WORK SESSION AGENDA

CITY COUNCIL WORK SESSION	**COUNCIL CHAMBERS**
TUESDAY	**211 WEST ASPEN AVENUE**
DECEMBER 9, 2025	**3:00 P.M.**

All City Council Meetings are live streamed on the city's YouTube page (https://www.youtube.com/@FlagstaffCityGovernment)

PUBLIC COMMENT

Verbal public comments not related to items appearing on the posted agenda may be provided during the "Open Call to the Public" at the beginning and end of the meeting and may only be provided in person.

Verbal public comments related to items appearing on the posted agenda may be given in person or online and will be taken at the time the item is discussed.

To provide online verbal comment on an item that appears on the posted agenda, use the link below.

ONLINE VERBAL PUBLIC COMMENT

Written comments may be submitted to publiccomment@flagstaffaz.gov. All comments submitted via email will be considered written comments and will be documented in the record as such.

---

1. Call to Order

NOTICE OF OPTION TO RECESS INTO EXECUTIVE SESSION

Pursuant to A.R.S. §38-431.02, notice is hereby given to the members of the City Council and to the general public that, at this work session, the City Council may vote to go into executive session, which will not be open to the public, for discussion and consultation with the City's attorneys for legal advice on any item listed on the following agenda, pursuant to A.R.S. §38-431.03(A)(3).

2. Roll Call

NOTE: One or more Councilmembers may be in attendance through other technological means.

MAYOR DAGGETT
VICE MAYOR SWEET
COUNCILMEMBER ASLAN
COUNCILMEMBER GARCIA
COUNCILMEMBER HOUSE
COUNCILMEMBER MATTHEWS
COUNCILMEMBER SPENCE

3. Pledge of Allegiance, Mission Statement, and Land Acknowledgement

MISSION STATEMENT

The mission of the City of Flagstaff is to protect and enhance the quality of life for all.

LAND ACKNOWLEDGEMENT

The Flagstaff City Council humbly acknowledges the ancestral homelands of this area's Indigenous nations and original stewards. These lands, still inhabited by Native descendants, border mountains sacred to Indigenous peoples. We honor them, their legacies, their traditions, and their continued contributions. We celebrate their past, present, and future generations who will forever know this place as home.

4. **Open Call to the Public**

Open Call to the Public enables the public to address the Council about an item that is not on the prepared agenda. Comments relating to items that are on the agenda will be taken at the time that the item is discussed. Open Call to the Public appears on the agenda twice, at the beginning and at the end. The total time allotted for the first Open Call to the Public is 30 minutes; any additional comments will be held until the second Open Call to the Public.

If you wish to address the Council in person at today's meeting, please complete a comment card and submit it to the recording clerk as soon as possible. Your name will be called when it is your turn to speak. You may address the Council up to three times throughout the meeting, including comments made during Open Call to the Public and Public Comment. Please limit your remarks to three minutes per item to allow everyone an opportunity to speak. At the discretion of the Chair, ten or more persons present at the meeting and wishing to speak may appoint a representative who may have no more than fifteen minutes to speak.

5. **Review of Draft Agenda for the December 16, 2025 City Council Meeting**

Citizens wishing to speak on agenda items not specifically called out by the City Council may submit a speaker card for their items of interest to the recording clerk.

6. **December Work Anniversary Presentation**

Recognition of employees celebrating work anniversaries in December.

7. **Discussion of 2026 State and Federal Legislative Priorities**

Provide staff with feedback and input on the 2026 draft state and federal legislative priorities.

8. **Analysis of the Costs, Benefits, and Barriers to Building Highly Energy-Efficient and All-Electric Homes in Flagstaff, Arizona: Filling the Data Gap**

Informational only.

9. **Open Call to the Public**

10. **Informational Items To/From Mayor, Council, and City Manager; future agenda item requests**

11. **Adjournment**

CERTIFICATE OF POSTING OF NOTICE
The undersigned hereby certifies that a copy of the foregoing notice was duly posted at Flagstaff City Hall on _________________, at ________ a.m./p.m. in accordance with the statement filed by the City Council with the City Clerk. Dated this ________ day of _________________________, 2025. ____ Stacy Saltzburg, MMC, City Clerk

THE CITY OF FLAGSTAFF ENDEAVORS TO MAKE ALL PUBLIC MEETINGS ACCESSIBLE TO PERSONS WITH DISABILITIES. With 48-hour advance notice, reasonable accommodations will be made upon request for persons with disabilities or non-English speaking residents. Please call the City Clerk (928) 213-2076 or email at stacy.saltzburg@flagstaffaz.gov to request an accommodation to participate in this public meeting.

NOTICE TO PARENTS AND LEGAL GUARDIANS: Parents and legal guardians have the right to consent before the City of Flagstaff makes a video or voice recording of a minor child, pursuant to A.R.S. § 1-602(A)(9). The Flagstaff City Council meetings are live-streamed and recorded and may be viewed on the City of Flagstaff's website. If you permit your child to attend/participate in a televised Council meeting, a recording will be made. You may exercise your right not to consent by not allowing your child to attend/participate in the meeting.

6.

CITY OF FLAGSTAFF

STAFF SUMMARY REPORT

To:	The Honorable Mayor and Council
From:	Tiffany Snider, Executive Assistant
Date:	12/02/2025
Meeting Date:	12/09/2025

TITLE:
December Work Anniversary Presentation

DESIRED OUTCOME:
Recognition of employees celebrating work anniversaries in December.

Executive Summary:

Information:

Attachments: December Work Anniversaries

December Work Anniversaries

First Year Anniversaries

- Carrie Kayaani, Legal Specialist
- Chantel Jordan, Lifeguard
- Claire Marchant Collier, Library Specialist
- Deborah Ingram, Finance Specialist
- Gregory Kane, Police Officer
- John Hickey, Utility Locator
- Judith Barrett, Visitor Services Specialist
- Laurren Bauer, Lifeguard
- Reese Cole, Equipment Operator II

Tenth Year Anniversary

Stephanie Golding

Legal Specialist

Twenty-Fifth Year Anniversary

Rebecca Sayers

PROSE Director

For twenty-five years, Rebecca Sayers has graced many of us by working side by side, by leading, by collaborating, through teamwork, and most of all by listening. It is the latter adverb that surfaces in any form of communication with Rebecca as she listens, asks questions to listen more, all with the one goal in mind: to assist the organization to reach the highest service level which in turn assists every community member.

Rebecca is a scientist at heart who has had the opportunity over the years to “experiment” in City services with environmental, sustainability, facility maintenance, street maintenance, fleet, solid waste and landfill operations, along with the current “pros” of them all with parks, recreation, open space and events.

Twenty-Fifth Year Anniversary

Troy Dagenhart

Water Services Manager

Troy started his career with the City in 2000 as an operator at the Wildcat Hill Water Reclamation Plant. He was promoted to supervisor in 2005, had a short stint as interim manager and was promoted to manager in 2023. He takes pride in improving processes and in helping his team. When a new process was introduced to the plant he worked tirelessly to get it dialed in; frequently coming into the plant in the middle of the night to make small adjustments. He is also known to help operators understand the biology, chemistry and plant processes which is essential for their professional development.

In his free time Troy enjoys both watercolor and oil painting and hunting.

Thirtieth Year Anniversaries

Joe Almendarez

Water Services Supervisor

Joe joined the City on December 4, 1995, and has been a dedicated part of our team for three decades. After rising from Field Technician/Operator to Wastewater Collections Supervisor in 2019, Joe has continued to lead with reliability, skill, and an unwavering commitment to service. As he prepares for his upcoming retirement in January 2026, we're grateful that he plans to extend his time with us through the Smart Works Phased Retirement Program. Outside of work, Joe is known for his love of riding his Harley Davidson motorcycle, his involvement in annual toy drives for families in need, his two beloved Shih-Tzus, and the time he cherishes with friends and family. We're honored to recognize his remarkable service and the positive impact he brings to our organization and community.

Congratulations!

CITY OF FLAGSTAFF

STAFF SUMMARY REPORT

To:	The Honorable Mayor and Council
From:	Sarah Langley, Public Affairs Director
Date:	11/25/2025
Meeting Date:	12/09/2025

TITLE:
Discussion of 2026 State and Federal Legislative Priorities

DESIRED OUTCOME:

Provide staff with feedback and input on the 2026 draft state and federal legislative priorities.

Executive Summary:

The draft 2026 state and federal legislative priorities detailed in the attached documents represent an updated listing of last year's legislative priorities. City staff and lobbyists have made suggested updates to the legislative priorities based on the legislative landscape that we face in 2026, as well as accomplishments that have been achieved over the last year.

City staff and lobbyists are requesting Council input and direction on the draft state and federal legislative priorities. After this input is received, it will be incorporated, and a final version will be presented for Council approval at the December 16 Council Meeting. Once approved by the City Council, the 2026 legislative priorities will be used by City staff and lobbyists to guide their work throughout the year at both the state and federal levels.

Information:

On January 21, 2025, the Flagstaff City Council approved the 2025 legislative priorities.

Attachments: Draft State Priorities 2026
Draft Federal Priorities 2026

CITY OF FLAGSTAFF

Draft - 2026 State Legislative Priorities

GUIDING PRIORITIES

Preserve Local Control - Support legislation that preserves or enhances the City's ability to govern locally and oppose legislation that reduces or restricts the City's local authority.

State Shared Revenues - Protect (and recover) state shared revenues to municipalities and oppose new legislation seeking to divert shared revenues away from municipalities.

TRANSPORTATION & INFRASTRUCTURE

Transportation - Advocate for additional funding to plan, build, preserve, modernize, and expand transportation and infrastructure projects that impact northern Arizona and our tribal partners. Advocate for projects, policies and legislation that strengthen transformative transportation planning approaches, in line with complete street infrastructure.

Resilience and Preparedness - Advocate for assistance to upgrade infrastructure to withstand catastrophic events such as flooding, storms, and forest fires.

Flagstaff Pulliam Airport – Protect the State Aviation Fund (similar to HURF) and emphasize the need to use funds for airport maintenance and operations. Discourage transfers out of the fund for non-aviation expenditures.

COMMUNITY INFRASTRUCTURE

Housing - Support legislation and seek funding in support of affordable housing, including the renewal of the Arizona Department of Housing (ADOH), renewal of the State Affordable Housing Tax Credit program, funding for the Low Income Housing Tax Credit (LIHTC) program, and funding for the Arizona Housing Trust Fund. Join cities across the state in prioritizing the creation of housing units while retaining local control in areas related to housing development.

Short-Term Rentals - Work with stakeholders supporting legislation to allow for local regulations over residential properties used as short-term rentals and ensure equity with the hotel industry.

Rural Broadband - Support and encourage continuing state efforts to increase rural broadband access and capacity to encourage and develop economic activity, including allowing for remote education, business attraction, revenue creation, and the attraction of remote workers.

Wildfire risk reduction – Support state funding and partnership opportunities for private property owners to reduce their wildfire risk through the creation of defensible space and home hardening initiatives, thereby making properties more attractive for insurance providers.

ENVIRONMENT

Forest Health & Emerging Technologies - Advocate for robust state investments in forest management strategies that reduce wildfire risk and enhance regional resilience across all land types in northern Arizona. Support policies that expand mechanical thinning, beneficial fire, and biomass utilization to protect communities and infrastructure. Promote the development of technologies, such as biochar production, as tools for forest restoration, economic diversification, and long-term benefits for energy and soil health. Encourage workforce development programs that build technical capacity in forest operations and technological innovation.

Energy Independence - Support legislation and funding to advance Arizona's energy independence through investment in energy storage and emerging technologies. Prioritize workforce development and education programs that prepare communities for careers in energy technology.

Arizona Corporation Commission - Encourage the Arizona Corporation Commission to maintain and enhance programming that supports new technologies, efficiencies, distributed generation, and renewable energy credits, with a focus on their role in strengthening Arizona's energy independence and economic competitiveness. Advocate for policies that protect ratepayers from excessive energy costs while ensuring continued investment in reliable and modern energy infrastructure. Build strategic relationships with Commissioners to highlight the economic, reliability, and workforce development benefits of these programs, particularly in rural and forested regions.

Environmental Funding and Partnership - Support state funding and partnership opportunities to expand open space, parks, natural areas, trails, and wildlife corridor initiatives across northern Arizona. Support the restoration of funding to the Arizona State Parks Heritage Fund grant program for historic preservation. Promote the City's dark skies program and strengthen relationships with regional partners such as the Arizona Department of Transportation to increase understanding of the City's dark skies goals.

CITY OF
FLAGSTAFF

Draft - 2026 Federal Legislative Priorities

TRANSPORTATION & INFRASTRUCTURE

Rio de Flag Flood Control Project - Utilize the $84 million in federal and local funding to support expedited award and completion of Phase 4 of the project while working with the Army Corps, BNSF Railway, and the Arizona Department of Transportation to ultimately remove more than half of the City's residents, as well as the downtown and NAU areas, from the flood plain and protect more than $1 billion in assets.

Red Gap Ranch Regional Pipeline Project – Advocate for the Northeastern Arizona Indian Water Rights Settlement Act (NAIWRSA). Advocate for the Bureau of Reclamation (BOR) technical studies and federal funding of the Red Gap Regional Water Supply project. The Regional Project will assure water resiliency and water redundancy for the City of Flagstaff's future needs, while also providing important water quality, economies of scale, and economic opportunities for the Navajo Nation, Arizona State Land Department, and other stakeholders along the I-40 corridor. In July 2025, the BOR found in a value planning process with the City and Navajo Nation that the region is "one fire away" from needing the project online today.

Flagstaff Pulliam Airport – Advocate for funding for projects included in the Flagstaff Pulliam Airport five-year Capital Improvement Program, specifically the need for discretionary construction funding for the upcoming new Snow Removal Equipment (SRE) building.

Infrastructure Investment and Jobs Act (IIJA) - Pursue competitive grants and formula funds from the IIJA to finance high-priority infrastructure projects within the City, while also working to reauthorize the important programs from the IIJA in the surface transportation reauthorization bill.

Transportation - Advocate for projects, policies and legislation that strengthen transformative transportation planning approaches, in line with complete street infrastructure.

Water and Stormwater Infrastructure – Utilize funding dedicated by the IIJA and other legislation to complement and improve City water and stormwater infrastructure. Advocate for assistance to upgrade infrastructure to withstand catastrophic events such as flooding, storms, and forest fires.

ENVIRONMENT

Forest Health – Utilize federal funding to support important regional projects to reduce wildfire risk to forested communities, such as the Four Forest Restoration Initiative and the Flagstaff Watershed Protection Project. Advocate for collaborative beneficial fire policies that both increase acres treated and support the development of a technically skilled workforce. Promote policy action aligned with recommendations of the Wildland Fire Mitigation and Management Commission and the Fix Our Forests Act.

Energy Independence - Support legislation and funding to advance energy independence through investment in energy storage and emerging technologies. Prioritize workforce development and education programs that prepare communities for careers in energy technology.

Securing Arizona's Fair Share of Investments - Urge Congress to protect investments in Arizona's emerging technology, including federal funding that supports workforce training and jobs in northern Arizona.

COMMUNITY INFRASTRUCTURE

Flood Insurance – Advocate for affordable and accessible flood insurance policies for Flagstaff residents. Work to ensure that FEMA deems post-wildfire flooding during monsoon season as an emergency under the Public Assistance Program and Policy Guide (PAPPG).

Housing – Support legislation to create a middle-income housing tax credit. Promote direct funding for local governments to accelerate housing development, including CDBG, HOME, and the Housing Trust Fund. Promote full funding adjusted for inflation for Public Housing and capital funds, as well as the Section 8 Housing Choice Voucher Program and programs for veterans' housing. Remove income targeting requirements to establish a more streamlined and fair approach to housing eligible households, ensuring consistency regardless of variations in local and state minimum wages.

Rural Broadband – Utilize federal funding for rural broadband access and capacity to encourage and develop economic activity, including allowing for remote education, business attraction, revenue creation and the attraction of remote workers.

CITY OF FLAGSTAFF

STAFF SUMMARY REPORT

To:	The Honorable Mayor and Council
From:	Genevieve Pearthree, Senior Sustainability Planner
Date:	11/10/2025
Meeting Date:	12/09/2025

TITLE:

Analysis of the Costs, Benefits, and Barriers to Building Highly Energy-Efficient and All-Electric Homes in Flagstaff, Arizona: Filling the Data Gap

DESIRED OUTCOME:

Informational only.

Executive Summary:

This presentation will share the results of a study conducted by an external energy expert to evaluate the costs, benefits, and barriers to building energy-efficient and all-electric homes in Flagstaff. The results of this study can inform future program and policy development.

Information:

Introduction

The City of Flagstaff (the City) is committed to advancing its climate and housing goals, while maintaining a high quality of life for residents. A key strategy for reducing greenhouse gas (GHG) emissions and monthly utility costs is the expansion of energy efficiency and beneficial electrification in new residential construction. While several national studies provide evidence suggesting energy efficiency and electrification can bring health, economic, and other benefits to residents of cold climate Western cities, industry experience has shown that national studies may not always reflect local construction realities.

Recognizing this disparity, the City commissioned a study by Noverra Collective to evaluate the capital and operational costs, barriers, and opportunities of building highly energy-efficient and all-electric new construction. The intent of this analysis is to address a critical data gap and inform City decisions about how to reduce energy use and emissions in the built environment while prioritizing long-term affordability. Through this work, the City seeks to develop defensible, locally grounded cost insights that reflect Flagstaff's real-world construction practices, while highlighting both the economic and non-economic barriers to and benefits of energy-efficient, all-electric development.

