midwest, where multi-family electrification of existing buildings is in its infancy.
- **Replacement Timing:** The building mechanical systems were due for an upgrade at the property, so the proposed electrification upgrades worked well with the planned renovations for the property. Replacing relatively new equipment is less likely to see strong savings and is less favorable from a life-cycle perspective.
- **Equipment Options:** The property had already undergone recent building envelope improvements, including air sealing and insulation in 2013, allowing the heat pumps to be properly sized for the space. The existing ducted furnaces enabled the new air-source heat pumps to take advantage of the existing distribution system, rather than needing to add ductwork or design a new system (e.g., mini-splits) for proper distribution.
- **Tenant Impacts:** Because tenants already paid for in-unit heat, replacing their furnaces with heat pumps did not require a cost shift from the owner to the tenant (as is what could be the case when the existing heating system is central and owner-paid). Additionally, the heat pumps provide highly efficient, central air conditioning for all tenants at the property, whereas pre-electrification tenants provided and managed inefficient window units themselves. Given Chicago's prior experience with deaths during heat waves (CDC 1995) and the increasing likelihood of high-temperature events (IPCC 2021), integrated cooling represents a significant health and safety and quality of life improvement.

With these building conditions and BRC's enthusiasm for participating in BEP, Elevate moved forward by partnering with the engineering firm dbHMS to specify the electrification scope of work.

Retrofit Scope and Decision-Making

dbHMS, an engineering firm focused on delivering high-performance, efficient, and sustainable buildings, was selected to partner in the scoping and design of electrification retrofits at La Paz Place as they had previous design experience with electrification projects. In the final scope, electrification retrofits to space heating and cooling, domestic hot water, cooking, and clothes dryer end uses were included (Table 2). Our ultimate goals with the proposed measures were to save energy and carbon, maintain low installation costs, and minimally impact tenant comfort and cost. Envelope improvements (e.g., attic air sealing and insulation) were a screening criterion for buildings to be a part of the program since limited funding could not cover these improvements; therefore, envelope upgrades were not considered in the retrofit scope as they had already been implemented. The section below discusses major decision points and challenges in defining this final scope of work, which we expect to be relevant to many electrification retrofits in buildings with similar construction.

Table 2. Electrification Retrofit Scope

End Use	Pre-retrofit	Post-retrofit[2]
Space Heating	• Individual gas forced-air furnaces • 80% AFUE • Single-stage	• Ducted cold-climate air-source heat pumps • HSPF: 9.8-11.2 • SEER: 15.4-19.0 • Backup 5-10 kW electric heater in 3-bed and 4-bed units only
Space Cooling	• Window units, if provided by tenant	
Domestic Hot Water	• Central gas boiler water heater • Atmospheric vented, 80% efficiency	• Heat pump water heater (HPWH) • ENERGY STAR® Qualified • Energy Factor 3.4 • Multiple HPWHs are connected in parallel in each building
Cooking	• Natural gas stoves	• Non-induction electric • Ceramic
Clothes Dryers	• Natural gas dryers • Located in shared laundry room	• Electric resistance clothes dryers • Commercial-grade
Renewable Energy	• None	• 70 kW DC (estimated) solar PV array • Connected to house meter, and select larger units

For space heating, the team investigated two options: individual ducted cold climate air-source heat pumps (ccASHPs) and a centralized variable refrigerant flow (VRF) system. Individual ccASHPs were ultimately selected after weighing a number of factors, the decision driven primarily by the existing electrical service and technology efficiencies. Energy modeling was essential to inform key design decisions that would minimize electrical service upgrade needs, which heavily influence the project budget. La Paz Place has single-phase electrical service at both the common and in-units meters and installing a VRF system would require

---

[2] Efficiency ratings specified have a range because different systems are installed in units with different load conditions (e.g., orientation, number of bedrooms)

upgrading the electrical service to three-phase, a cost-prohibitive requirement. Energy modeling also indicated the VRF system would save only slightly more energy compared to high-efficiency ccASHPs. The project team selected premium ccASHPs with higher efficiencies, because less efficient ccASHPs would have required backup electric resistance heat in all units, which also would have demanded significant electrical upgrades. The selected ccASHPs limited electrical upgrade needs for space conditioning to 10 units[3].

