Denver's Net Zero Energy (NZE) New Buildings & Homes Implementation Plan

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DENVER
CLIMATE ACTION, SUSTAINABILITY & RESILIENCY

nbi new buildings institute

CONTENTS

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ABBREVIATIONS

ASHRAE – American Society of Heating, Refrigerating and Air-Conditioning Engineers

BMS – Building management system

Buildings – All Commercial Buildings (commercial, industrial, multifamily)

CASR –Denver's Office of Climate Action, Sustainability, and Resiliency

CPD – Denver's Community Planning and Development

Cx – Commissioning

DGC – Denver Green Code

DR – Demand response

Enclosure Cx – Enclosure commissioning

EUI – Energy Use Intensity

EV – Electric Vehicle

GHG – Greenhouse gas

Homes – All Single-family dwellings (attached and detached)

HOST - Denver's Department of Housing Stability

HVAC – Heating, ventilation, and air conditioning

IAQ – Indoor air quality

IECC – International Energy Conservation Code

ICC – International Code Council

LCC – Lifecycle cost

MBCx – Monitoring based commissioning

M&V – Measurement and verification

NZE – Net zero energy

pEUI – Predictive Energy Use Intensity

PV – Photovoltaics

REC – Renewable Energy Credit

RTU – Roof top unit

TOU – Time-of-use

VRF – Variable Refrigerant Flow

EXECUTIVE SUMMARY

Introduction

Climate change is not only the single greatest public health and environmental threat of our time, it is one of the biggest challenges. From local impacts such as worsening air quality and increasing frequency of extreme heat, to global impacts like reductions in food supply and sea level rise, the effects will be felt in Denver and around the world. Buildings and homes represent 64% of Denver's 2019 greenhouse gas (GHG) emissions and are a key component to addressing climate change.

Cities can bend the curve on atmospheric carbon because they are responsible for over 70 percent of GHG emissions globally. Denver can implement effective strategies that will help guide our city to a climate-safe future in a way that works for all of our businesses and residents. These strategies will also clean our air and water, make our communities more resilient, improve our health, and preserve the quality of life in the city that we love.

"Cities can bend the curve on atmospheric carbon because they are responsible for over 70 percent of GHG emissions globally."

The objectives of Denver's Net Zero Energy New Buildings & Homes Implementation Plan (NZE Plan) are to help create clean energy jobs, drive economic recovery, and improve energy equity through enhancements to the Denver Building and Fire Code with the goal of all new buildings achieving net zero energy by 2030. The milestones to reach this goal are:

- Net zero energy, all-electric new homes in the 2024 Building Code
- Net zero energy, all-electric new buildings in the 2027 Building Code
- New buildings perform as designed with performance verification in the 2030 Building Code

These goals and this plan were developed with extensive input from the Net Zero Energy (NZE) Stakeholder Advisory Groups and community feedback.

"The objectives of Denver's Net Zero Energy New Buildings & Homes Implementation Plan (NZE Plan) are to help create clean energy jobs, drive economic recovery, and improve energy equity."

In Denver's 2018 80x50 Climate Action Plan, the city pledged that in 2035 it would achieve NZE in new buildings and homes. In 2020, the Climate Action Task Force reviewed current climate science and recommended that all of Denver's buildings and homes achieve net zero by 2030. The Task Force also set milestones for net zero in building code to reach NZE by 2030 through highly efficient, all-electric, renewable energy, and grid-flexible goals. With this NZE Plan, Denver's Office of Climate Action, Sustainability, and Resiliency is updating the 80x50 NZE goals to align with the recommendations of the Climate Action Task Force.

What is Net Zero Energy?

Denver defines "Net Zero Energy (NZE)" as a new building or home that is highly energy-efficient and fully powered from on-site and/or off-site renewable energy. This means that new buildings and homes will be: (1) Highly Energy Efficient, (2) All-Electric, (3) Powered by Renewable Energy, and (4) Providers of Demand Flexibility for the Grid. Each of these is a foundation of net zero energy in Denver and addressed in detail in this NZE Plan.

What are the Costs and Benefits of Net Zero?

This NZE Plan details two cost studies of all-electric buildings, specific to Denver. One study found that building all-electric reduced upfront costs by 27% for single-family new construction and 8% for all-electric new construction commercial buildings, including rebates from Xcel Energy. New construction electric homes cost around $5,300 less to build compared with new construction mixed-fuel homes. New construction commercial buildings cost $18,100 less to build than mixed-fuel new buildings.

> ***"One study found that building all-electric reduced upfront costs by 27% for single-family new construction and 8% for all-electric new construction commercial buildings."***

The second study reported that building an all-electric home saved $2,900 in net present costs over 15 years and $2,700 in upfront costs, and that all-electric homes save 2% in annual utility costs compared to mixed fuel homes. The majority of the upfront savings that electric homes realize are from an avoided gas interconnection.

Building all-electric also offers co-benefits including efficiency, health, and cost savings, such as:

- Electric heat pumps are significantly (200-300%+) more efficient than gas equipment. As a result, there are operational cost benefits from this energy savings.
- Electric induction stovetops also improve safety through reduced risk of burns and fire, and another study explored in this plan found that children in homes with gas stoves have a:
    - 42% increased risk of experiencing asthma symptoms (current asthma)
    - 24% increased risk of ever being diagnosed with asthma by a doctor (lifetime asthma)
    - 32% increased risk of both current and lifetime asthma overall
- There are significant cost savings from avoiding installation of gas distribution supply lines and equipment.

Why Now?

By 2050, about 40% of Denver's building stock will be "new", having been built between 2020 and 2050, therefore, the city's GHG emissions will be significantly reduced if these buildings are net zero and all-electric. Denver is currently developing a Beneficial Electrification Implementation Plan for Existing Buildings, which will address how to strategically electrify the existing buildings within Denver; this plan is expected to be complete by the end of 2021.

Xcel Energy, the electricity provider in Denver, has committed to reducing emissions from electricity generation 80% by 2030 and 100% by 2050. Electricity comprises 66% of emissions and natural gas comprises 33% of the emissions in Denver's current building stock. By decarbonizing the grid, in 2030 electricity will comprise only 40% of building emissions and natural gas will comprise 60% of the building emissions. Moving toward net zero buildings swiftly will keep pace with the transformation of Xcel's grid, and maximize the opportunity to reduce Denver's GHG burden.

How Does this Plan Promote Equity?

The COVID-19 crisis has crystallized the connection between environmental quality and public health. Denver's low-income neighborhoods and communities of color are disproportionately impacted by climate change and energy insecurity. Affordability, equity and health have always been integral to Denver's climate work, and the stakeholders in this plan placed a heavy emphasis on addressing the impact of net zero implementation on Denver's most climate-burdened communities.

At scale, net zero buildings in Denver will have a noticeable positive impact on neighborhood-level air quality. A grid that is majority powered by renewable sources will generate fewer toxins and particulate matter than today's energy sources. Homes that have all-electric end uses will not have indoor sources of carbon monoxide, eliminating that danger for residents, especially those living with chronic respiratory conditions.

As Denver advances in this transition, the incentives discussed in this NZE Plan will need to focus on low- and moderate-income households, and the owners of buildings in which they live, to drive adoption of these recommendations while also protecting affordability. The forthcoming Beneficial Electrification Plan will present solutions to address the risk of low-income customers being the last on the system bearing the full weight of maintenance costs.

What is the Timeline?

The path to net zero requires technical changes to Denver's Denver Building and Fire Code and implementation of key supports, all of which are detailed in this plan. The NZE Stakeholder Advisory Groups established the following guiding principles for the path ahead:

- We will need incentives to equitably support new construction and the community.
- Denver will be net zero energy as a whole community of buildings and homes, not in every individual building and home.
- There will be different solutions for different buildings: our goal is to write an implementation plan that requires a fair and consistent level of effort across building types, sectors, and neighborhoods.
- Stakeholders will help us figure out this path.

Staffing and program support is needed internally at the city to ensure these goals will be met, and will provide the support needed for the community to succeed. Denver needs both IECC code enforcement staff as well as staff for incentives, fee reductions, and supports such as marketing and outreach, training and education, financing and incentives, and advocacy. Specific to education, the stakeholders identified the importance of the city providing education and training for design teams, developers, building owners, and the general public.

The NZE Plan presents a thorough timeline for each of the next four code cycles in 2021, 2024, 2027, and 2030. The table below is an abbreviated excerpt of the proposed code requirements for commercial buildings, illustrating that the 2021 code update presents a modest introduction to net zero, then gradually ramps up to full adoption in 2030.

Table 1. Summary of Proposed Requirements for Commercial Buildings

Commercial	2021	2024	2027	2030
HIGHLY EFFICIENT				
Energy Modeling Accuracy	Report on discrepancy in disclosure data	Within 15% of target	Within 10% of target	Achieve target
ALL-ELECTRIC				
Equipment requirement	All-Electric: *except heating & water heating* All-Electric Ready: *conduit for central*	All-Electric: *except water heating*	All-electric equipment	All-electric equipment
RENEWABLE ENERGY				
Minimum renewable offset	50%	75%	100%	100%
GRID FLEXIBLITY				
Grid flexibility requirement	Grid Flexible Equipment	Implementation of Grid Flexible Metric	Improving Grid Flexibility + Increased Storage	Improving Grid Flexibility + Increased Storage

Who is Involved?

Denver's Office of Climate Action, Sustainability, and Resiliency (CASR) produced this plan, in close collaboration with colleagues in the department of Community Planning and Development (CPD), and the two agencies will continue to implement this plan together. The code update process is managed by CPD, and CASR is providing significant staff support to the effort. The code update process also provides formal engagement opportunities for stakeholders and the public, and is likely to launch in the second quarter of 2021 and conclude by the end of the year.

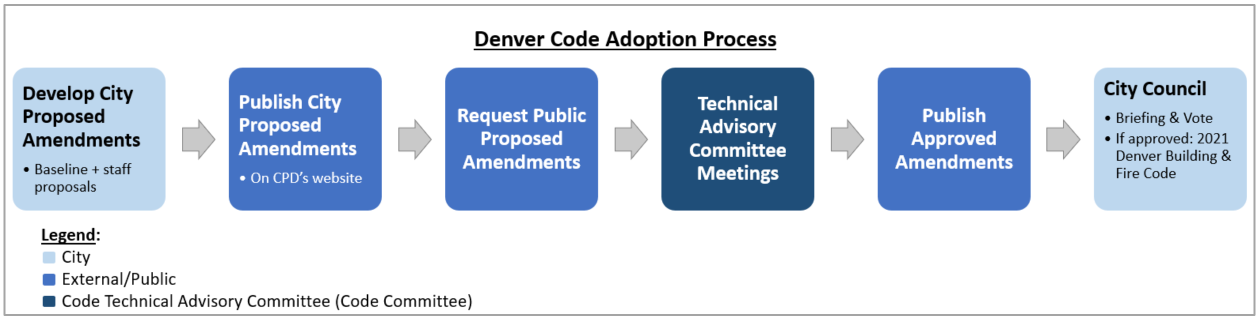


Figure 1. Denver Code Adoption Process

CASR has other stakeholder engagement forums related to this plan:

- The Beneficial Electrification Plan stakeholder groups are deliberating solutions related to the all-electric sections of this plan.
- The Energize Denver Task Force is deliberating similar and complimentary solutions to achieve net zero in existing buildings.
- The Buildings & Homes committee of the Sustainability Advisory Council provides an ongoing forum for discussing policy recommendations and implementation plans.

Under the leadership of Mayor Michael B. Hancock, the City and County of Denver is on track to achieve its net zero goal by 2030 through a process that has been centered on equity and developed in partnership with the stakeholders most impacted by this policy. With continued support and collaboration between agencies, external partners, and the public, implementing this NZE Plan will result in Denver being healthier, more resilient, and producing unto each generation the highest quality of life.

INTRODUCTION

Background

Denver's Net Zero Energy New Buildings & Homes Implementation Plan (NZE Plan) is designed to help create clean energy jobs, drive economic recovery and improve energy equity by passing new building code every three years to enable Denver to get to NZE by 2030 in support of net zero emissions. Net Zero Energy in Denver means that a building is highly energy efficient, all-electric, powered by 100% renewable energy and electricity, and provides demand flexibility to the grid. This NZE Plan details Denver's climate goals, the path to reach these goals, and the supports needed for success.

CENTERING CLIMATE ACTION IN EQUITY

While affordability, equity, and health have always been part of Denver's climate work, it is now more important than ever. In 2020, a number of acute and interrelated crises unfolded: a health crisis due to the COVID-19 pandemic, the associated economic crisis, and the social justice crisis further brought to light by the killing of George Floyd at the hands of a police officer. With each of these, we all became even more acutely aware that the climate crisis deeply intersects with social justice, economic health, and Denver's health and wellbeing. We know that Denver's low-income neighborhoods and communities of color are disproportionately impacted by climate change.

Because of this, it is our goal to view this NZE Plan and all of our work in buildings and homes through an equity lens. There are co-benefits of addressing climate within buildings and homes. We worked to ensure that equity and affordability were considered through our technical NZE Stakeholder Advisory Groups. Finally, we worked closely with Denver's Office of Social Equity and Innovation to ensure we received feedback on this NZE Plan regarding equity and held a public review input and briefing webinar for Denver's community.

Table 2. Co-benefits from Addressing Climate in Buildings and Homes

Co-Benefits	Detail
Social Equity	• **Energy costs have a disproportionate impact on lower income residents** • Energy efficiency measures lower energy bills, **saving money for households and businesses**
Local economy	• Reduction in building energy use reduces costs • When a business or household lowers their energy costs, the **savings can be spent elsewhere in the local economy** • Policies and related programs will create **a market for jobs** to support retrofitting existing homes and buildings
Energy Independence	• Reducing the use of imported fossil fuels **lowers the community's vulnerability to energy price and supply shocks**
Deferred Infrastructure	• Reducing energy consumption can help defer the need for new sources of energy generation
Public Health	• Reducing fossil fuel use in buildings and energy generation **reduces the emissions of air pollutants**, improving air quality and lowering risks of asthma, respiratory disorders, heart attacks, and cancer.

Source: CASR

NET ZERO ENERGY INPUT FROM STAKEHOLDERS

This NZE Plan is a collaboration between Denver's Office of Climate Action, Sustainability, and Resiliency (CASR) and Community Planning and Development (CPD). This collaboration ensures that it is based on Denver's climate goals from Denver's internal experts on new buildings, new homes and energy codes.

It was critical that this plan obtain thorough input from Denver's technical buildings and homes experts. To this end, the City committed to an extensive process of gathering input from technical stakeholders with a wide range of expertise from business-as-usual to high-performance building experts. The NZE Stakeholder Advisory Groups included technical experts for commercial, multifamily, and residential buildings. Additionally, we sought a mix of developers, general contractors, builders, architects, engineers, researchers, sustainability consultants, renewables, and utility experts.

Denver hosted seven (7) stakeholder meetings with the NZE Stakeholder Advisory Groups to provide specific and achievable pathways to NZE new buildings and homes. The meetings included:

- October 2019 – Phase 1 Meetings
  - Commercial Stakeholder Meeting
  - Residential Stakeholder Meeting
- December 2019 – Interim Meetings
  - Commercial Stakeholder Meeting
  - Residential Stakeholder Meeting
- October 2020 – Phase 2 Meetings
  - Commercial Stakeholder Meeting
  - Multifamily Stakeholder Meeting
  - Residential Stakeholder Meeting
- Public Input Meeting: October 2020

The Phase 1 Meetings focused on understanding from the stakeholders the challenges, opportunities, and solutions in achieving net zero as well as discussions on equity for each of the four foundations of net zero energy: highly energy efficient, all-electric, renewable electricity, and grid flexibility. The Interim Meetings focused on building policies and strategies for the Climate Action Task Force, including prioritizing supports and reviewing cost estimates to help Denver address climate change in the most impactful and equitable way. The Phase 2 Meetings focused on feedback on Denver's Draft NZE Plan as well as a review of targets for each building type. Stakeholders also finalized overarching goals and targets.

Denver then held the Public Input Meeting to reach out to the community on the Draft NZE Plan. Denver also conducted a survey to help learn what the community thought of the overarching net zero energy goal. The next section of this report details the goals and recommendations based on stakeholder and public input. Specifics from these meetings are available on Denver's Net Zero New Buildings web page. Denver also reached out to a number of local professional associations to update and ensure ongoing feedback throughout the development of this NZE Plan.

Denver's Climate Goals and Recommendations

UPDATED NZE GOALS SET IN THIS IMPLEMENTATION PLAN

The goal from the 80x50 Climate Action Plan and the recommendations from the Climate Action Task Force were the basis for discussions on timelines for each of the four net zero energy foundations: highly energy efficient, all-electric, 100% renewable electricity, and grid flexibility.

The NZE Stakeholder Advisory Groups reviewed the climate goals and recommendations. Denver also held a public input and briefing meeting to reach out to the community about the timeline. Ultimately, the NZE Stakeholder Advisory Groups recommended that this NZE Plan be developed to reach net zero energy by 2030 and align with the Climate Action Task Force Recommendations and feedback from the public.

Denver's updated NZE goals are:

- Net zero energy, all-electric new homes in the 2024 Building Code
- Net zero energy, all-electric new buildings in the 2027 Building Code
- Performance verification (outcome-based codes) for new buildings in 2030

80X50 CLIMATE ACTION PLAN

The City and County of Denver (CCD) has ambitious climate goals – an 80% reduction in greenhouse gas (GHG) emissions by 2050, according to the 2018 80x50 Climate Action Plan. There are additional goals for buildings and homes that apply as new buildings become existing buildings. Goals of the 80x50 Climate Action Plan are listed in the table below.

Table 3. Denver 80x50 Climate Action Plan Goals

Year	Buildings Goal	Homes Goal
2025		• Homes use 10% less energy
2030	• Buildings use 30% less energy	
2035	• Net zero energy new buildings	• Homes use 20% less energy
2040	• Buildings reduce heating emissions 50%	• Homes reduce heating emissions 25%

Source: CASR

CLIMATE ACTION TASK FORCE RECOMMENDATION

In 2020, Denver further addressed climate by facilitating a Climate Action Task Force charged with developing recommendations to strengthen Denver's work to address climate change equitably in buildings, transportation, 100% renewable electricity, industrial energy use, consumption emissions, and resiliency/adaptation. The Climate Action Task Force developed recommendations for buildings and homes beyond the 80x50 Climate Action Plan including:

- Net zero new homes in the 2024 Building Code
- Net zero new building in the 2027 Building Code
- Performance verification (outcome-based codes) for new buildings in 2030

The Climate Action Task Force defined net zero as highly efficient, all-electric, renewable energy, and grid-flexible.

Table 4. Denver Climate Action Task Force Recommendations for Buildings and Homes

Code Cycle	Buildings	Homes

2021 Building & Fire Code	• 2019 DGC becomes 2021 Base Code
	• Develop 2021 DGC
	  ○ All-electric new buildings
		• 2019 DGC becomes 2021 Base Code
		• Develop 2021 DGC
		  ○ Net zero new homes

2024 Building & Fire Code	• 2021 DGC becomes 2024 Base Code
	  ○ All-electric new buildings
	• Develop 2024 DGC
	  ○ Net zero new buildings
		• 2021 DGC becomes 2024 Base Code
		  ○ Net zero new homes
		• Develop 2024 DGC

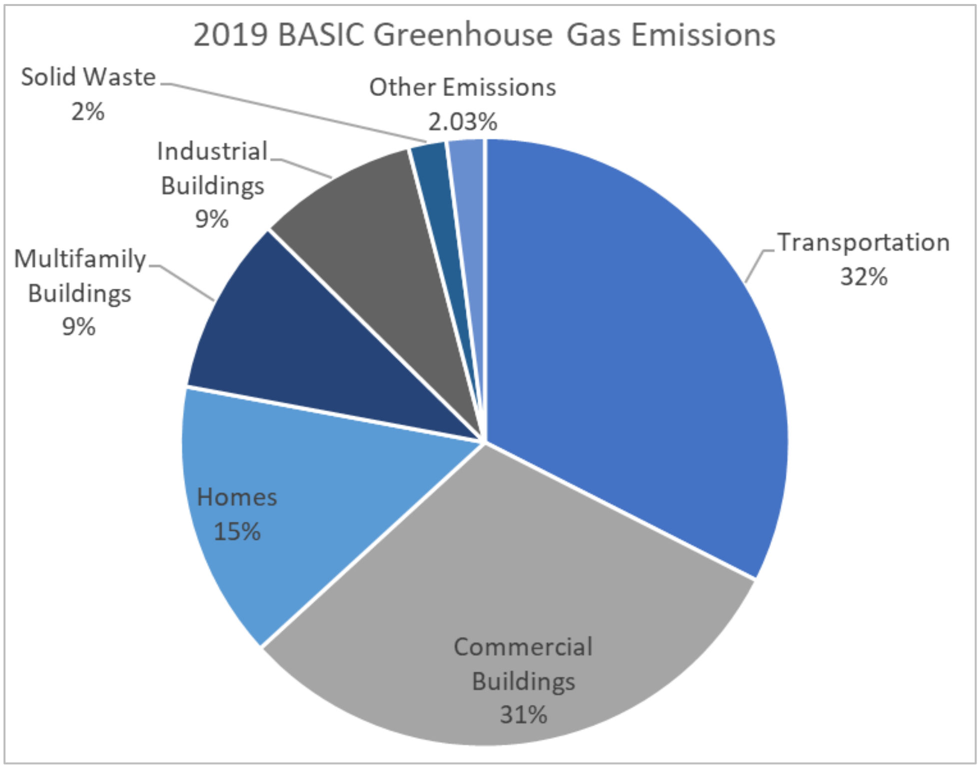
2027 Building & Fire Code	• 2024 DGC becomes 2027 Base Code
	  ○ Net zero new buildings
	• Develop 2027 DGC
	  ○ Performance verification (outcome-based code)
		• 2024 DGC becomes 2027 Base Code
		  ○ Net zero new homes
		• Develop 2027 DGC

2030 Building & Fire Code	• 2027 DGC becomes 2024 Base Code ○ Performance verification • Develop 2030 DGC	• 2027 DGC becomes 2024 Base Code • Develop 2030 DGC

Source: CASR

Denver's Emissions

Buildings and homes together represent 64% of Denver's 2019 emissions and are a key component to addressing climate change in Denver.



Source: CASR

Figure 2. 2019 BASIC GHG Emissions in Denver

Source: CASR

Figure 3. Buildings and Homes are 64% of Denver's 2019 BASIC GHG Emissions

Growth from New Buildings and Homes

Additionally, by 2050, about 40% of Denver's building stock will be "newly" built (buildings and homes built between 2020 and 2050). According to Dodge Data and Analytics – Denver City and County New Construction Projections, the five-year increase by building type is as follows.

Table 5. Denver's Projected New Buildings

Commercial & Multifamily Buildings	5-Year Increase (sqft)
Apartments & Condos	19,300,199
Office and Bank	6,716,497
Warehouses	1,725,054
Hotels	1,638,085
Schools	1,289,142
Misc. Non-Res	1,200,500
Hospitals	1,158,273
Stores/Restaurants	1,106,037
Source: Dodge Data and Analytics – Denver City and County New Construction Projections	

Table 6. Denver's Projected New Homes

Homes	5-Year Increase (sqft)
One Family Houses	18,876,629
Two Family Houses	859,211
Source: Dodge Data and Analytics – Denver City and County New Construction Projections	

Implications for Existing Buildings

This NZE Plan only applies to major renovations of existing buildings going through Denver's permitting process.

2019 Denver Codes and Code Adoption Process

The way that the targets detailed in this NZE Plan will become required in the Denver Building and Fire Code is through the ongoing Code Adoption Process. Denver's most recent Building and Fire Code was developed and adopted in 2019. The 2019 Denver Building and Fire Code is based on the 2018 edition of the International Code Council (ICC) codes including: the International Energy Conversation Code (IECC) as well as the IBC, IEBC, IPC, IMC, IRC, IFGC, and IFC. The 2019 Denver Code was approved by City Council on December 23, 2019, and the Mayor signed the bill on December 26, 2019. The code went into effect on July 31, 2020.

The 2019 Denver Green Code is a voluntary stretch code based on the 2018 edition of the International Green Conservation Code (IgCC). The intent is that the current Denver Green Code will be the basis for the next base code in the upcoming Building and Fire Code Adoption Process.

Denver's code adoption process follows the Code Development Cycle of the International Code Council (ICC) codes. Denver staff votes as part of the code adoption process and recently participated in voting on the 2021 ICC Codes. The final versions of each code will be available in 2020 and as a result Denver will begin our next code adoption process in 2021.

DENVER'S NET ZERO DEFINITION

Denver's goal is to be net zero energy, in support of reaching net zero emissions as a whole community of buildings and homes. While this is a community goal based on emissions, the metric within this NZE Plan for each individual building or home is energy because of renewable attributes in Denver. There will be different solutions for different buildings and homes to ensure a fair and consistent level of effort across building types, sectors, and neighborhoods. Additionally, it will frame reaching the NZE goal through Denver's Code Adoption Process by detailing individual building or home requirements as well as the supports needed for the community to reach these goals equitably.

Denver developed a definition of Net Zero Energy and guiding principles as the basis for this NZE Plan and based on the climate goals detailed in the 80x50 Climate Action Plan. In conjunction with stakeholders, Denver determined that each net zero new building will address energy efficiency, reduce greenhouse gas (GHG) emissions through all-electric equipment, use renewable energy and electricity, and provide demand flexibility to the grid. These are detailed further below.

Guiding Principles

Denver developed four guiding principles for net zero energy new buildings and homes including:

- We will need incentives to equitably support new construction and the community.
- As a whole community of buildings, we want to achieve this goal. We will not achieve it in every individual building.
- There will be different solutions for different buildings: our goal is to write a NZE Plan that requires a fair and consistent level of effort across building types, sectors, and neighborhoods.
- Stakeholders will help us figure out this path.

Accounting in Denver

The community goal is to reach net zero emissions with energy as the metric for each individual building or home. The reason for this is because Xcel Energy typically retains the renewable energy credits (RECs). Denver's priority, therefore, is to add renewable capacity and also work with Xcel so that they retire the RECs to reach net zero emissions.

Denver's Net Zero Energy New Building Definition

Denver defines net zero energy as a new building or home that is highly energy-efficient and fully powered from on-site and/or off-site renewable energy. This means that new buildings and homes will be: **1. Highly Energy Efficient, 2. All-Electric, 3. Powered by Renewable Energy and Electricity, and 4. Providers of Demand Flexibility for the Grid**.

In 2030, new buildings and homes in Denver will be:

1. ***Highly Energy Efficient***
   - Highly energy-efficient buildings on site
   - Target Energy Use Intensity (EUI) for commercial buildings;
     Target Energy Rating Index (ERI) for homes
   - Buildings will have to perform as designed where practical for that building type.
   - Energy efficiency is the step that decreases costs through energy savings .
2. ***All-Electric***
   - Reduce greenhouse gas emissions through all-electric equipment in buildings.
   - New buildings and homes free from natural gas
3. ***Powered by Renewable Energy and Electricity***
   - On-site or off-site renewables focused on additional production.
   - REC's (renewable attributes) need to be retired by the customer or the utility and not sold.
   - By 2050 the grid will be 100% renewable. Buildings are part of that equation.
4. ***Providers of Demand Flexibility for the Grid***
   - Energy storage, grid integration, and flexibility to respond to grid signals.

The next four sections of this NZE Plan address each of these four foundations of Denver's Net Zero Energy Goal.

TECHNICAL GUIDANCE: QUICK START

This NZE Plan will help Denver get to net zero in the upcoming Code Adoption Cycles in order to meet Denver's climate goals. As a result, details the goals, targets, and milestones for each upcoming code cycle. It is intended for:

- The City & County of Denver
- Denver's buildings and homes community of developers, architects, engineers, etc.
- Those on the Code Committees in future code cycles

This is a technical document to consider equity costs, support, technologies, gaps, and barriers for new buildings and home. This NZE Plan is extensive to address all of this for each foundation of net zero (highly energy efficient, all-electric, renewable electricity, and grid flexible). Subsequently, this section is a summary of the technical guidance as a "quick start" summary of the detailed content within future sections.

Highly Energy Efficient

The first foundation of Denver's net zero energy (NZE) definition is that new buildings and homes will be highly energy efficient. Energy efficiency is the step that makes all of the foundations more cost effective. Energy efficiency is the first foundation of NZE to ensure that buildings and homes are increasingly energy efficient when getting to net zero energy and saving energy on-site prior to considering renewables.

Energy efficiency for new buildings will be incorporated into future codes through Denver's Code Adoption Process and will be detailed primarily in the IECC. In addition, there are a number of considerations needed in getting to buildings that perform as designed. The first consideration is the prescriptive and performance paths as well as the calibration needed to keep the paths aligned.

Ultimately, the methodology for getting to buildings that perform as designed is through Denver moving to outcome-based (performance verification) codes. Denver will need to address a number of items to be successful including:

- Develop Performance Targets
    - Develop and set performance targets by building type
    - Highly efficient – pEUI targets
    - Address other building types
    - Using EUI targets
- Detail Performance Verification
    - Develop and implement policies for buildings to perform as designed
- Refine Energy Modeling
    - Streamline modeling paths – streamline energy modeling paths within code
    - Address modeling accuracy – increasing focus on predictive accuracy through guidelines
    - Predictive modeling – scaling from comparative to predictive energy modeling
    - Modeling unregulated loads – incentivize improvements without a loophole

    - Modeling normalization – what factors are you willing to adjust for in design and operation
- Specify Backstops
    - Eliminate trading out envelope improvements for renewables

DENVER'S HIGHLY EFFICIENT PERFORMANCE TARGETS

To determine the performance targets, an analysis was completed by building type and considered Denver's current building performance from Energize Denver data and the energy use intensity targets for each building type based on the maximum site efficiency using current technologies (without renewables). Denver also asked the NZE Stakeholder Advisory Groups to review the resulting predictive energy use intensity (pEUI) targets for buildings and energy rating index (ERI) targets for homes. Below are these targets based on the analysis for Denver by building type and code cycle.

Table 7. NZE 2027: Commercial pEUI Targets for Denver Code

Building Type	2021	2024	2027	2030 Performance Verification
Small Hotel	47	41	35	35
Large Hotel	68	61	54	54
Medium Office	26	24	21	21
Large Office	54	45	37	37
Standalone Retail	39	34	28	28
Warehouse	13	11	9	9

Table 8. NZE 2027: Multifamily pEUI Targets for Denver Code

Building Type	2021	2024	2027	2030 Performance Verification
Mid-Rise Apartment	35	29	23	23
High-Rise Apartment	38	33	29	29

Table 9. NZE 2024: Residential ERI Targets for Denver Code

Building Type	2021	2024
Single-family Homes	Max ERI = 50 & ERI w/PV = 40	Max ERI = 45 & ERI w/PV = 0

Other Building Types

Some buildings will have a design target predictive energy use intensity (pEUI) that ratchets down over time as detailed in the tables above. However, building types that do not lend themselves to a target EUI will model a baseline and a percent improvement over that baseline.

Table 10. Energy Savings Targets for Other Building Types

ASHRAE 90.1-2016	2021	2024	2027
% Savings Over Baseline	15%	30%	45%

This results in two modeling options:

1) pEUI targets for typically predictable building types. Developers can model to prove they meet the pEUI for those building types.
2) Alternately, projects can be modeled to a baseline and a percent better than baseline.

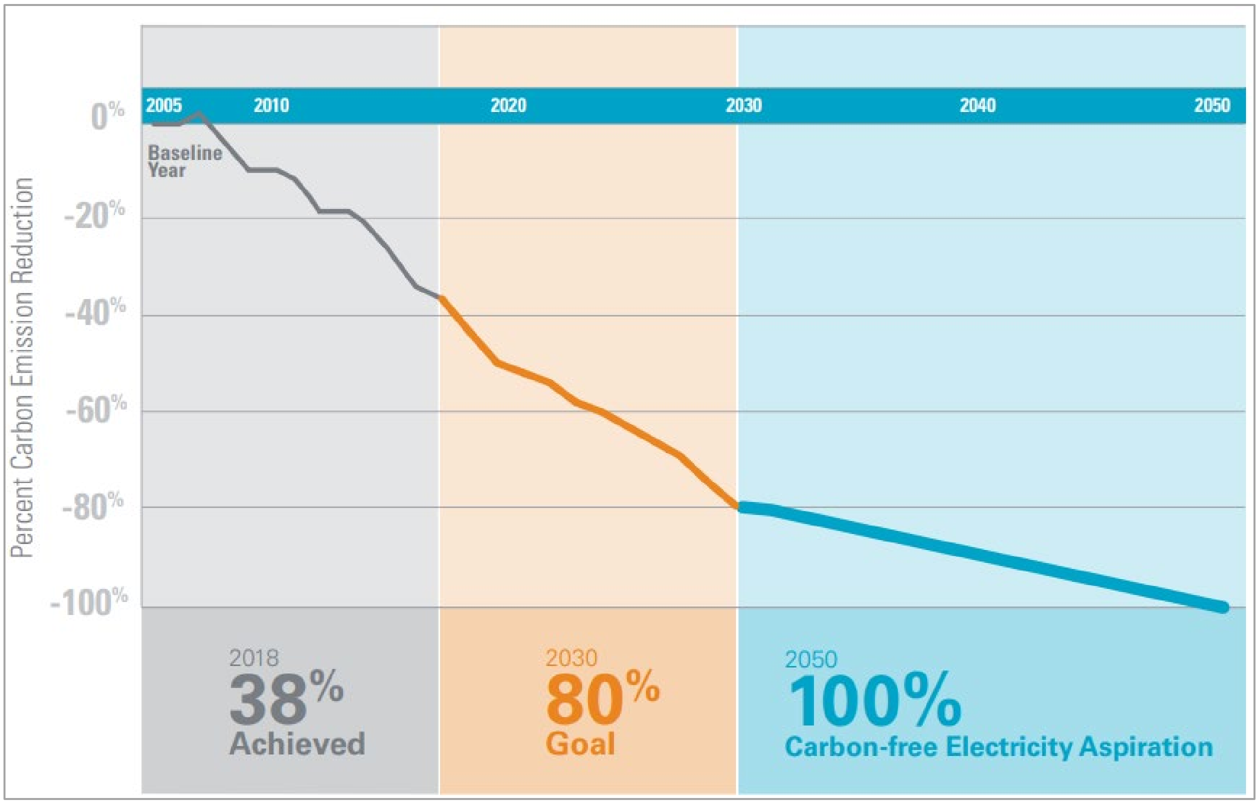
Setting performance targets by building type ensures that considerations are made for that building type and allow developers, owners, and design teams the flexibility to determine the most cost-effective way to meet the energy efficiency targets for a specific project. Additionally, because the performance and prescriptive paths in code will be aligned through modeling, this also allows multiple code paths for a building or home to comply with code.

All-Electric

All-electric is part of Denver's net zero definition and is important in getting to net zero energy in support of reducing emissions. The majority of the emissions from buildings and homes are due to space heating and water heating. Because 40% of buildings will be "new" in 2050, Denver's GHG emissions will be significantly reduced if these are net zero and all-electric. Denver is also working on a Beneficial Electrification Implementation Plan for Existing Buildings. This plan will address how to strategically electrify the existing buildings within Denver and is expected to be complete by the end of 2021.

"Mixed-fuel buildings" have utility connections for both electricity and natural gas, the two major energy fuel sources for buildings in the U.S. An all-electric building is a building whose only utility infrastructure is electricity and major energy systems are served by electricity. Electric loads can be directly offset with renewables, while gas combustion cannot. Therefore, as the supply for the electrical grid decarbonizes, all-electric buildings can leverage increasingly clean fuel sources to achieve long-term carbon reductions beyond what can be accomplished in mixed-fuel buildings.

In addition to addressing the onsite emissions from buildings and homes, another component to reducing emissions within Denver is addressing emissions from electricity generation. Xcel Energy, the electricity provider in Denver, has committed to reducing emissions from electricity generation by 80% in 2030 and 100% by 2050. Currently in Denver's building stock, electricity comprises 66% of building emissions and natural gas comprises 33% of the building emissions. As the grid is decarbonized so swiftly, in 2030 electricity will comprise only 40% of building emissions and natural gas will comprise 60% of the building emissions.



[Source: Xcel Energy Carbon Report](#)

Figure 4. Xcel Energy Carbon Reduction Trajectory: Clean Energy Transition 2030 and 2050

There are a number of considerations in getting to all-electric buildings. The first is if all-electric is technically feasible in Denver. This looks at the equipment needed for all-electric buildings and homes including equity considerations. Second, is if the market in Denver is ready for all-electric through interviews with stakeholders. The goal was to understand if all-electric equipment and expertise (installation) is available, the code and regulatory gaps and barriers, and supports needed (incentives, education, outreach, etc.). From this, the proposed all-electric targets are detailed. All-electric also connects buildings and transportation through electric vehicles. While Denver has a Denver Electric Vehicle (EV) Action Plan, the connection of these two is another consideration. Each of these all-electric considerations are detailed within the NZE Plan to determine the targets for all-electric as part of net zero energy in support of net zero emissions.

DENVER'S ALL-ELECTRIC TARGETS

The all-electric targets for each code cycle are in the tables below. These were reviewed by the NZE Stakeholder Advisory Groups. The discussion about all-electric targets determined that system type should be the basis of consideration for commercial buildings. In addition, Denver is considering how best to define "all-electric ready" to ensure that requirements are helpful for buildings and homes that convert from gas to electricity in the future and that these consider cost implications.

Table 11. Commercial Building All-Electric Targets for Denver Code

<table>
<tr><th>Building Type</th><th>2021</th><th>2024</th><th>2027</th></tr>
<tr><td>Small Hotel</td><td rowspan="6">All-Electric: except heating & water heating

All-Electric Ready: conduit for central systems & panel space</td><td rowspan="6">All-Electric: except water heating</td><td rowspan="6">All-Electric</td></tr>
<tr><td>Large Hotel</td></tr>
<tr><td>Medium Office</td></tr>
<tr><td>Large Office</td></tr>
<tr><td>Standalone Retail</td></tr>
<tr><td>Warehouse</td></tr>
</table>

Table 12. Multifamily Building All-Electric Requirements for Denver Code

Building Type	2021	2024	2027
3-story townhome & Low-Rise Apartment	Required	Required	Required
Mid-Rise Apartment (R-2: 4-7 stories)	All-Electric Ready: *conduit & panel space*	Required	Required
High-Rise Apartment (R-2: 8 or more stories)	All-Electric Ready: *conduit & panel space*	All-Electric Ready: *conduit & panel space*	Required

Table 13. Residential Home All-Electric Targets for Denver Code

Building Type	2021	2024
Single-family Homes	All-Electric Ready: conduit & panel space	Required

In addition to emissions reductions, there are a number of co-benefits from building all-electric including efficiency, health, and cost savings. While energy efficiency is a separate foundation within this report, it is important to note that when transitioning from gas to electric heating (both space and water), heat pumps are significantly (200-300%+) more efficient than gas equipment. As a result, there are operational cost benefits from this energy savings.

Cooking is another common end use for natural gas. When cooking with electric stoves, especially induction stoves, there not only are emissions benefits but significant improvements to indoor air quality. As detailed in the study Health Effects from Gas Stove Pollution, a meta study looking at the association between gas stoves and childhood asthma found children in homes with gas stoves have a:

- 42% increased risk of experiencing asthma symptoms (current asthma),
- 24% increased risk of ever being diagnosed with asthma by a doctor (lifetime asthma), and
- 32% increased risk of both current and lifetime asthma overall.

There are additional benefits from induction including energy efficiency and safety through reduced burns and lower risk of fire.

Finally, there is a cost benefit (savings) from constructing an all-electric building. When gas is removed entirely from a building there is a significant cost savings from eliminating the need for gas distribution as well as gas supply to the building. The cost benefits are further detailed below in the "Cost Considerations and Study: All Electric" section.

Powered by Renewable Energy and Electricity

The third NZE foundation within Denver's net zero energy definition is that new buildings and homes will be powered by renewable energy and electricity. Once buildings and homes are highly energy efficient and all-electric, they will be fully powered from on-site and/or off-site renewable energy.

Denver's 100% Renewable Electricity Action Plan details that by 2030 renewable electricity will offset 100% of new building energy use for buildings permitted under the code. Code will require increasing minimum levels of renewable electricity in the code cycles leading up to 2030. Additionally, by 2050, the electric grid will be 100% renewable and buildings are part of this equation.

It is important to make sure that renewables are not used to offset basic building performance to a significant degree because a wide range of energy efficiency strategies remain less expensive to deploy at the building level than renewable energy. Indeed, energy efficiency and demand management will make the 100% renewable electricity goal more feasible and cost-effective for buildings. Powering 100% of building operations with renewable power is made more achievable if the building lowers its electricity demand through energy efficiency. For this reason, see the 'backstop code' for which renewable deployment cannot offset basic building performance.

Net zero energy building guidelines in other jurisdictions or states, such as California, say that renewable electricity may only count towards compliance if the building owner retains the Renewable Energy Credits, or RECs, for that renewable electricity. Denver's guidelines differ by prioritizing the addition of new renewable electricity capacity onto the electrical grid beyond what would have been developed otherwise (i.e., "additive RECs"). This is inclusive of renewable energy options, such as Solar*Rewards, in which additive RECs are generated, transferred to and retired by Xcel Energy towards system-wide decarbonization. Whether additive RECs are retired by the utility on behalf of all customers or by individual customers within the system, there is the same net effect on the total renewable content of the overall system. This methodology ensures that local investments in rooftop solar and community solar gardens (CSG) are not inadvertently discounted and discouraged simply because Xcel Energy retains and retires the REC's associated with them.

Denver's renewable vision is to enable a rapid and equitable transition to a 100% renewable electric system in Colorado. By 2030, 100% of Denver's community-wide electricity use will contribute to this vision. The 2030 goal for Denver's electricity use to "contribute to" a 100% renewable electric system is unique compared to goals to be "powered by" 100% renewable electricity. This is in part due to the recognition that Denver is a part of a larger electric system operated by Xcel Energy in Colorado. Denver cannot be powered by 100% renewable electricity until the entire system is powered by 100% renewable electricity.

DENVER'S RENEWABLE ENERGY TARGETS

As part of this NZE Plan, Denver asked the NZE Stakeholder Advisory Groups to review the renewable energy goals and targets for buildings and homes to determine the recommendation for upcoming code cycles shown in the table below.

Table 14. Commercial and Multifamily Building Renewable Energy Targets for Denver Code

	2021	2024	2027	2030
Minimum renewable offset	50%	75%	100%	100%
Minimum % Roof Area	25%	50%	70%	70%

This recommendation includes both a minimum renewable offset that can be met by on-site or off-site solar in order to equitably require solar for varying building types and shapes. Additionally, there is a minimum percentage roof area for on-site solar to encourage on site production.

For residential, the table in the highly efficient section combines efficiency and on-site solar. For this reason, there is not a minimum percent roof area envisioned. However, there is still a minimum renewable offset as detailed in the table below.

Table 15. Residential Home Renewable Energy Targets for Denver Code

	2021	2024	2027	2030
Minimum renewable offset	50%	75%	100%	100%

In addition, based on the NZE Stakeholder Advisory Groups meetings, the renewables for all building types (commercial, multifamily, and residential):

a. Offset total building energy use including natural gas
b. Can be met by creating new solar capacity in Denver by either:
    i. Installing on-site solar
    ii. Paying into a Renewable Denver Community Solar Fund (where the city will build community solar gardens)

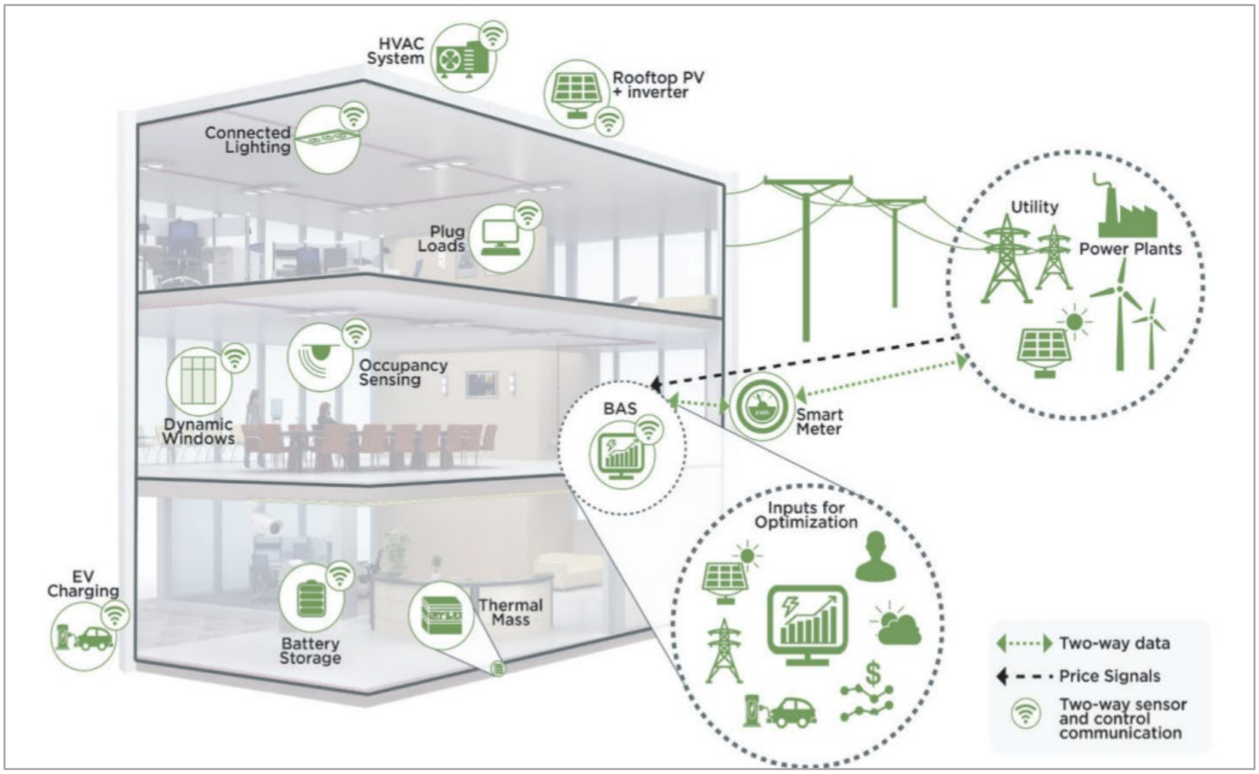
RENEWABLE DENVER COMMUNITY SOLAR FUND

To ensure that all buildings and homes are able to meet the renewables requirement, Denver is currently working to develop a fund – the Renewable Denver Community Solar Fund – that will build community solar gardens. As with any fund, Denver will perform a rate study. The in-lieu rate must be rationally related to the overall cost for the City to provide an equivalent benefit.

Providers of Demand Flexibility for the Grid

The fourth NZE foundation within Denver's net zero energy definition is that new buildings and homes will be providers of demand flexibility for the grid. This includes energy storage, grid integration, and the flexibly to respond to grid signals. There is not a specific climate goal within the 80x50 Climate Action Plan for grid flexibility, however this will be needed as buildings and homes are increasingly all-electric.