Methodology

This study was informed by two research methods:

1. Interviews and a focus group with 13 Flagstaff architects, builders, general contractors, and sub-contractors who provided feedback on estimated capital costs, modeled operational costs, barriers, lessons learned, and recommendations.
2. Modeling to explore capital costs and the impacts of different Arizona Public Service (APS) electricity plans on operational costs for single- and multi-family homes (APS is the electricity provider for the Flagstaff region). Scenarios explored the differences in capital and operational (utility) costs for mixed-fuel (natural gas/electric), homes, all-electric (ducted and ductless) homes, and highly energy-efficient (HEE) homes. HEE homes were modeled as a 24% improvement in energy efficiency over Flagstaff's current energy code. Scenarios include:

Scenarios Modeled	
Single-family home (2,500 sf)	**Multi-family home (990 sf)**
Base case: Mixed-fuel (electricity and natural gas) Scenario 1: Ducted all-electric Scenario 2: Ductless all-electric Scenario 3: Mixed-fuel, highly energy-efficient (HEE) Scenario 4: Ducted all-electric, HEE Scenario 5: Ductless all-electric, HEE	Base case: Mixed-fuel (electricity and natural gas) Scenario 1: Ductless, all-electric Scenario 2: Mixed-fuel, HEE Scenario 3: Ductless all-electric, HEE

Key Findings

Costs for single family homes:

1. It is less costly to construct an all-electric, ductless single family home, compared to a mixed-fuel home in Flagstaff; all-electric ducted homes cost more to construct than a mixed-fuel home.
2. It costs less to operate an all-electric ductless home than a mixed-fuel home on all APS electricity plans.
3. For all-electric ducted homes, the picture is mixed: using the APS Time of Use (TOU) Plus Demand Charge Plan reduces costs versus a mixed-fuel home; on all other APS plans, it is more costly to operate an all-electric ducted home.
4. Energy efficiency features add to construction costs for all home types but lead to long-term utility cost savings.

Costs for multifamily homes:

1. It is less expensive to construct an all-electric ductless multifamily home than a mixed-fuel home in Flagstaff.
2. It costs less to operate all-electric multifamily homes than a mixed-fuel home on all APS rate plans. Greatest utility cost savings come from the APS TOU Plus Demand Charge Plan.
3. Energy efficiency features add to construction costs for all home types but lead to long-term utility cost savings, although the cost savings are lower than for single-family homes because multifamily homes tend to use less energy (they are smaller, and attached housing is more energy efficient).

Report development was informed by valuable insights from 13 local building practitioners. The report discusses barriers that local practitioners face in building energy-efficient and electric homes, including a small labor pool, client preferences for gas stoves and fireplaces, existing high construction costs, and ideological leanings. It also discusses common narratives that may act as a barrier, some of which the report found to be misconceptions, including:

- Highly energy-efficient and all-electric homes are too costly to install and operate
- The City bans, or at a minimum, strongly discourages wood-burning fireplaces
- Electric heat pumps do not work in cold climates
- Electric heat pumps will shut down should a power grid outage occur, while natural gas appliances will still work

The report also details the non-economic benefits of energy efficiency and electrification in new homes:

- Improved indoor air quality in all-electric homes
- Improved safety in all-electric homes
- Homeowner pride in highly-energy efficient and all-electric homes
- Reduced greenhouse gas (GHG) emissions up to 58% in energy-efficient, all-electric homes (compared to mixed-fuel homes built to Flagstaff's current energy code)

Recommendations:

The report concludes with recommendations based on study findings to advance energy efficiency, electrification, and reduce monthly utility costs for Flagstaff residents:

1. Adopt the 2024 International Energy Conservation Code (IECC) and Appendix RG: 2024 IECC Stretch Code to improve energy efficiency over Flagstaff's current energy code.

2. Encourage new homes to be all-electric through education, outreach, and incentives. Focus on electric heating and cooling, since these appliances are responsible for the bulk of energy usage.
3. Adopt the 2024 IECC Appendix RK: Electric Ready Construction to make it easier for residents in mixed-fuel homes to switch to electric appliances in the future.
4. Provide extensive education and outreach to encourage energy efficiency and beneficial electrification in new home construction.
5. Offer incentives and equipment purchasing support for energy efficiency and/or all-electric features to reduce upfront costs and shorten the return on investment, such as a heat-pump bulk-buy co-op, and an incentive to offset additional costs of installing all-electric features (particularly ducted, all-electric systems).
6. Strengthen relationships between the City, APS and the building community.

Attachments: Full Energy Efficiency & Electrification Report
Full Energy Efficiency & Electrification Presentation
Energy Efficiency & Electrification Report - EXECUTIVE SUMMARY - FINAL

Analysis of the Costs, Benefits, and Barriers to Building Highly Energy-Efficient and All-Electric Residential Homes in Flagstaff, Arizona

Filling the Data Gap

Submitted to the City of Flagstaff | November 2025

Prepared by Noverra Collective, LLC

Executive Summary

The City of Flagstaff (the City) is committed to advancing its climate and housing goals, while maintaining a high quality of life for residents. A key strategy for reducing greenhouse gas (GHG) emissions and monthly utility costs is the expansion of energy efficiency[1] and beneficial electrification[2] in new residential construction. While several national studies provide evidence suggesting energy efficiency and electrification can bring health, economic, and other benefits to residents of cold-climate Western cities,[3] industry experience has shown that national studies may not always reflect local construction realities.

Recognizing this disparity, the City commissioned a study to evaluate the capital and operational costs and barriers, as well as the opportunities of building highly energy-efficient and all-electric new single- and multi-family homes. The intent of this analysis is to fill a critical data gap and inform City decisions about how to reduce energy use and emissions in the built environment while prioritizing long-term affordability.

Through this work, the City seeks to develop defensible, locally-grounded cost insights that reflect Flagstaff's real-world construction practices, while highlighting both the economic and non-economic benefits of energy-efficient, all-electric development.

Conclusions

This analysis finds that building all-electric, highly energy-efficient (HEE) homes is both technically and financially feasible in Flagstaff. A key takeaway is that building energy systems are complex and require nuanced considerations: costs and benefits vary with the degree of builder's familiarity with building systems and technology, available rate plans, heating and cooling system types, and other external factors. Energy usage and energy costs determined in this study are illustrative and will vary in practice.

Stakeholder and market research supported significant new findings on the cost of building electric, highly energy-efficient homes in Flagstaff. Among the many conclusions, we find:

- **For single-family homes**: It is less costly to construct an all-electric ductless single-family home, compared to a mixed-fuel single-family home in most cases, while it costs more to construct an all-electric ducted home compared to a mixed-fuel home. It costs less to operate an all-electric ductless home than a mixed-fuel home on all Arizona Public Service (APS) electricity plans. For all-electric ducted homes, the picture is mixed: using APS' Time-of-Use (TOU) Plus Demand Charge plan reduces costs versus a mixed-fuel home; on all other APS plans, it is more costly to operate an all-electric ducted home[4].

---

[1] For the purposes of this work, "energy efficient" and "highly energy-efficient" are defined as those measures that align with the 2024 International Energy Conservation Code (IECC) Appendix RG: 2024 IECC Stretch Code.

[2] Beneficial electrification is the process of strategically replacing natural gas-powered equipment with electric-powered equipment that brings the most benefits to the consumer through improving indoor air quality, optimizing energy use, providing the potential for lower monthly energy costs, reducing carbon emissions, and improving grid management. All references to "electrification" made in this report refer to "beneficial electrification".

[3] See RMI's The New Economics of Electrifying Buildings, NREL's Field Application of Air-Source Heat Pumps for Cold Climates, Government of Canada's Cold-Climate Air Source Heat Pumps, Joule's Coming in from the Cold: Heat Pump Efficiency at Low Temps

[4] APS offers several different electricity plans that residents can choose from. These plans offer different electricity rates, depending on the amount of energy used and the time of day and are discussed in detail in the Definitions and Assumptions section of this report. Also see APS rate plans.

- **For multi-family homes:** It is less expensive to construct an all-electric ductless multi-family home than a mixed-fuel home in Flagstaff. It also costs less to operate all-electric multi-family home than a mixed-fuel home on all APS rate plans.

Advancing highly energy-efficient and all-electric systems is not a straightforward process, but with City intervention at key points, particularly through education and outreach, these homes can be built more cost effectively. Highly energy-efficient, electric homes are worth pursuing as these homes produce cleaner air and fewer carbon emissions and provide resilience against a changing climate. The City can help address misconceptions and concerns through targeted outreach, while increasing builder and homeowner confidence in highly energy-efficient and all-electric homes.

Methodology

To reflect local realities, thirteen local practitioners – architects, builders, general contractors, and subcontractors – provided feedback on estimated capital costs, modeled operational costs, barriers, lessons learned, and recommendations that the City can consider to advance its climate and housing goals.

Practitioner feedback was complemented by modeling to explore capital costs, and the impacts that different APS electricity plans have on operational costs. Capital costs are "all-in" and include all required equipment for each modeling scenario. The base case and ducted and ductless scenarios were modeled to Flagstaff's current energy code (the 2018 International Energy Conservation Code— 2018 [IECC]) and Flagstaff's weather. The highly energy-efficient scenarios were modeled to the 2024 IECC and accompanying appendix -- Appendix RG: 2024 IECC Stretch Code (Stretch Code). The 2024 IECC and Stretch Code are estimated to provide a 24% improvement in energy efficiency over Flagstaff's current energy code[5]. Table ES-1 presents the modeled single- and multi-family scenarios.

Table ES-1. Modeled Single- and Multi-Family Scenarios

Scenarios Modeled	
Single-family home (2,500 sf)	**Multi-family home (990 sf)**
Base case: Mixed-fuel (electricity and natural gas)	Base case: Mixed-fuel (electricity and natural gas)
Scenario 1: Ducted all-electric[6]	Scenario 1: Ductless, all-electric
Scenario 2: Ductless all-electric	Scenario 2: Mixed-fuel, HEE
Scenario 3: Mixed-fuel, highly energy-efficient (HEE)	Scenario 3: Ductless all-electric, HEE
Scenario 4: Ducted all-electric, HEE	
Scenario 5: Ductless all-electric, HEE	

[5]Per the Department of Energy (DOE), Pacific Northwest National Laboratory (PNNL), and the International Code Council (ICC). 2024 IECC base code: DOE report. PNNL report. Stretch code improvements: DOE report and NAHB.

[6] Ducted systems may also be referred to as "heat pumps" or more specifically cold-climate air-source heat pumps (ccASHPs) and ductless systems may also be referred to as "mini-split heat pumps" or simply "mini-splits".

Findings

This analysis indicates that **building highly energy-efficient, all-electric homes is feasible and can bring health benefits and cost savings to Flagstaff residents, in addition to reducing greenhouse gas emissions from the built environment**[7]**.** However, the development picture is nuanced, and the actual costs and cost savings vary by system type and APS's electric rate plan.

Capital Cost Findings: Single-Family Homes

1. **All-electric ductless single-family homes cost less to construct than a mixed-fuel home.** Costs for ductless systems (mini-split systems) are lower because these systems do not require ductwork, as is required with a mixed-fuel and ducted all-electric system. All-electric homes also avoid costs associated with natural gas connections and plumbing.
2. **All-electric ducted homes cost slightly more to construct than a mixed-fuel home,** when both are built to Flagstaff's current energy code.
3. **Energy efficiency features add to construction costs for all home types.** However, many builders already build beyond the current code and capital cost estimates shared during this study may be overstated for some builders. Further, though a ducted all-electric, highly energy-efficient single-family home may cost the most to build, its additional costs are likely to be no more than 3% of total building costs based on estimates of building costs provided by practitioners.

Table ES-2: Capital cost comparison for single-family homes

Scenario	Total Cost	Range	Cost Difference (vs. Base Case)
Base case: mixed-fuel	$14,500*	$8,500 - $18,500	--
1: All-electric, ducted	$17,000	$14,000 - $20,000	+$2,500
2: All-electric, ductless	$14,000	$12,000 - $16,000	-$500
3: Mixed-fuel, HEE	$23,000*	$15,000 - $30,500	+$8,500
4: All-electric, ducted, HEE	$25,500	$19,000 - $32,000	+$11,000
5: All-electric, ductless HEE	$22,500	$17,000 - $28,000	+$8,000

Green = Costs are lower than the mixed-fuel base case. Orange = Costs are higher than the mixed-fuel base case.

**A $2,000 UniSource natural gas connection rebate may not be available for all projects, so the average capital cost of mixed-fuel homes is calculated without the rebate.*

Operational Cost Findings: Single-Family Homes

1. Utilizing APS' **TOU Plus Demand Charge plan provided the greatest electricity cost savings** across all scenarios when compared to the APS Fixed Energy Charge or TOU rate plan.
2. **Highly energy-efficient homes have lower utility costs than homes built to Flagstaff's current code because the** energy efficiency features reduce the amount of energy used by the consumer.

[7] The ranges for capital cost estimates are large and vary by the practitioner's familiarity with the technology, design of the home, equipment manufacturer, and other construction features. *The values presented here are illustrative.*

3. **It costs less to operate an all-electric ducted home on the APS TOU Plus Demand Charge Plan, compared to a mixed-fuel home.** On all other APS plans, it is more costly to operate an all-electric ducted home than a mixed-fuel home.
4. **It costs less to operate an all-electric ductless home than a mixed-fuel home** on all APS electricity plans. These systems provide targeted heating and cooling and eliminate the need for ductwork. Also, shifting heating to electric heat pump systems is a much more efficient use of energy.
5. **Utility cost savings from energy efficiency improvements were greater for all-electric homes than for mixed-fuel homes.** Per unit, electricity is more expensive on the APS fixed rate plans than natural gas, although the picture is nuanced on APS TOU plans. Therefore, reducing natural gas usage will typically yield lower cost savings than reducing electricity usage by the same amount. In addition to use-based rates, energy costs include fixed fees, which are not reduced as energy usage decreases.
6. **Utility cost savings from energy efficiency improvements were greater for all-electric ducted homes than for all-electric ductless homes.** Because ducted systems use more electricity than ductless systems, energy efficiency improvements had a bigger impact on utility costs.

Table ES-3: Monthly energy cost comparison for single-family homes

Scenario	Fixed Rate (Medium)	TOU	TOU plus demand
Base case: Mixed-fuel	$159	$158	$138
1: All-electric, ducted	$182	$172	$128
2: All-electric, ductless	$131	$127	$97
3: Mixed-fuel, HEE	$138	$137	$116
4: All-electric, ducted, HEE	$141	$136	$103
5: All-electric, ductless, HEE	$128	$124	$95

Green = Costs are lower than the mixed-fuel base case. Orange = Costs are higher than the mixed-fuel base case.

Capital Cost Findings - Multi-family Homes

1. **It costs less to construct an all-electric ductless multi-family home than a mixed-fuel home.** Costs for ductless mini-split systems are lower because these systems do not require ductwork, which is required with both mixed-fuel and ducted heat pump systems. Though at times, installers may choose slim-duct systems, which may slightly increase costs compared to a ductless system[8]. All-electric homes also avoid costs associated with natural gas connections and plumbing.
2. **Energy efficiency features add construction costs for all home types.** However, many builders already build beyond the current code, and the additional capital cost estimates of energy efficiency features shared during this study may be overstated for some builders.

[8] Slim-ducts are commonly used in condos because they take up less space than traditional ductwork. They are smaller, shorter, and typically installed within conditioned spaces.

Table ES-4: Capital cost comparison for multi-family homes

Scenario	All-in cost	Range	Cost difference vs. base case
Base case: Mixed-fuel	$12,500	$8,300 - $15,800	--
1: All-electric, ductless	$11,300	+/- $4,000	-$1,200
2: Mixed-fuel, HEE	$19,000	$13,200 - $27,800	+$6,500
3: All-electric, ductless, HEE	$17,800	$11,300 - $27,300	+$5,300

Green = Costs are lower than the mixed-fuel base case. Orange = Costs are higher than the mixed-fuel base case.

Operational Cost Findings - Multi-family Homes

1. **It costs less to operate an all-electric, ductless multi-family home than a mixed-fuel home on all APS plans.**
2. **It is least expensive to operate a highly energy-efficient, all-electric ductless multi-family home -** with the lowest utility costs occurring under the TOU Plus Demand Charge plan.
3. **Energy efficiency improvements reduce energy use at varying rates, depending on the location of each multi-family unit in the building.** Units on the top floor experienced the greatest reduction in energy use, followed by units on the middle and bottom floors.
4. **The cost savings from energy efficiency improvements were higher for mixed-fuel homes than for ductless all-electric homes.** Mixed-fuel homes start with lower-efficiency heating and cooling equipment, so efficiency upgrades reduce a larger share of their total energy use. In contrast, all-electric cold-climate heat pumps already operate at very high efficiency, leaving less opportunity for additional savings.

Table ES-5: Monthly energy cost comparison for multi-family homes

Scenario	Fixed rate (small)	TOU	TOU plus demand
Base case: Mixed-Fuel	$77	$82	$71
1: All-electric, ductless	$63	$69	$55
2: Mixed-fuel, HEE	$71	$76	$65
3: All-electric, ductless, HEE	$61	$68	$54

Green = Costs are lower than the mixed-fuel base case. No all-electric costs exceed the mixed-fuel base case.

Energy Efficiency Improvements and Utility Cost Savings in Single-Family and Multi-Family Homes

1. **Energy efficiency improvements in the HEE homes reduced energy use by 3-27%** over homes built to Flagstaff's current energy code. This is a wide range compared to the national estimates of a 24% for Flagstaff's climate zone. However, actual energy cost savings varied by home and fuel type, and were impacted by the chosen energy efficiency measures.

