HOUSING TAX CREDIT BUILDING ELECTRIFICATION REPORT

December 9, 2021

Prepared for: Colorado Housing and Finance Authority

Prepared by: Group14 Engineering - Michael Levinson, Sarah Hong, Michael Harris and Erik Swanton

TABLE OF CONTENTS

Definitions

Adaptive reuse	A project where all or part of an existing building was adapted for another use.
All-electric	A site where building heating, domestic hot water, and cooking use electricity as the sole fuel type.
Continuous exhaust	Ventilation strategy where fresh air is brought into the unit by depressurizing it via a constant volume fan.
Corridor-fed	A building with units accessed via a central, conditioned corridor.
Greenhouse gas	A gas that absorbs heat energy emitted from the Earth's surface and reradiates it back to Earth, resulting in an increase in surface temperature (ig. CO2, CH4, N2O)
Heat pump	HVAC system that uses refrigerant to draw heating/cooling from a given source to distribute into a unit. Heat pumps can be air, water, or ground source.
Highly efficient all-electric	An electric space heating and water heating system that uses advanced heat pump technologies that can perform up to 3 - 4 times the efficiency of standard efficiency electric systems.
Mixed-fuel	A site where unit heating and/or domestic hot water are produced by gas-fired equipment.
Partially-electric	A building with electric space heating and gas domestic hot water systems.
Primary heat source	Primary technology used for heating a unit.
Regulated utility	These utilities are subject to Colorado Public Utility Commission requirements. The regulated electric utilities are Xcel Energy and Black Hills Energy. The regulated natural gas utilities are Xcel Energy, Black Hills Energy, Atmos Energy and Colorado Natural Gas.
Roof assembly R-value	The combined insulative value of a roof assembly including, framing, insulation, and other components.
R-value	A measure of thermal resistance used to indicate the performance an insulating material. The higher the R-value, the greater the insulating power.
Schedule of values	A comprehensive list of work items and payments values that represents the entire project from beginning to end.
Split DX	Type of cooling system with an indoor evaporator coil and an outdoor condensing unit.
Split heat pump	Air source heat pump with separate indoor distribution and outdoor heat pump elements. This equipment can be ducted or ductless.
Standard efficiency all-electric	An electric space heating and water heating system that relies mostly on electric resistance heat.
Supplemental heat	Heating that is intended to support the primary heating system and is mainly to be used on the coldest days of the year.
Total site amps	Combined amperage of the main distribution panels for all buildings onsite.
U-factor (or U-value)	A measure of thermal transmittance that is equal to the inverse of the R-value. The lower the U-factor, the greater the insulating power.
Variable refrigerant flow	Type of central conditioning system made up of air handlers in the unit and central air source heat pumps located outdoors.
Ventilation (PTAC/VTAC)	Unit ventilation that is handled by outdoor air drawn and conditioned via the PTAC/VTAC serving the unit.
Walk-up	A building where the units open onto an exterior walkway.
Wall assembly R-value	Combined insulative value of a wall assembly including, framing, insulation, and other components, not including windows.

List of Abbreviations

ASHP	Air Source Heat Pump
CD	Construction Document
DD	Design Development
DHW	Domestic Hot Water
DX	Direct Expansion
ERV	Energy Recovery Ventilator
FCU	Fan Coil Unit
GHG	Greenhouse Gas
HPWH	Heat Pump Water Heater
HRV	Heat Recovery Ventilator
HVAC	Heating, Ventilation, and Air Conditioning
HTC	Housing Tax Credit
IECC	International Energy Conservation Code
LCCA	Life Cycle Cost Analysis
MAU	Make-up Air Unit
MEP	Mechanical, Electrical, and Plumbing
PTAC	Packaged Terminal Air Conditioner
PTHP	Packaged Terminal Heat Pump
QAP	Qualified Allocation Plan
SD	Schematic Design
SOV	Schedule of Values
VRF	Variable Refrigerant Flow
VTAC	Vertical Terminal Air Conditioner
VTHP	Vertical Terminal Heat Pump

LETTER OF INTRODUCTION

chfa

denver
1981 Blake Street
Denver, CO 80202
303.297.chfa (2432)
800.877.chfa (2432)

PO Box 60
Denver, CO 80201
800.659.2656 tdd
www.chfainfo.com

western slope
348 Main Street
Grand Junction, CO 81501
970.241.2341
800.877.8450

December 9, 2021

Dear Partner,

Colorado Housing and Finance Authority (CHFA), in partnership with the Colorado Energy Office (CEO) and the Department of Local Affairs (DOLA), commissioned the enclosed technical study to advance understanding of the opportunities, benefits, and challenges to building new and preserving existing affordable multifamily housing that is all-electric.

This technical study includes analysis of:

- 24 Housing Tax Credit developments, including 13 all-electric and 11 mixed-fuel multifamily projects that are occupied, under construction or in predevelopment;
- opportunities and challenges surrounding electrification for affordable multifamily developments including the impact on energy costs for residents in affordable housing and upfront costs and design decisions; and
- overview of the regulatory and utility landscape in Colorado.

CHFA is pleased to share this information in partnership with CEO, DOLA, and our stakeholders as we support Colorado meeting its Renewable Energy and Climate Action goals.

Sincerely,

DocuSigned by:
Cris A. White
EDFF662D77D24B7...
Cris A. White
Executive Director and CEO
Colorado Housing and Finance Authority

DocuSigned by:
Will Toor
A95ABA34282049B...
Will Toor
Executive Director
Colorado Energy Office

DocuSigned by:
Rick Garcia
8EBCA2C8EB6741E...
Rick Garcia
Executive Director
Department of Local Affairs

Overview of the Housing Tax Program

What are low income housing tax credits?

The Low Income Housing Tax Credit (LIHTC) program was created by Congress in 1986 as Section 42 of the Federal Tax Reform Act. Its purpose is to encourage the construction and rehabilitation of low income rental housing by providing a federal income tax credit as an incentive to investors. Corporate investors may receive 10 years of tax credits in return for investing equity capital into the development of eligible housing projects.

How do they work?

Federal housing tax credits are awarded to developers of qualified projects. Developers then sell these credits to investors to raise capital (or equity) for their projects, which reduces the debt that the developer would otherwise have to borrow. Because the debt is lower, a tax credit property can in turn offer lower, more affordable rents.

If the property maintains compliance with the program requirements, investors receive a dollar-for-dollar credit against their federal tax liability each year over a period of 10 years. The amount of the annual credit is based on the amount invested in the affordable housing.

What's the state affordable housing tax credit?

Colorado's state affordable housing tax credit raises private-sector equity for affordable rental housing development. The program is modeled after the nationally recognized federal housing tax credit program. Colorado's program was originally established in 2001 and later renewed in 2014, 2016, and 2018. In 2019, the program was expanded, authorizing CHFA to allocate $10 million in state housing tax credits annually in 2020–2024.

What is CHFA?

CHFA's mission is to strengthen Colorado by investing in affordable housing and community development. We offer loan programs and homebuyer education to support responsible homeownership. We provide loans and tax credits to developers of affordable rental housing, so all Coloradans may have access to a place to call home; and we help business owners access the capital they need to grow and support jobs. CHFA is self-funded. We are not a state agency. CHFA's operating revenues come from loan and investment income, program administration fees, loan servicing, and gains on sales of loans. CHFA receives no direct tax appropriations, and its net revenues are reinvested in its programs and used to support bond ratings. CHFA's work revitalizes neighborhoods and creates jobs. We are proud to invest in Colorado's success. Visit www.chfainfo.com for more information.

EXECUTIVE SUMMARY

Colorado is facing immediate, local impacts from climate change. Snowpack evaporates early and wildfires endanger homes. Heat intensity shortens school schedules. Drought threatens regional water supplies and agriculture. Respiratory health is compromised by wildfire smoke and ozone. Across the state, low income Coloradans are often the most vulnerable to the negative effects of climate change.

The best available science says that global temperature rise should be limited to 1.5°C above pre-industrial levels to prevent truly catastrophic consequences. A 2021 UN report puts the world on track to warming of 2.7°C by the end of the century (United Nations, 2021).[1] New action by industry and government is needed to avert worst case scenarios.

Colorado is also experiencing a housing crisis. A 2020 Root Policy Research report estimated 150,000 households were considered severely cost burdened in early 2020, paying more than 50% of their income on housing. The number was projected to rise to 360,000 households by the end of 2020. The report also states that statewide, households with children are five times more likely than those without children to be behind on rent (Root Policy, 2020).[2] When a family is severely cost burdened by housing, preventing homelessness often takes priority over healthcare, education, and adequate nourishment. The need for more affordable housing is painfully acute.

The state has recognized the need for action on both affordable housing and climate change. The American Rescue Plan Act (APRA) in conjunction with recent state legislation (HB21-1271, SB21-242 and HB21-1329) have together authorized nearly $1 billion in new housing funding for Colorado. In 2021, Colorado also released its Greenhouse Gas (GHG) Pollution Reduction Roadmap with a plan to reduce emissions 50% by 2030 and 90% by 2050 (State of Colorado, 2021).[3]

Scenario Projections of Colorado's GHG Emissions

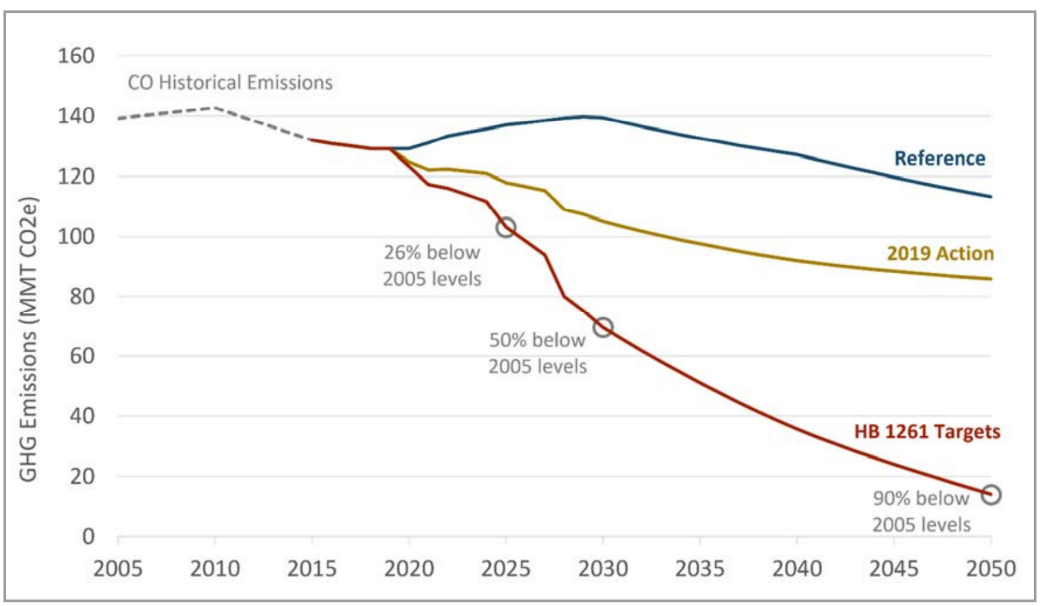


Figure 1

The chart on left comes from the State of Colorado's Greenhouse Gas Pollution Reduction Roadmap. Retrieved from: https://energyoffice.colorado.gov/climate-energy/ghg-pollution-reduction-roadmap

Electrification of affordable housing lies at the intersection of the housing and climate crisis. The greening of Colorado's electricity grid makes the elimination of on-site fossil fuel use a critical GHG reduction strategy. This study found that standard efficiency all-electric design reduced GHG emissions by 32% over the 50 year life of a Low Income Housing Tax Credit (HTC) property. Highly efficient all-electric buildings that fully embrace heat pump technology would see more significant emission reductions. Standard efficiency all-electric systems rely heavily on resistance heat for cold weather operation and domestic hot water heating, and consume three times the energy of heat pump systems.

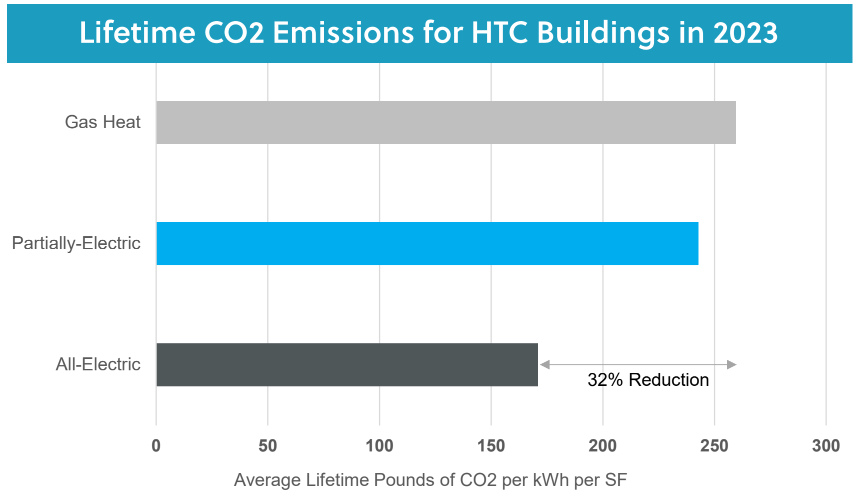


Figure 2

All-electric systems offer benefits to HTC properties beyond climate change mitigation. The elimination of in-unit carbon monoxide sources increases resident safety. Removing other combustion products from exterior venting improves local air quality and resident health outcomes. In some retrofit scenarios, air source heat pump technology offers a cost effective way to add cooling to affordable housing that currently lacks these systems. All-electric design future proofs building infrastructure against future permitting requirements that don't allow for natural gas equipment.

Most project teams interviewed for this study reported that reduced GHG emissions did not drive site fuel use decisions (with two exceptions). Fuel use selection was made early in design, and flowed from other project fundamentals - cost, site location, resident impact, etc. Typically, the fuel use choice that resulted in the lowest construction and operating cost profile was deemed the most financially feasible. For 9% and state tax credit projects, cost containment also offered a perceived bump in HTC application competitiveness

Developers reported, and this study's findings confirmed, **that HTC building electrification as currently implemented challenges financials with substantially increased operating costs.** A snapshot of nine recently built HTC-supported projects found that the average energy cost for all-electric construction was $1.37/SF compared to only $0.77/SF for projects with all-gas heating. This represents a nearly 78% utility cost increase for conventional all-electric design. These all-electric designs relied heavily on resistance heating technology for low temperature heating and DHW, which is affordable to install but costly to operate. Even partially-electric buildings (all-electric except gas fuel DHW) still saw operating costs increase to $1.14/SF on average.

A SNAPSHOT OF NINE RECENTLY BUILT HTC-SUPPORTED PROJECTS FOUND THAT THE AVERAGE ENERGY COST WAS....

$1.37/SF

FOR PROJECTS WITH ALL ELECTRIC

$1.14/SF

FOR PROJECTS WITH PARTIALLY ELECTRIC

$0.77/SF

FOR PROJECTS WITH ALL GAS HEATING

Operational Costs of All-Electric, Partially-Electric and Gas Heat Projects

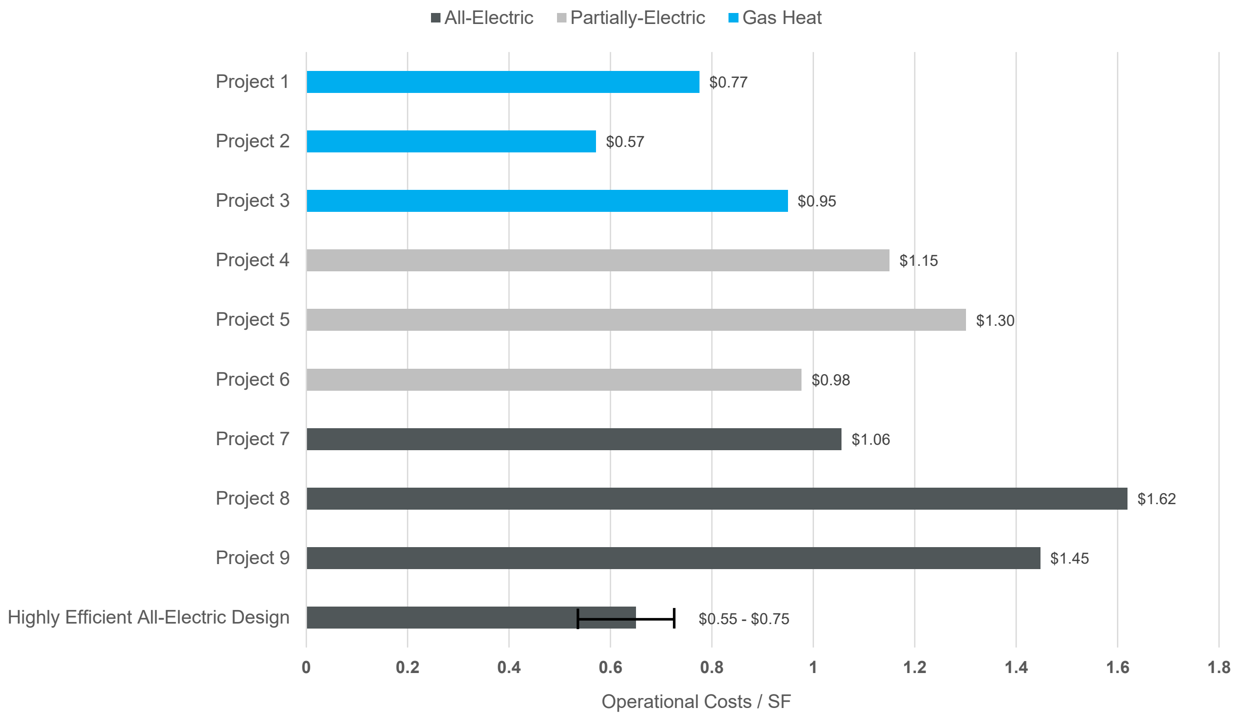


Figure 3

Higher electricity costs have the potential to increase the percent of household income spent on energy (energy burden) for low income residents. Current utility allowance methodologies don't always properly account for the variability in utility costs associated with current practice all-electric HTC design. Additionally, some jurisdictional utility allowance schedules don't provide options for heat pump electric heat, which would reduce utility allowances and increase rental income. This poses challenges for developers in certain locations to finance the added capital costs associated with highly efficiency all-electric systems without the additional rental income.

The energy cost profiles presented in Figure 3 above represent buildings that meet, but do not substantially exceed, jurisdictional code requirements. The advantage of standard efficiency design is that construction costs fall within an acceptable range. Among the 24 study participant projects, no meaningful difference could be found in new construction and major renovation construction budgets due to fuel use type. There was slightly more variability in mechanical, electrical, and plumbing (MEP) costs of all-electric buildings, but some were the most affordable in the data group.

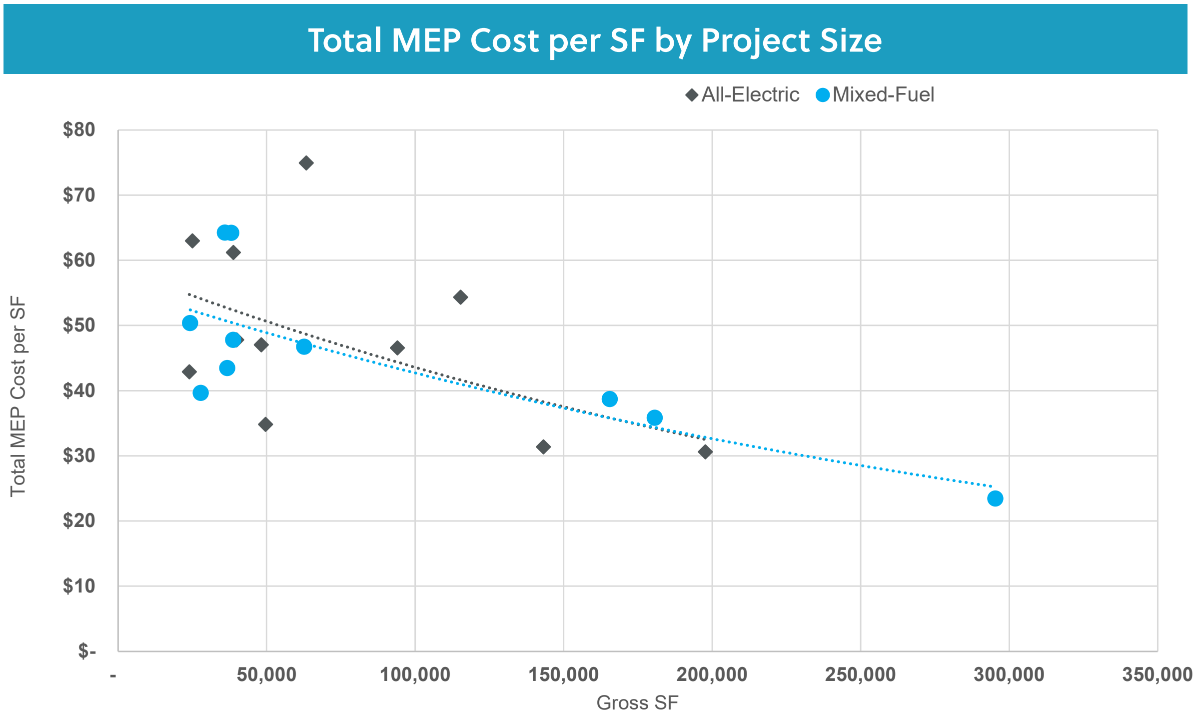
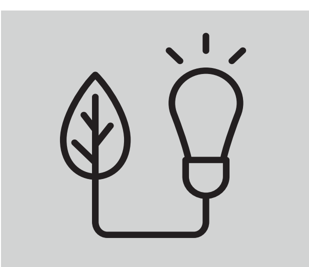


Figure 4

Key Findings



Solution: Adoption of highly efficient systems

The solution to all-electric operating cost challenges is the **HTC market adoption of highly efficient building systems**. Improved envelope assemblies and installation practices, cold climate heat pumps, energy recovery ventilation, heat pump DHW systems, and solar photovoltaics are all widely available, commercialized technologies proven to reduce energy costs. Heat pump systems are becoming more common, but must be designed for cold conditions to optimize heat pump operation. This will avoid resistance backup heating which can cause demand spikes and three times the energy consumption. More efficient designs are being deployed by a few HTC-supported projects either under construction or recently completed. Utility data was not yet available for analysis, but energy models indicate that **high-performing all-electric operational costs can be competitive with all-gas projects ($0.55/SF - $0.75/SF).**

Barrier: Construction costs of efficient systems

The most significant barrier to the adoption of highly efficient building systems was construction cost. Teams indicated that project financial feasibility is the main driver of early design decisions. The perception is that highly efficient building systems would increase construction costs, which in turn would threaten project viability. That most projects in this study show limited adoption of highly efficient building systems speaks to the strong construction cost containment pressures exerted by the HTC application and funding ecosystem. The shallow adoption of these systems has in turn limited design teams' experience with many high-performance design options. This creates a reinforcing cycle that supports the continued use of code minimum design. Teams also reported significant variability in the availability and expertise of technical consultants, building trades, and service/repair technicians across different parts of the state. This highlights the need for system simplicity in highly efficient all-electric design.

Recommendation Summary

The challenge before Colorado's HTC industry is finding ways to align with the state goals of:

1. Encouraging highly efficient, all-electric new construction to reduce GHG emissions and deliver other electrification co-benefits;
2. Avoiding increased construction costs that would reduce the number of affordable housing units placed in service;
3. And, ensuring reasonable utility costs to both building owners and residents.

Group14 Engineering has identified several policy, funding, and technical assistance initiatives that would advance these goals. These recommendations are informed by input from HTC developers and design teams, a literature review of other state affordable housing electrification programs, and Qualified Allocation Plan (QAP) electrification approaches from around the country.

New funding for all-electric highly efficient building systems in affordable housing

Supplement existing utility incentive programs with funding tied to all-electric design and high efficiency performance.

- Timing: Funds will have the greatest impact on project planning if they are committed in conjunction with the HTC award.
- Amount: Similar programs around the country support $2,500 - $6,000 per unit to offset added construction costs.
- Clear Requirements: Require all-electric new construction plus advanced energy performance standards.

Design playbook for highly efficient, all-electric building systems in Colorado

Leverage the expertise of local construction trades, design professionals, developers, nonprofits, and energy consultants to assemble best practices for HTC building electrification. A key focus of the Design Playbook should be system simplicity, both to speed market transformation and ease operation and maintenance.

Statewide affordable housing electrification resource hub

Create a statewide resource hub dedicated to affordable housing to set HTC projects up for electrification success. Key services could include technical assistance and facilitating access to funding and incentive programs. State agencies or nonprofits like Energy Outreach Colorado may be positioned to launch this kind of resource.

Incentivize electrification through the Qualified Allocation Plan (QAP)

In November of 2021, CHFA proposed a 2021-2022 QAP Amendment to add guiding principles that support Colorado's GHG emission reduction goals, advanced energy performance standards, and electrification-ready construction of affordable housing. This includes requiring a project construction or renovation narrative that demonstrates an electrification-ready project.

Electrification can be further incentivized through the QAP via the following amendments:

- In 2023-2024, add a guiding principle to the QAP that states "To support affordable housing that is constructed to be highly efficient and all-electric."
- In 2028-2029, add a requirement that all new construction projects be all-electric and meet advanced energy performance standards. The timeline for implementing this requirement should be adjusted based on the assessed impact to Housing Tax Credit supported project financial feasibility. Amendment language should be published and go through public comment at least three years in advance of adoption.

Other state QAPs offer a tiered scoring approach to incentivize mostly-electric, all-electric, and carbon neutral design.

Utility meter and allowance advocacy

Master metering an entire property for both consumption and solar production is essential to maximize on-site renewable opportunities. Some utilities require that each apartment receive an individual, utility owned residential meter. This increases utility service charges and makes significant solar installations cost prohibitive. HTC Stakeholders should advocate for change.

- Utility allowance schedules and heat pumps - Ask all jurisdictions and housing authorities to include a line item for electric heat pumps in utility allowance schedules.

Additional research

There are a number of research areas beyond the scope of this study that would be invaluable for affordable housing electrification:

- Comparative Life-Cycle Cost Analysis for highly efficient vs standard efficiency building systems
- Moderate rehab and retrofit all-electric opportunity and challenge analysis
- Statistically representative sample of Colorado HTC utility cost profiles by fuel use and building type
- Embodied carbon analysis of common HTC construction typologies
- Detailed case studies of high efficiency all-electric HTC projects
- Operation and maintenance resources and challenges for all-electric systems
- Modular construction opportunities to reduce the cost of highly efficient electric buildings

SCOPE & METHODOLOGY

The Colorado Housing and Finance Authority (CHFA), the Division of Housing (DOH), and the Colorado Energy Office (CEO) commissioned an analysis to better understand the impacts of building electrification in affordable family projects. The study population was defined by new construction and acquisition/rehab properties supported with State and/or Federal Low Income Housing Tax Credits (HTC/Housing Credit). This report represents data collection and analysis conducted in the second half of 2021. Key study scope items include:

- Project characteristic survey of 24 Colorado HTC projects, including fuel use mix, energy related building systems, utility provider, energy related funding sources, market served, metering strategy, energy code, and green certification
- Regulatory and utility landscape review as it relates to electrification, energy performance, and carbon reduction
- Capital and operating cost analysis for all-electric and mixed-fuel projects
- Opportunity and challenge synopsis for all-electric and mixed-fuel design and development

The 24 HTC projects selected for the study were all awarded tax credits between 2016 and 2020. Thirteen projects are all-electric and 11 are mixed-fuel. For reference, 223 total HTC awards were made during this time period. CHFA staff choose study participants based on an internal project fuel use survey. The study project group is not meant to serve as a statistical representation of all Colorado HTC projects. Instead, recent all-electric and mixed-fuel projects from across the state were selected with the goal of presenting a broad cross-section of development, design and operation use cases.

It should be noted that CHFA invited most of the all-electric projects that received HTC awards in the last five years to participate in the study. While all-electric projects make up the majority of study participants, they represent a small fraction of overall HTC buildings. Most HTC buildings have natural gas service for one or more end uses.

Canopy at Red Oak Park in Boulder, CO, is one of the 13 all-electric projects featured in this study.

Data Sets

Study data includes a mix of qualitative and quantitative sources with self-reported and measured data points. Information was solicited from CHFA, utility providers, and project team members (developer, architect, MEP engineer, general contractor, and property management).

Existing Data: CHFA provided select HTC application documents subject to the Colorado Open Records Act, including the application project cost summary, application project narrative, and final cost summary when available.

Drawing/Plan Set: The project team provided construction drawings and specifications, including the civil, architectural, mechanical, electrical, and plumbing sets.

Utility Data: Utilities provided master meter electricity and natural gas data (consumption, demand, and cost). When residents paid utility bills via a submetering platform, this data was solicited from property management.

Costs: Construction cost data including mechanical, electrical, and plumbing schedule of value totals, costs for natural gas service, piping and venting, EV parking, and some electrical line item detail. All construction cost data was self-reported by the general contractor, taken from construction pay apps or drawn from the final project cost summary submitted to CHFA.

Interviews: Zoom interviews were conducted with project team members as available including the developer, architect and MEP engineer(s). The interviews included a standard list of questions tuned to mixed-fuel or all-electric projects. The Zoom survey question list is presented in Appendix A - Survey Questions.

Data Challenges

Key Findings

There were two data sets that were difficult to assemble during study analysis: Resident-paid, apartment-level utility data and equipment-specific capital costs. Both categories of information are important to fully assess the barriers and opportunities around all-electric construction. The obstacles associated with collecting these data sets are presented below.

Above: Apex East, the all-electric complex located in Englewood, CO.

Resident-Paid Utility Data

Typically, there are two metering approaches to resident-paid utilities. The first is installing utility owned meters at each apartment. In this case, the utility company bills the tenant directly and usually considers each resident's utility data to be confidential in nature. While each utility has its own process and forms, a tenant signature is typically required for the release of apartment level utility data to a third-party (including property management). **Securing utility release form authorization from residents is a significant administrative burden**, especially as some residents may have concerns about the misuse of their data. One long term solution is for property management to include the utility release form as a standard part of the lease agreement.

The second resident-paid utility metering approach is to install property-owned, apartment-level submeters. **Often, submeter data can be technically difficult to access.** When submeters are not needed for billing residents, property management rarely goes through the effort of collecting and reviewing submeter data. If a process for collecting submeter data is not established in year one of building operation when the installing contractor is actively engaged, it can be even more difficult to access these metering systems.

In cases where submeter data is accessed and used for resident billing, **the allocation basis of building level electricity costs to apartment level usage is sometimes unclear**. For electricity, these submeters report kWh consumption to property management or another third-party entity who in turn bills residents. Building ownership will pay the utility directly, and collect payments from residents for their portion of the utility cost. As will be further discussed in the Operating Cost section of this report, many master metered HTC properties are on an electric rate schedule with both consumption and demand-based cost components. It is unclear how billing entities are properly allocating the whole building utility bill demand cost component via a submeter that only measures consumption. One area for further research is to document common allocation practices for demand-based electricity costs via resident submeters.

Equipment Capital Costs

The study's capital cost data collection methodology focused on high level engagement with general contractors. This proved to be effective for obtaining a construction schedule of values (SOV) with summary cost information. **However, equipment level cost detail often was held by trade subcontractors.** Time limitations prevented another round of subcontractor engagement before study publication. More thorough documentation of equipment level costs for key efficiency and electrification technologies should be an area for future study.