Heat pump water heaters (HPWHs) were the proposed replacement for the buildings' central gas water heating system due to their high efficiency compared to electric resistance-based water heaters. Regardless of the electric DHW system chosen, the electrical service on the common areas would need to be upgraded. This meant additional cost out of the DHW budget. As the existing water heaters were in the basement, noise and having adequate space for HPWH operation was not a concern. Unitary and split HPWH systems were considered, and ultimately the team opted for a unitary system after deciding that split HPWH technology was not mature enough for cold climates. To have enough hot water capacity, multiple unitary HPWHs were connected in parallel in each building.

The design team considered several options for electrifying the stoves: traditional electric resistance coil-top stoves, ceramic-top electric resistance, and electric induction. While induction stoves are the most efficient option, they require specific cookware. Based on the project goals, the design team decided it was unacceptable to impact the tenants in this manner, especially given the minimal energy savings it would achieve. Additionally, from an inventory consistency and maintenance perspective, BRC preferred electric resistance stoves. Additional electrical wiring would not be needed in the event that BRC would like to switch to induction stoves in the future. Of note, running the wires for the new stove outlet was an additional electrical cost that was heavily influenced by how close the stove is to the electrical panel.

The existing gas dryers were replaced with electric resistance dryers. Because of the multi-family application, it was decided the longer drying times and lower capacities of heat pump dryers were not appropriate for this application where many families live in the units. The project still opted to transition from gas to electric resistance to eliminate the fixed monthly fee on the common area meter and to open the option for the property to upgrade to heat pump dryers as the technology matures in the multi-family market. Transitioning from gas to electric dryers required an electrical service upgrade; this was done on the same common area panel that also fed the HPWHs.

Solar panels were added on to the project scope after energy modeling revealed an increase in owner costs. In addition, modeling showed that four of the ten units with electric resistance backup heat may experience an increase in utility costs. An outside funder for an approximately 70 kW solar system was identified, which was fed into the electrical panels in the common areas and in-unit panels for tenants with electric resistance heat (10 units total).

The engineering team modeled expected energy and cost with the proposed retrofit scope. The modeling results are detailed in the Results section of this report.

---

[3] These units were larger (3-bed or 4-bed) and had higher heating loads based on size and orientation.

Evaluation Approach

The primary goal of BEP is to reduce on-site combustion of fossil fuels in a way that results in carbon savings and healthier living environments. For La Paz Place, an early participant in BEP, the project team sought to understand the impacts of electrification in greater detail and pursued additional funding to enhance the project evaluation. Our goal was to answer these key research questions:

1. What are the project annual energy (kWh and therms) and CO2 impacts of switching to electric end use equipment in multi-family residential buildings across heating and cooling, water heating, and cooking?
2. What is the utility cost impact of the electrification retrofit? What are the time-of-use impacts on electricity usage?
3. What are the IAQ implications of the electrification retrofit?

The methodology to answer these questions consisted of utility bill analysis and modeling, pre- and post-electrification monitoring, and tenant interviews.

Utility bill analysis and modeling. Energy savings and cost impacts were estimated using simulation-based energy models for a sampling of units where it was critical to evaluate in more detail. The energy and cost impact across the entire property was estimated with spreadsheet analyses calibrated to 2019 utility data for each building. Post-retrofit, the aggregated actual utility data will be collected again to determine actual versus estimated savings and costs to partially answer research questions 1 and 2.