Table ES-6: Energy efficiency improvements vs. utility cost savings for single- and multi-family homes

	Scenario	Modeled Energy Efficiency Improvement	Actual Energy Cost Savings
Single-family homes	3: Mixed-fuel, HEE	27%	13-16%
	4. All-electric, ducted, HEE	27%	19-22%
	5: All-electric, ductless, HEE	3%	2-3%
Multi-family homes	2: Mixed-fuel, HEE	21%	7-9%
	3: All-electric, ductless, HEE	3%	2-3%

Return on Investment: Single-Family and Multi-family Homes

1. **The return on investment (ROI) for single-family homes varied from 0 - 18 years, and for multi-family homes from 0-30 years[9].** This is the amount of time it could take utility cost savings to offset the additional capital cost of all-electric and energy-efficiency features on the TOU Plus Demand Charge Plan. While the presented return on investment is relatively long, they may be conservative given the large variability of capital costs needed to improve home efficiency. Further, capital costs exclude any potential rebates or incentives, which could significantly offset first costs and shorten the ROI.
2. **All-electric ductless single- and multi-family homes had the shortest payback period; mixed-fuel, highly energy-efficient homes had the longest payback period.**

Table ES-7: Maximum expected ROI for all-electric and highly energy-efficient systems in single-family homes

Scenario	Capital Cost Differential		First Year Utility Cost Savings Compared to Mixed-Fuel Base Case*	Return on Investment[10]
	Stakeholder Provided Estimate	Market Research Provided Estimate		
1: All-electric, ducted	+$2,500	+$3,000	$130	<15 years
2: All-electric, ductless	-$500	---	$500	Immediate
3: Mixed-fuel, HEE	+$8,500	+$6,500	$270	<18 years
4: All-electric, ducted, HEE	+$11,000	+$9,500	$430	<17 years
5: All-electric, ductless, HEE	+$8,000	+$6,500	$520	<11 years

Green = ROI is shorter than the mixed-fuel base case. Orange = ROI is longer than the mixed-fuel base case.
**Based on TOU plus demand rates and projected energy rate escalation.*

[9] ROI was calculated using the simple payback period, which focus on the upfront costs and utility cost savings only. It does not include mortgage costs or potential impacts of higher upfront construction costs on monthly rent.
[10] Utility cost increases are based on Energy Information Administration (EIA) projects and industry best practice, and assume that electricity rates increase by 3.5% and natural gas rates increase by 5% in 2026. Thereafter, both energy rates are projected to increase by 3%.

Table ES-8. Maximum expected ROI for all-electric and highly energy-efficient systems in multi-family homes

Scenario	Capital Cost Differential		First Year Utility Cost Savings Compared to Mixed-Fuel Base Case*	Return on Investment[11,*]
	Stakeholder Provided Estimate	Market Research Provided Estimate		
1: All-electric, ductless	-$1,200	-$2,000	$200	Immediate
2: Mixed-fuel, HEE	+$6,500	+$4,000	Up to $100	<30 years
3: All-electric, ductless, HEE	+$5,300	+$4,000	$200	<15 years

Green = ROI is shorter than the mixed-fuel base case. Orange = ROI is longer than the mixed-fuel base case.
**Based on TOU plus demand rates and projected energy rate escalation.*

Co-Benefits of All-Electric Homes

While the financial impacts of building highly energy-efficient and all-electric homes are subject to a variety of conditions, the ancillary benefits are clear, especially when compared to mixed-fuel homes.

Co-benefits are the additional advantages to the community beyond cost savings that improve health, reduce emissions, and improve resiliency. These include the following:

- **Healthier indoor air:** All-electric homes eliminate gas combustion indoors, improving air quality and reducing pollutants linked to asthma and other respiratory illness.[12]
- **Improved safety:** All-electric homes are safer to operate than mixed-fuel homes because they do not burn natural gas, avoiding the associated risks of carbon monoxide poisoning from malfunctioning natural gas appliances and explosions from natural gas leaks.
- **Homeowner pride.** Some builders shared that homeowners take a great deal of pride in highly energy-efficient and all-electric homes, and that pride extends to a greater sense of pride in their neighborhood and community.
- **Potential to support market evolution.** Some builders shared that building energy-efficient, all-electric homes in Flagstaff can support the local labor pool by creating a common approach to installing electric systems and participating in the market evolution towards all-electric homes.
- **Lower carbon emissions:** APS's grid was 51% carbon-free in 2024**.** Using electricity produces fewer greenhouse gas (GHG) emissions than burning natural gas in the home, especially as the grid adds renewables. By 2050, highly energy-efficient, all-electric ductless homes will emit approximately 58% fewer greenhouse gas emissions annually than a mixed-fuel home built to Flagstaff's current code. A high-efficiency mixed-fuel home will emit approximately 25% fewer emissions.

[11] Ibid.
[12] International Journal of Environmental Research and Public Health.

Table ES-9. Greenhouse gas emissions savings compared to mixed-fuel base case

Scenario	Difference in Cumulative Carbon Emissions (present through 2050) Compared to Mixed-Fuel Base Case*	
	Single-Family Homes	Multi-Family Homes
1: All-electric, ducted	-38%	Not applicable
2: All-electric, ductless	-56%	-43%
3: Mixed-fuel, HEE	-25%	-18%
4: All-electric, ducted, HEE	-53%	Not applicable
5: All-electric, ductless, HEE	-58%	-45%

Green = reduction in emissions compared to the mixed-fuel base case (no scenarios produced more emissions than the mixed-fuel base case).

**It should be noted that the modeled parameters chosen to represent "high efficiency" affect the way that savings are experienced. For instance, ductless systems start with a better baseline of energy performance (and lower carbon emissions) due to a variety of factors, such as lower distribution losses, and may not be as affected by the measures chosen to represent "high efficiency".*

Barriers to Energy Efficiency and Electrification

Thirteen members of the building community shared narratives that may serve as barriers to building energy-efficient and all-electric homes. These narratives reflect impressions that the building community may have and are presented with additional context, including information gathered from this study.

1. **We heard that highly energy-efficient and all-electric homes are too costly to install and operate.** Our report shows that there is often an additional capital expenditure for electric homes, though at times it's nominal, and that all-electric ductless systems are less expensive to build than mixed-fuel systems.
2. **We heard that clients typically want gas stoves and fireplaces.** While no data suggests that gas stoves are superior to induction cooking, much of the general public assumes that they are, resulting in a preference for the "experience" of gas cooking and gas fireplaces. As a result, these are the types of appliances that contractors typically sell and install.
3. **We heard that the City bans, or at a minimum, strongly discourages wood-burning fireplaces.** The City does not ban wood-burning stoves or fireplaces. However, this belief incentivizes general contractors to plan for gas connections in new construction. The City offers a rebate for replacing an older wood stove with an EPA-certified wood stove.
4. **We heard that electric heat pumps do not work in cold climates.** Ample evidence shows that heat pumps work effectively in cold climates such as Flagstaff's(see product information from Carrier, Mitsubishi and Trane). Further, a local installer has installed up to 500 cold-climate air-source heat pumps (ccASHP) in Flagstaff and has not received a single negative report about their ability to meet heating and cooling loads.
5. **We heard that heat pumps will shut down should a power grid outage occur.** Should the grid go down, most gas appliances will be equally affected.

6. **We heard that electric tankless water heaters should be installed as part of all-electric systems.** Generally, electric heat pump water heaters are preferred due to their high efficiency and demonstrated performance within Flagstaff.
7. **We heard different viewpoints on whether to adopt stronger energy codes.** Some builders would like to keep Flagstaff's current energy code (the 2018 IECC) and apply cost savings from not installing additional energy efficiency features toward home electrification and on-site solar. However, getting to net-zero without reducing energy consumption first means that a home will have higher utility bills and pay more for a larger solar photovoltaic system than they would if energy consumption were reduced. In contrast, we also heard that the only way to increase energy efficiency across the board is increase the minimum energy efficiency standards through updated Building and Fire Codes, including the energy code.
8. **We heard that ideology may influence who builds energy-efficient and all-electric construction.** Incentives or rebates to offset the additional costs of all-electric construction, for example, could help increase the amount of all-electric homes that are built by builders from across the ideological spectrum.
9. **We heard that there is a limited pool of subcontractor expertise and how this increases construction costs.** A lack of a deep pool of local expertise to install energy efficiency features and heat pumps can lead builders to seek labor from outside of Flagstaff, which requires subcontractors to travel and increases costs.

Recommendations

To support practitioners' concerns while advancing highly energy-efficient and all-electric homes, we make the following recommendations for the City's consideration:

1. **Adopt the 2024 IECC and Appendix RG: 2024 IECC Stretch Code** to advance energy efficiency by an average of 24% - 27% over Flagstaff's current energy code. Advancing energy efficiency is good for the community: it will save operational costs, it is healthier, safer, and cleaner for our planet, and has proven to improve occupant comfort. Several builders noted that the only way to ensure that Flagstaff's community realizes these benefits is by requiring it of all new builds through the adoption of new building codes. This is particularly important for Flagstaff's low-income residents, who are disproportionately burdened with high energy costs.
2. **Encourage new home construction to be all-electric.** The City can advocate for and encourage new builds to be all-electric through education, outreach, and incentives.
3. **Adopt Appendix RK Electric-Ready Residential Building Provision of the 2024 IECC.** This appendix will make it easier and less costly for residents living in mixed-fuel homes to switch from natural gas to electric appliances in the future.
4. **Adopt Appendix RB Solar-Ready Provisions – Detached One- and Two-Family Dwellings and Townhouses of the 2024 IECC.** This appendix will make it easier for residents to install on-site photovoltaic panels and battery storage and will allow them to achieve partial or full energy independence with associated long-term cost savings. Note: Flagstaff adopted the 2018 version of this appendix as part of its current energy code.
5. **Provide extensive education and outreach to encourage energy efficiency and beneficial electrification in new home construction.** Reference the barriers in outreach materials, prioritize building science training with subcontractors and general contractors, provide informational materials on cost savings from switching to APS TOU plans, conduct outreach on gas stoves and fireplaces, and focus outreach on electric heating and cooling equipment, since these appliances are responsible for the bulk of energy usage.

6. **Host a gas stove vs induction stove cooking demonstration exhibit for the public and members of the building community.** Providing in-person demonstrations of induction (electric) cook stoves will likely build support and encourage residents to move away from natural gas cook stoves and towards electric ones.
7. **Set-up a heat pump co-operative program for new residential construction.** Set up a co-operative for new construction similar to the one that exists for installing solar photovoltaic panels and battery storage on existing homes. Contractors stated they would be willing to share these prices as part of their outreach with clients.
8. **Offer incentives and equipment purchasing support.** Provide monetary incentives, such as up to $3,000 per project, when a general contractor proceeds with an all-electric home. Members of the building community noted that rebates could significantly help more electric homes be built.
9. **Strengthen relationships with APS and the building community.** Set up regular working meetings between APS to identify ways in which APS can better support the building community, leverage this study as an in-roads to building stronger relationships with members of the building community, and facilitate peer-to-peer educational opportunities and coalition building through a Builders Association or other means like a City-sponsored panel.

Acknowledgements

This document summarizes feedback collected from the City of Flagstaff's building community. Comments are not attributed to specific individuals or organizations, whose opinions varied widely. This document reflects their collective expertise. We are grateful for their time and insights regarding the building process in the City of Flagstaff.

- Capstone Homes: Clint Whiting and Charity Lee.
- City of Flagstaff: Sustainability, Housing, and Planning and Development Services staff, including Tiffany Antol, Nicole Antonopoulos, Justyna Costa, Sarah Darr, Jennifer Mikelson, Michelle McNulty, Jenny Niemann, Genevieve Pearthree, Danae Presler, and Amy Tressler.
- Coconino County: Nina Schmidt and Amanda Seigle.
- Cozy Home: Michael Scott.
- Flagstaff Comfort Systems: Steve Hanson.
- Green Mountain Construction: Ian Hublitz.
- Hope Construction: David Carpenter.
- Mandalay Homes: David Everson.
- Miramonte Homes: Chris Kemmerly.
- Radiance Heating and Plumbing: Tom Scheel.
- Stang Architecture: Aude Stang.
- Tesano Contracting: Tom Phelan.
- Trinsic Construction: Todd Gosselink.
- Smith Architecture: Ryan Smith and Tyler Scantlebury.
- UpDesign: Anne Mead.

Contents

Definitions and Assumptions

This section presents definitions of key terms used throughout this report. Modeling assumptions are listed in Appendix A.

1. **All-electric ducted:** Assumes installation of a cold-climate air source heat pump -- a ccASHP. This is also referred to by Mitsubishi as a "hyper heat" air source heat pump. The exact size varies depending on the home's construction features. These systems may include internal heat strips. In this memo, these are referred to as "ducted ccASHP" or "ducted all-electric systems".[13]

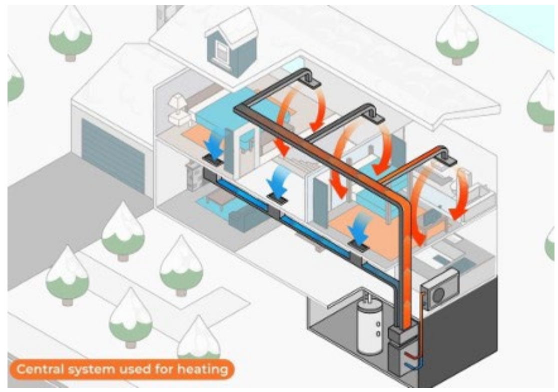


Illustration of an example an-electric ducted system

2. **All-electric ductless (mini-split):** Assumes installation of a cold-climate air source mini-split heat pump. These systems do not include heat strips. In some cases, small condos may still be served by short ducts located in conditioned spaces – slim-ducts. Heat losses associated with these ducts are very small since heat lost stays inside the home and the duct run is much less than traditional ducts. For modeling purposes, all mini-split systems were assumed to be ductless. This may slightly understate fan power/duct losses relative to slim-ducted configurations. In this memo, these are referred to as "ductless mini-split" or "ductless all-electric".[14]

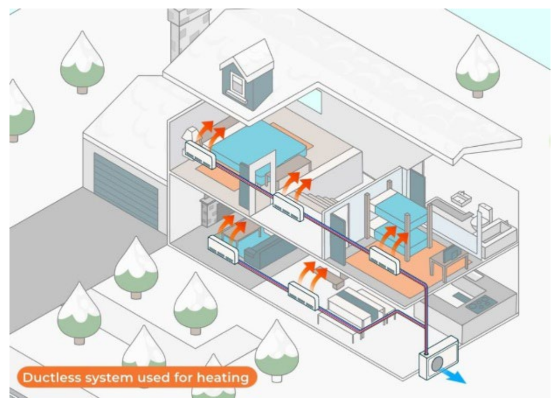


Illustration of an example an-electric ductless system

3. **Arizona Public Service (APS):** The electric utility provider for much of central and northern Arizona, including for residents living in the City of Flagstaff.
4. **APS Fixed Energy Charge Plan**: Under a fixed-rate plan, APS bills residential electricity customers for two charges: a basic service charge (a flat rate per day) and an energy charge (an energy use charge per kilowatt-hour [kWh]). Fixed rates include three tiers: small tier for customers who use an average of 600 kWh or less per month, medium tier for customers who use 601 kWh to 1,000 kWh, and a large tier for customers who use 1,001 kWh or more.
5. **APS Time-of-Use Plan**: Under an APS Time-of-Use (TOU) plan, APS bills electricity customers based on how much electricity they use and when they use it. This rate is intended to award customers with lower bills if they minimize electricity use during "on-peak" times (4 – 7 pm weekdays, excluding holidays) when rates are higher, and concentrate electricity use during off-peak times (any time that is not "on-peak") when rates are lower. APS bills electricity customers for two charges: a basic service charge (a

[13] Image source: Irbis HVAC.
[14] Ibid.

flat rate per day) and an energy charge (an energy use charge per kilowatt-hour [kWh]). The energy charge is further defined by season (summer or winter) and by the time of day (On-Peak, Off-Peak, and Super Off-Peak). Residents can lower utility costs even further by concentrating electricity usage during Super Off-Peak hours (10 am – 3 pm November – April), when the electrical load for space heating in Flagstaff is highest.[15]

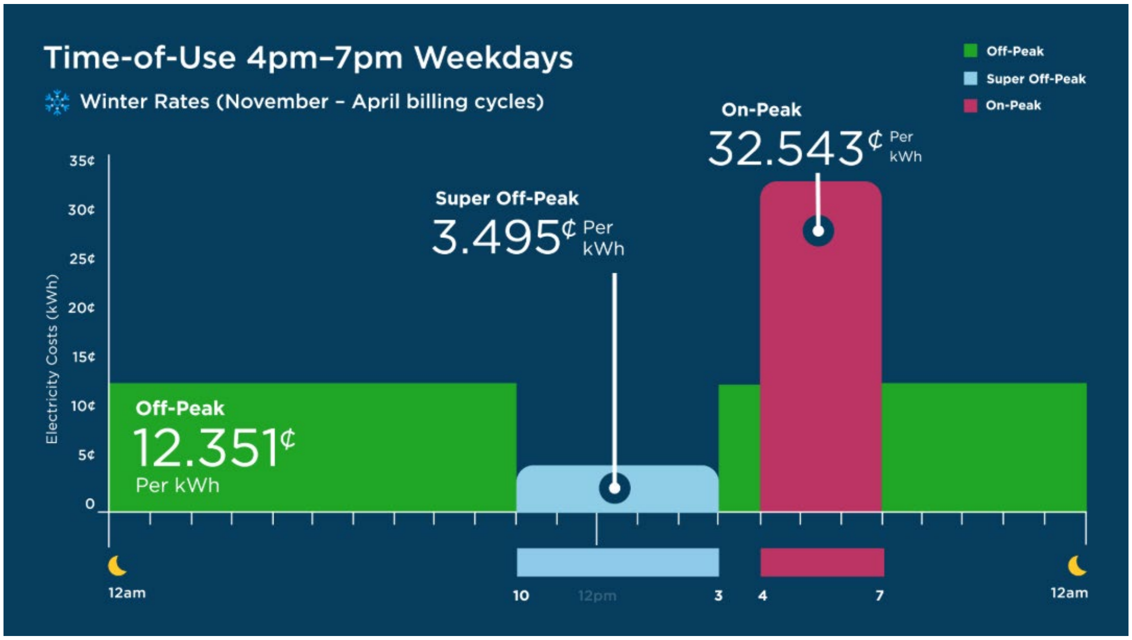


Illustration of winter electricity rates on the APS Time of Use Plan

6. **APS Time-of-Use with Demand Charge Plan:** Under a Time-of-Use (TOU) with Demand Charge Plan, APS bills residential electricity customers based on how much electricity they use and when they use it. This plan offers the lowest electricity rates per kWh and is intended to award customers with lower bills if they choose to use electricity during "off-peak" hours (any time except for 4 pm – 7 pm weekdays; excluding holidays). APS bills electricity customers for three charges: a basic service charge (a flat rate per day), an energy charge (an energy use charge per kilowatt-hour [kWh]), and a demand charge (the highest amount of demand as kilowatt [kW] averaged in a one-hour On-Peak period for that month). The energy charge is further defined by season (summer or winter) and by the time of day (On-Peak, Off-Peak, and Super Off-Peak), and the demand charge is further defined by season. Residents can lower utility costs even further by concentrating electricity usage during Super Off-Peak hours (10 am – 3 pm November – April), when the electrical load for space heating in Flagstaff is highest.[16]

[15] Image source: APS customer portal.
[16] Ibid.