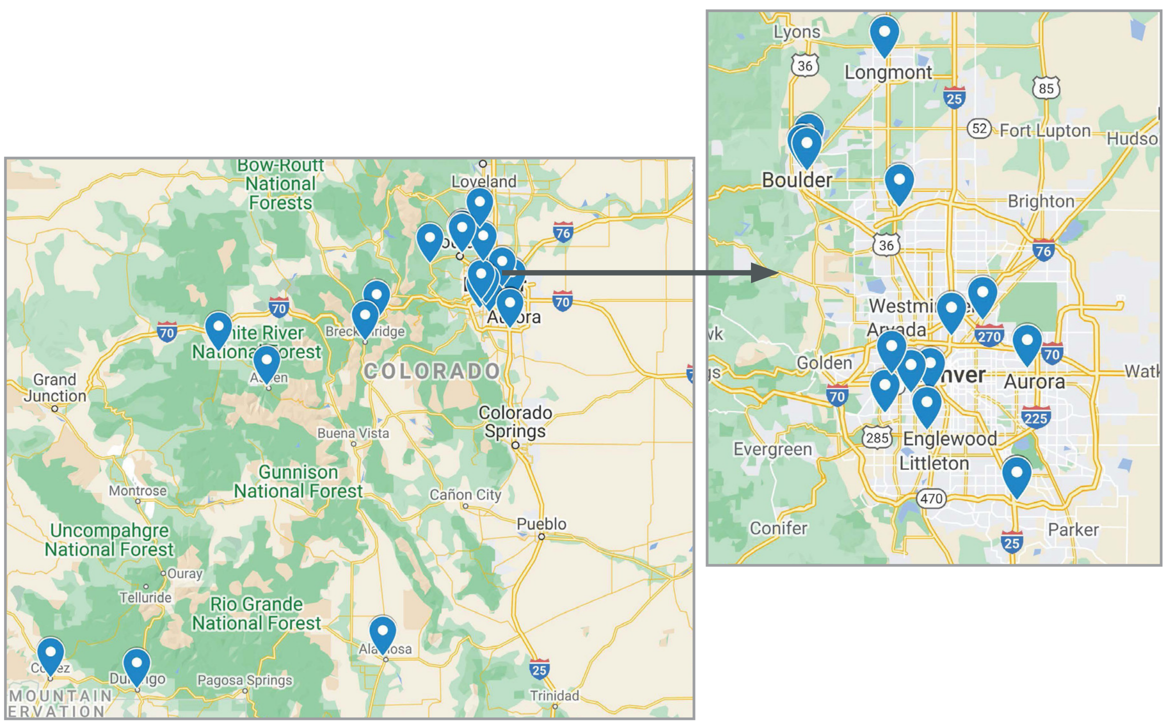
Participant Profile

PROPERTY PROFILE: COPPER STONE APARTMENTS
MARKET: Family
SIZE: 260 UNITS, 295,290 SF
LOCATION: LAFAYETTE, CO
FUEL SOURCE: MIXED-FUEL
HTC DEAL TYPE: 4% FEDERAL

Summary

CHFA selected 11 mixed-fuel and 13 all-electric HTC funded properties for this study. While the project set isn't statistically representative of all CO HTC deals, a primary goal was to ensure the study included a broad range of geographic locations, deal types, developer and design teams, and building layouts.

The participants are located across Colorado, with project types ranging from urban 200+ unit family complexes to rural 30-unit supportive housing. The project applications ranged from 2016-2020 and were evenly split between currently operational and still under construction. Recent projects were targeted to incorporate the most relevant budget information. However, the large number of projects currently under construction meant that access to operating cost data was somewhat limited. Top level project details are summarized in the tables on the following page.



Above: A high concentration of the projects studied were located in the Denver Metro Area, as well as Boulder and Larimer County. However, the sample also included projects in Summit County and Garfield County, as well as projects located in rural areas of southwest Colorado.

Project Information - All-Electric & Mixed-Fuel

All-Electric

Project	Status	Location	Units	Bldgs	Stories	Gross Sq.Ft.
30Pearl	Operational	Boulder	120	3	4	115,284
Alta Verde	Construction	Breckenridge	80	3	2	94,032
Apex East	Operational	Englewood	156	6	3	143,180
Apex South	Construction	Englewood	208	10	3	197,715
Calkins Commons	Construction	Cortez	42	3	3	56,656
Canopy at Red Oak Park	Operational	Boulder	41	8	3	48,256
Castle Creek Apartments	Operational	Aspen	24	1	3	25,011
Eiber Village at Garrison Station	Operational	Lakewood	50	3	1	38,849
Iron Horse	Construction	Alamosa	41	4	2	39,948
Pancratia Hall Lofts	Construction	Denver	74	1	6	63,333
Red Hill Lofts	Construction	Carbondale	30	2	2	22,356
Spark West	Construction	Boulder	45	5	3	49,614
Tungsten Village	Operational	Nederland	26	1	3	24,888

Figure 5

Mixed-Fuel

Project	Status	Location	Units	Bldgs	Stories	Gross Sq.Ft.
Apartments at Cinnamon Park	Construction	Longmont	25	1	2	24,260
Copper Stone Apartments	Operational	Lafayette	260	11	3	295,290
Espero Apartments	Construction	Durango	40	1	3	27,801
Fifty Eight Hundred	Operational	Lakewood	152	2	7	165,529
Greyhound Park Apartments	Construction	Commerce City	223	1	4	256,154
Liberty View	Construction	Aurora	59	1	4	62,647
Palo Park Community, LLP	Operational	Boulder	35	6	3	38,724
Rhonda's Place	Construction	Denver	50	1	3	38,104
Sage Corner	Operational	Lakewood	43	1	3	35,937
Stella	Operational	Denver	132	1	4	180,692
Wintergreen West	Operational	Keystone	40	1	3	36,722

Figure 6

Market Served

Most projects covered in the study served general family populations. The mixed-fuel projects showed slightly more diversity in the populations served, compared to the all-electric projects.

Market Served

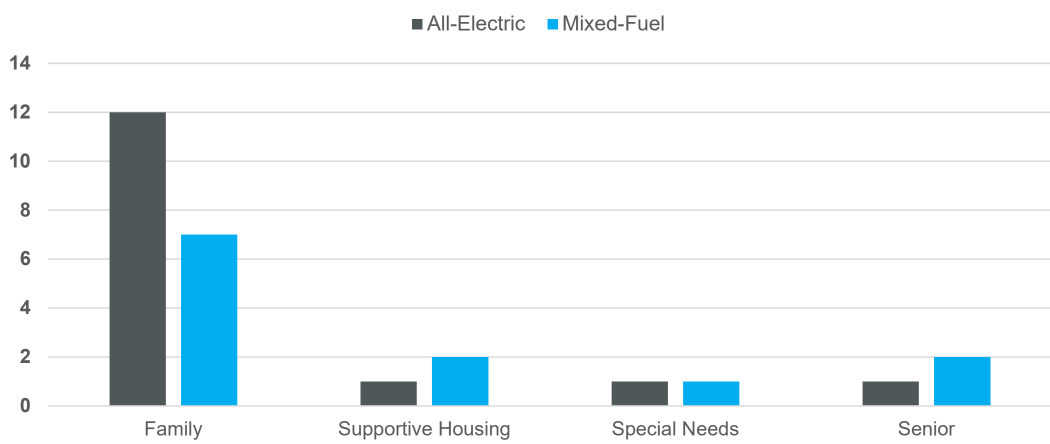


Figure 7

With the exception of the few adaptive reuse projects, the bulk of study projects are wood-framed structures, four stories or under. The main correlation between fuel-source and building type was in the adaptive reuse category with the majority of projects opting for all-electric technologies. This may in part be due to the cost savings associated with retrofitting electric only equipment into an existing building. Outside of fuel choice, building structure types tended to track with population served, with senior and supportive housing projects opting for corridor fed (units accessed via a central, conditioned corridor) buildings and family projects spanning the range of building types.

Building Structure Type

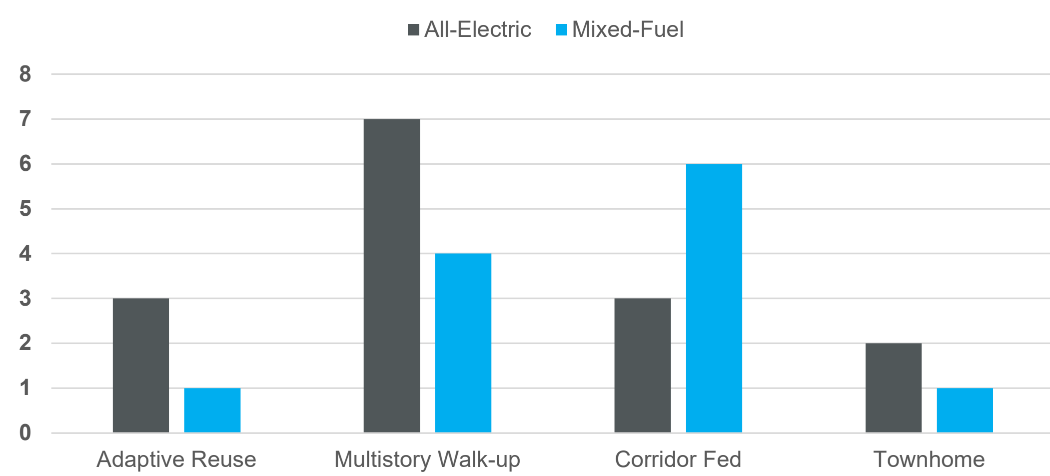


Figure 8

Project Funding Profiles

Sources: HTC projects utilize a diverse capital stack to successfully fund affordable developments. The housing tax credit deal combinations of 9% Federal competitive, 4% Federal non-competitive, or 4% Federal and State competitive were equally represented in the study. The most commonly used third-party funding sources for study participants are municipal or county low-interest loans and funding from the Colorado Department of Local Affairs' (DOLA) Division of Housing. Beyond these core funding sources, the dollar amount and frequency of use drops dramatically for the remaining types of funding.

Distribution of Deal Type

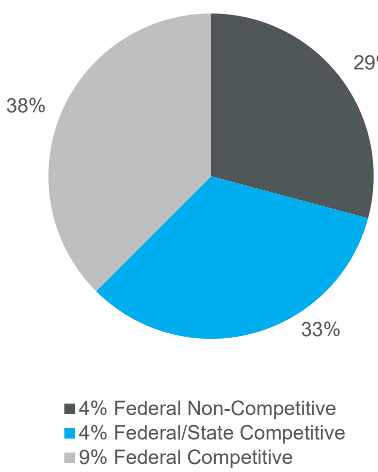
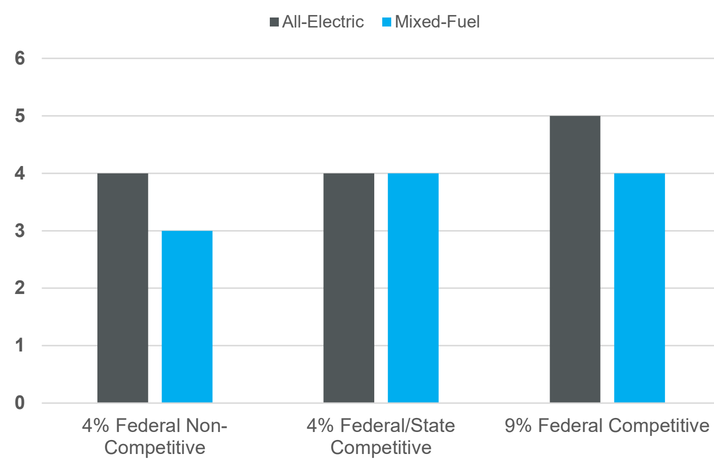


Figure 9

Deal Type and Fuel Source



Above: The tax credit type did not seem to influence the fuel use choice.

Figure 10

Frequency of Funding Sources Used After Housing Tax Credit Equity

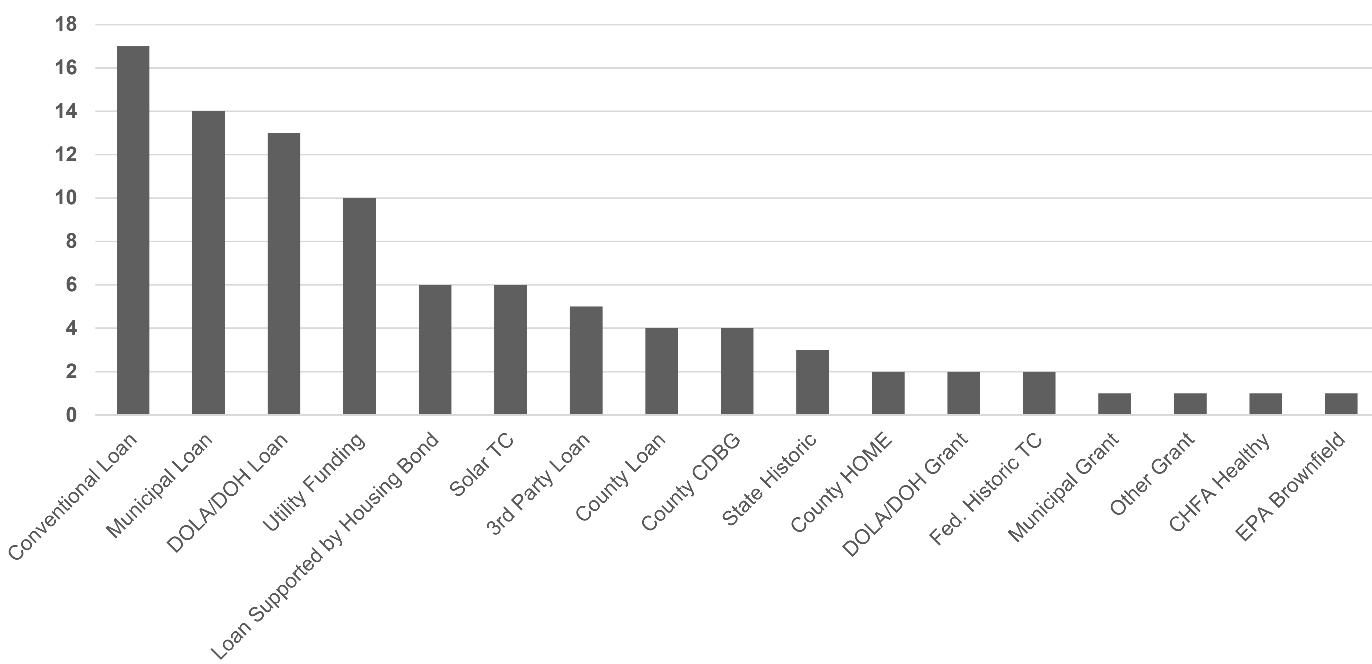


Figure 11

Incentives

The two main incentives related to electrification and building efficiency are solar tax credits and utility incentive funding. These sources were used frequently with over 60% of the projects accessing one or both incentives. In terms of overall dollar amount, however, project teams reported that these sources total less than 1% of the funding profile. As discussed in the All-Electric vs Mixed-Fuel Design Decisions section on page 26. These incentives don't seem to have a meaningful impact on fuel use decisions. Group14 Engineering's budget analysis shows typical incentive value at the following amounts:

- Utility Efficiency Rebates Provide: $10,000 - $70,000 depending on utility, project size and efficiency
- Solar Tax Credits: Approximately 25% - 30% of the installed cost of the solar PV installation

THE ALTA VERDE PROJECT OFFERS AN EXAMPLE OF HOW LOCAL PARTNERSHIPS CAN HELP MOVE PROJECTS TOWARDS HIGHLY EFFICIENT, ALL-ELECTRIC DESIGN

Incentives That Change Design

The Town of Breckenridge provided more than $1M - $1.5M , which includes their match from the Department of Local Affairs-- with the requirement that Alta Verde strive for an all-electric Net Zero Energy (NZE) design. This led the design team to bundle a well-insulated envelope, highly-efficient heat pumps, and a substantial solar PV array to achieve modeled NZE energy performance. This case study highlights the substantial investment necessary to enable HTC projects to afford NZE all-electric building systems and the importance of new funding sources to help transition affordable housing to a zero carbon future.

Case Study: Alta Verde- Breckenridge, CO

The Town of Breckenridge's Alta Verde project is an 80-unit workforce housing development located along a river and bike trails. The project, which broke ground in 2021, will provide housing for people whose income falls within 30% to 60% of the median income for the area. Gorman & Co., in partnership with the town of Breckenridge, is the developer and is pursuing Net Zero Energy (NZE) certification through Zero Energy Ready Homes (ZERH). This involves offsetting 100% of the electricity consumed by the property with energy generated by on-site solar PV.

The all-electric design utilizes energy recovery, low-ambient split DX heat pumps, optimized insulation, and photovoltaics. With the solar production, operating costs are expected to be less than $0.25/SF.

Utility Provider Overview

Electric Providers

Colorado has a substantial number of electric providers ranging from large corporations to small-electric cooperatives. Only a fraction of electric providers are regulated by the Public Utility Commission (PUC). The PUC creates utility requirements around rates, service, safety, and infrastructure. Regulated providers serve the bulk of Colorado's population in the Front Range. The study sample reflects this as well with 19 of the 24 projects purchasing electricity from Xcel Energy. The only other electric utility with more than one study project was Holy Cross Energy, the utility provider for the Roaring Fork and Eagle River Valley. The chart below shows the electric providers' service areas across Colorado.

Colorado Electric Provider Map

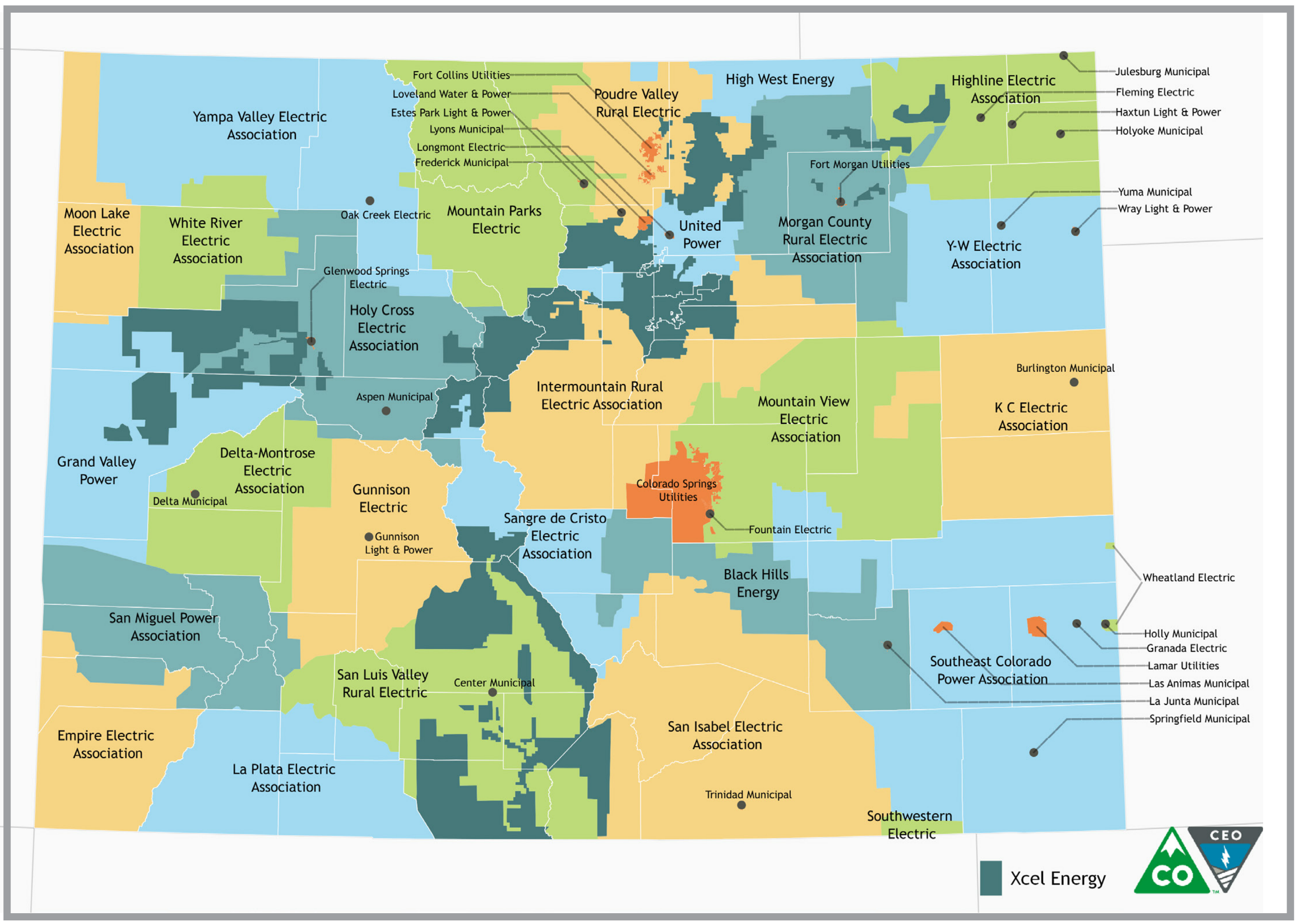


Figure 12
The above map, "Colorado Electric Utilities Service Territories," was published by the Colorado Energy Office and retrieved from https://energyoffice.colorado.gov/electric-utilities

Distribution of Electric Providers

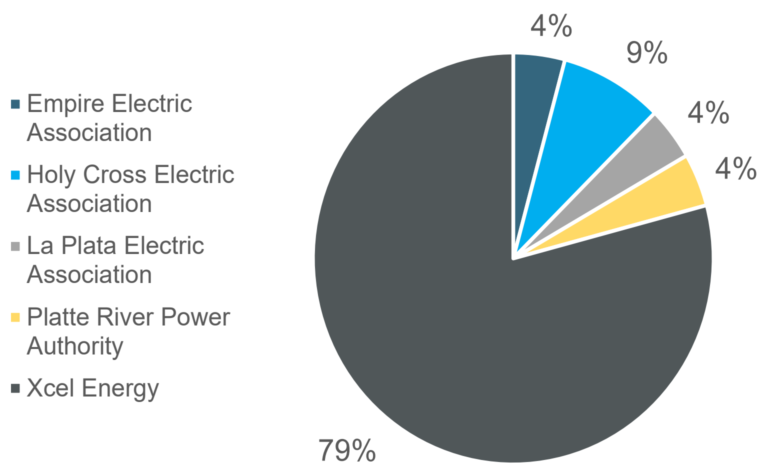


Figure 13

Distribution of Xcel Electric Rates

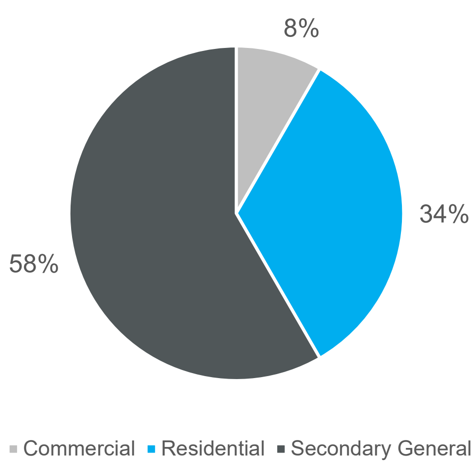


Figure 14

Distribution of Natural Gas Providers

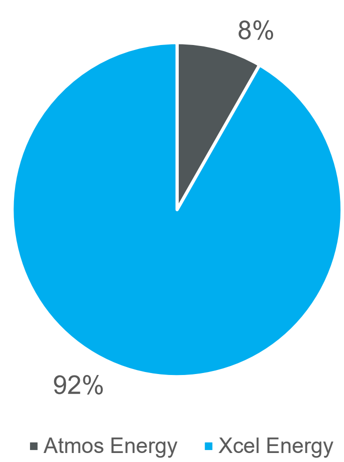


Figure 15

Xcel Energy Rate Structures: The operational projects covered in the study were primarily on Xcel Energy's Secondary General rate structure with the remaining projects split between the Commercial and Residential rates. Xcel Energy's rate structures are covered in greater detail in the appendix section on page 84. The cost impacts of these rate structures are covered under the Operating Costs section, starting on page 46.

Gas Providers: The properties covered in the study are only served by two gas providers: Xcel Energy and Atmos Energy. The diversity of natural gas providers in Colorado is much lower than electric providers, with the majority of providers being larger corporations serving wider geographic areas and a small number of municipal providers. The size of gas providers means that the majority of providers are regulated by the Public Utility Commission.

Codes & Certifications

IECC Code Level

The projects covered in the study spanned a variety of International Energy Conservation Code (IECC) adoption levels and requirements. There was not a correlation between the code level requirements and what fuel source was chosen for the building (see chart below). In general, IECC codes set the minimum floor for project performance, with few projects opting to significantly exceed code level requirements.

IECC Version and Fuel Choice

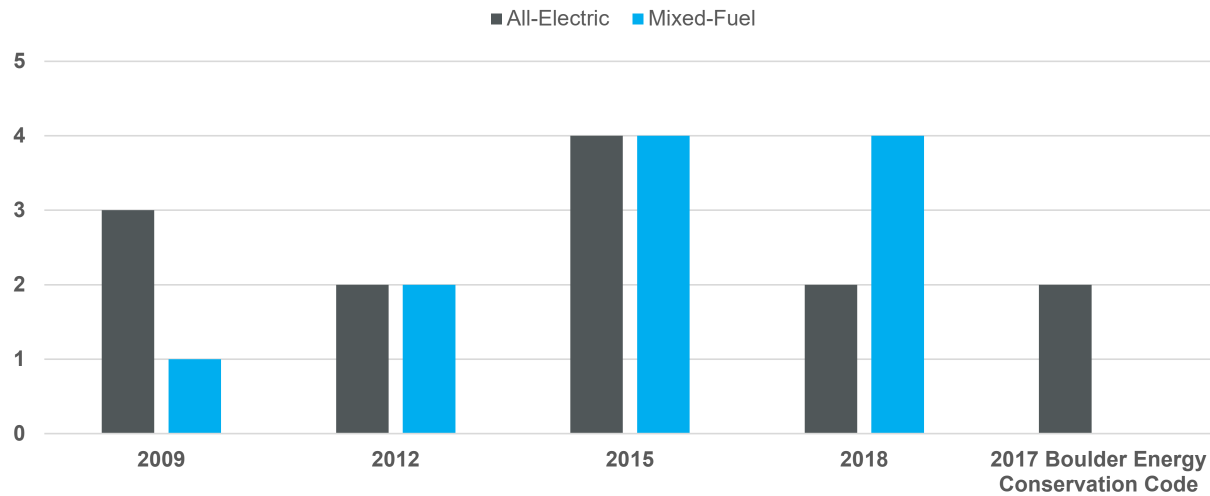
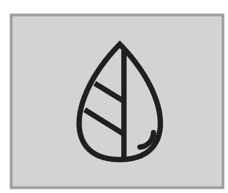


Figure 16

Green Certification

The majority of study projects opted for Enterprise Green Communities (EGC) certification. ENERGY STAR certification was typically added if required by Enterprise Green Communities. Project sustainability compliance approach appears to be driven by the Qualified Allocation Plan and certification system requirements at the time of application:

- Projects with funding award year 2016 - 2019 mostly pursued 2015 EGC self-certification (which triggers ENERGY STAR for Homes on some projects)
- In funding award year 2020 - 2021, projects began to explore Zero Energy Ready Homes as a way to increase tax credit award competitiveness. The National Green Building Standard certification also became more popular as EGC 2020 and ENERGY STAR Family New Construction increased the rigor of their certification products.



GREEN CERTIFICATION

In 2020, HTC projects began to explore Zero Energy Ready Homes certification when incentivized by the QAP.

Green Certification and Fuel Source

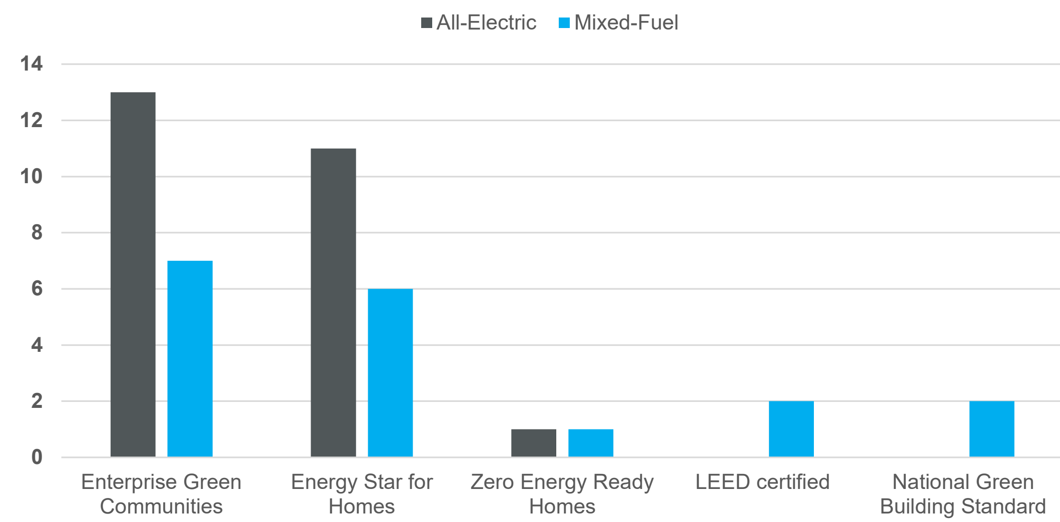


Figure 17

All-Electric Vs Mixed-Fuel

Fuel Use Decision Drivers:

Each project team was interviewed to identify key factors that influenced whether a project pursued a mixed-fuel or all-electric design. Site fuel use was often determined early in the design process. Teams reported settling on a fuel use direction during conceptual design and before submitting the HTC application to CHFA. Many considerations influenced decision making - economics, perceived funding partner goals, existing site infrastructure, sustainability targets, and more. Most developers reported that project fuel use felt like a "natural consequence" of these other factors rather than a fundamental project requirement from which other design choices followed. However, two developers, Boulder Housing Partners and Hartman Ely Investments, stated that their organizations have made a commitment to all-electric sites, which in turn drives project design.

The following sections explore the most influential factors that impacted fuel use choice for study participants.

Financial Feasibility

Operating Cost and Resident Impact

Location and Gas Service Cost

Design, Installation, & O&M Team

Jurisdictional Authority Preferences

Sustainability Goals

Utility Costs and HTC Financing:

Unlike market rate housing, HTC deals must absorb all utility costs, even if they are tenant-paid. Section 42 of the Internal Revenue Code establishes that the maximum allowable rent (30% of the Area Median Income associated with the HTC apartment unit's designated set-aside must also include a budgeted amount for resident-paid utilities). This is called a utility allowance. The higher the utility allowance, the lower the rental income. If the owner pays all utilities, they can claim maximum rents, but must then pay for utility costs as part of their operating budget. Either way, increased utility costs reduce Net Operating Income for an HTC property. Any change to pro forma Net Operating Income impacts overall project financing.

Ryan Lunsford, the Principal of WJL Affordable Housing Consultants, describes the impact of utility costs this way.

"HTC developments are laser focused on providing the most affordable housing per dollar of available funding. Deal pro formas are tight, so much so that even an increase in utility costs of $10 per unit per month can put a project's financials underwater. This means that we can take less debt against the property and consequently must shrink the size of the deal to fit the financing. This means less affordable units will be produced. Operating costs are a significant focus during design so that undue impacts on residents and the owner can be properly managed."

Financial Feasibility

Nearly all teams reported that the fundamental driver of early design decisions, including fuel use, was these decisions' perceived impact on financial feasibility. Cost was the most important consideration linking site fuel use and project viability given equity constraints. Specifically, reducing construction and operating costs associated with building system selection was noted as a core concern.

9% and state tax credit study participants also identified cost containment as one of the top factors influencing whether a project would receive an HTC award. Cost containment was associated with the ability to place the highest number of affordable housing units in service with the requested tax credit amount. The fuel use choice that resulted in the lowest construction and operating cost profile was deemed the most competitive for the HTC application. Construction and operating cost sensitivity, when paired with one of the factors noted below, often pushed a development into either a mixed-fuel or all-electric design.

Operating Cost & Resident Impact

Most mixed-fuel study participants identified operating costs as the primary reason for avoiding an all-electric design. Historically, natural gas has been a cheap fuel source in Colorado, and natural gas systems are familiar to developers, designers, and end users. The perception is that electrification of domestic hot water and ventilation systems would significantly increase utility costs. Higher utility costs pose the following concerns for HTC applicants:

1. Reducing Net Operating Income for the property, and therefore reducing tax credit award competitiveness
2. Creating a financial burden for low-income residents due to a mismatch between utility allowances and actual electricity costs

Many mixed-fuel projects understood that highly efficient building systems could reduce the operation costs associated with all-electric design, but these systems were either perceived as too expensive for an HTC construction budget, difficult to implement with apartment configurations, or both.

Here are what some project teams had to say:

Copper Stone, Lafayette - We considered going all-electric, but the utility allowances associated with an all-electric design were too high. MEP design was driven by the delta between upfront and operational costs. There was pressure from CHFA to have lower utility allowances. The UA schedule we referenced had no credit for heat pump electric heat. It was actually more expensive construction cost wise to use natural gas systems, but the operating cost calculation made it worth it.

Sage Corner and Fifty Eight Hundred, Lakewood - Both of our projects considered going all-electric - we like the concept. However, there was a significant concern that in seeking to balance operating costs with construction costs, we would end up with all-electric systems that were more expensive to install and more expensive to operate than the mixed-fuel alternative.

Rhonda's Place, Denver - For permanent supportive housing units, apartment layout is a big deal. Every square foot is optimized for resident use, so there isn't room for an in-unit domestic hot water heater (and we want to reduce unit entry for O&M as much as possible). When considering all-electric central domestic hot water boilers with electric resistance heating coils, the projected demand costs are high. Alternatively, central condensing gas boilers are cheap to operate and not much different to install construction cost wise.