In order to electrify everything – our buildings, homes, and vehicles – and then power all those end uses with 100% renewable electricity, we must have systems both to add flexibility to electricity consumption as well as store electricity. New buildings become existing buildings and so need to have grid flexible capabilities installed up front. The following graphic shows ways a building might provide grid flexibility and storage for the grid.



Source: Navigant Consulting

Figure 5. Grid Flexibility and Storage Methods for Buildings

Successful grid flexibility and storage capabilities require both the building and homes as well as third party demand response (DR) aggregators, the grid, and the utility to work together. Buildings and homes must have infrastructure such as water heaters, air conditioning, and HVAC and lighting controls, capable of receiving DR requests or responding to price signals from the utility and implementing load adjustments. The utility must offer demand response programs or structure their pricing to compensate customers when they provide services to the grid.

Denver has current building code requirements for storage, EVs and grid-flexible equipment (demand response – DR capable). Denver's 2019 IECC required that all buildings be battery storage ready. Denver's 2019 IECC also requires the installation of electric vehicle (EV) charging stations – and electric vehicles may play a role in providing grid flexibility in the future. See the EV section of this NZE Plan for details. Finally, Denver's voluntary 2019 Denver Green Code requires that building controls are designed with demand response infrastructure capable of receiving request from the utility for adjustments to:

- HVAC system setpoints
- Variable-speed equipment speed adjustments

- Lighting power demand adjustments

Denver will build upon this foundation to increase the grid flexibility of buildings in Denver over the upcoming code cycles in 2021, 2024, 2027 and 2030.

DENVER'S GRID FLEXIBLE TARGETS

As part of this NZE Plan, Denver asked the NZE Stakeholder Advisory Groups to review grid flexible goals and targets for buildings and homes to determine the recommendation for upcoming code cycles as shown in the table below.

Table 16. Building and Home Grid Flexible Requirements for Denver Code

	2021	2024	2027
All Buildings & Homes	Grid Flexible Equipment	Implementation of Grid Flexible Metric	Improving Grid Flexibility + Increased Storage

Ultimately Denver will work to require grid flexibility in all new buildings when the utility offers programs and rate structures that compensate building owners effectively for the services buildings provide to the grid with these measures.

Technology Adoption

Both the NZE Stakeholder Advisory Groups meetings discussions and the stakeholder interviews indicated that technology is not a particular issue for net zero energy, all-electric buildings and homes. Many of the distributors provide products nationally and have, or could have, efficient equipment available in Denver. However, there is a cost consideration as newer products typically cost more, and the cost decreases as these products are used and installed more frequently.

Building Code/Policy Updates

Ultimately, the targets in this NZE Plan will have to go through each Denver Code Adoption process to be incorporated into the Denver Building and Fire Code. Denver plans to align our code updates with national code updates which are updated every three years and would include 2021, 2024, 2027, and 2030. Denver is committed to ensuring that each of our code adoption processes are open and inclusive.

Denver's code adoption process follows the I-code development process. Key components of Denver's Code Adoption Process are requesting amendment proposals from the public and balanced-interest Code Committees that review and decide upon each proposal. A summary of each Code Committees' decision on each amendment proposal and Committee modification of an approved amendment proposal, if any, will be posted on Denvergov.org.

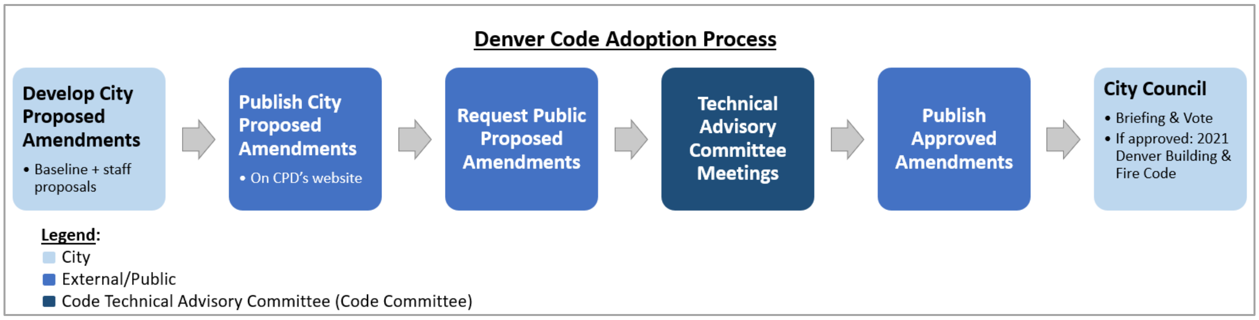


Figure 6. Denver Code Adoption Process

How It All Comes Together

It is critical that all components come together, so planning has been thorough to ensure the application of zoning and supports to reach net zero energy by 2030 with highly efficient, all-electric, renewable energy and electricity, and grid flexibility in mind. Components of the code will need to evolve over the next code cycles to meet Denver's Climate Goals and Recommendations and ensure that buildings perform as designed. This comes together in a timeline for commercial code and residential code that was reviewed and discussed through the NZE Stakeholder Advisory Groups process.

The table below indicates the timeline of each code element through the individual code cycles, and the potential relationship of these transitions to each other through the various code cycles for commercial buildings and residential homes.

Table 17. Denver's Commercial Buildings Code Timeline

Commercial	2021	2024	2027	2030
HIGHLY EFFICIENT				
Prescriptive Path	Add renewables	Add renewables	Small /Remodel Projects only	Small /Remodel Projects only
Performance Target	Meet EUI targets by type & year	Meet EUI targets by type & year	Meet EUI targets by type & year	Meet EUI targets by type & year
Energy Modeling Accuracy	Report on discrepancy in disclosure data	Within 15% of target	Within 10% of target	Achieve Target
Energy Modeling Normalization	Report on discrepancy	Document use changes in model	Document use changes in model	Document use changes in model
Energy Modeling Unregulated Loads	Some flexibility w/ pre- approval	Flexible w/ pre-approval	Flexible	Flexible
Efficiency Backstop	IECC Thermal Envelope Specs	IECC Thermal Envelope Specs	IECC Thermal Envelope Specs	IECC Thermal Envelope Specs
Performance Verification Enforcement	Certificate of Occupancy, Disclosure	Disclosure; Bond or Solar Credit	Disclosure; Bond or Solar Credit	Bond or Solar Credit
ALL-ELECTRIC				
Equipment requirement	All-Electric: *except heating & water heating* All-Electric Ready: *conduit for central*	All-Electric: *except water heating*	All-electric equipment	All-electric equipment
RENEWABLE ENERGY				
Minimum renewable offset	50%	75%	100%	100%
Minimum % Roof Area	25%	50%	70%	70%
GRID FLEXIBLITY				
Grid flexibility requirement	Grid Flexible Equipment	Implementation of Grid Flexible Metric	Improving Grid Flexibility + Increased Storage	Improving Grid Flexibility + Increased Storage

Table 18. Denver's Multifamily Buildings Code Timeline

Multifamily	2021	2024	2027	2030
HIGHLY EFFICIENT				
Prescriptive Path	Add renewables	Add renewables	Small /Remodel Projects only	Small /Remodel Projects only
Performance Target	Meet EUI targets by type & year	Meet EUI targets by type & year	Meet EUI targets by type & year	Meet EUI targets by type & year
Energy Modeling Accuracy	Report on discrepancy in disclosure data	Within 15% of target	Within 10% of target	Achieve Target
Energy Modeling Normalization	Report on discrepancy	Document use changes in model	Document use changes in model	Document use changes in model
Energy Modeling Unregulated Loads	Some flexibility w/ pre- approval	Flexible w/ pre- approval	Flexible	Flexible
Efficiency Backstop	IECC Thermal Envelope Specs	IECC Thermal Envelope Specs	IECC Thermal Envelope Specs	IECC Thermal Envelope Specs
Performance Verification Enforcement	Certificate of Occupancy, Disclosure	Disclosure; Bond or Solar Credit	Disclosure; Bond or Solar Credit	Bond or Solar Credit
ALL-ELECTRIC				
3-story townhome & Low-Rise Apartment	All-electric equipment	All-electric equipment	All-electric equipment	All-electric equipment
Mid-Rise Apartment (R-2: 4-7 stories)	All-Electric Ready: *conduit & panel space*	All-electric equipment	All-electric equipment	All-electric equipment
High-Rise Apartment (R-2: 8 or more stories)	All-Electric Ready: *conduit & panel space*	All-Electric Ready: *conduit & panel space*	All-electric equipment	All-electric equipment
RENEWABLE ENERGY				
Minimum renewable offset	50%	75%	100%	100%
Minimum % Roof Area	25%	50%	70%	70%
GRID FLEXIBLITY				
Grid flexibility requirement	Grid Flexible Equipment	Implementation of Grid Flexible Metric	Improving Grid Flexibility + Increased Storage	Improving Grid Flexibility + Increased Storage

Table 19. Denver's Residential Homes Code Timeline

Residential	2021	2024	2027	2030
HIGHLY EFFICIENT				
Prescriptive Path	Add renewables	Add renewables	Add renewables	Add renewables
Performance Target	Meet ERI targets by size & year	Meet ERI targets by size & year	Meet ERI targets by size & year	Meet ERI targets by size & year
ALL-ELECTRIC				
Equipment requirement	All-Electric Ready: *conduit & panel space*	All-electric equipment	All-electric equipment	All-electric equipment
RENEWABLE ENERGY				
Minimum renewable offset	50%	75%	100%	100%
Energy Rating Index (ERI)	Max ERI = 50, & ERI w/PV = 40	Max ERI = 45, & ERI w/PV = 0	Max ERI = 45, & ERI w/PV = 0	Max ERI = 45, & ERI w/PV = 0
GRID FLEXIBLITY				
Grid flexibility requirement	Grid Flexible Equipment	Implementation of Grid Flexible Metric	Improving Grid Flexibility + Increased Storage	Improving Grid Flexibility + Increased Storage

Preparing for the 2021 Code Cycle

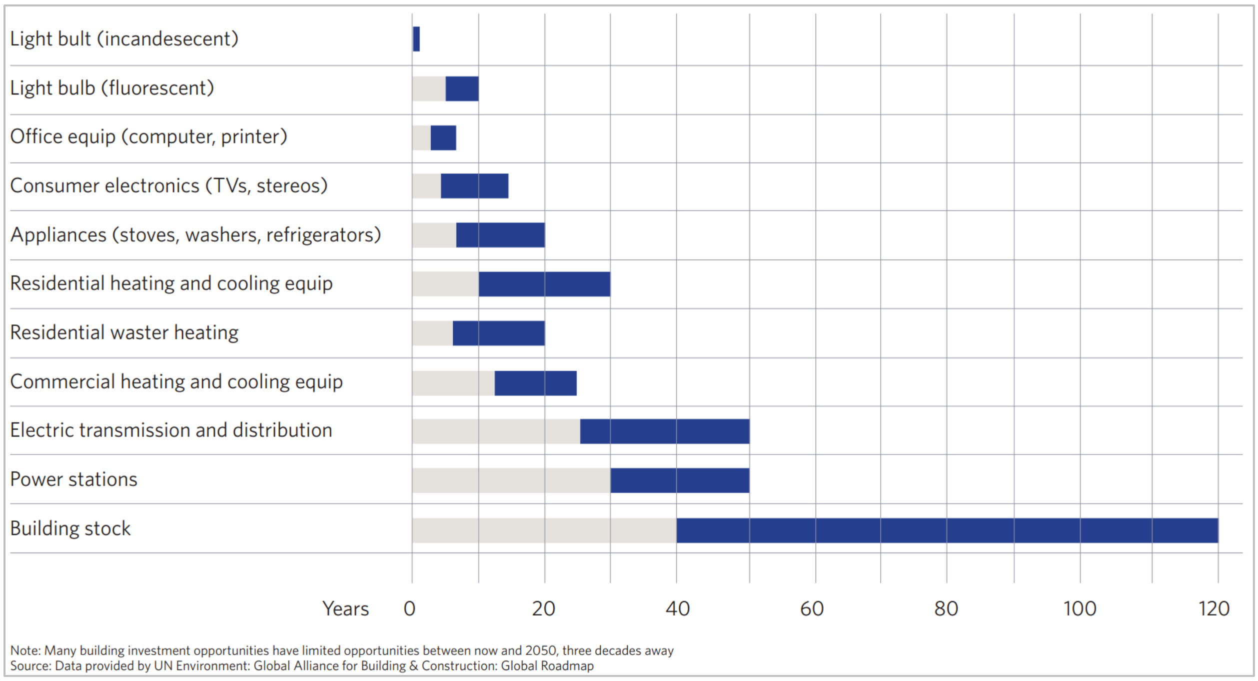
As a next step, Denver is working with New Buildings Institute (NBI) to develop draft code proposals based on the 2021 IECC that meet the goals, targets, and milestones within this NZE Plan. Denver plans to have preliminary meetings to begin gathering feedback in early 2021.

Reducing Emissions: Carbon Considerations

Although this NZE Plan is focused on energy, all four foundations have implications for the carbon emissions of Denver's building stock. Denver is working with New Buildings Institute (NBI) to understand how the goals of each NZE foundation impact Denver's carbon emissions. While energy will remain the metric for this NZE Plan, the carbon impact of the four NZE foundations will continue to be used to inform the implementation of NZE in Denver over the upcoming code cycles. This is an ambitious yet achievable plan to reach net zero energy in support of reducing carbon emissions in Denver.

NZE: HIGHLY ENERGY EFFICIENT

The first foundation of Denver's net zero energy (NZE) definition is that new buildings and homes will be highly efficient. Energy efficiency is the step that makes all of the foundations more cost effective. Energy efficiency is the first foundation of NZE to ensure that buildings and homes are increasingly energy efficient and saving energy on-site prior to considering renewables. This is also important when looking at the lifespan of the building or home as shown in the figure below.



Source: Climate Bonds Initiative

Figure 7. Typical Lifetimes for Buildings and Equipment

Denver is on a path to net zero energy for all new buildings and homes. In addition, for new buildings, Denver wants the buildings to perform as designed.

Goal

Highly energy efficient buildings and homes will be achieved through the code adoption process to reach the goal of net zero energy buildings and homes by 2030. In addition, this NZE Plan includes the milestones for new homes to be net zero and all-electric by 2024 and new buildings to be net zero and all-electric by 2027 as recommended by the Climate Action Task Force.

Table 20. NZE by 2030 Goals and Milestones

Code Cycle	NZE by 2030 Milestones
2021	2019 Denver Green Code becomes base code
2024	New Buildings: All-electric
	New Homes: Net zero
2027	New Buildings: Net zero
2030	New Buildings: Performance verification (*outcome-based*) codes for new buildings to perform as designed
Denver's Goal of Net Zero New Buildings & Homes by 2030	

The 2019 Denver Energy Code is based on the 2018 edition of the International Energy Conservation Code (IECC). The IECC is a national model energy code developed by the International Code Council. During the 2019 code adoption process, Denver made multiple modifications to the 2018 IECC in order to more closely align it with the progress needed to meet Denver's climate goals. As a result, the commercial section of the 2019 Denver Energy Code is estimated to be about 15% more stringent than the 2018 IECC, and the residential section is about 10% more efficient. The 2021 IECC is estimated to be approximately 7% to 12% better than the 2018 IECC for commercial buildings depending on building type and 10% better for residential buildings. However, much of these savings are due to proposals that have already been adopted in the 2019 Denver Energy Code. As a result, future advancements in the Denver Energy Code will need to go beyond the 2021 IECC in order to stay on pace to zero.

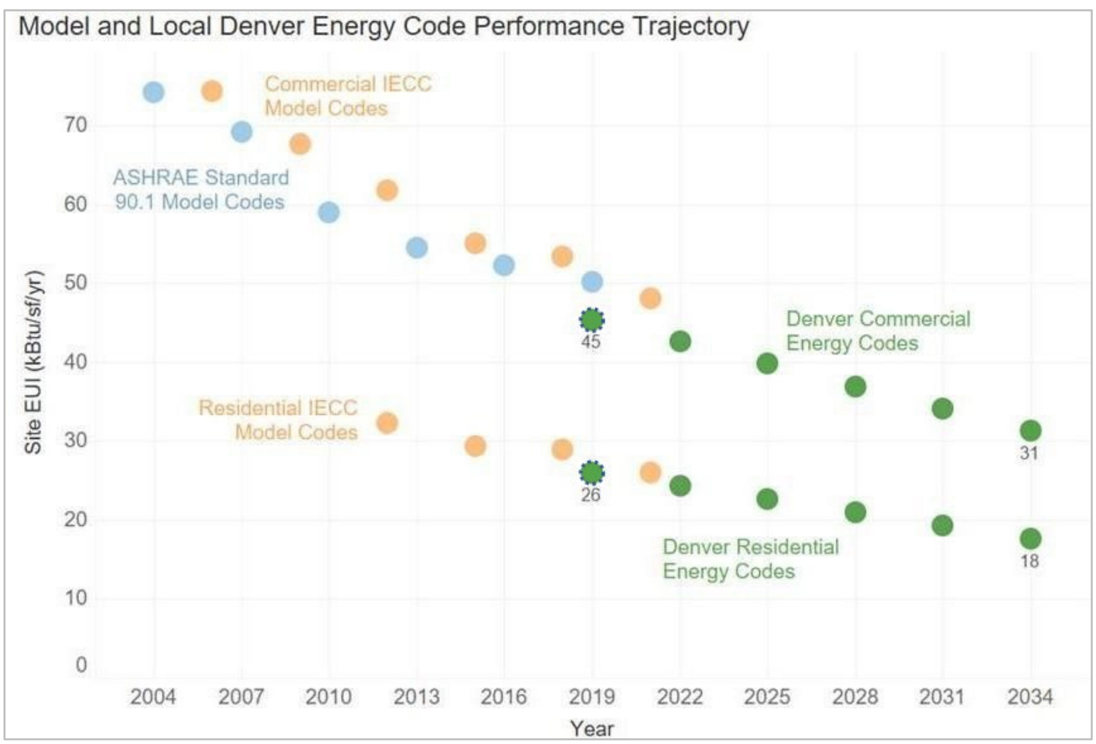


Figure 8. IECC, ASHRAE 90.1 and Denver Code Progression Over Time

NZE Foundation: Highly Energy Efficient

Energy efficiency for new buildings will be incorporated into future codes through Denver's Code Adoption Process and will be detailed in the IECC. In addition, there are a number of considerations needed in order to achieve buildings that perform as designed. The first consideration is the prescriptive and performance paths as well as the calibration needed to keep the paths aligned. Ultimately, the methodology for getting to buildings that perform as designed is to develop performance targets, detail performance verification, refine energy modeling and specify backstops. Additional considerations for achieving buildings that are highly energy efficient include energy code enforcement, cost considerations, technology adoption and building code/policy updates. The following sections detail each of these considerations.

Like most energy codes, the Denver Energy Code (based on the IECC) includes options to comply with the code with either prescriptive or performance approaches. Prescriptive compliance paths are composed of a series of specific requirements for building components that a project must meet to comply with the code. Performance compliance paths allow computer energy modeling to demonstrate that the project complies with the code. In order to meet Denver's goal of highly efficient buildings, the Denver Energy Code will need to increasingly focus on performance. This entails both a greater utilization of performance-based compliance paths and a sharper focus on the actual performance of buildings through performance verification. Additionally, Denver needs to include calibration as part of the Code Adoption Process to ensure that paths are relatively equivalent for each energy code. Ultimately for Denver, code compliance will need to become an outcome-based approach where buildings will have to perform as designed when practical for that building type.

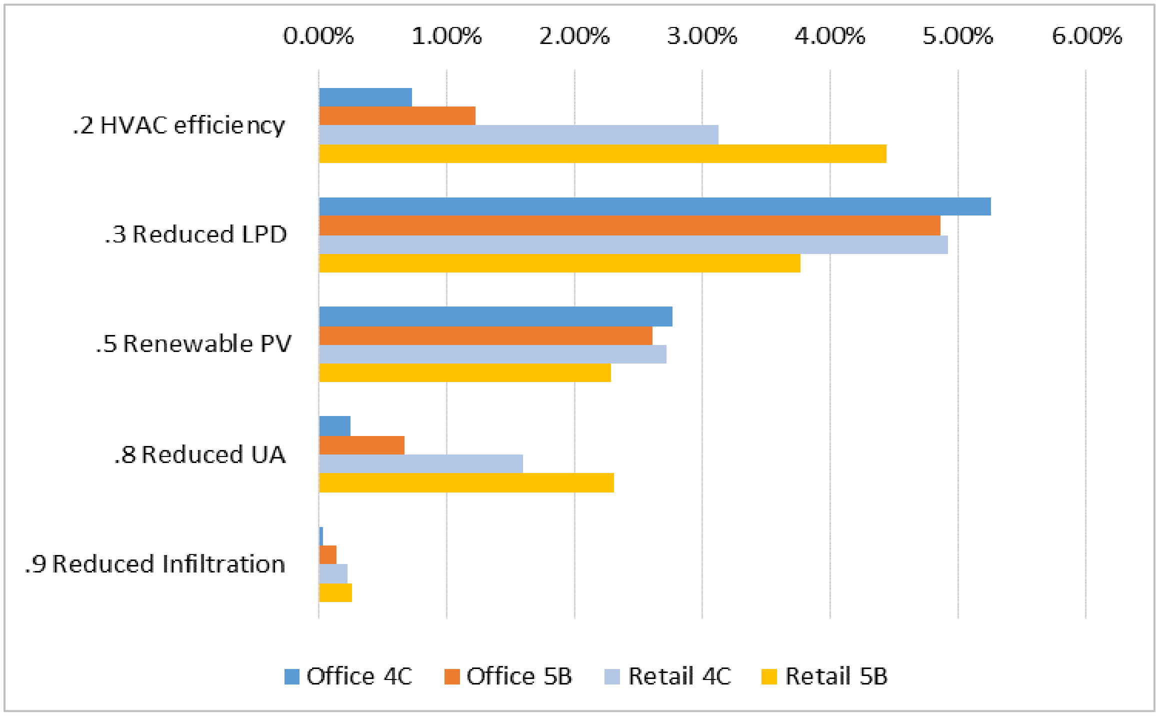
Denver's IECC Prescriptive Path

The long-term viability of the prescriptive path is something that Denver will need to assess in each code adoption cycle. The prescriptive path is inherently more limited in the levels of performance that it can deliver compared to modeling-based approaches. However, it can be helpful for small projects and/or alterations. Advances in stringency in future versions of Denver's prescriptive path will come from two sources: advancements in the IECC model code itself and Denver-specific modifications made to that model code to meet Denver's climate goals.

In both the residential and commercial sections of the energy code, the advancement of the prescriptive compliance paths will require the greater leverage of points-based approaches. Points-based approaches allow prescriptive paths to achieve higher levels of stringency while maximizing flexibility. Many energy efficiency strategies and technologies can save significant energy but may not save that energy in all climates or for all building types and so would not be appropriate as a universal prescriptive requirement. In a points-based approach, various energy efficiency strategies are assigned points based on their potential energy savings. The code then requires a minimum number of points, and project teams choose the points options that best fit their projects.

NEW BUILDINGS – COMMERCIAL IECC PRESCRIPTIVE PATH

In the 2021 edition of the IECC, a new points-based additional efficiency requirement was introduced to replace the older additional efficiency package requirement in Section C406. This section was introduced into the 2012 IECC commercial code in an effort to make the prescriptive path more flexible and able to deliver greater savings without energy modeling. The reason for updating from a package to a points approach in Section C406 is that different packages can deliver different levels of savings in any particular building type or climate zone. In 2018, the Pacific Northwest National Lab (PNNL) analyzed the eight options in C406[21] and found that the savings could range from very little actual savings to over 5% savings on an energy cost basis as shown in Figure 9.



Source: PNNL

Figure 9. Variation in Building Cost Savings for C406 Options

The 2021 edition of the IECC remedies this issue of unequal savings for the various options across building types and climate zones. The new section C406 transitions away from a “pick one” options approach. Instead, it assigns points to each option for a particular building type and climate zone. Based on the PNNL technical analysis, each point is worth 0.25% savings, and the 2021 IECC requires teams to choose one or more options that amount to ten points total (or a 2.5% savings).

[1] www.pnnl.gov/main/publications/external/technical_reports/PNNL-28370rev.1.pdf

Table 21. Points Values of the C406 Options from IECC-2021 for Denver

Building Type	Group B	Groups R & I	Group E	Group M	All Other
C406.2.1: 5% Heating Equipment Efficiency Improvement	1	1	1	2	1
C406.2.2: 5% Cooling Equipment Efficiency Improvement	2	1	1	1	1
C406.2.3: 10% Heating Equipment Efficiency Improvement	2	2	3	3	3
C406.2.4: 10% Cooling Equipment Efficiency Improvement	4	1	2	2	2
C406.3.1: 10% Lighting Power Allowance	7	2	8	12	7
C406.4: Digital Lighting Control	2	NA	2	NA	2
C406.5: Renewable	9	7	6	7	7
C406.6: Dedicated Outside Air System	5	8	NA	2	5
C406.7.1: Solar Water Heating Heat Recovery	NA	14	1	NA	14
C406.7.2: Solar Water Heating Natural Gas Efficiency	NA	9	2	NA	9
C406.7.3: Solar Water Heating Heat Pump	NA	5	1	NA	5
C406.8: 85% Weighted-Average U-factor	10	4	2	4	5
C406.9: Low Leakage Building	11	9	1	3	6
Total available points (without renewable energy)	44	56	47	36	60

The 2021 IECC commercial section C406 points option has several advantages for Denver. The first is simplicity of the mechanism for jurisdictions seeking greater energy savings, such as Denver, to easily require more savings. After adopting 2021 IECC, Denver simply can improve the stringency of the prescriptive path by changing the points target in Section C406. Knowing that each point is worth 0.25% savings, it becomes easy to calibrate the points to a particular savings target for the code cycle.

Another major advantage of this approach is that it will not require significant changes to the base model code, only a change in the number of required C406 points. This effectively limits the need to duplicate the intense stakeholder effort conducted to modify the 2018 IECC model code for local use in Denver. Instead of an extensive and time-consuming process of proposal development; stakeholder engagement; code committee meetings; and proposal vetting, debate and revision; the City can focus stakeholder engagement on the question of the most appropriate level of performance for the code cycle and adjust the points required accordingly.

A third advantage to leveraging the points approach is that it maximizes consistency between Denver's code requirements and the codes in neighboring communities and other markets. Changing the C406 points target leaves the rest of the code aligned with the model code. The base lighting power densities, base insulation requirements, and window requirements all remain the same. This creates a greater level of consistency for designers and builders who work in multiple jurisdictions. The consistency not only will help with market acceptance, it should also improve code enforcement.

Finally, using section C406 means that only minimal changes will be necessary to modify the COMCheck code compliance tool. Denver's 2019 Energy Code required fairly extensive modifications to COMCheck, delaying its availability for use in Denver. And while the U.S. Department of Energy is committed to helping jurisdictions modify the tools to respond to local conditions, future funding availability is uncertain with more jurisdictions going beyond code to meet their own energy and climate goals. Therefore, restricting changes to just the number of points in section C406 means that fewer changes would be needed for COMCheck, and it may even be possible to use it unaltered with just a simple addendum form.

Implementing the points approach in Denver is a relatively simple matter since it is already built into Section C406 in the 2021 IECC.

NEW HOMES – RESIDENTIAL IECC PRESCRIPTIVE PATH

For residential, the IECC-2021 has a package approach and the 2019 Denver Energy Code included a very similar package options approach in Section R407. Through requiring additional packages, this approach may be able to provide the savings required for the next code cycle. Additionally, the packages will help pave the way for a points approach in future code cycles just as it did in the commercial code.

Multiple points options were proposed for the 2021 IECC. These ICC proposed code amendments did not move forward nationally due to political and market issues (rather than technical issues). However, as mentioned above in the discussion of the commercial points option, **the residential code ultimately will need to transition from the package options to a points option which will achieve the net zero goal, streamline additions to the prescriptive path, and address consistency.**

THE FUTURE OF THE PRESCRIPTIVE PATH IN DENVER

Although meeting Denver's goals for highly efficient buildings will require an increasing shift to the performance approach, the prescriptive approach will play an important role in Denver in both the short and long term. The prescriptive path will be valuable for small projects and alterations, even if Denver reaches a point where it is no longer viable for new construction projects, at which time the prescriptive path may need to be tailored for alteration projects on existing buildings.

The main body of the code will continue to advance, and it is likely that additional points options will continue to be added, extending the viability of the prescriptive path. Denver will need to invest in the development of additional points options to achieve this extended viability.

Some possible additional options could leverage even higher performance HVAC or water-heating equipment, natural ventilation, passive approaches (e.g. passive solar heating), or the selection of inherently more efficient HVAC distribution systems such as ductless heat pumps. Since the options deliver different levels of savings for different building types, the prescriptive path may remain a viable compliance option for some building types longer than for others. As the Denver Energy Code becomes increasingly stringent in future code cycles, the prescriptive path may become too restrictive for many projects, effectively requiring projects to choose the modeled performance-based path.

Path Calibration

Path calibration will ensure that the prescriptive path is delivering the same performance as the modeled performance path. Denver will need to calibrate the prescriptive path to performance targets (and vice versa) each code cycle as it did with the 2019 Denver Energy Code, which is estimated to be about 15% more stringent than the 2018 IECC.

The stringency of the 2021 IECC has been estimated to be at least 10% better than the 2018 edition and the points currently available would allow it to achieve another 7-13% efficiency above that (without counting renewable energy production toward compliance). **Moving forward, part of the calibration**

process for each code cycle will need to include an assessment of whether the prescriptive path can deliver the level of savings required to meet the code performance goal for that code cycle. The performance targets to which the prescriptive requirement will need to be calibrated are discussed in the section "Energy Performance Targets for Denver."

From Prescriptive to Performance

As the Denver Energy Code becomes increasingly stringent in future code cycles, the prescriptive path may become too restrictive for many projects, effectively requiring projects to choose the modeled performance-based path. The future of the prescriptive path also will need to accommodate additional considerations such as electrification and grid integration – not just energy efficiency – as Denver works toward its 2030 goals. Denver's goals will make the performance path increasingly the most cost-effective compliance path.

- The cost of modeling will decrease as modelers and designers gain more experience with modeling, and more modelers enter the market to meet demand.
- The performance path allows buildings to gain savings from strategies that cannot be codified in the prescriptive path.
- The performance path provides flexibility for projects to pursue the most cost-effective strategies for their particular design.

Denver's IECC Performance Path

One of the biggest advantages of performance-based code compliance paths – such as the modeling path in the energy code – is the flexibility they provide. Prescriptive compliance paths are clear and straightforward, but they also have a limited flexibility that in turn limits their ability to deliver higher levels of efficiency. In a performance-based path, modeling tradeoffs can be made between different building elements in order to achieve the whole-building goal.

The future of Denver's performance path lies on the path to net zero as shown in the charts below. The Energy Use (vertical axis) uses the Zero Energy Performance Index (zEPI) as an indication of how buildings are performing in relation to net zero energy goals.

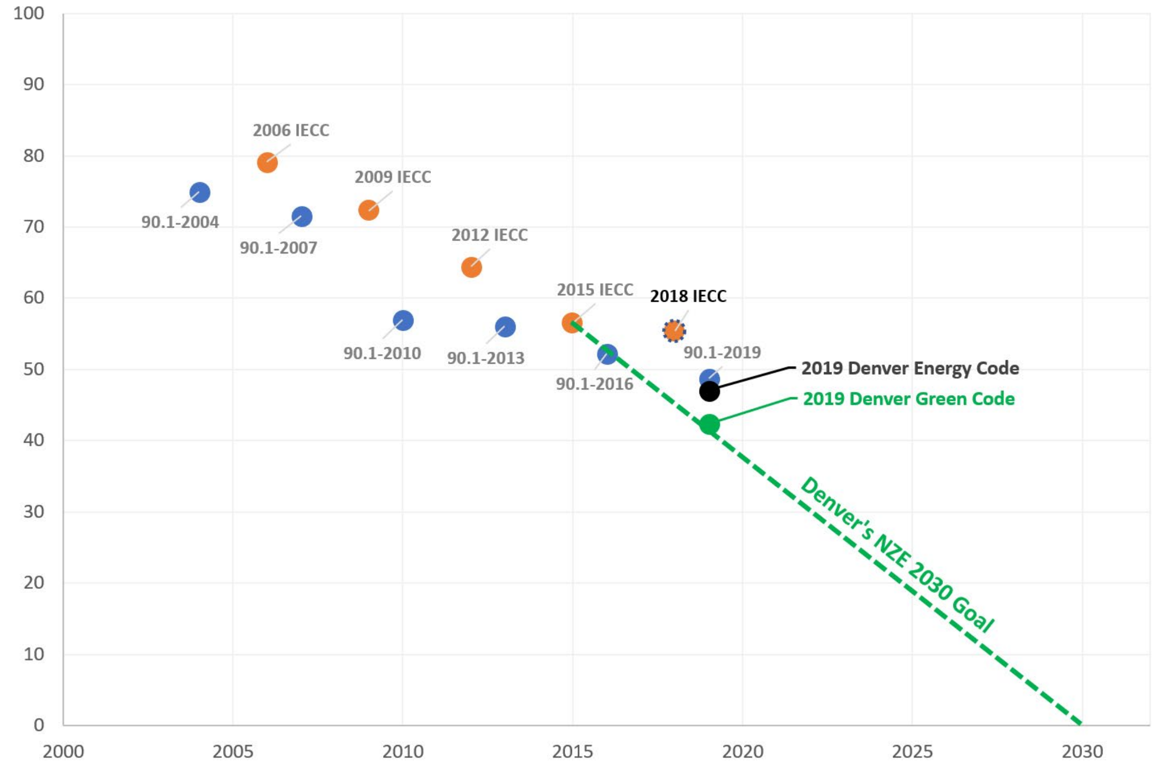


Figure 10. Denver's Path to Net Zero Energy – Commercial

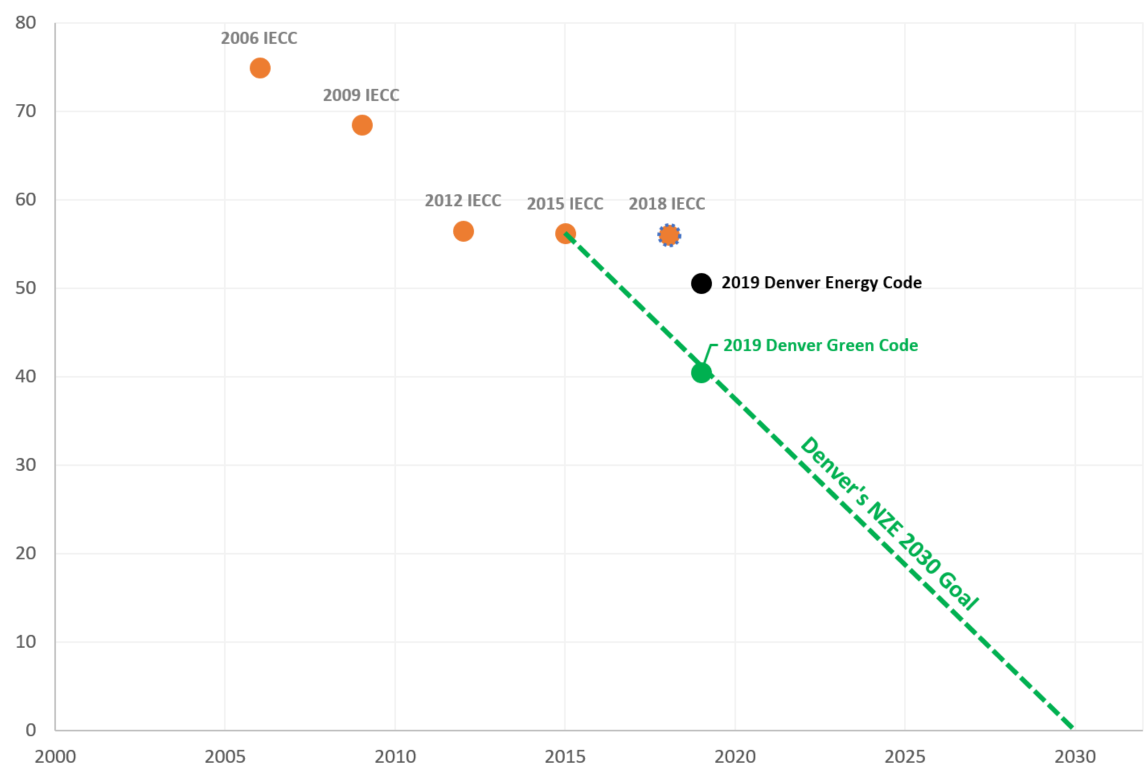


Figure 11. Denver's Path to Net Zero Energy – Residential

ENERGY PERFORMANCE TARGETS IN CODE

The inclusion of energy targets into energy codes and building policies represents a significant departure from the approaches applied by current model energy codes and standards as developed and published by the International Code Council (ICC) and ASHRAE. Leveraging the building performance energy modeling approach shifts the focus from prescribing component-level efficiency to whole building performance.

Incorporating energy targets into the modeling process is an essential step in bridging the gap between code compliance and actual measured energy performance in buildings. Modeling targets provides information about how a code-compliant building could be expected to perform in actual operation. The comparison of code targets to actual performance will inform building owners about potential problems, practitioners about the effectiveness and accuracy of their designs, and regulators about how well buildings are meeting code and policy goals.

Recently, performance targets have started to appear in energy codes, including the 2020 City of Boulder Energy Conservation Code, the 2015 Seattle Energy Code, and the 2018 British Columbia Energy Step Code. The jurisdictions that have taken steps to incorporate energy performance targets into their local adopted energy codes have typically done so by developing a project submittal and verification methodology that is applied as an alternative compliance pathway. In addition, some have established code roadmaps or plans that outline transitions over multiple code cycles from modeled predictions of energy targets to eventual verification of building energy consumption with actual performance data.

Denver's ultimate goal for the performance path is to reach performance verification codes so buildings will have to perform as designed where practical for that building type. Additionally, the Climate Action Task Force recommended that Denver move to outcome-based (performance verification) codes. As a framework, Denver needs to develop and address the following:

- Develop Performance Targets
    - Develop and set performance targets by building type
    - Highly efficient – pEUI targets
    - Address other building types
    - Use EUI targets
- Detail Performance Verification
    - Develop and implement policies for buildings to perform as designed
- Refine Energy Modeling
    - Streamline modeling paths – streamline energy modeling paths within code
    - Address modeling accuracy – increase focus on predictive accuracy through guidelines
    - Predictive modeling – go from comparative to predictive energy modeling
    - Modeling unregulated loads – incentivize improvements without a loophole
    - Modeling normalization – factors to adjust for in design and operation
- Specify Backstops
    - Eliminate trading out envelope improvements for renewables

Each of these items is detailed in the following section. Additionally, energy modeling enforcement plays a critical role in ensuring that buildings perform as designed.

Energy Performance Targets for Denver (by building type)

The development of energy performance targets focuses on the identification of potential targets for certain commercial building types in Denver and the incremental improvement that would be necessary in each code cycle to get to those targets by 2030. The first step is to determine EUI targets (Max Tech EUI) for Denver to place "book ends" on the code by defining where we are starting and where we are going with regard to energy performance targets by building type.

Energy Target Methodology

The research methodology used to generate energy targets utilizes multiple sources of data about building performance. These include specific data about the performance of Denver's existing building stock, determination studies about existing codes, multiple studies that assess the performance levels required to achieve zero net energy, and research into the maximum performance potential of existing technologies. This information is used to inform energy performance target setting in Denver by establishing "book ends" of how buildings are performing now, and how they will need to perform in order to meet the net zero goal in 2035 detailed in Denver's 80x50 Climate Action Plan as a first step. Then this data was used to align with the Climate Action Task Force recommendations to be net zero in Denver by 2030.

Existing building performance provides context on where the building stock is today. Code performance estimates suggest where the starting "book end" is in this new construction code approach today. Zero energy data sets are used to set far "book end" targets that would be required to meet Denver's goals. Extrapolating between those two points reveals discrete energy targets for the code cycles between now and 2030. These targets represent building energy use and do not include the renewable energy that would be required to achieve zero net energy in an individual building. Therefore, the targets never actually achieve "zero."

In the analysis, building types are separated because different building types have different performance characteristics and expected energy use. High-energy use in one building type may be low for another. Therefore, targets have been developed by building type. In addition, data in this analysis accounts for the Denver climate zone.

It is important to note that these EUI targets are "site EUI" and only consider energy consumed at the building rather than the complete supply chain and fuel types that contribute to source energy. Also, this analysis looks at energy that is related to, but is not the same as, carbon or greenhouse gas emissions.

Building Type Selection

The project team drafted and reviewed a list of priority building types to include in this research based on Denver's benchmarking data, the extent of code jurisdiction, and new construction forecasts. These building types represent the majority of buildings permitted and built in Denver, specifically: mid-rise and high-rise apartments, small and large hotels, medium and large offices, standalone retail, and warehouses.

Information on hospitals and restaurants are included in this report for context only. These two building types are not necessarily good candidates for energy targets in codes at this time because there is insufficient data to determine reasonable targets and limited data on performance of similar buildings to inform the effort. Additionally, the energy use of these building types can vary greatly based on factors outside the scope of energy codes, such as operating hours and plug and process loads.

Existing Building Performance

Denver shared commercial building energy benchmarking data as collected from the Denver commercial building disclosure ordinance. While data was collected in 2016, 2017, and 2018, the 2018 dataset is solely referenced in this analysis because a separate analysis suggested that the 2018 dataset appears to have more buildings included, which may be due to increased reporting in our disclosure ordinance. This data represents existing building energy performance for certain building types listed above. To represent typical energy performance in Denver, the analysis reports the median weather-normalized site EUI, as calculated by Energy Star Portfolio Manager in the disclosure data from the City.

Table 22 details the building characteristics from the disclosure data, including building sizes, property types, sample sizes and site EUI. Figure 12 offers a different view of that data; it shows the performance of each building type by vintage. Using initial data processing completed by the city, the analysis only included buildings tagged as appropriate for use in energy analytics. The analysis also used the "Property Type" for Percentile field included in the disclosure data file generated by the city to match buildings in the disclosure data to the list of ten building types studied. The "Property type for percentile" field is a consolidation of similar space use types reported in Portfolio Manager to simplify the analysis to fewer, more common building types. Note that restaurants did not have any samples in the 2018 dataset studied.

Table 22. Denver Benchmarking Data Included in the EUI Analysis by Building Type

Building Type	Property Type for Percentile	Size Range (ft²)	Samples (n)	Weather-normalized Median Site EUI (kBtu/sf/yr)
Mid-Rise Apartment	Apartment	0-80,000	202	61
High-Rise Apartment	Apartment	80,000+	281	92
Small Hotel	Hotel	0-100,000	43	66
Large Hotel	Hotel	100,000+	41	72
Medium Office	Office	40,000-100,000	166	64
Large Office	Office	100,000+	146	56
Standalone Retail	Retail Store	All sizes	26	79
Warehouse	Non-Refrigerated Warehouse	All sizes	124	45
Hospital*	Hospital (General Medical & Surgical)	All sizes	5	236
Restaurant*	-	-	0	-

**Hospitals and restaurants may not be good candidates for EUI targets for a number of reasons, including significant unregulated loads and little data to inform the analysis.*

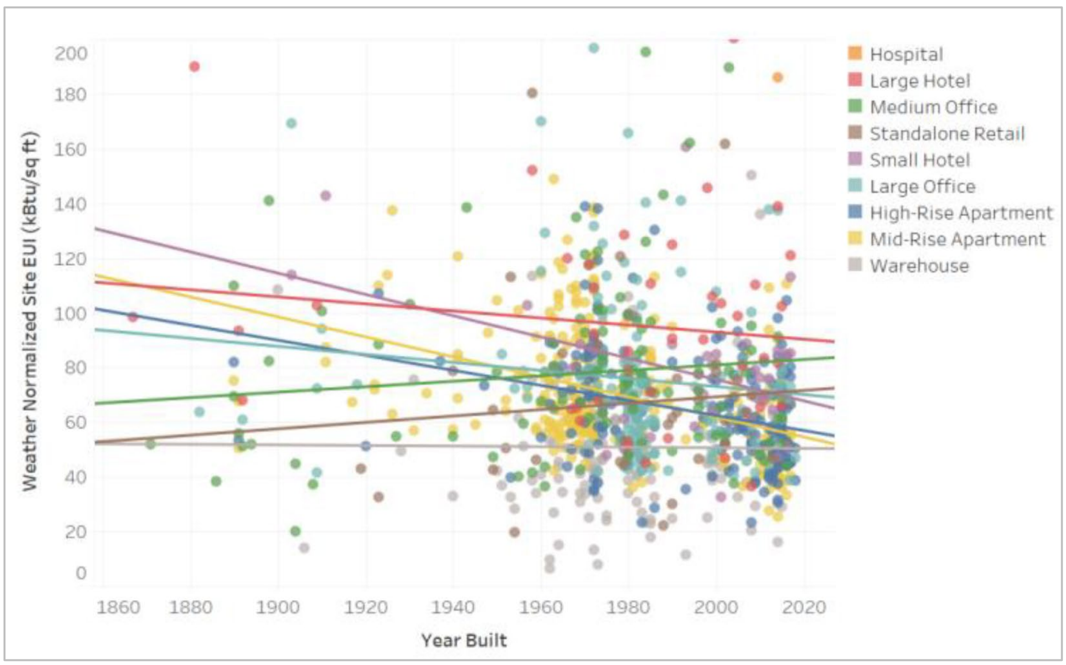


Figure 12. Building Performance by Age for Select Building Types

Energy Code Performance

For energy code performance predictions, NBI typically leverages energy modeling determinations by the U.S. Department of Energy[2]. Code determinations establish the expected energy performance for the national model base codes, including the IECC and ASHRAE 90.1. Code determinations are specific to climate zones, and Denver falls into climate zone (5B).

Denver has just adopted the 2019 edition of its energy code, which is a locally customized version of the 2018 IECC. Since U.S. DOE has not issued a code determination for IECC-2018, NBI has based code savings estimates on proprietary internal data, which suggests that IECC- 2018 is 3-5% better than the IECC-2015 and that Denver's 2019 energy code is about 15% more stringent than IECC-2018.

Zero Energy Performance Targets

Zero energy performance targets are the energy use intensity targets for each building type based on the maximum site efficiency using current technologies (without renewables). These targets represent the 2030 "book end" for the potential savings analysis. Zero energy performance levels are based on research compiled and conducted by NBI, which compiles a mix of modeled analyses and measured performance data for existing zero energy buildings in North America. Each data source represents a particular building type and is specific to Denver's climate zone (5B). Table 23 summarizes the measured performance data, technical potential studies and energy modeling analyses that support the zero energy EUI target development.