Carbon reduction. Elevate calculated lifetime carbon reductions on the building level by comparing the amount of CO2 saved by removing fossil fuels to the amount of CO2 added for increased electricity consumption. For natural gas, the standard emissions factor was used.[4] For electricity, it was important to reflect the impact of the increasing clean electric grid over the project lifetime, rather than using today's eGrid emissions factor. To reflect this grid impact, we referred to RMI's 2020 study which was based on modeling using NREL's Cambium tool. This paper provided an average electricity emissions intensity for 2020-2036 for the PJM region.[5]

Pre- and post-electrification monitoring. Utility bill analysis cannot give insights about specific end uses or Indoor Air Quality (IAQ). To answer the research questions, energy and IAQ monitoring was implemented pre- and post-electrification on a subset of units. Monitoring in this case means using in-building technology to obtain real-time data on electrical draw, setpoints, and more. The monitoring team (Elevate, Slipstream, and ComEd EE R&D) evaluated a variety of sensor configurations to respond to our research questions.

There were several challenges that came up when defining the monitoring scope. With limited funds and ample possibilities for monitoring, the project team first set to define the scope

---

[4] https://www.eia.gov/tools/faqs/faq.php?id=73&t=11

[5] https://rmi.org/its-time-to-incentivize-residential-heat-pumps/

of the monitoring and number of tenant units desired to be monitored. With three separate buildings and the upfront cost to monitor in a new building, it was decided to only monitor units in one building. Not knowing how many tenants would opt in for the monitoring, we selected the building with the greatest number of units (3535 W Dickens). The most interesting and relevant research questions pertained to the air-source heat pump performance, heat pump water heater performance, IAQ in relation to removing the gas stove, and potential cost impacts of demand-based electric rates. These connect to all three of our central research questions listed above.

The finalized monitoring scope to answer these research questions is shown in Table 3. While there was substantial interest in monitoring the actual performance (i.e., COP) of the heat pump water heater, this was removed from scope due to funding limitations and the complexity of the heap pump water heater setup.

Table 3. Summary of Monitoring Instrumentation

Data Point	Central or In-Unit	Pre-retrofit	Post-Retrofit	Instrument
(Gas) Water heater operation	Central	Yes	No	State logger
(Gas) Range operation	In-Unit	Yes	No	Temperature sensor
(Gas) Furnace operation	In-Unit	Yes	No	Temperature sensor
Indoor air quality (IAQ)[6]	In-Unit	Yes	Yes	IAQ sensor
Outdoor temperature	N/A	Yes	Yes	Temperature sensor
Heat pump water heater power	Central	No	Yes	Real power meter
Heat pump power	In-Unit & Central	No	Yes	Real power meter
Dryer power	Central	No	Yes	Real power meter
Range power	In-Unit	No	Yes	Real power meter
Solar PV power	Central	No	Yes	Real power meter

Implementation of monitoring in units involved substantial tenant engagement. Since pre- and post-retrofit monitoring was proposed, there were a minimum of three site visits in each unit monitored (pre-retrofit installation, post-retrofit installation, and equipment removal). The monitoring team met with the BRC tenant engagement team to determine the best approach for tenant recruitment, engagement, and incentives. We offered a $300 incentive to be a part of the monitoring study, with additional incentives if more site visits were needed (e.g., sensor connectivity troubleshooting). BRC staff first approached tenants in the 3535 W Dickens building to talk through in person the monitoring study, what was involved, and how they would

---

[6] Includes PM2.5, CO_2, TVOC, temperature, and humidity

be paid. Then Elevate staff followed up with the tenants who said they were interested in participating in the study to schedule a time to come on site. Our goal was to recruit 10 tenants to sign up for the monitoring study, of the 14 active tenants in the W Dickens building, 9 signed up to participate in the monitoring study. As of May 2022 (9 months into the monitoring period), one tenant has dropped out of the study due to moving away from the apartment complex.

Another challenge in the monitoring implementation was timing data collection with the construction of retrofits. This required close coordination with members of the construction team. It was a priority to collect as much pre-retrofit data as possible before electrification retrofits were installed. The initial construction timeline would have limited us to just a few months of pre-retrofit data; however, significant supply chain related delays as well as opting to monitor the building planned to be retrofitted last allowed us to collect pre-retrofit data for a year from August 2021 to July 2022. The post-retrofit monitoring period is expected to be from July 2022 to June 2023.