Greyhound Park, Commerce City - Past experience is that electric heat systems are more expensive to operate than Aquatherm fan coils served by a central gas domestic hot water heater plant. A central gas hot water system also saves on real estate in the unit, which is critical for smaller apartments.

Wintergreen West, Keystone and Stella, Denver - We need to come in with a per unit tax credit ask that is in line with the competition. CHFA is focused on the overall cost of the HTC project. The higher our OpEx, the less permanent debt financing we can secure. We can do electric air source heat pumps for apartment heating pretty easily, but all-electric domestic hot water is going to be more expensive to operate.

Rendering: Rhonda's Place in Denver, where permanent supportive housing units and functional layouts led to central gas DHW systems.

Location and Gas Service Costs

Utility costs to provide gas service can vary significantly based on site location (see the Gas Service section for study participant cost data on page 63). Some of the all-electric projects in this study made the choice to eliminate natural gas based on utility connection costs. One mixed-fuel project considered an all-electric design due to proposed gas service costs but switched back to mixed-fuel when gas service became more reasonable. Design team comments are shared below:

- **Alta Verde, Breckenridge** - While municipal partner preference was the main driving factor, the utility gas line was not close to the property. Gas service would have been a significant cost, which the project was happy to avoid. We likely saved six figures overall by not using natural gas.
- **Iron Horse, Alamosa -** Upfront cost of natural gas service to site was a significant factor in our all-electric design choice.
- **Sage Corner, Lakewood -** Initially, Xcel told us that due to local gas service capacity issues, the cost to resize the gas service for the site would be north of $40,000. We started down the road of an all-electric design briefly before Xcel reduced the gas service charge significantly, at which point we transitioned back to mixed-fuel.
- **Tungsten Village, Nederland -** While there were a number of factors driving our decision to go all-electric, the utility notified us that there were possible slope issues at the site that could increase the cost of gas service significantly. The move to all-electric eliminated this cost.

Design, Installation, and O&M Team Experience

Developers identified five parties as important constituencies when making site fuel use decisions: MEP engineers, general contractors, subcontractors, residents and maintenance staff. On the design side, mechanical and plumbing engineers hold liability around a building design's capacity to deliver adequate heat, cooling, fresh air, and hot water under worst case conditions. These professionals can be wary of experimenting with technology or design principles that they are less familiar with or that are perceived to be untested in Colorado climate zones.

On the installation side, surveyed architects noted that a general contractor and their subcontractor pool's familiarity with building system types can impact pricing presented to design teams. Pricing goes beyond material costs to encompass the means and methods of installation. Subcontractor experience with the selected building systems reduces the risk for general contractors holding a guaranteed maximum price contract.

A common theme from many surveyed team members was that **building system simplicity** was critical for operations and maintenance. If building systems are not intuitive to use, or if there is friction between an ask for and the delivery of comfort, this can result in energy waste and reduced system durability. Affordable housing maintenance staff experience high turnover and do not typically have access to significant technical resources. This means that complicated building system controls and cumbersome preventative maintenance tasks are less likely to be managed properly. **Many projects located in rural areas also identified a lack of local service technicians with the expertise needed to repair complex electrical HVAC or DHW equipment.** Some projects pointed to the potential expense of installing systems that would require a three hour round trip from a qualified service technician to make any needed repairs.

Jurisdictional Authority Preferences

There were three jurisdictional entities that study participants identified as having influence on fuel use choices at the time of project design. Different levels of influence were noted.

- **Breckenridge:** For the Alta Verde project, the Town of Breckenridge was a key development partner. Early on, the City expressed a strong interest in an all-electric NZE design. They also offered a matching grant that unlocked DOLA funds to make these building systems possible. This was the driving force behind the project's fuel use and efficiency design.
- **City of Boulder:** All Boulder projects noted the jurisdictional preference for all-electric projects, which is formally incentivized via the City of Boulder Energy Conservation Code.
- **Aspen**: Though there were no financial incentives offered, the City of Aspen expressed preference for an all-electric design for Castle Creek.

Utility Incentives - Not a Factor in Fuel Use Decisions

One surprising finding was that utility incentives did not meaningfully influence either fuel use or major building system design choices for HTC properties. Two reasons for this were identified:

1. Amount of the incentive - Typically, utility rebates are less than 10% of the installed cost of the efficiency measure in question. This can be an effective incentive to select the next step in efficiency performance level for a specified piece of equipment, such as transitioning from a 80% efficient furnace to a 94% efficient furnace. However, these amounts are typically too small by an order of magnitude to incentivize teams to switch building technologies or fuel use type all together. Especially when considering fuel switching or newer technologies, teams reported that incentive levels need to meaningfully counter-balance the risk associated with installation and operating costs.
2. Timing of the incentive - Utility rebates amounts are typically defined at 100% Design Development or later, and the funding is provided after efficiency measures are installed. Many HTC projects need to make key fuel use and building system design decisions before the HTC application is submitted to define project budget. This means that decisions are being made in conceptual or early Schematic Design. Since teams can't depend on a fixed level of utility funding early in project development, these incentives are not factored into design decisions.

All design teams expressed a need for more meaningful, well-timed incentives around highly efficient, all-electric building systems. Recommendations included:

- Significantly increase incentive amounts for highly efficient all-electric design.
- Make the funding contingent on modeled performance or prescriptive requirements to establish a clear goal that teams can commit to in order to qualify for the funding. Then, budgets and design can be built around funding requirements.
- Pair the incentive funding commitment with the tax credit award, so it can be fully factored into project design.

Sustainability Goals

Two developers, Hartman Ely Investments and Boulder Housing Partners, identified sustainability goals as a key factor in their choice to go all-electric. Unlike the rest of the study participants, their project teams were instructed to start from an all-electric framework. Jim from Hartman Ely Investments had this to say, "All-electric buildings are simply the right thing to do. We won't be able to avert a climate crisis without decarbonizing the building sector, and electrification is a critical piece of this."

"All-electric buildings are simply the right thing to do. We won't be able to avert a climate crisis without decarbonizing the building sector, and electrification is a critical piece of this." - Jim Hartman, Hartman Ely Investments

Building Systems

Unit Heating

The majority of study projects selected electric heating for in-unit conditioning, regardless of the overall fuel mix. This points to the fact that electric space heating is generally lower first cost and can have lower operating cost with the higher efficiency air source heat pumps available today. Most mixed-fuel buildings with electric heat continue to use natural gas for domestic hot water systems. Teams cited operating cost as the most significant barrier to electrifying hot water production.

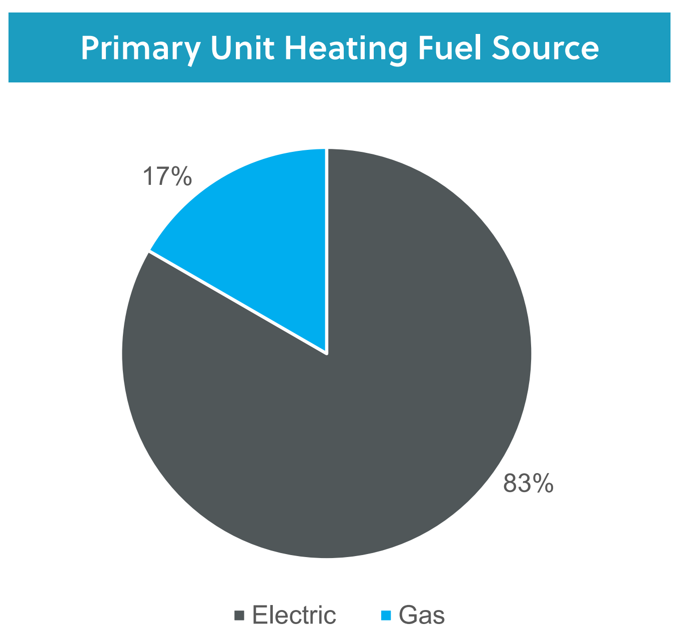


Figure 18

All-electric buildings show a greater diversity of in-unit heating systems, ranging from complex variable refrigerant flow systems to electric baseboard only heat. The most common type of unit heating and cooling system across both building types were packaged terminal heat pumps (PTHP). PTHP systems are preferred due to their low first cost, ease of installation, and simple operation. Some teams also discussed the downsides of PTHP including limited useful life, noise, minimal filtration capabilities, leaky building envelope penetrations, and the inability to circulate conditioned air throughout an apartment.

Other air-source heat pump systems found in a smaller number of all-electric study sites are configured with separate air handler and heat pump components.

Examples include ductless mini-splits, split system fan coil units, or variable refrigerant flow systems. These operate on similar principles: the air handler portion inside uses exterior heat pump equipment to pull heat from outside air and transfer it to the unit via a refrigerant (and vice versa during cooling mode).

How heat pumps operate in cold temperatures is a key driver of heat pump efficiency in Colorado's heating dominated climate. When heat pumps can't operate in heat pump mode (250% - 400% efficient) at cold outside air temperatures, they revert to backup electric resistance heat (100% efficient). Very few study participants had heat pumps that could operate in heat pump mode below 15°F. Newer cold climate heat pump products can operate as low as -22°F, but this equipment has a higher initial cost.

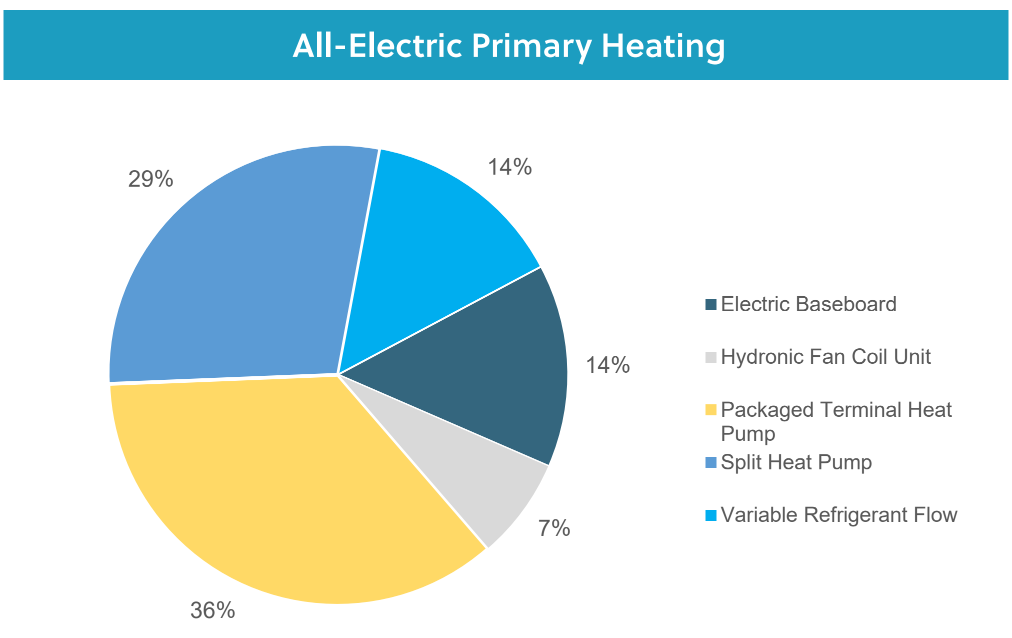
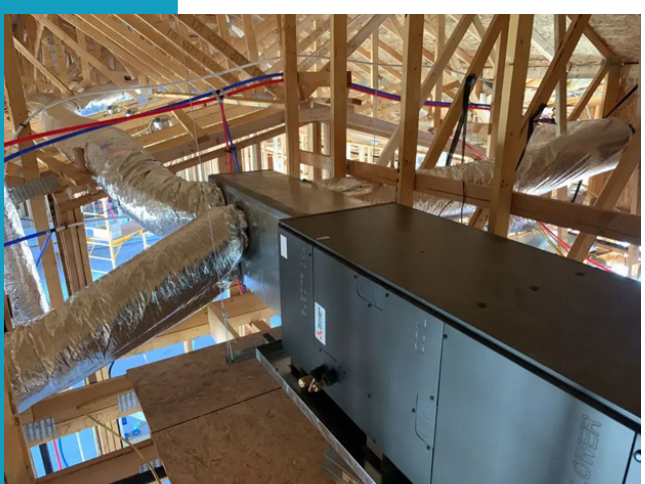


Figure 19

ALL-ELECTRIC BUILDINGS SHOW A GREATER DIVERSITY OF IN-UNIT HEATING SYSTEMS

Above: Ductless Mini-Split Heat Pump

Above: Packaged Terminal Heat Pump



Above: Ducted Heat Pump

Two of the all-electric participants opted for electric baseboard as the only form of heating in-unit. Electric baseboard units use electric resistance heating elements and convection to heat and circulate air. Of all the system types covered by this study, this technology has the lowest first cost but one of the highest operating costs.

For the mixed-fuel properties, PTHPs were also the most popular apartment heating system. The second most popular system is a similar technology - Vertical Terminal Heat Pumps/ Air Conditioners. These units are also packaged air source heat pump systems where the equipment is connected directly to the outside through a penetration in the wall, similar to a PTHP. However, a Vertical Terminal Heat Pump includes a more powerful fan and can duct conditioned airs throughout an apartment. The upside of these systems is that they are simpler and cheaper to install than a standard furnace or fan coil unit, but like PTHPs they create building penetrations and lack options for serviceability.

A final type of system seen across both fuel types is hydronic fan coil units. These systems are ducted and use hot water from a boiler or water heater to heat the air in the unit. In the case of a combined heat system, sometimes referred to as an aquatherm system, the boiler/water heater providing hot water to the fan coil unit also serves as the source of domestic hot water. Hydronic fan coil units typically have longer useful lives, circulate air well, offer standard air filtration, and can be quieter than other systems. However, they are typically more expensive to install than PTHPs or baseboard.

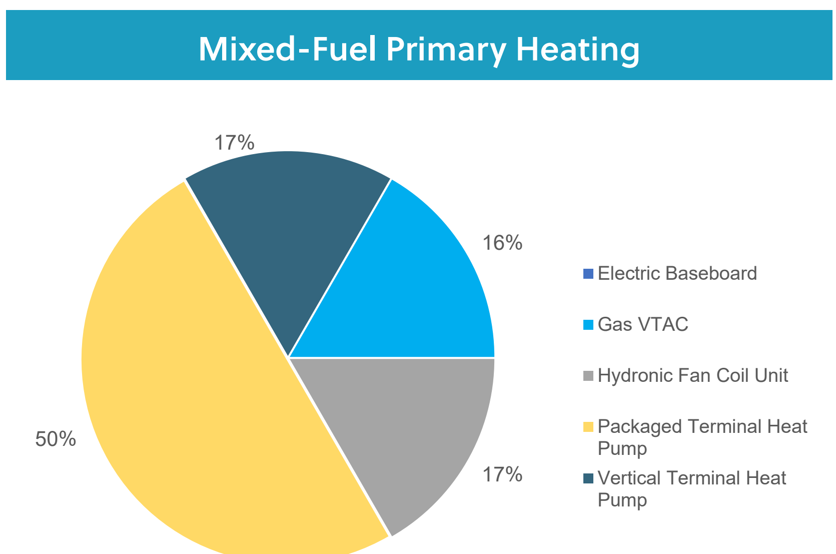


Figure 20

THE POWER OF HEAT PUMPS

A heat pump is a type of heating and cooling system that is powered by electricity. Unlike heating equipment that generates heat by combusting fuel or through electric resistance, heat pumps transfer heat between air, water, or the ground. The most common type of heat pumps are "air source", meaning that they transfer heat between the air inside a home and the air outside a home. This transfer can go in either direction, allowing heat pumps to both heat and cool a space.

Because heat pumps transfer heat instead of generating it, this technology is highly efficient. Traditional heat sources are 80% - 100% efficient. Heat pumps often operate at 300% - 375%+ efficiency, meaning that one unit of energy can transfer 3-4 units of heat from the outside to the inside. Recent advances in technology have seen the US commercialization of cold-climate air-source heat pumps. This equipment can achieve the same transfer of heat from the outside to indoors, even when it's -22^{0}F outside.

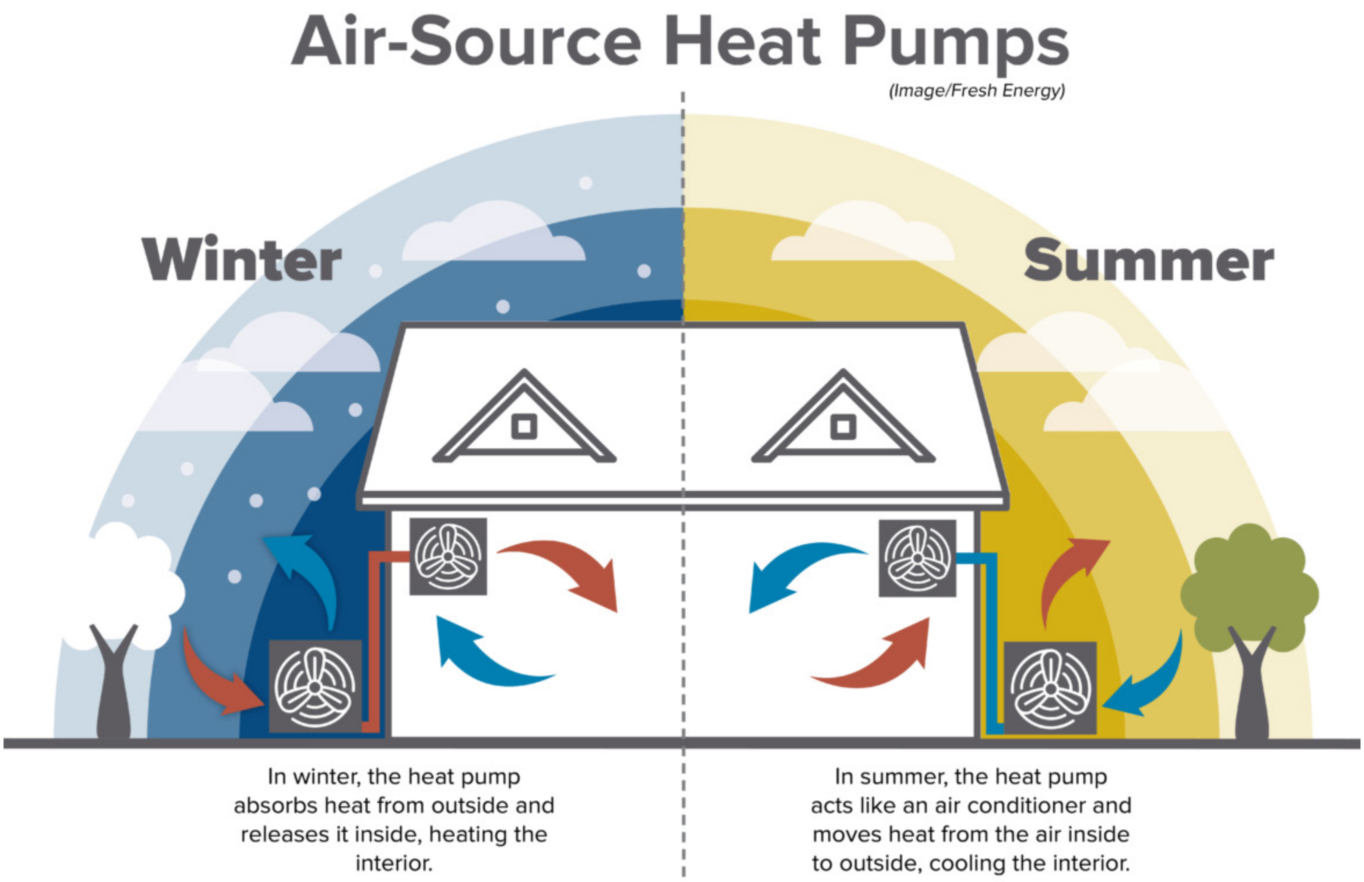


Figure 21

The above image is from a 2021 Fresh Energy article, "What's up with heat pumps," and was retrieved from https://fresh-energy.org/whats-up-with-heat-pumps

Supplemental Heating by Primary System Type

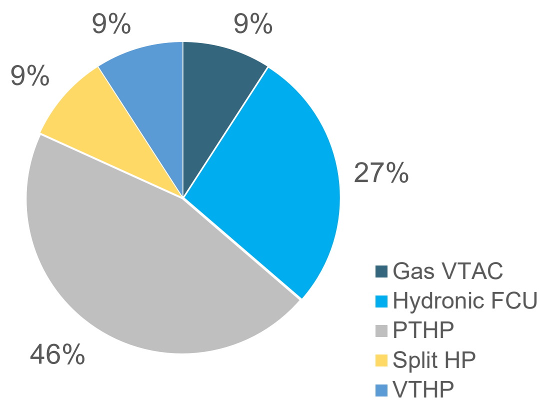


Figure 22

Supplemental Heating Systems:
In addition to the primary heating systems listed in Figure 22, a number of projects installed supplemental electric baseboard heating systems. The use of supplemental heating was evenly distributed between all-electric and mixed-fuel projects. The choice to add supplemental heating is often tied to the limitations of the primary heating method. Supplemental heating was most commonly used in conjunction with PTHPs as they serve a limited area and additional capacity is necessary to meet the full heating load.

The amount of supplemental heat provided was driven by heating loads unmet by the primary heating system. Climate zone, building envelope, and primary heating system capacity all impact supplemental heat sizing. The largest amount of supplemental electric baseboard heat in the study population was 5 to 10 KW per unit, primarily in mountain projects (climate zone 6 or 7). For the rest of the state (climate zone 5b), supplemental electric baseboard heat typically ranged from 2 - 3.5 KW. heat.

Unit Cooling

Cooling in apartments can typically be defined by the combination of three characteristics: ducted or unducted, packaged or unpackaged, and evaporative or direct expansion (DX). On one end of the cost spectrum are unducted, packaged systems (PTHP) that represent lower efficiencies and first costs.

On the other end of the cost spectrum are split systems with outdoor units (either evaporative or DX) that have higher first costs and more complicated maintenance, but offer a higher range of system efficiencies. Two of the projects covered in the study did not offer any cooling at all, a design decision that is increasingly uncommon in Colorado and is mainly limited to the mountainous areas of the state.

All-Electric Cooling Types

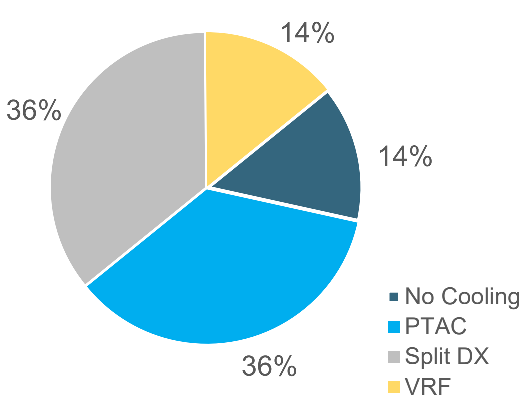


Figure 23

Mixed-Fuel Cooling Types

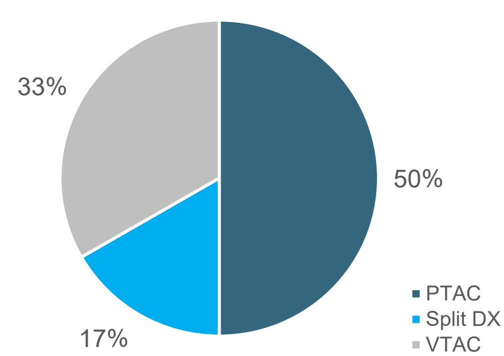


Figure 24

Domestic Hot Water Systems

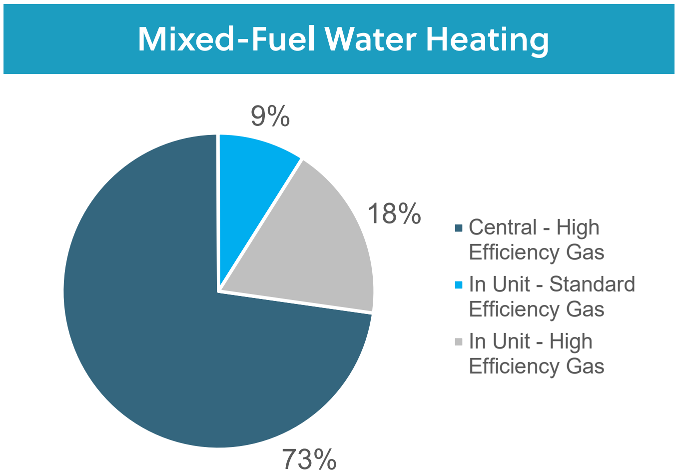


Figure 25

Mixed-Fuel Buildings:
The mixed-fuel buildings generally opted for central water heating systems over in-unit water heaters, mostly due either to installation cost considerations or in an attempt to maximize livable space in apartments. All gas systems were high efficiency with the exception of a single project covered in the study. The central heating systems were largely packaged tank water heaters, with only two projects opting for boilers with sidearms. Packaged tank water heaters generally have lower first-costs, but can also have a shorter useful service life than boiler plants with stand-alone storage tanks.

All-Electric Buildings:
The vast majority of all-electric buildings in the study opted for individual water heaters, with the majority of these systems being electric resistance units. A single project opted for a central/shared heat pump water heater plant that services 15 units (each plant). The prevalence of in-unit electric resistance water heaters points to one of the key issues with all-electric buildings in Colorado's climate: **life cycle cost-effective electric water heating is still a challenge.**

The high efficiency alternative to electric resistance water heaters are heat pump water heaters (HPWH). These work similarly to heat pumps for space heating. The most widely adopted HPWHs are air source, in that they pull heat from the air around them, transfer that heat to water, and discharge cool air as a byproduct. Cold temperature HPWHs with options for the ducted exhaust of cold discharge area is a rapidly developing technology. However, at this time, market penetration is limited in Colorado affordable housing.

The primary challenge in Colorado's heating dominated climate is designing HPWHs to manage the heat transfer dynamic optimally for all seasons. The goal is to maximize heat pump mode operation and minimize electric resistance back-up heat while also ensuring discharged cool air isn't increasing heating loads for HVAC systems.

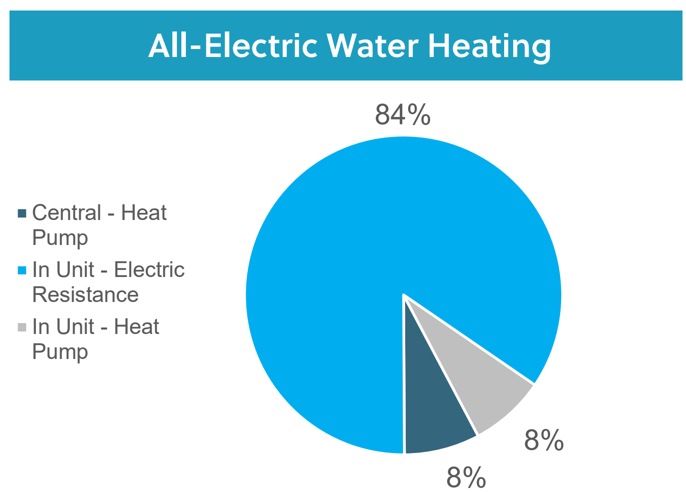


Figure 26

Ventilation Systems

Ventilation systems have become more critical with the advent of modern building codes. In the past (2009 IECC and earlier) natural ventilation via operable windows was the primary way HTC apartments were ventilated. Current versions of the IECC and International Mechanical Code (IMC) require some kind of mechanical ventilation for family buildings. Ventilation design is important for two reasons:

- Fresh air is essential to ensure proper indoor air quality with the tighter building envelopes mandated by current codes;
- And, conditioning fresh air has significant impacts on heating and cooling operating costs.

Ventilation Distribution

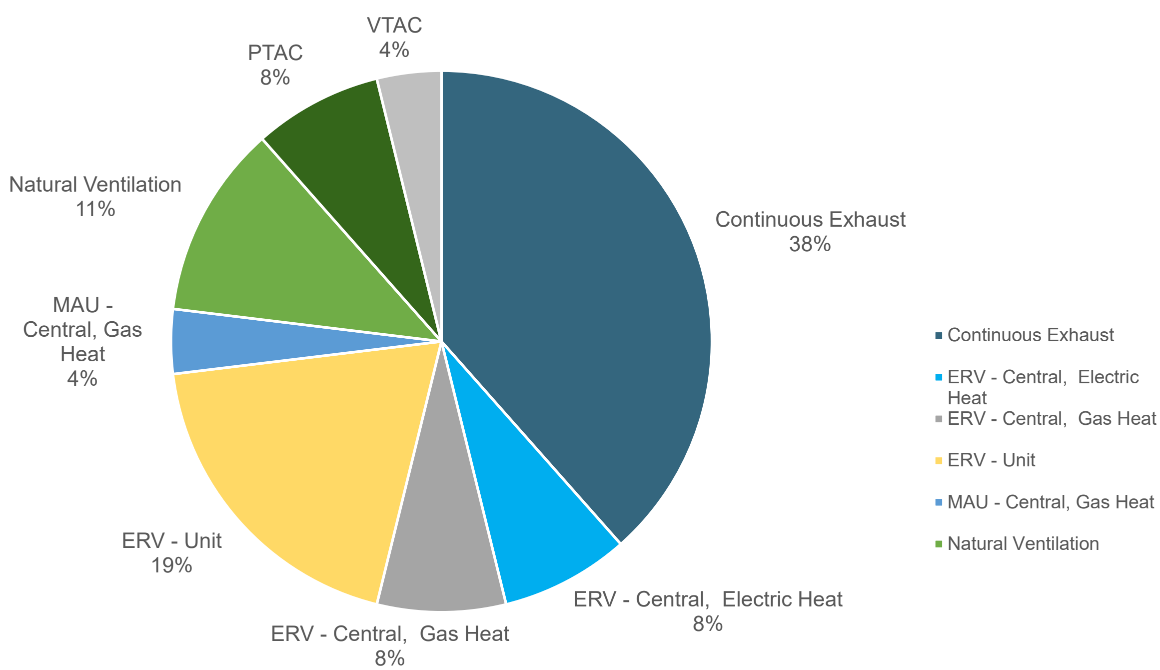


Figure 27

Natural ventilation is only present where allowed by the jurisdiction. The most common system across all building types is continuous exhaust ventilation, where a continuously running exhaust fan depressurizes the apartment, drawing in a constant supply of fresh air via envelope infiltration. With continuous exhaust, the source of make-up air is not controlled or filtered. The most sophisticated systems are balanced, energy recovery ventilator (ERV) or heat recovery ventilator (HRV) systems. These systems introduce and exhaust air at a controlled, balanced rate, and use a heat exchanger to transfer energy between outgoing air and incoming air. Oftentimes these systems also have filters to ensure that incoming air is free of contaminants, an increasing concern in Colorado with the worsening wildfire seasons.

When comparing the study participant set by fuel use type, a much higher percentage of the mixed-fuel buildings opted for continuous exhaust ventilation, while a greater percentage of the all-electric buildings used energy recovery ventilation to bring in filtered, conditioned fresh air.

All-Electric Unit Ventilation Type

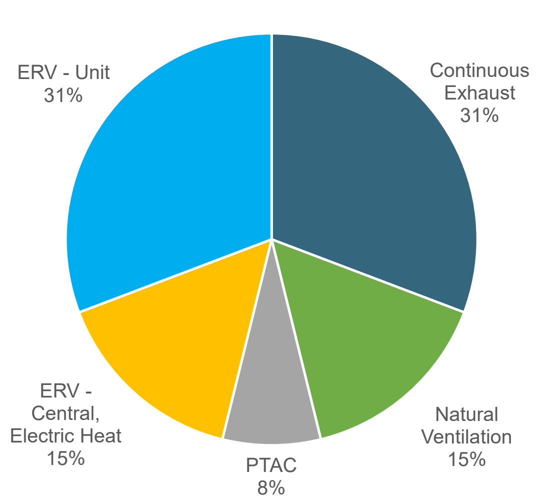


Figure 28

Mixed-Fuel Unit Ventilation Type

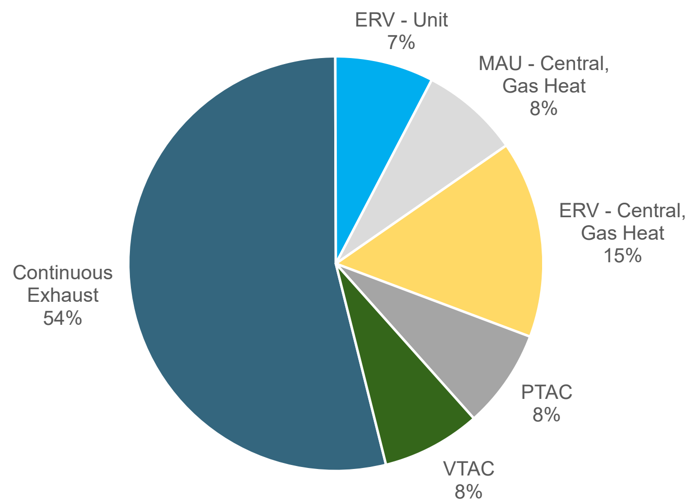


Figure 29

Common Area Heating, Cooling, and DHW Systems:
Common area systems varied significantly across study sites. In large part, the common area system selection was dictated by cost, structure type, and space programming as opposed to fuel source. Study participant common area systems included gas furnaces, electric resistance fan coil units, split heat pump fan coil units, electric baseboard, roof top units, and make up air units.