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[2] https://www.energycodes.gov/development/commercial/prototype_models

Table 23. Published Sources Informing the Performance Target Development

Title	Author	Description	Publication Year	Measured/ Modeled
NBI Getting to Zero Database [3]	NBI	Continuously updated collection of zero energy buildings in North America	2019	Measured and Modeled
Advanced Energy Design Guides [4]	Multiple	Detailed design guide for K-12 school and office buildings to achieve zero energy operation	2019	Modeled
The City of Toronto Zero Emissions Buildings Framework [5]	Multiple	Study to identify feasible maximum performance targets for zero energy buildings in the city of Toronto to meet its climate goals	2017	Modeled
Development of Maximum Technically Achievable Energy Targets for Commercial Buildings [6]	GARD Analytics	National study of best anticipated building performance using best-practice design and operations strategies	2015	Modeled
The Technical Feasibility of Zero Net Energy Buildings in California [7]	ARUP	Study of the best achievable building performance as a basis for zero energy code targets	2012	Modeled
Built to Perform: An industry led pathway to a zero carbon ready building code [8]	Multiple	Australian modeling analysis to establish zero carbon ready building targets	2018	Modeled

Zero energy performance targets based on these data sets are shown in Figure 13. This figure plots how zero energy sources compare by building type. Generally, the net zero performance target combines an average of maximum technical potential studies (i.e. studies that quantify the lowest energy building possible via modeling) and median EUI values for existing zero energy projects. In combining the data from those sources to establish the net zero energy performance target, NBI gave greater weight to measured data from existing buildings than modeling studies. NBI also normalized measured data from various climate zones to Denver's climate using conversion factors to equitably compare energy use between different climate zones.[9]

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[3] https://newbuildings.org/resource/getting-to-zero-database/

[4] https://www.ashrae.org/technical-resources/aedgs

[5] https://www.toronto.ca/wp-content/uploads/2017/11/9875-Zero-Emissions-Buildings-Framework-Report.pdf

[6] http://www.gard.com/

[7] https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=10721

[8] https://www.asbec.asn.au/wordpress/wp-content/uploads/2018/10/180703-ASBEC-CWA-Built-to-Perform-Zero-Carbon-Ready-Building-Code-web.pdf

[9] For more details, please see the Zero Energy Target Setting summary report available here: https://newbuildings.org/resource/zero-energy-commercial-building-targets/.

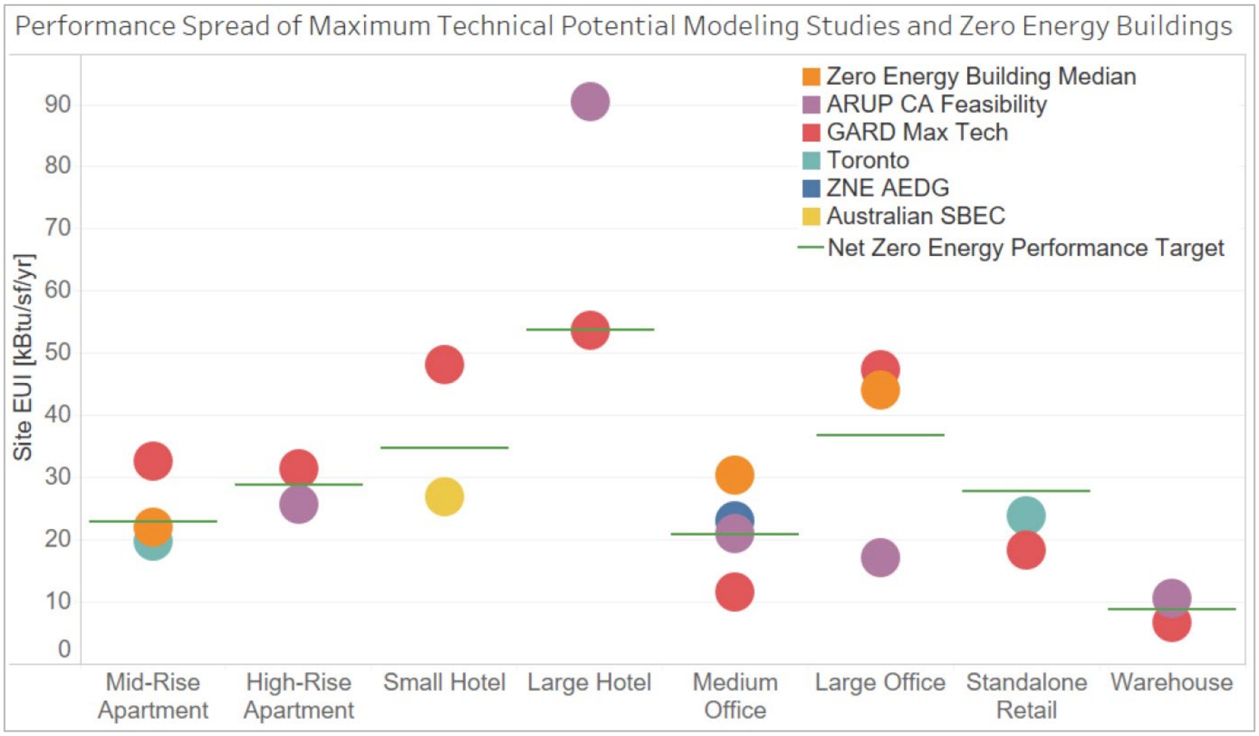


Figure 13. Net Zero Energy Data and Performance Targets by Building Type for Denver Climate Zone

EUI Analysis

Figure 14 plots EUI data from the multiple sources listed above, combining important information for stakeholders and policymakers to consider in setting energy performance targets for each code cycle going forward. It gives context to the performance targets such as current performance levels and net zero energy performance levels established in existing research. This also can help support the transition to a performance code compliance path that relies on absolute energy targets rather than "percent better" reductions. Of course, actual energy performance also will have to consider weather conditions and specific characteristics of individual building designs that may merit an increase or decrease in the energy target.

In Figure 14, the modeling analyses representing zero energy performance levels are shown as dark blue circles, measured Denver benchmarking medians are shown as teal circles, and the estimated 2019 Denver Energy Code (based on the 2018 IECC) performance levels are grey circles. The measured energy data for existing zero energy buildings in the Denver climate zone are included as orange circles, where available.[10]

[10] For large office, the plot points for Denver's benchmarking data and code-level performance are closer to net zero than expected. This is because the code determination studies include data centers within large office, a substantial energy load that may not be common in Denver's office buildings.

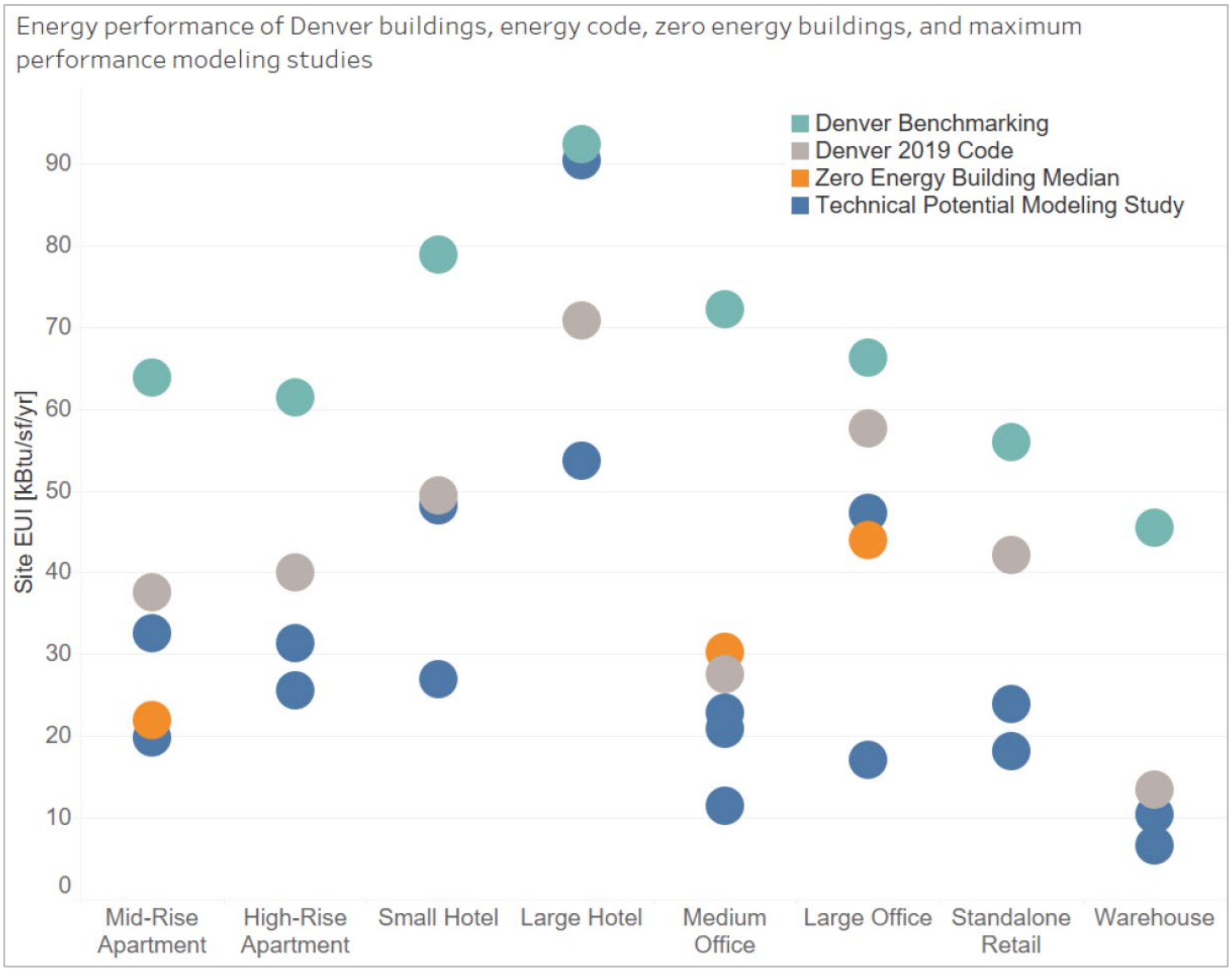


Figure 14. Site EUI from Multiple Data Sources by Building Type for Denver

Research by NBI and others suggest that whole-building energy performance levels, measured in Energy Use Intensity (EUI) of kBtu/square foot per year, are achievable with currently available technology and advanced design practices. Design guidance for reaching low energy consumption levels in various building types are available in NBI's zero energy resources hub,[11] including measured performance data, technical potential studies, and energy EUI.

Table 24 summarizes the site EUIs for the three data sets: existing building energy performance as defined by the Denver Benchmarking Median, the estimated 2019 Denver Energy Code Performance, and the NBI suggested net zero performance targets by building type.

[11] https://gettingtozeroforum.org/technical-resources/

Table 24. Published Sources Informing the Performance Target Development

Building Type	Denver Benchmarking Site EUI Median Performance	Building Type	Denver Benchmarking Site EUI Median Performance
Mid-Rise Apartment (R-2 - 4-7 stories)	64	38	23
High-Rise Apartment (R-2 – 8 or more stories)	61	40	29
Small Hotel (R-1 – 0-100,000 sf)	79	49	35
Large Hotel (R-1 – 100,000 sf and larger)	92	71	54
Medium Office (Group B office –40,000-100,000 sf)	72	28	21
Large Office (Group B office –100,000 sf and larger)	66	58	37
Standalone Retail (Group M)	56	42	28
Warehouse (Group S)	45	13	9
Hospital (I-2, Condition 2)	236	107	n/a
Restaurant (Group A-2 w/commercial kitchen)	-	321	n/a

The zero energy ready targets we propose are significantly lower than the existing building median in Denver, typically by half or more. This variation is expected given that the vast majority of existing buildings may predate modern energy codes.

Figure 15 illustrates the extent that buildings and code have reached net zero energy targets at this point in time. This gap between energy consumption in existing buildings and net zero targets is expected to be shored up by a combination of advancing energy codes and policies, as well as operational practices in buildings to reach and maintain high-performance. Due to technological advancements, the performance level of buildings that achieve net zero energy may improve over time, so the performance target end point also may change for the better.

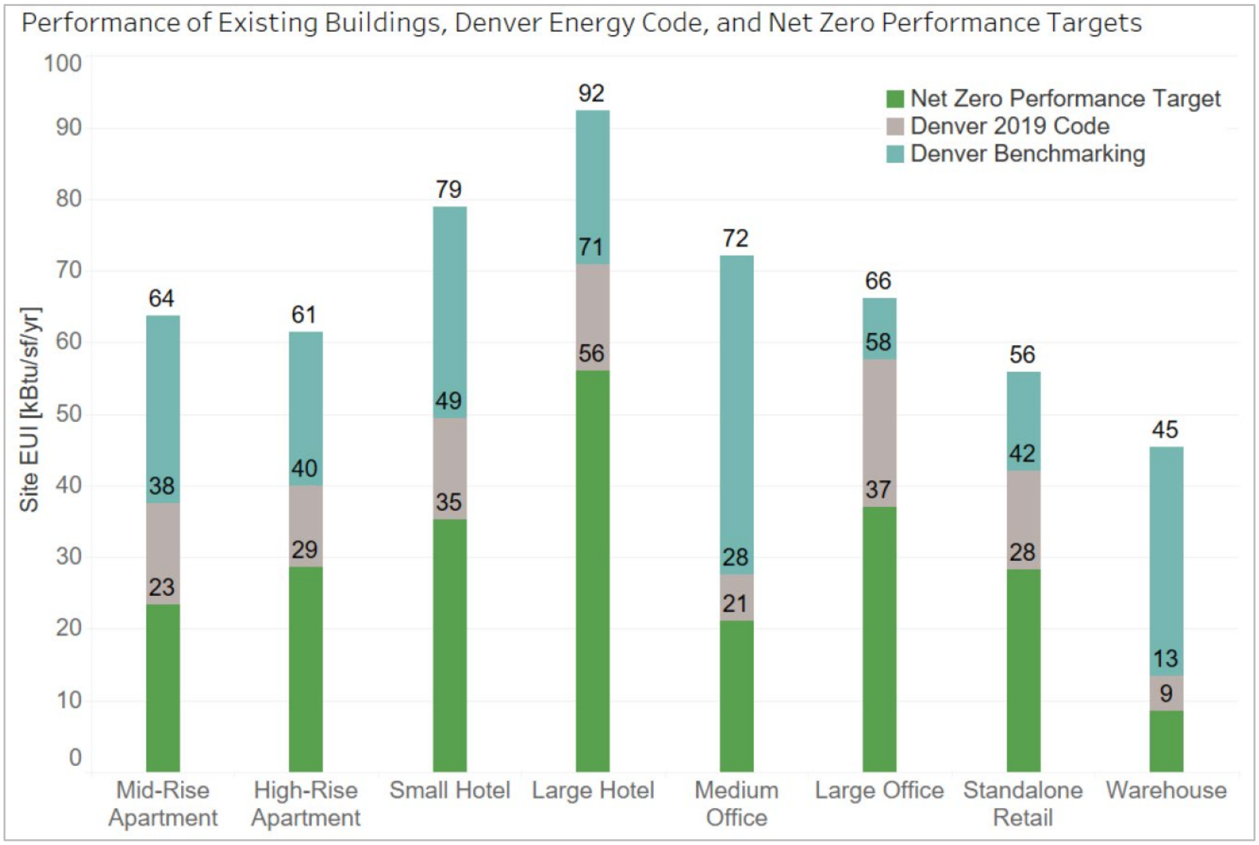


Figure 15. Energy Performance of Existing Buildings, Energy Code, and Net Zero Targets by Building Type

Implications for the Denver Energy Code

The next step is to focus on the getting from Denver's code today and net zero performance. Figure 16 plots a course for predicted building performance improvements to zero by 2035. The 2016 points represent the old Denver code (based on 2015 IECC). The 2019 points show the recently adopted 2019 version of the code (which is better than 2018 IECC). For each building type, Figure 16 extrapolates from current code estimates to net zero performance (assuming a three-year code improvement cycle). Then, assuming equal Energy Use Intensity (EUI) progress in each cycle to get from where we are to where we are going, we plot a straight line for each building type. **This does not consider the probability that net zero buildings in the future may perform even better from an energy perspective. If this is the case, the net zero end points need to be recalibrated at each code cycle increment.**

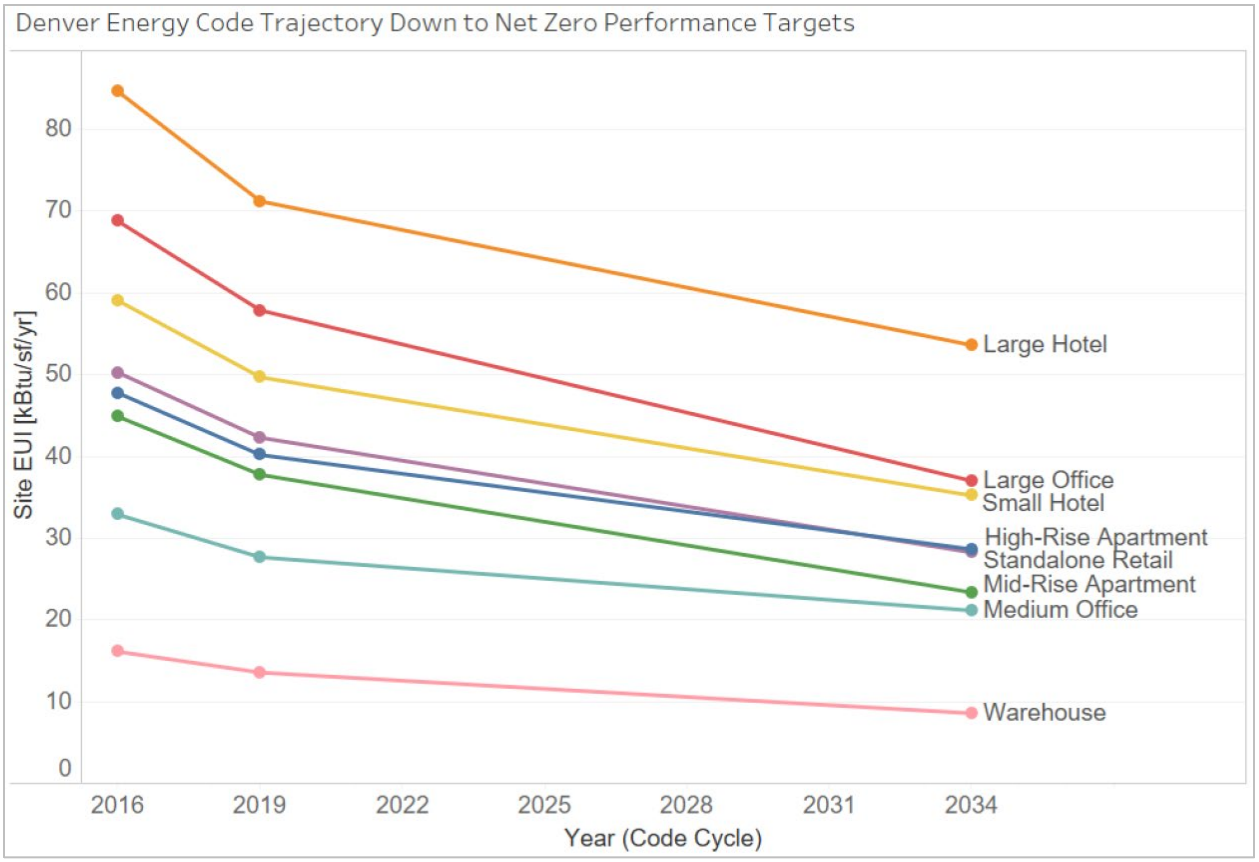


Figure 16. Energy Code Performance Trajectory to Zero Energy by Building Type

Table 25 details the site EUI for each building and code cycle from the plotted scenario. The savings for the upcoming code cycles will need to average 8% (Range: 5-10%) across building types. Looking historically at energy code improvements of both ASHRAE Standard 90.1 and IECC suggests that consistent savings of 8% may be out of the range of expectations for national model codes. **It will therefore be imperative for Denver to continue to push beyond model codes.** The current approach of leveraging the voluntary stretch code along with other policies will help Denver reach net zero energy performance by 2035 and aligns with the current Denver 80x50 Climate Action Plan.

Table 25. Code Performance Trajectory to Zero Net Energy Performance by 2035 (by building type)

Building Type	Site EUI (kBtu/square foot/year)							Average Savings/ Cycle
	2016	2019	2021	2024	2027	2030	2033	
Mid-Rise Apartment (R-2 - 4-7 stories)	45	38	35	32	29	26	23	10%
High-Rise Apartment (R-2 – 8 or more stories)	48	40	38	36	33	31	29	7%
Small Hotel (R-1 – 0-100,000 sf)	59	50	47	44	41	38	35	7%
Large Hotel (R-1 – 100,000 sf and larger)	85	71	68	64	61	57	54	6%
Medium Office (Group B office – 40,000-100,000 sf)	33	28	26	25	24	22	21	5%
Large Office (Group B office –100,000 sf and larger)	69	58	54	50	45	41	37	9%
Standalone Retail (Group M)	50	42	39	37	34	31	28	8%
Warehouse (Group S)	16	14	13	12	11	10	9	9%

Table 25 outlines a building-type specific path to zero energy in commercial buildings. These are focused primarily on the energy performance of the building as measured in site EUI. They do not consider renewables or that fuel sources for electricity in Denver will become less carbon intensive over time.

The adoption of predicted energy performance targets puts a significant burden of proof on the energy modeling process. Certain aspects of this process easily can be misrepresented, resulting in a building that performs very differently from what the energy model estimates predicted.

Despite this, energy modeling will continue to be an essential tool not only in reducing energy loads in buildings but also to help determine energy code compliance. As these tools continue to advance and be utilized by designers and building departments, it is essential that there is feedback and accountability in this process. The simple act of going back to update and understand energy modeling accuracy closes an important feedback loop for the design community and pushes the industry toward more accountability on predictive modeling. Over time with this enhanced feedback loop, the discrepancy between predicted performance and outcome performance will be reduced, and accuracy of models will improve.

As the NZE Stakeholder Advisory Groups reviewed the climate goals and recommendations, they ultimately recommended that this plan be developed to reach net zero energy by 2030 and align with the Climate Action Task Force recommendations. Because of this, the analysis above was used to determine what the site EUI requirements need to be to meet net zero energy by 2030 as shown in the Table 26.

Table 26. Code Performance Trajectory to Zero Net Energy Performance by 2030 (by building type)

Building Type	Site EUI (kBtu/square foot/year)					
	2016	2019	2021	2024	2027	2030
Mid-Rise Apartment (R-2 – 4-7 stories)	45	38	35	29	23	23
High-Rise Apartment (R-2 – 8 or more stories)	48	40	38	33	29	29
Small Hotel (R-1 – 0-100,000 sf)	59	50	47	41	35	35
Large Hotel (R-1 – 100,000 sf and larger)	85	71	68	61	54	54
Medium Office (Group B office – 40,000-100,000 sf)	33	28	26	24	21	21
Large Office (Group B office –100,000 sf and larger)	69	58	54	45	37	37
Standalone Retail (Group M)	50	42	39	34	28	28
Warehouse (Group S)	16	14	13	11	9	9

Denver's Energy Targets

This section finalizes the energy targets based on the analysis above for Denver by building type and code cycle. These targets will enable Denver to reach net zero energy new buildings and homes by 2030. This also includes the milestones for new homes to reach net zero energy and all-electric by 2024, and for new buildings to reach net zero energy and all-electric by 2027. As part of this NZE Plan, Denver asked the NZE Stakeholder Advisory Groups to review the predictive energy use intensity (pEUI) and energy rating index (ERI) targets for buildings and homes respectively to determine recommendation for upcoming code cycles.

Table 27. NZE 2027: Commercial pEUI Targets for Denver Code

Building Type	2021	2024	2027	2030 Performance Verification
Small Hotel	47	41	35	35
Large Hotel	68	61	54	54
Medium Office	26	24	21	21
Large Office	54	45	37	37
Standalone Retail	39	34	28	28
Warehouse	13	11	9	9

Table 28. NZE 2027: Multifamily pEUI Targets for Denver Code

Building Type	2021	2024	2027	2030 Performance Verification
Mid-Rise Apartment	35	29	23	23
High-Rise Apartment	38	33	29	29

Table 29. NZE 2024: Residential ERI Targets for Denver Code

Building Type	2021	2024
Single-family Homes	Max ERI = 50 & ERI w/PV = 40	Max ERI = 45 & ERI w/PV = 0

Other Building Types

Some buildings will have a design target predictive energy use intensity (pEUI) that ratchets down over time as detailed in the tables above. However, building types that do not lend themselves to a target EUI will model a baseline and a percent improvement over that baseline.

Table 30. Energy Savings Targets for Other Building Types

ASHRAE 90.1-2016	2021	2024	2027
% Savings Over Baseline	15%	30%	45%

This results in two modeling options:

1) pEUI targets for typically predictable building types. Developers can model to prove they meet the pEUI for those building types.
2) Alternately, projects can be modeled to a baseline and a percent better than baseline.

Use of Predictive Energy Use Intensity (EUI) Targets

The pEUI targets outlined above are an important cornerstone of the code strategy to zero energy in Denver. **They serve as a clear indicator to building owners and designers on how buildings of a specific type in the Denver market will be expected to perform going forward.** Below is a brief outline of how pEUI targets might be used by the city and local building market actors. The prescriptive and the performance code approaches are topics for future work by NBI under the American Climate Cities Challenge project.

- In the **prescriptive approach**, pEUI targets can be used to calibrate the performance goals for future iterations of the prescriptive code in order to ensure that it is sufficient to achieve the energy performance targets for various building types. This will be done through energy modeling and calibration. If pEUI targets are not achieved, Denver can leverage new provisions in the 2021 International Energy Conservation Code (specifically section C406 options in commercial and the flex points packages in residential) to increase savings required locally. These code provisions, which are new in the 2021 IECC, offer flexibility and provide an easy mechanism for the city to require increased efficiency while minimizing modifications to the model code.

- In the **performance approach**, pEUI targets can be used to eliminate the need for a "percent better than code" modeling approach. For certain building types where pEUI targets are appropriate, energy modelers can simply create a building model where the predicted pEUI meets the target, as opposed to needing to create a code baseline model for comparison. Eliminating the need for a code comparison model will save time and money for the energy modeler, and therefore the building owner, using the performance approach as the path to code compliance. However, it is imperative that energy modeling assumptions are standardized, even beyond what is already required in the ASHRAE Appendix G Performance Rating Method.
- In the **benchmarking and disclosure** program, energy targets will align with predicted pEUI disclosed in the code compliance documents. With this data, the city will be able to inform owners (and their energy modelers) about how the building actually performs compared to these predictions, closing an important feedback loop in the buildings market. Most energy modelers have no way of knowing how the buildings that they model actually perform, so this information will help inform and improve their modeling process. This is key to transitioning energy modeling from an estimation tool to a predictive one. Conversely, most building owners do not know how their buildings were intended to perform. This information will provide information to owners and facilities staff about how well buildings are meeting their design expectations.
- In **building energy performance standards**, pEUI targets in new construction codes create a connection between code compliance in today's new construction as they transition to compliance with tomorrow's existing building performance standards. Energy targets for each code vintage can have their own standards, which are more efficient than those set for existing buildings today. This helps to ensure that newly constructed and recently renovated buildings are set to a higher standard than today's existing building stock and contribute to meeting Denver's ambitious climate goal.

Performance Verification

Traditional code compliance paths – both prescriptive and modeled performance – are effective at regulating the features that go into a building, but not at how those buildings are operated. If Denver is going to meet its climate goals, it will need to ensure that the energy code delivers the energy savings that policy-makers expect. By comparing the performance expected from the energy code with actual performance, performance verification can support both of these goals. Performance verification is a type of outcome-based code that was recommended by the Denver Climate Action Task Force. Additionally, performance verification will connect the design process with the benchmarking requirement in buildings over 25,000 square feet.

IMPROVING THE ENERGY CODE AND OTHER POLICIES

Performance verification can validate and refine energy code requirements and modeling methodologies. It verifies that recently constructed buildings are performing as expected by comparing the actual performance against the performance expected from the code. It creates a feedback loop between the energy code, building designs and actual performance. A performance verification policy will give design teams information about the actual performance of their designs, which will allow them to see how well various design decisions are translating to actual performance and to assess the quality of their energy analysis efforts. The feedback loop also provides information to policy-makers, allowing them to see whether code requirements and modeling methodologies are leading to the expected performance as well as whether code enforcement efforts are effective. The result is that both design practice and the energy code itself can be improved by the information that performance verification provides. **The enforcement mechanism provides far more impetus to designers and owners to pay attention to the relationship between designs and actual outcomes than a disclosure law.**

Performance verification also can reinforce and enhance other policies and supports to the community that have a performance component. For example, some cities use above-code performance as a requirement for development bonuses or tax credit programs. Performance verification can be integrated into these policies to provide greater certainty that participants are delivering the performance levels expected, and refine the program offering. Performance verification also will give the public more confidence that these projects are actually providing a real, verifiable benefit to the community. **Implementing performance verification for these kinds of policies can serve to build capacity in staff and acceptance in the market for other, more comprehensive outcome-based policies in the future.**

IMPLEMENTATION CONSIDERATIONS

There are some specific considerations to address in the crafting and implementing of a performance verification policy. Enforcement of a performance verification policy needs to bridge the time between construction and actual performance. There are a handful of ways this can be done including:

- **Temporary Certificate of Occupancy (TCO):** Before occupancy, buildings receive a TCO, and a full Certificate of Occupancy (CO) is not issued until they have demonstrated that they meet the performance target. This approach has the potential to be highly effective since buildings with TCOs can be difficult to refinance and sell. However, building officials often are reluctant to utilize TCOs, which can be difficult to enforce and do not fit well into the existing inspection processes of many building departments.
- **Code Violation:** If the building fails to demonstrate compliance, then the building is issued a code violation that can be cleared only by demonstrating compliance. This can be effective when code violations are an obstacle to leasing, selling or financing a building.
- **Fines:** Buildings that fail to meet the performance target of the code are fined. The success of this approach depends on the magnitude of the fine, which needs to be high enough not to be relegated to the cost of doing business.
- **Surety Bond:** The building owner provides a surety bond before the building receives a CO and receives the bond back when the building meets the performance target. An advantage of a surety bond over a fine is that many commercial buildings are built as speculative developments and the bond is effectively transferred with the building when the building is sold. It also simplifies collection. Jurisdictions might struggle to collect fines after the fact, but easily can get a surety bond that is a pre-requisite for the CO. As with fines, the bond needs to be substantial enough to incentivize compliance. A jurisdiction also needs a way to hold the bond.

An important consideration is the compliance period – how long a building is required to demonstrate actual performance that meets the target. If a building needs 12 months of continuous performance data to demonstrate compliance, the compliance period will need to be longer. Most buildings have about a six-month period when tenancy ramps up and systems are fine-tuned. Say the compliance period were limited to 18 months, then that still would not be enough time to remedy any problems with the building that arose during full operation. A **24- to 36-month compliance period is recommended** to provide a buffer for the building to reach full operation and remedy issues. A longer compliance period also benefits building owners, helping to reduce market resistance to the policy.

ENERGY CODE REQUIREMENTS THAT SUPPORT PERFORMANCE VERIFICATION

A performance verification policy is more likely to be successful if new buildings include features that enable more efficient and effective operations. When crafting a policy, it is beneficial to pair it with a set of enhancements to the energy code to make it more likely a building will be able to perform as expected. Some examples include:

- **Metering and Monitoring:** While a utility bill can provide the information needed to enforce a performance verification policy, it does not provide enough information to effectively monitor a building's performance. Whole-building interval metering of all fuels with a clear energy display will give building operators information that can be used to track how the building is performing and identify issues as they occur.
- **Sub-metering and Load Segregation:** While a lot can be learned from whole-building metering, even more can be learned from sub-metering the various buildings systems. By segregating different load types – HVAC, lighting, water heating, plug loads, etc. – from each other and metering them separately, building operators are able to pinpoint which systems may be the source of performance issues when whole building metering only allows them to see that there was an issue somewhere in the building.
- **Granular Control Zones:** Large control zones for space conditioning, and especially lighting and ventilation, result in large portions of the building being active even when those zones are only partially occupied. Smaller control zones limit the energy impact of irregular or uneven occupancy schedules.
- **Automatic Controls:** Manual controls require occupants to consistently manage them. Automatic controls allow loads to be reduced by limiting reliance on occupants.

Modern model codes have many of these features, so Denver does not need to create them from scratch but simply ensure they are adopted as part of the energy code.

Refining Energy Modeling for Performance Targets and Verification

There are a number of items to address regarding energy modeling to ensure that performance verification is possible in Denver. As mentioned previously, Denver will need to calibrate the performance path and prescriptive path each code cycle to ensure each path is delivering the same performance. Along with calibration, Denver will need to streamline energy modeling paths, address modeling accuracy, go from comparative to predictive modeling, address unregulated loads, and detail modeling normalization.

STREAMLINING ENERGY MODELING PATHS

Within the IECC, current energy modeling paths offer varying results and have different levels of guidance and specifications for whole building/unit energy modeling. An additional complication is that the mandatory requirements for each path vary. The whole building modeling pathways in the 2018 IECC include:

- Commercial 2018 IECC modeling paths
  - 2018 IECC: C407 Total Building Performance
    - C407.2 Mandatory requirements
    - Energy cost analysis
    - Limited guidance on modeling/analysis
  - ANSI/ASHRAE/IESNA 90.1-2016: Chapter 11 Energy Cost Budget Method
    - 11.2 Mandatory requirements
    - Energy Cost Budget analysis
    - Limited guidance on modeling/analysis
  - ANSI/ASHRAE/IESNA 90.1-2016: Appendix G Performance Rating Method
    - G1.2.1 Mandatory requirements
    - Performance Cost Index (PCI) analysis
    - Extensive guidance on modeling/analysis
    - Appendix G used for LEED energy modeling methodology, though the PCI method is new
- Residential 2018 IECC modeling paths
  - 2018 IECC: R405 Simulated Performance Alternative
    - R405.2 Mandatory requirements
    - Energy cost (with exception allowing source energy use analysis)
    - Limited guidance on modeling/analysis
  - 2018 IECC: R406 Energy Rating Index (ERI) analysis
    - R406.2 Mandatory requirements
    - Energy cost
    - Detailed guidance on modeling/analysis
    - ANSI/RESNET/ICC 301 is the basis for a HERS Index and used by raters

As codes progress, the first task is to streamline these paths for Denver to minimize the options and assist with code enforcement while providing appropriate flexibility to the community. As a first step in the 2019 code, Denver eliminated the ANSI/ASHRAE/IESNA 90.1-2016 Chapter 11 Energy Cost Budget Method to reduce the commercial whole building modeling pathways to two. **Depending on feedback from Denver's community, there is potential in the next code cycles to further reduce the number of pathways.**

ENERGY MODELING ACCURACY

Approaches to increase proficiency and accuracy of energy modeling for commercial/multifamily and single-family are needed in Denver. There are a number of resources and studies on the accuracy of energy modeling. The only effective way to increase accuracy is through predictive energy modeling that is then normalized (calibrated) to account for actual weather, building occupancy, schedules and more.

The following steps are intended to prepare the market for a future outcome-based code.

Near-term Steps:

- Introduce predicted energy use intensity (pEUI) as an option for the modeled performance approach using the pEUIs that have the highest levels of confidence.
- Establish a local network of energy modeler expertise and incentives and trainings to improve that expertise.
- Encourage the network to compare modeled assumptions to actual performance. Research how the city can ensure this through reporting procedures to communicate predicted EUIs compared to actual measured results back to modelers, designers and owners.

Mid-term Steps:

- Expand pEUIs available based on additional data from more data sources including code submittals and make the pEUI approach mandatory for certain building types.

Long-term Steps:

- Make pEUI mandatory for all modeled performance compliance.

Enhancing energy modeling accuracy is the basis of getting to predictive modeling, which is key in performance verification.

Energy Modeling Guidelines

To increase accuracy of energy modeling, Denver will need to establish modeling guidelines for commercial/multi-family and single-family. Denver is currently creating a checklist for energy modeling requirements, and the city is collaborating with Boulder to align performance path documentation requirements and learn from each other as modeling is increasingly used for code compliance.

Currently, Denver staff provide guidance on the expectations for energy modeling in response to Site Development Plan (SDP) submittals, prior to CDs being submitted for permit

Energy Mode Expectations for Accuracy:

Denver CPD staff provides expectations for energy modeling at superstructure permit submittal that helps streamline GBO review including:

- Per GBO R+Rs Article IV Section 4.04(c)(ii), please provide energy model data indicating estimated annual average electricity usage including both site and source pEUI values. If the building includes parking please provide four pEUI values: site and source for the building excluding parking, and site and source for the building including parking.

- With this data, please provide a statement pertaining to identifiable limitations to reasonably anticipated accuracy of data. Please do your best to speak to limitations you think will create the biggest challenges specific to this project, related to anticipated occupants, building design features, team structure, or other characteristics.

- This statement should focus most on limitations imposed by modelling approach taken (code compliance as opposed to predictive performance, eg), but may also speak to expected impact that might be associated with factors such as project team coordination of occupant use assumptions and ownership building operations; building envelope and building system detailing and controls; expected construction quality / constructability of details; inability of energy modeling approach to account accurately for air infiltration and/or thermal bridging; expectations for facilities maintenance; or other factors the team deems relevant.

- Please include a ROM best professional estimate for percentage swing in accuracy of values / anticipated difference between anticipated (pEUI) and actual energy use (EUI), understanding that EUI data will become available each year following construction via Denver's mandatory (shown in the sidebar). This also empowers design teams to streamline the project's Green Buildings Ordinance (GBO) review.

The energy modeling industry takes time to understand accuracy. One example is Boulder, where they do not yet require performance but do report back to developers/modelers via benchmarking so they get feedback and start to learn how to model more accurately. Within the next code cycle in Boulder, energy modeling will have to be within ~15% of the target. The following code cycle, ~10% is the required tolerance, then ~5%, and in 2031 actual performance is required in Boulder. **For Denver, this also will be the basis for moving toward performance verification.**

PREDICTIVE ENERGY MODELING

One challenge to advancing the stringency of the performance path – and to the greater alignment of modeled performance with actual performance – is that the current modeling approach within code is a comparative model. Both the IECC section 407 and ASHRAE modeling are a proposed building model compared to a baseline. Fundamentally, a comparative model is not a predictive model. In some cases, the proposed model is assumed to use baseline systems and components due to modeling protocols.

In order to address this limitation, the modeled performance path will need to transition away from a comparative model to the use of performance targets. The inclusion of energy targets into energy codes and building policies represents a significant departure from the approaches applied by current model energy codes and standards as developed and published by the International Code Council (ICC) and ASHRAE. **Leveraging the building performance energy modeling approach shifts the focus from prescribing component-level efficiency to whole building performance.**

MODELING UNREGULATED LOADS

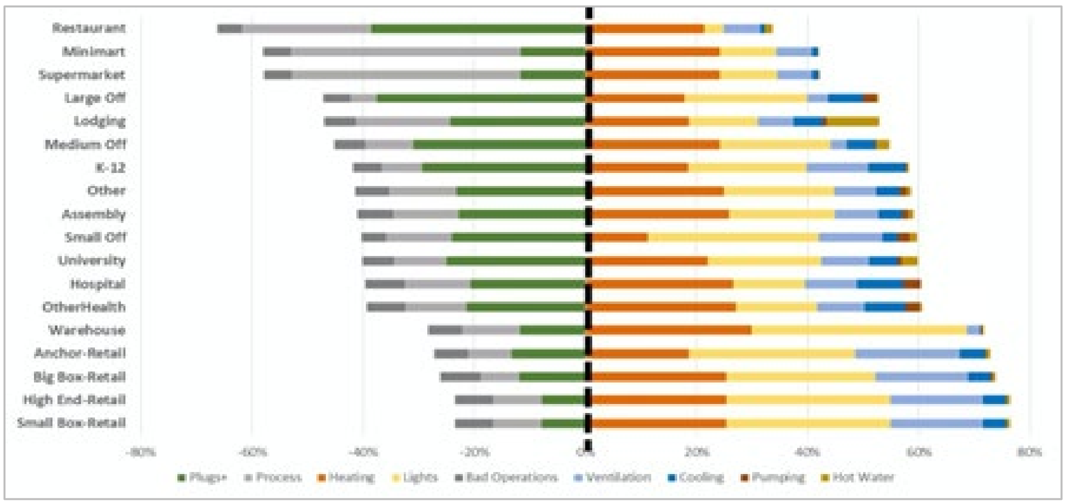
One of the most significant things that performance verification can do is provide a way to regulate the loads that traditional energy codes leave unregulated and under-regulated. Performance verification will allow Denver to ensure that the maximum limit for unregulated loads in the performance target are actually met. Buildings will be unlikely to meet a performance target if their plug and operational loads exceed those anticipated in the target. By lowering that limit over time, building occupants will be incentivized to choose efficient equipment and operate it efficiently.

Even the regulated loads in new buildings are not completely regulated by the energy code. Many operational factors can impact the actual performance of the systems that are regulated by the energy code. Factors like thermostat set-points and automatic control configuring (or disabling) can have a significant impact on building performance. While existing energy codes cannot impact these post-occupancy issues, a performance verification policy can.

An additional advantage of addressing unregulated loads is that it reduces reliance on regulated loads as the only option for meeting Denver's climate goals for new construction. A performance verification policy allows a jurisdiction also to generate energy savings from unregulated and operational loads. This in turn can result in simpler energy codes that are easier to follow and enforce, and less controversial to adopt.

To encourage projects to address the impact of unregulated loads on building energy use, specific credits may be allowed in the modeling process to account for commitments by the project to reduce unregulated load energy use. In the early stages of this, credit for unregulated load reduction will be limited to 10 percent of anticipated loads. As the building department and projects become acquainted with strategies to pursue and document reduction in unregulated loads, the amount of savings allowed in this category may increase. By the 2030 cycle, managing unregulated loads will be an integral part of achieving NZE building performance.

Denver can develop policies to better address unregulated loads. Figure 17 includes an example of this issue from Washington state. It shows the regulated vs. unregulated end uses by building type. In order to meet Denver's performance goals, it will be necessary to address these unregulated loads that are beyond the scope of the energy code as part of performance verification policies.



Source: NBI

Figure 17. Regulated and Unregulated End Uses by Building Type Based on the Washington State Energy Code [12]

NORMALIZATION FOR ENERGY MODELING

Despite the best intentions of designers, energy modelers, and building operators, building energy use can vary from year to year based on factors outside the control of these groups. Changing weather will introduce variability, as will changes in tenants, occupant density, building use, etc.

These are perfectly normal reasons for building energy use to fluctuate and must be accounted for in considering whether a building is achieving its performance goals/requirements. Adjusting building energy targets based on these factors is called 'normalization' of performance expectations. Once enforcement mechanisms focus on measured building performance data, performance targets will need to be able to account for normalization strategies so that buildings can carry on with their typical market function of adding and reducing occupants, changing use types (like adding a deli on the main floor), and maintaining comfort in a particularly cold winter.

Normalization accounts for routine weather and market variability that is an expected part of building operation. Normalization factors will account for performance variability that is not the result of poor operations and inefficient system operation, so that buildings can adjust performance targets over time

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[12] *Washington State Energy Code Roadmap.* Prepared by New Buildings Institute. 2015.

based on actual weather and use characteristics. It is to be anticipated that individual projects may request specific adjustments to performance criteria based on unanticipated tenant and operating characteristics. This ability to adjust performance targets will become more critical over multiple code cycles, as buildings are expected to perform more closely to the performance targets set in the design process.

There may be potential normalization factors that are needed to address reasonable variables that must be considered (change of use, abnormal weather conditions, etc.) Eventually Denver could develop and publish normalization protocols to clarify for energy modelers the allowable normalization factors.

The normalization recommended for 2021 is including discrepancy reporting between modeling and design. In future code cycles, the recommendation is to include normalization for occupancy, schedules, and weather.

PERFORMANCE PATH BACKSTOPS

In a performance-based path, modeling tradeoffs can be made between different building elements in order to achieve the whole-building goal. However, one danger of tradeoffs is that buildings might lower the performance of a building component too far. Code backstops ensure that certain minimum standards are met even while there is flexibility above those absolute minimums.

Backstops are already present in the energy code, such as mandatory minimums which ensure that certain building features do not get traded off for efficiency elsewhere. In the IECC, these include minimum requirements for items such as building air leakage, lighting controls and HVAC equipment efficiency. Modeling protocols in the performance path are a less obvious example of a backstop. These protocols set rules for how building features are modeled. This kind of backstop limits the impact that modeling variables can have on whether a building complies with the code or not.

Backstops could play another important role specifically in Denver. Denver's NZE Plan is structured with multiple "foundations" where energy efficiency and renewable energy are addressed separately. However, as Denver moves closer to its 2030 goals, it may become necessary to have some interaction between those foundations, and backstops would play an important role in managing the impact of that interaction, ensuring that efficiency is not simply traded off for more renewables.

Backstops play an especially important role in any code or policy requirements that are based on actual building performance. As Denver progresses towards its 2030 goals, its energy policies will need to directly address operations in buildings. Backstops ensure that new buildings have the features necessary to allow them to be operated to meet the performance goals.

- Backstops play multiple roles in the energy code and take multiple forms including mandatory minimums and modeling protocols.
- Mandatory minimums provide guidance to the design community, ensure that critical building features meet minimum performance standards, and set minimum requirements for building features that modeling does not fully address.
- Modeling protocols are a form of backstop that applies to how a building must be modeled instead of the features that must go into a building.
- Backstops that are necessary to address limitations in modeling, including those for hot water distribution systems, how models address thermal bridging, and daylighting.

- Addressing building operations through outcome-based codes requires that actual performance requirements be linked with building feature backstops.
- Alternate metrics can be used as a part of a backstop to achieve specific goals like renewable energy and electrification. Examples of alternative metrics might be a greenhouse gas use intensity, thermal energy demand, and peak energy/carbon load per square foot.

Backstops can be used to extend the viability of the prescriptive path while minimizing the integration of the energy efficiency and renewable energy within Denver's NZE Plan.

Energy Code Enforcement

One challenge with the IECC is ensuring that code is enforced. This becomes even more important when implementing performance verification policies to ensure that a design meets code prior to construction. In 2019, Denver conducted an assessment to determine how compliant the city was at applying the IECC code. The study was conducted by the Institute for Market Transformation (IMT) and Natural Resources Defense Council (NRDC). Researchers and Denver's Community Planning and Development (CPD) selected several projects for the evaluation.

The scope of the research was to "assist the city in meeting its climate goals by reviewing the previous report and determining which recommendations have been implemented, repeating the full CEP Assessment Methodology, providing recommendations for IECC compliance under the current and updated code, and identifying potential barriers to compliance with the IgCC and any subsequent reach code."

The results of the project showed that many issues arose during the construction, permitting and inspection processes of these buildings, which resulted in the city receiving a 65% compliance rate. Many of the issues had to do with lack of communication, poor knowledge of building codes, vague communication and difficulty communicating with people involved in the construction of the building. The two biggest issues involving communication were centered around internal and external communication.