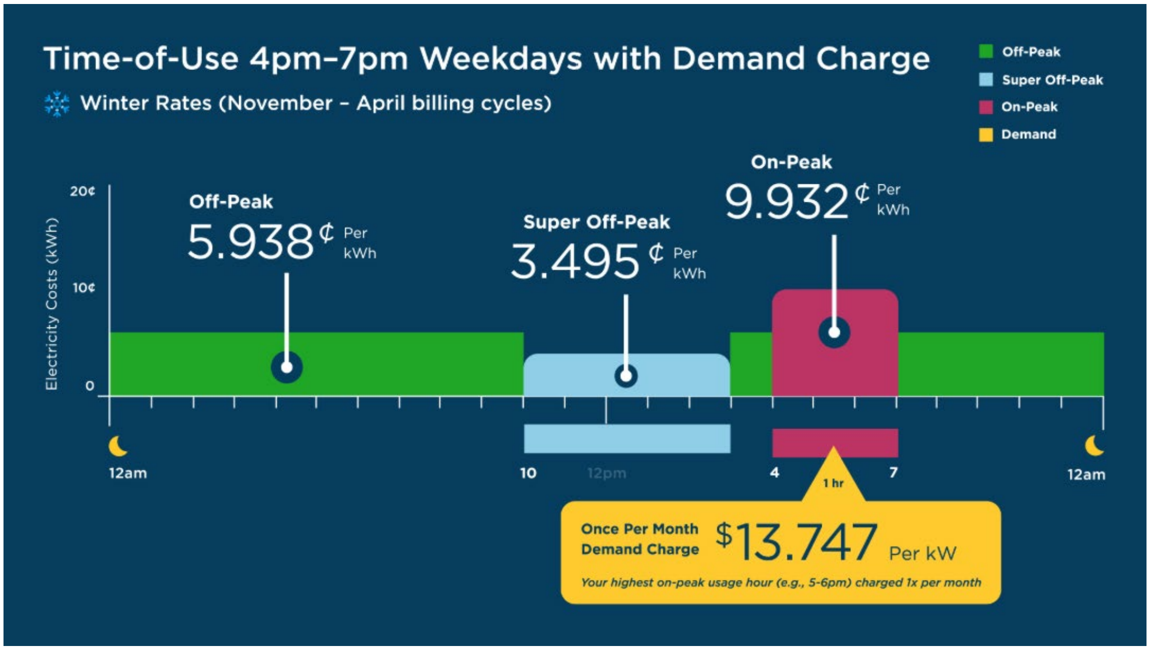


Illustration of winter electricity rates on the APS Time of Use Plus Demand Charge Plan

7. **Beneficial electrification**: Electrifying equipment with the goal to provide consumer benefits such as reducing carbon emissions, improving grid management, improving indoor air quality, optimizing energy use, and providing the potential for lower monthly energy costs. (According to the Regulatory Assistance Project[17] at least one of these goals must be met to qualify as "beneficial electrification".) Beneficial electrification can only be achieved with highly efficient heating and cooling appliances such as heat pumps; its goal is not met with other inefficient, electric heating devices such as electric furnaces, electric baseboard heating, or space heaters. All references to "electrification" made in this report refer to "beneficial electrification".

8. **Capital costs**: The first costs required to purchase and install equipment in a new home. Members of Flagstaff's building community were able to provide several cost estimates for single-family homes (including mixed-fuel and all-electric), but only one developer was able to provide cost estimates for multi-family homes. Therefore, the cost estimates for multi-family homes were heavily based on internet research.

9. **Coefficient of performance (COP):** A measure of a heat pump's efficiency, specifically the ratio of heat output (the amount of heat serving the home) to heat input (i.e., electricity). COPs are expressed as discrete numbers, but they can also be interpreted as percentages. For example, a COP of 3.5 represents an efficiency of 350%; this means that for 1 kBtu of electricity input to the heat pump, the heat pump provides 3.5 kBtu of heating. This occurs because the heat pump "moves" heat rather than creating it through combustion as is the case with fossil fuel-based heating equipment.

10. **Cold climates**: Climates located in climate zone 4 or above according to the Northwest Energy Efficiency Partnership (NEEP). Flagstaff is located in climate zone 5.[18]

---

[17] Regulatory Assistance Project.
[18] Climate zone maps.

11. **Cold-climate air-source heat pump (ccASHP):** Air-source heat pumps designed to operate efficiently at very low temperatures. These are specifically designed to provide heating for cold climates, such as Flagstaff's, which is located in climate zone 5. Some manufacturers note that their ccASHPs can operate effectively at temperatures as low as -22 deg F without a separate backup heating system.[19] These are different from other heat pumps in that a ccASHP is specifically designed to operate at colder temperatures with the addition of higher performing refrigerants, advanced compressors, and enhanced heat exchangers.[20]

    Demonstration of a heat pump operation

    Cold-climate air-source heat pumps are among the most efficient way to heat a home. For example, a ccASHP with a typical coefficient of performance (COP) of approximately 3.5 to 4.5 under moderate outdoor temperatures is equivalent to an efficiency of 350% to 450%. This means that every unit of electricity used to run the heat pump produces 3.5-4.5 units of heat. In colder weather, the COP may drop to 1.7 (170% efficient) but will always be more efficient than a gas or electric resistance furnace, whose efficiency will never reach 100%.
12. **Energy recovery ventilator (ERV)**: Energy recovery ventilators bring in fresh outdoor air to replace stale, indoor air. Though not required, all contractors stated that they routinely installed ERVs in all new construction to offset reduced air leakage from air-tight, energy-efficient homes and to protect indoor air quality.
13. **Gas hookup:** The costs required to connect the new home to a gas line including infrastructure, piping, metering, and plumbing. These costs are charged by the gas company, UniSource, and by the installers.
14. **HSPF2**: Heating Seasonal Performance Factor 2. This is a measure of a heat pump's heating efficiency; a higher value indicates a more efficient system.
15. **Heating, ventilation, and air conditioning (HVAC):** A building's equipment that controls indoor climate, humidity, and air quality. Examples include natural gas furnaces, air conditioners, heat pumps, and ERVs.
16. **Highly energy-efficient:** Energy efficiency measures that go beyond what is already required in the IECC 2018 (the City's Flagstaff's current building code) and align with the 2024 IECC and Appendix RG: 2024 IECC Stretch Code such as: reduced air leakage and improved insulation. For our modeling purposes, highly energy efficient homes included ERVs, wall insulation of R-20 and R-5 continuous insulation, air leakage of 3 air exchanges per hour under a pressure of 50 pascals, R-10 with 3 ft insulation under the floor slab, and the assumption that 90% of ducts will be installed in conditioned spaces.
17. **IECC:** International Energy Conservation Code – the adopted code that requires minimum standards for energy efficient building design. Flagstaff adopted the 2018 IECC with local amendments in 2019.
18. **Induction cooking:** A highly efficient cooking method that uses electromagnetic energy to directly heat

[19] Carrier.
[20] Image source: Weaver Energy.

pots and pans. It offers many benefits to cooking with a natural gas or traditional electric stove, including improved speed, safety, easy cleanup, and efficiency.

19. **Mixed-fuel**: Assumes a 92.5% AFUE (annual fuel utilization efficiency) gas furnace and a central air conditioning unit with a SEER2 (seasonal energy efficiency ratio 2) rating of 14.3.
20. **Northeast Energy Efficiency Partnership**: Nationally recognized non-profit energy efficiency organization that provides information and guidance to professionals advancing building decarbonization.
21. **Operational costs**: The costs associated with "operating" the home; synonymous with energy utility costs that are charged by the electric and natural gas companies.
22. **Off-Peak**: As defined by APS, all other times that are not On-Peak or Super Off-Peak and select holidays as defined in the rate schedule.
23. **On-Peak**: As defined by APS, between 4 pm and 7 pm on weekdays.
24. **R-Value**: An R-value is a measure of thermal resistance, where a greater value indicates that the material has a greater potential to prevent heat from moving through.
25. **SEER2:** Seasonal Energy Efficiency Ratio 2. This is a measure of air conditioning efficiency; a higher value indicates a more efficient system.
26. **Super Off-Peak**: As defined by APS, between 10 am and 3 pm on weekdays between November and April.
27. **Unisource**: the natural gas utility provider for much of northern Arizona, including for residents living in the City of Flagstaff.
28. **UniSource Billing Structure:** UniSource bills natural gas customers for three charges: a customer charge (a flat rate per month), a delivery charge (a delivery charge per therm used [th]), and a cost of natural gas charge (a rate per th). The energy charge is based on customer's average monthly energy consumption.

1. Introduction

The City of Flagstaff (the City) is committed to using the region's energy resources efficiently, while maintaining a high-quality of life for its residents. To support these goals, the City is evaluating how highly energy-efficient and electric homes can support Flagstaff's climate and housing goals,[21] while bringing health, affordability, and comfort benefits to Flagstaff residents. Energy efficiency reduces energy consumption and can improve housing affordability, while beneficial electrification optimizes electric usage, improves electric grid management, improves indoor air quality, and provides the potential to reduce monthly energy costs[22]. Note: All subsequent references to "electrification" refer to "beneficial electrification"—the electrification of equipment intended to provide benefit to the consumer and community.

In the last decade, organizations focused on energy efficiency have produced well-resourced reports that analyze the costs of building highly energy-efficient, electric homes. These studies have generally found that new efficient, electric homes are the same price to build or less expensive than mixed-fuel homes — even in cold-climate locations similar to Flagstaff.[23] However, the City seeks to understand if these cost estimates are accurate within Flagstaff's construction landscape. Additionally, previous planning experience has demonstrated that published studies do not always yield the same results in reality as defined on paper.

To better understand the potential costs, benefits, and barriers to highly energy-efficient and all-electric homes in Flagstaff, the City commissioned an analysis of the capital and operational costs of building single- and multi-family homes informed by local practitioner feedback. Six scenarios were evaluated for single-family homes:

	Single-family Home Scenarios	**Fuel type**	**Air distribution**	**Highly efficient?**
Base case	Mixed-fuel (electricity and natural gas)	Gas, Electric	Ducted	
1	Ducted, all-electric	Electric	Ducted	
2	Ductless, all-electric	Electric	Ductless	
3	Mixed-fuel, highly energy-efficient (HEE)	Gas, Electric	Ducted	✓
4	Ducted, all-electric, HEE	Electric	Ducted	✓
5	Ductless, all-electric, HEE	Electric	Ductless	✓

Key: (flame) = gas (lightning) = Electric (grid) = Ducted (air) = Ductless

[21] See the Flagstaff Carbon Neutrality Plan and the Flagstaff 10-Year Housing Plan.
[22] References made to "electric" or "electrification" refer to beneficial electrification.
[23] Example studies: RMI, Energy Monitor, ACEEE, and NAHB.

There are four scenarios for multi-family homes:

Multi-Family Home Scenarios		Fuel type	Air distribution	Highly efficient?
Base case	Mixed-fuel (electricity and natural gas)	gas, electric	ducted	
1	Ductless, all-electric	electric	ductless	
2	Mixed-fuel, HEE	gas, electric	ducted	✓
3	Ductless, all-electric, HEE	electric	ductless	✓

Key: (flame) = gas (lightning) = Electric (grid) = Ducted (air) = Ductless

The goal of this work is to share defensible cost findings that more closely reflect real-world new construction in Flagstaff, while also identifying perceived and real barriers and opportunities to advancing enhanced energy efficiency and electrification in single- and multi-family residential development. Costs were informed by traditional modeling and during interviews with members of the building community who design and install heating, ventilation, and air conditioning (HVAC) equipment.

The findings in this study can also inform larger community conversations on new development, including the City's Land Availability and Site Suitability + Code Analysis Project (LASS + CAP)[24], the City's upcoming Building and Fire Code update including the 2024 International Energy Conservation Code (IECC), and other conversations about energy, affordability, and public health in the built environment.

2. Methodology

Two complementary research methods inform study results on capital and operational costs: engagement of local practitioners through interviews and a focus group and modeling to emulate the process that a contractor would use to price out heating and cooling equipment.

Practitioner Engagement

We interviewed 13 local practitioners -- architects, builders, general contractors, developers, and subcontractors -- to collect real capital and operational cost data and to identify major implementation barriers and benefits. These practitioners built a range of home types including single-family homes, multi-family homes and mixed-fuel, energy efficient, and all-electric homes. Some of these practitioners have had extensive careers in designing and building all-electric and highly energy-efficient homes, while others are newer to this field. Some supported advancing these types of homes through incentives and mandates, while others opposed intervention and encouraged market forces to guide future building trends.

A discussion guide and modeled heating and cooling loads and common home sizes were provided to participants ahead of the conversation. We then engaged in individual virtual 60-minute, freeform discussion, where we collected anonymous feedback and synthesized key observations, anecdotes, and recommendations, which are included herein. Following the completion of a draft memo, these same implementors were invited to a focus group where they were provided a final opportunity to share feedback and recommendations within a group setting, amongst their peers. Their feedback informed

[24] Flagstaff's LASS + CAP Project.

this final work product. The results of this data collection effort represent the aggregate of their combined feedback and are presented to help inform future policy decisions.

Modeling Approach

Scenario Development

For the single-family home scenarios, the City provided a building drawing package that served as a "representative" 1,800 square foot (sf) home. Per conversations with the City, this home size is small compared to the average size of new construction currently on the market, so the home size was increased to 2,500 sf to determine more realistic heating and cooling loads.

Each scenario included the all-in (total) capital costs for all required equipment for six scenarios -- a base case and five alternative scenarios:

- **Base case: Mixed-fuel home** included a 92.5% efficient natural gas furnace, central air conditioning with a SEER2 of 14.3, gas water heater, and gas stove. Building construction features were based on the 2018 IECC.
- **Scenario 1: Ducted, all-electric home** included a ccASHP with a SEER2 of 20.9 and HSPF2 of 8.9, an electric heat pump water heater (HPWH), and induction stove. Building construction features were based on the 2018 IECC.
- **Scenario 2: Ductless, all-electric home** included a mini-split with a SEER2 of 26 and HSPF2 of 11.3 and three to four heads, an electric HPWH, and an induction stove. Building construction features were based on the 2018 IECC.
- **Scenario 3: Highly energy-efficient mixed-fuel home** included a 95% efficient natural gas furnace, central air conditioning with a SEER2 of 14.3, gas water heater, and gas stove. Building construction features aligned with Appendix RG: 2024 IECC Stretch Code's (Stretch Code) energy savings intent.
- **Scenario 4: Highly energy-efficient, ducted, all-electric home** included a ccASHP with a SEER2 of 20.9 and HSPF2 of 8.9, an electric HPWH, and induction stove. Building construction features aligned with the Stretch Code's energy savings intent.
- **Scenario 5: Highly energy-efficient, ductless, all-electric home** included a mini-split with a SEER2 of 26 and HSPF2 of 11.3 and three to four heads, an HPWH, and induction stove. Building construction features aligned with the Stretch Code's energy savings intent.

For the multi-family home scenarios, the City provided a building drawing package that served as a "representative" multi-family building. Three separate units of varying sizes from this package were modeled to estimate the potential energy use of an individual, representative unit: a top (3^{rd} floor) north-west facing unit of 1,085 square feet, a middle (2^{nd} floor) south-west facing unit of 1,080 square feet, and a ground south-west facing unit of 810 square feet. The average square footage was 990. Multi-family homes were modeled as individual units, and each was assumed to have its own heating and cooling system. The multi-family analysis included the same base case and Scenarios 2, 3, and 5. The results used the average heating and cooling loads to inform capital costs.

Modeling Approach

This work aims to emulate the process that a contractor would use to price out heating and cooling equipment. The City provided representative drawing sets approved for construction for a single-family home and multi-family housing structure under the 2018 IECC (Flagstaff's current energy code). For this study, a multi-family home was assumed to be three stories and fall under the Residential IECC[25].

Details from these drawing sets were input into a web-based heating and cooling load calculator called CoolCalc. CoolCalc is a popular tool used by contractors to model loads and was created by Distributor Corporation of New England (DCNE). It is an ACCA-approved tool for Manual J heating and cooling load calculations, as is required by the IECC for sizing heating and cooling equipment.

Heating and cooling loads were then used to inform capital costs for a mixed-fuel home (serviced by a natural gas furnace and a central air conditioner), a mixed-fuel and highly energy-efficient home; an all-electric home; and a highly energy-efficient, all-electric home. The latter two scenarios were also modeled with and without energy recovery ventilators (ERVs). Distinctions between ERV installations were later removed, since all interviewed contractors noted that ERVs are included with every new build. They noted that energy efficiency requirements in the 2018 IECC create houses with such minimal leakage that builders consider ERVs a necessary part of the build.

Operational costs (annual utility costs) were simulated using outputs from the Building Energy Optimization Tool (BEopt), using Flagstaff weather data[26]. BEopt was created by the National Renewable Energy Laboratory (NREL) and is a commonly used tool among building science professionals to assess a residential building's energy usage. Details were extracted from the drawing sets provided by the City and entered into BEopt to model annual energy usage from mixed-fuel, mixed-fuel and highly energy-efficient, all-electric, and highly energy-efficient and all-electric homes. Outputs from BEopt were entered into a separate spreadsheet and converted into annual energy costs using Arizona Public Service's (APS) three different residential utility plans: fixed, time-of-use (TOU), and TOU plus demand. Modeling used BEopt's default values for energy usage; no additional adjustments were made to account for occupant behavior to reduce energy use during peak hours. Default values were based on hourly load profiles from the Building America House Simulation Protocols,[27] which provides a standard and consistent approach to simulating energy usage in homes.