Corridor-Fed HVAC Strategies:
Common area square footage is substantially higher in corridor fed buildings. Due to this, common area system selection has a larger impact on operating costs. Corridor fed buildings also have higher common area fresh air requirements. A large percentage of the corridor-fed buildings in the study chose to combine these functions in the form of corridor ERVs or make-up air units.

Envelope

Building envelope insulation performance - walls, roof, and windows - generally tracked code required minimums. These code minimums in turn are driven by the IECC iteration adopted by the local jurisdictional authority and the project's climate zone. Insulation value is typically measured in "R-value" and "U-factor", with a higher R-value and lower U-factor indicating better performance. Improving wall/roof R-values or window U-factors can be a significant cost, so design teams often went with the most cost-effective option.

However, all-electric projects did invest in moderately more efficient wall and roof assemblies, as can be seen by the chart on page 39, Figure 30. The higher operating cost associated with electric heat, especially electric resistance heat, yields a higher return on investment in building insulation compared to cheaper natural gas heat. It should be noted that few study participants employed a highly efficient building envelope system.

Wall and Roof Assembly R-Values by Fuel Source

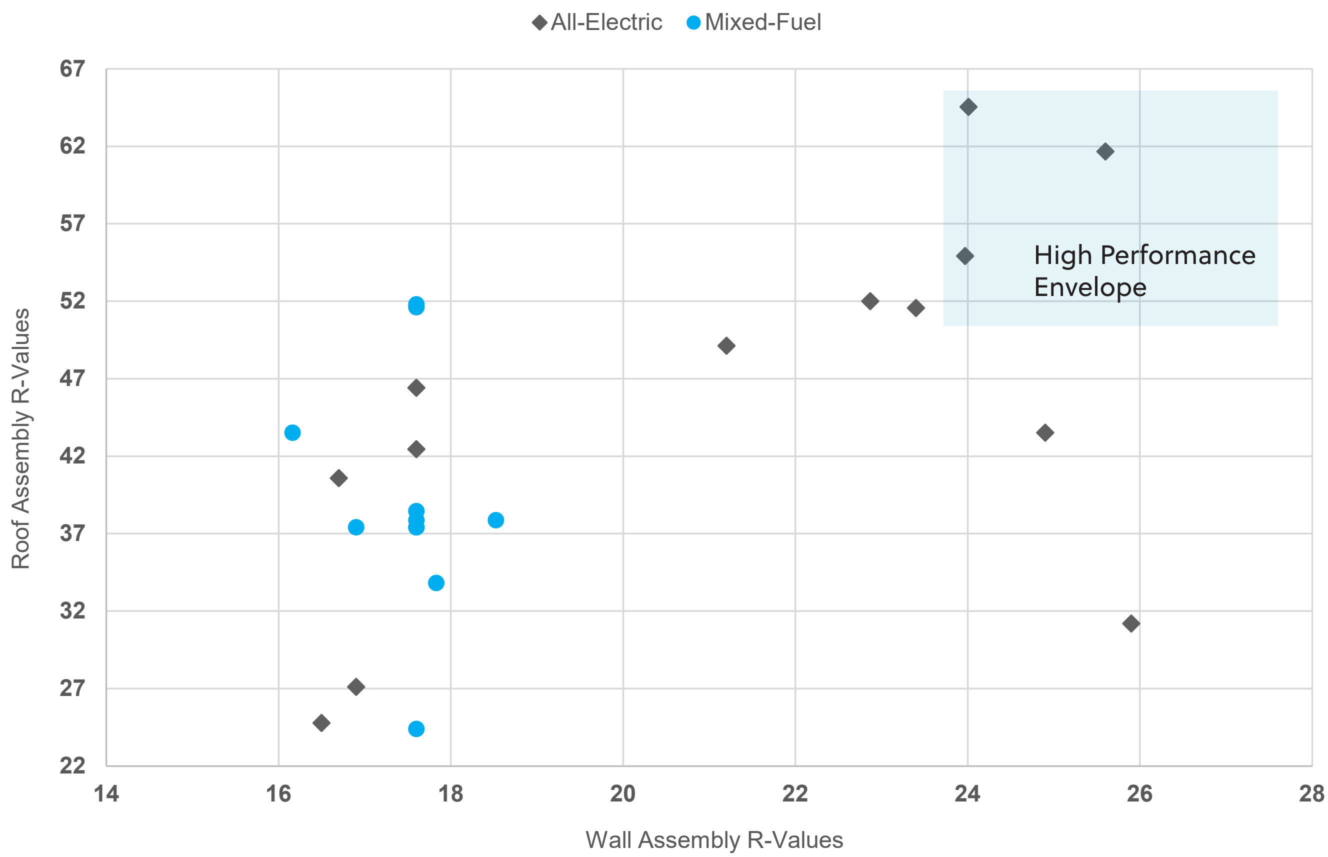


Figure 30

Distribution of Window U-Factors by Fuel Source

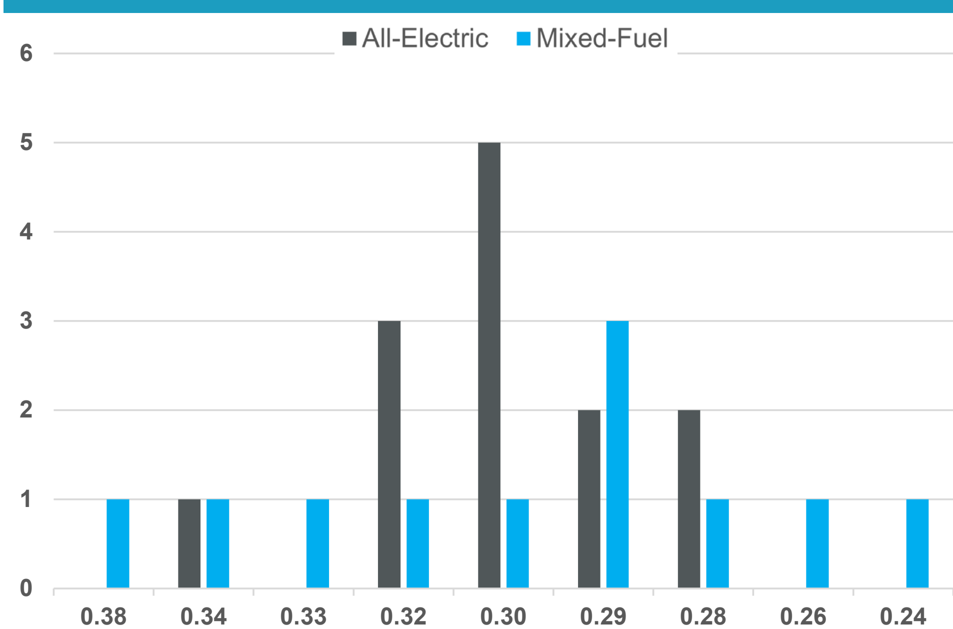


Figure 31

Air sealing detailing tracked with the type of green certification pursued by the project. For projects that pursued ENERGY STAR certification, certain air sealing and insulation details were required. As more projects moved to mandatory ENERGY STAR certification, these details became more prevalent in construction drawings. Similar to envelope R-values, air sealing detailing improved when specific air leakage targets were mandated by a jurisdiction.

Lighting, Appliances, and Plumbing Fixtures

The overwhelming majority of projects opted for LED lighting in both common area and residential spaces. The combination of LED cost-effectiveness, long-lifespan, high efficiency, and green building requirements have made LED lighting standard industry practice.

There was also consistency in appliance fuel use and efficiency levels for the study projects. Every project in the study opted for electric ranges, likely due to safety considerations and lower first cost. The vast majority of projects opted for ENERGY STAR refrigerators and dishwashers to comply with green building certification program requirements.

Similar to lighting and appliance choices, almost every project opted for low-flow plumbing fixtures due to green building requirements and significant operating cost-savings. High efficiency lighting, plumbing and appliances are standard HTC design practice.

Above: Lighting fixtures in Canopy at Red Oak Park in Boulder, CO. This project, like many others, opted for low-flow plumbing fixtures, and LED lighting.

Renewables

Solar photovoltaics was the only renewable system installed by study participants, with PV installations found across both mixed-fuel and all-electric sites. Project size had a positive correlation with PV installation: larger projects installed solar PV at a higher rate than smaller projects. This suggests that larger projects, due to budget, roof space, or other factors, may have greater capacity to implement renewables than smaller buildings.

Solar PV Choice by Fuel Source

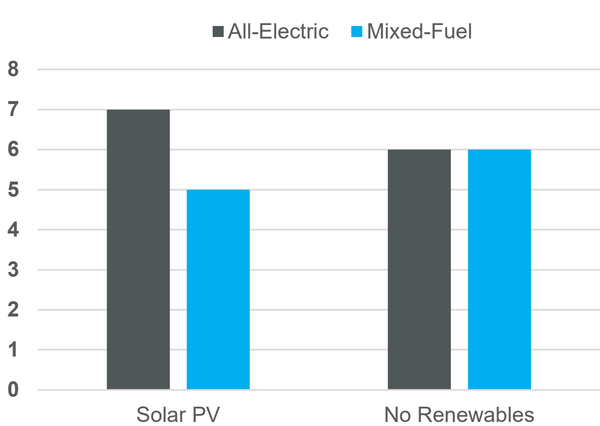
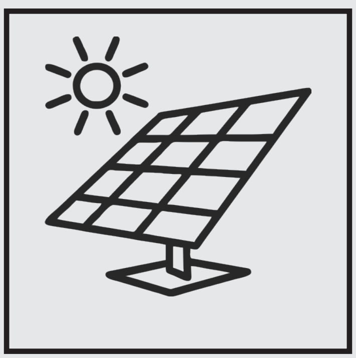


Figure 32

PROJECT SIZE HAD A POSITIVE CORRELATION WITH PV INSTALLATION, WITH LARGER PROJECTS INSTALLING SOLAR PV AT HIGHER RATES THAN SMALLER PROJECTS.

Above: Rooftop solar panels at Spark West in Boulder, CO.

SOLAR SUPERCHARGE



Four percent tax credits can supercharge on-site renewable economics. Currently, the investment tax credit for solar PV offers a 26% credit on 100% of installation cost. For most 4% HTC deals, the HTC eligible basis can increase as project construction costs increase, as long as these construction costs benefit residents. This means that added costs for a renewable system that offsets on-site energy consumption qualify for additional 4% tax credits in addition to the solar investment tax credit. 4% HTC value varies based on a number of factors including credit pricing, but a recent 4% solar deal analysis put the credit value at ~40% of total solar system cost. Additionally, there are proposed regulatory changes that no longer require projects to reduce HTC eligible basis by 50% of solar tax credit value. This yields a combined credit equal to ~66% of the solar installation value for 4% deals. When utility incentives, Renewable Energy Credits (RECs), and the solar production value is factored in, systems often have less than a 15 year payback.

A key limitation of 4% solar is utility regulation around allowable metering. Solar production must offset on-site consumption needs to be eligible for HTC basis. Additionally, a certain minimum system size and configuration is needed to bring PV installation costs down to a point where project economics work. This typically requires a site master meter that serves apartments in addition to common area spaces. Some utilities, most notably Colorado Springs Utilities, require each apartment to have a utility owned residential meter. This renders solar PV unworkable for 4% HTC deals.

Panel/Service Size:
Electrical service, both for the site as a whole and at individual apartments, was expected to vary based on fuel use selection. To quantify this, the study analyzed 1-bedroom panel sizes across all projects and total site amps per square foot.

One-Bedroom Panel Size by Fuel Source

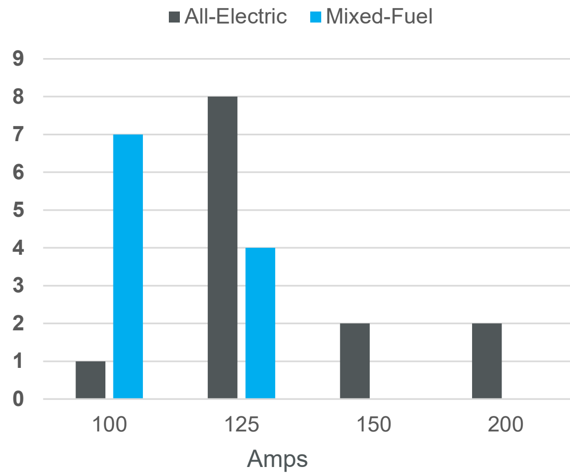


Figure 33

In general, the mixed-fuel projects used smaller size panels at the unit levels than the all-electric projects. In addition to fuel use, apartment panel size is driven by the amount of in-unit supplemental electric resistance heat and whether electric domestic water heaters are located in apartments.

Total Site Amps per Gross Square Foot

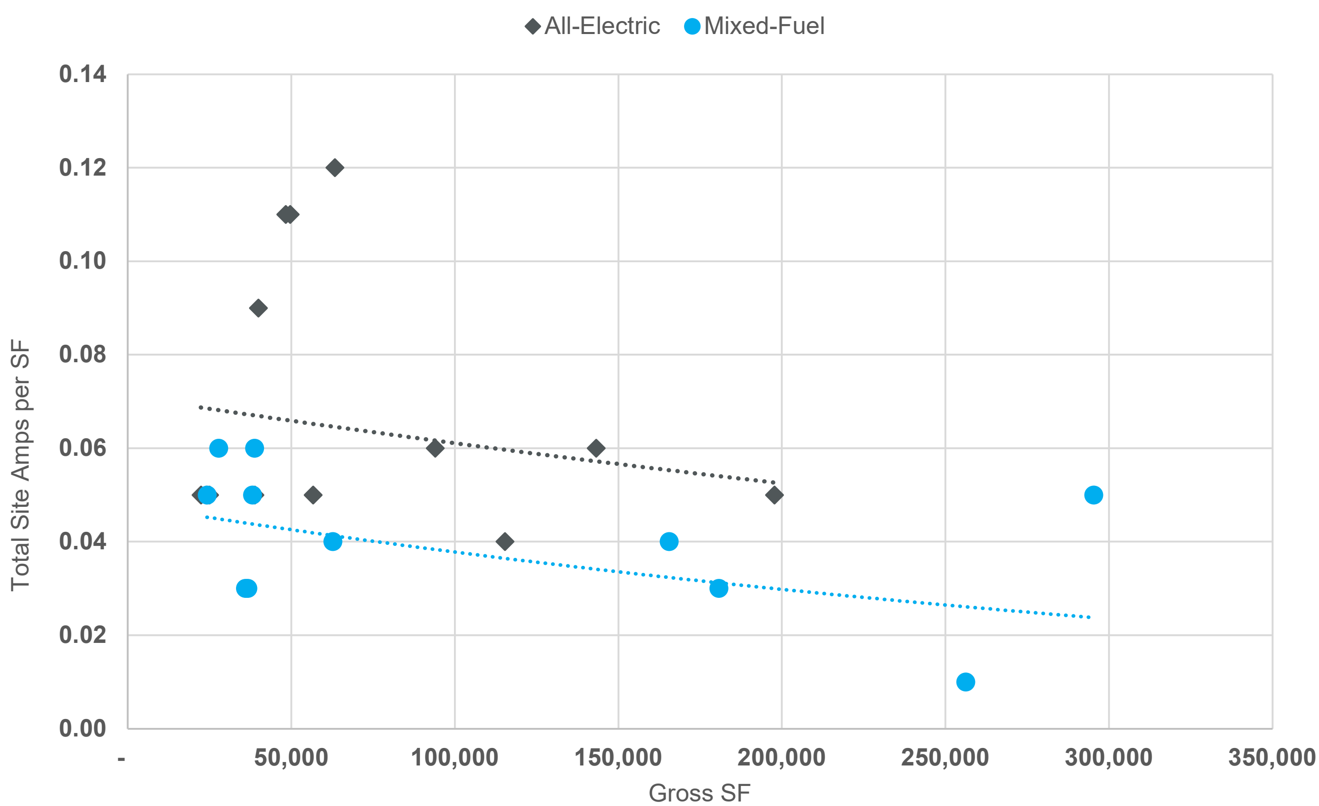


Figure 34

As expected, mixed-fuel properties require smaller building electrical service than all-electric projects. Cost implications of increased electrical infrastructure are discussed in the Capital Cost section on page 60.

Metering

The majority of projects opted to have tenants pay for in-unit electricity costs, regardless of site fuel use mix. Resident population type had the strongest correlation with resident-paid billing structure. Higher percentages of senior and supportive housing properties opted to include electricity charges in gross rent.

Distribution of Electricity Payment

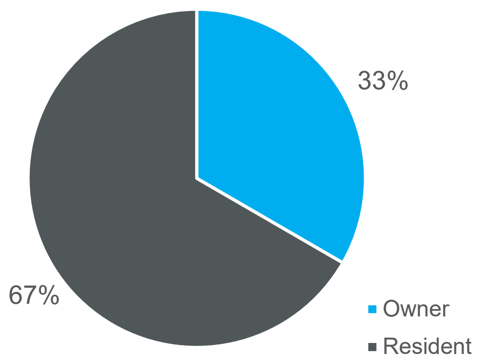


Figure 35

THE MAJORITY OF PROJECTS OPTED TO PASS ON ELECTRIC COSTS TO TENANTS REGARDLESS OF FUEL SOURCE

Greyhound Park Apartments, Commerce City- This new construction supportive housing development will serve formerly homeless individuals and families as well as individuals exiting the criminal justice system. The apartments are part of a development that will be certified under the advanced pathway Zero Energy Ready Home certification program.

MIXED-FUEL & ELECTRIFICATION CHALLENGES & OPPORTUNITIES

Greenhouse Gas Emissions

Building electrification is a powerful GHG reduction strategy for HTC-supported developments. This opportunity is created by the greening of Colorado's electricity grid. As noted earlier in the study, House Bill 19-1261 commits the entire state to emission reduction targets 26% by 2025, 50% by 2030 and 90% by 2050 (from 2005 levels). This will require engagement with all utility providers to decarbonize their power generation mix.

All nine buildings that provided utility data for this study purchase electricity and natural gas from Xcel Energy. Actual utility consumption profiles were used in combination with Xcel Energy's projected grid conversion factors to model the carbon dioxide emissions, present and future. The data below shows each of the nine properties' energy usage with fuel consumption amounts multiplied by the appropriate Xcel Energy's grid conversion factor. For natural gas, the US Energy Information Administration's carbon dioxide coefficient is used.

As of 2021, annual GHG emissions from all-electric buildings are roughly equivalent to the emissions of mixed-fuel buildings. In fact, gas heat buildings show a slightly lower GHG emissions profile compared to the electric buildings evaluated. However, as the electricity grid decarbonizes, the emissions associated with electricty use plummets for all projects. For gas heat projects, the carbon emissions associated with natural gas heating will remain elevated. As shown in the chart below, this results in a lower emissions profile for even standard efficiency all-electric projects by 2030.

Pounds of CO2 Per kWh Per SF

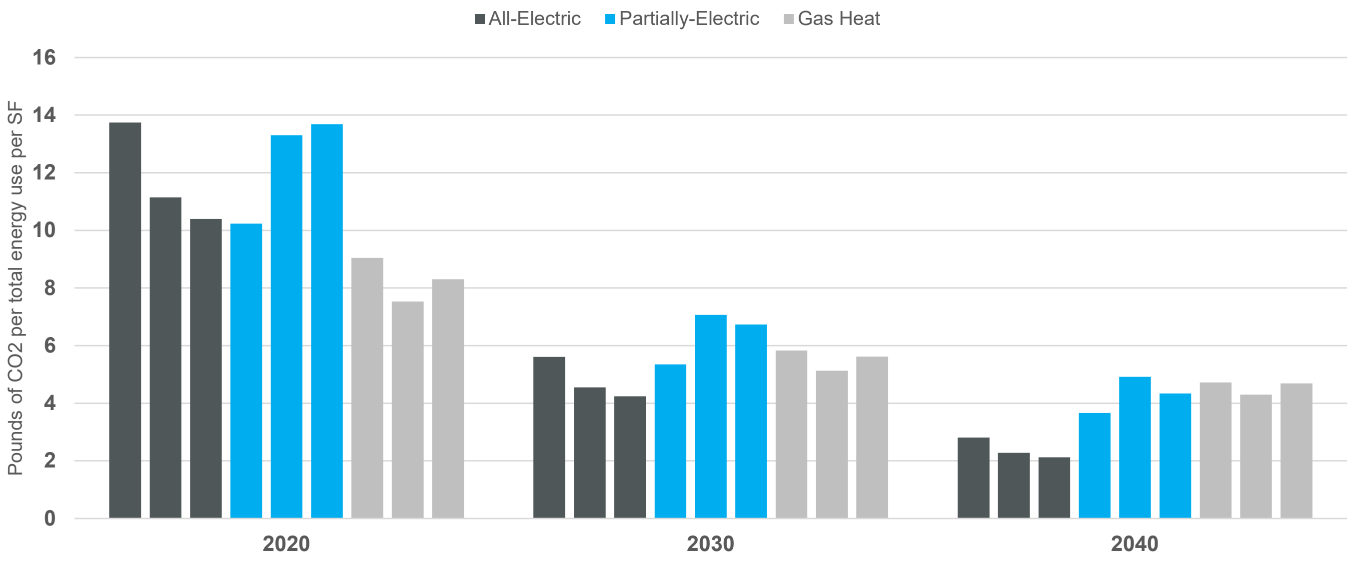


Figure 36

GHG Emissions Over the Building Lifespan

In addition to calculating per building emissions at set milestones, the average per SF emissions by fuel mix type was established. Then, an annual emissions profile for each fuel mix type was projected over 50 years. For buildings placed in service in 2020, the all-electric sites have approximately 26% fewer carbon dioxide emissions than their mixed-fuel counterparts.

Average Lifetime Pounds of CO2 Per kWh Per SF

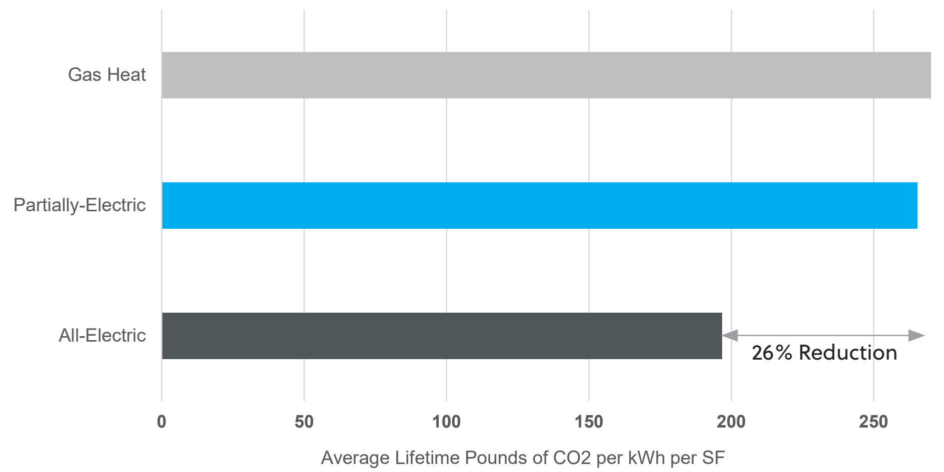


Figure 37

Lifetime CO2 Emissions for HTC Buildings in 2023

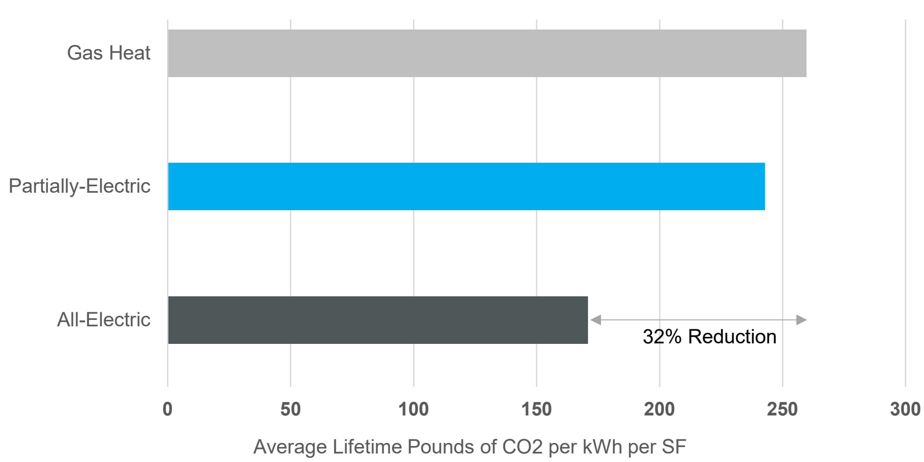


Figure 38

FOR ALL-ELECTRIC BUILDINGS PLACED IN SERVICE IN 2023, EMISSIONS ARE REDUCED BY 32%

Operating Costs

The following section analyzes actual utility costs from the all-electric and mixed-fuel projects currently in operation. To better understand the drivers of operating cost, mixed-fuel projects with in-unit electric heating and gas water heating (partially-electric) were distinguished from fully gas heat projects.

The operational data analyzed for this study was limited by the number of projects with sufficient utility data. Projects with less than 80% occupancy and/or less than three months of data were excluded from the analysis.

Annual Operational Costs of All-Electric, Partially-Electric and Gas Heat Projects

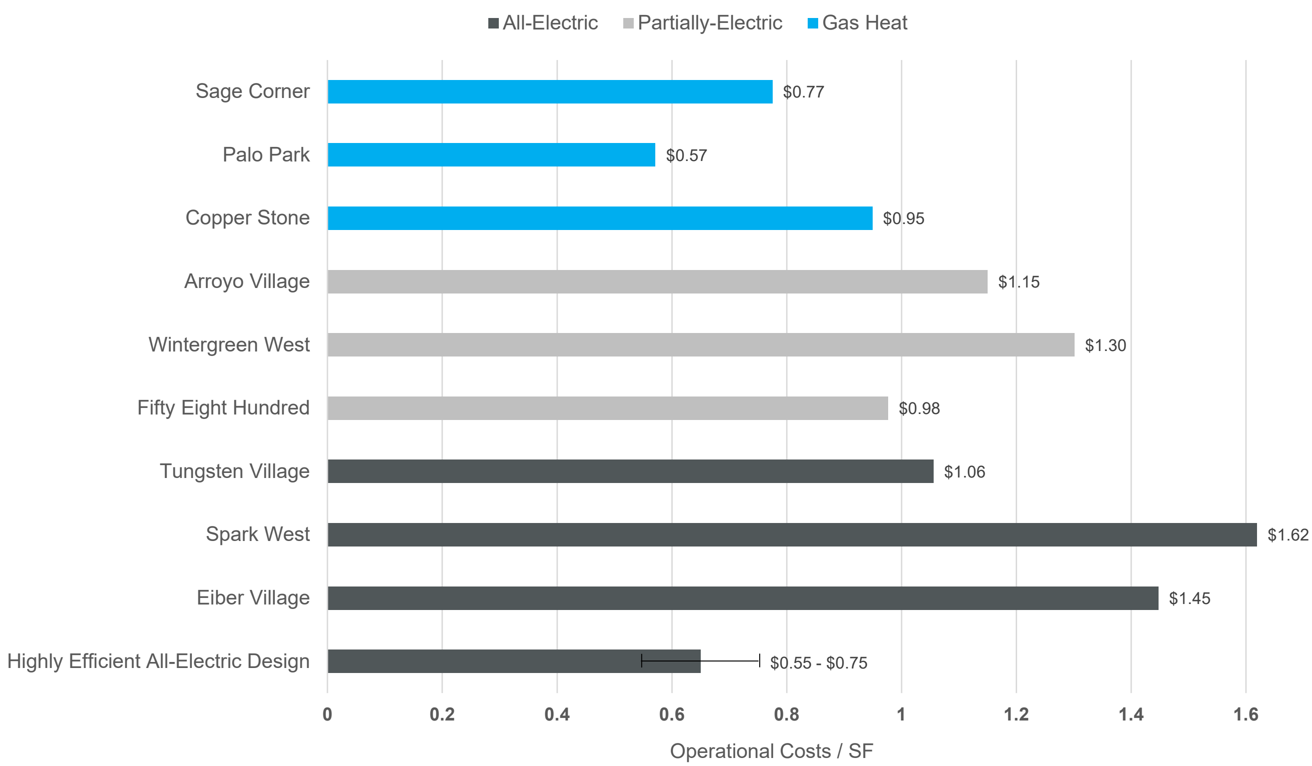


Figure 39

The average operational cost for each building type was $1.37/SF for all-electric, $1.14/SF for partially-electric, and $0.77/SF for gas heat projects.

MORE THAN HALF OF THE TOTAL ELECTRICAL BILL WAS ATTRIBUTED TO DEMAND CHARGES. FOR PROJECTS UNDER A SECONDARY GENERAL RATE, THIS INDICATES A SIGNIFICANT OPPORTUNITY FOR COST SAVINGS BY IMPLEMENTING DEMAND CONTROL STRATEGIES.

Annual building operating costs ranged from $0.57/SF to $1.62/SF. The more electrified designs were typically more costly to operate. An average all-electric design cost $1.37/SF while an average gas heated building cost $0.77/SF annually. Buildings with electric heating in residences and gas heating elsewhere (partially-electric designs) cost $1.14/SF to operate on average.

However, more recent all-electric building designs were not represented in the available data set. All-electric projects with utility data available incorporated standard efficiency HVAC and DHW equipment that relied substantially on electric resistance heating instead of high efficiency heat pump technology. The operational buildings with electric heating systems exclusively used resistance baseboards, PTHPs, and VTHPs paired with electric resistance water heaters. None of the projects with sufficient utility data incorporated advanced electric systems, such as split heat pumps, VRF, or heat pump DHW heaters. Such highly efficient all-electric designs could substantially decrease operating costs.

Additionally, more than half of the total electrical bill was attributed to demand charges. For projects under a Secondary General rate, this indicates a significant opportunity for cost savings by implementing demand control strategies.

Though not reflected in the analyzed projects, there is potential for an all-electric design to have comparable operational costs to gas heat buildings without significantly higher upfront costs. The greatest drivers of demand and consumption were related to ventilation strategy, heat pump efficiency at low temperatures, DHW selection, system controls, and rate structure. A combination of energy-efficient system selection and cost effective demand control strategies would help speed the adoption of electrification in affordable housing.

MEP Systems & Energy End Use

In multifamily buildings, space heating is the largest energy end-use, accounting for about 43% of end-use loads in family buildings. As such, the fuel source and space heating equipment type was a key driver in the operational costs. This is clear in the operational cost increases for partially-electric buildings that relied on electric resistance heating compared to all gas heated buildings.

Domestic hot water systems are the second largest end-use of energy in family buildings, and account for 19% of building energy consumption on average. Design of water heating in all-electric buildings therefore has a substantial effect on operating costs.

Right: Chart Source- U.S. Energy Information Administration.