Internally there were many administrative issues involved in these processes. Researchers found that there were an overwhelming number of permits and inspections for the staff and that incentives encouraged approving permits at high volume. Hiring more staff and building better review policies for permitting and inspections were suggested remedies. Creating better outlined and more efficient building inspection sheets for inspectors and builders also was put forth.

External problems included unclear instructions, poor builder training and knowledge, and shortcuts. Suggestions for improvement included writing notes to the builder in clear, informative and concise language to foster a better understanding of instructions. It was recommended that Denver host events to educate city staff and builders to help inform both sides about building codes. Also suggested was a secondary internal review of externally submitted check sheets or compliance forms to check for accuracy. Finally, ensuring the calibration of energy modeling systems used in these processes was a concern.

The most significant suggestions from this study were focused on increasing communication internally and externally, educating builders and city staff about code, creating better administrative form review and submission processes, creating more efficient communication routes between city staff/builders/designers and creating more effective inspection check sheets to ensure nothing is skipped or missed during inspection.

It has become clear that Denver's CPD team will need additional staff to support compliance for the IECC based on the "City and County of Denver Energy Code Assessment Report" from IMT and also requires additional staff to reach the climate goals detailed in this NZE Plan. Currently, Denver has only 2.5 full-time equivalent (FTE) staff supporting the IECC – a far cry from what will be needed to accomplish the work. To that end, Denver reached out to both Seattle and Washington, D.C. to understand how many staff in similar cities support IECC implementation. After comparing, it became apparent that Denver needs to grow its CPD team to an additional 11-16 FTEs supporting energy code enforcement in order to increase the compliance rate and support Denver's Climate Goals and Recommendations.

Cost Considerations: Highly Energy Efficient

There are a number of costs to consider with net zero new buildings and homes. A key consideration is that supports are integral to ensure that the goals and recommendations to reach net zero are equitable and affordable. Costs for net zero new buildings and homes include costs to the city of managing equitable codes, policies, and programs as well as construction costs and operational costs.

CONSTRUCTION COSTS

The first NZE Stakeholder Advisory Groups meetings asked attendees about costs to reach net zero. The primary takeaway from the stakeholders was that if net zero is designed from the outset, there will be little impact on construction costs. If NZE is intentionally incorporated early into the design process, net zero can be achieved within the budget for a building. However, the later it is incorporated, the more redesign will be necessary, and construction costs will increase.

Concern about additional costs or even perceived costs is a barrier to overcome. Stakeholders said that the solution is to assure the community with example projects demonstrating that additional cost is not an issue. Pilot programs, education, and outreach as detailed in the supports section will serve to address these perceptions. Incentives as well are part of the solution to address costs. An example of this with green buildings from the USGBC is a 2007 public opinion survey conducted by the World Business Council for Sustainable Development. **It found that respondents believed, on average, that green features added 17% to the cost of a building, though a study of 146 green buildings found an actual average marginal cost of less than 2%.** Additionally, for lower levels of LEED certification (such as LEED Certified) the premium is between 0-4%. This is particularly applicable to the highly efficient portion of Denver NZE because the savings realized are typically due to energy cost savings.

NET ZERO COST STUDIES

Denver is currently conducting a feasibility analysis for Affordable Housing Zoning Incentives and studying the 2019 Denver Green Code (DGC) costs as part of this effort. This includes both LEED Certified as an equivalent to DGC and net zero energy. While the full results will be available in 2021, an initial literature search shows the following regarding NZE costs.

Buildings NZE Costs

- One of the first studies to evaluate cost premiums for net zero buildings was conducted in 2012 by New Buildings Institute (NBI) and was based on a small sample of net zero projects, most of which were smaller buildings (20,000 square feet or less). Results were inconclusive but anecdotally suggested the incremental cost for net zero buildings was 0 to 10 percent higher than similar conventional buildings. An update to that study in 2014 indicated that cost premiums for net zero are closer now to conventional costs (though the premiums were not actually quantified).

- A 2013 analysis of net zero commercial buildings in Washington, D.C. found that increasing certification from LEED Platinum to net zero created an additional premium of 5 to 19 percent (over LEED Platinum costs).

Homes NZE Costs

- A study by Rocky Mountain Institute, updated in 2019, found that premiums on net zero construction of single-family homes were about 6 to 8 percent over conventional homes. Zero energy ready homes had an even lower premium of 0.9 to 2.5 percent.

- Evidence from the Pennsylvania Housing Finance Authority, who recently added points in their competitive tax credit allocation process for passive house standards, indicates limited and declining cost premiums for construction with the Passive House certification for affordable multi-family units.[13] Affordable housing developers anticipated passive house compliance would add 15 to 20 percent to construction costs but actual applications indicated a 5.8 percent premium relative to conventional applications the first year points were offered (2015), a 1.6 percent premium in year two (2016), and a discount of 3.3 percent relative to conventional applications in 2018.[14]

As a result, cost studies are showing that NZE is about a 5-19% additional first cost for buildings and 6-8% for homes. Initial interviews as part of this Affordable Housing Zoning Incentives work align with these ranges.

OPERATIONAL COSTS

Building operations are an important consideration in terms of cost. For most highly efficient buildings, additional up-front costs for energy typically results in operational savings. Yet for all-electric buildings, the operational cost can be a significant barrier, according to interviews with stakeholders (detailed in the section "Market Barriers to All-Electric Buildings"). In most cases, operational costs can be optimized for each building but do require active management of building operations. Operational costs can be lowered through training and educational supports.

[13] Denver Green Code includes compliance paths for Residential Energy Efficiency that include a "Passive House Approach" with certification under either Passive House Institute US (PHIUS) or Passive House Institute (PHI).

[14] No data for 2017 as tax credits were not awarded that year.

Technology Adoption: Highly Energy Efficient

Both the NZE Stakeholder Advisory Groups meeting discussions and the stakeholder interviews indicated that technology is not an issue for highly efficient buildings. Many of the distributors provide products nationally and have efficient equipment available or accessible in Denver. However, there is a cost consideration as newer products typically cost more, and the cost decreases as products are used and installed more frequently.

Energy Efficiency Building Code/Policy Updates

Ultimately, the targets within this NZE Plan will have to go through each Denver Code Adoption process to be included in the Denver Building and Fire Code. Denver plans to align its code updates with national code updates that are updated every three years and will include 2021, 2024, 2027, and 2030. **Denver is committed to ensuring its code adoption processes are open and inclusive.**

Denver's code adoption follows the I-code development process. Key components of Denver's Code Adoption Process are requesting amendment proposals from the public and balanced-interest code Committees that review and decide upon each proposal. A summary of each Code Committees' decision on each amendment proposal or modification of an approved amendment proposal will be posted on Denvergov.org.

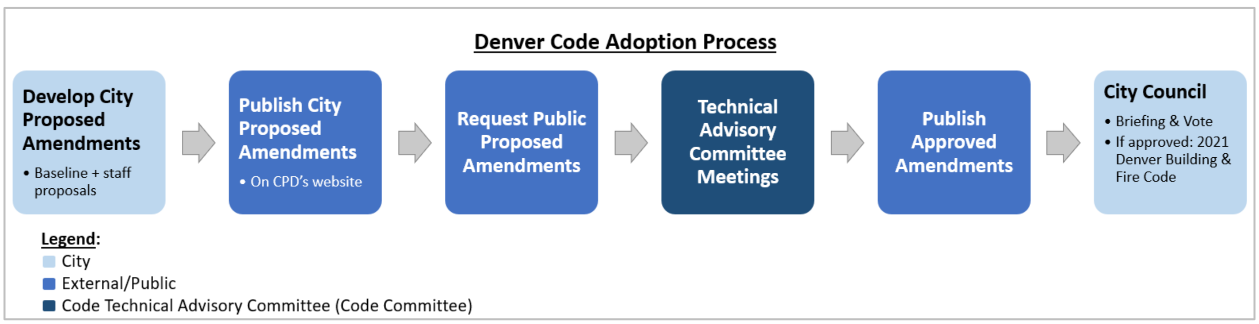


Figure 18. Denver Code Adoption Process

For the 2021 Code Adoption Process, Denver plans to facilitate a separate IECC pre-Committee (different members than the code committee) that will have preliminary meetings to gather stakeholder input from the community as part of developing the initial proposed City-Staff amendments to meet Denver's climate goals and recommendations detailed within this NZE Plan. For the IECC process, the Code Adoption process will include:

- Preliminary energy meetings, detailed below, to develop:
  - A comprehensive set of IECC energy proposals that align with Denver's climate goals and recommendations in this NZE Plan
  - Energy recommendations for the Denver Green Code (DGC) and IgCC Committee
- Developing and publishing proposed City (Staff) amendments
- Requesting public proposed amendments
- IECC Committee reviewing, addressing and voting on each amendment in the formal code committee public meetings

- Providing summaries of the proposed amendments and track changes versions online

NEXT STEPS IN CODES

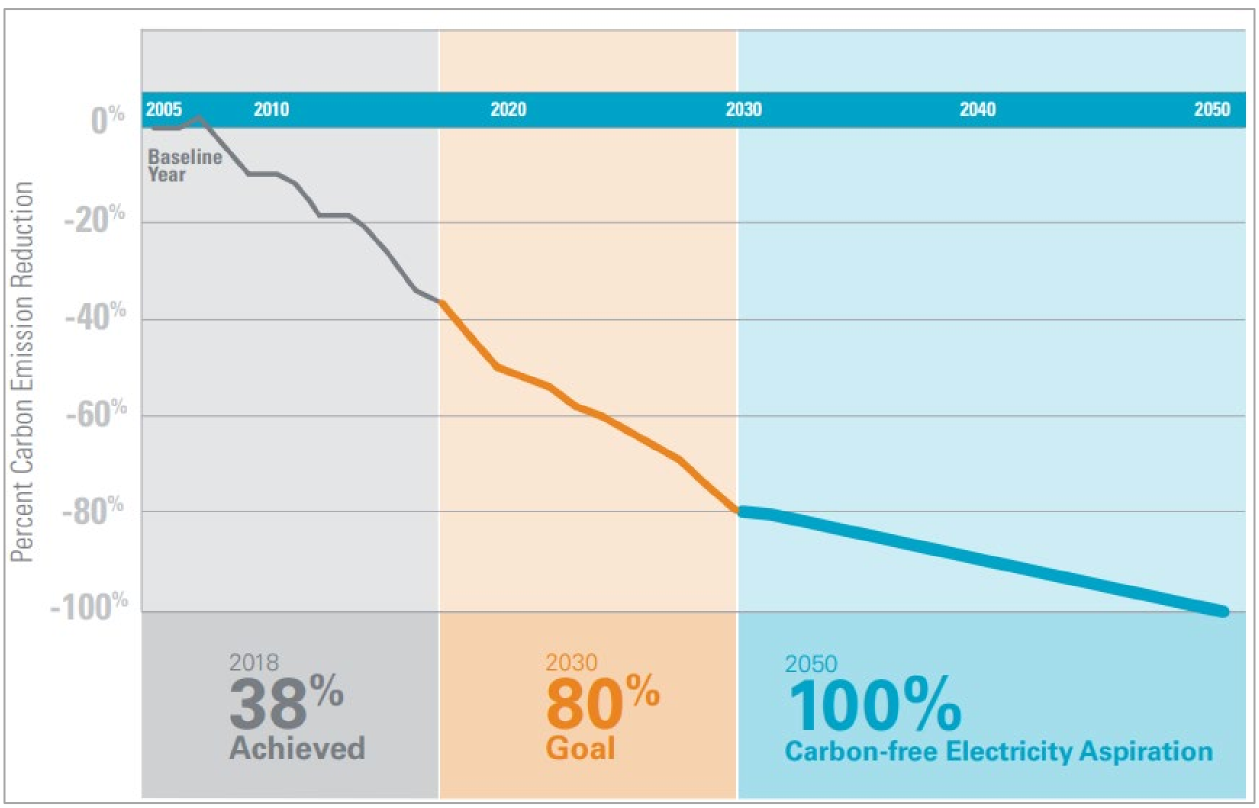
Denver is working with NBI to develop draft code proposals based on the 2021 IECC that meet the goals and recommendations in this NZE Plan. This is further detailed at the end of this report in "How it All Comes Together." More broadly, the transition to a performance-based code that includes predicted energy use targets represents a significant paradigm shift. As Denver embarks on this process there are a number of important considerations that must be considered in future code cycles. These include:

- Selecting **performance metrics** that are compatible with existing modeling software, encourage building efficiency, and are aligned with Denver's objectives, especially in regard to promoting electrification.
- **Periodically calibrating the energy targets to the prescriptive path so that they deliver reasonably consistent energy outcomes.**
- Addressing **building verification** and how outcomes will be enforced. In early code cycles, this is expected to start by simply comparing modeling estimates to the code performance targets for a particular building type. **In future code cycles, the actual performance of buildings would be compared against the modeled energy targets.**
- Developing a **feedback loop** for energy modelers to develop capacity in the use of assumptions and tools so modeling outcomes become more predictive of actual energy outcomes. **Comparing building verification to benchmarking data will enable a feedback loop between actual performance outcomes and the energy code.** It will also inform the code development process so that lessons learned about modeling best practices can be integrated into the modeling requirements.
- Clarifying **backstop requirements** to ensure efficiency is consistently incorporated in buildings and to prevent projects from trading-off building efficiency with renewable sources.
- **Creating normalization approaches and procedures that address variations in performance due to weather, occupancy, and/or other factors for when actual performance is compared to code targets.**
- Ensure that **stakeholders** are informed and capable to deliver new code approaches, including using lessons learned from performance verification to educate other practitioners in the energy modeling community.
- Work to **integrate efficiency with overall decarbonization**, electrification and renewables approaches and goals.
- **Clarify how energy is related to carbon to ensure that this aim for zero energy is achieving carbon reduction goals, recognizing that the relationship between energy and carbon is dynamic and will continue to change over time as the grid is decarbonized.**
- Developing policies that can better address **unregulated loads**. Figure 17 includes an example of this issue from Washington state. It shows the regulated versus unregulated end uses by building type. In order to meet Denver's performance goals, it will be necessary to address these unregulated loads that are not within the scope of the energy code through a policy such as an outcome-based code or building performance standard.

NZE: ALL-ELECTRIC

The second foundation of NZE within Denver's net zero energy definition is all-electric buildings and homes. Buildings and homes together represent 64% of the 2019 GHG emissions. Because Denver is a heating climate, the majority of the emissions from buildings and homes are from heating and water heating. As previously mentioned, 40% of buildings will be "new" in 2050. As a result, if these 40% of "new" buildings are net zero and all-electric, that will significantly reduce Denver GHG emissions. Denver is also working on a Beneficial Electrification Implementation Plan for Existing Buildings. This will address how to strategically electrify the existing buildings within Denver.

In addition to addressing on-site emissions from buildings and homes, another aspect of reducing emissions within Denver is addressing emissions from electricity generation. Xcel Energy, the electricity provider in Denver, has committed to reducing emissions from electricity generation by 80% in 2030 and 100% by 2050. Currently in Denver's building stock, electricity comprises 66% of building emissions and natural gas comprises 33% of the building emissions. As the grid is decarbonized so swiftly, in 2030 electricity will comprise only 40% of building emissions and natural gas will comprise 60% of the building emissions.



Source: Xcel Energy Carbon Report

Figure 19. Xcel Energy Carbon Reduction Trajectory: Clean Energy Transition 2030 and 2050

Benefits of Electrification

In addition to emissions reductions, there are a number of co-benefits from building all-electric including efficiency, health, and cost savings. While energy efficiency is a separate foundation within this report, it is important to note that when transitioning from gas to electric heating (both space and water heating), heat pumps are significantly (200-300%+) more efficient than gas equipment. As a result, there are operational cost benefits from this energy savings.

Cooking is another common end use for natural gas. **When cooking with electric stoves there are not only emissions benefits but significant improvements to indoor air quality.** As detailed in the study Health Effects from Gas Stove Pollution, a meta study looking at the association between gas stoves and childhood asthma found children in homes with gas stoves have a:

- 42% increased risk of experiencing asthma symptoms (current asthma),
- 24% increased risk of ever being diagnosed with asthma by a doctor (lifetime asthma), and
- 32% increased risk of both current and lifetime asthma, overall.

There are additional benefits from induction including energy efficiency and safety with reduced burns and lower risk of fire.

Finally, there is a cost benefit (savings) from constructing an all-electric building. **When gas is eliminated entirely from the building, there is a significant cost savings by removing gas distribution and gas supply to the building.** The cost benefits are detailed below in the "Cost Considerations and Study: All Electric" section.

Goal

The current goal is that heating emissions are reduced 50% by 2040. Additionally, the Climate Action Task Force recommends that all new homes are net zero emissions by 2024 and all new buildings are net zero emissions by 2027. This goal is the result of all-electric equipment for heating, hot water heating and cooking in buildings and homes.

While the focus of this NZE Plan is new buildings and homes, Denver also has all-electric goals for electric vehicles (EVs). Because charging stations are increasingly tied to buildings and homes, EVs in the code are also included in this section. Denver's current 80x50 Climate Action Plan goal is for 100% of light-duty vehicles to be electric by 2050. Additionally, the Climate Action Task Force recommends an emissions-free transportation system by 2040. This is further detailed in the Denver Electric Vehicle (EV) Action Plan.

The two major energy fuel sources for buildings in the U.S. are electricity and natural gas. "Mixed-fuel buildings" have utility connections for both electricity and natural gas. An all-electric building is a building where the only utility infrastructure is electricity and major energy systems are served by electricity. Electric loads can be directly offset with renewables, while gas combustion cannot. Therefore, as the supply for the electrical grid decarbonizes, all-electric buildings can leverage increasingly clean fuel sources to achieve long-term carbon reductions beyond what can be accomplished in mixed-fuel buildings.

NZE Foundation: All-Electric

Getting to all-electric as part of Denver's net zero energy definition will reduce greenhouse gas emissions through all-electric equipment in buildings and homes. There are a number of considerations in getting to all-electric buildings detailed in the sections below. The first is whether all-electric buildings and homes are technically feasible in Denver. This looks at the equipment needed for heating, water heating, and cooking. Secondly is if the market in Denver is ready for all-electric through interviews with stakeholders to understand available equipment, code and regulatory gaps and barriers, and support (incentives, education, outreach, etc.) needed. Next, the proposed all-electric targets are detailed including considerations for electric vehicles. Finally, all-electric cost considerations are detailed to understand the impact for buildings and homes in Denver.

All-Electric Feasibility in Denver: Heating, Water Heating and Cooking

Many jurisdictions have or are considering electrification policies to meet carbon reduction goals. Cities in California have led this effort thorough the adoption of electrification reach codes. It is important to note that while carbon impact is one of the driving motivations for electrification, most of them are prohibiting new gas hookups based on life safety issues such as indoor air quality, fire safety and earthquake safety. Cities like Berkeley and San Jose have prohibited natural gas hook-ups in some or all new buildings. Other cities have adopted reach codes that incentivize all-electric buildings by requiring greater efficiency from mixed-fuel buildings and electrification-readiness for gas loads.

Work done to support these policies in California can inform Denver on the issues of electrifying buildings. Work done to date includes cost effectiveness studies done for all-electric buildings and an "experts roundtable" meeting in San Jose. The roundtable brought together stakeholders and technical and market experts and provided significant insight into the barriers and opportunities for building electrification.

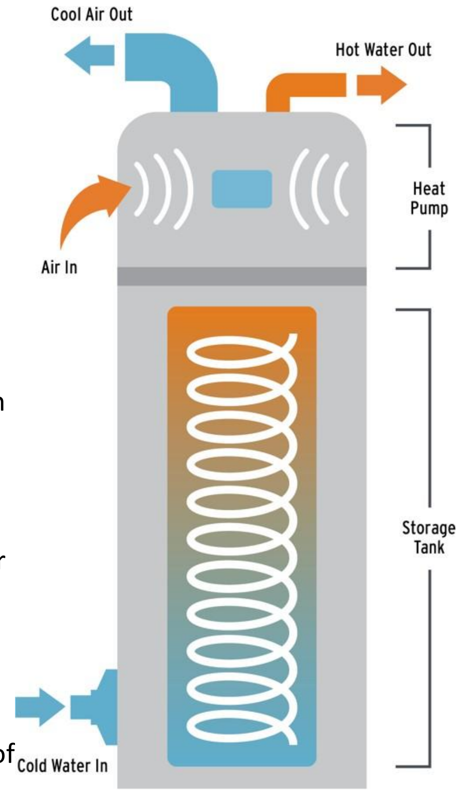
The loads commonly served by gas include water heating, cooking, space conditioning and miscellaneous loads. Different loads may pose greater or lesser degrees of difficulty to electrify. The feasibility of all-electric buildings has multiple facets including: the availability of electric equipment, the availability of the expertise necessary to design and install that equipment and the market acceptance of that equipment. While market acceptance is not a technical feasibility issue, it is an important consideration because consumer perception and preferences can create a non-technical barrier to electrification.

WATER HEATING

Not all electric water heating is the same. The electric water heating equipment category includes both lower-efficiency electric resistance and higher-efficiency heat pump technology. Electric resistance equipment generates excess heat resulting in poor efficiency. In fact, buildings with resistance water heating may have a difficult time complying with Denver's energy code. Therefore, this section focuses on the feasibility of the more efficient heat pump water heater (HPWH) systems and the technical issues related to that technology.

Heat pump-based systems move heat from the surrounding air or another source into the water. Since they work by moving heat rather than creating it, HPWHs are capable of achieving levels of efficiency 3-4 times their electric resistance counterparts and 4-5 times as efficient as their gas counterparts.

There are a handful of high-level technical considerations in the use of heat pump equipment for water heating:



Source: The Environmental Center

Figure 20. How a HPWH Operates

- ***Storage Tank Size.*** Heat pump water heaters are generally slower at heating water than electric resistance or gas water heaters, therefore they tend to require larger storage tanks to act as a buffer against demand. For example, a load that could be served by an electric resistance or gas water heater with a 30-gallon tank would generally require a 50-gallon tank with a heat pump water heater, or a 65-gallon tank for a heat pump water heater replacing a 40-gallon gas or electric resistance water heater. These larger tanks need to be incorporated into the building design, and the space requirements could have impacts on building layouts if not considered early in the design process.
- ***Access to air source.*** Since HPWHs move and concentrate heat instead of creating it, they need a source of heat. Most HPWHs simply use ambient air, so generally the source of heat is the air around the heat pump. The heat pump therefore needs access to a large enough volume of air to provide the heat to "pump" into the water. If heat pumps are located in a traditional water heater closet or "boiler room"-sized space, this poses a challenge for heat pumps, because they will quickly extract all of the heat from the air in the room.
- ***Impact on space conditioning.*** Even in a heating-dominated climate like Denver's, a HPWH's impact on space heating when located within the conditioned space is much less than the efficiency gains. Taller buildings tend to be more dominated by internal heat gains than shorter residential buildings, so those buildings may even see a space conditioning benefit from the HPWH's cooling and dehumidifying impact.
- ***Other sources besides air.*** Some HPWHs utilize water source heat pumps that use another source of water (such as a ground source loop that pulls heat from underground, or warm wastewater) and therefore do not need access to a minimum volume of air.
- ***Dehumidification***. Since air-source HPWHs take heat from the surrounding air, they will cool and dehumidify the area where they are located. This can actually be advantageous in some circumstances, especially in buildings dominated by cooling loads.
- ***Acoustics***. Heat pump water heaters generate noise, similar to chillers, air-handlers and other types of equipment. The level of noise varies considerably but is lower than earlier generations of HPWH equipment. Noise can be an issue in some applications – such as apartments – but water heaters are often located in locations where noise is not a significant issue.

- ***Efficiency***. Some heat pumps are far less efficient when heating warm versus cold water. This has an impact on the design and equipment selection in central water heating systems (discussed in greater detail below).
- ***Capacity and electric service size***. The larger storage tanks used for heat pump water heater systems mean that heat pump water heating systems generally use equipment with a much lower equipment capacity than their gas counterparts. This reduces the impact on electric service size.

Individual vs. Central Systems

Hot water is delivered by two basic configurations of equipment: individual systems and central water heating systems with recirculation loop.

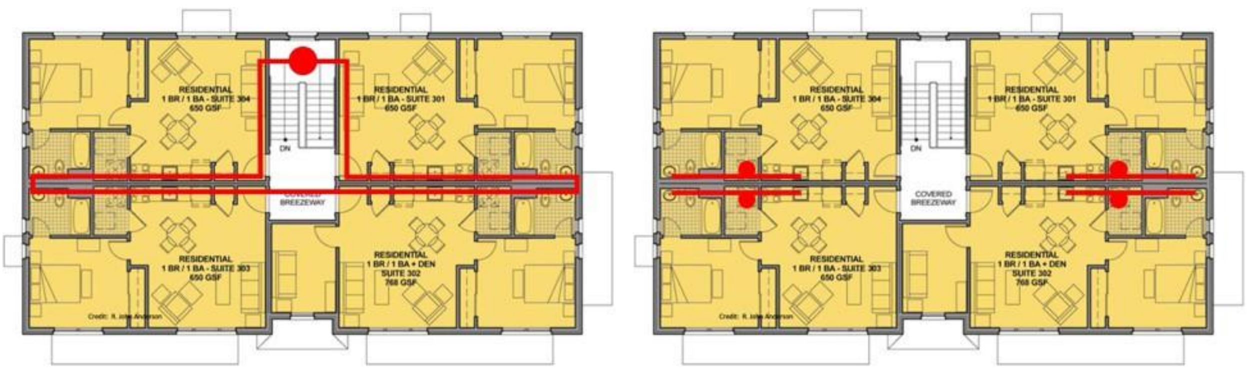


Figure 21. Central Water Heating with Recirculation Loop (left) vs. Individual Water Heaters (right) Connected Directly to the Hot Water Points of Use

In individual water heating systems, the water heating equipment and the points of use for hot water are located close together; hot water flows directly from the equipment to the point of use. They cannot be located too far apart or else it will take too long for a user to get hot water from the equipment. Long wait times are an inconvenience to users, and hot water cooling in the pipes is a major source of energy losses. Individual systems are generally smaller (in a single-family residence) but can be quite large in applications such as restaurants or laundries.

The decision to use a central system generally is driven by the space constraints of taller buildings. In a central system, there is greater distance between the water heating equipment and the points of use, and the points of use are not connected directly to the equipment. Instead, both the equipment and the points of use are connected to a recirculation loop that distributes hot water around the building. The recirculation loop ensures that there is always hot water near the points of use even though they may not be near the water heating equipment. The recirculation loop has to be kept hot when hot water draws are needed, which can be most of the day in buildings like apartments. **The heat losses from a central system's distribution system mean that, on a whole-system basis, they are generally less efficient than individual systems.**

Individual Systems

Individual systems are used in both residential and commercial occupancies in both low-rise and high-rise buildings. Smaller individual systems are generally integrated heat pump water heaters where the heat pump and the water storage tank are integrated in a single piece of equipment. Although they exist, split systems where the tank is separate from the heat pump are not common in individual systems.

Smaller individual systems are used in single-family homes. The type of HPWH used in this building type is already widely available and most of the barriers can be solved with thoughtful but simple design solutions. Basements and garages are good locations for HPWHs since they provide noise isolation and air temperatures that are more temperate than Denver's outdoor temperatures, especially in the winter. Locating equipment in a garage does create thermal envelope penetrations, so these will need to be carefully addressed in the air barrier sealing.

Individual dwelling units in multifamily buildings also may have individual HPWH units. Individual water heaters generally become less common as multifamily buildings get taller and space becomes more valuable, and this holds true for HPWHs. The larger space required for heat pump water heaters only exacerbates that issue. The need for access to a volume of air can be an issue in multifamily applications. Split-systems are generally not possible because of the building size and the distance that would be required between the heat pump and the tank. Putting the heat pump water heater in a closet with a louvered door is not likely to provide sufficient air flow for efficient or even effective operation, and the noise generated by the heat pump can be a problem in the compact dwelling units typical of mid-rise multifamily.

Some heat pump water heaters can be vented to the outside, but that creates envelope penetrations and adds the expense of ductwork. Some projects have acoustically isolated the heat pump water heater from the dwelling unit and connected it to the air of the corridor instead. This confines the noise to the corridor where acoustics are less critical. This approach may make individual systems more practical in some multifamily projects. Another potential solution is to design the dwelling units so that their hot water points of use are all clustered together which allows multiple units to be served by an individual water heater. The efficient pipe layout keeps hot water wait times acceptable without the use of a recirculation loop. One of the advantages of individual water heaters in each dwelling unit is that it vastly simplifies metering each dwelling unit. This approach creates complexities for energy metering similar to those for central systems with a recirculation loop.

Individual systems are frequently used in commercial buildings for individual lavatories or kitchenettes. These are often smaller integrated units. Larger equipment is also used for commercial kitchens and laundries. Larger systems are more likely to utilize split systems where the tank is separate from the heat pump. Multiple integrated heat pump water heaters can be combined to provide sufficient capacity for a larger hot water load. Likewise, multiple split-system heat pumps can be connected to a single larger storage tank to provide sufficient capacity for a larger load. Currently, the latter appears to be the more common approach for larger loads.

Central Systems

In central systems, the water heating equipment is located in a central location or distributed central locations. Central systems are far more common than individual systems in buildings with larger, but distributed, water heating loads, especially mid- and high-rise multifamily buildings and hotels. If the loads are smaller and distributed – like bathrooms and kitchenettes in a large office building – multiple individual water heating systems are typically used. Central systems also will sometimes utilize multiple larger integrated heat pump water heaters piped together to increase capacity, but this is less common than split systems in central systems.

In larger buildings, it can make sense to break the building into multiple water heating zones, but this is not unique to heat pump water heater systems. In fact, most of the more challenging technical issues in central water heating systems in taller buildings are not due to electric versus gas equipment at all. In tall buildings, managing the pressure that results from piping water vertically is often the most complex issue.

Figure 22. Central Gas Water Heating System (left) and Central Heat Pump Water Heating System (right)

The defining feature of the central system is the recirculation loop. Hot water is pumped through the recirculation loop to bring hot water closer to the points of use. The water in the recirculation loop needs to be kept hot when hot water draws are expected. In effect, there are two hot water loads: heating cold water for use in the building and maintaining the temperature in the recirculation loop. In a gas boiler system, these two loads are typically served simultaneously by the boiler. The return water from the recirculation loop is simply routed back through the boiler to get it hot again. However, this strategy can create an issue for some heat pump water heaters because some heat pump water heaters are not as effective at reheating warm water as they are at heating cold water (also an issue for high efficiency condensing natural gas boilers). Therefore, if warm water is recirculated to the heat pump, the efficiency of the system can drop dramatically to levels delivered by electric resistance equipment.

The recommended approach for addressing this issue is to separate the water heating and recirculation loop temperature maintenance loads and serve them with separate equipment. With this strategy, a heat pump water heater that is more effective at heating cold water can be selected to heat incoming cold water while a heat pump water heater that is more effective at heating warm water can be used to keep the recirculation loop hot. Some practitioners have developed highly effective and very sophisticated strategies to maximize the efficiency of this approach. However, it also can be done with more straightforward and effective designs.

The large storage tank of hot water used in central heat pump water heating systems acts as a buffer for demand but also can pose a design issue. Gas systems typically use large-capacity gas boilers with smaller tanks instead of buffer tanks to meet hot water demand. With electric HPWH systems, designers will need to accommodate larger tanks – which could contain thousands of gallons of water in some buildings – in their designs. Ideally, this is done very early on in order to minimize the cost to change the layout of the mechanical rooms.

Just as with individual systems, access to sufficient air for central HPWH systems can be an issue. Heat pumps cannot be located in the same kind of small rooms typically used for boilers. The ambient air simply will not have sufficient heat for the larger water heating loads. Therefore, mechanical rooms might be vented to bring in air through louvers or ductwork. The heat pumps themselves can be vented to another space, and most split system units are designed to accommodate this venting. Heat pumps even can be ducted to the exhaust air of the building and recover the waste heat and improve efficiency, or a garage exhaust system can be used as a source of outside air. Parking garages provide more temperate air than the outdoors and can be an ideal location for central HPWH equipment in Denver's climate.

Transforming the Market for Central Heat Pump Water Heating

Industry and incentive programs (including Xcel Energy) are already actively engaging in widespread market transformation efforts for smaller individual HPWHs. The biggest barrier to the electrification of central water heating systems in new construction is that the gas equipment cannot just be replaced with a heat pump water heater. A central heat pump water heater system has different design requirements that, while not especially complicated, are different from the standard designs for gas systems that have prevailed for years. According to interviews with some practitioners, the learning curve for central heat pump systems is much less than other high-performance systems such as chilled beams or ground source heat pumps.

While the technology for these systems is widely available, finding the equipment through distributers can still be an issue. Without more practitioners with experience and expertise with these systems, distributors tend not to stock the equipment, which creates a bit of a catch-22. Right now, a small number of firms are successfully designing central HPWH systems. Leveraging and highlighting their success provides an opportunity to transfer the knowledge and lessons learned by these pioneers to the broader market. Xcel Energy is working with distributers on midstream incentives to distributors regarding HPWHs as part of their Xcel Store. Xcel Energy also has rebate programs promoting HPWHs that could be expanded. This is valuable for both new construction and existing building retrofits, which can be more complicated, especially when transitioning from gas to electric equipment.

Denver might employ a number of strategies to address the barriers of lack of product availability and lack of awareness, including:

- ***Design workshops***. Denver could host professional development workshops where more experienced practitioners can train their peers how to effectively design central heat pump water heater systems. These workshops would preferably come with professional education credits since practitioners already have a need for continuing education.
- ***Technical support from the City.*** Denver could contract with some of the more experienced practitioners to assist and mentor project teams with less experience. In this way, the experience of the small number of experienced practitioners is spread out more broadly. Practitioners who are new to the design approaches would learn from more experienced practitioners and would have greater success in their early projects.

- ***Guidance Documents.*** **A technical guide on how to design central heat pump water heating systems could be used by practitioners unfamiliar with the systems.** Since there is a broader need for this kind of guidance, Denver may be able to partner with other cities (e.g., San Jose) and organizations (e.g., NBI) to create this guidance document.
- ***Equipment Manufacturers*****.** Many manufacturers of equipment hold regular education and training sessions at their distributors or in the offices of design engineers. Denver could host similar training sessions open to the profession.
- ***Utility Incentive and Continuing Education Programs***. Denver can continue to work with Xcel Energy and its incentive programs to promote HPWHs, as well as leverage Xcel's existing trade allies' programs to disseminate resources**.**

SPACE HEATING

Heating is the primary HVAC load that uses natural gas combustion, since air conditioning and ventilation are already almost universally provided by electric equipment. In the transition from gas to electric, it is critically important to note that electrifying heating loads does not mean utilizing electric resistance heat. **Just as heat pump water heaters can produce hot water far more efficiently than resistance water heaters, heat pump space conditioners can produce warm air far more efficiently than resistance heat systems.** It can be difficult, if not impossible, to meet Denver's new energy code with electric resistance equipment unless they are serving small loads.

Historically, performance of heat pumps in cold climates like Denver's has been a challenge. However, many manufacturers have released cold climate models that can efficiently deliver heat down to -17 degrees Fahrenheit. These models tend to be more efficient in all temperature ranges. The Northeast Energy Efficiency Partnership has a cold climate heat pump initiative and has both guidance and product lists that are relevant to Denver.

Electrification of Mid-Rise and High-Rise Heating Systems

Electric heating technologies already are widely used in mid- and high-rise buildings and generally understood. Some mid-rise buildings can use the same technologies and equipment as low-rise buildings. For example, some multifamily buildings use split-system heat pumps where each unit has its own outdoor heat pump located on the roof. Many buildings can also use variable refrigerant flow (VRF) systems where multiple indoor units are connected to a single outdoor heat pump. There are limits on the length of the refrigerant line that connects the indoor and outdoor units (these vary by equipment), so they are more common in mid-rise buildings. The through-the-wall packaged heat pumps that are common in hotels can be used in taller buildings, and only become less common when buildings start to use curtain wall systems for the building envelope.

As buildings get taller, they have fewer system options in general, not just when considering all-electric buildings. Mixed-fuel high-rise buildings generally use a chiller and boiler to provide cooling and heating loops that serve equipment inside the building. Heat pumps and "reverse chillers" can be used to provide heating in these systems instead of boilers. It is important to note that as buildings get taller, they become more and more dominated by cooling loads and less by heating loads. This means that a tall building can be providing air conditioning to the spaces even during the winter when people's homes would be providing heat. **As a result, as buildings get taller, cooling equipment becomes more**

dominant and heating equipment becomes smaller. This makes it more feasible to electrify the heating equipment for larger buildings.

COOKING

While cooking ranges and cooktops are the primary issue for gas use in residential cooking, commercial kitchens have a much wider array of gas equipment that includes equipment such as fryers. Electric equipment already exists for both residential and commercial kitchens. In fact, portions of the U.S. do not use gas (for example, in parts of Florida where ground conditions preclude gas infrastructure) but rely primarily on electricity for their energy needs. Equipment availability is not the primary issue for electrifying cooking loads because in both residential and commercial kitchens, electric alternatives to all major appliances are readily available.

Technically, there is a difference between cooking on gas ranges and traditional electric ranges. With gas ranges, the temperature can be changed more quickly and more minutely than traditional electric stoves. Electric resistance coil and ceramic cooktops tend to have a significant lag when changing temperatures and this has an impact on cooking. However, electric induction ranges offer a solution to this issue. These use an electromagnet field to “induce” heat in ferrous cooking vessels like pots and pans. They allow the temperature to be changed as quickly and minutely as gas. **Therefore, for cooking ranges, induction stoves offer an adequate alternative to gas.**

The issues for the electrification of cooking loads are very different for residential and commercial kitchens as discussed further below.

Residential Cooking

In residential cooking, the primary barrier is a market preference for gas cooking by some consumers, and developer perception of market preferences. Gas cooking is seen as an amenity, and sometimes an essential amenity in higher-end projects. There are recent studies indicating that customer perception may change with increased exposure to induction cooking. A recent customer research study conducted by the Sacramento Municipal Utility District (SMUD) found that 79% of customers had a negative impression of induction cooking prior to trying it, but a 91% positive impression afterwards.[8] Additionally, many people believe that “gourmet” stoves are gas models, but in 2018 Consumer Reports rated induction cooktops far ahead of gas in terms of performance.

Induction models are often more expensive than electric resistance or gas models. Induction cooking provides a cooking experience more like gas cooking, but induction cooking is not the only electric cooking option and many consumers are satisfied with electric resistance cooking.

2018 – 10 Top Rated Cooktops

	Score	Cooktop
1.	100	Induction - Samsung $2,000
2.	100	Induction – Dacor $3,100
3.	99	Induction – GE $1,800
4.	99	Induction – GE $1,440
5.	99	Induction – GE $2,600
6.	99	Induction – Kenmore $1,600
7.	99	Induction – Bosch $1,700
8.	97	Induction – Kenmore $1,200
9.	97	Induction – Frigidaire $700
10.	97	Induction – Frigidaire $820
...	94	top rated Electric cooktop $900
...	94	top rated Electric cooktop $1,400
...	89	top rated Gas cooktop $1,350

Source: Consumer Reports

Figure 23. Consumer Reports 2018 – 10 Top Rated Cooktops

The decision to use gas cooking in residential actually comes at a considerable cost. The infrastructure required for gas cooking is substantial, especially in multifamily buildings. Gas cooking also creates the need for more indoor ventilation, which increases the size and cost of the ventilation system. Gas cooking is also very inefficient, with only about 30% of the energy consumed making it into the food, while electric cooking equipment can approach 90% efficiency.[15] **Perhaps most significantly, gas cooking has a tremendous impact on indoor air quality. Gas cooking can release levels of pollutants that, if they were measured outside, would violate the Clean Air Act.**[16] As a result, households with gas cooking have nearly three times the rate of treatment for asthma.[17]

Outreach and education programs can be used to address these issues. Denver could create an induction check-out program where residents could check out an induction countertop unit to give it a try and could host induction cooking workshops. As first step for outreach, through the American Cities Climate Challenge, the city worked with Sierra Club who developed a one-minute video that explains the concept of building electrification and the indoor air quality issues of gas cooking.

Commercial Cooking

As for residential cooking, the electric equipment for commercial kitchens is readily available. National food restaurants, for example, have both gas and electric options for their restaurants depending on what utilities are available. However, in many commercial kitchens, the use of gas is more than just a market preference. Commercial cooking is a production process and comprises part of the business model of restaurants. Professional chefs are often trained on gas equipment and the cooking processes

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[15] Frontier Energy. "Residential Cooktop Performance and Energy Comparison Study." Prepared for Sacramento Municipal Utility District, July 2019.

[16] Gillis, J. and Nilles, B. (2019). "Your Gas Stove Is Bad for You and the Planet" The New York Times. http://www.nytimes.com/2019/05/01/opinion/climate-change-gas-electricity.html

[17] Jarvis et al. (1996) "Evaluation of asthma prescription measures and health system performance based on emergency department utilization." https://www.ncbi.nlm.nih.gov/pubmed/8618483

in kitchens have often been built around the specifics of gas equipment. **Therefore, electrification requires a change to production and business practices, not just market perception.**

However, induction cooking is making inroads, even in commercial kitchens. Since it only heats the pots and pans, induction cooking is safer than gas or electric resistance cooking. There is less chance of a fire, and less risk of burns for cooking staff. Induction ranges also put less heat into the kitchen, making them more comfortable and more likely to meet the new OSHA indoor occupational heat standards while reducing cooling loads. Many of the commercial kitchens in Silicon Valley tech office buildings are all-electric, and some global tech firms are now working to transition all of their kitchens from gas to electric. **Denver could work with a handful of local restaurants and top chefs to pilot all-electric kitchens to provide an example for other commercial kitchens.**

OTHER GAS LOADS

There are a number of other smaller gas loads that need to be considered in any electrification strategy.

- **Clothes Dryers:** Electric clothes dryers are widely available at the residential scale. Larger "commercial" electric dryers are also widely available. However, electric models are less common among very large commercial dryers such as those used in commercial laundries and hotels. **All-electric buildings with very large laundry loads may need to alter their designs to accommodate different equipment layouts that utilize different dryer models.** Heat pump dryers also can be an effective alternative to gas dryers.
- **Gas Fireplaces:** There are electric alternatives to indoor gas fireplaces. One technology utilizes LED lighting to create a fairly convincing approximation of flames. **It is worth noting that gas fireplaces were introduced as an alternative to wood fireplaces, and they too were only an approximation of the wood fires they replaced.**
- **Gas Barbecues:** There are electric alternatives to free-standing gas barbecues. Additionally, most free-standing barbeques are fueled by portable propane tanks instead of being connected to natural gas infrastructure. These would not be impacted by a policy that addresses natural gas utility hook-ups.
- **Swimming Pools:** Swimming pools often use gas boilers or water heaters to maintain pool temperature. Heat pump boilers are capable of filling this purpose. Additionally, many pools make use of solar thermal systems that use solar energy to heat water, so it is possible to eliminate this gas load without adding any electric load or equipment. **The lower water temperatures needed for pools makes solar thermal heating particularly well-suited to pool water heating.**

IMPACT ON ELECTRICAL INFRASTRUCTURE

The increased electrical load that can result from electrification may have an impact on costs and the electrical infrastructure that serves all-electric buildings. These considerations include the impact on electrical service and transformer size. There are several important considerations that can mitigate the impact of electrification on the electrical capacity of a building:

- Denver's new energy code is more stringent than most other energy codes in the U.S. **New buildings in Denver will be considerably more efficient than buildings in other jurisdictions.**

The impact of electrifying gas loads is therefore less than other jurisdictions with similar climates and less efficient buildings.

- **Where a building also has cooling, electrifying the heating load has less, or even no impact on the building's electrical capacity.** When heating can be provided by the same equipment that provides cooling – as is the case with heat pumps – electrifying the heating load frequently does not require any additional electrical capacity.
- The heating capacity (output of equipment) required for heat pump water heater systems is considerably less than gas counterparts. The capacity of heat pump systems can be one-quarter to one-third the capacity required by gas water heating systems.
- Electrical service and transformer sizes are not very granular. There can be large steps between one transformer and the next size larger transformer and one electrical service size and the next size larger. As a result, some buildings have capacity to spare and some do not. It is very possible that some buildings will not need any additional capacity to accommodate the additional load, while others may trigger an increase in transformer service size. As a result, the impact of electrification on electrical service infrastructure costs (both in the building and from the utility) are difficult to predict.
- **Any costs from increases in electrical capacity would be mitigated by the savings from not installing gas infrastructure to the site. In a set of cost-effectiveness studies for California's Electrification Reach Code, all-electric buildings cost less to construct in most cases examined.** [1815]
- Electrical codes allow the required capacity of the electrical service to be reduced when load management equipment is installed in the building. Load management equipment turns off or reduces the power to parts of the building in response to the amount of electrical capacity that is otherwise available. This equipment can be leveraged by the utility to reduce or even avoid the need for increased electrical infrastructure in buildings due to the electrification of loads or even the addition of electric vehicle charging infrastructure. While load management equipment has historically been targeted toward larger buildings and larger loads, "smart" electrical panels and other smaller equipment is bringing this functionality to smaller buildings, even single-family homes.

IMPACT ON EQUITY

While any market transformation effort comes with its own set of equity considerations, electrification brings to the table the unique challenge of natural gas infrastructure acting as a stranded asset. The cost of safely maintaining the natural gas system is set to grow while infrastructure costs and safety upgrades combine with a decline in demand as buildings transition away from fossil fuels. **It is vital that the most vulnerable populations, whether they be low-income, communities of color, renters or others, are not the last customers to electrify.**

Within the new construction context, it is imperative to place an exaggerated focus on building new low-income housing as all-electric, such that property owners are not delaying the electrification of their building at the expense of their tenants increasing heating bills. Heat pumps also provide the

[18] "2019 Nonresidential New Construction Reach Code Cost Effectiveness Study." Prepared by TRC Advanced Energy and EnergySoft for California Energy Codes and Standards Statewide Utility Program. Draft – 2019.

opportunity to provide air conditioning for low income residents who previously may have foregone cooling as an unaffordable luxury. This is especially crucial due to heat island effects. Due to lack of green space, and a high density of heat trapping concrete and asphalt, marginalized neighborhoods in Denver can be upwards of 12 degrees Fahrenheit hotter than other neighborhoods throughout the city. In addition, marginalized communities experience higher level of respiratory diseases due to poor indoor and outdoor air quality, providing yet another reason for electrification of any and all low-income housing.