Tenant interviews. Interviews with tenants about their experiences in the months after decarbonization retrofits have been completed are critical to understand successes and lessons learned of the upgrades. Interviews are expected to be completed during the Summer 2022, however are dependent on the construction timeline. These interviews will seek to understand the tenant's overall satisfactory with their new heating, cooling, hot water, and stove systems.

Results

Table 4 contains the expected annual site energy impacts based on our utility bill analysis and modeling. La Paz Place is projected to offset annual site energy use by 65% across the entire property, including the impact of solar PV. These savings represent a total across the entire portfolio – the amount of expected energy saved from electrification is dependent on factors such as the time of year and tenant unit size and orientation. The change in utility costs from electrification also varies between owner- and tenant-paid utilities, as seen in Table 5 where the annual cost impacts of decarbonization are shown based on current electric rates for ComEd[7]. Across all tenants, utility costs are expected to be reduced by 21%, including the impacts of solar (although solar represents a small portion of cost savings for tenants, approximately 1%). Owner costs are expected to be reduced by 4%, including the impacts of solar. Solar helps mitigate increases in owner utility costs; without solar, owner utility costs would increase by nearly $7,000 annually. This is for two reasons: (1) the increase in water heating costs on the common area meter, and (2) the relatively low impact of removing the fixed gas fee relative to the impact this had for tenant units. While the HPWHs are still expected to save energy compared to the existing gas central water heaters, this technology is still expected to have higher utility costs. In addition, while removing gas service from the building eliminates fixed gas fees for both owners

---

[7] ComEd supply charge of $0.125/kWh was used. Initially during the modeling phase, we used the average electric rate because this is the accepted standard for estimating utility cost impacts in energy efficiency programs. While the average rate provides a conservative estimate for utility bill savings, marginal rates will improve the estimate accuracy, especially for electrification projects where multiple end uses previously fueled by gas are now electric and electric use is impacted significantly more than a typical efficiency project (e.g., lighting upgrades).

and tenants, the monthly fixed gas cost (approximately $35) substantiates a much higher portion of tenants' monthly bill as compared to the owner's common area gas meter. As mentioned, because of the increase in owner utility costs, we pursued adding solar to the project to offset these costs.

In addition, there is some variation in the expected energy and cost savings across tenant units. This is primarily because larger tenant units have air-source heat pumps with larger capacity, which in this case have lower efficiencies compared to smaller units. These ccASHPs serving units with larger heating loads have electric resistance back up heat, which also reduced energy savings. From the energy modeling, it was predicted that four of these units could potentially increase utility costs. Because of this, all units with electric resistance back up heat were also connected to the solar system to reduce the risk of increased utility bills.

Table 4. Projected Annual Site Energy Use and Savings from Electrification

	Electric Use		Gas Use	
Metric	kWh	kBtu	Therm	kBtu
Pre-retrofit	211,536	721,760	41,457	4,145,650
Post-retrofit (modeled)	563,170	1,921,536	0	0
Electric production (solar added)	63,140	215,435	NA	NA
Site energy savings (with solar) – 3,161,310 kBtu (65% savings)				

Table 5. Projected Annual Cost Savings from Electrification

	Pre-retrofit Annual Cost (with solar)	Post-retrofit Annual Cost (without solar)	Post-retrofit Annual Cost (with solar)	Percent Cost Savings
Tenant	$61,452	$49,362	$48,811	21%
Common Areas	$14,253	$21,034	$13,692	4%
Total	$75,705	$70,396	$62,504	17%

Table 6. Projected Annual Carbon Savings from Electrification

	Pre-retrofit Annual Carbon Emissions (lbs CO2)	Post-retrofit Annual Carbon Emissions (without solar) (lbs CO2)	Post-retrofit Annual Carbon Emissions (with solar) (lbs CO2)	Percent Carbon Savings (with solar)
Total	635,661	400,977	356,021	44%