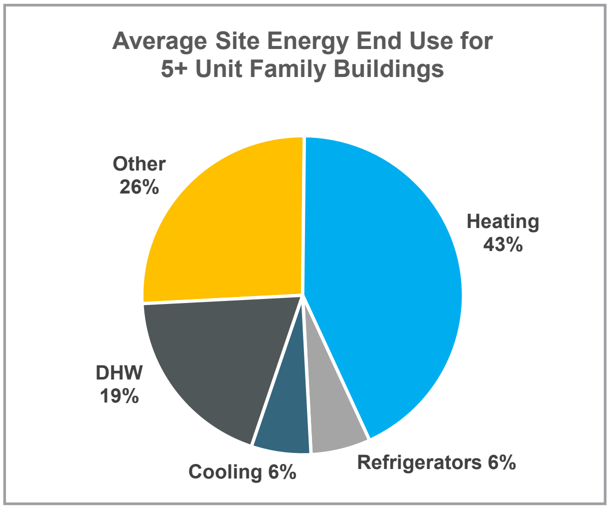


Figure 40

Although combined with space heating in the chart above, ventilation design also plays a significant role in operating costs, especially in Colorado's heating dominated climate. Ventilation strategies range from natural ventilation (lowest capital cost) to pre-conditioned outside air supply through a Make-up Air Unit or MAU (highest capital cost). Energy recovery systems, with or without supplemental heat, can provide fresh air directly to dwelling units and are generally considered the best-in-class strategy for ventilation. All-electric ventilation without energy recovery is more likely to rely on electric resistance heating during cold conditions and drive up operational costs. In-unit mechanical systems are summarized in the table below:

In-Unit Mechanical Systems by Building Ventilation

All-Electric	**Tungsten Village**	**Spark West**	**Eiber Village**
	Heat: Electric baseboard Cool: None DHW: Electric resistance Ventilation: Cont. exhaust, ERV in common area Solar: Yes	Heat: PTHP Cool: PTHP DHW: Electric resistance Ventilation: Natural Solar: Yes	Heat: PTHP Cool: PTHP DHW: Electric resistance Ventilation: PTHP Solar: No
Partially-Electric	**Wintergreen West**	**Fifty Eight Hundred**	**Arroyo Village**
	Heat: VTHP Cool: VTHP DHW: Central HE gas Ventilation: Cont. exhaust, electric FCU in common area Solar: No	Heat: PTHP, VTHP Cool: PTHP, VTHP DHW: Central HE gas Ventilation: MAU w/ gas heat Solar: Yes	Heat: PTHP Cool: PTHP DHW: Central HE gas Ventilation: Cont. exhaust, MAU w/ gas heat in common area Solar: Yes
Gas Heat	**Sage Corner**	**Palo Park**	**Copper Stone**
	Heat: Gas VTAC Cool: VTAC DHW: Central HE gas Ventilation: Cont. exhaust Solar: Yes	Heat: Aquatherm FCU Cool: DX split system DHW: Individual HE gas Ventilation: HRV Solar: Yes	Heat: Gas VTAC Cool: VTAC DHW: Individual HE gas Ventilation: VTAC + Cont. exhaust Solar: Yes

Figure 41

Gas heat projects showed the lowest average $/SF of all analyzed projects due to the lower relative cost of gas, which services both the space heat and the DHW systems. The most common gas heat systems in HTC projects consisted of hydronic fan coils (aka. aquatherms) and gas VTACs. Gas DHW systems also showed much lower operating costs than standard electric resistance systems.

Ventilation strategies around continuous exhaust or bringing in unconditioned outside air through PTHP/VTHPs generally led to higher energy use. Projects using MAUs and ERV/HRVs to duct conditioned outside air directly into dwelling units had comparatively lower operational costs. Projects with low infiltration rates achieved through advanced air-sealing measures and fewer envelope penetrations also showed reduced operational costs.

Location also appears to play a more significant role for electric heat systems than gas heat systems. Projects that relied on standard PTHP/VTHPs in colder climate zones had higher utility bills due to the inoperability of heat pumps throughout a large part of the heating season. Although the data is not included here, cold climate heat pumps that can operate down to 0^0F are critical in Colorado, with the greatest impact realized in alpine areas (CZ6-7).

Capital vs. Operational Costs

Life Cycle Cost Analysis (LCCA) is a useful framework for evaluating capital vs operating cost tradeoffs. LCCA totals the cost to install, operate, maintain, and replace a system over the life of a building, creating a holistic financial metric for developers. Conducting an LCCA for key all-electrical design operational cost drivers - space heating, domestic hot water, demand management, and ventilation systems - is a critical area for future study. LCCA fell outside the scope of this study due to the lack of equipment level pricing data and documented operational costs from highly efficient buildings.

Energy modeling of recent HTC projects suggest that LCCAs can vary from project to project. Depending on utility rate structure, contractor pricing, and the system type in question, an LCCA can recommend a more or less efficient building technology. However, there is always a meaningful portion of high efficiency system capital costs that are offset by reduced operating expenses.

One high efficiency technology that typically has a favorable LCCA are heat pump water heaters. Electric resistance water heaters - the least efficient DHW option - do have lower capital cost. The fact that electric resistance hot water heaters were used by many all-electric projects in this study speaks to their appeal. However, when taking into account maintenance and energy costs, the standard electric resistance model often shows a much higher LCCA than heat pump hot water heaters (HPWHs).

Participant Profile

PROPERTY PROFILE: CANOPY AT RED OAK PARK
MARKET: Family
SIZE: 41 UNITS, 48,256 SF
LOCATION: BOULDER, CO
FUEL SOURCE: ALL-ELECTRIC
HTC DEAL TYPE: 4% FEDERAL/STATE

All-Electric Operating Cost Challenges

THE KEY CHALLENGES ASSOCIATED WITH ALL-ELECTRIC CONSTRUCTION CONSIST OF RELATIVELY HIGHER COSTS INCURRED DURING THE BUILDING'S OPERATIONAL PHASE DUE TO INCREASES IN ELECTRICAL CONSUMPTION, DEMAND PEAKS, AND SUBSEQUENT DEMAND CHARGES

Key points:

- Demand charges contribute up to 57% of the total electrical bill. With such a large portion of electrical bills attributed to demand charge, demand control strategies are a significant opportunity for operating cost savings.
- For electric heat projects, reducing peak demand in the winter is critical for minimizing the ratchet charge that can impose higher utility costs throughout the following summer.
- Recommendations for reducing utility costs include strategies around building envelope, ventilation, DHW, demand control, heat pumps, rate structure, and renewables.
- Through carefully considered design, operating costs for an all-electric project will be comparable to gas heat projects.

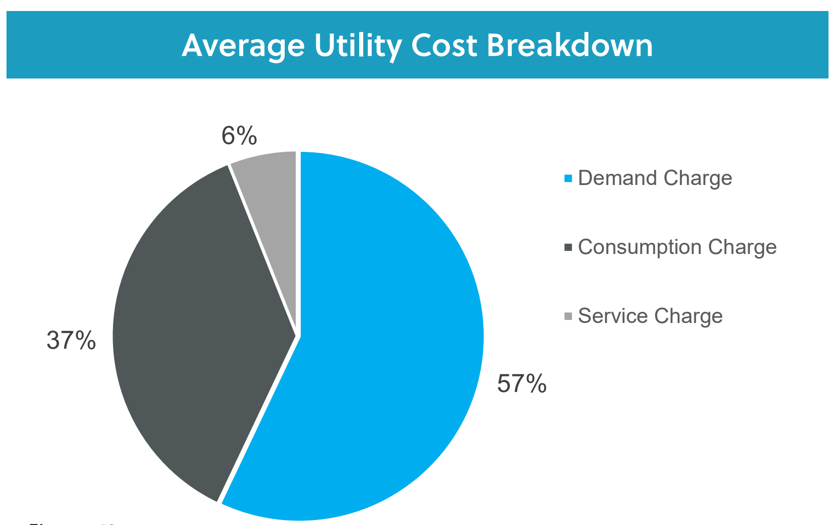


Figure 42

Electricity Utility Rates Compared to Natural Gas:

The main challenge with all-electric systems is that the cost per Btu for electric heat is significantly greater than the cost per Btu for gas heat. It should be noted that gas costs have been lower in recent years, but may increase significantly in the future. In addition to service fees and consumption charges, electric bills also typically include a demand charge, which is dependent on the amount of power used in a period of time.

Across all projects under the Secondary General rate, the demand charge accounted for roughly 57% of the total electrical bill. Consumption charges amounted to 37% of the bill with the remaining 6% attributed to various utility service charges. Standard efficiency all-electric buildings without demand control strategies experience substantial increases in operating costs compared to comparable mixed-fuel projects.

Heating Performance at Low Temperatures:

PTHPs are among the most commonly selected HVAC system among HTC projects, but even with high performance heat pump technology, PTHPs have a tendency to result in high operational costs. Part of the reason is that standard models cease to operate in heat pump mode at colder temperatures (32 - 45 ^{0}F), switching to electric resistance mode and potentially tripling the cost of operation.

Additionally, due to common installation issues and high leakage rates, PTHPs are prone to increased heating loads. It is not uncommon for PTHPs and VTHPs to be installed incorrectly with the knockouts opened or the dampers positioned such that outside air is brought into the space, even when the system has not been designed for ventilation.

Increased Electric Demand:

In addition to heat pump performance, electric consumption and demand are significantly impacted by ventilation, DHW, and system control strategies.

Where projects must meet ventilation requirements through mechanical means, the most common strategy is to bring in outside air through PTHP/VTHPs or to use continuous exhaust from bathroom or kitchen fans. However, both strategies have the disadvantage of introducing unconditioned air into the space, which increases the heating and cooling loads and can drive up demand costs.

Standard electric resistance models were the most common DHW system for electric buildings, but they operate at three times the cost of standard gas water heaters and contribute significantly to electrical consumption. Heat pump water heaters have the potential to have much lower costs than the standard electric model, but efficient operation is highly dependent on the design and installation. A less-than-optimal design compromises the efficiency of the heat pump technology and may lead to high operational costs regardless of its rated efficiency. Size, ducting requirements, noise, and difficulties with placement all contribute to the challenges of a heat pump water heater system design.

Night setback strategy typically maintains lower space temperatures during "Unoccupied" hours and is generally recommended as an energy efficiency measure. However, for projects under a demand rate structure that rely heavily on electric heat systems such as PTHPs for common areas, this measure can lead to unexpectedly high utility bills. In the effort to reduce loads during unoccupied hours, a night setback causes multiple units to run simultaneously at high power in the early morning, causing spikes in the peak demand that may trigger the ratchet clause and set the peak for high demand rates for the subsequent 11 months.

Above: Open Damper

Demand Ratchet Charges:

In an effort to reduce the stresses and expenses incurred by utilities during high peak demand periods, some utilities, including Xcel Energy, include a "ratchet clause" to incentivize customers to use power in a more consistent pattern throughout the year.

At Wintergreen West, the ratchet clause took effect during the summer months (highlighted in the table to the right), when utility data shows that actual measured demand was lower, but the billed distribution demand was charged at the higher kW rate. During April-Sept one year, the 97 kW rate was charged due to a high demand peak experienced in the previous heating season, when demand had presumably reached a maximum of 194 kW (=97*2). The distribution demand charge was continued to be billed at the higher rate for this 6-month period, despite an actual demand that ranged from 38 to 76 kW. At a distribution demand rate of $5.63/kW, this resulted in excess fees of roughly $1,290 for the property during this period. A breakdown of the total electrical bill showed that distribution demand charges alone accounted for 25% of the total electrical bill during the ratchet charge period, while during other months the distribution demand charges were on average 16% of the total bill.

Due to demand peaks set in the winter season, less efficient electric heat systems are at risk of being penalized with high demand charges that last for the duration of the year. With demand charges accounting for the majority of the electrical bill, reducing the demand peaks should be a significant consideration for all-electric designs.

Demand Charges Wintergreen West

Month	Actual Demand (kW)	Billed Distribution Demand (kW)
Jan	124	124
Feb	117	117
Mar	114	114
Apr	73	97
May	48	97
Jun	38	97
Jul	40	97
Aug	76	97
Sep	76	97
Oct	134	134
Nov	132	132
Dec	136	136

Figure 43

PROPERTY PROFILE:
WINTERGREEN WEST

MARKET:
Family/
WORKFORCE

SIZE:
40 UNITS, 36,722 SF

LOCATION:
KEYSTONE, CO

FUEL SOURCE:
MIXED-FUEL

HTC DEAL TYPE:
9% FEDERAL

Opportunities for Highly Efficient Electric Systems and Strategies to Reduce Operating Costs

All-electric energy consumption can be effectively managed with well-designed building systems paired with cost-efficient demand control strategies.

Potential strategies for improving the operational costs of all-electric buildings include:

Above: Continuous Air Barrier Building Envelope

Above: In-Unit ERV

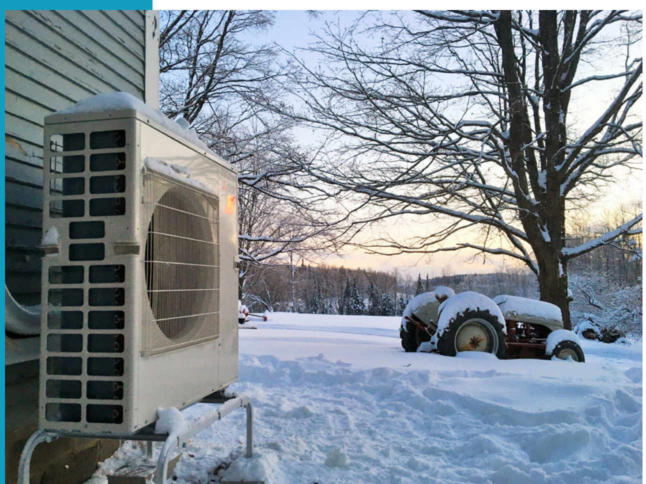
High Performance Building Envelope:
Highly efficient envelope systems last throughout the service life of the building, reducing energy loads independently of the MEP system. A tightly constructed, high performance building envelope can improve tenant comfort and requires less powerful HVAC equipment. Smaller sized equipment reduces both fuel consumption and electricity demand. Details for high performance envelope strategies include:

- Continuous insulation on the exterior of walls and around foundation walls.
- Roof insulation above a deck in at least two layers with staggered joints.
- Window area approximately 20% of the exterior gross wall area to provide natural light, views, and passive solar gains.
- Window U-factor of 0.30 Btu/hr-ft2-F or less, with SHGC tuned by orientation. With all-electric buildings, a higher SHGC (~0.40) may be more energy efficient and have a lower first cost.
- A tightly air-sealed envelope may have a greater energy reduction impact than insulation levels.

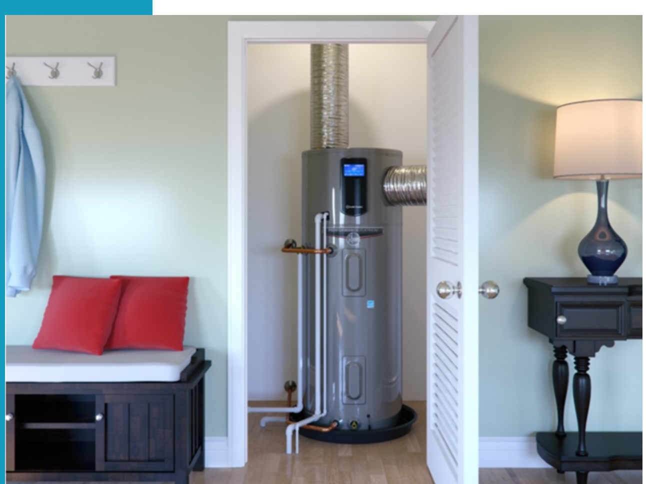
Efficient Ventilation Strategy:
Heating fresh air in the winter is the largest component of Colorado heating energy consumption. All-electric central ventilation systems can be very efficient, especially when coupled with energy recovery ventilation (ERV) to temper outside air using the heat from exhaust air. This avoids very cold air reaching the heat pump systems which boosts heat pump efficiency.

- Outside air through PTHP/VTHP is not recommended unless there is an integrated energy recovery ventilator.
- Low temperature PTHPs and VTHPs with integrated energy recovery ventilators are becoming more widely available. Compared to standalone ERVs, they can reduce equipment installation and ducting costs while limiting the maintenance needs during building operation.
- The cost decision between central versus in-unit energy recovery ventilation is tied to building layout and ducting costs.
- An advantage with central ventilation air systems is that enhanced filtration, such as MERV 13 or higher, is easier to implement from a fan capacity and maintenance perspective.

Above: ERV at 30Pearl



Above: Cold Climate Heat Pump



Above: In-unit DHW Heat Pump

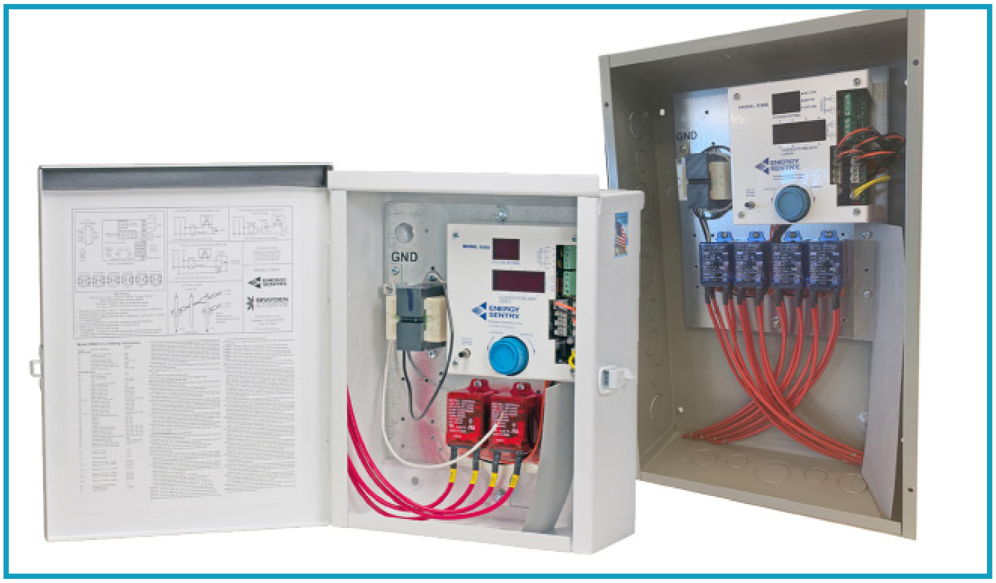
Cold Climate Heat Pumps:
Manufacturers are introducing more heat pump systems with advanced technology such as high efficiency compressors with inverter technology, alternative refrigerants, and cold climate models that operate at lower ambient temperatures experienced in Colorado. As competition within this market grows, performance is expected to improve while the cost of equipment is anticipated to go down.

- Cold climate heat pumps that operate near 0⁰F can be more impactful to utility costs than higher peak efficiency ratings. The lower temperature operation decreases resistance heating operation and the associated demand peaks and efficiency drop.
- Increased heating capacity at lower temperatures creates an opportunity to eliminate or downsize the backup heating element (ie. installing a 5kW backup heat strip instead of 10kW).
- Ductless mini split systems are used throughout the world and some are able to operate at temperatures as low as -22⁰F.

Heat Pump Domestic Hot Water Heaters:
DHW heat pumps can reduce energy consumption considerably compared to standard electric resistance water heaters. However, in cold climates such as Colorado, there are several challenges around installation due to reduced efficiencies at lower temperatures and the need to exhaust cool air.

For individual in-unit heat pump DHW, locate air intakes and cold air exhaust to avoid tenant discomfort and improve system performance. Fully ducted designs without louvered doors can help avoid noise concerns in the unit. Each manufacturer is different, but typical venting options to consider are:

- Fully duct the intake and the cold air exhaust to the outside and avoid introducing unwanted cold air into conditioned spaces. This minimizes burden on the space heating system, but most heat pump water heaters will revert to resistance heating when outside temperatures drop below 35⁰F.
- Duct the intake and the cold air exhaust to an adjacent hallway. This will place an additional heating burden on the corridor HVAC system, but the water heater will be able to operate in high efficiency heat pump mode regardless of the outside air temperature. This strategy is most efficient when paired with a high efficiency corridor HVAC system that includes heat recovery.
- Cold air exhaust can be ducted to the return plenum of the in-unit space heating system if available. While this increases run time of the space heating system, it also allows DHW heat pump operation during cold weather to avoid demand and consumption spikes from resistance heating operation. This strategy pairs well with electric fan coils and low temperature split system heat pumps.
- Split system DHW avoids venting and noise issues, but requires an exterior location for all the outdoor heat pump equipment. Additionally, most of these systems run water lines to the exterior which require freeze protection.



Left: Standalone demand controllers shift demand automatically by temporarily (a few minutes or less) shutting off equipment as the building approaches a preset demand limit.

Electricity Demand Management:
With the demand charge driving a significant portion of the total cost, cost saving opportunities can be realized by shifting the load during certain periods of the day. Increasing energy efficiency will be a significant driver in reducing total energy usage, but the key for controlling demand charges is to implement strategies that reduce the amount of power being used simultaneously.

- **System controls.** Control of HVAC, DHW, and ventilation equipment should be configured with demand management in mind. For example, thermostats should not be programmed to have a standardized night setback schedule. When this happens, all of the units call for heat at the same time in the morning and set a high demand which results in a high peak demand charge. This can be easily avoided by staggering schedules or eliminating night setback modes altogether.
- **Energy Storage.** Energy storage and demand management systems use electricity from the grid to charge the storage system during off-peak periods when electricity costs are lower. The system learns the building's energy use patterns, anticipates when the building is approaching peak demand, and then discharges electricity from storage during the on-peak hours, allowing for peak demand "shaving." Through a battery energy storage system, peak demand can be effectively capped, significantly reducing utility demand charges. Additionally, energy storage can increase resiliency by providing back-up power for critical operations during the event of a power outage.
- **Demand Controllers.** Standalone demand controllers shift demand automatically by temporarily (a few minutes or less) shutting off equipment as the building approaches a preset demand limit. Standalone demand controllers can be strategically paired with non-critical loads like domestic hot water systems and in-unit HVAC systems to defer operation briefly without significantly affecting comfort or convenience.

Renewable Energy:
Installation of renewable energy like solar PV will offset electricity consumption on site. Solar PV also offers opportunities for lower rates and should be considered during design. Some methods for making solar PV attainable for HTC projects include:

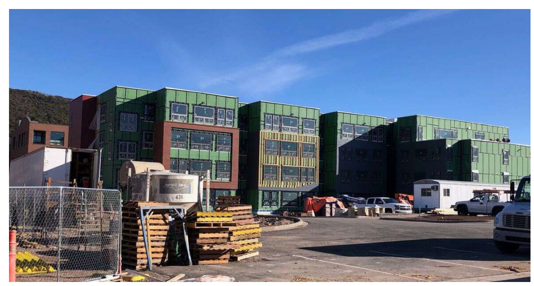
- Pursue utility rebates and public incentives for installing renewables on affordable housing.
- Investigate community solar gardens as an alternative to installing renewables on the project.
- Invite community partners to sponsor the installation of renewables on the project.
- Consider solar hot water integrated with central hot water systems and storage.

Rate Structure Selection:
Available rate structure options should be carefully considered during design, especially in conjunction with solar PV, as this can be a key driver in utility costs. For projects that have at least 30 kW of solar PV installed, Xcel Energy offers a Solar PV Time-of-Use rate structure that offers reduced demand rates. For Alta Verde, a project achieving Zero Energy Home Certification and currently under construction, the SP-TOU rate allows for operational cost estimates as low as $0.25/SF. Without PV and under the Secondary General rate, consumption estimates for Alta Verde are modeled at $1.18/SF. This demonstrates a significant opportunity for savings at all-electric projects with the eligible amount of solar PV.

Benchmarking and Monitoring Based Commissioning:
Once a building is occupied, active management of the utility spend will ensure installation, operating, and maintenance errors don't increase utility costs. This effort should include benchmarking the building using a tool like ENERGY STAR Portfolio Manager, comparing actual costs to modeled costs, and proving this data to property management teams. More sophisticated fault detection and diagnostic systems can provide real time analytics of building system operation, notifying the owner when issues occur to prompt timely resolution.

Modeled Example of High Performance All-Electric Design

Willits Block, a 135,000SF workforce housing project currently under construction in Basalt, CO (CZ6) is not an HTC-supported project. However, it's an excellent example of how a family all-electric project can achieve operating costs similar to a gas heat project. Under the Holy Cross demand rate structure and without including solar PV, consumption estimates for Willits Block are modeled at $0.72/SF, which is within the range of standard gas heat projects**. The all-electric building system design consists of the following features:**



In-Unit Mechanical	• Split DX heat pump • SEER 16, HSPF 8.5, cold climate model with 0F minimum heat pump operation • Significant savings shown over VTACs ($7,300 annual savings, payback of 11 years) • Ventilation: ERV with electric heat to provide 55F outside air
Common Area Mechanical	• First floor common area: Air-cooled VRF system with fresh air through fan coil units • Corridors: PTHP
DHW	• Split system heat pump, cold climate model with COP = 5.2 (Sanden SanCO2) • Additional savings would be possible with drain energy recovery added
Envelope	• Standard 2015 IECC envelope for CZ6 with argon-fill windows
Other Features	• Lighting power densities specified by 2015 IECC for CZ6 • Low-flow plumbing fixtures • 86 kW size PV system (offset 30% of electrical consumption) • Demand rate structure (showed $10,000 annual savings over TOU rate structure)

Additional Operating Cost Considerations

For all projects analyzed with operational data, the utility metering structure consists of building-level master meters paid by the owner, with the exception of one resident-metered project (Copper Stone). The mixed-fuel projects are under a resident-paid utility structure, with submeters installed by a third party to track resident consumption and allow owners to bill residents accordingly. The three all-electric projects are under an owner-paid structure using gross rents, in which resident consumption was not tracked or individually billed.

Utility Metering Structures

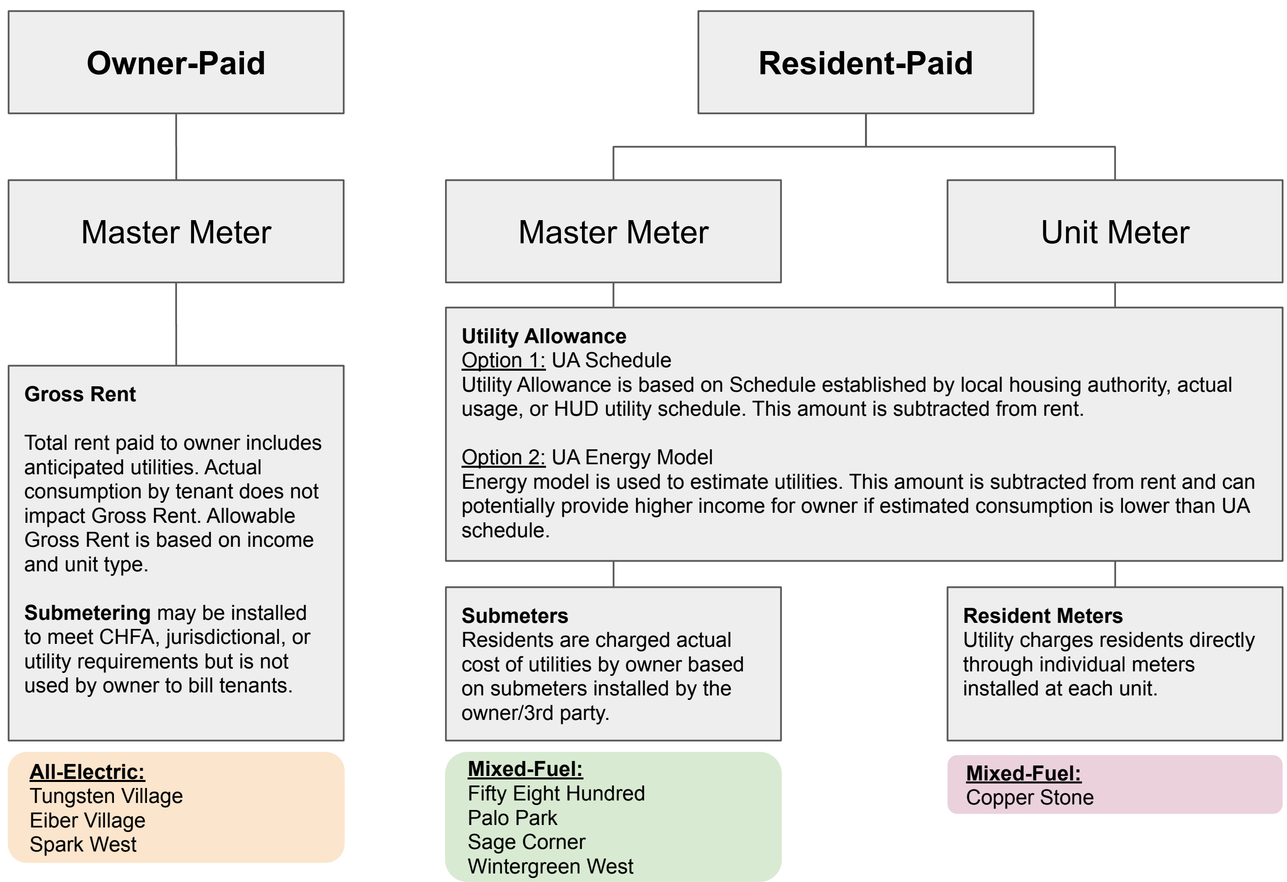


Figure 44

Although the all-electric and mixed-fuel projects with utility data were similarly grouped together by owner and resident-paid structures, the remaining 17 projects show a more random mix that includes all-electric projects under individually-metered units and mixed-fuel projects with owner-paid utilities.

Variability Analysis: Resident-Paid Utilities & Electric Space Heat

A variability analysis was conducted using Fifty Eight Hundred, a partially-electric project that had full occupancy for at least one year. The chart on the left shows the range in electrical consumption for one-bedroom unit types across 12 months. The chart on the right shows a normal distribution curve with a significant standard deviation of 223 kWh for the month of February.

Range of Electrical Consumption for One Bedroom

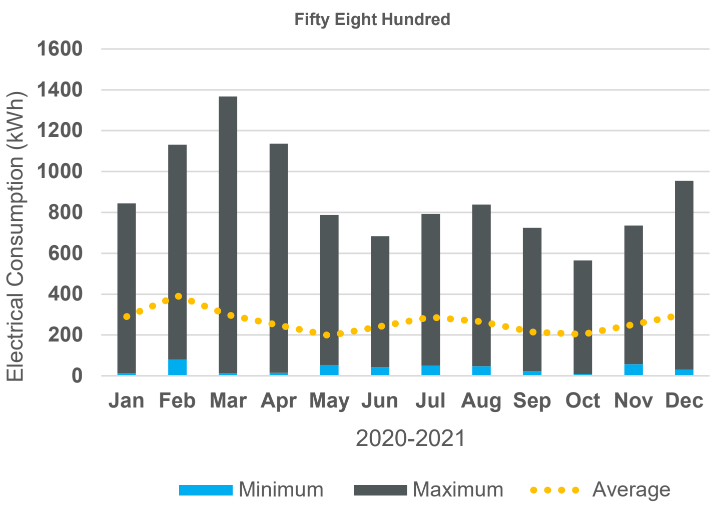


Figure 45

Natural Distribution of Electrical Consumption

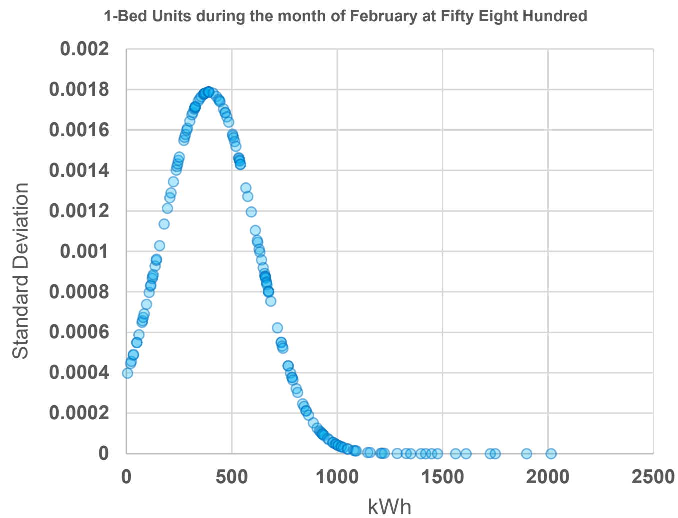


Figure 46

With an average consumption of 391 kWh, this indicates that 68% of all tenants consumed between 169 and 615 kWh of electricity, with a large portion of the remainder consuming up to 2,014 kWh. Similar bell curve trends were observed in other unit types.

Variations in actual consumption within the same unit types are due to several factors, including the floor, the orientation, glazing area, and the location of the unit within the building that may affect the ratio of exterior to interior wall area (corner unit vs. inside unit). Variability in consumption is also supported by energy models, which can vary up to 15% in monthly use between a middle floor interior unit and a top floor corner unit of the same size. Tenant behavior, including the use of lighting and appliances, plug loads, occupancy schedule, and preferred thermostat setpoints also have a significant impact on consumption. Resident-paid utility structures have generally shown that there's a benefit in residents being responsible for moderating their own consumption, with results showing a sitewide reduction of electrical use when compared to payment structures under a gross rent system.

The wide variability seen within the same unit type highlights some of the challenges that projects face in calculating utility allowance estimates in a fair and equitable manner to all tenants.