ALL-ELECTRIC FEASIBILITY IN DENVER: KEY CONSIDERATIONS

The key considerations regarding all-electric feasibility in Denver include:

- **Equity must be a key consideration in electrification strategies.**
- Equipment most often served by gas in buildings includes space heating, hot water heating, kitchen loads, and miscellaneous loads such as gas dryers, fireplaces, barbeques and swimming pools.
- Electric replacements for gas equipment are generally available, although there may be some challenges with local distributers stocking practices for some electric equipment. This is expected to decrease with more local examples. Incentives and education programs can help accelerate this transition.
- The load that poses the greatest difficulty for electrification is central water heating systems in multifamily buildings and hotels. **The equipment is available, and the design approaches are well established. The issue with central water heating systems is that there is a need for more practitioners who have experience and expertise to effectively design them.** Possible ways to address this barrier include training workshops, technical resources, and technical assistance.
- Kitchen equipment faces a strong perceived market preference for gas, especially in higher end residential and in restaurant settings. Developers of multifamily buildings may see gas as a sales point, and restaurant staff have frequently been trained on gas equipment so cooking processes revolve around gas equipment. Addressing these issues may require public outreach and pilot programs that demonstrate the advantages of all-electric cooking over gas cooking and help overcome the market perception and business practice hurdles.
- Electrification of buildings could have an impact on the electrical infrastructure needed both on- site (service size and on-site transformers) and the grid. This impact can be unpredictable from building to building and can be mitigated through the use of load management equipment.
- **The elimination of gas infrastructure comes with significant first-cost savings that can offset increased life cycle costs that might result from electrification.**
- There are both long-term and short-term equity issues, and as markets continue to electrify on their own, those members of society least able to electrify their buildings will have to bear an increasing share of the cost to maintain natural gas infrastructure.

Denver Market Readiness Assessment for All-Electric

The current state of all-electric buildings is a critical consideration for Denver to reach net zero emissions. This section outlines the state of Denver's market, and its readiness to adopt all-electric building designs more broadly. It addresses the lack of market adoption of all-electric buildings and the low level of awareness or market readiness which will need to be overcome to achieve carbon neutral buildings. It also discusses the market barriers to all-electric design that have led to its low to non-existent adoption and strategies that Denver could adopt to address those barriers.

While the market readiness assessment for all-electric examines the market barriers for building electrification in detail, there are a few high-level, fundamental issues including:

- There is no functional all-electric building market in Denver yet. There are all-electric buildings, but they are rare and the result of happenstance or niche building such as accessory dwelling units (ADUs). There is a very low starting point for an effort at market transformation in Denver and the market will need to be educated about building electrification.
- Operating costs pose the most substantial market barrier. The very low cost of natural gas and Denver's heating-dominated climate mean that building electrification, when not paired with (perhaps substantial) efficiency, can have a significant impact on utility bills. This issue is particularly pronounced in residential buildings, which are generally dominated by space and water heating loads. **As a result, housing affordability is one of the dominant concerns and creates critical equity issues in any electrification policy that the City crafts.**
- Widespread building electrification of both new and existing buildings and homes will create substantial new loads that will need to be accommodated on the grid.

The basis for this assessment is a combination of sources including:

- Market issues that have been discussed on the national level and in other markets including:
  - A targeted "Electrification Experts Roundtable" held in San Jose in 2019
  - Multiple electrification sessions and the zLab electrification workshop at the 2019 Getting to Zero Forum
- A set of targeted interviews with 14 interviewees in Denver, conducted between June 15 and 30, 2020, with stakeholders active in both the Denver Commercial and Residential New Construction Markets including practitioners (architects, engineers, consultants, etc.), owners/developers, and code officials. An interviewee list and the interview instrument are included in Appendix A.
- Several reports on electrification issues including:
  - Equitable Building Electrification: A Framework for Powering Resilient Communities (Greenlining Institute)
  - The Economics of Electrification (RMI)
  - Building Electrification: Research Perspectives on Technologies, Policies, And Mitigation Strategies (Energy Innovation)
  - Building Electrification Report (Emerald Cities Collaborative)

NEW CONSTRUCTION VS. RETROFIT

The technical challenges of electrification can be very different for new construction and existing building retrofits, and these differences lead to some different market barriers. However, most of the market barriers identified– particularly issues around market perception and operating costs – are applicable to both new construction and existing building retrofits. The discussion of market barriers identifies those cases where an issue is specific to new construction or retrofits or between new construction and retrofits. Further detail on electrification of existing buildings in Denver will be part of a separate Implementation Plan specifically focused on Strategic Electrification for Existing Buildings and Homes.

THE STATUS OF ALL-ELECTRIC CONSTRUCTION IN DENVER

The stakeholders interviewed for this section uniformly stated that all-electric buildings are very uncommon and not often considered in Denver where heating demand is high and gas prices are inexpensive. Accessory Dwelling Units (ADUs) are the exception to this larger trend. For both code compliance and cost reasons, nearly all of the ADUs in Denver are all-electric.

Market Drivers

As all-electric buildings are still very rare in Denver, interviewees were asked about the drivers that are leading projects to *consider* all-electric design. They identified a handful of market drivers including ideologically motivated or mission-driven owners, zero net energy design, and limited regulatory drivers.

IDEOLOGICALLY/MISSION MOTIVATED OWNERS

The interviewees noted that owners motivated by ideology or mission are the primary driver for considering above-code building designs in general and all-electric designs in particular. These owners consider all-electric designs for various reasons including:

- **Carbon reduction:** Interviewees appear to have some doubts about whether all-electric buildings actually deliver lower carbon consumption with Denver's climate and electric generation mix (see "Market Perception" below). However, electrification is seen as a way to reduce carbon consumption now, or at least in the future, particularly when paired with renewable energy.
- **Air quality:** Electrification is seen as a way to improve both indoor air quality (particularly from cooking) and outdoor air quality, and by extension, a way to improve the health of occupants.
- **Zero Energy:** According to the interviewees, many net zero energy buildings in Denver do include natural gas. However, factors such as the International Living Future Institute's Zero Energy Certification gas prohibition are making all-electric design a larger consideration for net zero energy building projects.
- **Market Differentiation:** Some owners and developers are looking at low-carbon design as an option for creating market differentiation. This is in response to a couple of factors. The first is the increasing focus on carbon in the sustainable market. The second is that traditional market differentiators such as LEED have become more common and are less able to provide market differentiation.
- **Affordable Housing:** **Affordable housing owners tend to have a more holistic view of cost and are therefore more likely to consider the first cost savings that can be possible from an all-electric design.** Additionally, many of the Colorado Housing and Finance Authority programs

require the Enterprise Green Communities Criteria, which incentivizes all-electric design. (However, they are also more likely to consider the impact on operating costs for tenants, which could hinder the adoption of an all-electric design.) Affordable housing is not subject to the market pressures for gas cooking discussed in the "Market Perception" section.

REGULATORY FACTORS

The interviewees only identified one regulatory driver for all-electric design. Eliminating combustion and combustion penetrations makes it easier to meet the air leakage requirements for ADUs.

COST FACTORS

As discussed in the "Cost Barriers" section below, cost is a complex issue. Only one interviewee was able to think of a project that had considered an all-electric design based on the cost savings of eliminating gas infrastructure, and that was in a nearby market, not Denver.

However, cost is a factor in the decision for ADUs. Many of the costs for gas infrastructure are relatively fixed on a per-building basis. As a result, the infrastructure cost for gas is very high on a square-foot basis for ADUs with their small size. Additionally, ADUs are less likely to be impacted by the market drivers for gas cooking discussed in the "Market Perception" section.

Considerations for Market Buildout

One interviewee raised an issue that is important for consideration. This interviewee anticipated that the City of Denver itself effectively would be built out before Denver's 2030 goal. Once this occurs, most of the construction in Denver will be retrofits, site scrapes and multifamily projects. If this prediction is accurate, it will have a significant impact on how Denver structures its policies. It would make near-term new construction policies more important in order to have a more significant impact. It also would make existing building electrification strategies even more important beyond the near term.

MARKET BARRIERS TO ALL-ELECTRIC BUILDINGS

The interviews with the stakeholders revealed several market barriers to greater acceptance of all-electric construction. These barriers are all generally variations on cost and familiarity. Before addressing these issues in greater detail, it is important to address one overarching issue that emerged from the interviews. The interviewees frequently had a hard time distinguishing between all-electric buildings and zero energy buildings. Many responses focused on issues for zero energy buildings that have little or no bearing on all-electric buildings. The issue of familiarity is not just an issue with understanding how to create all-electric buildings – design, finance, build, market, etc. – but an issue understanding what all-electric buildings even are. The tendency to revert to thinking about zero energy buildings reveals how fully those buildings have taken over the mind-space for above-code, sustainable buildings. Electrification policies will therefore need to begin with establishing a basic level of understanding of what an all-electric building is and the role that they play in meeting Denver's goals.

Cost Barriers

Cost by far was identified as the major barrier to adopting all-electric designs. However, the issue of cost is more fundamental than whether projects can find cost-effective strategies in design and development. Natural gas is less expensive than electricity in Denver – "stupid cheap" as one interviewee characterized it – so all-electric buildings are not considered an option in the Denver market. Beyond the lack of market awareness, all-electric buildings pose several cost barriers discussed below.

OPERATING COSTS

The very low cost of natural gas combined with Denver's cold climate means that operating costs of all-electric buildings can be substantially higher than mixed-fuel buildings, especially for residential buildings with higher space and water heating loads. While interviewees did not provide specific details, the overall perception was that it would take a substantially above-code performance for an all-electric building to have similar operating expenses to a code-compliant, mixed-fuel building. Denver's cold climate reduces the efficiency advantages of heat pump technology which means that the efficiency premium that an all-electric building needs to reduce the cost gap with a mixed-fuel building is at its lowest exactly when space heating loads are highest.

This operating cost gap was identified by the interviewees as serious particularly in residential buildings and especially problematic in affordable housing. Operating expenses for homes have a very direct impact on consumers and are often the second largest home expense (after mortgage/rent). Interviewees repeatedly raised the issue of housing affordability, both in terms of upfront and utility costs.

Affordability and Equity

The issue of operating costs is particularly important for housing affordability. Even small impacts on operating costs can have a substantial impact on households with constrained incomes, especially those already making monthly decisions about whether to pay for utilities, food or medicine. With Denver's cold climate and relatively inexpensive natural gas prices, there is the potential for significant impacts on housing affordability from electrification. **These potential cost impacts will be very important for Denver to address in its electrification policies to ensure equity.**

EQUIPMENT COST

Studies that have found that all-electric buildings are cheaper to build in other markets also have used a holistic approach to assessing cost-effectiveness. The lower cost of all-electric buildings typically relies mostly or entirely on the cost savings of eliminating the gas infrastructure on the site. In the discussions with the interviewees, it was clear that most projects are not considering cost in this holistic, project-wide manner, but at an individual equipment level. Electric equipment is often more expensive than its gas equivalent, therefore partial electrification generally comes with higher costs.

The interviews often assumed induction technologies when electric cooking was discussed. Induction cooktops are considerably more expensive than typical natural gas cooktops, creating the impression that electric cooking equipment is more expensive overall. This may represent an example where early market outreach around the effectiveness of induction cooking to replace gas cooking may have had unintended negative consequences.

RISK PREMIUM

When designers and installers are unfamiliar with a strategy or technology, they are more likely to add a "risk premium" to the cost of the project to insure against unexpected costs that stem from that unfamiliarity. The interviewees gave mixed messages about whether this would be an issue in Denver. About half of the interviewees took it as a given that risk premiums would impact cost, while the other half did not expect a risk premium to be an issue. This difference in perspective did not align with any readily apparent factor, such as a focus on commercial or residential buildings.

Follow-up questions did reveal more detail. **Risk premiums were seen to be more likely when systems are more complex, and the market would be less familiar, which generally aligns with commercial systems.** Risk premiums also were seen to be more likely when subcontractors have more influence on design decisions. Many installers, especially those working on residential and small commercial projects, also provide the system engineering. A couple of the interviewees noted that installers were more likely to inflate their prices when faced with an unfamiliar technology due to the increased risk in proper installation. Additionally, these installers anticipate service calls if something does not work right, so they carry the highest risk. They also tend to have narrow profit margins that depend on replicability to maintain profitability. Installers even at times will overinflate the estimate on unfamiliar options specifically to drive projects toward familiar technologies and approaches. One interviewee brought up that these risk premiums had been applied to technologies like Variable Refrigerant Flow (VRF) when they entered the market but had since largely disappeared when the market became more familiar with them.

Design teams do not typically have the budget to put together a cost estimate to counter inflated costs from installers, giving the mechanical subcontractors significant influence on equipment selection. Additionally, estimates given earlier in a project are more likely to include padding to account for any unknowns, which only exacerbates this issue.

MARKET TRANSFORMATION COST

Interviewees noted that one of the strategies for keeping design and installation costs down is to use or adapt the same designs for building components over and over for projects, even reusing the same drawing elements and specification sheets from project to project. A bidder who can reduce the cost of their bid by leveraging existing design work is more likely to get the job. This introduces an additional "market transformation cost" to the adoption of new technologies and strategies. **Practitioners will need to invest time and effort into the creation of new standard designs and construction document templates.**

Grid and Service Capacity

Multiple interviewees expressed concerns about the impact of the increased electrical capacity that would be required by widespread electrification of buildings. This concern was two-fold: the ability of the grid to sustain significant increases in electricity demand and the impact on the electrical service size for buildings.

The interviewees repeated a concern that has often been expressed in other jurisdictions about whether the grid could handle such increased demand. This concern is exacerbated by the fact that PV and electric vehicle charging are also being simultaneously introduced to the grid. Even though PV is not a load, it still requires capacity on the grid.

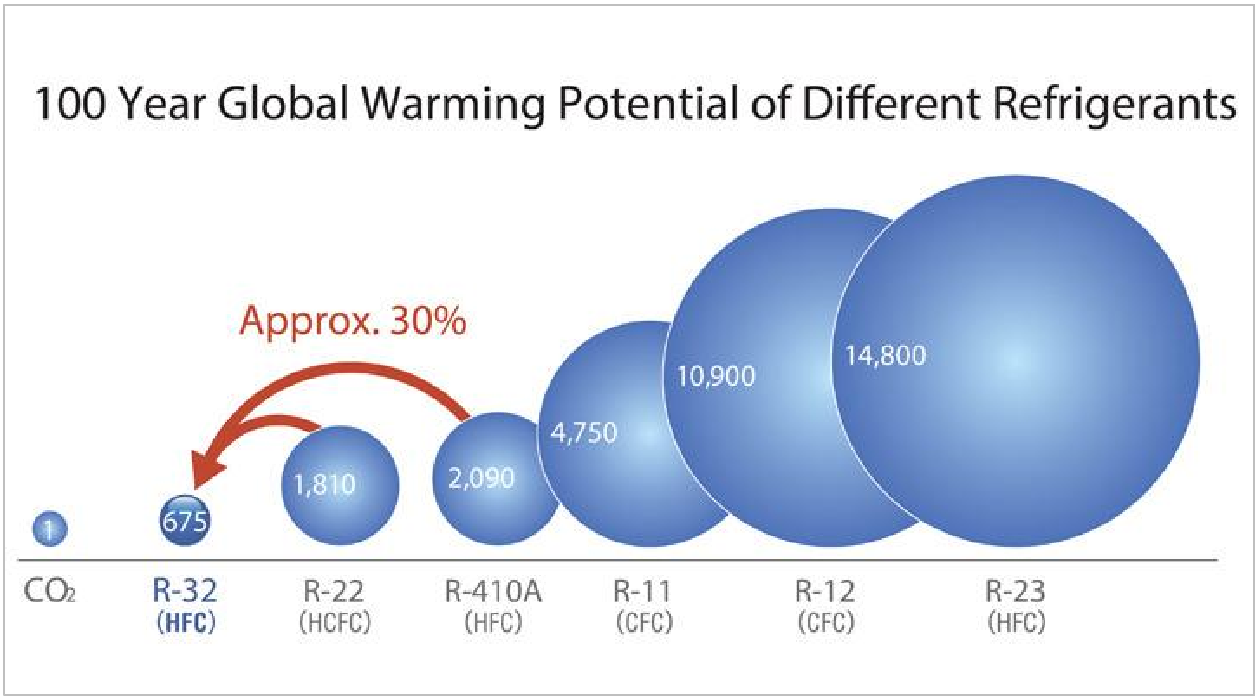
The impact on service size was seen as real but not significant. For most commercial buildings, the increased cost was considered likely to be minimal and not a leading issue. In residential, the impact depends on the market segment. Many builders are already moving to 200A service in single-family homes, which was seen as sufficient capacity for an all-electric home. However, some low-end builders are still using 150A services, which could be problematic depending on the specific development and house.

A related issue with PV was noted by one interviewee. He reported that Xcel Energy uses a general rule to limit allowable capacity of an on-site PV system that is based on the home size. This approach lacks flexibility with no consideration for realistic production from the PV system (only system size). This also generally results in a system size that would be insufficient to achieve zero net energy in an all-electric home. Considering the overlapping motivations for zero net energy and all-electric buildings, this could force motivated home builders/owners to choose one or the other .

Market Perception

One of the biggest issues with market perception identified by the interviewees was that perception about heat pumps was often based on outdated information. The interviewees noted that perceptions of heat pumps – among both consumers and practitioners – was based on heat pump technology from 20-30 years ago or incorrect entirely. **Even some of the interviewees were not aware of recent developments in heat pump technology, particularly low-temperature heat pumps that have been designed to be effective in climates like Denver's.** One interviewee identified an unexpected common professional perception. He said that home inspectors often denigrate heat pumps during home sales based on issues from previous technologies. This gives a good sense of the scale of the fundamental issue of familiarity in the market perception of heat pumps.

Some of the interviewees also raised concerns among practitioners who are familiar with heat pumps about the impact of refrigerants. The global warming potential (GWP) of refrigerants can be thousands of time greater than that of CO2. The market is making progress in producing and adopting less harmful refrigerants and better safety precautions, but even these "cleaner" refrigerants can have a GWP hundreds of times higher than CO2. One interviewee noted that she had worked on a project that had a refrigerant leak that completely wiped out all the climate gains of the heat pump system in one event.



Source: Daiken Corporation

Figure 24. Global Warming Potential of Common Heat Pump Refrigerants

The interviewees identified a series of common perceptions from consumers, as well. The first is the same issue of familiarity. Consumers frequently know nothing about heat pumps or hold misconceptions. Many consumers are not aware of heat pump water heaters. Heat pumps are also seen as an expensive premium, or as one interviewee put it, “the Cadillac option.”

The result is that market perception is a multi-faceted issue that needs to be addressed at the consumer and practitioner level. Market perception of all-electric buildings is hindered by a combination of unfamiliarity and outdated information, creating at least two distinct market education needs.

PERFORMANCE CONCERNS

The interviewees also identified legitimate construction concerns about the performance of heat pumps. These largely come down to heating capacity. For space conditioning, there was a concern if heat pumps would be able to output enough heat for larger homes due to the inherent inefficiency of larger homes and the more limited performance of HPs in cold weather. A couple of interviewees said that heat pumps often are installed in hybrid configurations with gas backup. The heat pump provides high-efficiency performance at less extreme temperatures and the gas equipment allows the heating load to be met at any temperature.

For heat pump water heaters (HPWH), there is a concern about running out of hot water because of the longer recovery times. One interviewee noted that plumbers sometimes amplify these concerns with the reality that Denver’s inlet water temperature is colder than average. There was also a concern about the impact of locating a HPWH in a conditioned space and increasing the heating load or “stealing” heat from the space conditioning system. One interviewee noted that installers often set HPWHs to run primarily in resistance mode out of a concern for heat pump mode performance issues leading to service calls.

Another concern raised by a couple of interviewees was whether all-electric buildings would really be less carbon-intensive than natural gas buildings. This concern brings together the issue of heat pump performance in Denver's climate and the perceived "dirtiness" of the electrical supply (grid). Denver's electricity generation continues to have a high percentage of coal generation. Natural gas messaging about it being a clean alternative to coal has been successful in reinforcing the idea that electric heating is therefore dirty. This can be addressed through the supports needed to reach NZE such as marketing and education.

COOKING

The interviewees identified cooking as a particularly challenging issue. Gas cooking is seen as an amenity, and a requisite amenity in higher end but even market-rate housing. Electric resistance cooking is seen as something that only goes into non-premium housing. One interviewee noted that the gas infrastructure for including gas cooking in multifamily is significant yet is still the norm. Where induction cooking is known, it is often seen as a fringe technology that will require an investment in all new pots and pans on top of the higher equipment cost. As one interviewee put the market perception: "Electric resistance is seen as cheap and induction is crazy."

Availability of Equipment

The consensus of the interviewees was that the availability of electric equipment is generally not an issue. They noted that most local distributers are representatives for larger regional or national companies. Heat pump equipment for smaller projects might not be as available in supply houses as smaller gas equipment, but it can be ordered readily. For larger projects, equipment is generally ordered anyway.

The major issue identified was that heat pumps for space heating do not offer the same level of equipment diversity as there is for gas equipment. Mechanical engineers don't solely select equipment based on matching equipment size to conditioning loads. Equipment size has to be large enough to meet the peak load of the building, yet the building doesn't always operate at its peak load but at partial load. Mechanical engineers also select equipment based on performance curves, matching the peak performance of the equipment to the most common space conditioning load conditions in the building. While there is generally enough diversity of sizes in the heat pump market, the more limited diversity in performance curves for heat pump equipment relative to gas equipment may cause issues for some designs.

Fireplaces are the one equipment type with few alternatives to gas equipment. The interviewees noted that gas fireplaces are very popular in the Denver market. They are not an essential piece of equipment, and are not regulated by the energy code, but are still a consideration. Electric fireplaces are available, but while the flame effects for these fireplaces has improved tremendously in recent years, they are still markedly different from the flames in a gas fireplace. It is worth noting that the market adjusted to gas fireplaces, which originally faced the same market resistance.

Availability of Expertise

Interviewees agreed that the availability of expertise to design all-electric buildings is a concern but the issue varies based on building type and equipment type.

RESIDENTIAL

Interviewees working in the residential market stated that residential practitioners – for both single-family and low-rise multifamily – generally have experience with heat pump space conditioning equipment, even if they push back somewhat against it. However, there were concerns raised about the design tools used in residential designs. Denver building officials noted that the sizing calculations that come with residential designs frequently have issues, both from the tools themselves and the use of the tools by contractors. They noted that these issues are present for both gas and electric equipment, but more problematic with heat pump designs. Therefore, while there may not be an issue with the availability of practitioners who can design and install heat pump systems, there may be quality issues that require planning and care.

Xcel Energy's heat pump water heater (HPWH) program has help spread the market exposure of HPWHs. HPWHs don't really require new skills – the electrical hookups are the same, and the condensate drain that is required is similar but simpler than the one required for high efficiency gas water heaters. The only significant issue is the requirement for access to air for the heat pump.

COMMERCIAL

On the commercial and high-rise multifamily side, interviewees said that local practitioners generally do not have the expertise needed for some of the larger electric systems. They pointed out that practitioners are familiar with systems such as VRF that have been in the market for a while, but less so with gas boiler alternatives for central water heating and space heating systems. They did, however, consistently express the belief that local practitioners are fully capable of learning these technologies. All-electric design strategies and equipment were not seen as something any harder to learn than any other new technologies that have come on the market in the past.

The interviewees noted that the issue of the availability of expertise cannot be considered only locally. Many of the firms operating in Denver are actually national or regional firms that may have more experience in other offices where they can draw. Many of them have other offices in markets – such as California or Seattle – where electrification is more common. One interviewee noted that this has a potential downside. Firms that have team members in other markets with more experience in all-electric buildings may submit bids for projects, but there is no guarantee that the team members with relevant experience will work in Denver. This issue has been raised in other areas. When San Jose held a stakeholder meeting on the issue of building electrification, one participant said that even though his firm was a leader in all-electric design in California, parts of his firm were not familiar and would struggle to successfully design some electric systems. **As a result, the issue of practitioner expertise cannot just be addressed at the firm or company level; it needs to be addressed at the level of individual practitioners, as well.**

Regulatory Barriers

Interviewees identified a handful of regulatory barriers to all-electric buildings.

UTILITY REGULATION

One of the primary regulatory barriers identified by interviewees was utility rates. Utility costs are not driven purely by market factors, and several interviewees identified the regulation of utility rates in a way that keeps gas cheap as a barrier to wider electrification. **However, any discussion of rates will need to engage issues of affordability.** A rate-based approach to narrowing the gap between electricity and natural gas costs that increases the cost of natural gas will have a negative impact on the affordability of existing gas-fired systems. This will be a critical consideration for affordable housing.

Another utility-related issue that was identified by one interviewee was the nature of peak charging in building campuses. Xcel Energy does not allow aggregation of multiple buildings on a campus for the purpose of calculating peak charging. Therefore, one building with very good peak performance or available on-site renewable energy production cannot be used to offset the peak load of another building on the campus. Since all-electric buildings can have poor heating season peak periods, this would put all-electric designs on a campus at a disadvantage.

ENERGY CODE

In the code, two essential barriers for all-electric buildings were the code baseline/metric and code enforcement.

Code Baseline/Metric

Some interviewees noted one broader barrier to all-electric buildings in the code: code envelope requirements. Better envelopes reduce heating loads, which decreases heat pump system sizing and reduces heat pump operating costs. Without advancing envelope requirements in the code, heating loads in buildings will remain higher in new buildings, exacerbating both first- and utility-cost barriers.

In the commercial code, one of the primary modeling compliance paths – ASHRAE 90.1 Appendix G – is based on energy cost and has gas equipment in the reference building. These structural issues place all-electric buildings at a disadvantage as they have to be much more efficient in the rest of the building to make up for that disadvantage. Stakeholders in the 2019 Denver Energy Code development process identified these modeling issues as one of the primary barriers to all-electric buildings. The Denver code allows the use of source energy in the Appendix G approach and that reduces the advantage of gas systems. Source energy still disadvantages all-electric buildings, but not as much energy cost, so while it reduces the disadvantage, it does not eliminate it entirely. Denver currently allows the use of IECC Section 407 for modeled compliance and utilizes site energy for the metric, which places electricity at much less of a disadvantage. However, Section 407 is not as well defined as other modeling paths. Unfortunately, converting Appendix G to site energy would require substantial modification.

There is a similar issue on the residential side. The ENERGY STAR for Homes program (used for both single-family and low-rise multifamily homes) penalizes all-electric designs since it is source energy-based, and the source energy conversion for electricity is much higher than for natural gas.

Code Enforcement

All-electric buildings and homes can simplify code enforcement through reducing enforcement time and costs because they lack natural gas service connections, piping, and hookups. This could be a significant advantage for Denver. However, the current model of code enforcement in Denver may not be equipped for a large number of all-electric buildings. Building officials interviewed noted that since there are not many all-electric projects currently, staff do not have much familiarity with some electric equipment or design strategies (e.g. central HPWH systems, reverse chillers, etc.). Therefore, they will require education to effectively check all-electric designs. This issue is different for commercial and residential, however. According to building official interviewees, larger residential projects and PV systems already go to commercial staff for review. Commercial staff are required to maintain professional certifications (architecture, engineer, ICC) that require ongoing education courses. **This creates a natural opportunity to implement additional training for all-electric technologies and strategies if trainings include continuing education units that can be used to fulfill ongoing professional education requirements.**

The interviews also identified some issues specific to residential code enforcement. Currently, plan reviewers do not check plumbing, mechanical or electrical systems. Enforcement for these items is through inspections. This may necessitate some procedure changes to ensure that certain issues (such as electric service capacity) are included in plan review. Additionally, Denver does not require professional licensure for residential projects, and building officials noted that there is a very high level of variability in the quality of submittals with some of them being very sub-par. As noted in the "Availability of Expertise" section, this issue is exacerbated for heat pump designs. Shifting the market to greater use of all-electric designs will require more enforcement oversight.

More Challenging Building Types

Interviews revealed some building and equipment types where they believed electrification would be more difficult:

- **Large central water heating systems:** Due to unfamiliarity with the systems and very different space requirements, this was seen as the major barrier in particularly large multifamily residences and hotels. This was also identified as a barrier for healthcare buildings, which can have high hot water loads.
- **Restaurants:** Buildings with commercial cooking were seen as particularly challenging since electrification would require business practice changes and workforce education.
- **General Multifamily:** Multifamily was seen as challenging due to very thin margins. This makes it more susceptible to cost impacts due to factors such as disrupting standard designs or impacting market positioning due to the lack of gas cooking.
- **Industrial/Manufacturing:** Any industrial building with gas-driven industrial or manufacturing process (including food production) would be very difficult to electrify since it would require the development of a new process. One interviewee noted that it might be necessary to draw a clear line between building loads and process loads to avoid this problem.

ELECTRIFICATION STRATEGIES

Most of these market barriers can be addressed with various market transformation and regulatory strategies. This section contains electrification strategies that have been suggested more broadly at the national level and in other markets as well as some strategies suggested by the interviewees.

Regulatory Drivers

Several interviewees stated that electrification was unlikely to see meaningful adoption without a regulatory driver that explicitly or effectively requires it. They identified Denver's Green Ordinance as one of the primary drivers of above-code performance and one of the bigger opportunities to foster electrification in Denver.

Education

As discussed in the "Availability of Expertise" section, the interviewees were generally confident in the ability of local practitioners to learn about electrification strategies and technologies. However, it was noted that part of the low market awareness and accurate familiarity was due to the fact that most practitioners, developers, owners and code officials are simply too busy to research these technologies on their own. They identified education as a critical need and suggestions generally aligned with education opportunities identified in national and other market discussion, including:

- **Design Workshops**. Denver could host professional development workshops where practitioners can learn how to effectively design all-electric buildings.
- **Technical Support from the City.** Denver could contract with some of the more experienced practitioners in the market to assist and mentor project teams with less experience.
- **Equipment Manufacturers**. Many manufacturers of equipment hold regular education and training sessions at their distributors or in the offices of design engineers. Denver could host similar training sessions open to the profession. However, interviewees noted that many practitioners and owners can react negatively if they feel like they are being given a sales pitch, so this strategy should be approached with care.
- **Utility Incentive and Continuing Education Programs**. Denver can work with Xcel Energy and its incentive programs to promote electric systems, as well as leverage Xcel's existing trade ally programs to disseminate resources**.**

Due to the business of practitioners, continuing education credits for training sessions are critical. Many practitioners – especially those who are licensed – are required to take a minimum number of continuing education credits each year, creating an opportunity to drive increased participation of electrification education sessions to earn those credits.

The building official interviewees identified the need for education of building officials. **They noted that code enforcement staff would require both fundamental education in all-electric designs and equipment and training in any enforcement issues.**

Market Outreach

Market outreach could be framed as education for the consumer. The interviewees identified several areas where consumer ignorance would be an obstacle to the adoption of all-electric buildings but that it could be addressed in market outreach. **Low public awareness about all-electric design requires a market outreach plan that covers the basics on all-electric buildings – not just the benefits and reasons consumers should want them.** It also would need to address commonly held but dated perceptions of heat pumps in the Denver market.

INTERIOR AIR QUALITY (IAQ)

Interviewees identified health and interior air quality (IAQ) as a major opportunity for market outreach messaging. The market is already emphasizing filtration as a value-add for buildings to improve IAQ. An outreach plan could capitalize on IAQ and health advantages of all-electric buildings. Interviewees said the focus needs to be on cooking since most other gas combustion equipment including furnaces and boilers have sealed combustion chambers in the Denver market.

COOKING

IAQ might provide one of the more potent messages for addressing the strong market preference for gas cooking identified in the "Market Perception" section. The viability of induction cooking could be another market message that could help mitigate the strong market preference for gas cooking. Recent studies indicate that customer perception may change with increased exposure to induction cooking. For example, the Sacramento Municipal Utility District (SMUD) found that 79% of customers had a negative impression of induction cooking prior to trying it, but a 91% positive impression afterwards.[19] Additionally, many people believe that "gourmet" stoves are gas models, but in 2018 Consumer Reports rated induction cooktops far ahead of gas in terms of performance. In addition, San Jose has an induction "hot plate" check-out program where residents can check out an induction hot plate and experience how they work for themselves. A program like this could be run at relatively low cost and help introduce people to the technology.

The commercial market will require different messaging. Several strategies have been considered in other markets. **One strategy would focus on recruiting prominent local and national chefs to endorse induction cooking in commercial cooking in order to both introduce the market to the technology as a viable alternative and ideally foster a trend.** Another focuses on safety and emphasizes induction cooking as a safer alternative to gas cooking since there are no flames, no hot surfaces and only the pans and the food in them get hot.

Market Differentiation

Interviewees identified cooking as one of the larger market obstacles for both residential and commercial buildings. In residential cooking, the primary barrier is a market preference for gas cooking by many consumers, and developer perception of market preferences. Gas cooking is seen as an amenity, and sometimes an essential amenity in higher-end projects.

Interviewees noted that developers, especially production residential builders, are always looking for market differentiation. The market outreach plan could position all-electric to offer them that differentiation. However, the existing prevalence of zero net energy goals in Denver – and the frequent confusion between zero net energy and all-electric buildings – means that Denver will very likely need to select one of the two to be Denver's "gold standard" for net zero emissions.

Incentives

Like national and other market stakeholders, interviewees identified incentives as a potentially powerful tool for increasing market penetration of all-electric buildings. They identified a few considerations that could be important for incentive programs in Denver:

- **Design Incentives.** Equipment incentives are important, but design incentives can help practitioners cover the additional time required to design all-electric buildings as they gain proficiency.

[19] http://2019.utilityforum.org/Data/Sites/5/media/posters/smud-induction-infographic-poster2.pdf

- **Market Segment.** Incentives need to be targeted at the mass market and not just go to the top end of the market. Since high-efficiency heat pumps are sometimes seen as the "Cadillac" option, incentives could be seen as give-away to the top end of the market. One interviewee said that ideological leanings of many Colorado residents could lead to backlash if the public feels they are paying for incentives that are "just paying for some rich guy's efficiency."
- **Expedited Permitting.** The adage that "time is money" is especially true in real estate development where higher-interest "hard money" and bridge loans are used to get from land acquisition through construction. One interviewee noted that the real opportunity is the land-use approval – as opposed to building permit approval – since that is the approval that can take months, incurring significant financing costs.

Incentive programs need to be structured to specifically benefit affordable housing, as that is the segment of the market where utility costs are most critical. This is particularly the case for financial incentives. It may make sense to reserve all or most financial assistance for buildings that will be used for affordable housing or businesses owned by disadvantaged communities.

Pilot Projects

Interviewees frequently identified the value of pilot projects. Pilot projects can be helpful with the issues of market awareness and market perception. They give a concrete, local proof-of-concept for all-electric buildings and can be used in market pushes and promotion. Pilot projects also can build market capacity for practitioners who gain proficiency in all-electric design.

One interviewee offered a word of warning about using municipal projects as pilot projects. Municipal projects can be seen as having generous budgets that do not reflect real-world projects. These are often building types not found in the commercial market – fire stations, schools, etc. – and so may not have as much of an impact as an office or similar building type.

LOAD CURVE ANALYSIS

Multiple interviewees expressed concerns about the impact of the increased electrical capacity with widespread electrification of buildings. This NZE Plan does not go into detail regarding load curves, however, a load curve analysis would assist in determining technologically how things must roll out for the grid. This effort is shaped with Denver's Strategic Existing Building Electrification Plan and further detail will be available when that is finalized.

MARKET READINESS ASSESSMENT FOR ALL-ELECTRIC: KEY CONSIDERATIONS

The key considerations regarding market readiness include:

- Cost is overwhelmingly the most significant factor in the current status of all-electric buildings in Denver and is the largest market barrier to the wider adoption of all-electric buildings in Denver.
    - Operating cost is a far larger issue than construction cost due to the very low relative cost of natural gas compared to electricity and the high heating loads in Denver.
    - Operating cost creates a significant issue for equity and affordability that will need to be addressed as an integral part of any policy strategy.
    - Construction cost barriers are due largely to projects considering the cost of the electrification of different systems in isolation rather than whole-building electrification strategies that allow for the significant cost savings of eliminating natural gas infrastructure.

- Considering the substantial cost market barriers, regulatory drivers likely will be critically necessary to meaningfully drive all-electric building market penetration.
- High heating loads in Denver, combined with low natural gas prices, create a situation where substantial gains in efficiency may be required to close the utility cost gap between mixed-fuel and all-electric buildings.

- The familiarity with current heat pump technologies is relatively low in Denver, leading many practitioners and consumers to have a negative perception of heat pumps based on older generations of equipment.
  - Practitioner familiarity with many important electric design strategies – particularly central heat pump water heater systems – is rather low. This creates barriers to all-electric design in the form of pushback and higher costs.
  - Low familiarity with all-electric building technologies creates a need for fundamental market education.
- Gas cooking is a significant market barrier in both residential and commercial buildings. In residential buildings, cooking is a market differentiator. Gas cooking is the norm in commercial kitchens and would require significant market transformation efforts.
- There appears to be a conceptual connection in the Denver market between zero energy buildings and all-electric buildings. This could pose challenges for outreach and market education. **It also can provide an opportunity if building electrification slots into the market space already occupied by zero net energy.**

Denver's All-Electric Targets

This section details all-electric requirements to reach the goal of net zero energy all-electric buildings and homes by 2030. In addition, this includes the milestones for new homes to be net zero and all-electric by 2024 and new buildings to be net zero and all-electric by 2027. As part of this NZE Plan, Denver asked the NZE Stakeholder Advisory Groups to review the targets for buildings and homes respectively to determine the recommendation for upcoming code cycles.

Table 31. Commercial Building All-Electric Targets for Denver Code

<table>
<tr><th>Building Type</th><th>2021</th><th>2024</th><th>2027</th></tr>
<tr><td>Small Hotel</td><td rowspan="6">All-Electric: except heating & water heating

All-Electric Ready: conduit for central systems & panel space</td><td rowspan="6">All-Electric: except water heating</td><td rowspan="6">All-Electric</td></tr>
<tr><td>Large Hotel</td></tr>
<tr><td>Medium Office</td></tr>
<tr><td>Large Office</td></tr>
<tr><td>Standalone Retail</td></tr>
<tr><td>Warehouse</td></tr>
</table>

Table 32. Multifamily Building All-Electric Requirements for Denver Code

Building Type	2021	2024	2027
3-story townhome & Low-Rise Apartment	Required	Required	Required
Mid-Rise Apartment (R-2: 4-7 stories)	All-Electric Ready: *conduit & panel space*	Required	Required
High-Rise Apartment (R-2: 8 or more stories)	All-Electric Ready: *conduit & panel space*	All-Electric Ready: *conduit & panel space*	Required

Table 33. Residential Home All-Electric Targets for Denver Code

Building Type	2021	2024
Single-family homes	All-Electric Ready: conduit & panel space	Required

Buildings and Electric Vehicle Charging Infrastructure

Denver's Electric Vehicle (EV) Action Plan (EV Action Plan) details the city goals for electric vehicles and how this fits into Denver's larger picture. One element within Denver's 80x50 Climate Action Plan is promoting the adoption of light-duty electric vehicles (EV), which have been shown to significantly reduce GHG emissions compared to gasoline vehicles.

The EV goals include:

- 2025: 15% of Denver vehicle registrations are electric
- 2030: 30% of Denver vehicle registrations are electric
- 2050: 100% of light-duty vehicles are electric

There are three key themes including: EV adoption is one piece of Denver's larger mobility picture, EV equity is a critical consideration, and the EV Action Plan focuses on light-duty plug-in EVs.

EVS IN CODE

In addition to the EV Action Plan, Denver also has code requirements for new buildings to support EV charging infrastructure. Because charging stations are increasingly tied to buildings and homes, considerations for electric vehicles within the code and the relationship to buildings is also included in this section. Denver's current 80x50 Climate Action Plan goal for EVs is 100% of light-duty vehicles to be electric by 2050. Additionally, the Climate Action Task Force recommends an emissions-free transportation system by 2040.

In 2019, Denver adopted one of the most aggressive EV-ready building code amendments in the country. Implementation of this code is planned to begin in August of 2020.

A consideration for future code cycles will be if the EV-ready code amendment should be more or less targeted for commercial buildings. Currently, the amendment focuses on six types of building occupancy (as defined in the IBC): assembly, business, educational, institutional, mercantile and low hazard storage. These building occupancies were chosen to focus on places where people are likely to park cars and have opportunities to charge during the day. It may be that additional occupancy types should be included to maximize the coverage of EV charging at different locations. It is also possible that within each occupancy type, the scope could be narrowed as several of these types have subclassifications.

An additional possibility in future code would be to allow DC fast charging stations to replace a certain number of Level 2 stations. The code currently requires Level 2 stations, but some of the commercial buildings with shorter dwelling times may be better suited for DC fast charging.

BUILDINGS AND TRANSPORTATION

Currently most electric vehicle charging takes place at the residence of the EV owner. This is the easiest and often least expensive place to recharge an electric vehicle. Many EV owners rely on basic Level 1 charging (a regular 110V outlet) in their garage or driveway, which can add around 40 miles of electric range during twelve hours of overnight charging, meeting the daily driving demands of many people.

Having access to charging at home is important for EV ownership. While some early adopters are able to take advantage of workplace or publicly available charging, most people desire convenient access to affordable charging. The current estimate of charging location is: 80% at home, 10% at work and 10% at public stations.

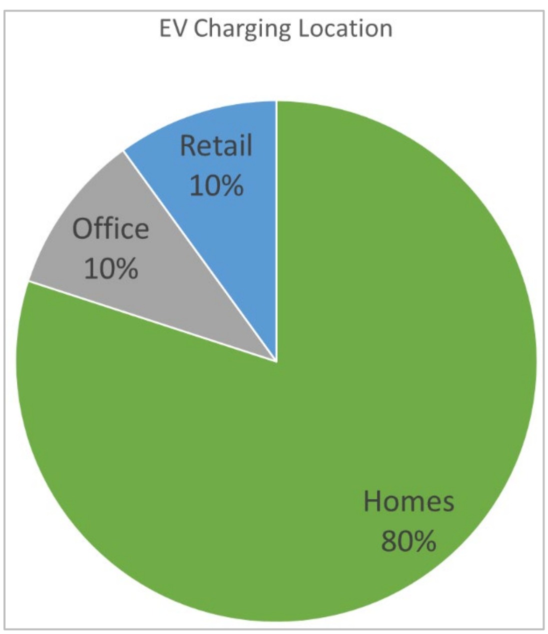


Figure 25. EV Charging Location: Homes, Office, Retail

Two trends are likely to encourage more charging outside the home. First, there will be more publicly available charging stations added in Denver in the future, in part due to the EV Ready building code amendments discussed above.

Second, if EV sales are to expand to meet the City's vehicle electrification goals, EV ownership will need to expand beyond those Denver households with access to home charging.

ESTIMATES OF ADDITIONAL ENERGY FROM EVS

There are considerations of the additional electrical use by electric vehicles. To do this analysis, Denver needs to understand or estimate the number of EVs registered, the miles/year and kWh/year that the EVs use, and the location of EV charging. As a first step, the number of EVs registered in Denver as well as projected numbers are shown in the table below.

Table 34. Baseline Total Number of EVs Registered in Denver

# EVs Registered	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Battery Electric Vehicle (BEV)	2,600	4,000	6,000	8,800	12,700	17,700	24,000	31,400	39,800	49,100	59,000	69,900
Plug-in Hybrid Electric Vehicle (PHEV)	1,700	2,400	3,300	4,200	5,200	6,200	7,400	8,600	9,800	11,100	12,300	13,700
Total Plug-in Electric Vehicles (PEVs)	4,300	6,400	9,300	13,000	17,900	23,900	31,400	40,000	49,600	60,200	71,300	83,600

Next, estimates are needed for annual mileage for Battery Electric Vehicle (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs). These include:

- Battery Electric Vehicle (BEVs)
  - Travel about 10,000 miles/year
  - Each BEV will use 3,300 kWh/year
- Plug-in Hybrid Electric Vehicles (PHEVs)
  - Travel about 7,500 miles/year
  - Each PHEV will use 2,500 kWh/year

Finally, Denver can estimate EV charging locations to be 80% residential, 10% office/workplace and 10% public (mainly retail).[20] From these parameters, future energy use was estimated for Denver.

[20] https://www.sciencedirect.com/science/article/pii/S136192091930896X#b0225; https://www.energy.gov/eere/electricvehicles/charging-home

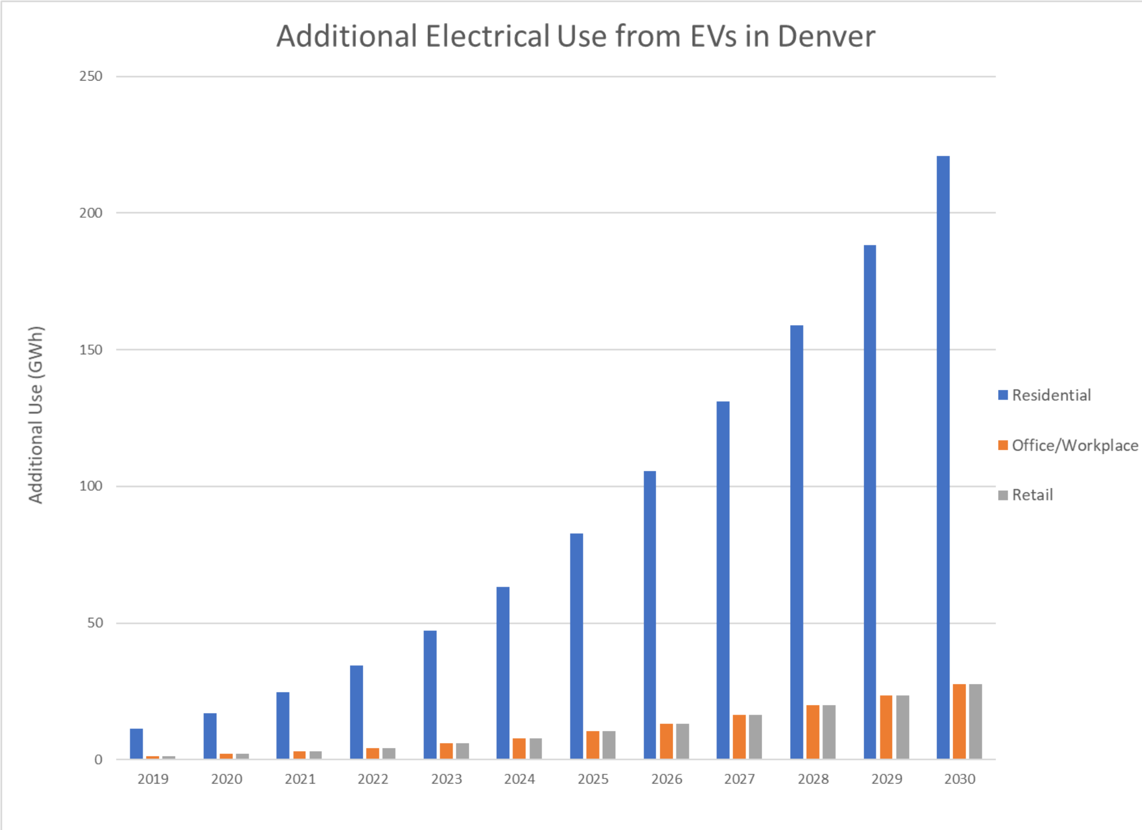


Figure 26. Additional Electrical Use from EVs in Denver

Charging Stations

A building's size can help determine the number of charging stations required. For most commercial buildings, adding one or two Level 2 charging stations should not have a significant impact on the building's electrical load. However, EV charging stations can negatively affect a building's demand charge if they are on a commercial rate. For most residential buildings, they currently do not have a demand charge. Xcel Energy does have a pilot program for residential time-of-use rates with demand charges that could result in savings if residential charging happens at off-peak times.