For the pre- and post-electrification monitoring, we have thus far estimated the pre-retrofit energy by end-use and have pre-retrofit data on the air quality in tenant units. The first research question aimed to assess the annual energy impact of electrification by end-use. The first step to answering this question is calculating the pre-retrofit energy by end-use (Table 7 and Table 8). This was computed using monthly gas bills, monitoring of the DHW operation, electric AMI data at 30-minute intervals, and weather data. One finding of the analysis thus far is likely inefficiencies in the central water heater and common area furnaces. A circulation pump runs constantly between the central water heater and storage tank, causing frequent cycling and excessive heat loss.

Table 7. Pre-retrofit Estimated Annual Consumption by Gas End-Uses in 3535 W Dickens Building

End-use	Total (Therms)	Per Housing Unit (Therms)
Central water heater	3,310	195
Common-area furnaces (weather-normalized)	2,490	146
Central clothes dryers	550	32
Unit furnaces (weather-normalized)	4,690	276
Unit ranges	380	22
Total	11,420	671

Table 8. Pre-retrofit Estimated Annual Consumption by Electric End-Uses in 3535 W Dickens Building

End-use	Total (kWh)	Per Housing Unit (kWh)
Common-area furnace fans (weather-normalized)	1,000	59
Common-area other	7,280	428
Unit furnace fans (weather-normalized)	5,800	341
Unit window air conditioners (weather-normalized)	7,520	442
Unit other	39,130	2,300
Total	60,730	3,570

The third research question aimed to assess the impact of electrification on air quality in tenant units. We expect these results to show improved air quality via reductions in particulate matter after the gas stove is replaced with an electric stove. One year of post-retrofit air quality monitoring will be compared to 10-12 months (depending on the unit) of pre-retrofit air quality monitoring.

Discussion

This case study demonstrates the electrification of an affordable multi-family property in the Midwest. Project challenges and elements for successful electrification are documented below across the candidate selection, retrofit scope development, construction, and evaluation stages of the project. These process improvements also highlight important policy elements to scale similar programs to support affordable multi-family decarbonization.

As this project is in process during the writing of this paper, there are several next steps to highlight. Electrification construction is expected to be complete across the property by the Summer 2022, with the installation of rooftop solar to follow. Our aim is to conduct tenant interviews in the Summer 2022, focusing on the units that received retrofits first and therefore have more experiences with electrified equipment. Evaluation monitoring will continue through the Summer of 2023, with our aim to have a full year of post-decarbonization monitoring. While the discussion below documents lessons learned so far – focusing on the retrofit design choices and tenant engagement processes – later case studies and reports will contain findings such as actual cost and energy impact after the evaluation phase has ended in 2023.

Lessons Learned

A holistic approach to assessments, focus on tenant utility bill impacts, and engagement with tenants at multiple touchpoints were integral steps to develop the final scope of work for electrifying an existing affordable housing complex in a cold climate. It was crucial to assess energy efficiency, electrification options, and solar viability early in the process. Our approach comprehensively assessed what was needed to conduct a deep energy retrofit with electrification, while still reducing tenant utility costs. Energy modeling results directly informed where electric resistance heat was required and where upgrading the power to the buildings was necessary, both of which has a significant impact on the project budget. Modeling also gave insight into tenant utility bills, a key insight for an affordable housing context. The key design decisions that enabled tenant utility bills to be reduced were: (1) premium cold-climate air-source heat pumps whose high efficiency made it that electric backup heat was not required, and (2) electrification of all end-uses so the fixed gas fee was removed from tenant bills.

Shifts in utility costs to tenants or owners is an important consideration that is dependent on existing site conditions and retrofit choices. It is important for a project team to have conversations early on about the existing billing structures and options the owner is open to post-electrification to inform the design options. In this case study, tenants and owner utility cost structure remained consistent across the electrification retrofit. While this is the simplest and possibly preferred approach in many cases, it is not an option in some scenarios depending on the existing site conditions and design recommendations. For example, if individual furnaces that tenants paid for are replaced with a central VRF system, the owner would then be responsible for heating and cooling costs. In an affordable housing application, the owner could consider shouldering those costs or offsetting them through utility allowance and rent adjustments.