Detailed modeling assumptions and key representative building characteristics can be found in Appendix A. Reviewers are encouraged to evaluate high-level cost differentials and trends as noted in the main body of the study, rather than to focus on the detailed inputs as they may vary between members of the building community. *These results are meant to be illustrative and will vary in practice.*

Insight into Key Modeling Inputs

Key Energy Efficiency Parameters

The City's current adopted energy code is the 2018 IECC with local amendments -- all new residential construction must adhere to the requirements for energy efficiency and heating and cooling as outlined in this code. Every three years, an updated IECC is released and available for City adoption, and each new code generally brings with it a more stringent set of energy efficiency requirements. The City is on a 6-year building and fire code update cycle and in 2026 will consider adopting the 2024 IECC, which includes a base code and various appendices that cities can choose to adopt with local amendments. Several of these appendices include additional energy-related measures for single-family and multi-

[25] There is a Residential IECC and a Commercial IECC.

[26] The location selected for the modeling was Flagstaff, AZ, 86001.

[27] NREL created the Building America House Simulation Protocols to estimate consistent energy usage patterns for homes across the country. They are used as the standard best practice when modeling energy usage.

family homes. Homes built to the standards in the base 2024 IECC are expected to save approximately 14% more energy than homes built to the base 2018 IECC[28]. This is accomplished with enhanced energy efficiency measures such as reduced air leakage, better insulation, and improved HVAC equipment.

One appendix that the City could adopt is Appendix RG: 2024 IECC Stretch Code (Stretch Code). Under this appendix, new construction must achieve greater energy savings than the base 2024 IECC, using one of the following methods: a prescriptive pathway, simulated building performance, or an energy-rating index (ERI) based compliance. Industry organizations estimate that the measures identified in the stretch code could result in an additional 10% of energy use savings over the base 2024 IECC[29]. By adopting the 2024 IECC and Stretch Code (Appendix RG), the City can expect new homes to use 24% less energy relative to the current 2018 IECC baseline, based on industry estimates.

Select code requirements for measures that have significant impacts on energy performance are shown in Table 1[30]. Some requirements are not prescriptive, and builders may choose their preferred measures. For example, a "wood-framed wall R-value" may equal R-30 cavity insulation, R-20 with R-5 continuous insulation (ci), R-13 with R-10ci, or R-0 with R-20 ci. Since the Stretch Code provides flexibility to the builder to choose measures, modeling inputs were chosen to represent incremental improvements (e.g., higher insulation, tighter air-sealing, etc.) that could yield approximately 10% lower total energy use than a home built to the base 2024 IECC. *These values are illustrative.*

Table 1. Select inputs for various IECC options

Building Measures	Current: 2018 IECC base	2024 IECC Base Option	Modeled Parameters in Alignment with 2024 IECC Appendix RG
Wall insulation	R-20 or R-13 and R-5 continuous insulation (ci)	R-30, R-20 and R-5 ci, R-13 and R-10, or R-20ci	R20 and R-5ci
Ceilings	R-49	R-49	R-49
Air Leakage	4 air changes per hour at 50 pascals (ACH50)	3ACH50	3ACH50
Floors	R-10 for 2 ft	R-10 for 3 ft	R-10 for 3 ft
Duct Leakage	4 cubic feet per minute per 100 square feet (4 CFM/100 ft^2 Ducts located outside of a conditioned space	4 CFM/100 ft^2 Outside conditioned space	4 CFM/100 ft^2 90% ducts inside conditioned space
Ventilation	Exhaust	Exhaust	60% ERV

[28] A quantitative analysis conducted by the Department of Energy (DOE) in December 2024 indicates that adopting the base 2024 IECC reduces energy use by 7.3% over the base 2021 IECC for climate zone 5 while Pacific Northwest National Laboratory (PNNL) found that the 2021 IECC was shown to save approximately 8.5% over the 2018 IECC. DOE report. PNNL report. Taking into account that the 7.3% savings are on top of an already realized 8.5% savings, the total savings are expected to be approximately 14%.

[29] Stretch code improvements: DOE report and NAHB.

[30] 2024 Base IECC.

It should be noted that there are multiple ways to represent the energy savings in both single- and multi-family homes that support the intent of the Stretch Code. These "packages" of measures will vary in real-world construction, and at times, these measures may understate the potential that could exist to reduce energy in a certain system. For instance, the measures chosen for this study assume 90% ducts are located inside conditioned spaces. While this assumption reduces the impact that efficiency has in ductless systems, it was chosen because this approach aligns with local best practices that are most commonly pursued in home building and may require a lower capital cost investment than other energy efficiency measures.

Mixed-Fuel Parameters

As with energy efficiency measures, real-world variability exists when choosing the efficiency of heating and cooling equipment. The City's local amendment to the 2018 International Residential Code (IRC) Chapter 4-02 requires that furnaces installed in new construction be condensing and have an efficiency of at least 90%.[31] Yet, based on representative drawings and conversations with City and Coconino County staff, several builders exceed this value, and gas furnaces with efficiencies of 92.5% and higher are more common. Historically, central air conditioners were not common in new residential homes in Flagstaff due to the City's cold climate. As a result, the City has not established local efficiency requirements for air conditioning equipment; yet when installed, such systems must meet the federal minimum efficiency standards referenced by the 2018 IECC[32]. Federal standards require that single-stage air conditioners installed in new homes in Arizona have a minimum SEER rating of 14 and an EER rating of 11[33]; these are equivalent to the updated rating systems of a SEER2 of 13.4 and EER2 of 10.6.

Modeling inputs for mixed-fuel homes assumed 92.5% efficient gas furnaces and single-stage SEER2 14.3 air conditioners. These values were chosen based on stakeholder feedback and City code requirements. For highly energy-efficient mixed-fuel homes, the modeling assumed a 95% efficient condensing gas furnace paired with an air conditioner with a SEER2 rating of 14.3. Appendix RG does not specify efficiencies of these units, so these values were chosen to approximate the overall improvement in energy usage of 10% related over the base 2024 IECC.

All-Electric Parameters

Flagstaff is in climate zone 5 and qualifies as a "cold climate" per the Northeast Energy Efficiency Partnership's (NEEP), which states that highly efficient heating appliances should be installed in climate zones 4 and higher; these types of heat pumps are referred to as cold-climate air-source heat pumps (ccASHP). Neither the 2024 IECC nor the federal minimum efficiency standards reference "cold climate" performance metrics, but the voluntary NEEP program does provide guidance. NEEP specifies that a ducted ccASHP must have a SEER2 greater than 14.3 and HSPF2 greater than 7.7, and ductless ccASHP have a SEER2 greater than 15 and an HSPF2 greater than 8.5. The intent of requiring additional efficiency over standard heat pumps is to ensure that the heat pumps can efficiently provide heating at low outdoor temperatures, since heating performance decreases as the outdoor temperatures decreases. Performance curves for individual units can be viewed on manufacturer websites and at NEEP[34].

Given the builder's manufacturer preference and the variability of performance and costs, builders choose different ccASHP efficiencies based on the application. During the focus group, members of the

---

[31] See the City's code requirements.
[32] Details on code requirements.
[33] Air conditioner efficiency requirements.
[34] NEEP cold climate heat pump list.

building community noted that they install heat pumps with SEER2 values ranging from 17.8 to 25 and HSPF2 values ranging from 9 to 11.

Modeling inputs for all-electric ducted ccASHP assumed a SEER2 of 20.9 and HSPF of 8.9; all-electric ductless mini-splits assumed a SEER2 of 26 and HSPF2 of 11.3, which considered NEEP requirements and stakeholder feedback. It should be noted that the efficiencies of ducted ccASHPs and ductless mini-splits are not directly related. The efficiency ratings are informed by the Department of Energy's test conditions, which shows that ductless systems have lower fan power and no duct distribution losses, while ducted systems will experience energy losses through duct air leakage and resistance. This means that the ductless systems will always show an improved efficiency rating.

3. Results

Capital Cost Findings

We determined capital costs using input from members of the building community and from online research using modeled heating and cooling loads for representative single- and multi-family homes. For detailed inputs for each scenario, refer to the Methodology section (above) and Appendix A.

Equipment costs are expected to vary based on a variety of factors, including system size, efficiency, and manufacturer. Installation costs vary depending on the comfort level of the installer. Through stakeholder interviews, we found that those with previous experience and a high comfort level expected a low to negligible cost differential between mixed-fuel systems with all-electric and/or highly energy-efficient and all-electric systems. Tables use a shorthand of HEE when referring to "highly energy-efficient" homes.

Presented costs are estimates and may vary depending on the exact system chosen. These findings are meant to serve as an order-of-magnitude estimate when evaluating the first costs associated with different building scenarios.

Single-Family Homes

Tables 2 through 7 present estimated first costs and a range of costs for all equipment (primary and ancillary equipment) and labor based on stakeholder feedback, which tend to be higher than market-researched costs. Market-research costs are presented in the section, Return on Investment. Costs are provided for the base case (Table 2) and five alternate scenarios (Tables 3 through 7).

Base Case: Mixed-Fuel Single-Family Home

Table 2 presents the estimated average and range of costs for installing a mixed-fuel system in a single-family home. Features included a 92.5% efficient natural gas furnace, central air conditioning with a SEER2 of 14.3, gas water heater, and gas stove. Building construction features were based on the 2018 IECC. Gas hookup fees include UniSource Gas's natural gas connection fee and associated plumbing fees. It should be noted one member of the building community stated that UniSource provides a rebate of approximately $2,000 per lot for single-family subdivisions as part of their Facility Extension Agreement.[35] However, Facility Extension Agreements are developer-specific; no other developer was aware that this rebate was provided to partially offset natural gas hookup fees so it cannot be assumed that this rebate is available for all projects.

[35] A developer provided this information over email, which was provided to the City.

Additionally, even though energy recovery ventilators are considered an energy efficiency measure and are not included in the 2018 IECC, all builders noted that they install ERVs as part of their standard building practices. This cost is not reflected in Table 2.

Table 2. Summary of capital costs for new mixed-fuel single-family homes

System	Average Cost	Range
Mixed-fuel	$11,500	+/- $2,000
Natural gas hookup	$3,000	+/- $2,000*
Total mixed-fuel	**$14,500**	**$10,500 to $18,500**

**Includes a $2,000 UniSource rebate, which may not be available to all builders.*

Scenario 1: Ducted All-Electric Single-Family Home

Table 3 presents the estimated average and range of costs for installing an all-electric ducted system in a single-family home built to the 2018 IECC. Typical components of an all-electric ducted system include a ccASHP, ductwork, utility infrastructure and wiring, refrigeration lines, electric water heater, appliances (including an induction stove), and labor. All builders noted that the current electric panel size required by the 2017 National Electrical Code adopted by the City of Flagstaff is sufficient to support an all-electric ducted system; therefore, no cost was assigned to upgrading the electric panel. The electrical panel is based on the load demands of the home and is typically a 200-amperes panel.

Table 3. Summary of capital costs for new ducted all-electric single-family homes

System	Average Cost	Range
All-electric ducted	$17,000	+/- $3,000
Additional electric panel capacity	$0	$0
Total all-electric ducted	**$17,000**	**$14,000 to $20,000**

Scenario 2: Ductless All-Electric Single-Family Home

Table 4 presents the estimated average and range of costs for installing an all-electric ductless system in a single-family home built to the 2018 IECC. Typical components of an all-electric ductless system include a mini-split system, utility infrastructure and wiring, refrigeration lines, electric water heater, appliances (including an induction stove), and labor. As with the ducted system, the existing electric panel is expected to meet all loads. The ductless system assumes the installation of a mini-split system with three to four central "heads" that serve the primary areas of the home. Its cost is expected to be lower since there are no ducts or associated labor.

Table 4. Summary of capital costs for new ductless all-electric single-family homes

System	Average Cost	Range
All-electric ductless	$14,000	+/- $2,000
Additional electric panel capacity	$0	$0
Total all-electric ductless	**$14,000**	**$12,000 to $16,000**

Scenario 3: Mixed-Fuel and Highly Energy-Efficient Single-Family Home

Table 5 presents the costs for a mixed-fuel, highly energy-efficient single-family home. Costing energy efficiency measures should be interpreted with caution: Some builders already implement energy efficiency measures that go beyond the City's currently adopted code as a standard part of their building practice, and therefore, these estimates may be overinflated. These values represent the cost difference between moving from the 2018 IECC to the Stretch Code. For example, all interviewed builders noted that ERVs are typically installed as part of their standard builds; these costs are separated out for review. Traditionally, ERVs support the additional efficiency achieved with the Stretch Code.

Table 5. Summary of capital costs for new mixed-fuel, highly energy-efficient single-family homes

System	Average Cost	Range
Mixed-fuel	$11,500	+/- $2,000
Natural gas hookup	$3,000	+/- $2,000*
ERV	$1,500	+/- $500
Energy efficiency measures	$7,000	+/- $3,000
Total mixed-fuel, HEE	**$23,000**	**$15,500 to $30,500**

**Includes a $2,000 UniSource rebate, which may not be available to all builders.*

Scenario 4: Ducted All-Electric, Highly Energy-Efficient Single-Family Home

Table 6 presents the costs for an all-electric ducted, highly-energy efficient single-family home. Previous notes regarding electric panel size, energy efficiency costs, and ERVs apply here.

Table 6. Summary of capital costs for new all-electric, ducted highly energy-efficient single-family homes

System	Average Cost	Range
All-electric ducted	$17,000	+/- $3,000
Additional electric panel capacity	$0	$0
Energy efficiency measures	$7,000	+/- $3,000
ERV	$1,500	+/- $500
Total all-electric ducted, HEE	**$25,500**	**$19,000 to $32,000**

Scenario 5: Ductless All-Electric, Highly Energy-Efficient Single-Family Home

Table 7 presents the costs for an all-electric ductless, highly-energy efficient single-family home. Previous notes regarding electric panel size, ducts, energy efficiency costs, and ERVs apply here.

Table 7. Summary of capital costs for new all-electric ductless, highly energy-efficient single-family homes

System	Average Cost	Range
All-electric ductless	$14,000	+/- $2,000
Additional electric panel capacity	$0	$0
Energy efficiency measures	$7,000	+/- $3,000
ERV	$1,500	+/- $500
Total all-electric ductless, HEE	**$22,500**	**$17,000 to $28,000**

Single-Family Capital Cost Comparison

Table 8 summarizes capital costs for the base case and each scenario. Capital costs exceeding the average base case cost of $12,500 are shaded in orange, while those below the average base case are shaded in green.

Table 8. Capital cost comparison for single-family homes

Scenario	Total Cost	Range	Cost Difference (vs. Base Case)
Base case: mixed-fuel	$14,500*	$8,500 - $18,500	--
1: All-electric, ducted	$17,000	$14,000 - $20,000	+$2,500
2: All-electric, ductless	$14,000	$12,000 - $16,000	-$500
3: Mixed-fuel, HEE	$23,000*	$15,000 - $30,500	+$8,500
4: All-electric, ducted, HEE	$25,500	$19,000 - $32,000	+$11,000
5: All-electric, ductless HEE	$22,500	$17,000 - $28,000	+$8,000

Green = Costs are lower than the mixed-fuel base case. Orange = Costs are higher than the mixed-fuel base case.

**A $2,000 UniSource natural gas connection rebate may not be available for all projects, so the average capital cost of mixed-fuel homes is calculated without the rebate.*

Key Findings and Additional Considerations

Key Observations

1. An all-electric ducted single-family home, with and without energy efficiency, is likely to cost more than a mixed-fuel single-family home.
2. An all-electric ductless single-family home is likely to cost slightly less (or about the same) as a mixed-fuel single-family home when UniSource's gas connection rebate is not available.
3. Energy efficiency measures increase a home's first costs.
4. There is a large cost range for each scenario.

Key Takeaways

1. **All-electric ductless systems can likely achieve cost parity with mixed-fuel systems.** Costs for ductless systems (mini-split systems) are lower because these systems do not require ductwork, as is required with a mixed-fuel and ducted, all-electric system.

2. **Adding energy efficiency measures does increase capital costs.** However, many builders already build beyond code, and energy efficiency cost estimates could be overestimated for some builders. Also, energy efficiency will *save money* in the long run, see the section "Operational Costs: Single-Family Homes".
3. **Given each home's unique nature, it is difficult to accurately pinpoint an exact cost for each system.** These values should be considered illustrative.

Additional Considerations

1. During our focus group, most participants noted the range of presented capital costs for single-family homes was in alignment with their experience. One noted that the costs for mixed-fuel family homes may be high. This was because this developer receives a UniSource gas connection rebate, which might not be available to other builders.
2. Some builders only build homes with in-floor radiant heating and cooling. These builders noted that the cost differential between all-electric systems and a standard natural gas boiler and electric chiller were negligible.
3. Estimated building costs were collected during stakeholder interviews; costs ranged from **$160/sf to $850/sf**. The additional costs incurred through either all-electric and/or energy efficiency measures yields a slight increase in overall building costs. For example, assuming the low range of building costs ($160/sf) and the highest capital cost differential ($9,500 for a highly energy-efficient, all-electric ducted ccASHP), building costs for a 2,500 sf new home could **increase by up to 3%.**

Capital Costs: Multi-Family Homes

Tables 9 through 12 present the average capital costs of all three units including a base case of a mixed-fuel, multi-family home (Table 9) and three alternative scenarios (Tables 9 through 12).[36] The all-electric system is based on a ductless mini-split system, which is widely used and increasingly common in multi-family units.

Base Case: Mixed-Fuel Multi-Family Home

Table 9 presents the estimated average and range of costs for installing a mixed-fuel system in a multi-family home. Gas hookup fees include UniSource Gas's natural gas connection fee and associated plumbing fees. No information was provided on a possible gas connection fee rebate for a multi-family home, and is therefore, not included. Additionally, even though energy recovery ventilators are considered an energy efficiency measure and are not included in the 2018 IECC, all builders noted that they already install ERVs as part of their standard building practices. This cost is not reflected in Table 9.

Table 9. Capital costs of HVAC systems per unit for mixed-fuel new multi-family homes

System	Average Cost	Range
Mixed-fuel	$11,000	+/- $3,000
Gas hookup	$1,500	+/- $300
Total mixed-fuel	**$12,500**	**$8,300 to $15,800**

[36] All-electric ducted systems were not modeled in the multi-family scenarios because ductless mini-split heat pumps are becoming more common in all-electric development due to their high energy efficiency, avoided costs associated with installing ductwork, effectiveness at heating smaller spaces, and the ability to provide individual temperature control for each unit.