GRID FLEXIBILITY

The additional load from EVs can impact grid capacity, but the main issue is timing.

- Residential load is likely to occur between 6 p.m. and 6 a.m. and is primarily single-family residential.
- Workplace/office charging occurs between 9 a.m. and 2 p.m.
- Retail/public charging occurs between 9 a.m. and 6 p.m., with peaks likely during commute times.

VEHICLE TO GRID

The potential for electric vehicles as mobile power generators providing power back to the grid is limited to small pilot projects currently. For electric vehicle batteries to become grid resources in the future, a number of issues will need to be overcome.

First, the number of EVs on the road will need to increase by significant amounts to make the potential volume of distributed power large enough to have an appreciable impact on the grid.

Also, vehicle and battery manufacturers will need to become more comfortable with vehicle-to-grid power flow. Only one major manufacturer (Nissan) allows vehicle to grid without voiding the warranty on the vehicle's battery.

Finally, communication between vehicles, charging stations and utilities will need to be developed and refined. Utilities will need clear information on vehicles locations in order to rely on them for power.

Cost Considerations and Study: All-Electric

All-electric buildings have a range of costs compared with mixed-fuel equivalents. Two cost impact studies were done for the Denver market to quantify the cost differences between all-electric and mixed fuel buildings. A handful of studies also have been done for other markets, and these contain important lessons on cost impact of building electrification. Combined with feedback from Denver stakeholders, these studies can help frame considerations for electrification in Denver.

ALL-ELECTRIC COST STUDIES

Only a limited number of formal studies have examined the cost impact of electrification for buildings and homes. Specifically for Denver, Group 14 completed a building electrification study including an office building and single-family home – Electrification of Commercial and Residential Buildings. The Rocky Mountain Institute (RMI) studied a number of climates for single-family homes including Denver in The Economics of Electrifying Buildings. The most comprehensive all-electric cost studies have been done for California with a smaller study done for Salt Lake City, and these offer lessons and insights for Denver.

Calculating the Cost of All-Electric Buildings

The cost of all-electric buildings can be considered in two primary ways: first cost and lifecycle cost (LCC). First cost includes only the cost of design and construction and does not include operating costs. The LCC includes both first cost and the operating costs over a set period of time.

To evaluate the first cost of an all-electric building, the cost of design and construction is compared to a mixed-fuel building. A first cost assessment needs to go beyond just the equipment in the building; it also needs to account for the costs savings of the building's energy infrastructure and utility connections. For example, an all-electric building could have higher costs from a larger electric service size, on-site transformers or additional electrical wiring, but lower costs from the elimination of a natural gas service connection and piping in the building.

Lifecycle cost (LCC) goes beyond first cost by including operating costs. The definition of the length of the lifecycle can vary from one LCC approach to another. Some common time periods include the service life of the building (typically 30 or 50 years), the service life of the equipment being considered, or the length of a typical mortgage (often 30 years for residential and 15 years for commercial buildings). The way that future costs are calculated also varies from one LCC approach to another. For example, future utility costs could be held constant or change based on projections from an analysis of future utility costs.

Additionally, some LCC calculations include a net present value (NPV) calculation that discounts the value of costs and benefits by how far in the future they are. NPV calculations are common in making real estate development and investing decisions and may be important to certain stakeholders. The bottom line is that LCC calculations can be complex and vary considerably by approach.

ELECTRIFICATION OF COMMERCIAL AND RESIDENTIAL BUILDINGS

The office building and single-family home study Electrification of Commercial and Residential Buildings included an evaluation of system options, economics and strategies to achieve electrification. It focused on upfront and long-term cost estimates of electrification from data retrieved from a single-family home in Arvada , CO and a commercial office building in Lakewood, CO.

The study found that constructing an all-electric home had 27% lower upfront costs for single-family new construction. The study included Xcel Energy rebates currently available for heat pumps. As a result, new construction electric homes cost around $5,300 less to build when compared to new construction mixed fuel homes. This includes the cost savings on natural gas connections.

	End-of-Life Replacement		New Construction[1]	
Description	**Heat Pump**	**Natural Gas**	**Heat Pump**	**Natural Gas**
Central heating/cooling system (including install)	$15,000	$15,000	$13,000	$13,000
Tank type domestic hot water heater	$3,300	$2,600	$3,100	$2,400
Electrical modification	$2,100	----	$500	----
Natural gas connection and piping (new construction only)	----	----	----	$6,500
Total Cost	**$20,400**	**$17,600**	**$16,600**	**$ 21,900**
Delta in Cost for Heat Pump		***$2,800***		***$ (5,300)***

[1]The costs shown in the table are estimated for custom installations at a single-family home. Larger projects by developers are expected to have lower first costs. Developer first costs are estimated to be around $12,250 total for the heat pump option compared to $18,200 total for the natural gas option, including the electrical and natural gas connections, which is a cost savings of **$5,950** or **33%**.

Source: Electrification of Commercial and Residential Buildings

Figure 27. Single-Family Homes All-Electric First Costs

The study also found that constructing an all-electric office building had 8% lower upfront costs, showing that constructing commercial buildings costs about $18,100 less.

	End-of-Life Replacement		New Construction	
Description	Heat Pump	Natural Gas	Heat Pump	Natural Gas
Central heating/cooling system (including install)	$234,000	$234,000	$216,000	$216,000
Tank type domestic hot water heater	$4,200	$2,600	$3,800	$2,400
Electrical modification	$3,000	----	$1,500	----
Natural gas connection and piping (new construction only)	----	----	----	$21,000
Total Cost	**$ 241,200**	**$ 236,600**	**$ 221,300**	**$ 239,400**
Delta in Cost for Heat Pump		***$ 4,600***		***$ (18,100)***

Source: Electrification of Commercial and Residential Buildings

Figure 28. Office Building First Costs

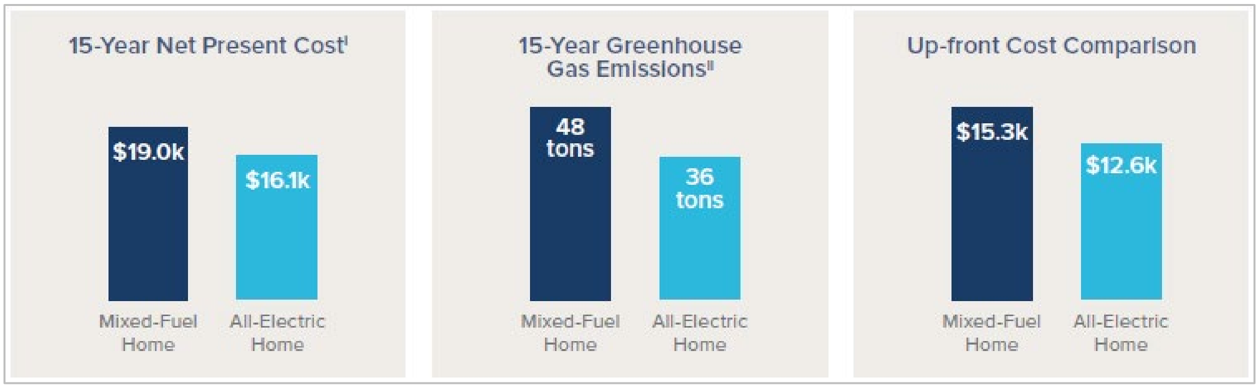
Denver also reached out to local builders who reviewed the costs in this study. They responded to the costs and identified supports needed including:

- All Electric First Cost Considerations
  - First costs from a builder with a real example in Denver are higher than shown in the studies
  - Incentives offsetting the actual first cost for heat pump heating and water heating would be beneficial
  - Incentives for developer of all-electric communities would be beneficial
  - Utility rate changes are needed to incentivize all electric through reduced operating costs
- Supports Needed for All Electric
  - Significant marketing and education
  - Consumer awareness of all electric products and their operation
  - Benefits of all-electric need to be understood by consumers
  - City needs to understand consequences that may affect the acceptance, marketability and sale of new residential construction

The technical details and costs in this NZE Plan should be considered in conjunction with the supports needed to reach the goals, targets and milestones to successfully reach net zero energy. Supports are further detailed in the "Cost and Supports Needed for NZE" section.

RESIDENTIAL NEW CONSTRUCTION: DENVER, SINGLE-FAMILY HOMES

The Rocky Mountain Institute (RMI) studied a number of climates for single-family homes including Denver for The Economics of Electrifying Buildings – Residential New Construction: Denver, Single-Family Homes. This study outlined upfront and lifetime cost estimates for new construction of an all-electric single-family home and a new construction mixed fuel single-family home, both in the Denver region. The all-electric home cost $2,700 less in up-front costs. The majority of the upfront savings that electric homes realize are by avoiding gas interconnection.



Source: The Economics of Electrifying Buildings

Figure 29. Economics of Electrifying Buildings in New Single-Family Homes in Denver

The study also found that building an all-electric home saved $2,900 in net present costs over 15 years and that all-electric homes have 2% lower annual utility costs than mixed fuel homes.

THE CALIFORNIA ELECTRIFICATION REACH CODE EXPERIENCE

In 2019 and 2020, several California jurisdictions began to implement electrification reach codes. These reach codes were configured specifically to foster electrification in new buildings. In general, they did this by requiring mixed fuel buildings to achieve higher levels of efficiency than all-electric buildings and to include electrification-readiness requirements. The intent was for the additional cost of mixed-fuel buildings to incentivize all-electric design.

To support this effort, the California Codes and Standards Statewide Utility Program[21] developed a collection of cost studies. To date, these studies offer the most comprehensive examination of the cost impact of all-electric buildings by far. These studies included a comprehensive analysis of the cost of multiple above-code scenarios that included different combinations of efficiency measures, photovoltaics (PV) and on-site storage. This is an important element of this exercise: under California's energy code, both PV and on-site storage can be used to contribute to code compliance. In 2019, two studies were released. The low-rise residential study[22] included single-family homes and low-rise multifamily scenarios. The non-residential study[23] included office, retail and mid-rise hotel scenarios. In California, a mid-rise hotel prototype is typically used to represent high-rise multifamily, as well.

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[21] The California Codes and Standards Statewide Utility Program is an initiative funded and administered by the California utilities that supports code advancement. Through their involvement in the code development process, the California utilities are able to claim a portion of the savings from the energy code toward their state-mandated energy efficiency goals. See https://localenergycodes.com for more about the reach code.

[22] "Cost-effectiveness Study: Low-Rise Residential." Prepared by Frontier Energy, Inc. & Misti Bruceri & Associates, LLC for The California Codes and Standards Statewide Utility Program. 2019. (https://localenergycodes.com/download/73/file_path/fieldList/2019%20Res%20NC%20Cost-eff%20Report)

[23] "2019 Nonresidential New Construction Reach Code Cost Effectiveness Study." Prepared by TRC Advanced Energy & EnergySoft for The California Codes and Standards Statewide Utility Program. 2019. (https://localenergycodes.com/download/74/file_path/fieldList/2019%20NR%20NC%20Cost%20Effectiveness%20Report)

However, the issue of central heat pump water heating[24] created the need to address mid-rise[25] and high-rise multifamily scenarios directly.

The studies identified the maximum above-code performance that could be achieved cost effectively[26] for both all-electric and mixed-fuel buildings. The studies then used this information to compare the cost of all-electric and mixed fuel buildings. They calculated the cost differential of an all-electric building by using a code-compliant mixed fuel building as the baseline and characterized the difference in terms of first costs, annual on-bill costs and lifecycle costs.

Relevance of Results to Denver

Differences in utility costs, construction costs, code baseline and climate mean that the results from these California studies are not directly applicable Denver. However, the incremental cost information from California is still relevant to Denver in that it demonstrates broad trends.

- **Climate:** The climates in Denver and most of California are very different, however, parts of Northeast California are in Climate Zone 5B (see Figure 30, left: US Climate Zones. California uses a custom set of climate zones for code (see Figure 30, right: California energy code climate zones), and California's Climate Zone 16 is the most relevant for Denver.
- **Energy Costs:** California has generally higher energy rates compared to those in Denver. For example, the rate for residential electricity in Denver is $0.05461 to $0.11876 per kWh[27] but is $0.14189 to $0.53525 per kWh for the Climate Zone 16 case in the California Cost Effectiveness studies.[28] Likewise, the residential natural gas rate for Denver is $0.13268/therm[29] but $1.4552 to $2.05353/therm for the Climate Zone 16 case in the California Cost Effectiveness studies.[30] The much higher energy rates in California mean that energy efficiency is going to tend to be more cost effective.

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[24] See ACCC Report: "Technical Feasibility of All-Electric Design." Prepared for the City of Denver by New Buildings Institute

[25] "2019 Mid-Rise New Construction Reach Code Cost-Effectiveness Study." Prepared by Frontier Energy, Inc. & Misti Bruceri & Associates, LLC for The California Codes and Standards Statewide Utility Program. 2019. (https://localenergycodes.com/download/492/file_path/fieldList/2019%20Mid-rise%20NC%20Cost-Eff%20Report.pdf)

[26] The California Energy Commission (CEC) has set a set of standards to test cost effectiveness for changes made to Title 24, California's energy code. This is the cost effectiveness standard followed by the reach code cost effectiveness studies. The CEC allows either on-bill cost or Time Dependent cost Valuation (TDV cost takes into account the varying cost of energy production based on time of day and time of year) to be used as part of the cost effectiveness calculation.

[27] "Public Service Company of Colorado Electric Tariff Index." (https://www.xcelenergy.com/staticfiles/xe-responsive/Company/Rates%20&%20Regulations/Regulatory%20Filings/CO%20Recent%20Filings/PSCo_Electric_Entire_Tariff.pdf)

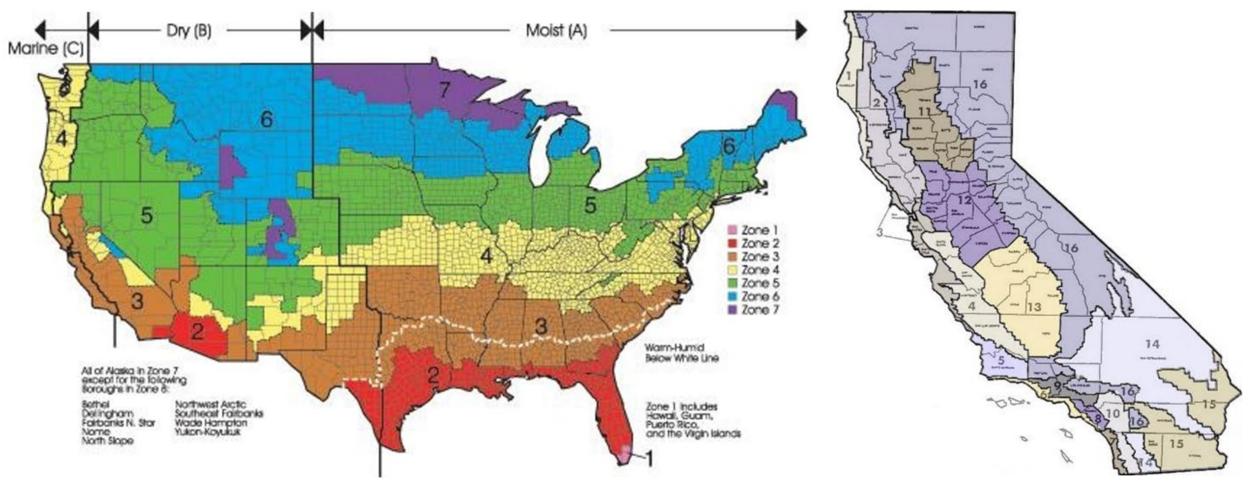
[28] Residential Time of Use. (https://www.pge.com/tariffs/Res_Inclu_TOU_Current.xlsx)

[29] Public Service Company of Colorado Gas Tariff Index. (https://www.xcelenergy.com/staticfiles/xe/PDF/Regulatory/psco_gas_entire_tariff.pdf)

[30] Residential Non-CARE and CARE Gas Tariff Rates. (https://www.pge.com/tariffs/Res_Current.xlsx)

- **Gas Costs:** The cost disparity between the gas rates is much higher than the disparity between the electric rates, which means that the operating costs' impact of electrification will be far greater in Denver than the California experience. The variables used in the California cost studies likely underrepresent future gas costs. At the same time, California gas utilities are facing major capital expenditures in the near future to comply with seismic safety requirements for their infrastructure and electrification is already a major trend in California. As a result, increased infrastructure costs will need to be supported by a smaller customer base. These issues may not represent the situation in Colorado, but they highlight the impact that future cost can have on life-cycle cost-effectiveness.
- **Time-of-Use Rates:** California also has a more robust set of time-of-use rates than Denver. As a result, technologies that save peak energy have a larger impact on energy costs.

- **Construction Costs:** The California cost effectiveness studies assume California labor rates, which will be generally higher than those in Denver. However, there is another element of construction cost that is more difficult to quantify. Due to California's longer-standing carbon reduction efforts, milder climate and relatively more expensive natural gas costs, all-electric design is more common in California than Denver. Therefore, costs for all-electric buildings in Denver may be increased by designers and contractors applying "risk premiums" to projects to account for the additional costs that they could incur as a result of their lower level of familiarity with all-electric designs. Anecdotally, a risk premium as high as 60% has been seen in a central heat pump water heater (HPWH) design in the Northwest.



Source: PNNL (left), California Energy Commission (right)

Figure 30. US Climate Zones (left), California Energy Code Climate Zones (right)

COST EFFECTIVENESS RESULTS

At the time of writing, results are available for single-family, low-rise multifamily, office, retail, mid-rise hotel and supplemental results for mid-rise multifamily. The non-residential and residential follow slightly different methodologies and report the results differently. However, in all cases there are key pieces of information: first cost and lifecycle utility cost impact.[31] The first cost impact of an all-electric building type is lower if the number is positive and higher if the number negative. The lifetime on-bill impact is better for an all-electric building type if the number is green and worse for a number that is red. The relevant results are summarized in the table below.

Table 35. Summary of CA CZ 16 Results by Building Type

Building Type [a]	First Cost Impact (+ savings/- expense)	Lifetime On-Bill Impact [b]
Single-Family: Code Compliant	+$5,349	($12,042)
Single-Family: Above Code	($11,279)	+$19,813
Low-Rise Multifamily: Code Compliant	+$2,337	($3,725)
Low-Rise Multifamily: Above Code	($2,061)	+$6,600
Mid-Rise Multifamily: Code Compliant [c]	+$531	($1,268)
Mid-Rise Multifamily: Above Code [c]	($2,635)	NA
Office: Code Compliant	+$64,096	($247,469)
Office: Above Code	($309,046)	+$399,822
Retail: Code Compliant	+$25,771	($58,338)
Retail: Above Code	($189,562)	+$511,477
Mid-Rise Hotel: Code Compliant	+$1,275,575	($1,426,771)
Mid-Rise Hotel: Above Code	+$1,263,534	-$905,844

a. Results for single-family are per home, results for multifamily are per dwelling unit, results for all others are per building.
b. Green numbers indicate that the scenario is cost-effective, red numbers indicate that the scenario is not cost-effective. Negative numbers can still be cost effective and positive numbers can still be not cost effective.
c. As of the writing of this report, the results for the mid-rise cost-effectiveness study are still preliminary and the results for the high-rise cost-effectiveness study are not available at all. Information in this table for mid-rise multifamily are from "2019 New Construction Cost-effectiveness Studies: Mid-Rise Multifamily Residential Cost-effectiveness Study Preliminary Results" presented by Misti Bruceri at the CA Reach Codes Team monthly coordination call on March 5, 2019.

Single-Family

The first cost of a code compliant all-electric single-family home in the study was lower by $5,349 than the first cost for mixed-fuel homes (resulting in a first cost savings). These savings were due mostly to the elimination of the natural gas utility connection, internal piping and the elimination of combustion exhaust. However, the lifetime utility cost increase was more than double the first cost savings. An all-electric home therefore costs less to build/buy, but more to operate on an annual and lifecycle basis. However, the study also evaluated cost effective above-code all-electric scenarios. With the addition of cost-effective efficiency measures, the benefit cost ratio was increased above 1 and the lifetime on-bill impact was $19,813 (single-family: above code).

Low-Rise Multifamily

A code-compliant all-electric building is not cost effective on an on-bill basis for low-rise multifamily. Like the single-family analysis, the all-electric low-rise multifamily building costs less to construct ($2,337), but more to operate. It is important to note that increased cost is just over $10 per month; this highlights that a pure cost-effectiveness analysis does not give a sense of real-world dollar impact.

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[31] For the low-rise residential study, the lifecycle period is 30 years. For the non-residential study, the lifecycle period is 15 years. Due to the use of a Net Present Valuation calculation and utility rate annual increase factor, the lifetime utility cost impact cannot simply be divided by the lifecycle period to generate the annual utility impact.

However, while this impact may be minimal for some households, even a small increase in utility cost can be a substantial burden to resource-constrained households.

The low-rise multifamily code-compliant scenario is closer to being cost effective than the single-family code-compliant scenario. This is due in large part to the fact that multifamily generally has a higher load density than single-family homes and is therefore less heating-load dominated, which mitigates the impact of costlier electric heating. Like with single-family, adding a cost-effective amount of energy efficiency results in the all-electric building being cost effective on an on-bill basis.

Office

The office prototype uses a VAV system and includes a heat pump and electric resistance re-heat in the all-electric version. This is not a particularly efficient all-electric approach, especially when time of use charges are considered, and so the cost effectiveness is particularly poor. Moving to a cost-effective above-code design is cost effective on an on-bill basis. The selection of a heat pump system with better performance during peak periods with demand rates could also improve the cost effectiveness.

Retail

The all-electric retail prototype is also less costly to construct but costlier to operate and does not meet the cost-effectiveness test. The lifecycle utility costs are nearly twice the first cost savings. Also, like the other building types, a cost-effective level of performance makes the all-electric design cost effective on an on-bill basis.

Mid-Rise Hotel

The midrise hotel results show substantial first cost savings for the all-electric approach. They also almost show cost-effectiveness on an on-bill basis. However, the prototype model used for the mid-rise hotel utilizes individual water heaters for each room, a very unlikely approach in a mid-rise hotel. Hotels typically use central water heating systems even though they are far more expensive because of the space savings they afford. The cost effectiveness would look very different if a central heat pump water heating system were compared to a central gas boiler system. The preliminary results for the mid-rise multifamily prototype below make this comparison and probably give a more realistic assessment of the costs for a hotel.

Some mid-rise multifamily units do use individual water heaters. These water heaters are generally electric because of the cost and complications of running gas piping and exhaust vents for gas water heaters through a mid-rise building.

Mid-Rise Multifamily

Mid-rise multifamily was assessed separately (as of the writing of this report, the high-rise cost-effectiveness study is not yet complete). The mid-rise study looked at two “central” HPWH systems: a clustered approach and a true central system. The clustered approach does not use a recirculation loop and includes multiple water heaters distributed throughout the building.

The central system uses a central HPWH plant connected to a recirculation loop. The clustered approach has a lower first cost than a central gas boiler system but the central HPWH system has a higher first cost. California requires the installation of a minimally sized solar thermal system for gas boilers. Denver has a similar requirement, but Denver’s requirement allows a project to install a higher efficiency boiler instead, which can be achieved at minimal or even zero incremental cost. When the cost of the solar thermal system is removed from consideration, the clustered HPWH approach also has a higher incremental cost.

	Central Gas Boiler (CZs 1-9)	Central Gas Boiler (CZs 10-16)	Clustered HPWH	Central HPWH
System Quantity/Description	1 boiler recirc		32 units 80 gal. each no recirc	15 units .1,200-gal total recirc
Total Equipment Cost	$98,733		$126,778	$213,364
Solar Thermal	(20% SF) 110,096	(35% SF) $131,817	-	-
Solar PV	-	-	-	$23,580 (8.8 kW_{DC})
Total First Cost	$202,920	$224,641	$126,778	$236,944
Maintenance/Replacement Cost (NPV)	$69,283	$69,283	$81,374	$120,683
Total Cost (NPV)	$272,203	$293,924	$208,152	$357,627
Incremental Cost CZ 1-9 (NPV)			($64,051)	$85,424
Incremental Cost CZ 10-16 (NPV)			($85,772)	$63,703

Source: 2019 Mid-Rise Residential New Construction Cost-Effectiveness Study

Figure 31. First Cost of a Central and Clustered Water Heating System in a Mid-rise All-Electric Building [32]

With the study's first cost, the clustered approach is not cost effective on an on-bill basis. The central system is not analyzed since its higher first costs make cost-effectiveness impossible. These results are very relevant for Denver since central HPWH systems have also been identified as the gas load that poses the greatest technical and market barriers to electrification.

SUMMARY

This series of cost effectiveness studies for California present a clear pattern when it comes to costs in all-electric construction. In most cases, all-electric buildings have lower first-costs than mixed-fuel buildings. This is due largely to the savings from the elimination of the gas service and on-site gas infrastructure.[33] **As a result, all-electric buildings are less expensive for developers and builders to construct and many California developers and builders are doing just that in order to reduce construction costs.** However, the higher lifecycle costs of using electricity for space heating, water heating and cooking often exceed those savings. Denver's substantially cheaper gas prices exacerbate that issue.

[32] From "2019 New Construction Cost-effectiveness Studies: Mid-Rise Multifamily Residential Cost-effectiveness Study Preliminary Results." Presented by Misti Bruceri at the CA Reach Codes Team monthly coordination call on March 5, 2019.

[33] There is an additional cost savings from the elimination of the gas service that the studies do not include. Scheduling utility connections poses a major risk for delays, which come with potentially significant costs. Eliminating one of the two utility hook-ups eliminates that delay risk.

Pairing energy efficiency and electrification can address the operating cost issue. **Electric equipment is capable of achieving much higher levels of efficiency than their gas counterparts, and that efficiency can be leveraged to cost-effectively reduce operating costs**. Electric water heating with HPWHs creates another opportunity for operating cost savings. The larger tanks typically used in HPWH systems can be used as a buffer to shift equipment operation to off peak hours. With the greater use of time-of-use rates, this load-shifting capacity could result in substantial savings.

THE SALT LAKE CITY EXPERIENCE

In 2019, the Building Electrification Initiative and Cadmus conducted an incremental cost study of all-electric new multifamily construction. Salt Lake City is in IECC Climate Zone 5B like Denver, and likely has a weather profile that is more similar to Denver than California Climate Zone 16.

Due to limited City resources to support electrification, the study focused on scenarios where an economic analysis based on the customer could support electrification aiming to:

- Identify buildings and retrofits with positive customer economics under today's conditions,
- Prioritize strategies the City or local utility can employ to improve customer economics, and
- Educate and engage the building community on increasing heat pump installations.[34]

This analysis is comprised of multiple variations that included additional variables such as increased efficiency and PV. Results are presented in first-year savings, simple payback and lifecycle (NPV). The utility rates for Salt Lake City are also much more comparable to Denver – electric rates of $0.088 to $0.145 per kWh and gas rates of $0.587 to $0.713 per therm – though still substantially higher.

EE Measures	PV (Solar Subscriber)	Incremental upfront cost (w/ incentive)	First year net operating savings	Payback period (simple)	NPV *(10% discount rate)*	NPV *(5% discount rate)*
Without Air Sealing/ Insulation	Without PV	$2,250	$108	0 years	$3,290	$3,720
	With PV	$2,250	($37)	0 years	$2,780	$3,160
With Air Sealing/ Insulation	Without PV	$1,270	$119	0 years	$2,420	$2,890
	With PV	$1,270	($25)	0 years	$1,900	$2,310

Source: Building Electrification Initiative Salt Lake City: Customer Economic Analysis

Figure 32. Incremental Cost for New All-Electric Mid-rise Multifamily

Figure 32 shows the results for a new all-electric mid-rise multifamily building. This scenario utilizes individual HPWHs and includes the impact of locally available incentives. In most cases, the first-year

[34] "Building Electrification Initiative Salt Lake City: Customer Economic Analysis." Prepared for Salt Lake City by The Building Electrification Initiative and Cadmus. November 5, 2019

results (first cost plus first year of operating costs) showed cost savings. In all cases, the simple payback was less than a year and the lifecycle impact resulted in total savings.

The bulk of the up-front cost savings resulted from the elimination of the gas utility connection and on-site gas infrastructure and from utilizing ductless heat pumps and eliminating ductwork and soffit costs (Figure 33). The study also identified savings from eliminating envelope penetrations and identified space savings from eliminating gas exhaust infrastructure.

Input Description	Input	Unit	*Notes/ Sources*
Avoided gas connection costs	$425	$/unit	*Local Interviews*
Avoided construction costs related to gas	$2,000 – ductwork $300 – combustion air shafts $200 – envelope penetrations	$/unit	*Local Interviews*
Added electrical cost	$857	$/unit	*Local Interviews*
Avoided monthly fixed cost	$6.75	$/ month	*Dominion*
Subscriber Solar	$0.117 (fixed over 20 years)	$/kWh	*Rocky Mountain Power*

Source: Building Electrification Initiative Salt Lake City: Customer Economic Analysis

Figure 33. Line Item Cost Impacts of All-Electric Design

One important thing to note about this study is that the all-electric building includes an inherent performance advantage. The gas equipment in the baseline only meets the code minimums while the electric equipment in the all-electric case is significantly more efficient than code minimums and the rest of the building features are held constant. The all-electric building therefore has an advantage reducing operating costs compared to a code-compliant all-electric building. In this way, this study resembles the above-code scenarios in the California Reach Code studies more than the code-compliant scenarios.

	Counterfactual Equipment			Electrification Equipment		
Input Description	Natural Gas Furnace	Central A/C	Air Exchange	Ductless mini-split	Air Exchange	Notes/Sources
System info	10 kbtu	0.6 ton	Air exchange - Air King BFQ80	0.75 ton *0.5 ton – w envelope measures*	Panasonic FV-08VKS3 Exhaust Fan	*BEopt outputs*
System efficiency	80% AFUE	14 SEER		12 HSPF, 22 SEER (cold climate)		*BEopt defaults*

Source: Building Electrification Initiative Salt Lake City: Customer Economic Analysis

Figure 34. Efficiency Levels of Gas and Electric Equipment

ALL-ELECTRIC COST IN DENVER

Incremental cost can be very nuanced, and this section summarizes a series of key issues for considering the cost of all-electric buildings. These considerations ensure that any discussion or research of the costs of all-electric buildings are complete, targeted and accurate.

- **Take a holistic approach to cost that accounts for both the increased costs and the cost savings of all-electric buildings.** The most important issue for considering the incremental cost of all-electric buildings is to compare the costs of mixed-fuel and all-electric buildings holistically. In interviews with Denver stakeholders, it was clear that when electrification is being considered in the Denver market, it is rarely being considered on a whole-building basis. More typically the cost considerations are solely a switch from one piece of equipment to another.
- **Use anecdotal cost information with caution; do not use speculative or estimated cost information.** Actual buildings are sometimes used as a source of cost information. Anecdotal information from real projects can be very useful but should be considered with caution. It can be misleading since it is based on the circumstances of a specific project that may not apply to other projects.
    - Anecdotal cost information based on estimated expectations of cost are particularly problematic. It is not based on either prototypes that represent average building characteristics or the proven costs of actual buildings. Prototypes and actual projects provide the specific details of the building systems that are necessary for accurate cost estimation. It is very difficult to meaningfully estimate costs without that specific information.
- **Utilize a lifecycle analysis that incorporates both the upfront and ongoing costs of building electrification.** A lifecycle cost analysis will consider both up-front and long-term costs. Long-term costs can include utility costs, maintenance costs, financing costs and even equipment replacement costs if the lifecycle term is long enough. A lifecycle analysis also can incorporate a net present value calculation (such as the case in the California reports), which can put future costs (and savings) in terms of present dollars. When assessing these long-term costs, there can be substantial differences between mixed-fuel and all-electric buildings:
    - The annual costs of maintenance for electric and gas equipment can be very different.
    - **Upfront cost savings can also result in ongoing financing cost savings.**
    - The escalation rates (the rate at which costs like utility costs increase from year to year) can be very different for natural gas and electricity.[35]
- **Consider who pays which costs.** Related to the issue of lifecycle cost, it is important to consider who pays which costs of electrification. **In buildings that are rented rather than owned, upfront costs and operating costs can be paid by different parties.** Any program that is meant to address potential cost increases from electrification needs to pay special attention to these issues. Incentives that reduce up-front costs are unlikely to pass to occupants and effectively address utility cost affordability.

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[35] Escalation rates can be a challenging topic. Natural gas is currently relatively cheap in Denver due to factors such as hydraulic fracking, but those costs could change dramatically with changes in regulations on natural gas. Costs could also change notably if electrification becomes far more common and the cost of maintaining gas infrastructure falls on a significantly smaller customer base.

- **Use prototype buildings as the basis for any costing exercise. Prototypes generally do not resemble any specific building, and that is their strength.** It allows them to be used to produce information that is widely applicable and is less impacted by the design features that are specific to a design that has been built. The Pacific Northwest National Lab has developed prototype buildings that are used for modeling the energy impact of the national model energy codes. These buildings also can be used as the basis for assessing incremental cost. This can save the effort of creating prototypes, but it means the energy impact of electrification can be directly related to the costs of electrification in order to calculate cost-effectiveness.
- **Base cost information on up-to-date electrification technologies/strategies and up-to-date costs for those technologies/strategies.** Cost databases sometimes contain older data for building equipment and materials. **Additionally, the cost of many pieces of electric equipment have come down considerably in the last few years.** The market for electric equipment, particularly heat pumps, has advanced recently, creating new options for electrification strategies that may not have been available before.
    - This relates to issues using cost data for actual projects. For strategies or technologies that are rapidly evolving, such as heat pumps, costs can change quickly and projects that already have been constructed are more likely to have dated cost data either because prices have changed or the strategies/technologies they used have been supplanted in the market.
- **Include only the costs that are directly related to electrification.** It is important to only include the costs from electrification in the all-electric building case. As noted by some of the Denver stakeholder interviewees, heat pumps can sometimes occupy the premium end of the market. The models that are more familiar or readily available in the Denver market might also be the models with premium features like advanced controls, remote access, grid interactivity or other features that are not necessary for electrification. The cost of electrification should not include the cost of these additional features.

  This issue can get complicated due to the high efficiency of most heat pump equipment available on the market. **Most heat pump equipment is considerably more efficient than code minimums.** If gas equipment in a design is replaced with heat pumps – and other changes are made to the design – the resulting incremental cost represents both electrification and additional efficiency. In order to eliminate the portion of the cost premium due to efficiency, the design would need to be altered to reduce the efficiency in other parts of the building. (The chart below depicts this conceptually. While not depicting actual costs, it shows the impact of accounting for efficiency in the total cost of an all-electric building.)

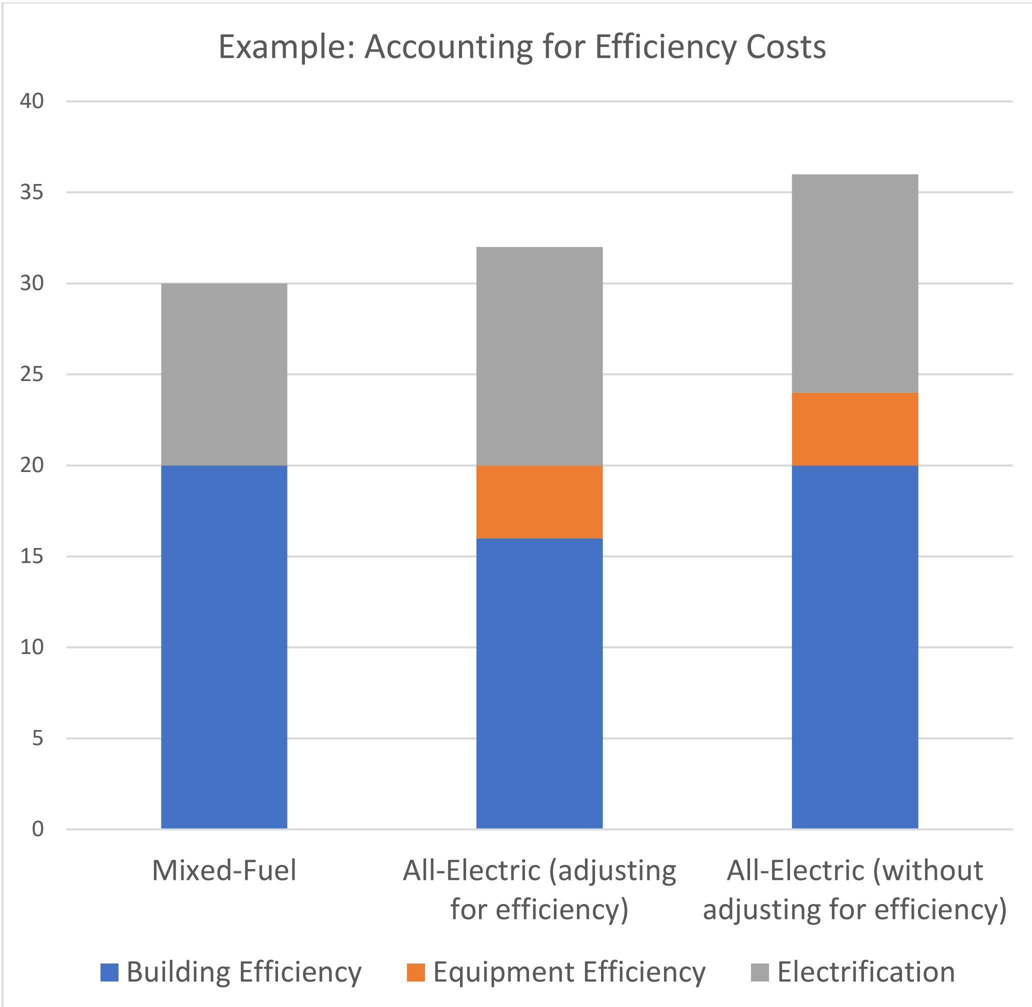

Figure 35. Example: Account for Efficiency Costs

- **The cost of electrification should be based on the most cost-effective option.** When evaluating the cost of electrification for policy decisions, it is important to identify the most cost-effective strategy available as the basis for the cost of the policy. **Sometimes the most cost-effective solution is not the most common solution or the solution that is preferred by the market.** However, the cost impact of electrification policies still should be based on the most cost-effective solution. Individual projects may choose to go with a costlier option due to factors specific to their project – such as familiarity, design constraints, etc. – but that increased cost would be due to the design decisions of the project team, not due to electrification itself. If individual project teams decide to adopt an approach that is not cost-effective, that does not mean that electrification itself is not cost effective.

  For example, central heat pump water heating systems for multifamily often have higher upfront costs than central gas boiler water heating systems. However as discussed in the "The California Electrification Reach Code Experience" section, a distributed HPWH system can have lower first costs. **By distributing smaller HPWHs and storage tanks around the building that each serve a small zone of hot water uses, the complexity and costs of equipment and the**

distribution system can be reduced. This approach requires changing the internal layouts of buildings and adopting system designs that may be unfamiliar to design teams. Some design teams may be unwilling to adopt the most cost-effective solution. When a design team makes that decision, that additional cost should not be attributed to electrification.

It is therefore important to base the cost differential of all-electric buildings relative to mixed-fuel buildings on the most cost-effective option available.

These considerations can help guide both the discussion of all-electric building costs and the development of any studies that might be done in the future.

In summary, it is true that electric equipment can be more expensive than its natural gas counterpart in a one-for-one replacement. However, the cost impact of all-electric buildings is about more than just individual systems. Avoidance of natural gas infrastructure is the source of considerable cost savings in new construction. This includes avoiding both gas piping in a building and gas service to a site. In most cases, infrastructure costs are substantial and far exceed any additional costs from electric equipment.

Technology Adoption: All-Electric

Both the NZE Stakeholder Advisory Groups meetings discussion and the stakeholder interviews indicated that technology is not a particular issue for all-electric buildings. Many of the distributors are national and have access to efficient, all-electric equipment. More pressing is to ensure that an all-electric design is considered as explained further in the all-electric section. The primary gap here continues to be low gas prices as well as training and education on the benefits of electrification.

NEXT STEPS IN ALL-ELECTRIC

Denver is working with NBI and stakeholders to develop code proposals based on the 2021 IECC that meet the goals and recommendations of this section. The transition to all-electric buildings represents a significant change in the way that Denver buildings are powered, and comes with some important considerations:

- Denver's all-electric foundation is focused on building loads. Manufacturing and industrial natural gas loads are a separate issue that are not addressed in this NZE Plan.
- Equity must be a key consideration in Denver's electrification strategy. Electrification needs to be thoughtfully combined with efficiency and incentives in order to ensure that operating expenses do not increase as buildings move away from cheap natural gas.
- Electric replacements for gas equipment are generally available. In the near term, there may be some challenges with availability at local distributers. As adoption rates of all-electric buildings increase – due to education, incentives and pilot projects – stocking practices should respond naturally to the increased demand.
- The building load that poses the greatest difficulty for electrification in Denver is central water heating systems in multifamily buildings and hotels. The equipment is available, and the design approaches are well established. The issue with these systems is that there is a need for more practitioners who have experience and expertise to effectively design these systems. Possible ways to address this barrier include training workshops, technical resources and technical assistance.

- Kitchen equipment faces a strong perceived market preference for gas, especially in higher end residential and in restaurant settings. Developers of multifamily buildings may see gas as a selling point. Restaurant staff have been trained on gas equipment for cooking. Addressing these issues may require public outreach and pilot programs that demonstrate the advantages of all-electric cooking over gas cooking and help overcome the market perception and business practice hurdles.
- All-electric buildings generally cost less to construct than mixed-fuel buildings due to the substantial savings from eliminating natural gas infrastructure. However, with Denver's cold climate and especially low cost of natural gas, all-electric buildings are generally more expensive to operate. **Investing construction savings in increased efficiency can narrow or eliminate the operating cost advantages of natural gas.** Denver's current grid mix is not as clean as other jurisdictions aggressively pursuing carbon reductions. As a result, electrification in Denver would not have as significant of a carbon-reducing impact on its own as it does in regions with less carbon-intensive electricity supply. This makes electrification more reliant on policies to decarbonize the electricity supply for the grid or the individual building, particularly the installation of on-site renewable energy systems.
- Familiarity with the latest heat pump technologies (particularly cold-climate heat pumps) is relatively low in Denver, leading many practitioners and consumers to have a negative perception of heat pumps based on older generations of equipment. This creates a significant need for education of both practitioners and consumers.

All-Electric Building Code/Policy Updates

As the electricity supply for Denver continues to decarbonize, one of the most effective strategies for reducing the carbon intensity of building operations is to electrify buildings. Other jurisdictions, especially those in California who are leading on this issue, have leveraged strategies such as electrification-readiness requirements, higher performance requirements for mixed fuel buildings and even gas infrastructure prohibitions to foster electrification. Additionally, efforts to electrify the transportation sector through electric vehicle charging infrastructure requirements will have an impact on the prescriptive path. Incorporating these kinds of requirements into the code also will have an impact.

Electrification raises an additional consideration for the prescriptive path. All-electric buildings are not inherently efficient. Heat pump technologies for space and water heating allow for very high levels of efficiency, but other electric technologies such as resistance space and water heating are much less efficient. Therefore, as electrification plays a bigger role in Denver, it will need to be balanced with efficiency. **Special care will need to be given to ensure that the use of low-efficiency electric technologies, such as resistance heat, is restricted to only very limited and minor uses.**

Electrification-Readiness

Electrification-readiness requirements are forward-thinking requirements that ensure that the electric infrastructure exists to convert new gas loads to electricity at some point in the future. This serves a dual purpose. The first is that it is much more cost effective to build this infrastructure during initial building construction than in a retrofit, which reduces the future obstacles to electrification retrofits.

The second is that these requirements also increase costs for gas applications, which provides an incentive to electrify the load from the beginning.

Some examples of electrification-readiness requirements include:

- A 240V, 50A circuit to gas stove locations
- A 240V, 30A circuit to gas water heater locations, as well as a requirement for a condensate drain and access to a minimum volume of air for the heat pump

Electrification-readiness requirements could be located in the electrical code or in the energy code. If they are placed in the energy code, then the prescriptive path will need to accommodate these as mandatory requirements.

Higher Performance Requirements for Mixed-Fuel Buildings

Another strategy for fostering electrification in new buildings is to require a higher level of efficiency for mixed fuel buildings than all-electric buildings. This creates an incentive to build all-electric buildings without prohibiting buildings from installing natural gas. Cities in California have adopted performance premiums between 5% and 15%. These cities were constrained by options that met the California Energy Commission's cost effectiveness requirements.

Naturally, a higher performance premium will provide a stronger incentive to build all-electric buildings, and a mixed fuel option that is still cost effective is less likely to provide a strong incentive.

Requiring higher performance is a simple matter in the performance path; the EUI target can be reduced or the compliance margin relative to the reference building can be increased. In the prescriptive code, Denver would leverage the points approach and require additional points from mixed-fuel buildings. However, the prescriptive path's limitations for delivering increasing levels of performance may mean that there are no additional points available to require for mixed fuel buildings. If this electrification strategy is chosen, it may add an additional reason to augment the points approach with additional points options for Denver.

Gas Infrastructure Prohibitions

A more aggressive electrification policy approach is to prohibit gas infrastructure in some or all new buildings. A prohibition like this is not within the scope of the energy code, so most jurisdictions that are pursuing this approach are adopting it within the building or zoning codes. The justification is that gas combustion in a building creates significant indoor air quality issues and a fire hazard, so the infrastructure is being prohibited as a life-safety issue rather than an energy or carbon issue. While these prohibitions may not be located in the energy code, they would impact the energy code and prescriptive path. A prohibition would make many of the requirements in the prescriptive path non-functional.

NEXT STEPS IN CODES

Denver is working with NBI to develop draft code proposals based on the 2021 IECC that meet the goals and recommendations in this NZE Plan. This is further detailed at the end of this report in "How it All Comes Together."

NZE: POWERED BY RENEWABLE ENERGY AND ELECTRICITY

The third NZE foundation within Denver's net zero energy definition is that new buildings and homes will be powered by renewable energy and electricity. Once buildings and homes are highly energy efficient and all-electric, they will be fully powered from on-site and/or off-site renewable energy.

Goal

Denver's 100% Renewable Electricity Action Plan details that by 2030, renewable electricity will offset 100% of new building energy use for buildings permitted under the code. Code will require increasing minimum levels of renewable electricity in the code cycles leading up to 2030. Additionally, by 2050, the electric grid will be 100% renewable and buildings are part of this equation.

It is important to make sure that renewables are not used to offset basic building performance to a significant degree because a wide range of energy efficiency strategies remain less expensive to deploy at the building level than renewable energy.