BRC and Elevate were committed to keeping tenants informed throughout the electrification process. This was important from a practical standpoint since all work was being completed with tenants staying in their units, but also to reflect our values of inclusion and feedback. BRC's tenant coordinator staff positions were instrumental in this work. Organizations that do not have this capacity already established will need to make a concerted effort early in the process to establish communication channels and build trust. For La Paz Place, the tenant engagement strategy included:

- A property-wide community meeting for all tenants pre-construction to discuss the planned renovations and timeline for implementation
- CUB (Citizens Utility Board) overview presentation on utility bill impacts and how to read their bills
- Flyers to document and explain how their utility bills will change (i.e., no more gas bill)
- Door-knocking prior to the community meeting to talk through the retrofits one-on-one and encourage meeting attendance
- Tenant incentives of $50 per person living in an apartment
- Additional incentives for tenants participating in the monitoring study

These multiple tenant touchpoints as well as ongoing communication between tenants and tenant organizers gave us valuable information about the project. One surprising learning was how excited residents were about receiving air conditioning, and how few complaints we heard about giving up gas stoves. We were anticipating pushback since cooking is such a personal activity and electric stoves may have negative perceptions, but it makes sense that in Chicago air conditioning is seen as a major quality of life and health improvement.

Policy and Scaling

In order to provide decarbonization retrofits in the affordable housing market at scale, we offer a few policy and regulatory solutions. A key barrier to electrification upgrades, particularly in affordable housing, is upfront cost. In this existing multi-family building retrofit, the cost and technical challenges associated with electrical (and related) upgrades were substantial. Older housing stock will require added electric capacity, and multi-family housing will be limited by having single-phase versus three-phase power supply, limiting the ability to convert to VRF or other centralized technologies. Utility ratepayer funds for energy efficiency or federal subsidizes could be used to socialize the costs of these improvements. Colorado, for example, recently passed legislation to consider the social cost of methane in its energy efficiency cost effectiveness calculations, which will provide additional ratepayer dollars to support building electrification (Energy News Network 2021). Also, proposed federal programs such as the High-Efficiency Electric Home Rebate Program would incentivize switching to electric end-use equipment. These federal programs should be bundled with energy efficiency and solar programs where possible to streamline retrofit approaches and more efficiently disperse funding.

Ongoing utility costs are of course a barrier, with current electric rates not accommodating of all-electric retrofits. Along with continuing to provide incentives for rooftop solar to directly offset increased electric usage, utilities and policy makers should continue to explore additional rate design options. These options could include reexamining electric space heat rates to have a larger bill impact, developing time of use rates that reflect the demand curves of electrified buildings, and additional options that are the topics of ongoing research projects. Electrification-specific rates would be helpful to incentivize adoption and minimize cost impacts on tenants experiencing energy burden.

Additionally, improvements are needed for residents who receive LIHEAP to seamlessly transfer that benefit from their natural gas account to their electricity account once electrification occurs. For a typical gas-heated home, the resident would apply in the fall for gas benefits and then in the spring for electric benefits, reflecting the periods of higher cost for each fuel. Tenants electrifying outside of those time frames are at risk of losing benefits. For La Paz Place, the first cohort of units that electrified in December would not use the full amount of their natural gas credit and would not be able to apply for electric credits until receiving utility confirmation of being converted to electric heat. In this case, Elevate developed a solution specific to this project by identifying funding to reimburse those who lost LIHEAP benefits; however, this is not replicable for every project. Building owners should support tenants in the process of closing the gas account if they fully electrify every end use, and in transitioning to an electric space heating electricity rate if their utility offers it. Ideally, the LIHEAP program would shift from funding assistance for only the primary heat source to funding assistance for the total energy bill. This would ensure that, as the heating source moves from gas to electricity, customer benefits are not denied or reduced. This would, however, require the United States Department of Health and Human Services to make changes to the program.