Scenario 1: Ductless All-Electric Multi-Family Home

Table 10 presents the estimated average and range of costs for installing an all-electric ductless system in a multi-family home. The existing electric panel is expected to meet all loads. The ductless system assumes the installation of a mini-split system with central "heads" that serve the primary areas of the home. Its cost is expected to be lower since there are no ducts or associated labor.

Table 10. Summary of capital costs of HVAC systems per unit for all-electric multi-family homes

System	Average Cost	Range
All-electric ductless	$11,300	+/- $4,000
Additional electric panel capacity	$0	$0
Total all-electric ductless	**$11,300**	**+/- $7,300 to $15,300**

Scenario 2: Mixed-Fuel and Highly Energy-Efficient Multi-Family Home

Table 11 presents the costs for a mixed-fuel, highly-energy efficient multi-family home. Costing energy efficiency measures should be interpreted with caution: Some builders already implement energy efficiency measures that go beyond the current code as a standard part of their building practice, and therefore, these estimates may be overinflated. These values represent the cost difference between moving from the 2018 IECC to the Stretch Code. For example, all interviewed builders noted that ERVs are typically installed as part of their standard builds; these costs are separated out for review. Traditionally, ERVs support the additional efficiency achieved with the Stretch Code.

Table 11. Summary of capital costs for new all-electric ductless multi-family homes

System	Average Cost	Range
Mixed-fuel	$11,000	+/- $3,000
Gas hookup	$1,500	+/- $300
ERV	$1,500	+/- $500
Energy efficiency measures	$5,000	- $2,000 / +$5,000
Total mixed-fuel, HEE	**$19,000**	**$13,200 to $27,800**

Scenario 3: Ductless All-Electric and Highly Energy-Efficient Multi-Family Home

Table 12 presents the costs for an all-electric ductless, highly-energy efficient multi-family home. Previous notes regarding electric panel size, ducts, energy efficiency costs, and ERVs apply here.

Table 12. Summary of capital costs for new all-electric ductless, highly energy-efficient multi-family homes

System	Average Cost	Range
All-electric ductless	$11,300	+/- $4,000
Additional electric panel capacity	$0	$0
Energy efficiency measures	$5,000	- $2,000 / +$5,000
ERV	$1,500	+/- $500
Total all-electric ductless, HEE	**$17,800**	**$11,300 to $27,300**

Multi-Family Capital Cost Comparison

Table 13 summarizes capital costs for the base case and each scenario. Capital costs exceeding the average base case cost of $12,500 are shaded in orange, while those below the average base case are shaded in green.

Table 13. Capital cost comparison for multi-family homes

Scenario	All-In Cost	Range	Cost Difference (vs. Base Case)
Base case: Mixed-fuel	$12,500	$8,300 - $15,800	--
1: All-electric, ductless	$11,300	+/- $4,000	-$1,200
2: Mixed-fuel, HEE	$19,000	$13,200 - $27,800	+$6,500
3: All-electric, ductless, HEE	$17,800	$11,300 - $27,300	+$5,300

Green = Costs are lower than the mixed-fuel base case. Orange = Costs are higher than the mixed-fuel base case.

Key Findings and Additional Considerations

Key Observations

1. All-electric ductless mini-splits are less costly to install than a mixed-fuel system.
2. Adding energy efficiency measures does increase capital costs for the ductless mini-split scenarios. However, many builders already build beyond code, and energy efficiency cost estimates could be overestimated for some builders.

Key Takeaways

1. **The lowest capital costs can be achieved with an all-electric ductless mini-split system**. Costs for mini-split systems are lower because these systems do not require ductwork, as is required with a mixed-fuel system. Though at times, installers may choose slim-duct systems, which may slightly increase costs[37].
2. **Adding energy efficiency measures increases capital costs for the ductless mini-split scenarios.** However, many builders already build beyond code, and energy efficiency cost estimates could

[37] Slim-ducts are commonly used in condos because they take up less space than traditional ductwork. They are smaller, shorter, and typically installed within conditioned spaces.

be overestimated for some builders. Also, energy efficiency will *save money* in the long run, see the section "Operational Costs: Single-Family Homes".

3. **Given each home's unique nature, it is difficult to accurately pinpoint an exact cost for each system.** These values should be considered illustrative.

Additional Considerations

1. During our focus group and interviews, most participants stated that they had limited experience building multi-family homes; therefore, they had little insight to offer on the presented capital costs.

Operational Cost Findings

Operational costs (annual energy costs) were determined using inputs from representative single- and multi-family home building plans. Inputs varied by building scenario, including a mixed-fuel base case and five additional scenarios that considered variations of electric and energy efficiency homes. These scenarios are the same as those modeled for capital costs. Costs were then evaluated against different APS residential electricity plans' rates: Fixed Energy Charge (fixed rate) with small, medium, and large tiers, TOU, and TOU Plus Demand Charge. Costs also included UniSource's residential gas rates, which do not vary across plan types. Hourly energy usage was simulated using BEopt's default values, which were based on hourly load profiles from the Building America House Simulation Protocols.[38] These protocols provide a standard and consistent approach to simulating energy usage in homes. no additional adjustments were made to account for occupant behavior. See Appendix A for detailed modeling inputs.

Members of the building community were unable to verify operational costs; they typically do not follow-up with clients after their homes have been built. However, one builder noted anecdotally that ccASHPs provide greater operational savings than what is shown here, particularly for air-to-water heat pumps (which are out of the scope of this study). *Presented costs are estimates and may vary depending on the exact inputs chosen – R-value, insulation type, etc. These findings are meant to serve as a rough guide when evaluating the operational costs associated with different building scenarios.*

Operational Costs: Single-Family Homes

Base Case: Mixed-Fuel Single-Family Home

The modeled home shown in Table 14 was estimated to use approximately **542 kWh of electricity and 823 th of natural gas** on average per month. Real-world occupant behavior would influence actual usage, and a mixed-fuel single-family home's average monthly usage could realistically fall under the APS small or medium tier Fixed Rate plan. Both tiers are shown for comparison.

[38] NREL created the Building America House Simulation Protocols to estimate consistent energy usage patterns for homes across the country. They are used as the standard best practice when modeling energy usage.

Table 14. Summary of energy costs for new mixed-fuel single-family homes

Base Case: Mixed-Fuel Single-Family Home				
Electricity Rate Plan	Annual Electricity Costs	Annual Gas Costs	Total Annual Energy Costs	Average Monthly Energy Costs
Fixed Rate, Small Tier	$973	$821	$1,794	$150
Fixed Rate, Medium Tier	$1,082	$821	$1,903	$159
TOU	$1,077	$821	$1,898	$158
TOU Plus Demand Charge	$841	$821	$1,661	$138

Green = lowest total energy cost. Orange = highest total energy cost.

Scenario 1: Ducted All-Electric Single-Family Home

Table 15 illustrates the energy usage for a single-family home, where natural gas has been replaced with electricity in a ducted system. Under this scenario, the average monthly electricity usage was modeled to be approximately **1,200 kWh**. Under different occupant usage behavior, usage could be subject to either the medium or large tier Fixed Rate plan. All tiers are shown for comparison.

Table 15. Summary of energy costs for new ducted all-electric single-family homes

All-Electric Ducted Single-Family Home					Mixed-Fuel Base Case Compared to All-Electric	
Electricity Rate Plan	Electricity Costs	Gas Costs	Total Annual Energy Costs	Average Monthly Energy Costs	Average Monthly Energy Cost	Cost Difference
Fixed Rate, Small Tier	NA: Monthly average exceeds small tier limit	$0	NA	NA	$150	+21%*
Fixed Rate, Medium Tier	$2,180	$0	$2,180	$182	$159	+15%
Fixed Rate, Large Tier	$2,375	$0	$2,375	$198	NA: Usage falls within small or medium tier	+25% and +32%**
TOU	$2,065	$0	$2,065	$172	$158	+9%
TOU Plus Demand Charge	$1,533	$0	$1,533	$128	$138	-8%

Green box = lowest total energy cost
Orange box = highest total energy cost.
Red text = all-electric utility costs are higher than mixed-fuel base case utility costs.
Green text: all-electric utility costs are lower than mixed-fuel base case utility costs.

**Compares the cost difference between all-electric ducted systems in APS' fixed rate medium tier vs mixed-fuel small tier.*
***Compares the cost difference between all-electric ducted systems in APS' fixed rate large tier vs mixed-fuel small (+32%) and medium tiers (+25%).*

Scenario 2: Ductless All-Electric Single-Family Home

Table 16 illustrates the energy usage from a single-family home, where natural gas has been replaced with electricity in a ductless system. This modeled home was estimated to use approximately **835 kWh** of electricity on average per month; it most likely falls under the medium Fixed Rate plan depending on occupant behavior.

Table 16. Summary of energy costs for new ductless all-electric single-family homes

Electricity Rate Plan	All-Electric Ductless Single-Family Home				Mixed-Fuel Base Case Compared to All-Electric	
	Electricity Costs	Gas Costs	Total Annual Energy Costs	Average Monthly Energy Costs	Average Monthly Energy Cost	Cost Difference
Fixed Rate, Small Tier	NA: Monthly average exceeds small tier limit	$0	NA	NA	$150	-12%*
Fixed Rate, Medium Tier	$1,576	$0	$1,576	$131	$159	-17%
TOU	$1,528	$0	$1,528	$127	$158	-19%
TOU Plus Demand Charge	$1,167	$0	$1,167	$97	$138	-30%

Green box = lowest total energy cost. Orange box = highest total energy cost.
Green text: highly energy-efficient mixed-fuel costs are lower than base case mixed-fuel utility costs.

**Compares the cost difference between all-electric ductless system falling into APS' medium tier vs. mixed-fuel small tier.*

Scenario 3: Mixed-Fuel and Highly Energy-Efficient Single-Family Home

This modeled home was estimated to use approximately **535 kWh of electricity and 45 th of natural gas** on average per month. Real-world occupant behavior would influence actual usage, and average monthly usage could realistically fall under the APS small or medium tier Fixed Rate plan

This home was shown to use approximately **27% less total energy** (electricity and natural gas) under the Stretch Code, compared to the current 2018 IECC. This is slightly higher than the predicted 24% energy savings as noted in other studies, refer to the section "Methodology" for more information. Table 17 presents its energy costs. While the modeled home was shown to use approximately 27% less energy than the mixed-fuel base case, the **energy cost savings ranged from 13% to 16%.**

Table 17. Summary of energy costs for new mixed-fuel, highly energy-efficient single-family homes

Electricity Rate Plan	Mixed-Fuel, Highly Energy-Efficient Single-Family Home				Mixed-Fuel Base Case Compared to All-Electric	
	Electricity Costs	Gas Costs	Total Energy Costs	Average Monthly Energy Costs	Average Monthly Energy Cost	Cost Difference
Fixed Rate, Small Tier	$962	$584	$1,547	$129	$150	-14%
Fixed Rate, Medium Tier	$1,069	$584	$1,654	$138	$159	-13%
TOU	$1,063	$584	$1,648	$137	$158	-13%
TOU Plus Demand Charge	$810	$584	$1,395	$116	$138	-16%

Green box = lowest total energy cost. Orange box = highest total energy cost.
Green text: highly energy-efficient mixed-fuel costs are lower than base case utility costs.

Scenario 4: Ducted All-Electric and Highly Energy-Efficient Single-Family Home

Table 18 presents the energy costs for a single-family home, where natural gas has been replaced with electricity in a ducted system, and energy efficiency measures have been installed that align with the Stretch Code. The average monthly electricity usage was modeled to be **905 kWh**, and usage could place the home in the medium or large Fixed Rate plan depending on occupant behavior. While the modeled all-electric ducted home was shown to use approximately **27% less energy** than the highly energy-efficiency all-electric home, the energy **cost savings ranged from 19% to 22%.**

Table 18. Summary of energy costs for new all-electric ducted, highly energy-efficient single-family homes

Electricity Rate Plan	All-Electric Ducted, Highly Energy-Efficient Single-Family Home				Mixed-Fuel Base Case Compared to All-Electric	
	Electricity Costs	Gas Costs	Total Energy Costs	Average Monthly Energy Costs	Average Monthly Energy Cost	Cost Difference
Fixed Rate, Small Tier	NA: Monthly average exceeds small tier limit	$0	NA	NA	$150	-6%*
Fixed Rate, Medium Tier	$1,693	$0	$1,693	$141	$159	-11%
Fixed Rate, Large Tier	$1,842	$0	$1,842	$154	NA: Usage falls within small or medium tier	-3% and +3%**
TOU	$1,635	$0	$1,635	$136	$158	-14%
TOU Plus Demand Charge	$1,235	$0	$1,235	$103	$138	-26%

Green box = lowest total energy cost. Green text: all-electric utility costs are lower than mixed-fuel base case utility costs.
Orange box = highest total energy cost. Red text = all-electric utility costs are greater than mixed-fuel base case utility costs.

**Compares the cost difference between all-electric ducted systems in APS' medium tier vs. mixed-fuel small tier.*
***Compares the cost difference between all-electric ducted systems in APS' large tier vs. mixed-fuel small (+3%) and medium tiers (-3%).*

Scenario 5: Ductless All-Electric and Highly Energy-Efficient Single-Family Home

Table 19 presents the energy costs for a single-family home, where natural gas has been replaced with electricity in a ductless system and energy efficiency measures have been installed that align with the Stretch Code. The average monthly electricity usage was modeled to be **810 kWh**, which would place the home in the medium tier (among the Fixed Rate plan tiers), depending on occupant behavior. While the modeled highly energy-efficient, all-electric ductless home was shown to use approximately **3% less energy** than the all-electric ductless home, the **energy cost savings ranged from 2-3%.**

Table 19. Summary of energy costs for new all-electric ductless, highly energy-efficient single-family homes

Electricity Rate Plan	All-Electric Ductless, Highly Energy-Efficient Single-Family Homes				Mixed-Fuel Base Case Comparison	
	Electricity Costs	Gas Costs	Total Energy Costs	Average Monthly Energy Cost	Average Monthly Energy Cost	% Cost Difference
Fixed Rate, Small Tier	NA: Monthly average exceeds small tier limit	$0	NA	NA	$150	-14%*
Fixed Rate, Medium Tier	$1,535	$0	$1,535	$128	$159	-19%
TOU	$1,492	$0	$1,492	$124	$158	-21%
TOU Plus Demand Charge	$1,138	$0	$1,138	$95	$138	-32%

Green box = lowest total energy cost. Orange box = highest total energy cost.
Green text: all-electric ductless utility costs are less than mixed-fuel base case utility costs.

**Compares the cost difference between all-electric ductless systems falling into APS' medium tier vs. mixed-fuel small tier.*

Single-Family Energy Efficiency and Operational Cost Comparison

Tables 20 and 21 presents all annual and monthly utility costs for the base case and each scenario. The Fixed Rate (small tier) and Fixed Rate (large tier) columns are blank for some all-electric scenarios because modeling indicated the home did not use the relevant amount of energy to be placed in those energy plans.

Table 20. Annual utility costs for all single-family scenarios against the base case

Scenario	Fixed Rate (Small)	Fixed Rate (Medium)	Fixed Rate (Large)	TOU	TOU plus demand
Base case: Mixed-fuel	$1,794	$1,903	---	$1,898	$1,661
1: All-electric, ducted	---	$2,180	$2,375	$2,065	$1,533
2: All-electric, ductless	---	$1,576	---	$1,528	$1,167
3: Mixed-fuel, HEE	$1,547	$1,654	---	$1,648	$1,395
4: All-electric, ducted, HEE	---	$1,693	$1,842	$1,635	$1,235
5: All-electric, ductless, HEE	---	$1,535	---	$1,492	$1,138

Green boxes = Costs are lower than the mixed-fuel base case. The darkest green box is the lowest overall cost.
Orange boxes = Costs are higher than the mixed-fuel base case. The darkest orange box is the highest overall cost.

Table 21: Monthly energy costs for new 2,500 sf single-family mixed-fuel homes

Scenario	Fixed Rate (Small)*	Fixed Rate (Medium)	Fixed Rate (Large)*	TOU	TOU plus demand
Base case: Mixed-fuel	$150	$159	---	$158	$138
1: All-electric, ducted	---	$182	$191	$172	$129
2: All-electric, ductless	---	$131	---	$127	$97
3: Mixed-fuel, HEE	$129	$138	---	$137	$116
4: All-electric, ducted, HEE	---	$141	$154	$137	$103
5: All-electric, ductless, HEE	---	$128	---	$124	$95

Green boxes = Costs are lower than the mixed-fuel base case. The darkest green box is the lowest overall cost.
Orange boxes = Costs are higher than the mixed-fuel base case. The darkest orange box is the highest overall cost.

Table 22 compares the modeled energy efficiency savings for single-family homes compared to the actual energy cost savings. Energy **cost reductions are lower than energy efficiency savings** from the Stretch Code (a reduction of 27% corresponded to an energy cost savings of up to 13% - 22% for single-family home). All-electric ducted homes experienced the greatest cost savings, followed by mixed-fuel homes, and all-electric ductless homes.

Table 22. Summary of energy savings compared to utility cost savings from energy efficiency features in single-family homes

Scenario	Modeled Energy Efficiency Improvement	Actual Energy Cost Savings
3: Mixed-fuel, HEE	27%	13-16%
4. All-electric, ducted, HEE	27%	19-22%
3: All-electric, ductless, HEE	3%	2-3%

Differences in energy efficiency and cost savings occur for several reasons:

1. Energy efficiency reduces both electricity and natural gas usage, and each fuel type has **different rates.** Per unit, electricity is typically more expensive than natural gas (although this is more nuanced under APS TOU plans). Therefore, reducing natural gas usage will typically yield lower cost savings than reducing electricity usage.
2. In addition to use-based rates, energy costs include **fixed fees**, which are not reduced as energy usage decreases.
3. TOU and demand charges are affected differently, since energy efficiency also affects **when and how** energy is used.
4. All-electric ductless ccASHPs are already **extremely efficient**, so energy efficiency improvements have a smaller impact on energy use and costs.
5. Energy and cost savings are linked to the **specific energy efficiency features**. Choosing different features may produce different energy and cost savings.