PROPERTY PROFILE:
FIFTY EIGHT HUNDRED

MARKET:
Family

SIZE:
152 UNITS, 136,841 SF

LOCATION:
LAKEWOOD, CO

FUEL SOURCE:
MIXED-FUEL

HTC DEAL TYPE:
4% FEDERAL/STATE

Comparison of Resident-Paid Costs vs Utility Allowance Schedule

For projects with resident-paid utilities, there are several options for calculating the tenant utility allowance. Established utility allowance schedules can be used from either the jurisdictional housing authority, actual consumption data based on utility bills, or the HUD utility allowance schedule. Alternatively, utility estimates can be calculated using an energy consumption analysis model that takes into account specific factors including: unit size, building orientation, design and materials, mechanical systems, appliances, characteristics of the building, location, and historical weather data.

A comparison of average utility consumption against the jurisdictional utility allowance for Fifty Eight Hundred shows a significant opportunity for cost savings. Depending on the bedroom type, the average consumption across the unit types was on average 58% of the estimated utility allowance set by the local housing authority. For this particular project of ~150 units, using a utility allowance that tracks more closely to actual usage would amount to an additional ~$4,600 in rental income per year.

Fifty Eight Hundred- UA Schedule vs Actual

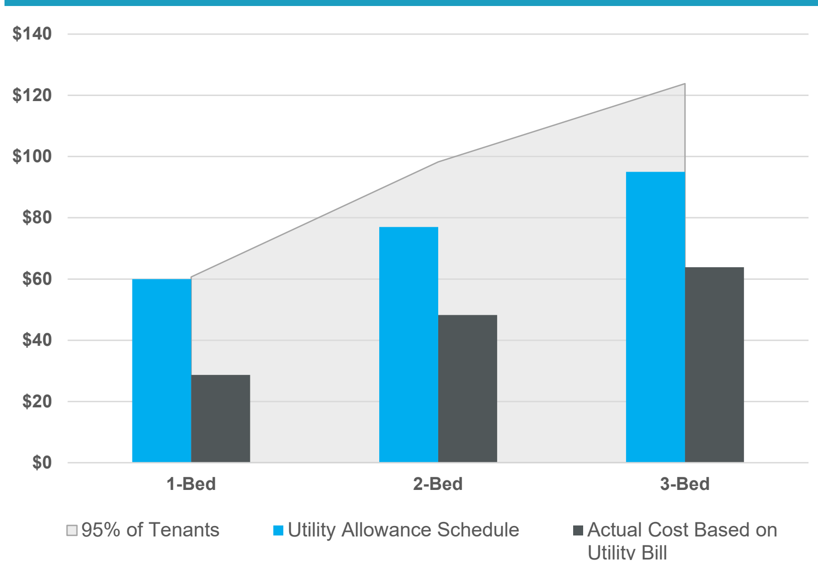


Figure 47

Utility Allowance Schedule

Size	Utility Allowance Schedule	Actual Cost Based on Utility Bill	Cost Savings per Unit	Maximum Cost for 95% Tenants
1-Bed	$60.00	$28.66	$31.34	$60.66
2-Bed	$77.00	$48.25	$28.75	$98.25
3-Bed	$95.00	$63.83	$31.17	$123.83

Left: The utility allowance schedule is often much higher than the average utility bill.

Figure 48

For projects in design, energy model estimates may provide a financial benefit. For projects that plan to invest in high performance systems, lower utility allowances will result in increased rental income.

However, an important consideration highlighted in the chart above is the variability in tenant utility bills. The shaded range represents the utility cost for 95% of the tenants (remaining 5% were excluded as outliers). Although the average utility cost to tenants is lower than the provided utility allowance, the variability in consumption means that for a large number of tenants, the average allowance is not enough to cover the bill. Although tenant behavior plays a role, it is important to consider that variability in utilities may be due to characteristics of the dwelling unit that are outside of occupant control (orientation, adjacent units, floor, etc).

Capital Costs

The capital costs analyzed for this project include construction and final costs provided by study participants. These costs were sourced from either construction phase GMP schedule of values or final cost summary documents submitted to CHFA (after the building was placed in service). Preliminary cost estimates included with tax credit applications were excluded from the analysis due to variability between initial application and final construction costs.

The main driving factor in $/SF project cost is project size: As project size increases $/SF drops due to economies of scale. When looking at overall construction cost per square foot by fuel use type, there is a small gap between the all-electric and mixed-fuel projects.

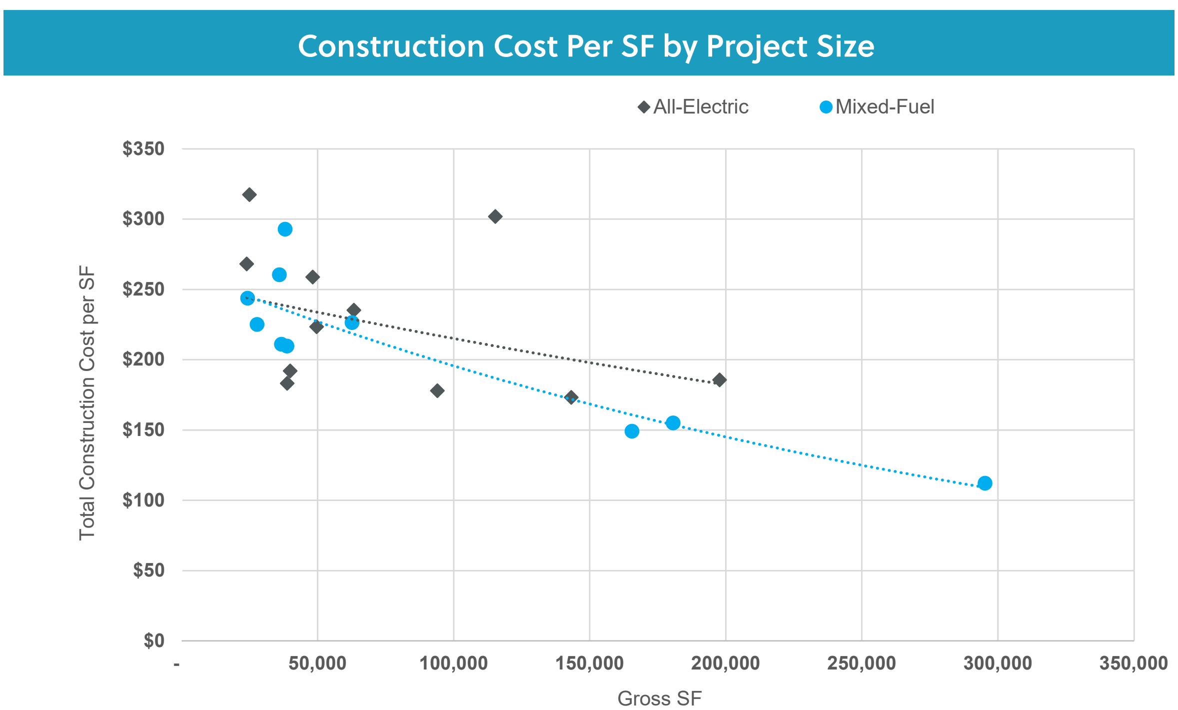


Figure 49

Average Costs Per SF Summary

Project Type	Average of Cost/SqFt	Average of MEP/SqFt
All-Electric	$225.03	$50.76
Mixed-Fuel	$208.46	$44.42
Grand Total	$217.78	$47.99

Figure 50

However, given the study's small data set (the table above represents 10 all-electric and nine mixed-fuel projects), it is unclear as to which factors are driving the variation on cost. As noted above, project size seems to be the determining factor. Other factors such as land costs, regional construction costs, year constructed, and building type likely have larger impacts than fuel use.

When narrowing the focus to Mechanical, Electrical, and Plumbing (MEP) costs/SF, the variance between fuel use types is minimal.

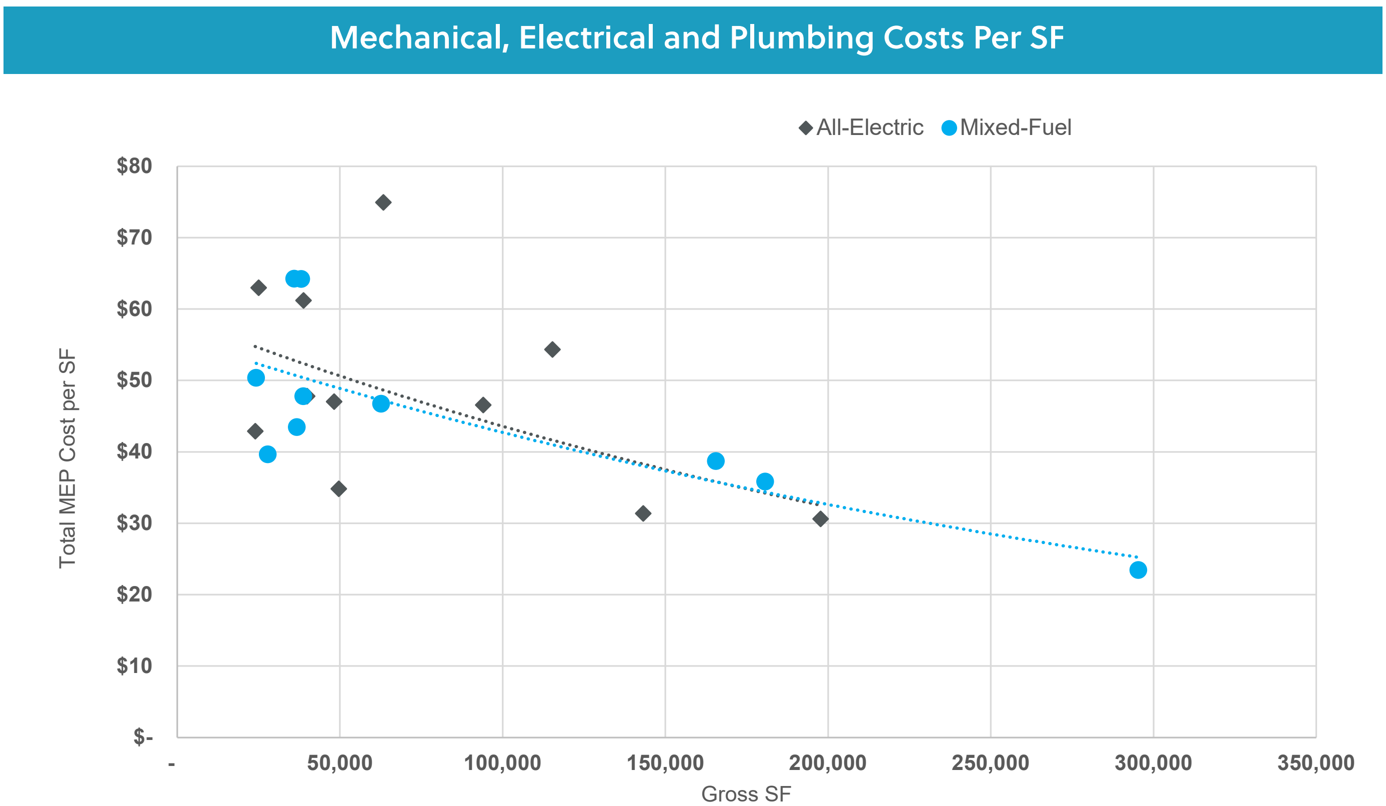


Figure 51

MEP & Electrical Cost/SF vs Total Project Cost/SF

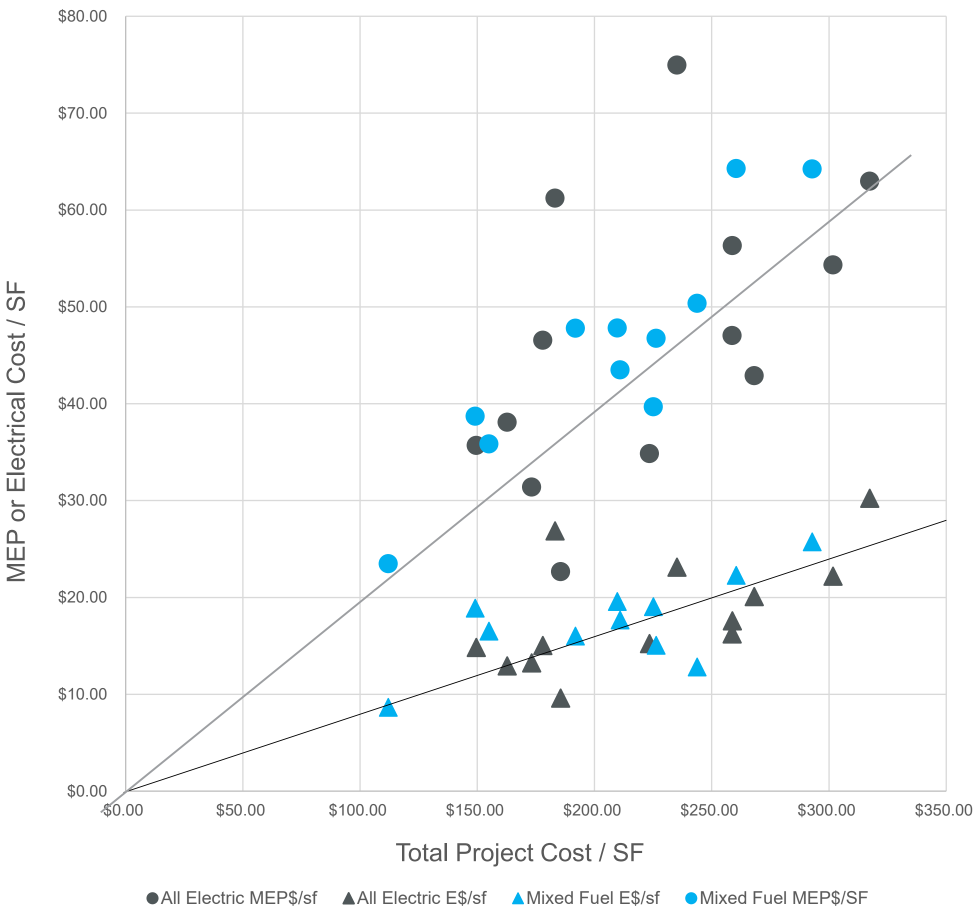


Figure 52

To get a better sense of how fuel use choice impacts construction cost, a scatter plot analysis of two data sets was developed: 1) MEP costs/SF vs. total construction costs/SF and 2) electrical costs/SF vs total construction costs/SF. For each data set, the study population was divided into all-electric (dark grey) and mixed-fuel (blue). In the chart to the left, this analysis reveals the relationship between a project's MEP/E costs and total construction costs.

From the chart, it is apparent that whether the study participant is mixed-fuel or all-electric has little to no bearing on how MEP costs correlate with total project cost. It is interesting to note that the two blue circles and triangles (all-electric projects) farthest above the average cost relationship line are both adaptive reuse projects with historic tax credits.

Mixed-Fuel Add Costs:

Project teams were able to quantify two major categories of cost adds associated with mixed-fuel projects: the cost of bringing gas service to the building, and the cost of gas piping to building equipment. While HVAC and DHW equipment costs can also vary by fuel source, general contractors could not provide equipment level cost data for analysis. Subcontractors, a data source not in the study scope, typically hold this information. It should be noted that system types, configuration, ducting, and efficiency performance likely all have a larger cost impact than fuel source.

As a percentage of overall MEP Schedule of Values (SOV) and total construction costs, gas service to the building and individual pieces of equipment is a minor cost. However, this cost increases when mixed-fuel buildings have gas service to each apartment, as opposed to central equipment only.

Gas Service

Of the 11 mixed-fuel study participants, five were able to provide documented costs for utility charged gas service to the building. Costs ranged from $5,000 to $10,620, with an average cost of $6,731.

Project	Location	Gas Service	% MEP SOV
Cinnamon Park	Longmont	$10,620	0.87%
Espero	Durango	Donated by Atmos Gas	0.00%
Liberty View	Aurora	$5,000	0.17%
Rhonda Place	Denver	$5,132	0.21%
Stella	Denver	$6,172	0.10%

Figure 53

Outside of this study, Group14 Engineering has observed similar gas service costs ($5,000 - $12,000) for urban projects. Gas service costs can be much larger for projects with site locations that prevent easy connection to existing utility infrastructure. As observed in the All-Electric vs Mixed-Fuel Design Decisions section, large gas service costs often pushed study participants towards an all-electric design.

Gas Piping and Venting

Of the 11 mixed-fuel study participants, four were able to provide documented costs for gas piping from the utility meter to gas fired equipment. As can be seen from the table below, price is a function of the location and quantity of gas fired equipment.

Project	Gas Piping	% MEP SOV	Areas Served
Espero	$5,720	0.52%	Central DHW
Rhonda Place	$15,000	0.61%	Central DHW, Roof Top Unit
Liberty View	$23,700	0.81%	Central DHW, Roof Top Unit, Community Room Fireplace
Palo Park	$49,723	2.69%	In-Unit Aquatherms (35 Units)

Figure 54

Gas equipment venting/flue costs were typically bundled into larger schedule of value line items, with detail located in subcontractor bids not accessible for this study. However, venting costs will also increase according to a similar logic, driven by the quantity and location of gas fired equipment.

Palo Park in Boulder, CO, reported a documented cost of $49,723 for gas piping

All-Electric Add Costs

The main cost adds teams identified for all-electric buildings are increased building electrical service size, apartment service size, and associated materials (feeder conduit, panels, etc). Utility side transformers are not typically a cost add, as this is covered by the utility. However, a small number of teams reported that the utility was not willing to provide as much transformer capacity as initially requested, due to local grid constraints.

As noted in the mixed-fuel section above, HVAC and DHW equipment costs can also vary by fuel source. However, system types, configuration, ducting, and efficiency performance likely all have a larger cost impact than whether the equipment is all-electric or not.

As a percentage of overall MEP Schedule of Values and total construction costs, increased building and apartment electric service size due to all-electric design is also a minor cost in new construction (estimated to be less than 2% of total MEP). In general, teams pointed out that these costs are material only, as labor costs aren't impacted by a moderate bump in electrical service size. It should be noted that the entire study population represents new construction and major rehab. **Add costs for increased electrical service would be much more significant in a moderate rehab or retrofit scenario.**

Tenant Electrical Service

General contractors were not able to provide apartment-level breakout costs for the electrical infrastructure components impacted by all-electric design. However, some general per unit cost numbers were provided by a few teams.

Apartment-level panel size variance was reported as a function of an all-electric project's approach to in-unit HVAC, back up/supplemental electric resistance heat, and DHW equipment. Given that a certain amount of lighting, appliances, and other plug loads are present regardless of these variables, the typical max panel size variation would be an increase of 25 - 50 amps (going from 100 amp to 150 amp panels) for a worst case all-electric design. The material cost increase associated with the larger panels is typically less than $50/apartment. A slightly larger material cost is driven by the need for a larger feeder (wire) size from the building load center to the apartments, but this is also a relatively small number.

The building-wide cost impact of larger apartment electrical service was considered to be less than 1% of the MEP schedule of value amounts.

Central Electrical Service

Increases to the main building electrical service can be moderately more expensive than apartment-level electrical infrastructure. Building electrical service typically is sized in 400-500 amp increments due to equipment sizing (1,600 amps, 2,000 amps, 2,400 amps, etc.). Each step up in size was reported to have a $20,000 - $30,000 impact on installed cost.

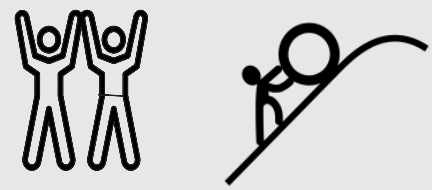
Interviewed electrical engineers stated that the typical impact of moving from a mixed-fuel design to an all-electric design for a 40-70 unit site is only one step up in service size. This results in an estimated increase of 1% of MEP costs. While the service size increase will be more for larger sites, the total MEP cost will increase as well, keeping the % increase similar.

It should be noted that some municipal EV charging infrastructure requirements are estimated to have a larger cost impact than all-electric design. For instance, Denver's current EV requirements are that all R-2 type construction (most family) have 5% of parking stations equipped with EV chargers, 15% be EV ready (conduit, electrical service, and distrubtion capacity) and the remainder of parking spaces be EV capable (conduit, space planning for future electrical distribution equipment). This typically results in a building service size bump (or two, depending on the number of spaces), plus the cost of charging stations, conduit, and other materials. Utility incentive programs in these jurisdictions (Xcel Energy) are responding to offset the non-electrical service components of this cost.

Opportunity & Challenge Summary

All-electric building systems offer a multi-benefit value proposition for HTC properties. Improved outcomes around health, safety, cooling (for some retrofit cases), and significant GHG emission reduction can all be achieved through all-electric design. However, there are significant challenges to widespread adoption of all-electric systems by the Colorado HTC industry. These include the high operating cost of standard efficiency all-electric buildings, the increased construction budget associated with highly efficient all-electric buildings, and concern that building system complexity will outpace affordable housing operation and maintenance capabilities.

OPPORTUNITIES & CHALLENGES



Opportunities

Lower GHG Emissions

Building electrification is a key decarbonization strategy that significantly reduces Greenhouse Gas emissions from the Colorado building sector. As noted earlier in this study, Colorado House Bill 19-1261 set aggressive GHG requirements for investor-owned electric utilities, culminating in a 90% reduction by 2050. WIll Toor, Executive Director of the Colorado Energy Office, notes "We got commitments from utilities representing 99% of the fossil fuel generation in the state to achieve at least 80% reduction in pollution by 2030. We have locked these commitments in through legislative requirements and action by state air and utility regulators" (Toor, 2021).[4] For affordable housing properties, an all-electric design capitalizes on a greening grid to reduce GHG emissions by 32% over the life of the asset.

Health

Low income communities and communities of color have increased rates of respiratory illnesses (Cheatham & Marechal, 2018)[5]. Many times, HTC properties have ventilation systems that don't bring in filtered outside air. This has a negative impact on indoor air quality, an impactful determinant of resident health. By eliminating the combustion products that are emitted from natural gas powered equipment, all-electric buildings enhance air quality and improve health outcomes. It should be noted that all study participants have already removed one of the biggest health risks by not installing gas stoves. Also, many mixed-fuel designs removed all natural gas fired equipment from apartments, reducing health risks from improper or failed combustion product venting. However, even properly vented gas equipment expels contaminants to the outside. The Denver Renewable Heating and Cooling Plan notes that the Denver Metro/North Front Range area faces significant public health impacts from poor outdoor air quality, of which emissions from the combustion of fossil fuels is a contributor.

Safety

One particular combustion product, carbon monoxide, poses an extreme safety risk. The CDC notes that "Carbon monoxide is an odorless, colorless gas. It is produced any time a fossil fuel is burned and it can cause sudden illness and death" (CDC website).[6] Gas system venting is designed to minimize carbon monoxide exposure. Additionally, Colorado state law has mandated the installation of carbon monoxide detectors in all apartments with gas fired appliances. However, in a Denver grant-funded weatherization program for income-qualified households, 30% of these home's gas appliances failed carbon monoxide safety tests (Denver Department of Climate Action, Sustainability, and Resiliency, 2021).[7] While HTC properties have more regulatory safeguards than other subsidized housing products, all-electric buildings completely eliminate the risk of carbon monoxide

Enhanced Cooling

Some older affordable housing properties have gas heat systems and insufficient or no cooling. Replacing these systems with air source heat pumps creates an opportunity to add high efficiency cooling capacity properly designed for the space. Especially as Colorado experiences increasing heat intensity as a result of climate change, adequate cooling is a life safety requirement (Bailey & Esposito, 2017).[8]

Challenges

Operating Costs

A snapshot of nine recently built HTC-supported projects found that the average energy cost for all-electric was $1.37/SF compared to $1.14/SF for partially-electric (electric space heat with gas domestic hot water and ventilation conditioning), and $0.77/SF for gas heat, domestic hot water, and ventilation conditioned projects. This represents a nearly 78% utility cost increase for all-electric designs. The significantly larger all-electric operating costs can fall on owners, tenants, or both, depending on a property's metering and utility allowance approach. As noted earlier in the report, the three major causes of operating cost disparity are:

- The current cheap cost of natural gas in Colorado. Even with projected gas cost increases this winter of 11% - 24% on the gas component of utility costs, the study gas heat participants' all in utility cost would only increase to $0.85/SF from $0.77/SF (Booth, 2021).[9]
- The high variability of electric equipment efficiency, which operates within a range of 100% to 400%, compared to the relative stability of natural gas equipment efficiency, which typically operates within a range of 75% - 98%. Lower cost electric heating designs that rely more frequently on electric resistance operation are the least efficient.
- The common use of standard efficiency building envelope systems, ventilation without heat recovery, and standard domestic hot water system design, which all increase loads on electric systems.

SOLUTION: Highly Efficient Building Systems - The use of highly efficient building systems reduces the modeled operating cost of all-electric to $0.55/SF - $0.75/SF. These systems are widely available, proven technologies. However, they typically represent a construction cost add that would reduce the competitiveness of an HTC application.

Adoption of Systems

The 24 projects in this study show limited adoption of the highly efficient building systems that would reduce the operating cost of all-electric buildings. This is representative of the broader Colorado HTC building population, and speaks to the strong construction cost containment efforts needed for financial feasibility. Additionally, the limited adoption of these systems due to cost has in turn limited design teams' experience with many high performance design options. This creates a reinforcing cycle that supports the continued use of status quo design.

SOLUTION: Funding and Technical Assistance - Other HTC markets, most notably California and New York, are beginning to have success driving the adoption of highly efficient affordable housing through targeted technical assistance and significant new funding for efficient building electrification. New grant funding needs to be substantial enough to make highly efficient building systems cost comparable with current HTC construction practice.

Under Resourced Operations/ Maintenance

HTC property management groups report having limited internal technical capabilities for operation and maintenance. Additionally, staff turnover limits the effectiveness of O&M training provided by contractors at the time of installation. This can reduce the efficiency of building systems with complex controls, and increase the cost of non-standard building system maintenance.

SOLUTION: Keep highly efficient all-electric design simple - High performance design can get complicated, but it doesn't have to be. Passive design strategies, intuitive choice architecture, and the use of proven HVAC/DHW equipment with basic controls are critical design principles for affordable housing. Simplicity is often its own efficiency measure, and can increase the durability of energy performance over the life of a building.

Recommendations

Group14 has identified several policy, funding, and technical assistance initiatives that could accomplish the dual goals of:

- Accelerating HTC project adoption of all-electric design.
- Avoid harm to low-income residents through increased utility costs not covered by utility allowances or via the construction of fewer affordable housing units.

These recommendations are informed by input from developers and design teams, a literature review of other state affordable housing electrification programs, and QAP electrification approaches from around the country.

New Funding for Electrification, Tied to HTC Awards

All-Electric Design Guide Playbook

Electrification Resource Hub

Electrification QAP Amendment

Utility Metering and Allowance Advocacy

Additional Research

New Grant Funding for Electrification, Tied to HTC Awards

A number of states and jurisdictions around the country have launched new incentive programs for highly efficient, all-electric design. There is a growing recognition that existing utility and federal incentive programs are insufficient to drive building electrification at the pace needed to meet climate goals. According to the ACEEE, 2020 electrification incentive budgets are estimated at $110 million dollars annually, up 70% from the prior year (Nadel, 2020).[10] Equity is a key focus of many electrification funding programs, with affordable housing front and center. Some examples of electrification incentive programs, many low-income focused, include:

- New York State Energy and Research Development - Electric heat pump incentives ranging from $900 - $4,000/ apartment for affordable family housing, which can be layered on top of on traditional utility incentives (NYSERDA, 2021).[11]
- Central Coast California Community Energy - New construction electrification funding $2,500/affordable unit of family housing (CCCE, 2021).[12] Developers can secure a Letter of Intent (LOI) that will reserve an incentive for up to 3.5 years until the development is complete.
- DC Low-Income Decarbonization Pilot - Offers $5,000 - $6,500 (projection) per home for building electrification and solar (DC Sustainable Energy Utility).[13]
- Vermont Zero Energy Now - Up to $8,000/unit for income qualified residents for electrification, efficiency, and solar, paired with technical assistance (Zero Energy Now, 2020).[14]
- Colorado Springs Utilities' Builder Incentive Program - $3,000/home for all-electric new construction.
- California's Low Income Weatherization Program for Family - The Association for Energy Affordability notes that this program offers $4,000 - $5,000 per metric ton of CO_2 emissions reduced by building systems (Hill, Dirr &Harrison, 2020).[15] This GHG emission reduction approach places an economic value on fuel switching (electrification) and incorporates renewables. These incentives are paired with a resource hub that provides access to other state and utility incentives as well as implementation technical assistance.

New grant funding for highly efficient all-electric HTC projects would help ensure that operating costs don't increase beyond industry standards. This is critical to avoid increasing the energy burden of residents covered by utility allowances that may not fully reflect the cost variability of inefficient all-electric design. It is also essential to maximize the number of affordable housing units that can be placed in service with existing tax credit funding levels.

Group14 recommends the following for an HTC electrification funding program:

- Amount: Funding amounts need to cover a substantial portion of added construction costs. A review of similar programs around the country (above) suggests $2,500 - $6,000 per apartment. This electrification funding should be in addition to any utility efficiency incentive programs.
- Timing: Funding needs to be committed in conjunction with HTC award. The funding commitment should be preserved for up to three-and-a-half-years to accommodate development and construction timelines.
- Clear Requirements: Funding should be tied to both all-electric design and modeled efficiency performance. Modeled whole building performance requirements based on enhanced IECC standards will align with the jurisdictional code review process and provide teams with maximum design flexibility.

All-Electric Design Guide Playbook

Group14 recommends commissioning a Design Playbook for highly efficient, all-electric affordable housing in Colorado. The state's climate conditions, project economics, and regional industry characteristics contribute to a unique set of design challenges. At the same time, Colorado is home to a great deal of professional expertise surrounding affordable housing and highly efficient design. This expertise - from the construction trades, design professionals, developers, nonprofits, and energy consultants - should be leveraged to assemble best practices for building electrification. A key focus of the Design Playbook should be system simplicity, both to speed market transformation and ease operation and maintenance.

Electrification Resource Hub

Group14 recommends the creation of a statewide affordable housing electrification resource hub. Navigating the many issues surrounding electrification, renewables, and energy efficiency can be difficult. With all of the new utility and state programs set to launch in 2022, this will become even more complex. Additionally, many areas of the state do not have access to a full range of technical consultants. A statewide resource hub dedicated to affordable housing could be a one stop shop that sets HTC-supported projects up for electrification success. Key services could include technical assistance and facilitating access to funding and incentive programs. CHFA, state agencies, or nonprofits like Energy Outreach Colorado may be positioned to launch this kind of resource.

Electrification QAP Amendment

In November of 2021, CHFA proposed a 2021-2022 QAP Amendment to add guiding principles that support Colorado's GHG emission reduction goals, advanced energy performance standards, and electrification-ready construction of affordable housing. This includes requiring a project construction or renovation narrative that demonstrates an electrification-ready project. A powerful tool for speeding the electrification of HTC-supported properties would be to add additional guiding principles and requirements around highly efficient all-electric design in later years. Other states have already taken similar steps in their QAP:

- Vermont's QAP rewards tax credit applications that commit to Net Zero Energy use.
- Connecticut's QAP includes a tiered approach to energy efficiency and electrification:
    - -Tier 1 - PV system to offset ≥75% of the annual energy demand for site and interior common area lighting.
    - -Tier 2 -PV system to offset ≥90% of the annual energy demand for site and interior common area lighting; and All-Electric Buildings (excludes backup generator); AND Backup Power to provide resiliency to Critical Systems, Emergency Lighting, and Access to Potable Water.
    - -Additional Point - All-Electric Buildings; AND Battery storage systems or fuel cell to serve as backup power to provide resiliency Critical Systems, Emergency Lighting, and Access to Potable Water.
- Massachusetts QAP adopts the reduction of GHG emissions and consumption of fossil fuels as a core sustainable development principle. Application points are awarded for the use of high efficiency electric heat pumps for space heating and domestic hot water.
- California's QAP does not reference electrification. However, another state entity that layers grants onto tax credit awards, the California Affordable Housing and Sustainable Communities program, offers tiered application points for near electrification/wired for electric ready and all-electric buildings.

For Colorado's QAP, Group14 recommends the following QAP amendments:

- In 2023-2024, add a guiding principle to the QAP that states "To support affordable housing that is constructed to be highly efficient and all-electric."
- In 2028-2029, add a requirement that all new construction projects be all-electric paired with advanced energy performance standards.

The timeline for implementing this requirement should be adjusted based on assessed impact to Housing Tax Credit-supported project financial feasibility. Amendment language should be published and go through public comment at least three years in advance of adoption. To ensure this language doesn't disadvantage some portions of the state, the change in QAP language should be paired with the implementation of state-wide resource recommendations."