NZE Foundation: Powered by Renewable Energy and Electricity

By 2030 renewable electricity capacity will offset 100% of new building energy use for buildings permitted under the code. Code will require increasing minimum levels of renewable electricity capacity in the code cycles leading up to 2030. It is important to make sure that renewables are not used to offset basic building performance to a significant degree because a wide range of energy efficiency strategies remain less expensive to deploy at the building level than renewable energy. Indeed, energy efficiency and demand management will make the 100% renewable electricity goal more feasible and cost-effective for buildings. Powering 100% of building operations with renewable power is made more achievable if the building lowers its electricity demand through energy efficiency. For this reason, the highly efficient foundation section includes details on providing a 'backstop' within code for which renewable deployment cannot offset basic building performance.

Many net zero energy building guidelines say that renewable electricity may only count toward compliance if the building owner retains the Renewable Energy Credits, or RECs, for that renewable electricity. Denver's guidelines differ by prioritizing the addition of new renewable electricity capacity onto the electrical grid beyond what would have been developed otherwise (i.e., "additive RECs"). This is inclusive of renewable energy options, such as Solar*Rewards, in which additive RECs are generated, transferred to, and retired by Xcel Energy towards system-wide decarbonization. Whether additive RECs are retired by the utility on behalf of all customers or by individual customers within the system, there is the same net effect on the total renewable content of the overall system. **This methodology ensures that local investments in rooftop solar and community solar gardens (CSG) are not inadvertently discounted and discouraged simply because Xcel Energy retains and retires the RECs associated with them.**

Denver's renewable vision is to enable a rapid and equitable transition to a 100% renewable electric system in Colorado. By 2030, 100% of Denver's community-wide electricity use will contribute to this vision. The 2030 goal for Denver's electricity use to "contribute to" a 100% renewable electric system is unique compared to goals to be "powered by" 100% renewable electricity. This is in part due to the recognition that Denver is a part of a larger electric system operated by Xcel Energy in Colorado. **Denver cannot be powered by 100% renewable electricity until the entire system is powered by 100% renewable electricity.**

REACHING 100% RENEWABLE ELECTRICITY BY 2030

The City's 100% renewable electricity goal is articulated such that to achieve it, we must obtain new sources of clean electricity rather than taking credit for existing renewable energy sources. Denver's renewable electricity contribution metrics adopt a holistic view of the electric system and Denver's place in it and measure progress towards system wide decarbonization. They include:

- **System Renewables**: The RECs inherent in the electricity Xcel Energy delivers to all retail customers that are not created by, subscribed to, or sold to other customers.
- **Distributed Solar**: The RECs created by Denver customers with on-site solar arrays or subscriptions to community solar gardens that are transferred to Xcel Energy and retired for system-wide decarbonization.
- **Utility-Scale RE Subscriptions**: The RECs retired due to participation in Xcel Energy's Renewable*Connect and Windsource programs by Denver customers.

Xcel Energy delivered 99% of Denver's community-wide electricity use in 2019. Fortunately, Xcel Energy is a national leader in the clean energy transition among investor-owned utilities (IOUs). Xcel Energy was the first IOU in the country to announce a voluntary target to deliver 100% carbon-free electricity by 2050 and to reduce carbon on their system 80% by 2030 from a 2005 baseline.[36]

By 2030, 100% of Denver's community-wide electricity use will contribute to a clean grid.

The following metrics track Denver's progress:

System Renewables

20.7% (2019) → 60-80% by 2030

System renewables account for nearly all of Denver's renewable electricity and are expected to continue to account for the majority of Denver's 100RE attainment in 2030. Xcel Energy projects it will retire RECs for approximately 60% renewable energy by 2030. Exceeding this target requires collaboration with Xcel Energy and regulatory engagement.

Denver is pursuing a 60-80% contribution from system renewables by 2030.

Distributed Solar

1.2% (2019) → 30-40% by 2030

Denver has significant untapped distributed energy potential that can be increased by strengthening building codes, supporting CSG and rooftop solar programs, and regulatory engagement.

Denver is pursuing a 30-40% contribution from distributed solar by 2030.

Utility-Scale RE Subscriptions

0.8% (2019) → 10-15% by 2030

Utility-scale renewable electricity subscriptions by Denverites to options such as Windsource and Renewable*Connect are necessary to fill any gap that system renewables and distributed solar leave below Denver's target of 100% renewable electricity by 2030. Community engagement and education is expected to be the primary driver to increase subscriptions.

Denver is pursuing a 10-15% contribution from utility-scale RE subscriptions by 2030.

Denver has some confidence in the rate at which renewable electricity will be added to grid thanks to 2019 legislation and Xcel Energy's commitment to its Certified Renewable Percentage approach. Xcel Energy will incrementally increase the amount of RECs retired on behalf of Colorado customers each

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[36] "Building a Carbon-Free Future." Xcel Energy. www.xcelenergy.com/environment/carbon_reduction_plan

year, allowing customers to count that increasing renewable percentage of their electricity mix towards their energy goals. [37, 38] The utility currently projects it will retire RECs for approximately 60% renewable energy by 2030. However, there is still a gap that Denver must close between Xcel Energy's renewable electricity trajectory and the City's goal.

Approximately 1,150 MW of distributed solar (on-site solar and community solar gardens) will need to be deployed over the next decade to reach a 30% contribution to Denver's goal. This can be accomplished if approximately 9% of total roof space in Denver is used for solar, and it can be supplemented by deploying solar over parking lots and at local vacant land parcels within and adjacent to Denver.

CLOSING THE GAP WITH NEW CONSTRUCTION

New buildings can help contribute to closing this gap by supporting the addition of distributed renewable energy capacity beyond what would have been developed otherwise. There are two ways new buildings can contribute additive distributed renewable energy resources:

1. On-Site Solar Deployment: Install on-site solar through Xcel Energy's Solar*Rewards program, including the option to act as a community solar garden site host.
2. Distributed Solar Support Fund: Pay into a City-directed fund to support the development of local solar deployment (i.e., community solar and behind-the-meter solar). A cost study will be needed to set the amount a developer must pay into the City directed solar fund per kW of capacity to be built.

By 2030, new buildings should install sufficient on-site solar panels and/or pay the City to develop sufficient distributed solar on their behalf such that 100% of the projected electricity needs of the building are covered. Requirements for new buildings to install or pay renewable energy capacity will step up over time toward the goal to cover 100% of their electricity needs.

Subscriptions to community solar gardens and Colorado renewable energy program options, while supportive of Denver's goal for community-wide electricity use to "contribute to" a 100% renewable electric system, are not possible due to administrative, regulatory, and legal reasons: 1) A developer's subscription contract may or may not be transferable to a future owner; and 2) It is impractical and inefficient for the City to monitor that renewable electricity contracts have been maintained, renewed, and/or transferred from one owner to the next over time. Additionally, some renewable energy subscription options do not bring new renewable energy onto the Colorado grid and/or only circulate what's already available.

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[37] Senate Bill 19-236 added Colorado Revised Statute §40-2-125.5 requiring Xcel Energy to file a "Clean Energy Plan" with the PUC by March 31, 2021. The plan will reduce carbon dioxide emissions associated with retail electricity sales by 80% from 2005 levels by 2030, and provide customers with energy generated from 100% clean energy resources by 2050.

[38] Xcel Energy Certified Renewable Percentage is described in filing number G_764613, proceeding 19AL-0268E. Colorado Public Utilities Commission.

The following types of renewable energy purchases, and any other programs outside of the two approved compliance pathways, will **NOT** be options for new buildings in Denver to achieve Net Zero Energy under the code:

Table 36. Renewable Options Not Available to Achieve NZE

Xcel Energy Renewable Subscriptions	Other REC Purchase Options
• Renewable*Connect • Community Solar Gardens • Windsource	• Purchases of unbundled RECs • Virtual Power Purchase Agreements • Expedited review

This is not to say that some of the above options do not create additive RECs or are not considered valuable to Denver's clean electricity objectives. Building tenants and electricity customers are indeed encouraged to subscribe to Colorado's renewable electricity program options and to pursue opportunities to create additive RECs that help to offset their local, national, or global carbon footprints.

This Code focuses on Denver's built environment and the opportunities which the City can control or exert meaningful influence over, and where the City can overcome challenges to implementation. As was mentioned previously, the City is prioritizing renewable electricity strategies that result in the addition of new renewable electricity capacity to the grid. The City's two compliance pathways create simplicity in administration and most effectively create new renewable electricity capacity and additive, local RECs.

Denver's Renewable Energy Targets

As part of this NZE Plan, Denver asked the NZE Stakeholder Advisory Groups to review the renewable energy goals and targets for buildings and homes to determine the recommendation for upcoming code cycles shown in the table below.

Table 37. Commercial and Multifamily Building Renewable Energy Targets for Denver Code

	2021	2024	2027	2030
Minimum renewable offset	50%	75%	100%	100%
Minimum % Roof Area	25%	50%	70%	70%

This recommendation includes both a minimum renewable offset that can be met by on-site or off-site solar in order to equitably require solar for varying building types and shapes. Additionally, there is a minimum percentage roof area for on-site solar to encourage on site production.

For residential, the table in the highly efficient section combines efficiency and on-site solar. For this reason, there is not a minimum percent roof area envisioned. However, there is still a minimum renewable offset as detailed in the table below.

Table 38. Residential Home Renewable Energy Targets for Denver Code

	2021	2024	2027	2030
Minimum renewable offset	50%	75%	100%	100%

In addition, based on the NZE Stakeholder Advisory Groups meetings, the renewables for all building types (commercial, multifamily and residential):

a. Offset <u>total building energy use including natural gas</u>
b. Can be met by either:
    i. Installing on-site solar
    ii. Paying into a Renewable Denver Community Solar Fund (where the city will build off-site community solar gardens)

Renewable Denver Community Solar Fund

To ensure that all buildings and homes are able to meet the renewables requirement, Denver will develop a fund, the Renewable Denver Community Solar Fund, that will build community solar gardens. As with any fund, Denver will perform a rate study. The in-lieu rate must be rationally related to the overall cost for the City to provide an equivalent benefit.

The scope of work defined for the in-lieu rate study is as follows:

- The study will show the cost the City would incur to install equivalent required renewables within community solar gardens as what would have been required to be installed on the building site. It will include items such as land value, construction, and operations and maintenance. Land costs are included because the rate has to be reasonably connected to the cost for the City to supply the service, and land purchases are sometimes potentially needed. This rate will be the fee-in-lieu rate for those buildings not doing any solar on-site.
- The rate also will include a reduced rate if a developer/builder maximizes solar roof coverage. This reduced rate will help ensure a similar return on investment as installing on-site solar. As a result, the study will:
    - Detail on-site solar return on investment
    - Recommend a lower rate for a developer/builder who maximizes solar roof coverage
    - Ensure that priority subscriptions are included with an appropriate duration such as 20 years (in the contract with the solar developer, adhere to requirements)
- The cost should be based on City pricing, not private pricing. The cost of an equivalent project contract with the City is often higher than the cost to a private developer because of City labor law and other requirements.
- Because the City will be administering the funds, the rate study will determine the necessary administrative costs of the City.
- The rate should include a recommendation regarding how the fee should best be increased in the future with a formula tying it to an index/value that is measured regularly.

The rate recommended is based on a compilation of costs including the following:

- Land Values (Costs): parking lots, rooftops, and land
- Capital Costs (Construction)
- Operations and Maintenance
- City Administrative Costs

NZE: PROVIDERS OF DEMAND FLEXIBILITY FOR THE GRID

The fourth NZE foundation within Denver's net zero energy definition is that new buildings and homes will be providers of demand flexibility for the grid. This includes energy storage, grid integration, and the flexibly to respond to grid signals.

Goal

There is not a specific climate goal within the 80x50 Climate Action Plan for grid flexibility, however it will be needed as buildings and homes are increasingly all-electric.

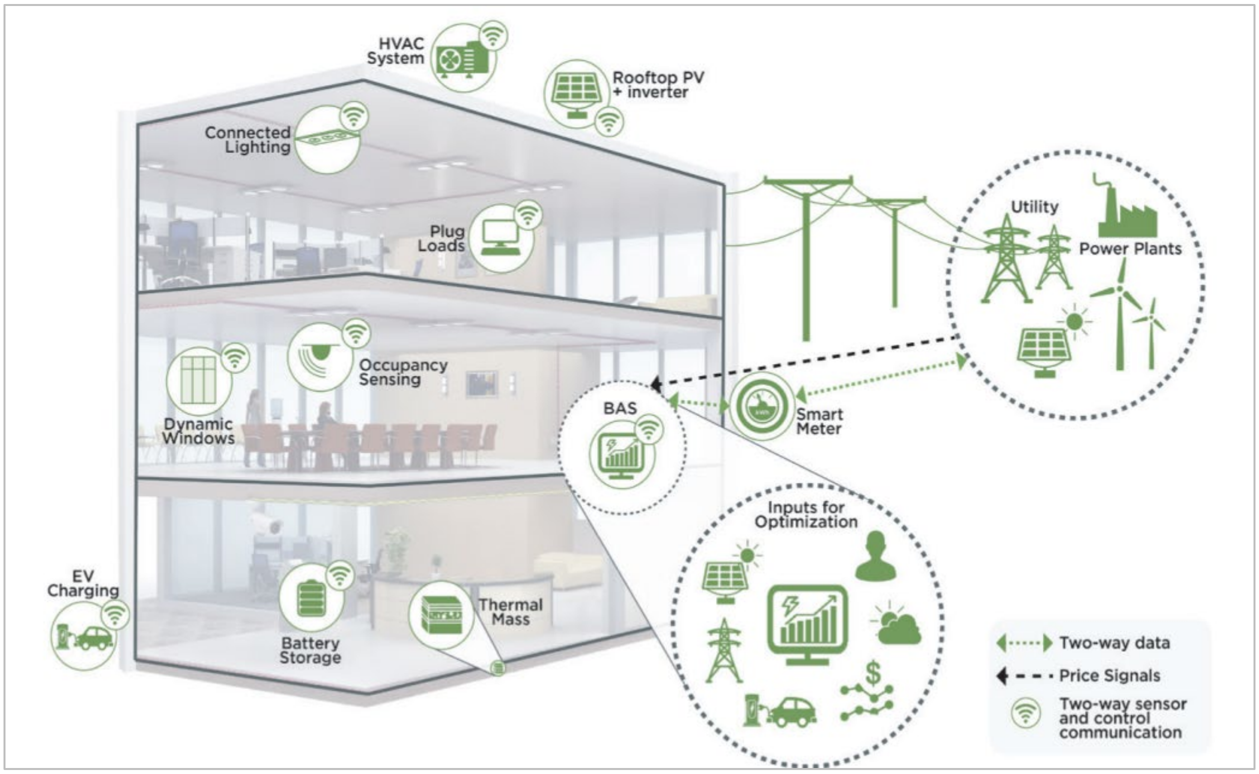
NZE Foundation: Providers of Demand Flexibility for the Grid

WHAT IS GRID FLEXIBILITY AND STORAGE?

Today, a significant amount of the electricity that is generated is simply wasted. The traditional utility business model is to match electricity production to consumption in real time. This leads to vast inefficiencies because consumption is far from constant over time. The intermittency of renewable electricity can create additional complications if not coupled with dispatchable resources, energy storage, and load management. Peaks in consumption that may occur for only a few hours every year result in expensive fossil fuel power plants being built to operate just a few days each year to meet those peaks.

Denver will need to increasingly pay attention to efficiency as a function of time of day. **An energy code requirement that saves more energy in total may actually be less desirable than an energy code requirement that can balance energy use throughout the day.** As a consequence, the prescriptive path and mandatory minimums in the modeled path will very likely need to incorporate grid-responsive requirements that recognize the importance of the quality as much as the quantity of energy savings.

In order to electrify everything – our buildings, homes and vehicles – and then power all those end uses with 100% renewable electricity, we must have systems to add both flexibility to electricity consumption and store electricity. New buildings become existing buildings and need to have grid flexible capabilities installed up front. The following graphic shows ways a building might provide grid flexibility and storage for the grid.



Source: Navigant Consulting

Figure 36. Grid Flexibility and Storage Methods for Buildings

There are two ways these grid flexible and storage resources in a building might be controlled:

1. ***Beyond the Building**.* The utility may be able to directly control systems in the building to adjust consumption and production of electricity to meet the grid's needs through automated demand response programs. Third parties such as demand response (DR) aggregators or other service providers also may be contracted by either the utility or the building owner.
2. ***At the Building**.* The building automation system, or even some individual systems, could take price or demand signals from the utility and enable the user to adjust both the building's consumption and production of electricity to match grid signals.

In both cases systems would be set up to primarily be adjusted in ways that would not negatively impact occupant comfort or occupant energy needs. For example, the walls and floors and other thermal mass of a building could be pre-cooled at night to reduce the cooling load needed during the day. Water heaters could heat and store very hot water when the grid has excess electricity, and a mixing valve could lower it to the user's set point when it is delivered. Occupancy sensors could ensure lights are off and ventilation is lower in rooms without occupants.

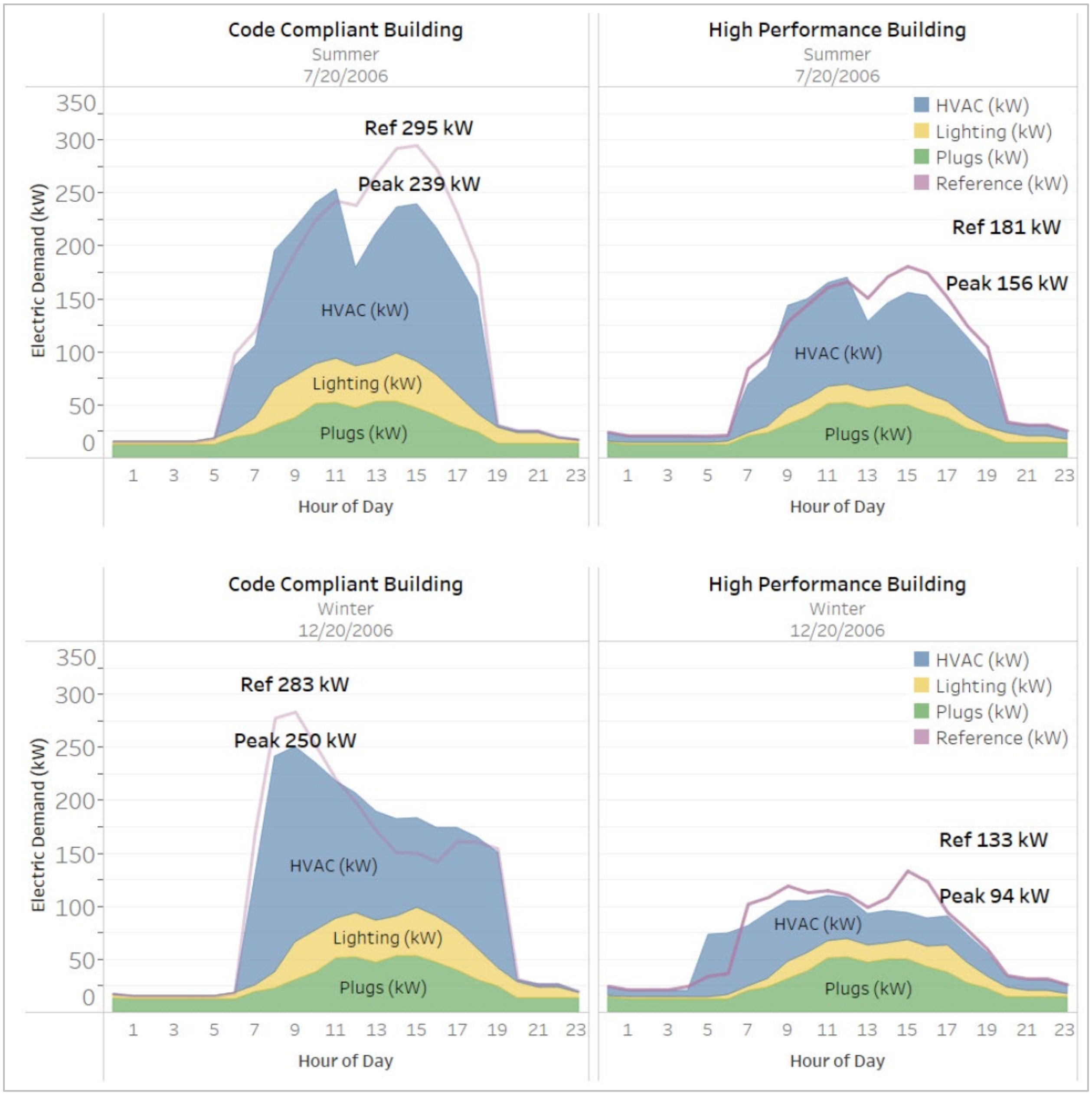
BENEFITS OF GRID FLEXIBILITY AND STORAGE

Grid-flexible and storage capable buildings have many benefits for the building owner and occupants as well as the grid:

- Significant potential GHG emissions benefits due to the ability to tune energy consumption patterns to better utilize energy when it is low-carbon and reduce loads when energy is high-carbon. This benefit accrues to society at large. This benefit grows as the grid decarbonizes (due to having more variable generation resources on the grid).
- **Small additional up-front costs have the potential to significantly lower energy bills over the life of the equipment because of the valuable services they provide to the grid.** Value may come to the building owner through:
  - Payment for participation in demand response programs with large equipment that can take a signal from the grid (automated demand response); often a third-party aggregator may aggregate controls on a large number of small pieces of equipment to offer larger "blocks" of load reduction capacity to the utility.
  - Reduced demand charges based on a facility having reduced peaks in demand.
  - The ability to use electricity only when it is cheapest with time of use rates or other time differentiated charges; or
  - "Critical peak pricing" programs offered by some utilities that can provide additional load management incentives.
  - Potential for reduced interconnection/hookup fees in cases where the utility can be confident that the facility's maximum demand will be less than what is theoretically possible.
  - These are best practice recommendations, and some are not in place in Denver yet.
- In some cases, there will be less frequent equipment replacement needs because equipment will be run more purposefully and less frequently.
- New services for tenants like greater power reliability, smart EV charging, and support for corporate sustainability through better building data and demonstrably lower greenhouse gasses attributable to their energy use.
- Increased resiliency and reliability through the ability to operate as a microgrid, insulating the building from grid outages. Critical facilities – such as hospitals, public safety and security facilities, military installations, and water and wastewater facilities – can be good buildings in which to do demonstration projects for microgrid, grid flexibility and storage functions to help them ride out outages without disruption.

GRID FLEXIBILITY AND STORAGE POTENTIAL

Buildings have the opportunity to reduce peaks through a variety of measures. The Commercial Building Load Modification and Flexibility Potential report from New Buildings Institute (NBI) shows a similar heating climate to Denver using Burlington, VT. The graphs below show the impact of grid flexibility measures showing similar trends to other climates. The largest observation in Burlington is the peak demand reduction from the Code Compliant Building to the High Performance Building. In winter, the peak demand is reduced by 54% before applying any measures. This is primarily due to the heat recovery ventilator and a higher thermally insulated envelope.



Source: Commercial Building Load Modification and Flexibility Potential Report

Figure 37. Seasonal Daily Power Demand by End Use (HVAC, lighting, plugs) in Vermont

This analysis produced a broad set of information about how building energy efficiency and controls strategies can be used to impact peak demand and demand shape. The key findings indicate that significant adjustments to building load shape are possible to support grid integration, and that load modification and energy flexibility measures may be best applied in packages.

TODAY IN DENVER

Successful grid flexibility and storage capabilities require both the building and homes as well as third party demand response (DR) aggregators, the grid, and the utility to work together. Buildings and homes must have infrastructure, such as water heaters, air conditioning, and HVAC and lighting controls, capable of receiving DR requests or responding to price signals from the utility and implementing load adjustments. The utility must offer demand response programs or structure their pricing to compensate customers when they provide services to the grid.

The City can require buildings and homes to have capable infrastructure through the building code, but it only can advocate to the utility and state regulators for the utility to offer programs and pricing that utilize that infrastructure. Today in Denver, most buildings do not have infrastructure capable of receiving DR requests or responding to price signals from the utility.

In Colorado, for non-residential customers, Xcel Energy offers several demand response options: Peak Day Partners, Peak Partner Rewards, Interruptible Service Option Credit and Critical Peak Pricing/EV Critical Peak Pricing. Also, the default rate for industrial customers has time of use (TOU) built into it. In addition, Xcel Energy offers an AC Rewards and Saver's Switch for Business.

Xcel Energy offers Tiered Pricing, which is a form of TOU, for residential, as well as the Saver's Switch/AC Rewards programs (DR). They are in the pilot phase for TOU pricing for other customers. The TOU pricing should phase in for all customers over the next 3-5 years. But it's not very dynamic (time-based on-peak/off-peak regardless of when renewables are on the system).

Denver's 2019 IECC required that all buildings be battery storage ready. The main electrical service panel shall have a reserved space to allow for installation of a two-pole/three-pole circuit breaker or disconnect switch for future electrical energy storage system installation. This space shall be labeled "For Future Energy Storage." Denver's 2019 IECC also requires the installation of electric vehicle (EV) charging stations – and electric vehicles may play a role in providing grid flexibility in the future. See the EV section of this NZE Plan for details on the EVs.

Denver's voluntary 2019 Denver Green Code requires that building controls are designed with demand response infrastructure capable of receiving request from the utility for adjustments to:

- HVAC system setpoints
- Variable-Speed Equipment speed adjustments
- Lighting power demand adjustments

Denver will build upon this foundation to increase the grid flexibility of buildings in Denver over the upcoming code cycles in 2021, 2024, 2027 and 2030 in this ambitious yet achievable plan.

CURRENT EXAMPLES FROM OTHER JURISDICTIONS

California

Title 24 gives mandatory requirements for demand management that include demand-responsive zonal HVAC controls and lighting controls in certain nonresidential buildings. In residential buildings, mandatory requirements for solar ready buildings make exceptions for residences with demand-responsive thermostats.

Washington (DC), Baltimore (MD), Rockville (MD), Carbondale (CO) and Snowmass (CO)

All of these cities and towns have adopted the 2012 IgCC as a mandatory code, which has similar demand response ready infrastructure requirements as the 2019 Denver Green Code.

FIRST STEP FOR DENVER IN 2021

Adjust the Prescriptive Path for Time-Specific Efficiency

The effectiveness of energy efficiency measures can vary by time of day. As a consequence, the prescriptive path should be adjusted to focus on requirements that save energy specifically during times of anticipated grid congestion and high marginal GHG emissions. This could take the form of additional mandatory minimums that apply to all compliance paths, or modifications to the points values to provide greater value to the options that provide efficiency during those times of grid congestion and high marginal GHG emissions.

Prescriptive Path and Mandatory Minimums Require Grid-flexible Equipment

Require the following capabilities to be installed in all buildings immediately when adopting code in 2021 to future-proof buildings so they are ready to participate in demand response programs and to take advantage of utility or other price signals when they become available. The following actions have a relatively low up-front cost with significant potential savings over the life of the asset. They should therefore be installed in buildings immediately, even before utility programs are in place.

- Incorporate the voluntary 2019 Denver Green Code requirements as base code. Require DR infrastructure capable of receiving requests from the utility for adjustments to HVAC system setpoints, variable-speed equipment, variable-speed equipment speed adjustments and lighting power demand adjustments. Update requirements to ensure they include but are not limited to:
    - Large buildings have BMS that can adjust HVAC setpoints, motors, drives and other variable speed equipment. Only large buildings need grid flexible lighting power demand adjustment capabilities.
    - Small buildings and homes have RTUs or and HVAC systems that are controlled by a thermostat with grid-flexible capabilities.
- Require different sizes of buildings to have storage capable space in the panel that are sized to match the potential load of the building.
- Require electric heat pump load controllable water heaters.
- Require all new electric water heaters installed to have the CTA-2045 modular communication interface. Tank-style water heaters are the only form of energy storage that are already in most customer’s homes. They can provide services to the grid and the customer by:
    - Lowering the setpoint: This will reduce energy consumption immediately and/or shift that load to a later time. Without increasing tank size or temperature, only small adjustments may be possible without affecting user comfort.
    - Increasing the setpoint: Importantly, this can only be done if a mixing valve is installed, to ensure users don’t get scalded. This strategy allows a utility to store heat in a water heater when there’s excess renewable energy on the grid. CTA-2045 can do a lot more

than just temp up/temp down. For example, HPWHs have four modes: electric resistance, heat pump only, energy saver (hybrid of those two), and vacation (off, basically). CEA-2045 could tell the HPWH to change modes as well as setpoints.
    - Providing a larger supply of hot water. Most HPWHs have larger tanks than their electric resistance equivalents. A home well served by a 40-gal electric resistance water heater might get a 50-gal HPWH.
- If a building has the following equipment installed, then it must be grid flexible capable:
    - On-site storage
    - On-site generation
    - EV charging

Advocate for Xcel's Energy Design Assistance program to help make sure technologies are installed.

GRID FLEXIBLITY: SHORT-TERM

Advocate to the utility and state regulators for more DR programs and time of use (TOU) rates or other time differentiated charges to be rolled out in ways that ensure communities and individuals with a greater energy burden don't see energy bills increase. Low-income customers often can't afford the technologies to shift/manage their load. We need complementary DR programs to make this effective. Pay customers to change their behavior (DR incentive) rather than penalize customers for being unable to afford to store/time-shift energy (TOU structure). Also, advocate to include GHG emissions as a consideration factor in ratemaking.

In 2024 Code:

- Require the implementation of the GridFlexible metric.
- Require different sizes of buildings to have storage capable locations in the building as needed that are sized to match the potential load of the building.

GRID FLEXIBLITY: LONG-TERM

Require the following to be done in all new buildings when the utility offers programs and rate structures that compensate building owners effectively for the services buildings provide to the grid with these measures. Generally, in 2027 and 2030 code adoptions Denver should require improved grid flexibility and increased storage. Specifically, this may mean:

- Performance Path – Consider moving to enhanced code compliance models so they are good to the hourly level and can be adjusted based on a building's static, dynamic, or on-call electric loads. Could be a trade-off or a minimum mandatory requirement. This could allow Denver to select most-critical load hours and credit targeted building load modifications during those hours. It could also be tied to carbon in Denver's requirements.
- Require commissioning to have a plan to set up the programming for load shifting in responses to price or demand signals from the grid. Require functional testing of capacity and duration during the commissioning process.
- Require Battery Storage controlled by an energy management system that is programmed to maximize value to the customer and the grid, including customer resiliency, carbon reductions, and system management. It is important to ensure that battery storage not be charging during

times of grid congestion and/or high GHG emissions. This can be done by programming the battery controls (end user control) or by having the battery behavior controlled in whole or in part by a utility or third party. In any case it is important to ensure that charge/discharge patterns align with GHG emissions and grid congestion.

Grid Interactive Capable buildings in 2030 can take and shed as much load as electric heat, solar PVs and EVs add on a net-basis. Metrics for grid interactivity do not exist, but people are working on them, and as they begin to exist Denver will assess how to incorporate them into policies. An initial draft of what these metrics may be are the grid flexible metric components that follow.

Table 39. Grid Flexible Metric Components

Grid Flexible Metric	Detail
Grid Peak Contribution	Degree to which building demand contributes to load on the grid during system peak hours
On-site Renewable Utilization Efficiency	Building's consumption of renewable energy generated on-site (not exporting to grid) over a year
Grid Carbon Alignment	Degree to which the building demand contributes to upstream (grid) carbon emissions over a year
Energy Efficiency vs. Baseline	Percent better than code (annual total energy use)
Short-Term Demand Flexibility	Building's ability to reduce demand (shed) for 1 hour
Long-Term Demand Flexibility	Building's ability to reduce demand (shed) for 4 hours
Dispatchable Flexibility	Building's ability to reduce demand (shed) for 15 minutes, controlled by utility/third party
Resiliency	Building's ability to island from grid and/or provide energy for critical loads for 4-24 hours; motor soft start capability to help grid restart after outage

GridOptimal is working on a single metric to assess whole building flexibility. Denver will eventually want to identify the level of GridOptimal scoring needed to achieve that goal on a scale of 0-100%. These metrics combine two basic approaches to evaluate the quality of building-grid interactions: (1) building energy consumption patterns (load shape or demand profile), and (2) building assets (capabilities).

Denver's Grid Flexible Targets

As part of this NZE Plan, Denver asked the NZE Stakeholder Advisory Groups to review grid flexible goals and targets for buildings and homes to determine the recommendation for upcoming code cycles as shown in the table below.

Table 40. Building and Home Grid Flexible Requirements for Denver Code

	2021	2024	2027
All Buildings & Homes	Grid Flexible Equipment	Implementation of Grid Flexible Metric	Improving Grid Flexibility + Increased Storage

COST AND SUPPORTS FOR NZE

In conjunction with technical solutions and recommendations to get to net zero emissions in Denver, there are additional strategies needed to support the community and enable the passage of equitable policies and incentives. Reaching the goals and recommendations for net zero will require supports. This includes Denver community support such as marketing, outreach, training, education, financing, advocacy, etc. as well as internal support such as staffing and resources. This section outlines the costs and supports needed. Consideration of costs and supports together is critical in ensuring that the goals and targets in this NZE Plan are met.

The potential cost considerations for highly energy efficient and all-electric are detailed within those sections. For NZE first costs related to energy efficiency, cost studies detail that NZE is about 5-19% additional first cost for buildings and 6-8% for homes. Operational costs, however, make up for any additional costs from efficiency to make this particularly attractive to owners and developers who are planning to hold the building longer-term. For all-electric, cost studies show that heat pumps do cost more compared to gas equipment. However, incentives from Xcel Energy for heat pumps and avoiding the natural gas connection and piping costs ensure that it is less expensive for both an all-electric building and home. Further detail on the all-electric costs by building type are detailed in the "Cost Considerations and Study: All-Electric" section of this report.

While these cost considerations are important to understand, market transformation still will require supports for equity and affordability. **The supports needed to get to net zero for building and homes include: marketing and outreach, training and education, financing and incentives, and advocacy.**

Supports needed include both supports for the community for net zero design and performance as well as supports for the city to help facilitate this through the Code Adoption Process as well as through code review and inspections. Denver has also worked with the Climate Action Task Force and the NZE Stakeholder Advisory Groups to understand needed supports.

NZE Supports

In the first NZE Stakeholder Advisory Groups meetings, the stakeholders identified that one key role of the city is to educate. This was also detailed and identified in later stakeholder meetings as well. Education includes bringing in expertise from other areas, educating design teams, and sharing technologies and training. Additional education for owners and the general public also was discussed as a need. Similarly, Denver's Climate Action Task Force recommendations included recommendations for supports for buildings and homes.

CLIMATE ACTION TASK FORCE SUPPORT RECOMMENDATIONS FOR NZE

The Climate Action Task Force process identified a number of supports needed to reach net zero by 2030. They identified priority incentives as part of identifying solutions for net zero new buildings as seen below.

Table 41. Climate Action Task Force Priority Incentives

Climate Action Task Force **Priority New Buildings and Homes Incentives** 2020-2022
Incentivize affordable housing through zoning in coordination with Denver's Department of Housing Stability (HOST).
Provide net zero energy new buildings and homes training for developers, design teams, contractors.
New construction net zero energy buildings and homes incentives. In particular, building height incentives and expedited permitting incentives should be considered.

Additionally, supports needed for all buildings and homes were recommended. These include the following support categories:

- **Marketing and Outreach**: Outreach to the public on the value of energy efficiency, healthy buildings, and beneficial electrification. Communicate Denver's climate goals and work.
- **Training and Education**: Provide training and education on energy efficiency and building electrification.
- **Financing**: Finance solutions for buildings and homes for energy efficiency and beneficial electrification.
- **Advocacy**: Advocacy at the state or federal level for policy change that parallels the recommendations of the Task Force.
- **Education**: Educate local officials in surrounding jurisdictions about Denver's codes, policies, and incentives so they can consider adopting similar ones.
- **Programs**: Programs to engage the community and connect incentives.

Each of the supports identified by the Climate Action Task Force were identified and then prioritized by phase of near-term (2020-2022), mid-term (2023-2025), and long-term (2025-2030). The tables below detail the support recommendations from the Climate Action Task Force prioritized by phase.

Table 42. Near-term Climate Action Task Force Supports for Buildings and Homes

Buildings and Homes Supports: Near-term: 2020-2022
Marketing: Educate general public on value of energy efficiency and healthy buildings and potential clean energy jobs in buildings. Work with schools to promote these career tracks.
Marketing: Education on energy efficiency, building electrification focused on health benefits and better indoor air quality.
Outreach: Summarize annual energy savings from buildings and homes to community.
Training: Develop training for building owners, operators, managers, developers, homeowners, and realtors (work with the Department of Regulatory Affairs to require training) focused on energy efficiency, net zero energy, and strategic building electrification.
Training: Workforce training for technicians and contractors to enhance energy efficiency and strategic building electrification. Encourage workforce training of contractors tied to contractor licensing and unions to encourage use of efficient equipment by contractors. Provide incentives or scholarships for existing trainings/certificates by industry associations, trade schools, and community colleges. Work with Denver Public Schools to promote careers in climate solutions, specifically sustainable buildings. Promote or subsidize extracurricular modes of education in sustainable building. Create green business incubators.
Training: Create training and jobs in the clean energy transition focused on our most impacted/vulnerable communities. Create market incentives for hiring green workforce.

Buildings and Homes Supports: Near-term: 2020-2022
Education: Develop an Energy Resource Center that provides support, guidance, and assistance to help owners, managers, contractors, etc. complete design and projects focused on energy efficiency and strategic building electrification.
Education: Promote models where tenants and building owners are educated on sustainable benefits to building improvements.
Advocacy: Xcel Energy Time of Use electricity rates to encourage use when the grid is less carbon intensive. Ensure that equity is part of the rate design to enable low-income households to take advantage of better rates and not unintentionally burden them with higher bills.
Advocacy: Regulatory changes at state level and Xcel Energy. Advocate for new construction incentives for affordable housing, in particular to enable electrification.
Programs: Connect/enhance low-income programs, include incentives that improve indoor air quality and health. Ensure ventilation is sufficient and that upgrades improve overall health and safety.

Source: CASR

Table 43. Mid-term Climate Action Task Force Supports for Buildings and Homes

Buildings and Homes Supports: Mid-term: 2023-2025
Marketing: Communicate Denver's goals, work, and health benefits to the community.
Outreach: Host/participate in events, meetings, and conferences.
Outreach: Build awareness and celebrate success.
Programs: Small commercial and multifamily, connect/enhance low-income programs, improve affordability through integration of existing programs (childcare and others).
Program: Connect Sustainable Neighborhoods program to energy and electrification. Target early adopters of renewables and efficiency with electrification messaging.
Financing: Solutions for commercial and multifamily buildings.
Financing: Solutions for homes.
Advocacy: Support residential PACE financing for zero energy ready homes by evaluating and advocating for it to be considered by Colorado's General Assembly, building on the work of the Colorado Energy Office. Any proposal should prevent predatory lending.

Source: CASR

Table 44. Long-term Climate Action Task Force Supports for Buildings and Homes

Buildings and Homes Supports: Long-term: 2025-2030
Policy/Code: Convert building types to reduce GHG.
Policy/Code: Historic home and building considerations; accessibility within historic buildings as a consideration; determine energy efficiency solutions for temporary housing through rental policies and affordable housing programs.
Program: Create a green certification or green credit program.
Advocacy: Reduce GHG through renewable natural gas and carbon-free hydrogen.
Connection-Waste: Address waste in buildings. [see consumption and waste recommendations]
Connection-Transportation: Reduce construction transportation emissions. [see transportation policies]

Source: CASR

NZE STAKEHOLDER ADVISORY GROUPS SUPPORT REVIEW

Once initial solutions and supports were developed by the Climate Action Task Force, Denver convened the NZE Stakeholder Advisory Groups to review the solutions and prioritize these for net zero. Similar groups reviewed the solutions, supports, and costs that were ultimately reviewed by a focused Climate Action Task Force buildings and homes group that provided recommendations to the entire Task Force.

Table 45. NZE Stakeholder Advisory Groups - Top Commercial Supports

Strategy	Detail
Development incentives for following Denver Green Code (non-monetary)	• Height incentive/density bonus • Reduced parking requirements • Expedited review • Others to be defined
Design and construction team incentives	• Incentive for the increased time requirement for designing a NZE building • NZE charrettes • pEUI modeling • Cx, MBCx, enclosure Cx • M&V
Permit fee reductions	• Permit fee reductions for following Denver Green Code
Cash rewards from City	• For efficiency technology (HVAC, controls, lighting, etc.) • Renewables • Storage • Electric HVAC and water heat • Performance (meeting NZE) • Land purchases for NZE buildings

For commercial buildings, the top strategies include zoning incentives, expedited review, design/ construction team incentives, and permit fee reductions.

As a result of these discussions, Denver's Community Planning and Development (CPD) took a first step in the Denver Green Code and Affordable Housing Pilot Program. The all new, voluntary Denver Green Code provides guidance for higher performing buildings and sites through energy efficiency, resource conservation, sustainable materials, indoor environmental quality, water safety, site development, land use, and overall building performance. CPD will identify five major commercial projects for the Denver Green Code pilot program. To qualify, projects must choose one of four paths:

- Comply with the provisions of the Denver Green Code as written;
- Achieve Platinum Certification using version 4.1 or later of the US Green Building Council's (USGBC) Leadership in Energy and Environmental (LEED) program;
- Achieve Zero Net Energy; or
- Achieve Passive House certification plus comply with the provisions of all non-energy chapters of the Denver Green Code as written.

The benefits include a fee reduction, enhanced site development process, and expedited building log plans review.

Table 46. NZE Stakeholder Advisory Groups - Top Residential Supports

Strategy	Detail
Cash rewards from City	• For efficiency technology (HVAC, controls, lighting, etc.) • Renewables • Electric HVAC and water heat • Low carbon construction materials • Performance (meeting NZE) • Land purchases for NZE buildings • Demand flexibility: storage, energy storage, water heater, PV
Development incentives for following Denver Green Code	• Density bonus • Setbacks • Lot layout: building orientation • Expedited review
Design and construction team incentives	• Incentive for the increased time requirement for designing a NZE building • NZE charrettes • pEUI modeling • Blower door testing • M&V
Permit fee reductions	• Permit fee reductions for following Denver Green Code

For residential homes, the top strategies include cash rewards, development incentives, and development design/construction team incentives.

As a result of these discussions, Denver's Community Planning and Development (CPD) took a first step in the Denver Green Code and Affordable Housing Pilot Program. All new detached single-unit homes and duplex construction projects (excluding master and type approved projects) that follow the Denver Green Code between November 1, 2020 and January 31, 2021 will receive expedited reviews.

Zoning Supports for NZE: Incentives and Considerations

One of the top supports identified above includes incentives as part of zoning such as additional height, density, setback, parking and others. Beyond building codes and policies, zoning is an opportunity to incorporate NZE specifications and incentives. Zoning is also critical to affordable housing within Denver and the pairing of affordability and sustainability can enhance both equity and affordability. In addition, Denver is currently working on an Affordable Housing Zoning Incentive Study that includes a feasibility analysis and considerations of cost in meeting the Denver Green Code through understanding costs of LEED Certified and net zero energy.

NZE AND ZONING INCENTIVES

Zoning incentives allow for higher value development on projects that promote public policy objectives. Zoning incentives influence the size and scale of buildings and often apply in a particular area within a city. Types of zoning incentives include up-zoning, Floor Area Ratio (FAR) bonuses, height bonuses and sometimes a contribution to public funds to pay for things such as parks or city infrastructure. An example of up-zoning is allowing for different zoning that supports a more valuable use (for example, from an industrial use to residential). A FAR bonus allows additional gross floor area to be added to the building lot size if certain objectives are met. Height bonuses allow developers to build a taller building than is allowed by right in zoning.

Eligibility requirements on how to achieve the incentive is generally considered during the long-term public process facilitated by the land use planning group within a city. Some cities have engaged in comprehensive community planning processes for a particular neighborhood which have resulted in suggestions on how development incentives can be used. In those cases, after the planning process, the requirements have to be vetted through normal zoning code processes.

Commonly used to promote affordable housing, an increasing number of jurisdictions are using these regulatory levers as a way to prevent the displacement of low- and moderate-income residents and to achieve climate goals and objectives. Municipalities also can use bonuses for buildings that design and construct to a stretch code and comply with energy outcomes. These incentives can precede code mandates and serve to increase familiarity with advanced measures. Local case studies can facilitate future code enhancements by paving the way through development of a track record of success for newer approaches. This also can serve to improve code compliance once new codes with these requirements are passed by educating early adopters in the market on new code approaches.

This section provides a review of regulatory approaches in the zoning code used by cities to promote energy efficient and green commercial and residential buildings. The analysis draws from other research, including analysis by BetterBuilt Northwest[39], a policy white paper by M-Group and Karen Warner Associates for the City of Santa Rosa[40], as well as a market scan conducted by *Architecture 2030* done in partnership with New Buildings Institute for the Urban Sustainability Directors Network and a dozen cities in the Zero Cities project during 2019. This assessment details how these approaches have been used by other jurisdictions, and share lessons learned on how they can be used to encourage net zero residential and commercial buildings in Denver.

Development and Zoning Approaches

Many cities in the United States have created zoning incentive programs to achieve a number of public policy objectives including affordable housing, green buildings, conservation of open spaces and agricultural lands, inclusion of common spaces and amenities for residents. The approaches researched and listed below include those focused on green building and energy performance.

Arlington, VA New development project teams may request additional bonus density and/or height in exchange for LEED certification and Energy Star Portfolio Manager certification within four years of occupancy. Projects designed and constructed to achieve at least LEED Gold certification plus two Arlington priority credits plus Net Zero Energy Building certification through the International Living Future Institute may apply for bonus density above 0.55 FAR. Affordable housing projects receiving tax credits from the Virginia Housing Development Authority (VHDA) are allowed to earn bonus density using the Earthcraft green building rating system at the Gold or Platinum certification level.

Austin, TX – Under Section 25-2-586 Downtown Density Bonus Program, developers can pay a fee instead of meeting the standard to receive density bonus to pay for neighborhood development or

[39] https://betterbuiltnw.com/

[40] https://srcity.org/DocumentCenter/View/18475/Density-Bonus-Policy-White-Paper?bidId=

affordable housing. Under section (E)(8) Green Building Community Benefit, owners may receive FAR bonus area or height bonuses if the project substantially complies with the Urban Design Guidelines as determined by the Design Commission. The applicant also must provide streetscape improvements along all public street frontages, consistent with the Great Streets Standards. In addition, the building must achieve two stars under the Austin Energy Green Building program. If the owner does not achieve the AEGB or LEED certification within nine months of occupancy, the owner must pay into the Affordable Housing Trust Fund the bonus fee that was initially granted.

Bar Harbor, ME – Within their code for Planned Unit Development, (6)(a)[d] provides a density bonus for an increase in the market-rate dwelling units that meet LEED standard "or an approved equivalent." The bonus applies in a Planned Unit Development and compliance is demonstrated with a certification program application or by affidavit of a team member.

Boston, MA - The City created plans that recommend new density bonus zoning for two major neighborhoods. The plans are allowing developers to increase height or floor area in exchange for low-income restricted units. The areas are distinctly different, and the resulting policies reflect this.