Key Findings and Additional Considerations

Key Observations

1. The **most expensive** home to operate is an all-electric ducted single-family home under APS' large tier Fixed Rate plan.
2. The **least expensive** home to operate is an all-electric ductless, highly energy-efficient single-family home under the TOU Plus Demand Charge plan.
3. All scenarios leveraging the TOU Plus Demand Charge plan yield **lower operational costs** than a mixed-fuel single-family home.
4. Without the TOU Plus Demand Charge plan, an all-electric, ducted single-family home will likely be **more expensive** to operate than a mixed-fuel single-family home.
5. An all-electric ductless home, regardless of the addition of energy efficiency measures, will likely be **less costly** to operate than a mixed-fuel single-family home.
6. Energy efficiency **reduces the operational costs** of all homes, although the cost savings varied by home type. All-electric ducted systems experienced the greatest cost savings, followed by mixed-fuel homes, and all-electric ductless homes.
7. The **chosen set of modeling scenarios** had a larger impact on the energy use of ducted systems as compared to ductless systems.

Key Takeaways

All-electric and highly energy-efficient homes have the potential to provide lower operational costs than a mixed-fuel home. The **lowest operational costs** can be achieved through:

1. **Energy efficiency**, which reduces the amount of energy the occupant pays for.
2. **APS TOU Plus Demand Charge plan**. Under this plan, energy that is consumed during on-peak (or high usage times as defined by APS) times is more expensive than energy used during off-peak times (or lower usage times as defined by APS). For example, the energy usage cost during on-peak times during the summer is $0.14227/kWh and the energy usage cost during off-peak times during the summer is $0.05943/kWh. The model uses built-in defaults that assume when energy is used by different appliances.
3. **All-electric ductless systems**, which provide targeted heating and cooling and eliminate the need for ductwork. This means fewer rooms in the home are being conditioned at any given time and there is no loss of energy due to leaks in the duct system, contributing to a lower demand and energy use. Shifting to heat pumps is the most efficient way to heat a home. In this study, gas furnaces range from 92.5% to 95% efficient, which means they convert 92-95% of the natural gas into heat (only 5-8% is lost). However, the same unit can be served by a cold-climate heat pump (mini-split) with a typical coefficient of performance (COP) of approximately 3.5 to 4.5 under moderate outdoor temperatures – equivalent to an efficiency of 350% to 450%. This means that every unit of electricity used to run the heat pump produces 3.5-4.5 units of heat. In colder weather, the COP may drop to 1.7 (170% efficient) but will always be more efficient than a gas furnace whose efficiency will never reach 100%.

Additional Considerations

1. During the focus groups and in individual interviews, participants shared a wide range of anecdotal evidence that suggested electrification may increase and, in other cases, reduce operational costs. However, because builders and contractors typically have limited communication with clients once a home is occupied, none were able to provide documented evidence to support either outcome—which is expected. The City may wish to consider future

follow-up with homeowners of newly built all-electric homes to collect actual operational cost data in the coming years.

2. The model **did not consider behavioral changes or additional "smart" technology** – technology that provides additional temperature and load switching controls -- which could **further reduce costs** under the TOU and TOU plus demand classes.
3. **Electricity rates are more expensive per unit than natural gas on the APS fixed rate plan, but the picture is nuanced under the APS TOU plans**.
   a. Under APS' small tier Fixed Rate plan, for example, electricity costs $0.12925/kWh, and under UniSource's plan natural gas costs $0.83/therm. Assuming a home uses 100 kBtu, this translates to $3.79 in electricity and $0.83 in natural gas.
   b. However, the APS TOU plans offer lower electricity rates, including as low as $0.03495 from 10am – 3pm in winter months. Depending on occupant behavior and time of year, the average price per unit of electricity on the TOU plans may be closer to the price per unit of natural gas, especially on the TOU Plus Demand Charge Plan.
4. Even with a higher electricity price per unit, **ccASHPs use electricity much more efficiently than furnaces use natural gas**. A natural gas furnace may use 100 kBtu of gas and, with an efficiency of 92.5%, produce about 92.5 kBtu of usable heat, with the remainder being waste heat. If a ccASHP uses 100 kBtu equivalent of electricity (about 29.3 kWh) and has a COP (a marker of heat pump efficiency) of 3.5, then it produces about 350 kBtu of usable heat because it absorbs heat from the outside air rather than creating it through combustion. As a result, for the same amount of usable heat, a ccASHP needs only a fraction of the input energy of a gas furnace, which can lead to similar or lower operating costs depending on energy rates and how efficiently the ccASHP operates over the season.

Operational Costs: Multi-Family Homes

Flagstaff provided a building drawing package that served as a "representative" multi-family building. Three separate units from this package of varying sizes were modeled to estimate the potential energy use of an individual, representative unit: a top (3rd floor) north-west facing unit of 1,085 square feet, a middle (2nd floor) south-west facing unit of 1,080 square feet, and a ground south-west facing unit of 810 square feet. The average square footage was 990. Tables 22 through 25 present the average annual energy costs of all three units including a base case of a mixed-fuel, multi-family home (Table 21) and three alternative scenarios (Tables 22 through 25). The all-electric system is based on a ductless mini-split system, which is widely used and increasingly common in multi-family units.

All of the modeled units experienced smaller energy cost savings compared to energy efficiency gains when going from Flagstaff's current code to the 2024 IECC + Stretch Code for many of the same reasons as the single family homes. However, energy savings in the multifamily varied by unit location: the top floor unit experienced the greatest energy efficiency improvement (and utility cost savings), followed by the ground floor unit, and the middle floor unit.

In each table, green shading signifies the lowest cost, while orange shading signifies the highest cost. Green text signifies an operational cost savings compared to the base case, and red text signifies an operational cost increase. *Presented costs are estimates and may vary depending on the exact inputs chosen – R-value, insulation type, etc. These findings are meant to serve as a rough guide when evaluating the operational costs associated with different building scenarios.*

Base Case: Mixed-Fuel Multi-Family Home

The representative multi-family home modeled in Table 23 was estimated to use approximately **280 kWh of electricity and 20 th of natural gas** on average per month. Actual energy usage will vary with occupant behavior, but a mixed-fuel multi-family home's average monthly usage is most likely to fall comfortably under the APS small tier Fixed Rate plan.

Table 23. Summary of operational costs for a mixed-fuel multi-family home

Mixed-Fuel Multi-Family Home				
Electricity Rate Plan	Electricity Costs	Gas Costs	Total Energy Costs	Average Monthly Energy Costs
Fixed Rate, Small Tier	$570	$350	$920	$77
TOU	$639	$350	$989	$82
TOU Plus Demand Charge	$504	$350	$855	$71

Green = lowest cost. Orange = highest cost.

Scenario 1: Ductless All-Electric Multi-Family Home

Table 24 illustrates the energy usage from a representative multi-family home, where natural gas has been replaced with electricity in a ductless system. This modeled home was estimated to use approximately **400 kWh of electricity** on average per month; it most likely falls under the small-Fixed Rate plan.

Table 24. Summary of energy costs for new ductless all-electric multi-family homes

Electricity Rate Plan	All-Electric Ductless Multi-Family Home				**Mixed-Fuel Base Case Comparison**	
	Electricity Costs	Gas Costs	Total Annual Energy Costs	Average Monthly Energy Costs	Average Monthly Energy Cost	% Cost Difference
Fixed Rate, Small Tier	$752	$0	$752	$63	$77	-18%
TOU	$830	$0	$830	$69	$82	-16%
TOU Plus Demand Charge	$658	$0	$658	$55	$71	-23%

Green = lowest cost. Orange = highest cost.

Scenario 2: Mixed-Fuel and Highly Energy-Efficient Multi-Family Home

Table 25 presents average energy costs for this home. This modeled home was estimated to use approximately **287 kWh of electricity and 16 th of natural gas** on average per month; it most likely falls under the small tier Fixed Rate plan. The average mixed-fuel multi-family home was shown to use approximately **21% less total energy** under the Stretch Code, compared to the 2018 IECC.

However, the range of energy (electricity and natural gas) savings between the Stretch Code and the 2018 IECC varied by unit: energy efficiency measures reduced energy by **30% in the top unit, 17% in the middle unit, and 15% in the ground unit**. This range is expected since each unit is affected by energy losses differently. For example, middle units receive heating and cooling from the top and ground units and benefit from thermal buffering from adjacent units, reducing the impact of envelope upgrades. Likewise, the ground unit will lose less heat due to the slab foundation. This pattern has been shown in other independent studies.[39]

The average energy **cost savings ranged from 6% to 9%.** The model showed that the greatest energy cost differential occurred for the top unit using the TOU Plus Demand Charge with a cost reduction of **14%**, while the smallest energy cost differential occurred for the middle unit using the Fixed Rate charge with a cost reduction of **3%**.

Table 25. Summary of energy costs for new mixed-fuel, highly energy-efficient multi-family home

Electricity Rate Plan	Mixed-Fuel, Highly Energy-Efficient Multi-Family Home				Mixed-Fuel Base Case Comparison	
	Electricity Costs	Gas Costs	Total Energy Costs	Average Monthly Energy Costs	Average Monthly Energy Cost	% Cost Difference
Fixed Rate, Small Tier	$578	$269	$847	$71	$77	-7%
TOU	$647	$269	$917	$76	$82	-7%
TOU Plus Demand Charge	$508	$269	$777	$65	$71	-9%

Green = lowest cost. Orange = highest cost.

Scenario 3: Ductless All-Electric and Highly Energy-Efficient Multi-Family Home

Table 26 presents the energy costs for a multi-family home, where natural gas has been replaced with electricity in a ductless system and energy efficiency measures have been installed that align with the Stretch Code. The average monthly electricity usage was modeled to be approximately **390 kWh**, and usage is most likely to fall under the small tier Fixed Rate plan. While the modeled highly energy-efficient, all-electric ductless home was shown to use approximately **3% less energy** than the all-electric ductless home, the energy **cost savings ranged from 2-3%**

The energy savings was smaller than for the other scenarios because of the chosen energy efficiency measures. Some of these savings from the chosen efficiency package come from having a portion of the ducts inside conditioned spaces, which reduces duct losses. The ductless system is already relatively efficient (due to no ducts and efficient mini-splits) and the additional savings from the Stretch Code will produce savings less savings than for a ducted system. While this assumption reduces the impact that efficiency has in ductless systems, it was chosen because this approach aligns with local best practices that are most commonly pursued in home building and may require a lower capital cost investment than other energy efficiency measures.

[39] Low-rise multi-family energy savings: OSTI, Research Gate, and DOE.

Table 26. Summary of energy costs for new all-electric ductless, highly energy-efficient multi-family home

Electricity Rate Plan	All-Electric Ductless, Highly Energy-Efficient Multi-Family Home				Mixed-Fuel Base Case Comparison	
	Electricity Costs	Gas Costs	Total Energy Costs	Average Monthly Energy Costs	Average Monthly Energy Cost	% Cost Difference
Fixed Rate, Small Tier	$734	$0	$734	$61	$77	-20%
TOU	$812	$0	$812	$68	$82	-17%
TOU Plus Demand Charge	$644	$0	$644	$54	$71	-24%

Green = lowest cost. Orange = highest cost.

Multi-Family Energy Efficiency and Operational Cost Comparison

Tables 27 and 28 present annual and monthly operational costs for the base case and each scenario. No operational costs exceed the highest mixed-fuel base operational cost; those that are below the lowest mixed-fuel operational cost are shaded in green.

Table 27. Annual operational costs for all scenarios against base case for multi-family homes

Scenario	Fixed rate (small)	TOU	TOU plus demand
Base case: Mixed-Fuel	$920	$989	$855
1: All-electric, ductless	$752	$830	$658
2: Mixed-fuel, HEE	$860	$929	$777
3: All-electric, ductless, HEE	$734	$812	$644

Green = costs that are lower than the mixed-fuel base case. No all-electric home scenario costs exceed the mixed-fuel base case.

Table 28. Monthly operational costs for all scenarios against base case for multi-family homes

Scenario	Fixed rate (small)	TOU	TOU plus demand
Base case: Mixed-Fuel	$77	$82	$71
1: All-electric, ductless	$63	$69	$55
2: Mixed-fuel, HEE	$72	$77	$65
3: All-electric, ductless, HEE	$61	$68	$54

Green = costs that are lower than the mixed-fuel base case. No all-electric home scenario costs exceed the mixed-fuel base case.

Energy **cost reductions are lower than energy efficiency savings** from the Stretch Code (a reduction of 3-22% corresponded to an energy cost savings of up to 2-9% for a multi-family home). Mixed-fuel homes experienced greater cost savings than all-electric ductless homes. Table 29 compares the modeled energy efficiency savings for multi-family homes compared to the actual energy cost savings.

Table 29. Summary of energy savings compared to utility cost savings from energy efficiency features in multi-family homes

Scenario	Modeled Energy Efficiency Improvement	Actual Energy Cost Savings
2: Mixed-fuel, HEE	21%	6-9%
3: All-electric, ductless, HEE	3%	2-3%

Differences in efficiency and cost savings occur for several reasons:

1. Energy efficiency reduces both electricity and natural gas usage, and each fuel type has **different rates.** Per unit, electricity is typically more expensive than natural gas (although this is more nuanced under APS TOU plans). Therefore, reducing natural gas usage will typically yield lower cost savings than reducing electricity usage.
2. In addition to use-based rates, energy costs include **fixed fees**, which are not reduced as energy usage decreases.
3. TOU and demand charges are affected differently, since energy efficiency also affects **when and how** energy is used.
4. All-electric ductless ccASHPs are already **extremely efficient**, so energy efficiency improvements have a smaller impact on energy use and costs.
5. Energy and cost savings are linked to the **specific energy efficiency features**. Choosing different features may produce different energy and cost savings.

Key Findings and Additional Considerations

Key Observations

1. The **most expensive** home to operate is a mixed-fuel, multi-family home under APS' small tier rate plan.
2. The **least expensive** home to operate is an all-electric ductless, highly energy-efficient multi-family home under the TOU Plus Demand Charge plan.
3. All scenarios leveraging the TOU Plus Demand Charge plan yield the **lowest operational costs**.
4. **Operational cost savings** are easily achieved under every ductless mini-split scenario when compared to mixed-fuel.
5. **Energy efficiency saves money** in every case, though savings are modest. The energy savings when using an mixed-fuel system are greater.
6. The TOU rate **increases operational costs** over the small-Fixed Rate due to the shift when energy is billed and the Fixed Rate's low energy costs.

Key Takeaways

All-electric and highly energy-efficient homes have the potential to provide **lower operational costs** than a mixed-fuel home.

1. **The lowest operational costs can be achieved through all-electric ductless systems.** This is likely due to smaller peak heating and cooling loads and the long and steady cycles executed by the variable-speed inverters located within ccASHPs and mini-split systems. In addition, ductless mini-splits provide targeted heating and cooling and eliminate the need for ductwork, factors which also contribute to a lower demand and energy use. Shifting heating to electric systems is a much more efficient use of energy. In this study, gas furnaces range from 92.5% to 95% efficient, but the same unit can be served by a cold-climate heat pump (mini-split) with a typical coefficient of performance (COP) of approximately 3.5 to 4.5 under moderate outdoor temperatures – equivalent to an efficiency of 350% to 450%. In colder weather, the COP may drop to 1.7 (170% efficient) but will always exceed a gas furnace's efficiency, which will never reach 100%.
2. **Energy and utility cost savings will vary by multi-family unit**; units that are in the middle of the housing structure will experience the least amount of savings, and units located near the top of the housing structure will experience the greatest amount of savings. This is confirmed by independent studies that suggest top units have the greatest potential for energy savings.[40]

Additional Considerations

- During the focus groups and in individual interviews, participants noted that they had limited experience with multi-family homes; therefore, their insight on the presented operational costs was limited.
- A different set of energy efficiency measures could further reduce energy costs for all-electric ductless multi-family homes. The **"best" savings package is highly site-specific** and will be chosen per home. For example, one contractor noted that additional insulation (i.e., R-49 vs R-60) shows diminishing returns and becomes less cost effective.
- The model **did not consider behavioral changes or additional "smart" technology** – technology that provides additional temperature and load switching controls -- which could **further reduce costs** under the TOU and TOU plus demand classes.
- **Although electricity rates are typically more expensive per unit than natural gas, ccASHPs use electricity much more efficiently** than furnaces use natural gas. See the single-family homes *Additional Considerations* section for a discussion on these topics (page 27).

Projected Capital and Operational Costs

The **"first cost" of equipment is expected to increase with time**. The American Innovation and Manufacturing Act requires new heat pumps to switch to refrigerants with a lower global warming potential than had been previously used, and these new refrigerants are expected to increase the cost of new heat pumps in the short-term[41].

In addition, **energy prices are expected to increase** locally and nationally. Locally, APS proposed a 13.99% increase in electric rates starting in 2026[42], and UniSource proposed an increased service charge from $10 per month to $15 per month[43]. These costs are in addition to annual projected price increases for both electricity and gas that are likely to occur regionally. It is important to note that the Arizona Corporation Commission will hear these rate cases in 2026, and there is no guarantee they will be

[40] Low-rise multi-family energy savings: OSTI, ResearchGate, and DOE.
[41] National Association of Home Builders.
[42] ABC15 Arizona.
[43] UniSource Energy Services.

approved. As such, modeling future utility cost increases are based on industry best practices as described below.

Historically, regional energy costs have increased due to growing demand for energy, rising fossil fuel costs (which affects both electricity generation costs and residential retail natural gas prices), inflation, and impacts from geopolitical events. In 2026, a large part of the rise in electricity costs is expected to result from new data centers that are being built to support the growing demand for artificial intelligence systems (AI)[44]. Additionally, rising wholesale natural gas rates are expected to contribute to rising electricity costs and residential rates. Natural gas makes up the largest portion of Arizona's electricity generation fuel mix at 46% in 2023[45]; therefore, rising natural gas costs will also increase electricity rates: the Energy Information Administration (EIA) notes the rising cost of natural gas is "key driver of rising electricity rates…"[46]. The EIA also notes that wholesale increases will lead to increased residential natural gas prices, which are expected to increase by over 5% in 2026.[47] The EIA speculates that these factors will likely increase regional electricity prices by 3.5% in 2026.[48]

The **best ways to partially insulate residents from rising utility costs are to build highly energy-efficient new construction and encourage residents to switch to a more cost-effective electricity plan**, including the APS TOU Plus Demand Charge plan, and for members of the building community to become familiar with the new regulations and technology.