Utility Metering and Allowance Advocacy

Master metering an entire property for both consumption and solar production is essential to maximize on-site renewable opportunities. Some utilities require that each apartment receive an individual, utility owned residential meter. This increases utility service charges and makes significant solar installations cost prohibitive. HTC stakeholders should advocate for change. Additionally, all jurisdictions and housing authorities should include a line item for electric heat pumps in utility allowance schedules. This will help projects statewide capture the operating cost benefits associated with heat pumps.

Additional Research

There are a number of research areas beyond the scope of this study that would provide invaluable resources for affordable housing electrification:

- Life Cycle Cost Analysis for highly efficient building systems
- Statistically representative sample of Colorado HTC utility cost profiles by fuel use and building type
- Moderate rehab and retrofit all-electric opportunity and challenge analysis
- Embodied carbon analysis of common HTC construction typologies
- Detailed case studies of high efficiency all-electric HTC-supported projects
- Operation and maintenance resources and challenges for all-electric systems
- Modular construction opportunities to reduce the cost of highly efficient electric buildings

These research projects would significantly advance the knowledge base around all-electric design and speed market transformation.

Appendix A - Regulatory & Utility Landscape

Federal

FEDERAL

Federal incentives have been instrumental in creating and shaping energy efficiency and renewable energy related industries.

Housing Tax Credit deals take place in a regulatory context that drives design requirements and project costs. This section explores the federal, state, jurisdictional (municipal), and utility programs and requirements that influence fuel use selection.

While federal building requirements are largely superseded by local code, national incentives have been instrumental in creating and shaping energy efficiency and renewable energy related industries. At this point in time, there are few federal incentives targeting electrification specifically but there are a number addressing related topic areas.

Minimum Energy Requirements:
The Department of Housing and Urban Development (HUD) requires 2009 IECC to be followed for any projects that receive HUD funding. For the projects covered in this study, local code met or exceeded this level in every case. However, this requirement could be impactful for HTC projects accessing HUD funding in rural areas with minimal building code requirements. The HTC program allows state agencies to establish their own green building requirements, which CHFA does via their annual Qualified Allocation Plan (QAP).

ENERGY STAR: While municipal building code typically sets requirements for energy design, broad-based federal programs like ENERGY STAR support and standardize efforts at the state and local level via efficiency certification programs. Seventy percent of the projects in this study were certified through the ENERGY STAR program in addition to the other certifications they pursued. ENERGY STAR has also helped push the industry forward by creating performance standards for appliances and water fixtures, allowing project teams to easily make efficient choices for their projects.

ENERGY STAR for Family New Construction is the current program iteration most applicable to HTC developments. While this program does not dictate fuel use or GHG emissions, it does have a number of efficiency and construction quality requirements:

- Prescriptive or modeled efficiency performance requirements across all building systems
- Water management checklist
- Duct and envelope air leakage testing
- HVAC and lighting system functional testing
- Insulation quality control and verification

70% OF THE PROJECTS IN THIS STUDY WERE CERTIFIED THROUGH THE ENERGY STAR PROGRAM IN ADDITION TO THE OTHER CERTIFICATIONS THEY PURSUED

Efficiency and Renewable Tax Credits: The federal government provides a range of tax credits and deductions for renewable energy systems and building system efficiency.

- **Renewable Energy Tax Credits** support the installation of solar PV, geothermal, biomass and fuel cell systems. A number of study participants utilized the tax credits for solar PV installations. While the value of these credits fluctuate based on legislation, current credit value at the time of study publication are:
    - -30% for systems placed in service by 12/31/2019
    - -26% for systems placed in service after 12/31/2019 and before 01/01/2023
    - -22% for systems placed in service after 12/31/2022 and before 01/01/2024
    - -10% for commercial systems placed in service after 12/31/2023 and before 01/01/2025

- **179D Tax Deductions for Commercial Buildings** are available to owners and developers when they build or renovate a commercial or family building. They are also available for the architect, engineering, or contracting firm of a government building that is energy efficient. The maximum deduction is $1.80/SF for qualifying improvements that achieve a 50% reduction from an IECC baseline. The three systems that are eligible for the deduction are the building envelope, HVAC/hot water systems, and interior lighting systems.

- **45L Tax Credit for Home Builders** provides tax credits of up to $2,000/unit for new, energy efficient homes. Apartments are eligible, but buildings must be three stories or under to qualify. Currently, the credit is authorized for buildings constructed between January 1, 2018, and December 31, 2021, but the timeline is frequently extended by Congress. Envelope requirements typically require above code system selection.

- **Build Back Better Legislation** - At the time of publication, the November 3rd reconciliation version of the Build Back Better legislative package has $325 billion in clean energy and efficiency related affordable housing tax credits from 2022 - 2031 (Lawrence, 2021).[16] If passed, many of these provisions would be transformational for HTC efficiency performance. All-electric design may also benefit from increased heat pump incentives depending on final legislation language. BBB legislation also includes extending the time horizon (and sometime increasing the benefit) of the existing programs noted above.

State

COLORADO

From 2019 to 2021, a number of landmark bills were passed by the Colorado legislature that will shape energy use and generation in the state for decades to come.

The state of Colorado primarily impacts HTC design via funding, legislation, and governor approval of CHFA's Qualified Allocation Plan. The State Building Program has adopted the 2018 International Energy Conservation Code (IECC) for construction by state agencies on state-owned or state lease-purchased properties or facilities. Additionally, the Division of Housing's Building Codes & Standards Section, part of the Department of Local Affairs, adopts and enforces building codes for family buildings in jurisdictions with no codes (The Colorado Energy Office).[17] However, as a home rule state, **building energy codes are adopted and enforced on a municipal or county level.**

Qualified Allocation Plan: The Qualified Allocation Plan (QAP) defines the state's tax credit award process (Colorado Housing Finance Authority, 2021).[18] In addition to local building code, QAP criteria profoundly shaped the design of projects in the study. The QAP establishes a number of criteria for tax credit award, including affordability levels, cost-effectiveness, location, and sustainability, among other factors.

In November of 2021, CHFA proposed a 2021-2022 QAP Amendment to add guiding principles that support Colorado's GHG emission reduction goals, advanced energy performance standards, and electrification-ready construction of affordable housing. This includes requiring a project construction or renovation narrative that demonstrates an electrification-ready project.

Additionally, existing 2021 QAP language establishes:

- A green certification requirement, with a stretch goal of either Zero Energy Ready Homes or Passive
- House Certification
- The provision of Electric Vehicle ready parking spaces at a 10% rate (100% PSH and Acq/Rehab projects are exempt)
- Post construction Energy Use Report via the ENERGY STAR Portfolio Manager Tool

Specific recommendations for potential QAP language to strengthen the incentive for low carbon design is included in the Recommendations section of this document.

State Requirements - Building Energy Use

A number of landmark bills were passed by the Colorado General Assembly legislature from 2019 - 2021 that will shape energy use and generation in the state for decades to come. Given the recent passage of some of these measures, implementation and program specifics are still in process.

A summary of some key pieces of legislation can be found on the following pages.

Energy Performance for Buildings (HB21-1286)

Beginning in 2022, the law requires owners of buildings with a GFA of 50,000 SF or greater to annually report their building energy use to the Colorado Energy Office (CEO). To use the study population as an example, this would be applicable to 11 (out of 24 total) projects.

- The bill directs CEO to convene a task force to recommend performance standards for covered buildings that achieve GHG reductions of 7% (compared to a 2021 baseline) by 2026 and 20% by 2030 (compared to the same baseline). The task force has 18 voting members, one of whom represents the affordable housing community. The task force must deliver its recommendations by October 1, 2022; the Air Quality Control Commission will adopt rules based on those recommendations by June 1, 2023.
- The law also requires covered building owners to pay a $100 annual fee that will fund the administration of the benchmarking and building performance program and enable CEO to provide outreach, training, technical assistance and grants to assist building owners with compliance. A substantial number of affordable housing properties will be required to meet both the benchmarking and performance requirements.

Transfer to Colorado Energy Office Energy Fund (SB21-230)

This act allocated $40 million in funding to the Colorado Energy Office to invest in a range of efficiency, clean energy, and electric vehicle projects.

- The bulk of the funding, $30 million, is allocated to the Colorado Clean Energy Fund (CCEF), a green bank that exists to help finance clean energy projects. The CCEF is in its early stages of development so it remains to be seen what type of work they will fund and what amounts will be available.
- $5 million of the funding is dedicated to the CEO Charge Ahead program which helps fund EV Charging infrastructure in Colorado.
- Seventy-five percent (75%) of the funding is required to be expended by July 1, 2022, so this will become available for affordable housing properties to access in the near future. The Charge Ahead program already exists and is currently accessible to affordable housing providers to help fund the cost of installing EV charging equipment.

Electric Utility Promote Beneficial Electrification (SB21-246)

This legislation requires regulated utilities (Xcel Energy, Black Hills Energy) to establish programs to support beneficial electrification similar to existing demand-side management (efficiency rebate) programs. Beneficial electrification in this context refers to replacing direct fossil fuel use with electricity and the associated co-benefits.

- Defines beneficial electrification as the conversion of "a nonelectric fuel source to a high-efficiency electric source, or avoiding the use of nonelectric fuel source in new construction" making this act applicable to new construction or renovations.
- The exact amount of funding and covered measures are not defined in the act, but are required to be presented by July 1, 2022. The mechanism for funding these programs will be similar to existing programs in the form of charges added to utility customer's bills. Whether or not this will be a new charge or come from existing funds is not currently decided. The act also defines mechanisms for including the social cost of carbon and methane emissions in demand-side management (DSM) cost-effectiveness calculations, meaning that all-electric technology will have additional funding. It also requires utilities to set aside at least 20% of their program funding for low-income households or disproportionately impacted communities.
- This bill should result in additional funding for HTC electrification retrofits and all-electric new construction.

State Requirements - Energy Supply Changes & Electrification

Climate Action Plan to Reduce Pollution (HB19-1261)

This bill sets large-scale, progressive GHG reduction goals for regulated electric utilities culminating in a 90% reduction by 2050.

- Section 3 of the act requires the Air Quality Control Commission to take into account the equitable distribution and implementation of greenhouse gas reduction policies. Low-income individuals are specifically called out as an impacted group that "potentially experience disproportionate environmental harms and risks" and therefore deserve special consideration for policy making. This points to potential future implications for affordable housing as policy is developed and implemented.
- This act requires the development of Clean Energy Plans for regulated utilities in Colorado that will outline their progress towards the mandated climate goals. This will provide better information around carbon emissions from the energy production of regulated utilities.
- Overall this act does not have direct financial or regulatory impacts for affordable housing providers, however it does shape the overall energy environment.

Adopt Programs Reduce Greenhouse Gas Emissions Utilities (SB21-264)

Sets sweeping GHG emission reduction targets for both regulated and municipal gas utilities.

- This legislation requires gas utilities to develop and submit clean heat plans to the Public Utilities Commission to demonstrate their progress towards 4% reductions in GHG emissions below 2015 levels by 2025 and 22% below the same baseline by 2030.
- The requirements in this bill will mean that the GHG emissions of gas utilities in Colorado will be more readily apparent and will reduce in the coming years, changing the balance of GHG emissions between electricity and natural gas.
- The bill removes prohibitions on placing incentives that help customers switch from natural gas to electric appliances. This removes the primary barrier for utility companies to provide rebates for fuel-switching, which they were not allowed to do until the passage of this act. This may open up new funding sources for affordable housing retrofits to transition away from natural gas during renovations.
- The bill specifically directs gas utilities to "prioritize investments that ensure low income-qualified programs benefit from the investments made," indicating that as these plans are developed, affordable housing providers may have access to new funding sources for gas efficiency measures.

Public Utilities Commission Modernize Gas Utility Demand-side Management Standards (HB21-1238)

This bill modifies existing natural gas demand side management programs to include the social cost of carbon and methane in cost effectiveness calculations.

- This bill enables regulated gas utilities to start using gas DSM funds to support electrification projects. This both increases existing funding sources for gas efficiency projects and opens up new potential opportunities for fuel switching.

Environmental Justice Disproportionate Impacted Community (HB21-1266)

This bill primarily addresses environmental justice, with a broad overlap between the disproportionately impacted communities covered in the bill and the residents of affordable housing developments.

- This bill transitions air quality fines from the general fund to a newly created community impact cash fund, which could pay for mitigation projects for low-income communities. This could potentially create new funding sources for affordable housing providers to address environmental quality issues on existing and proposed development sites.

Transportation

Electric Motor Vehicles Public Utility Services (SB19-77)

This bill directs regulated utilities to offer programs that support the transition to electric vehicles.

- This bill specifically calls out EV charging infrastructure for low-income family communities.

Sustainability of the Transportation System (SB21-260)

This bill introduces large-scale changes to the Colorado Department of Transportation (CDOT) and other government entities to support transportation electrification and other GHG emission reduction opportunities in the transportation system.

This bill creates a "community access enterprise" to help "rural, urban, and disproportionately impacted communities" reduce the environmental impacts of emissions from motor vehicles. This includes providing financial support for electric motor vehicle charging infrastructure. Additionally, the bill incentivizes owners of older, less fuel efficient vehicles to trade them in for EVs. This may give low-income individuals the opportunity to purchase EVs at an affordable price point.

Municipal

MUNICIPALITIES

Municipalities strongly influence HTC design through building codes.

Municipalities strongly influence affordable housing design through building codes. A 2021 Inside Climate News article noted that many jurisdictions across the United States have begun to impose requirements around electrification (Gearino, 2021).[19] To date, fuel use is typically not addressed by Colorado municipalities. Energy efficiency design requirements are established through the International Energy Conservation Code and jurisdictional amendments.

However, two municipalities stood out as having explicit building electrification goals paired with rigorous energy efficiency standards: Denver and Boulder. Most of the stated goals around electrification are for future permitting requirements. As such, they did not influence the design of study participants.

International Energy Conservation Code & Design

The International Energy Conservation Code (IECC) establishes minimum efficiency requirements for buildings. The IECC has mandatory requirements with additional prescriptive and modeled performance options to comply with code efficiency levels. These standards have become more rigorous over time. The Energy Efficient Codes Coalition plotted IECC version iteration against efficiency performance, with additional detail to show a pathway to Net Zero energy use in buildings (Energy Efficient Codes Coalition, 2021). [20]

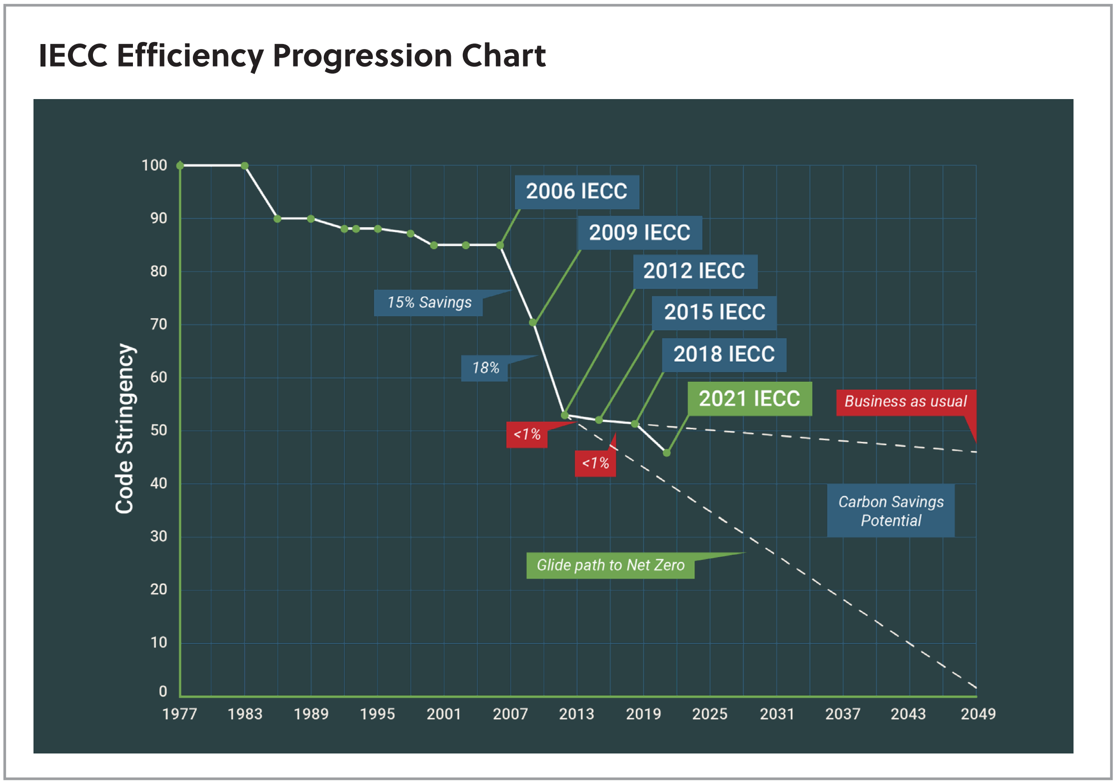
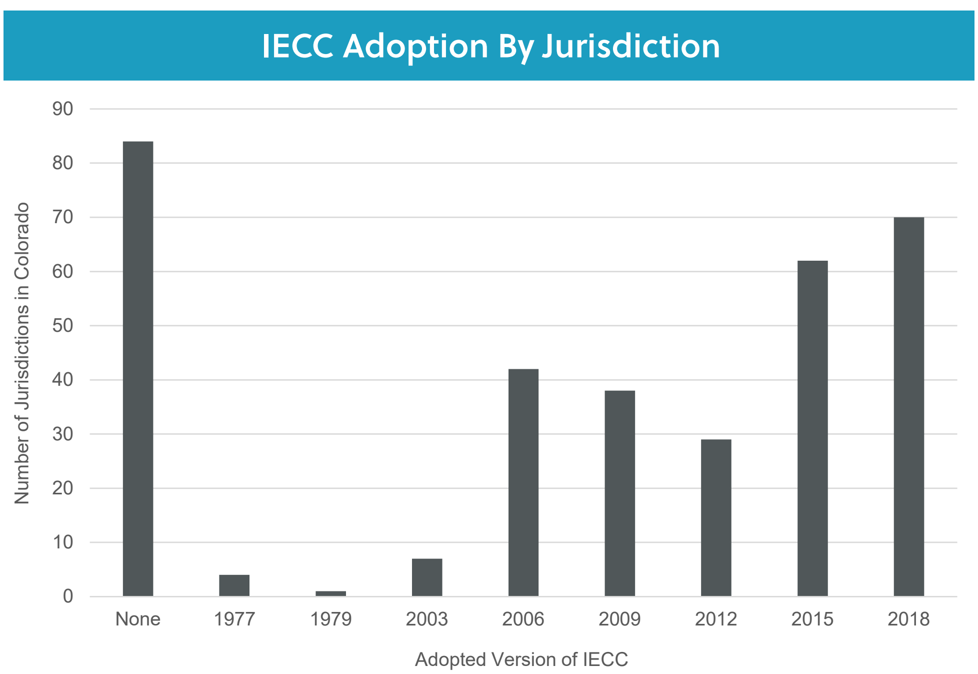


Figure 55

The chart on the left, 'Efficiency Improvements of IECC: Historic and Projected,' is from the the Energy-Efficient Codes Coalition website at https://energyefficientcodes.org/iecc/. Code Stringency refers to Energy Use Index, with a lower score indicating higher efficiency.

Future IECC efficiency gains, if continued at historical rates, will be insufficient to move buildings to Net Zero Energy use in the time frame climate science indicates is necessary. This may be why some jurisdictions have adopted above IECC code amendments around efficiency and electrification.

As a home rule state, Colorado has significant diversity in IECC version adoption. The Colorado Energy Office [21] provides a full list of adopted IECC generation by jurisdiction. The chart below shows distribution by jurisdictional count.



The jurisdictions with no adopted IECC will be covered by DOLA-CDOH's code requirements (2015 IECC). Also, it should be noted that Front Range jurisdictions, which tend to be 2015 IECC or later, house the majority of the state's population and HTC-supported developments. Sixteen (16) of 24 study participants were built under 2015 or 2018 IECC.

Figure 55

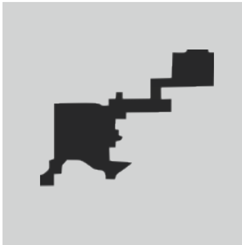
Denver

In 2018, Denver adopted the 80 x 50 Climate Action Plan to reduce Denver's carbon emissions 80% by 2050 from a 2005 baseline. This plan set energy reduction targets for both new construction and existing buildings. In 2021, Denver articulated new strategies in support of this goal via a Net Zero Energy policy. At the time of this study, the Energize Denver Task Force has also developed a final recommendation that Denver City Council is expected to adopt before the end of the year (Denver Department of Public Health and the Environment, 2018).[22]

Key elements and timeline milestones of these two plans include:

- 2022 - 2025: Provide incentives for building electrification and heat pumps
- 2024: All-electric new construction with the exception of water heating with 75% renewable offset
- 2025 - 2027: Require electric heat-pumps when existing buildings replace natural gas equipment (when nearly cost effective with incentives)
- 2027: All-electric new construction with 100% renewable offset
- 2030: All-electric new construction with 100% renewable offset and building performance verification

In 2022, Denver also plans to adopt the 2021 IECC (with amendments) and advance their 2019 voluntary green code. The city will be convening committees to hear/review code proposals in January of 2022 (Energize Denver Task Force, 2021).[23]



DENVER

In 2018, Denver adopted their 80 x 50 climate action plan to reduce Denver's carbon emissions by 80% from a 2005 baseline.

It should be noted that these are adopted policy goals, not formal changes to building codes or permitting requirements. However, these goals lay out a clear roadmap to a highly efficient, all-electric built environment.

Denver has adopted several above IECC requirements as part of its current code set. Key items that relate to electrification and efficiency include:

- Requiring an additional energy efficiency package option (two instead of one) for buildings using the prescriptive IECC compliance path
- Requiring 24% savings above 2018 IECC baseline (instead of 15%) for buildings using the performance IECC compliance path
- Family sites with more than 10 parking spaces must have EV charging stations for 5% of spaces, EV ready for 15% of spaces, and EV capable for the remaining 80% of spaces

BOULDER

In 2016, the City of Boulder adopted climate goals to achieve a 90% reduction in the community's greenhouse gas emissions.

Boulder

The City of Boulder has adopted climate goals to achieve a 90% reduction in the community's greenhouse gas emission generation (compared to 2005 levels) by 2050 (Boulder County Office of Sustainability, Climate Action & Resilience).[24]

In support of that goal, the City of Boulder adopted a highly-amended version of the IECC as the City of Boulder Energy Conservation Code (COBECC). Two of the projects covered in this study were developed under the 2017 version of this code, which has since been updated in 2020. A major component of COBECC is setting building performance targets that are 25% higher than those set in IECC. The 2020 COBECC also allows for reductions in building efficiency performance if the building is all-electric. This creates a code based financial incentive for building electrification.

In addition to code updates, Boulder started the Comfort365 program in the spring of 2017, combining outreach, marketing, and financial incentives to drive the adoption of high efficiency heat pumps. The program incentivizes replacing gas-fired equipment with heat pumps for both space heat and domestic hot water. A 2020 ACEEE topic brief notes that in the first year of the program, Boulder saw a 200% increase in heat pump installation (from a pre-pilot 20-30 unit baseline). The same study reports that at least half of Boulder new homes have incorporated heat pump systems since 2017 COBECC was implemented (Nadel, 2020).[25]

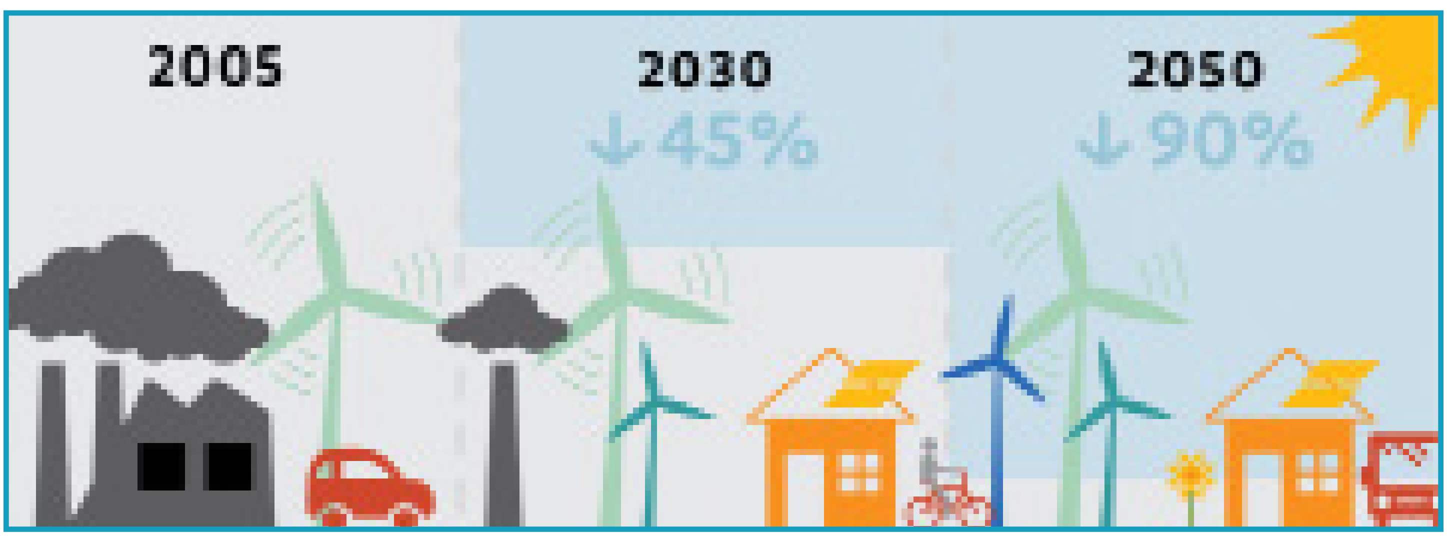
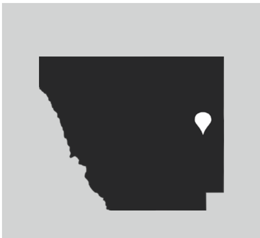


Image Credit: Climate Action in Boulder County, retrieved from https://www.bouldercounty.org/climate-action-2/



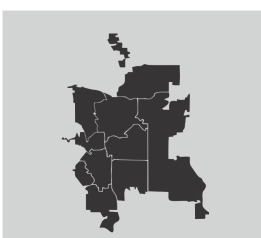
FORT COLLINS

The city is in the process of adding electrification and EV readiness requirements to their building code.

Fort Collins

Fort Collins is currently in the planning process for adding electrification and EV readiness requirements to their building code. These have not been formally adopted or finalized yet, but the goal is to target the following areas:

- Electric heat - Defined as being electric heat pump technology (ground or air source heat pump), with specific restrictions to limit the use of electric resistance to heat to buildings with very small heating requirements (i.e. at Passive House performance standards).
- Electric readiness - Requiring residential and commercial spaces to be pre-wired for future electric space heating, water heating, cooking and clothes drying.
- EV readiness - Requiring new construction to be on a range of EV installed to EV capable (conduit from panel to junction box). EV requirements would scale based on construction on building type and use, for example a greater percentage of parking spaces would need to be EV capable and a smaller percentage would need to be EV installed.



COLORADO SPRINGS

The city's municipal utility, CSU, has a program that rewards new-home builders for choosing efficient building techniques.

Colorado Springs

Colorado Springs has a municipal utility, Colorado Springs Utilities (CSU), that provides electric and gas for the community. CSU offers a Builder Incentive program that rewards new-home builders for choosing efficient home building techniques. In 2021, a pilot program was launched, offering rebates of up to $3,000 for all-electric homes that opt for heat pumps serving space heat and water heating needs (CSU, Builder Incentive Program). [26]

Energy Production & GHG Emissions Overview

The majority of Colorado's current electricity production currently relies on carbon-intensive fossil fuels (see chart below). Recent state legislation will shift this fuel mix towards renewables in the coming years. At the utility level, fuel mix, decarbonization plans, and incentive programs vary significantly. Additionally, not every utility publishes this information. This study summarizes the current/planned generation mix and building electrification programs of five utilities in the state: Xcel Energy, Holy Cross, Black Hills Energy, Tri-State Generation and Transmission, and the Platte River Power Authority. In combination, these utilities provide electricity to the vast majority of HTC developments, including all study participants.

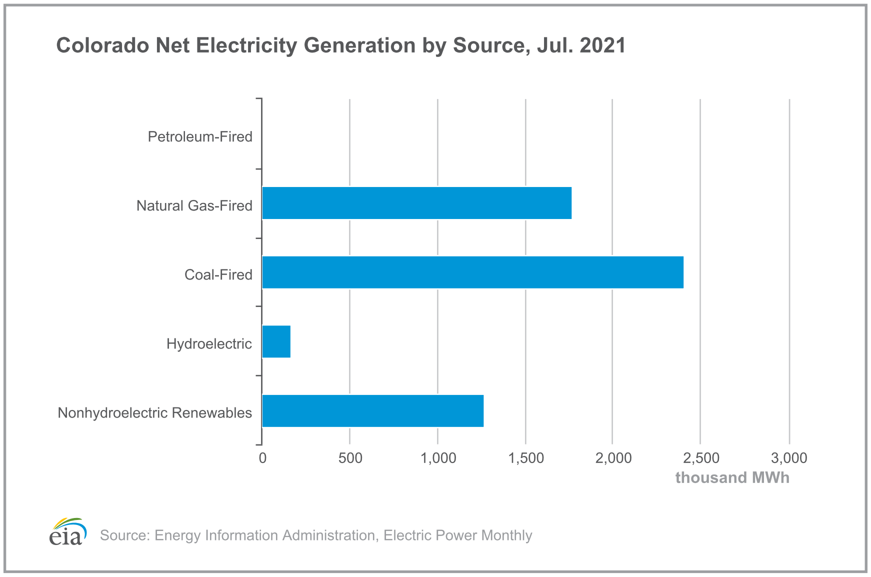


Figure 57

Source: U.S. Energy Information Administration's (EIA), Electric Power Monthly

Across the five utilities surveyed, an average of 44% of their energy currently comes from fossil fuels, 36% comes from renewable sources and roughly 24% is purchased from third parties. This fuel source mix is similar to the overall state EIA breakdown. The amount of third party purchased power is important to note as well, since that power is typically generated out of state.

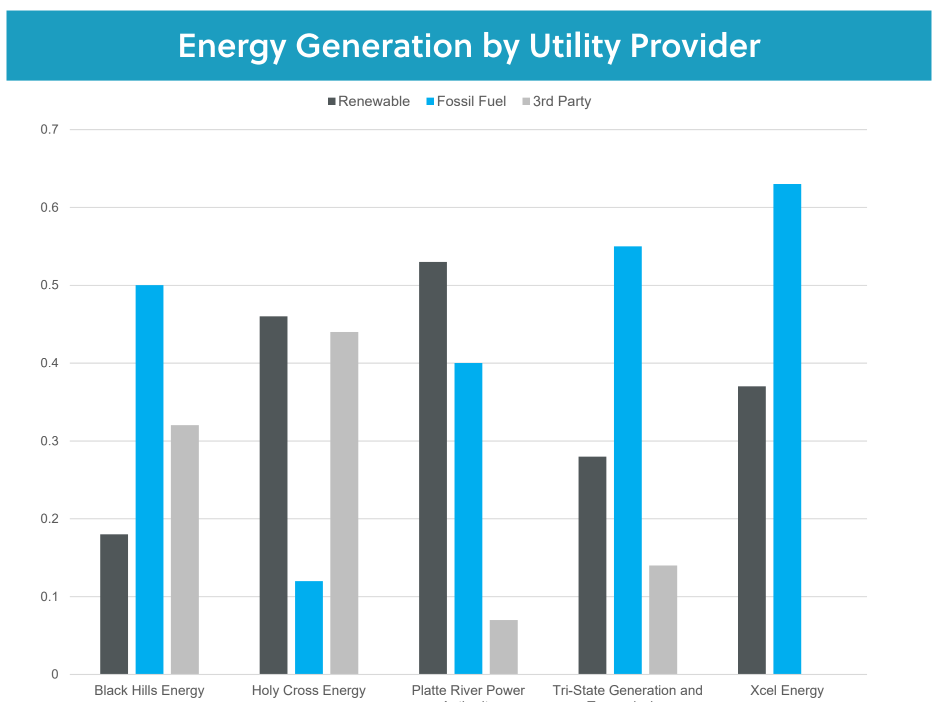


Figure 58

The utilities covered here have a range of goals around transitioning to renewable, decarbonized energy production. Some of these goals are aspirational, while others are firmly established in plans filed with the Public Utilities Commission (PUC). The HB 1261 and SB21-264 requirements around energy production mean that there will be more clarity around these guidelines in the coming years. Will Toor, Director of the Colorado Energy Office states "Xcel Energy, the largest utility in the state, filed a plan at the Public Utilities Commission (PUC) to achieve 85% by 2030, and based on our analysis, we are advocating for the PUC to approve a plan that gets to 90%. The second largest utility, Tri-State, has a plan to close every coal plant they have in Colorado and replace them primarily with wind and solar" (Toor, 2021). [27] It remains to be seen how state goals for grid decarbonization will be implemented as rule-making around the new legislation begins in earnest.