Conclusion

Decarbonization in the built environment is an important pathway for meeting low-carbon commitments, mitigating climate change, and improving housing quality in existing buildings. Affordable, multi-family housing is an existing building stock with ample opportunity for energy efficiency, electrification, and renewable energy. This housing stock can also benefit greatly from reduced utility bills and improved housing quality (e.g., air quality, central air conditioning). As decarbonization programs grow, there is an opportunity to design these programs in a way that make them more accessible to the affordable housing stock. In this case study, we document a pilot decarbonization project under the Building Electrification Program, which focuses on electrification for affordable, multi-family properties in the Midwest. The case study property consists of a three-building site owned by a nonprofit housing developer, and is typical of many affordable, multi-family buildings in Chicago. We show our process for identifying candidate electrification buildings, comprehensive approach for retrofit decision making, and evaluation methods for assessing electrification cost, carbon, and air quality impacts. Our findings highlight how building electrical service and gas-fixed costs drove retrofit decisions that are expected to reduce tenant and owner utility bills, while adding access to central air conditioning. The property is also expected save substantially on energy and carbon. Our evaluation approach will analyze the post-electrification energy and air quality performance in detail. Overall, this project expands the examples of multi-family decarbonization in a cold-climate to demonstrate the potential of electrification in creating low-carbon communities while maintaining the affordability of utility costs.

References

ACEEE (American Council for an Energy-Efficient Economy). 2022. “Building Decarbonization Solutions for the Affordable Housing Sector.” https://www.aceee.org/research-report/u2204.

Brant and Geller. 2020. “Incorporating Strategic Electrification Into a Multifamily Whole Building Energy Efficiency Program.” *2020 ACEEE Summer Study on Energy Efficiency in Buildings.*

CDC (Center for Disease Control). 1995. “Heat-Related Mortality -- Chicago, July 1995.” https://www.cdc.gov/mmwr/preview/mmwrhtml/00038443.htm.

CEE (Center for Energy and Environment). 2017. “Cold Climate Air Source Heat Pump.” https://www.mncee.org/sites/default/files/report-files/86417-Cold-Climate-Air-Source-Heat-Pump-%28CARD-Final-Report-2018%29.pdf.

Davis and Hausman. 2022. “Who Will Pay for Legacy Utility Costs?” *Energy Institute at Haas*. http://www.haas.berkeley.edu/wp-content/uploads/WP317.pdf.

Elevate. 2017. “Segmenting Chicago Multifamily Housing to Improve Energy Efficiency Programs.” https://www.elevatenp.org/wp-content/uploads/Chicago-Multifamily-Segmentation.pdf.

Energy News Network. 2021. “Social cost of methane changes the equation for Colorado utility policy.” https://energynews.us/2021/08/02/social-cost-of-methane-changes-the-equation-for-colorado-utility-policy/.

Gerdes. 2019. “Sacramento Wants to Electrify It’s Homes, Low-Income Families Included.” *Green Tech Media*. https://www.greentechmedia.com/articles/read/sacramento-wants-to-electrify-its-homes-low-income-families-included.

IPCC (Intergovernmental Panel on Climate Change). 2021. “Climate change widespread, rapid, and intensifying.” https://www.ipcc.ch/2021/08/09/ar6-wg1-20210809-pr/.

JCHS (Joint Center for Housing Studies of Harvard University). 2021. “The State of the Nation’s Housing.”https://www.jchs.harvard.edu/sites/default/files/reports/files/Harvard_JCHS_State_Nations_Housing_2021.pdf .

Slipstream. 2021. “Can Passive House help us build more efficient affordable housing?” https://slipstreaminc.org/research/passive-house-efficient-affordable-housing.

State of Illinois. 2021. “Gov. Pritzker Signs Transformative Legislation Establishing Illinois as a National Leader on Climate Action.” https://www.illinois.gov/news/press-release.23893.html.