> The Plan: JP/Rox Planning Report recommends design guidelines go beyond LEED standards to ensure new buildings and large development projects reduce carbon emissions and environmental impacts. Passive practices include efficient building envelopes and orientation while active, innovative strategies and technologies include building-integrated renewable energy, energy storage, and community solar.
>
> The Plan: South Boston Dorchester Avenue Planning Report recommends sustainability leadership and carbon free development as demonstrated by a minimum of LEED Gold, with platinum as the goal. The South Boston Dorchester Avenue neighborhoods also will require renewable energy. The work in Boston is not done. The next step is to develop EUI targets and renewable energy requirements that are required to achieve the carbon emission reduction goals outlined in both neighborhood plans.

Bothell, WA – Under Bothell Ordinance number 2028, developers who apply for LEED or the National Green Building Standard can reduce the required number of on-site parking spaces. In addition, the city offers a fee-bate for green buildings with up to a 50 percent rebate for achieving LEED Platinum or National Green Building Standard Gold.

Emeryville, CA - The Emeryville Municipal Code 9-4.204 Development Bonuses has a FAR bonus points schedule for affordable units. Half of the points needed to achieve FAR bonuses must come from affordable housing. Remaining points, up to 50, can be earned by providing a variety of community benefits. Fifty points can be earned for buildings that are zero net energy and produce as much energy as they create over the course of a year. A number of other options are provided to earn points, such as financial contributions to specific funds (citywide park fund, city underground utility fund, etc.) or public improvements.

Pittsburgh, PA - The City of Pittsburgh Zoning Code within 915.04. Sustainable Development Bonuses has both floor area and height that promote green building, LEED certified building, and waste reduction. LEED Certified buildings have a cap of 20% floor area (FAR) increase and 20% of height beyond of specifications in that district. The penalty for not achieving LEED certification is 1% of the construction costs.

Portland, OR – The City of Portland has an Administrative Rule covering Energy Efficiency Building Requirement for Planned Development Bonus in certain use zones. The rule places additional requirements on development in commercial/mixed use zones necessary in order to achieve floor area and height bonuses. The rule requires an energy target and certification program participation. It uses building type specific Energy Use Intensity targets as outlined below for 50,000-square-foot buildings.

Table 47. Energy Efficiency Standards for Planned Development Bonus

Use Type	Baseline EUI (kBtu/sf)	Baseline Reduction (percentage)	EUI Standard (kBtu/sf)
Residential			
Multifamily Dwelling	55.3	50	27.7
Commercial			
Financial Office*	73.1	70	21.9
Fitness Center	42.6	70	12.8
Hotel	69.3	70	20.8
Medical Office*	77.5	70	23.2
Office*	79.3	70	23.8
Retail*	72.0	70	21.6
Institutional			
Adult Education	71.0	70	21.3
College	131.9	70	39.6
K-12 School*	71.1	70	21.3
Library	103.6	70	31.1
Meeting Hall	30.7	70	9.2
Performing Arts	37.4	70	11.2
Preschool	73.2	70	22.0
Residence Hall*	74.2	70	22.2
Senior Care	107.5	70	32.2
Vocational School	63.1	70	18.9

* For these Use Types, the Baseline EUI and EUI Standard varies depending on building size, and the values presented on Table 1 are based on a 50,000 square foot building. The online Architecture 2030 Zero Tool may be used as an alternative to the table to determine the size-specific Baseline EUI. The size-specific EUI Standard is calculated by multiplying the Baseline EUI by a 70 percent reduction factor.

Source: Portland, OR Energy Efficient Building Requirements for Planned Development Bonuses

The rule allows for customized EUI; for example applicants can use of the Architecture 2030 Zero Tool to determine the EUI standard that must be achieved, or building projects in the Energy Trust of Oregon "Path to Net Zero" utility incentive program can use the EUI target as determined as a participant in that program. Owners must follow up with proof of certification and an as-built EUI which can be published publicly by the Bureau of Planning and Sustainability. Penalties for noncompliance can be up to 5% of the Project Valuation as set forth in the permit.

Sacramento, CA – In the Sacramento City Code 17.704.080, height bonuses are available to projects that are designed and built to exceed CALGreen reach code and are energy efficient. Reaching Tier 1 in CALGreen allows a 10% height bonus, while Tier 2 under CALGreen can receive a 20% height bonus. A separate bonus is allowed for green roofs, but together the height bonus cannot exceed 30%.

Santa Rosa, CA – This white paper describes recommendations for a point system where points are provided for the production of affordable housing, with additional points available for: open spaces, historic/landmark preservation, family-sized units, infrastructure/capital improvements, public art, or other innovative community benefit. The recommendation was to provide up to 60/80/100% of base density depending on considerations like capacity of the neighborhood, existing density of the residential neighborhood, access to transit, proximity to schools and single-family neighborhoods, existing site conditions, infrastructure, and impediments.

Seattle, WA – The City of Seattle has a number of incentives related to green and energy efficient buildings. The Living Building Pilot program (23.40.060) provides specific types of bonuses for up to 17 buildings that (1) participate in either the International Living Future Institute's Living Building Challenge or petal certification (water, energy or materials); (2) demonstrate an EUI target 25% below those used elsewhere in the Seattle Energy Code (section C401.3); (3) does not include gas combustion; and (4) uses only non-potable water. The Living Building pilot programs runs through December 2025. It allows developers to request additional departures from the Seattle Land Use Code through Design Review and earn the following benefits:

- Up to 25 percent more floor area
- Up to 30 percent more floor area if saving an unreinforced masonry structure
- 12.5 feet of additional height for residential construction or 15 feet of additional height for non-residential construction in zones with height limits of 85 feet or less
- 25 feet of additional height for residential construction or 30 feet of additional height for non-residential construction in zones with height limits greater than 85
- Additional design departures for the pilot programs as specified in SMC 23.41.012D

The Living Building pilot project must document certification with a report to the city within two years of occupancy. This provides a clear verification procedure, ensuring that targets are achieved. Penalties include $500/day for non-submittal of the report, up to 25% of the construction value according to a table provided in the pilot ordinance.

To qualify for the Architecture 2030 Challenge Pilot program, a project must:

- Qualify for design review or review by a special district or historic review committee
- Be located within an urban center, excluding lots within the shoreline or the international special review districts
- Renovate an existing structure that qualifies as a substantial alteration as determined in the Seattle Energy Code and the Seattle Existing Building Code
- Retain either the opaque portions of all exterior walls or the superstructure of existing structures (the foundation, structural frame, floor framing, and slabs of the structure)

The environmental requirements are to:

- Reduce predicted total energy use by 25 percent, or more based on the Energy Use Intensity (EUI) targets in the Target Performance Path of the Seattle Energy Code Section C401.3, and use no fossil fuel for space and water heating
- Reduce annual stormwater runoff and potable water use by at least 50 percent from program baselines

- Reduce single-occupant vehicle trips for work and non-work-related trips to percentages equal to or better than rates defined in the Seattle Comprehensive Plan

The Architecture 2030 pilot program in Seattle expires on December 31, 2025, or when 20 projects enroll in the 2030 Challenge Height Performance Existing Building Pilot. Architecture 2030 does not verify the performance of the energy or water outcomes. The city is responsible for verifying the predicted values meet the eligibility requirements.

Sunnyvale, CA – Sunnyvale has a Green Building Program that allows density bonuses for LEED certification. It provides a detailed table of incentives for projects to add floor area to an existing site and qualify for the incentive if all buildings at the existing site meet CALGreen and LEED. FAR bonuses are granted for new construction, core and shell, commercial interiors, existing buildings. Single-family, multifamily, commercial new construction and commercial tenant improvements are all eligible for the incentive.

West Hollywood, CA – Ordinance number 17-1005 rescinds the Green Building Policy which required all new commercial development with three or more units must either pursue LEED or comply with the Green Building Point System. The city allowed reduced parking in exchange for achieving at least 90 points from the points matrix to reach the 90-point threshold. Projects had to submit a preliminary and final green building plan if they were not pursuing LEED certification (at the lowest “certified” level). In addition, the old Green Building Policy incentives promoted green roofs in multi-family and mixed-used projects and allowed for tradeoffs between private and common open space. The 2007 Green Building Policy was rescinded because the city recognized the progress that the green building industry made including the establishment of several national sustainable design standards, the adoption of the CALGreen building code and the state trend toward zero net energy. West Hollywood has facilitated a series of working group meetings to update their policy. This involved soliciting feedback from stakeholders and representatives from the development, architecture, construction, housing, and sustainable design industries, as well as residents and local business owners.

ZONING INCETIVES FOR NZE: KEY CONSIDERATIONS

The key considerations regarding commercial zoning incentives include:

- Many cities have zoning and density incentives to promote affordable housing. A handful of cities are also tying bonuses to green building, energy efficiency and renewable energy.
- Incentives come in a variety of forms including up-zoning, Floor Area Ratio or height bonuses. Some incentives allow for bonuses when payments to city funds are made, for example, to the affordable housing fund, utility infrastructure fund, park fund, etc.
- Cities typically implement development incentives through the zoning code, although Portland, Oregon has used an administrative rule to institute an approach based on EUI targets. Sometimes land use planning staff at the city incorporate these requirements into comprehensive neighborhood planning or local improvement district processes and then run an additional public process to finalize language changes in the zoning code.
- Often cities focus the use of these bonuses in particular neighborhoods because one size does not always fit all. Some cities engage in a comprehensive public planning process which recognize the unique character of the neighborhood when developing incentive approaches.

This helps to ensure that the increased density is appropriate to the context of the local neighborhood.

- Bundling approaches (for example, affordable housing and efficiency) allows cities to create packages and achieve a variety of goals. However, cities should be clear regarding how the different bonuses layer on each other and what the maximum bonus is.
- Cities seem to be moving away from bonuses exclusively for green building. At least one city, West Hollywood, CA, has rescinded their green building policy which was established in 2008 and was based on LEED. According to the city's website, this was rescinded because the city recognized the progress that the green building industry made including the establishment of several national sustainable design standards, the adoption of the CALGreen building code, and California's trend toward zero net energy.
- **Increasingly, there is evidence that these policies should dovetail with policies that support equity, environmental justice and anti-gentrification.** For example, in Portland, Oregon, green building policies in the Williams/Vancouver/ Mississippi Avenue area have been seen by communities of color as being synonymous with gentrification.
- Bonuses for renewable energy should address how off-site procurement of renewable energy credits will be addressed to meet the requirement. If a city were to pursue bonuses for renewable energy, RECs should be purchased for a minimum of 15 years to offset energy consumption based on an agreed to calculation methodology. In addition, this should be noted as a covenant in the deed of sale guaranteeing continued participation for the required number of years.
- **Any type of zoning incentive should have a clear plan for penalizing buildings that do not achieve the intended result.** This is especially true for approaches that rely on a certification that will not be final until post occupancy.
- Cities should attempt to identify ways to streamline internal processes for long-term monitoring of properties under a bonus program. Program eligibility requirements and how they are achieved should be as clear and consistent as possible. Furthermore, the city should allot sufficient funding and time to ongoing review, and programs should be recalibrated regularly to ensure they respond to changing market conditions.
- Typically in cities, the regular zoning stakeholder process can be intensive. **Dovetailing efforts with other city land use planning efforts can be an effective way to manage costs.** If this is the path forward, it is imperative that those planning staff responsible for that process are familiar with the green or zero energy benefits that are trying to be achieved.
- Zoning bonuses can be an extremely effective way to align between where code is now, and where code needs to go to achieve Denver's aggressive climate goals. Denver might consider providing bonuses for developers who are willing to pursue the Denver Green Code or perhaps a particular path within the reach code, such as the passive house pathway.
- Finally, with regard to density bonuses, equity is key. **Any efforts that will increase property values to developers must consider how equity is addressed.**

NZE AND RESIDENTIAL ZONING

For NZE in residential single-family homes, one way to ensure that the home is as efficient as possible is through orientation on the lot. As a result, one consideration for residential zoning is to require or provide incentives for maximizing solar gain. This has the benefit of reducing loads within the home as well as optimizing solar and allows builders to orient homes optimally on lots. This was discussed as part of the NZE Stakeholder Advisory Groups meetings and would engage NZE with residential developers and allow NZE to start with developers, move to builders, and then to homeowners. This allows optimal savings from the beginning of a development.

Specifically, the Geos Neighborhood in Arvada was able to optimize home orientation because the developer and the builder were the same entity. As another example of the importance of working at the development level for incentives, the Northfield community in Denver required all builders in the community to build to a minimum energy savings level. This allows builders the flexibility of determining what to build but all be at similar performance levels.

Denver Staffing and Program Needs

Staffing and program support is also needed internally at the city to provide these supports for the community. **For staffing, Denver needs both IECC code enforcement staff as well as staff for the incentives, fee reductions, and supports detailed in the previous section.**

For code compliance, Denver needs additional staffing to improve IECC compliance, as detailed in the "Energy Code Enforcement" section. From analysis and outreach to similar cities including Washington, D.C., and Seattle, WA, Denver identified that 11-16 FTEs are needed in addition to 2.5 current FTEs for IECC enforcement.

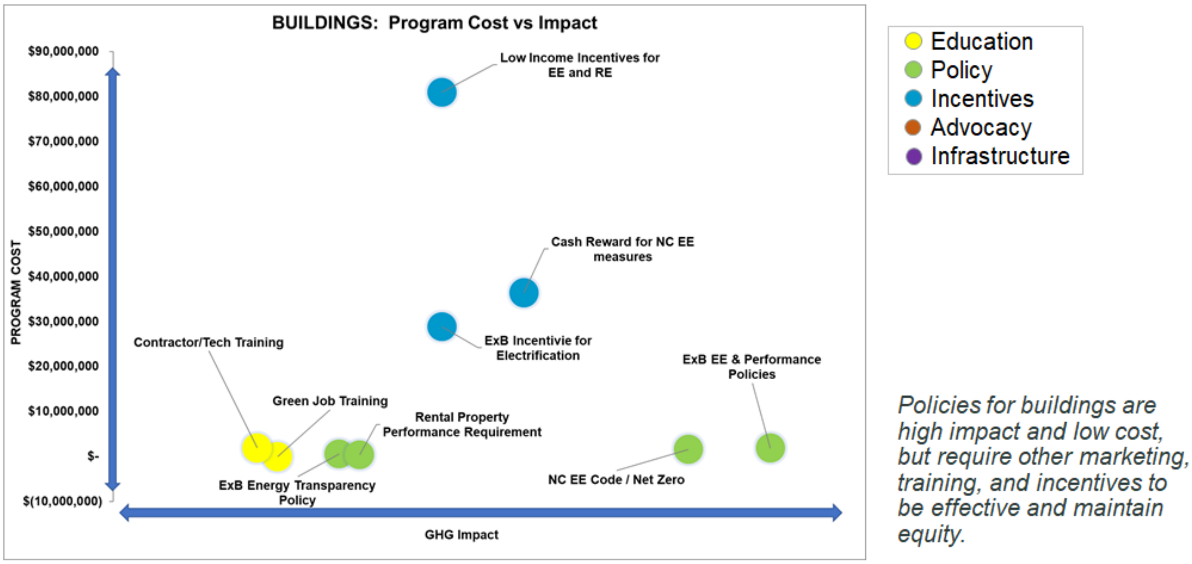
Staffing is also needed at the city to provide the supports for the community identified in the previous section development incentives (zoning and expedited reviews), design/construction team incentives, permit fee reductions and/or cash incentives. Denver has worked with Group 14 to identify and detail building and home supports needed as part of the Climate Action Task Force Process. The analysis looked at solutions, support, and costs in each of the critical areas including buildings and homes, transportation, 100% renewable electricity, industrial energy use, consumptions emissions and resiliency/adaptation. For buildings and homes, internal city resources including staffing were estimated at high, medium, and low costs to the city. The study resulted in 4-16 additional staff needed to support all of the identified commercial building supports. For homes, 3-12 additional staff are needed to support all of the identified residential homes supports.

Table 48. Staffing Estimates for Supports

City Staffing Needs	Commercial Buildings	Residential Homes
Low Estimate	4	3
Medium Estimate	7	6
High Estimate	14	12

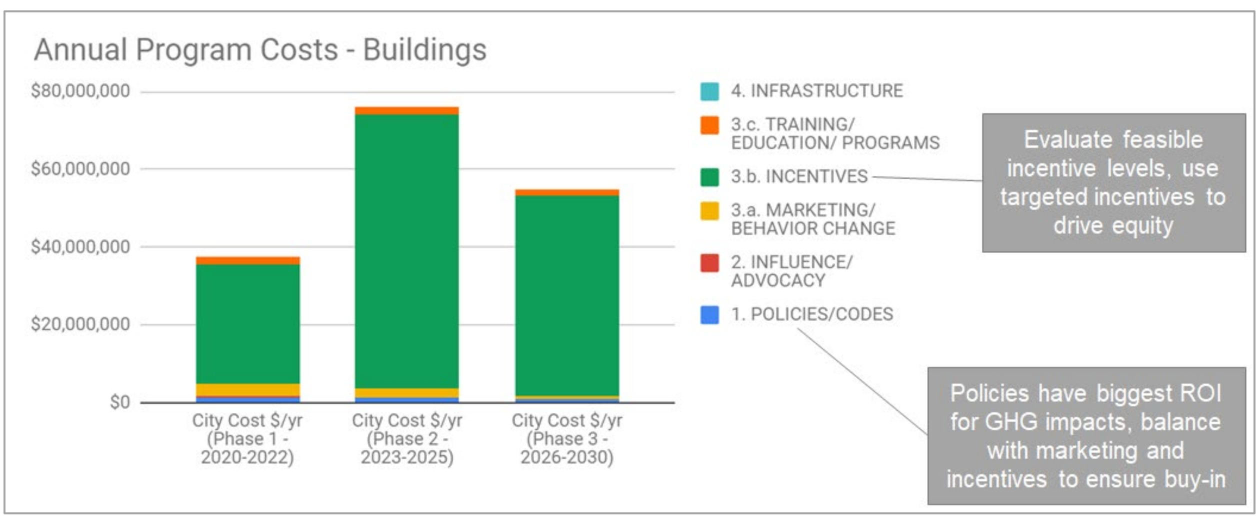
Source: Group 14's Climate Action Task Force Analysis for Denver

Beyond staffing, the city also needs funding for programs to ensure that Denver can meet the goals and recommendations for net zero. The Climate Action Task Force process identified building strategies and solutions as well as determined the annual program investment needed to support meeting the buildings and homes recommendations. Combining the solutions and support into strategies with cost considerations is critical. It is also essential that building policies and incentives account for a holistic assessment of environmental impacts to avoid unintended consequences. The following chart shows the estimated program cost and GHG impact of the strategies. **A combination of codes, policies, and support is needed to ensure equity and impact.**



Source: Denver's Climate Strategies Cost and Savings Analysis and Presentation by Group 14

Figure 38. Denver's Building Strategies for the Climate Action Task Force



Source: Denver's Climate Strategies Cost and Savings Analysis and Presentation by Group 14

Figure 39. Denver's Building Investment for the Climate Action Task Force

HOW IT ALL COMES TOGETHER: THE NEXT FOUR CODE CYCLES

One key element of this NZE Plan is how the components – highly efficient, all-electric, renewable energy and electricity, and grid flexibility – come together. While more detail on each of these is in previous sections of this report, this section details the components of the code that should evolve over the next four code cycles to meet Denver's Climate Goals and Recommendations and ensure that buildings perform as designed through performance verification. **This comes together in a timeline for commercial buildings, multifamily buildings, and residential homes that was reviewed and discussed through the NZE Stakeholder Advisory Groups process.**

The tables below indicate the timeline of each code element through individual code cycles (every three years aligning with national I-Code updates), and the potential relationship of these transitions to each other through the various code cycles for commercial buildings and residential homes.

Table 49. Denver's Commercial Buildings Code Timeline

Commercial	2021	2024	2027	2030
HIGHLY EFFICIENT				
Prescriptive Path	Add renewables	Add renewables	Small/remodel projects only	Small/remodel projects only
Performance Target	Meet EUI targets by type & year	Meet EUI targets by type & year	Meet EUI targets by type & year	Meet EUI targets by type & year
Energy Modeling Accuracy	Report on discrepancy in disclosure data	Within 15% of target	Within 10% of target	Achieve target
Energy Modeling Normalization	Report on discrepancy	Document use changes in model	Document use changes in model	Document use changes in model
Energy Modeling Unregulated Loads	Some flexibility w/ pre-approval	Flexible w/ pre-approval	Flexible	Flexible
Efficiency Backstop	IECC Thermal Envelope Specs	IECC Thermal Envelope Specs	IECC Thermal Envelope Specs	IECC Thermal Envelope Specs
Performance Verification Enforcement	Certificate of Occupancy, Disclosure	Disclosure; Bond or Solar Credit	Disclosure; Bond or Solar Credit	Bond or Solar Credit
ALL-ELECTRIC				
Equipment requirement	All-Electric: *except heating & water heating* All-Electric Ready: *conduit for central*	All-Electric: *except water heating*	All-electric equipment	All-electric equipment
RENEWABLE ENERGY				
Minimum renewable offset	50%	75%	100%	100%
Minimum % Roof Area	25%	50%	70%	70%
GRID FLEXIBLITY				
Grid flexibility requirement	Grid Flexible Equipment	Implementation of Grid Flexible Metric	Improving Grid Flexibility + Increased Storage	Improving Grid Flexibility + Increased Storage

Table 50. Denver's Multifamily Buildings Code Timeline

Multifamily	2021	2024	2027	2030
HIGHLY EFFICIENT				
Prescriptive Path	Add renewables	Add renewables	Small/remodel projects only	Small/remodel projects only
Performance Target	Meet EUI targets by type & year	Meet EUI targets by type & year	Meet EUI targets by type & year	Meet EUI targets by type & year
Energy Modeling Accuracy	Report on discrepancy in disclosure data	Within 15% of target	Within 10% of target	Achieve target
Energy Modeling Normalization	Report on discrepancy	Document use changes in model	Document use changes in model	Document use changes in model
Energy Modeling Unregulated Loads	Some flexibility w/ pre- approval	Flexible w/ pre-approval	Flexible	Flexible
Efficiency Backstop	IECC Thermal Envelope Specs	IECC Thermal Envelope Specs	IECC Thermal Envelope Specs	IECC Thermal Envelope Specs
Performance Verification Enforcement	Certificate of Occupancy, Disclosure	Disclosure; Bond or Solar Credit	Disclosure; Bond or Solar Credit	Bond or Solar Credit
ALL-ELECTRIC				
3-story Townhome & Low-Rise Apartment	All-electric equipment	All-electric equipment	All-electric equipment	All-electric equipment
Mid-Rise Apartment (R-2: 4-7 stories)	All-Electric Ready: *conduit & panel space*	All-electric equipment	All-electric equipment	All-electric equipment
High-Rise Apartment (R-2: 8 or more stories)	All-Electric Ready: *conduit & panel space*	All-Electric Ready: *conduit & panel space*	All-electric equipment	All-electric equipment
RENEWABLE ENERGY				
Minimum renewable offset	50%	75%	100%	100%
Minimum % Roof Area	25%	50%	70%	70%
GRID FLEXIBLITY				
Grid flexibility requirement	Grid Flexible Equipment	Implementation of Grid Flexible Metric	Improving Grid Flexibility + Increased Storage	Improving Grid Flexibility + Increased Storage

Table 51. Denver's Residential Homes Code Timeline

Residential	2021	2024	2027	2030
HIGHLY EFFICIENT				
Prescriptive Path	Add renewables	Add renewables	Add renewables	Add renewables
Performance Target	Meet ERI targets by size & year	Meet ERI targets by size & year	Meet ERI targets by size & year	Meet ERI targets by size & year
ALL-ELECTRIC				
Equipment requirement	All-Electric Ready: *conduit & panel space*	All-electric equipment	All-electric equipment	All-electric equipment
RENEWABLE ENERGY				
Minimum renewable offset	50%	75%	100%	100%
Energy Rating Index (ERI)	Max ERI = 50, & ERI w/PV = 40	Max ERI = 45, & ERI w/PV = 0	Max ERI = 45, & ERI w/PV = 0	Max ERI = 45, & ERI w/PV = 0
GRID FLEXIBLITY				
Grid flexibility requirement	Grid Flexible Equipment	Implementation of Grid Flexible Metric	Improving Grid Flexibility + Increased Storage	Improving Grid Flexibility + Increased Storage

Each of the code timeline tables includes each of the four foundations of net zero energy within this report of highly efficient, all electric, renewable energy, and grid flexibility. While the full sections have further detail, a summary of each is below.

Highly Efficient

Improving the performance of new buildings and homes through increased efficiency is the first foundation of Denver's NZE Plan. The Denver Energy Code, based on the International Energy Conservation Code (IECC), will need to be updated over the next four code cycles through Denver's Code Adoption Process. The goal is to achieve zero net energy performance levels by 2030 where buildings perform as designed. It is discussed in greater detail in the "NZE: Highly Energy Efficient" section and outlined below.

HIGHLY EFFICIENT COMMERCIAL AND MULTIFAMILY BUILDINGS

The Highly Efficient foundation maximizes the energy efficiency of new commercial and multifamily buildings through increasing the on-site energy efficiency for new construction, adding performance verification (outcome-based) requirements to ensure that new buildings are performing as designed and improving energy code enforcement. To get to buildings that perform as designed the steps include:

- Developing Performance Targets
- Detailing Performance Verification
- Refining Energy Modeling
- Specifying Backstops for Code

Energy Efficiency Performance Targets

This NZE Plan details the performance verification targets for buildings to meet Denver's NZE in 2030 and the milestone of net zero energy, all-electric buildings in the 2027 base building code. They are predictive energy use intensity (pEUI) targets by building-type to ensure nuances of individual building types are considered. Additionally, the energy paths within code (including performance and prescriptive) will be calibrated to ensure that the energy performance is equivalent between paths within Denver code each cycle. This allows projects the flexibility to select the prescriptive or performance path.

While the code timelines above are as comprehensive as possible, the one missing item are the pEUI targets by building type per code cycle. As a result, the targets by building type and code cycle are shown in the tables below.

Table 52. NZE 2027: Commercial pEUI Targets for Denver Code

Building Type	2021	2024	2027	2030 Performance Verification
Small Hotel	47	41	35	35
Large Hotel	68	61	54	54
Medium Office	26	24	21	21
Large Office	54	45	37	37
Standalone Retail	39	34	28	28
Warehouse	13	11	9	9

Table 53. NZE 2027: Multifamily pEUI Targets for Denver Code

Building Type	2021	2024	2027	2030 Performance Verification
Mid-Rise Apartment	35	29	23	23
High-Rise Apartment	38	33	29	29

DENVER COMMERICAL CODE: PERFORMANCE PATH

Each code cycle, these targets will be reevaluated to make sure that they remain in alignment with available technologies and Denver goals. The targets will be introduced into the Denver Building and Fire Code through proposed code amendments in future code cycles, giving the market time to adapt to this approach. Currently, some building types do not lend themselves to setting these absolute performance goals. The traditional reference model approach will continue to be available for those building types until targets can be reasonably and defensibly set in future code cycles.

DENVER COMMERICAL CODE: PRESCRIPTIVE PATH

Denver will be utilizing the "Additional Efficiency Options" in Section C406 of the upcoming 2021 edition of the IECC to ensure that the performance and prescriptive path are calibrated. This "credits" approach allows design teams to select a combination of efficiency options that are most appropriate for the specific project. Through increasing the number of credits required and adding additional credit options, Denver can increase the energy efficiency of the prescriptive path while maximizing its flexibility of the prescriptive path.

Performance Verification

Traditional code compliance paths – both prescriptive and modeled performance – are effective at regulating the features that go into a building, but not at how those buildings are operated. If Denver is going to meet its climate goals, it will need to ensure that buildings are performing as designed. Performance verification involves the comparison of a building's actual energy performance once in service to the energy performance expected by the design. This feedback loop allows owners, operators, occupants and regulators to identify performance issues after occupancy and take corrective action. This feedback also will provide the City of Denver information about the effectiveness of efficiency requirements in the energy code, informing future code advancements, refinements and enhancements.

Performance verification represents a new regulatory layer for buildings; therefore, it will be introduced gradually over multiple code cycles. At first, performance verification will be only informative, providing building owners and design teams with information about how the actual performance of the buildings compares to the expectations of the designs. As the code cycles progress, performance verification will be accompanied by increasingly stringent enforcement, including requirements to get closer and closer to the targets required by the energy code. Performance in buildings can reasonably vary due to many different factors; therefore, the enforcement of performance verification will need to be able to accommodate the normalization of the target to respond to these factors. Normalization and other issues related to performance verification is discussed in greater detail in the "Performance Verification" section.

Performance verification is a very similar policy to a Building Performance Standard (BPS), and can be thought of as a BPS with special performance targets for recently constructed existing buildings.

HIGHLY EFFICIENT RESIDENTIAL

Similarly, the Highly Efficient foundation of net zero energy (NZE) maximizes the energy efficiency of new residential buildings through increasing the on-site energy efficiency for new construction. This NZE Plan details the targets for homes to meet Denver's NZE goal in 2030 and the milestone of net zero energy, all-electric homes in the 2024 base building code.

Energy Efficiency Performance Targets

For residential homes, the energy performance targets proposed are energy rating index (ERI) targets. As with buildings, the energy paths within code (including performance and prescriptive) will be calibrated for homes to ensure that the energy performance is equivalent between paths within Denver code each cycle. This allows projects the flexibility to select the prescriptive or performance path.

While the code timelines above are as comprehensive as possible, the one missing item are the energy targets by building type per code cycle. As a result, the targets by code cycle are shown in the table below.

Table 54. NZE 2024: Residential ERI Targets for Denver Code

Building Type	2021	2024
Single-family homes	Max ERI = 50 & ERI w/PV = 40	Max ERI = 45 & ERI w/PV = 0

DENVER RESIDENTIAL CODE: PERFORMANCE PATH

A key element of achieving the residential ERI targets is the integration of an additional efficiency-credits approach into the residential code similar to the one adopted for commercial buildings in the 2021 edition of the IECC. Under this approach, the code requires a targeted number of additional efficiency credits and provides a series of efficiency options with varying credit values. Design teams select from that list to create a custom combination of measures and credits to meet the code goal. As discussed for commercial buildings above, this approach allows the stringency of the prescriptive path to be increased while maximizing design flexibility for design teams.

DENVER RESIDENTIAL CODE: PRESCRIPTIVE PATH

This "credits" approach for the residential portion of the IECC allows design teams to select a combination of efficiency options that are most appropriate for the specific project. Through increasing the number of credits required and adding additional credit options, Denver can increase the energy efficiency of the prescriptive path while maximizing flexibility of the prescriptive path. Both the number of credits required and the target for the ERI approach will be calibrated for the performance target of each code cycle.

All Electric

The second foundation of NZE within Denver's net zero energy definition is all-electric buildings and homes. All-electric is part of Denver's net zero definition and is important in getting to net zero energy in support of reducing emissions. The majority of the emissions from buildings and homes are due to heating and water heating. As Xcel Energy continues to decarbonize the electric grid and Denver effectively decarbonizes local electricity consumption through aggressive renewable energy goals, the emissions due to electricity consumption in Denver will continue to decrease to zero.

As a result, Denver's NZE Plan includes a future goal for all new buildings to be all-electric and is detailed in the "NZE: All Electric" section. The transition of Denver buildings away from natural gas equipment and to electric equipment will enable those buildings to take advantage of the ongoing emissions improvements from Denver's decarbonizing electricity supply.

Electrification of buildings in Denver works synergistically with Denver's goals for increasing efficiency. High performance electric heat pumps can achieve performance levels four to six times higher than their gas-fired counterparts. Heat pump technology has also been making substantial improvements in cold-weather performance in recent years, delivering performance advantages over gas even in Denver's climate. These high levels of performance will be increasingly necessary to meet Denver's efficiency goals.

Electrification also has an important connection to Denver's renewable energy requirements. Under Xcel's current plan for grid decarbonization, it would be several years before building electrification would lead to lifetime carbon reductions. However, Denver's renewable energy requirements effectively accelerate the decarbonization of the local electrical supply. As a result, electrification, efficiency, and renewable energy generation work together to reduce carbon emissions more than any one strategy could on its own.

The electrification of buildings will be progressing simultaneously with the electrification of the transportation sector. Buildings play a key role in this other electrification goal as well. Denver's Electric Vehicle (EV) Action Plan details the city goals for electric vehicles and how these fit into Denver's larger picture.

Renewable Energy

The third NZE foundation within Denver's net zero energy definition is that new buildings and homes will be powered by renewable energy and electricity. It will be necessary to deploy renewable energy to offset building energy use to achieve NZE performance. In order to achieve this, this NZE Plan includes renewable energy goals that increase over multiple code cycles. The goal is that 100 percent of community-wide new construction energy will be from renewable energy by 2024 for residential buildings and 2027 for commercial buildings. Renewable energy installations are already increasing, and there is no reason to delay accounting for renewable installations in the code process. Projects may choose to deploy more than the minimum amount of renewable energy production to meet overall code targets.

As renewable deployment requirements increase, some buildings may not be able to meet the renewable energy offset requirements. Some buildings are shaded, some have non-optimal solar orientation, some are tall with a high ratio of building square-footage to roof area, and some buildings (such as hospitals) have justifiably high energy usage rates. For this reason, Denver is currently working to develop a fund – the Renewable Denver Community Solar Fund – that will build community solar gardens. This will enable the renewable offset to be met by on-site or off-site through the Fund.

In addition, Xcel Energy has a goal to decarbonize its electricity supply by 2050. Renewable energy requirements in the code will allow Denver to meet its own sustainability goals by 2030. They will allow Denver to effectively decarbonize its own electricity supply ahead of Xcel. The Renewable Energy foundation is discussed in greater detail in the "NZE: Powered by Renewable Energy and Electricity" section.

Grid Flexibility

The fourth NZE foundation within Denver's net zero energy definition is that new buildings and homes will be providers of demand flexibility for the grid. As the quantity of renewable energy supply on the grid is increased, there is also an increasing misalignment between the time of day when energy is produced and when it is consumed. Grid flexibility is one strategy to address this potential misalignment. **As renewable deployment increases, the value of being able to spread building loads to time periods when renewables are not available increases significantly.** Through design strategies that minimize energy usage when renewable energy is less available, control strategies that can shift equipment operation to times when renewable energy is more available and other energy storage strategies, buildings can shape their energy consumption to more closely align with renewable energy availability. The Grid Flexibility foundation is discussed in greater detail in the “NZE: Powered by Renewable Energy and Electricity” section.

Preparing for the 2021 Code Cycle

Denver is currently working with New Buildings Institute (NBI) and stakeholders to develop drafts of the first round of proposed code amendments for Denver’s 2021 Code Adoption Process to modify the 2021 IECC. These proposals are being developed to specifically implement the goals, recommendations, and milestones in this NZE Plan. In early 2021, Denver will continue to engage more stakeholders and other interested parties to review and refine these proposals before taking them through the Code Adoption Process.

HIGHLY EFFICIENT

The general proposed updates for energy efficiency in commercial and multifamily buildings include adding the energy targets, streamlining the modeled performance compliance path, and expanding and enhancing the additional efficiency credits options in the prescriptive path. The general updates for energy efficiency in residential buildings include adding an additional efficiency credits section to the residential section for the prescriptive compliance path.

ALL-ELECTRIC

Natural gas equipment is currently typical in the Denver market, and the widescale adoption of all-electric buildings represents a substantial shift in the market. Therefore, the Denver NZE Plan does not include an immediate move to all-electric buildings. In the next code cycle, the proposed updates under consideration include basic “electrification-capable/ready” infrastructure such as conduit and panel space to enable easier, more effective and less costly electrification retrofits in the future. These specifications look different for commercial and residential buildings, as well as for small and large equipment.

The implications of the electrification retrofit of smaller natural gas loads found in both residential and commercial buildings are different than the implications of electrification retrofits of larger natural gas loads found in commercial and some multifamily buildings. These ”electrification-capable/ready” requirements will incentivize early adoption of all-electric buildings and will also enable future, cost-effective electrification of new mixed-fuel buildings. In future code cycles, consideration will be given to all-electric equipment for specific building loads (process loads such as those in manufacturing facilities will always need to be considered separately from building loads like space and water heating and cooking). Some gas end-uses are more challenging to electrify than others, and therefore Denver will evaluate each code cycle whether there are any reasonable or necessary specifications and considerations for proposed code amendments.

RENEWABLE ENERGY

“Net” energy is the balance of energy consumed on site and the renewable energy produced for the site. The next code cycles will include increasing renewable energy from on-site systems. Recognizing that some building types and some building sites make on-site renewable energy challenging; considerations will include options to meet those minimum renewable energy requirements with dedicated off-site renewable energy production.

Building performance requirements in Denver may approach technical limits in future code cycles, so there will be a need to allow a fraction of building performance goals to be provided by renewable energy. Projects may choose to deploy more or less renewable to achieve the targets, with increasing minimums for renewable deployment in subsequent code cycles. Basic building performance will be ensured by backstop code requirements to prevent over-dependence on renewables.

GRID FLEXIBILITY

Near-term code cycles will include requirements for the installation of grid-interactive demand response (DR) controls that are already available on the market, particularly for water heaters and thermostats. Through having these controls available, buildings will have the functionality necessary to participate in demand response programs as they become more prominent. In future code cycles, Denver will consider increased grid flexibility from buildings through the implementation of emerging grid flexibility metrics and standards as they become available and market-ready.

Reducing Emissions: Carbon Considerations

Although this NZE Plan for new buildings and homes is focused on energy, all four foundations have implications for the carbon emissions of Denver’s building stock. Denver is working with New Buildings Institute (NBI) to understand how the goals of each NZE foundation impact Denver’s carbon emissions. While the metric for this NZE Plan will remain energy, the carbon impact of the four NZE foundations has been and will continue to be used to inform the implementation of NZE in Denver to reach the climate goals, milestones, and targets over the upcoming code cycles.

Each of the four foundations of Denver’s NZE Plan have different considerations and can be considered using multiple metrics. As a result, it is challenging to understand the impacts between the foundations and over time as NZE progresses in Denver. One solution to this problem is to establish a way to convert the goals for each foundation to the same metric, and carbon emissions makes the most sense as a common metric.

As a result, New Buildings Institute (NBI) developed a system that considers all four foundations (efficiency, renewables, all-electric, demand flexibility) and can be used by Denver to understand progress towards emissions reductions. The goal is to help Denver answer: 1. how to estimate and represent all four foundations together each code cycle and 2. how to define the end goal in quantified, measurable terms.

The first steps of this work involved background research to determine the current status and end goal of each foundation and then approximate the foundation in terms of carbon emissions. It is important to note that, while this is rooted in sound data and assumptions, these results are approximations that use national level building energy use breakdown estimates, assumptions about fuel type for those end uses, and readily available information about the carbon intensity of the electricity grid in Denver. To explicitly calculate and model the carbon impact of Denver’s NZE Plan would require much more substantial background research, data, and analysis. However, this exercise can be used to inform implementation decisions by giving a broad-scale sense of the carbon emission impact of different policies and strategies.

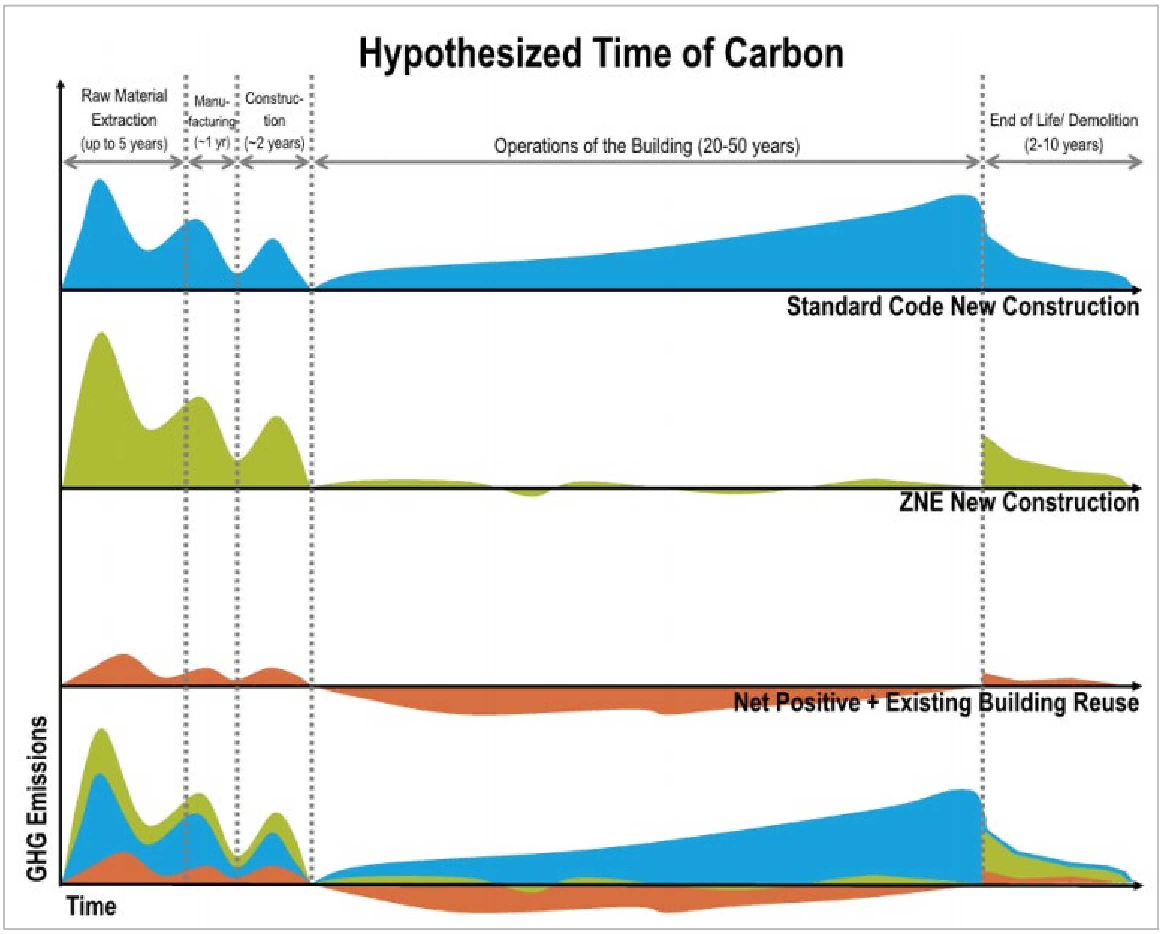
This carbon emissions exercise reveals some important insights about the impact of this NZE Plan including:

- **The most important takeaway of this exercise is the interrelatedness of the four foundations. Changes in policies for one foundation will influence the carbon impact of another foundation. This highlights the importance of considering the interactive effects of the different requirements implemented.**
- The carbon impact of all of the foundations increases until 2027 and then declines afterward. This is because 2027 is the year that the recommended renewable energy requirements reach 100% of commercial building energy usage. After 2027, the continuing decarbonization of the Xcel Energy grid mix means that the foundations have less of an impact on carbon emissions. Effectively, as the grid decarbonizes, reducing electricity from that consumption has less of an impact.
- The recommended requirements for renewable energy have the greatest carbon impact. This is for two reasons. The first is that the recommended renewable energy requirements are relatively aggressive. The second is that the carbon intensity of the Xcel Energy grid is still relatively high and is set to decline on a much longer timeline than Denver's NZE Plan in general and renewable energy goals in particular.
- The carbon impact of grid flexibility is relatively very low. This is because the importance of grid flexibility is less about direct carbon savings and more about support for increasing renewable energy production on the grid. Grid flexibility enables increases in renewable energy production by shifting building energy consumption to better align with the timing of renewable energy production.
- Due to the carbon intensity of Xcel Energy's electricity supply, the carbon impact of electrification is highly impacted by both efficiency requirements and renewable energy production. Without decarbonizing the building electricity supply or increasing building efficiency, electrification would actually result in higher carbon emissions in Denver. The efficiency requirements reduce the total energy required by the building and the renewable energy requirements reduces the effective carbon intensity of the electricity consumed. When combined, the three foundations are a potent carbon reduction strategy.
- Energy efficiency is an important prerequisite for effective renewable energy requirements. Energy efficiency reduces the total amount of renewable energy that will be required to meet the NZE goal, milestones, and targets. Without energy efficiency, the quantity of renewable energy required would be substantially higher, exacerbating the issues that arise from adding more renewable energy production to the grid.

EMBODIED CARBON

Denver is also working to understand embodied carbon in buildings through an inventory titled "Analyzing Denver's Building Sector Embodied Carbon Emissions." Denver currently has an initial draft and the study will be complete in early 2021.

The embodied emissions are significantly less than operational emissions for existing buildings and buildings built to code. For net zero buildings, the operations emissions are significantly lower. The figure below from The Total Carbon Study shows the rough order of magnitude evaluation in the total GHG emissions released over time (Cradle to Gate) related to buildings by comparing Standard code-compliant new construction, Zero Net Energy (ZNE) new construction, and Net Positive existing building reuse.



Source: The Total Carbon Study

Figure 40. Rough Order of Magnitude Evaluation in the Total GHG Emissions Released over Time (Cradle to Gate)

APPENDIX A. ALL-ELECTRIC MARKET READINESS ASSESSMENT INTERVIEWS

Interviewees:

- Alicia Bock – Building Official at City and County of Denver
- Joel Champagne – Building Official at City and County of Denver
- Julie Edwards – Associate, Director of Sustainability at Oz Architecture
- Cheryl Hoffman – Project Manager at Hensel Phelps
- Tom Hootman – Associate Principal, Senior Sustainability Consultant at Integral Group
- Nathan Kahre – Business Development Manager at EnergyLogic
- Don Larsen – SVP of Construction & Development Mgmt. at McWhinney
- Joshua Radoff – Senior Vice President at WSP
- Robby Schwarz – Principal Thinker at BUILDTank
- Tony Thornton – Senior Associate at Stantec
- Michael Walton – Building Official at City and County of Denver

Interview Guide:

1. How common are all-electric buildings in Denver?
2. What are the primary drivers for considering all-electric buildings?
3. What are the primary technical obstacles to all-electric buildings in Denver?
    a. Is the equipment readily available?
    b. Are there electrical panel/capacity sizing issues?
4. What are the primary market obstacles to all-electric buildings in Denver?
    a. Are there risk premiums being applied to the cost for new/unfamiliar electric equipment?
5. Are there any regulatory issues for all-electric buildings? Code compliance? Modeling? HERS?
6. Are there building types that are more challenging to make all-electric than others?
7. How do the heat pumps perform in Denver's climate?
    a. Do the low-temperature heat pumps operate better?
8. Based on your experience with individual heat-pump water heaters (like those used in single-family), please answer the following questions.
    a. What are the primary issues with using them in Denver?
    b. Do the trades have the necessary experience to install them?
    c. Do they create issues on electrical panel sizing?
    d. What have been the primary drivers for their adoption?
9. Based on your experience with central heat pump water heater systems (like those used in multifamily, please answer the following questions.
    a. What are the primary issues with using them in Denver?
    b. Are there mechanical engineers and/or design-build firms in the Denver market that have experience with these systems?
    c. What have been the primary drivers for their adoption?