Planned Energy Generation By Utility Provider

Utility	Renewable	Fossil Fuel	3rd Party	Target
Black Hills Energy	51%	39%	10%	2024
Holy Cross Energy	100%			2030
Xcel Energy	100%			2050

Figure 59

Third Party Power Purchasing

One item of note when considering a utility provider's power supply mix is the presence of third-party power purchasing. Many utilities don't own enough generation capacity to support 100% of their client's needs, so they purchase power on the open market to make up the difference. Publicly owned utilities operating in Colorado are subject to Colorado laws and the Public Utility Commission. Third-party providers fall under the jurisdiction of the Federal Energy Regulatory Commission. This jurisdictional overlap means that the implementation of some state grid decarbonization legislation may be complex.

Consumption vs. Demand

A central issue to consider regarding the cost of energy is the distinction between consumption and demand. Energy consumption is the total amount of electricity that a building consumes over a given period of time, measured in kilowatt hours. Demand is a measurement of the rate at which electricity is consumed. Using the analogy of a car, consumption would represent the odometer (number of miles driven) while demand would represent the speedometer (how fast the car is going at a particular point in time).

Demand considerations are paramount to utilities. The electric grid needs to be sized to meet peak demand in order to avoid black-outs. However, the vast majority of the time, the grid is not calling for peak demand. Most energy generation is built around the average load that needs to be produced. Whenever peak demand is required, additional sources of energy generation are brought online for short periods of time. This generation is costly and logistically complicated for the utility, so managing demand is a large concern for utilities. Utility rate structures have evolved to pass along the costs of peak demand to ratepayers.

Peak demand costs are typically passed through in one of two ways: directly in the form of demand charges or indirectly in the form of Time of Use rates. Demand charges, usually a dollar amount per kW, are based on a building's monthly peak demand value (highest 15 minute interval measured kW). Many utilities also offer time-of-use (TOU) rates that have variable costs of energy consumption (kWh) based on when that energy is used. These TOU rates financially incentivize utility customers to shift energy use to off-peak hours.

Electric Utility Provider Profiles

Xcel Energy

Energy Generation: Xcel Energy is the largest regulated utility in Colorado and serves roughly 22% of the state's population as of 2019. Xcel Energy's current energy generation in Colorado is majority fossil fuels, with 63% coming from coal or natural gas, with 37% coming from carbon free sources. Xcel Energy's 2021 Colorado Clean Energy Plan[28] outlines goals to reduce the carbon emissions by 85% compared to a 2005 baseline by 2030, with 100% carbon free generation by 2050. This plan also includes speeding up the retirement of Xcel Energy's remaining coal-fired power plants in Colorado. As of 2018, Xcel Energy had reduced carbon emissions by 38% compared to the 2005 baseline.

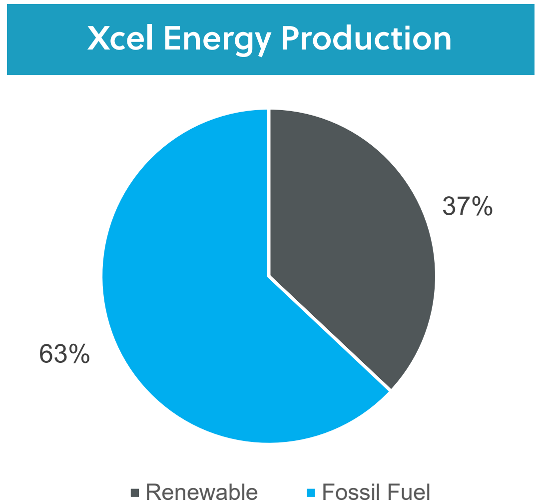


Figure 60

Energy Efficiency: Xcel Energy, as a regulated utility, must provide energy efficiency programs required by the Public Utility Commission.

Xcel Energy has two main offerings for new construction based building size: the Energy Design Assistance (EDA) program (>50,000SF) and the Energy Efficient Buildings (EEB) program (10,000-50,000SF). The EDA program combines incentives for energy modeling with rebates for energy efficiency performance above code. The EEB program targets smaller buildings and provides prescriptive incentives to help cover cost of higher efficiency equipment.

Xcel Energy also offers higher value incentives for affordable housing efficiency retrofits through Energy Outreach Colorado. It is important to note that this program does not support fuel-switching, so moving from natural gas to all-electric is not currently incentivized.

Electrification: Xcel Energy proposed and implemented a transportation electrification plan rider that took effect in March of 2021 (Xcel Energy, 2021)[29]. The rider will generate funds to support the development of electrified transportation infrastructure throughout their service territory. The program targets single family homes, family housing, and business owners to encourage system wide adoption of EVs. While Xcel Energy doesn't currently have offerings to incentivize fuel switching, it is anticipated that the utility will stand up these programs in 2022 to comply with SB21-246.

Relevant Rate Structures: Xcel Energy has three relevant rate structures for the buildings covered in this study: Residential, Commercial, and Secondary General. Residential rates will only be available for projects that opt for unit-level utility meters. Residential and commercial rates offer options for TOU pricing, but it is not required, whereas Secondary General automatically includes demand charges. Utility customers are placed on Commercial or Secondary General rates based on their peak demand, Commercial customers have a peak demand of 50 kW or less.

Holy Cross Energy

Energy Generation: Holy Cross Energy primarily serves the Roaring Fork Valley. Their current energy mix is 46% renewable, 12% fossil fuel based and 42% from third-party sources. In their 2020 strategic plan, Holy Cross set the aggressive goal of achieving 100% clean energy by 2030 while becoming completely net-zero by 2035 (Holy Cross Energy, 2021).[30]

Energy Efficiency: Holy Cross offers a range of fixed rebates for existing residential and commercial structures covering envelope and HVAC system measures. Prescriptive rebates for new construction are limited to LED lighting for commercial buildings. Holy Cross does offer a custom efficiency rebate option that provides flexible incentives for energy efficiency or fuel conversion for existing or new construction buildings. This incentive can provide up to two cents per kilowatt hour of energy saved over the life of the measure (up to 10 years), providing substantial incentives for efficiency in new construction.

Electrification: Holy Cross offers a wide variety of rebates to support electrification among its members, including EV charging station incentives, e-bike rebates, and a beneficial electrification pilot. Measures covered by the pilot program include air source heat pumps for space heating, electric heat pump water heaters, and induction cooktops to replace natural gas or propane equivalents. Since the program launched in 2020, over $90,000 in rebates have been issued. This includes 35+ separate projects, from single family homes to Aspen Ski Company family employee housing. The pilot also has an offering dedicated to electrifying mobile homes for income-qualified residents, targeting the dual benefits of carbon reduction and improved indoor air quality. Holy Cross is currently working with the Rocky Mountain Institute to determine how best to expand the program.

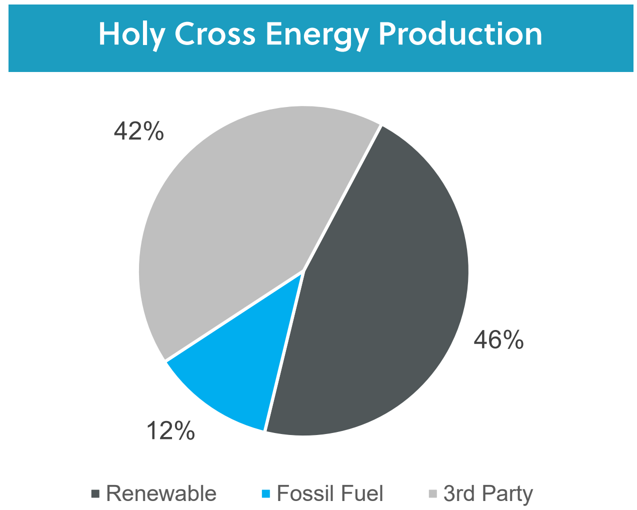


Figure 61

Holy Cross Electric is the utility provider for Red Hill Lofts, built in 2021, and located in Carbondale, Colorado.

Relevant Rate Structures: Holy Cross offers three applicable rates for this study: Residential, General Services - Small, and General Services - Large. The residential rate offers both a fixed pricing and TOU option. The general services rates are divided by demand, the cut-off point being 50 kW. Only customers with peak demand rates over 50 kW receive a demand charge on their monthly bill.

Platte River Power Authority

Energy Generation: Platte River Power Authority (PRPA) serves four communities in Northern Colorado: Fort Collins, Estes Park, Longmont and Loveland. They have a majority renewable energy mix with 53% of their generation coming from renewable sources. PRPA adopted a Resource Diversification Policy in 2018 that calls for a 100% non-carbon energy mix by 2030 (PRPA Strategic Plan, 2018).[31] Key components of this plan involve retiring existing coal-fired facilities, load reduction, and developing a wide range of renewable generation sources.

Energy Efficiency: PRPA and their member communities established the Efficiency Works program to help support energy efficiency efforts for residential and commercial PRPA customers. The program offers financial incentives for energy efficient envelope systems, appliances, and mechanical equipment, with additional incentives provided for all-electric homes. The program also connects customers with qualified contractors and a webstore to purchase rebated items.

Electrification: PRPA currently has few electrification offerings, mainly limited to an EV charging station rebate program. However, their 2020 integrated resource plan does include beneficial electrification as a specific call-out in the five year action plan. PRPA also incorporates increased adoption of all-electric systems in plan forecasts.

Relevant Rate Structures: Each PRPA member community sets their own rate structures, resulting in service territory electricity rate variability. In general, each community establishes separate summer and winter kWh rates. Some communities also offer or require TOU pricing on top of seasonal pricing. Similarly, demand charges are set at different levels by each community, with all communities setting seasonal demand rates. Designing buildings in PRPA territory requires attention to both seasonal and time of day demand pricing.

PRPA Energy Production

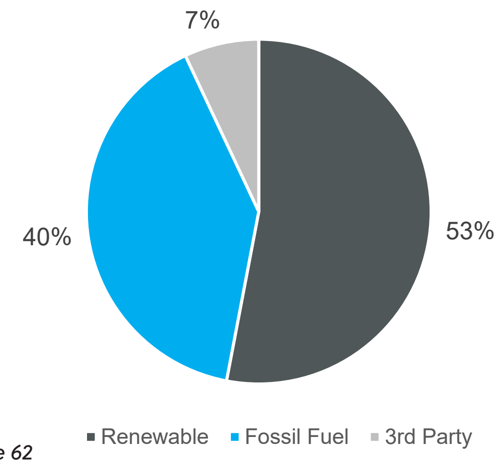
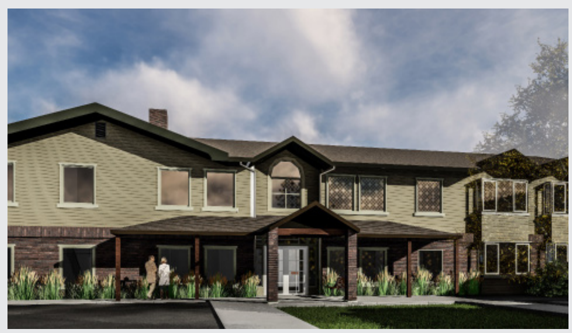


Figure 62



Platte River Power Authority is the utility provider for Cinnamon Park in Longmont, CO.

La Plata Electric Association

Energy Generation: La Plata Electric Association (LPEA) has committed to reducing their carbon footprint 50% from 2018 levels by 2030 (LPEA Power Supply Strategy, 2019).[32] Since they are in a long-term contract with Tri-State for 95% of their energy needs, Tri-State's fuel mix will ultimately determine decarbonization success or failure. Many smaller electric cooperatives are in a similar situation. For rural electric cooperatives, reducing GHG emissions may depend on contract negotiation and Federal Energy Regulatory Commission proceedings.

La Plata Electric Association (LPEA) is the utility provider for Espero Apartments, a 40-unit complex, in Durango, Colorado.

Energy Efficiency: LPEA's efficiency programs focus on equipment rebates and energy efficiency audits. Unlike other utilities, they do not offer any incentives for envelope improvements.

Electrification: LPEA has a number of incentives supporting the installation of high efficiency electric heating and hot water systems. They offer a wider range of incentives for air and ground source heat pumps than is typical. LPEA increases rebate value for electric water heating and induction cooktops when the client is transitioning away from fossil fuels.

LPEA also offers a unique Electric Thermal Storage program. This program uses efficient electric heaters with built-in thermal storage to enable off-peak charging. This strategy allows coop members and the utility to avoid the large spikes in demand that can result from electric heating systems.

Relevant Rate Structures: LPEA has optional TOU rates for residential and commercial customers, with an additional mandatory peak power charge that helps cover the cost of monthly peak demand. This charge is directly correlated to the customer's peak demand. Unlike traditional demand metering, LPEA's peak power charge is only in effect from 4:00 pm - 9:00 pm, not whenever a customer reaches the highest monthly kW draw. Demand billing is included in the residential rate class. This is unique in the utilities covered for this study, but may be a precedent for how electric billing evolves in the future.

Tri-State Generation and Transmission

Energy Generation: While not a regulated utility, Tri-State Generation and Transmission is a major energy producer in Colorado. As of 2016 Tri-State generated approximately 15,000,000 MWh of electricity with Colorado-based cooperatives consuming approximately 9,000,000 MWh of that total.

As such, Tri-State's efforts towards GHG reduction are a critical part of carbon reduction outside of the urban areas served by regulated utilities. A recent *Denver Post* article notes that Tri-State's current energy mix is 55% fossil fuels, 28% renewables, and an additional 14% purchased from Basin Electric Power Cooperative, which relies on coal for 50% of its annual production (Kohler, 2021).[33]

In 2019, Tri-State started the planning process for their Responsible Energy Plan, which outlines decarbonization goals for the coming years.

Tri-State Energy Production

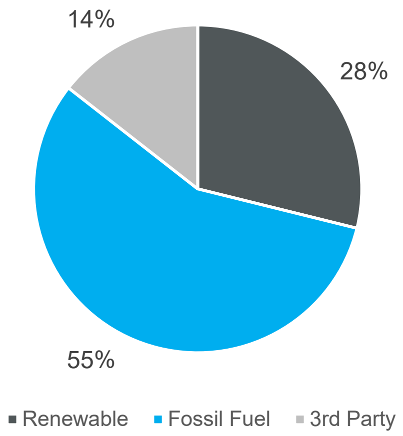


Figure 63

This includes generating 50% of their electricity from renewable sources by 2024, retiring existing coal-fired power plants in Colorado, and canceling the planned expansion of other coal-fired facilities. The plan also outlines goals to expand renewable energy generation in Colorado by 415 MW in the coming years. Finally the plan includes a process for reviewing the existing Tri-State contracts to examine the possibility of allowing members to add their own renewables. This is somewhat limited under the current contract structure.

Energy Efficiency: Tri-State offers incentives in partnership with their member utilities, similar to PRPA. The exact incentives and amounts offered vary depending on the particular cooperative in question.

Electrification: A central piece of Tri-State's Responsible Energy Plan[34] is a focus on funding EV charging stations and beneficial electrification. This plan includes providing each member $45,000 for the installation of EV charging infrastructure in rural areas. Their beneficial electrification include significant rebates for space heat and domestic hot water heat pumps.

Utilities Serving Project Participants

Black Hills Energy

Energy Generation: In early 2021, Black Hills Energy announced that they would release a 2022 Clean Energy Plan to comply with HB 1261 requirements (Black Hills Energy, 2021).[35] Black Hills is currently working on their Renewable Advantage plan, which includes the construction of 200 MW of solar in southern Colorado and would substantially transition their Colorado based generation mix into renewables. They currently project a 70% GHG reduction from the 2005 baseline by the year 2024 as the Renewable Advantage plan takes effect.

Building Electrification: Black Hills has provided little information regarding building electrification initiatives. A memo available on their website[36] titled "Preserving Energy Choice" indicates that they do not support "forced electrification" and that "the use of renewable natural gas could reduce residential emissions" at a lower cost than building electrification.

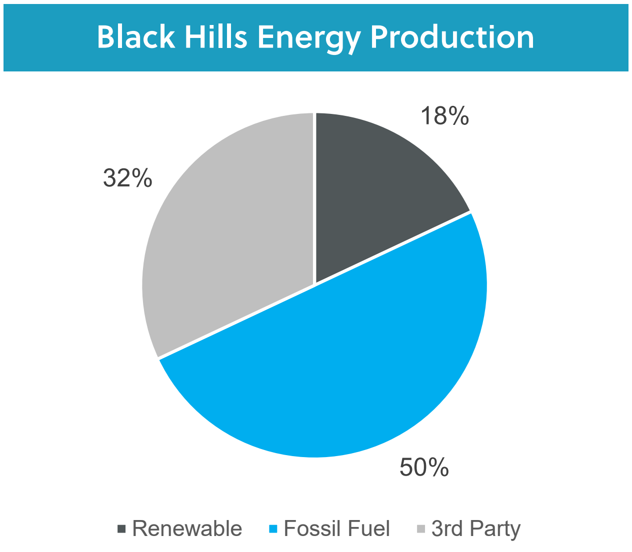
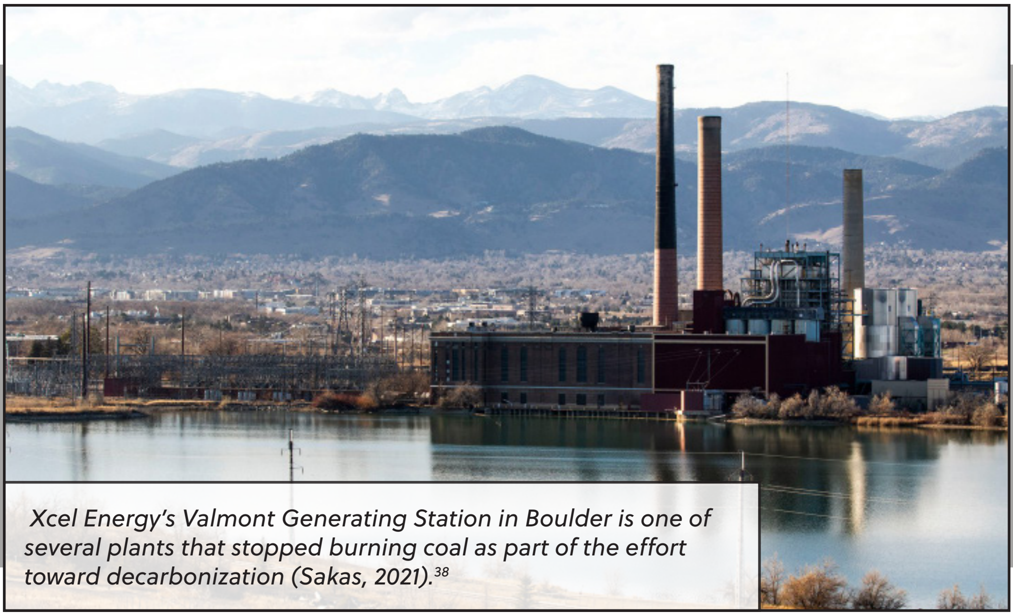


Figure 64

Energy Efficiency: Black Hills Energy is a regulated utility. As such, they must meet the statutory requirements for demand-side management programs. At the residential level, they offer a variety of HVAC equipment and envelope rebates, including air source and ground source heat pumps. Their commercial rebates are limited to HVAC technologies with a custom option covering anything that does not fit under the prescriptive rebates.

Relevant Rate Structures: Black Hills residential rates are a fixed price per kWh. They do not have a TOU option and only distinguish between summer and winter billings. Their Small General Service - Demand (10-50kW) and Large General Service (50-1400kW) both offer TOU options and have mandatory demand charges as rate components (Black Hills Energy, 2019).[37]



Xcel Energy's Valmont Generating Station in Boulder is one of several plants that stopped burning coal as part of the effort toward decarbonization (Sakas, 2021).[38]

Appendix B - Survey Questions

All-Electric Project Survey Questions

Survey Question
Did the project consider an all-electric design? If so, what drove this decision?
What systems are serviced by gas?
Were there challenges associated with attempting a near-electric design? If so, what were the top three challenges and how were decisions ultimately made?
What were the major construction cost adds associated with your design?
Were there major construction cost savings associated with the design?
Were building electricity utility costs a major factor in design decisions?
Describe any passive or active design strategies for limiting electricity demand costs.
Did the design team members and general contractor's previous experience factor into the final design decisions and if so, how?
Were HVAC loads, system sizing, or other electrical infrastructure items reduced due to enhanced insulation and tightly air sealed assemblies? If so, please describe.
If Air Source Heat Pump systems were used, what is the design strategy?
If Air Source Heat Pump systems were used, describe any back up heating source?
Were DHW systems sized for reduce peak hot water demand via a low flow fixture package?
Were DHW systems designed to store no more than 0.5 gallons in piping between the hot water source and fixture or use high efficiency recirculation systems?
If ASHP DHW is present, what is the design strategy?
For any of the following systems not selected – Were they considered? Were they priced as an add alternate by the General Contractor? Why were they not employed (rank the following four choices in order of impact: cost, lack of familiarity from design team, lack of familiarity from contractor, concerns about operation and maintenance)?
· Cold Temp Air Source Heat Pump heating and cooling for space conditioning
· Cold Temp Air Source Heat Pump heating and cooling for ventilation (outside) air
· Energy Recovery Ventilation
· Geothermal heating and cooling
· Air Source Heat Pump Domestic Hot Water/Hybrid Heat Pump Hot Water
· Demand Control Systems
· Solar PV
· Energy Storage (Thermal or Battery)
· EV Charging Stations
· EV Charging Station Load Management System
· Regenerative Drive Elevators (5 story+)
Were there any utility efficiency incentives/rebates or renewable tax credits applied to the project? If so, please describe.
Please list any state or local government grants or other incentives that the project received.
Has the building been pre-wired for a potential switch to all-electric in future? If so, what was the additional cost for doing so? If not, was this ever considered?
Has there been any major maintenance performed on HVAC? If so, please describe.
Are there any comfort issues, hot water shortages, high bill or noise complaints?

Mixed-Fuel Project Survey Questions

Survey Question
Did the project consider an all-electric design? If so, what drove this decision?
What systems are serviced by gas?
Were there challenges associated with attempting a near-electric design? If so, what were the top three challenges and how were decisions ultimately made?
What were the major construction cost adds associated with your design?
Were there major construction cost savings associated with the design?
Were building electricity utility costs a major factor in design decisions?
Describe any passive or active design strategies for limiting electricity demand costs.
Did the design team members and general contractor's previous experience factor into the final design decisions and if so, how?
Were HVAC loads, system sizing, or other electrical infrastructure items reduced due to enhanced insulation and tightly air sealed assemblies? If so, please describe.
If Air Source Heat Pump systems were used, what is the design strategy?
If Air Source Heat Pump systems were used, describe any back up heating source?
Were DHW systems sized for reduce peak hot water demand via a low flow fixture package?
Were DHW systems designed to store no more than 0.5 gallons in piping between the hot water source and fixture or use high efficiency recirculation systems?
If ASHP DHW is present, what is the design strategy?
For any of the following systems not selected – Were they considered? Were they priced as an add alternate by the General Contractor? Why were they not employed (rank the following four choices in order of impact: cost, lack of familiarity from design team, lack of familiarity from contractor, concerns about operation and maintenance)? · Cold Temp Air Source Heat Pump heating and cooling for space conditioning · Cold Temp Air Source Heat Pump heating and cooling for ventilation (outside) air · Energy Recovery Ventilation · Geothermal heating and cooling · Air Source Heat Pump Domestic Hot Water/Hybrid Heat Pump Hot Water · Demand Control Systems · Solar PV · Energy Storage (Thermal or Battery) · EV Charging Stations · EV Charging Station Load Management System · Regenerative Drive Elevators (5 story+)
Were there any utility efficiency incentives/rebates or renewable tax credits applied to the project? If so, please describe.
Please list any state or local government grants or other incentives that the project received.
Has the building been pre-wired for a potential switch to all-electric in future? If so, what was the additional cost for doing so? If not, was this ever considered?
Has there been any major maintenance performed on HVAC? If so, please describe.
Are there any comfort issues, hot water shortages, high bill or noise complaints?

Appendix C - Figure List

Appendix D - Endnotes

1 United Nations Environment Program (2021). *Emissions Gap Report 2021: The Heat Is On – A World of Climate Not Yet Delivered*. Retrieved from https://www.unep.org/resources/emissions-gap-report-2021

2 Root Policy Research (2020). *Findings of the Special Eviction Prevention Task Force*. Retrieved from https://cdola.colorado.gov/special-eviction-prevention-task-force

3 State of Colorado (2021). Greenhouse Gas Pollution Reduction Roadmap. Retrieved from https://energyoffice.colorado.gov/climate-energy/ghg-pollution-reduction-roadmap

4 Toor, W. (2021, November 5). There's a lot being done in Colorado to address climate crisis. *Boulder Daily Camera.* Retrieved from https://www.dailycamera.com/2021/11/06/guest-opinion-will-toor-theres-a-lot-being-done-in-colorado-to-address-climate-crisis/

5 Cheatham, D., Marechal, I. (2018). Respiratory health disparities in the United States and their economic repercussions. *Washington Center for Equitable Growth*. Retrieved from https://equitablegrowth.org/respiratory-health-disparities-in-the-united-states-and-their-economic-repercussions/

6 Center for Disease Control and Prevention. *Carbon Monoxide Poisoning*. Retrieved from: https://www.cdc.gov/co/default.htm

7 Denver Department of Climate Action, Sustainability, and Resiliency and Lotus Engineering and Sustainability (2021). *The Energize Denver Renewable Heating and Cooling Plan*. Retrieved from: https://www.denvergov.org/Government/Agencies-Departments-Offices/Climate-Action-Sustainability-Resiliency/High-Performance-Buildings-Homes/Renewable-Heating-Cooling

8 Bailey, M., Esposito, C. (2017). *Colorado's Climate and Colorado's Health.* Colorado Health Institute. Retrieved from: https://www.coloradohealthinstitute.org/research/colorados-climate-and-colorados-health

9 Booth, M (2021, November 5). Coloradans starting to see double-digit hikes in their gas utility bills. *The Colorado Sun.* Retrieved https://coloradosun.com/2021/11/05/colorado-utility-bill-gas-hikes/

10 Nadel, S (2020). *Programs to Electrify Space Heating in Homes and Buildings*. ACEEE Topic Brief June 2020. Retrieved from: https://www.aceee.org/topic-brief/2020/06/programs-electrify-space-heating-homes-and-buildings

11 NYSERDA (2021). *Multifamily Performance Program.* Retrieved from: https://www.nyserda.ny.gov/mpp

12 Central Coast Community Energy (2021). *New Construction Electrification Program*. Retrieved from: https://3cenergy.org/new-construction-electrification/

13 DC Sustainable Energy Utility. *Low-Income Decarbonization Pilot.* Retrieved from: https://www.dcseu.com/low-income-decarbonization-pilot

14 Zero Energy Now (2020). *Zero Energy Now One Pager.* Retrieved from: http://zeroenergynowvt.com/about/

15 Hill, S., Dirk, N., Harrison, T (2020). Equitable Electrification: Program Models that Work for Existing Low Income Family Buildings. *Association for Energy Affordability.* Retrieved from: https://www.energyefficiencyforall.org/ resources/equitable- electrification-program-models-for-existing-low-income-family-buildings/

16 Lawrence, P (2021, November 9). *Notes from Novogradac.* Novogradac: Affordable Housing Resource Center. Retrieved from: https://www.novoco.com/notes-from-novogradac/revised-175-trillion-build-back-better-reconciliation- legislation- includes-325-billion-green-tax

17 The Colorado Energy Office. *Building Energy Codes.* Retrieved from: https://energyoffice.colorado.gov/climate-energy/energy-policy/building-energy-codes

18 Colorado Housing Finance Authority (2021). *Qualified Allocation Plan 2021 to 2022, Amended Second Draft*. Retrieved from: https://www.chfainfo.com/arh/lihtc/qap

19 Gearino, D. (2021, August 19). Which State Will Be the First to Ban Natural Gas in New Buildings? *Inside Climate News*. Retrieved from: https://insidecli11matenews.org/news/19082021/inside-clean-energy-natural-gas-buildings/

20 Energy Efficient Codes Coalition (2021). *History of the International Energy Conservation Code.* Retrieved from: https://energyefficientcodes.org/iecc/

21 The Colorado Energy Office. *Building Energy Codes.* Retrieved from: https://energyoffice.colorado.gov/climate-energy/energy-policy/building-energy-code

22 Denver Department of Public Health and the Environment (2018, July). *Denver 80 x 50 Climate Action Plan.* Retrieved from: https://www.denvergov.org/files/assets/public/climate-action/documents/ddphe_80x50_climateactionplan.pdf

23 Energize Denver Task Force (2021, August 31). *Energize Denver Task Force Recommendations.* Retrieved from: https://www.denvergov.org/Government/Agencies-Departments-Offices/Climate-Action-Sustainability-Resiliency/High-Performance-Buildings-Homes/Energize-Denver-Task-Force

24 Boulder County Office of Sustainability, Climate Action & Resilience. *Climate Action in Boulder County.* Retrieved from: https://www.bouldercounty.org/climate-action-2/

25 Nadel, S (2020). *Programs to Electrify Space Heating in Homes and Buildings.* ACEEE Topic Brief June 2020. Retrieved from: https://www.aceee.org/topic-brief/2020/06/programs-electrify-space-heating-homes-and-buildings

26 Colorado Springs Utilities. Builder Incentive Program. Retrieved from https://www.csu.org/Pages/BuilderIncentiveProgram.aspx

27 Toor, W. (2021, November 5). There's a lot being done in Colorado to address climate crisis. *Boulder Daily Camera.* Retrieved from https://www.dailycamera.com/2021/11/06/guest-opinion-will-toor-theres-a-lot-being-done-in-colorado-to-address- climate-crisis/

28 Xcel Energy (2021). Colorado Clean Energy Plan Fact Sheet. Retrieved from: https://www.xcelenergy.com/staticfiles/xe-responsive/Working%20With%20Us/CO-clean-energy-fact-sheet.pdf

29 Xcel Energy (2021). *Transportation Electrification Plan.* Retrieved from: https://www.xcelenergy.com/company/rates_and_regulations/filings/transportation_electrification_plan

30 Holy Cross Energy (2020). *Strategic Plan.* Retrieved from: https://www.holycross.com/wp-content/uploads/2020/12/HCE-Strategic-Plan-121020-FINAL_R2_TOPOST.pdf

31 Platte River Power Authority (2018). *2018 Strategic Plan*. Retrieved from: https://www.prpa.org/future-planning/

32 La Plata Electric Association (2019). *2019 Power Supply Strategy.* Retrieved from: https://www.lpea.coop/sites/lpea/files/ pdf/board_resolutions/2019/201910LPEA_PowerSupplyStrategy.pdf

33 Kohler, J. (2021, February 4). Disputes between Colorado power supplier, cooperatives seen as 'bleeding edge' of changing energy landscape. *Denver Post.* Retrieved from: https://www.denverpost.com/2021/02/12/tri-state-generation- microcosm-of-changing-energy-landscape/

34 Tri-State (2020, January). *Responsible Energy Plan.* Retrieved from: https://tristate.coop/sites/tristategt/files/PDF/Responsible-Energy-Plan/Tri-State-Responsible-Energy-Plan-Jan2020.pdf

35 Black Hills Energy (2020, November 5). *Black Hills Corp. announces clean energy goals.* Retrieved from: https://www.blackhillsenergy.com/news/clean-energy-goals

36 Black Hills Energy. *Preserving Energy Choice.* Retrieved from: https://www.blackhillsenergy.com/sites/blackhillsenergy.com/files/cog-forced-electrification.pdf

37 Black Hills Energy (2019, September 3). Schedule Of Rates, Rules And Regulations For Electric Service. Retrieved from: https://www.blackhillsenergy.com/sites/blackhillsenergy.com/files/coe-tariff.pdf

38 Sakas, M. (2021, November 20). Boulder Ends Decade Long Pursuit Of City-Owned Power Utility. *CPR News*. Retrieved from: https://www.cpr.org/2020/11/20/boulder-ends-decade-long-pursuit-of-city-owned-power-utility/