Return on Investment

Simple payback periods – a return on investment (ROI) – provide an easy way to understand how long it will take for energy saving investments to get paid back through monthly utility cost savings. The simple payback period focuses entirely on energy costs and savings and does not include potential impacts of capital costs on mortgages and rents. Even so, calculating accurate simple payback ROIs can be challenging for several reasons.

1. The purpose of this study was to cite accurate costing data that may more realistically reflect what members of the building community are charging new homeowners. Single-family capital costs as referenced in the Capital Cost section were primarily collected through stakeholder interviews as an "all-in" cost – costs that included material, labor, and ancillary equipment. These costs were later averaged with internet research, and the average of market-based research is presented here.
2. Simple ROI calculations are highly sensitive to capital cost estimates, and therefore, **ROI values will vary as capital costs vary**. Table 26 presents a minimum ROI value for the five single-family home scenarios including varying ranges in capital cost and operational cost estimates. Operational cost differentials are calculated within the same utility rate, and the ROI is based on the lowest capital cost differential.
3. It should be noted that the capital cost of ERVs is included in the energy efficiency capital costs below even though builders routinely install them as part of standard builds. ROI estimates do consider rebates or incentive program to reduce upfront costs into considerations (rebates or incentives to reduce upfront costs can reduce the ROI).

---

[44] EnergyCap.
[45] Arizona's state energy profile.
[46] Energy Information Administration (EIA) natural gas contribution to electricity costs.
[47] EIA natural gas cost increases: (changed in residential retail from 12.07 $/ccf to 11.46 $/ccf for the "mountain region" of which Arizona is a part).
[48] EIA electricity cost increases: (change in residential sector from 17.24 cents/kWh to 17.92 cents/kWh).

Tables 30 and 31 present a minimum ROI value based on energy costs for the five single-family and three multi-family home scenarios including varying differentials in capital cost and operational cost estimates. Operational cost differentials are calculated within the same utility rate (the APS TOU Plus Demand Charge Plan), and the **ROI is based on the lowest capital cost differential and projected energy rate escalation**, see the section "Projected Capital and Operational Costs.". Practitioners noted that operational costs can vary widely; where some noted that they may be less than what is presented while others have heard that they can be much greater. The values presented here attempt to illustrate a **potential middle ground.** It should be noted that the capital cost of ERVs is included in the energy efficiency capital costs below even though builders routinely install them as part of standard builds.

Table 30: Summary of expected ROI for highly energy-efficient systems in single-family homes based on the APS TOU Plus Demand Charge Plan

Scenario	Capital Cost Differential		First Year Utility Cost Savings Compared to Mixed-Fuel Base Case	Return on Investment [49]
	Stakeholder Provided Estimate	Market Research Provided Estimate[50]		
1: All-electric, ducted	+$2,500	+$3,000	$130	<15 years
2: All-electric, ductless	-$500	---	$500	Immediate
3: Mixed-fuel, HEE	+$8,500	+$6,500	$270	<18 years
4: All-electric, ducted, HEE	+$11,000	+$9,500	$430	<17 years
5: All-electric, ductless, HEE	+$8,000	+$6,500	$520	<11 years

Green = ROI is shorter than the mixed-fuel base case. Orange = ROI is longer than the mixed-fuel base case.

[49] Utility cost increases are based on industry best practices and assume that electricity rates increase by 3.5% and natural gas rates increase by 5% in 2026. Thereafter, both energy rates are projected to increase by 3%.Energy rate increases past 2026 are based on extensive industry experience and supported by SolarInsure, SolarReviews, and other sources.

[50] DOE, HomeGuide1 and HomeGuide2 system costs.

Table 31: Summary of expected ROI for highly energy-efficient systems in multi-family homes based on the APS TOU Plus Demand Charge Plan

Scenario	Capital Cost Differential		First Year Utility Cost Savings Compared to Mixed-Fuel Base Case	Return on Investment[51]
	Stakeholder Provided Estimate	Market Research Provided Estimate[52]		
1: All-electric, ductless	-$1,200	-$2,000	$200	Immediate
2: Mixed-fuel, HEE	+$6,500	+$4,000	Up to $100	<30 years
3: All-electric, ductless, HEE	+$5,300	+$4,000	$200	<15 years

Green = ROI is shorter than the mixed-fuel base case. Orange = ROI is longer than the mixed-fuel base case.

Key Findings and Additional Considerations

Key Observations

1. While the presented ROIs are relatively long, they may be **conservative** given the large variability of capital costs and electricity rates for the selected APS plan.
2. Capital costs exclude any potential rebates, which have the potential to significantly offset first costs and shorten the ROI period.

Key Takeaways

1. The ROI for most scenarios can fall within the **expected useful lifetime** of the equipment. [53]
2. In addition to cost savings, it is worthwhile to pursue efficiency and electric equipment **for co-benefits** including reduced carbon emissions, better indoor air quality, and improved resilience.
3. **Rebates** on capital costs will improve ROI values**.**

Additional Considerations

1. Without published data specific to Flagstaff, it is difficult to compare ROI values against other studies. We would expect that ROI values for energy efficiency would be within the range of 10 – 15 years based on builder feedback and industry experience. The extended ROI values may be a function of over-inflated capital costs and/or underrepresented operational costs. However, the energy savings from implementing energy efficiency measures and overall trends of cost savings for the various scenarios do align with published studies.
2. **Incentives and rebates** to reduce capital costs could shorten ROI periods significantly.
3. Operational costs have the potential to vary widely due to the set of measures chosen.
4. Operational savings would be greater when comparing operational costs between a Fixed Rate plan and a TOU and/or a TOU Plus Demand Charge plan. The operational savings included in here compare only TOU Plus Demand Charge plans.

---

[51] Utility cost increases are based on industry best practices and assume that electricity rates increase by 3.5% and natural gas rates increase by 5% in 2026. Thereafter, both energy rates are projected to increase by 3%.
[52] Same as above.
[53] Carrier.

Net Zero Single-Family Homes: Capital Costs

Pairing highly energy-efficient and all-electric homes with an on-site solar photovoltaic system can result in a net zero home – a home that that offsets annual energy use with renewable energy produced on site, usually through solar panels. There are several advantages to these types of homes including:

- Reduced carbon emissions by removing reliance on fossil fuels; in some instances, the home may produce zero carbon emissions.
- Reduced energy costs and greater long-term energy price stability for occupants.
- Improved energy independence.
- Increased resiliency, particularly when paired with on-site battery storage.
- Potential higher resale value.
- Increased alignment with personal values.

Using outputs from PVWatts[54] and supplemental desktop calculations, the size and costs of on-site photovoltaic systems to attain net-zero energy use for Flagstaff's representative single-family home scenarios are. The size of the solar PV system needed to offset the home's total annual energy use **decreases as the home's energy use decreases**.

- **Base case:** Mixed-fuel single-family home: **14 kW** and $28,000 to $42,000.
- **Scenario 1:** Ducted, all-electric single-family home: **9 kW** and $18,000 to $27,000.
- **Scenario 2:** Ductless, all-electric single-family home: **6 kW** and $12,600 to $19,000.
- **Scenario 3:** Mixed-fuel, highly energy-efficient single-family home: **11 kW** and $22,000 to $33,000.
- **Scenario 4:** Ducted, all-electric and highly energy-efficient single-family home: **7 kW** and $13,600 to $20,000.
- **Scenario 5:** Ductless, all-electric and highly energy-efficient single-family home: **6 kW** and $12,000 to $18,500.

These are based on solar installation costs range from $2 per W to $3 per W[55], according to local cost estimates provided by Solar United Neighbors (SUN). It should be noted that a member from the building community advises all consumers to consider purchasing a 10 kW to allow for potential changes to the building, and these costs could be underestimated.

4. Additional Benefits to Energy Efficiency and Electrification

While the financial impacts of building highly energy-efficient and all-electric homes are subject to a variety of conditions, the ancillary benefits are clear, especially when compared to mixed-fuel homes. These homes have repeatedly demonstrated cleaner indoor air, translating to improved public health and safety outcomes, and produce fewer carbon emissions than mixed-fuel homes. Builders also shared

[54] PVWatts is a solar tool created by NREL and is commonly used in the industry to estimate energy production from rooftop solar photovoltaic systems.
[55] SUN's cost estimates are "all-in" and include panels, inverters, labor, and other necessary equipment. These costs do not consider additional home modifications.

that they can lead to increased homeowner pride in their home, support the local market evolution, and have the potential for increased investment value.

Improved Indoor Public Health

For years, researchers have documented the link between poor health outcomes, namely respiratory illness, and exposure to hazardous indoor air quality pollutants. Gas stoves and other gas appliance used inside the home release these pollutants, which include particulate matter, methane, benzene, and nitrogen dioxide. Per the National Library of Medicine: "We found that 12.7% of current childhood asthma in the US is attributable to gas stove use."[56] Researchers have also found that these contaminants are released even when the appliances are not in use. These findings have been supported by other independent research institutions.[57,58,59]

Some local builders also noted that all-electric homes have **superior indoor air quality** when compared to mixed-fuel home. They also shared that some homebuyers have read articles about the public health impacts of natural gas appliances and are beginning to ask for electric appliances.

Improved Safety

All-electric homes are **safer** to operate than mixed-fuel homes because they do not burn natural gas. This theme was brought up in the builder interviews. Malfunctioning natural gas appliances carry a risk of carbon monoxide poisoning, fire, and explosion (note: malfunctioning electrical equipment can also carry a risk of electric shocks and fires).

Homeowner Pride

We heard that homeowners take a lot of pride in highly energy-efficient and all-electric homes, and that this pride can spread to more **pride in their neighborhood and community**. Practitioners also noted that to ensure energy efficiency and all-electric systems work financially and practically, it is very important to have a strong design and high-quality construction of the home.

Support Market Evolution and Increased Investment Potential

We heard that building energy-efficient, all-electric homes in Flagstaff can **support the local labor pool** by creating a common approach to installing electrical systems and participating in the market evolution towards electric systems. Practitioners also noted that adding rooftop solar to a development may **increase the value** to potential investors by up to three times.[60]

Reduced Carbon Emissions

Carbon emissions are generated when energy (natural gas and electricity) is used in the home. Emissions are a function of the carbon intensity of the specific energy type consumed. The carbon intensity of natural gas stays constant over time (since the makeup of natural gas does not change), however, the **carbon intensity of electricity changes over time since these emissions are a function of the fuel types used to create electricity**. In 2024, APS's electric grid sourced an energy mix that was 51% zero carbon

[56] National Library of Medicine.
[57] RMI.
[58] John Hopkins University.
[59] Physicians for Social Responsibility.
[60] This anecdote was provided by a builder. The City does not have supporting data.

energy. As of 2025, this energy mix was such that **running equipment off electricity produces fewer carbon emissions** than equipment powered from a mix of electricity and gas.

Figures 1 and 2 demonstrate that the base case mixed-fuel homes generate more carbon emissions (as metric tons of carbon dioxide equivalents [CO_2e]) than any other scenario modeled in this study year after year.

Figure 1. Estimated carbon emissions by system type for a single-family home through 2035

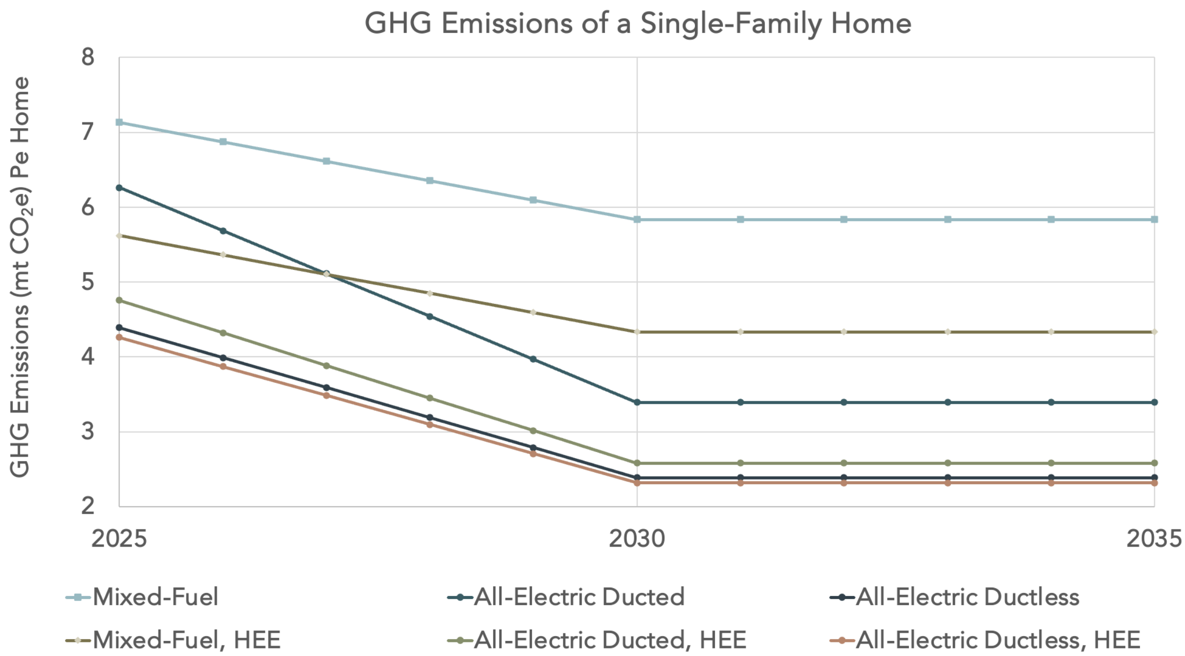
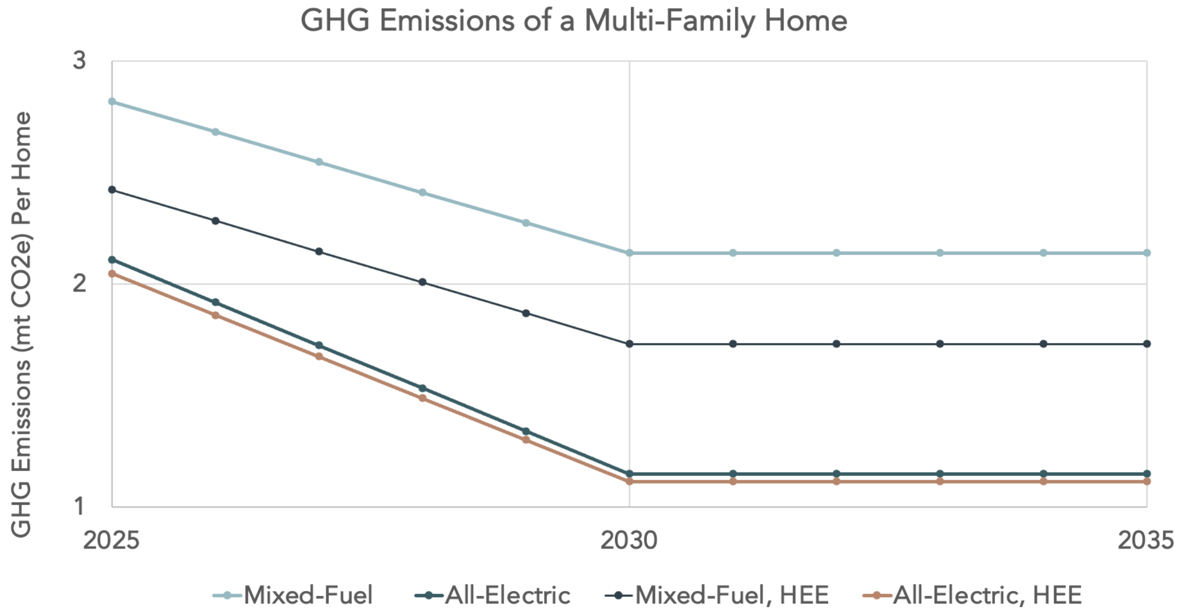


Figure 2. Estimated carbon emissions by system type for a multi-family home through 2035



Note: APS is currently re-evaluating their plans to diversify their fuel sources with more renewables, and therefore, expected carbon emissions are modeled assuming a flat carbon intensity rate from the year 2030 through 2035.[61]

When brought out to the year 2050, our analysis showed that every scenario produced fewer cumulative carbon emissions when compared to a mixed-fuel base case as shown in Table 32. All-**electric ducted homes are projected to produced up to 58% fewer greenhouse gas emissions** than a mixed-fuel home built to Flagstaff's current code.

Table 32. Greenhouse gas emissions reductions compared to mixed-fuel base case

Scenario	Difference in Cumulative Carbon Emissions (present through 2050) Compared to Mixed-Fuel Base Case*	
	Single-Family Homes	Multi-Family Homes
1: All-electric, ducted	-38%	Not applicable
2: All-electric, ductless	-56%	-43%
3: Mixed-fuel, HEE	-25%	-18%
4: All-electric, ducted, HEE	-53%	Not applicable
5: All-electric, ductless, HEE	-58%	-45%

Green = reduction in emissions compared to the mixed-fuel base case (no scenarios produced more emissions than the mixed-fuel base case).

**It should be noted that the modeled parameters chosen to represent "high efficiency" affect the way that savings are experienced. For instance, ductless systems start with a better baseline of energy performance (and lower carbon emissions) due*

[61] KJZZ Phoenix.

to a variety of factors, such as lower distribution losses, and may not be as affected by the measures chosen to represent "high efficiency".

Even as APS' renewable energy commitments fluctuate, APS is still expected to source more electricity from renewables, and it is highly unlikely that gas or coal will usurp existing renewable energy due to lower market rates. Over time, the carbon emission savings from electrification will continue to grow.

5. Barriers to Energy Efficiency and Beneficial Electrification

Thirteen members of the building community shared narratives, some of which may serve as barriers to building energy-efficient and all-electric homes. These narratives reflect impressions that the building community may have and are presented with additional context, including information gathered from this study.

1. We heard that highly energy-efficient and all-electric homes are too costly to install and operate

Builders, general contractors, and subcontractors provided a variety of perspectives on the capital and operational costs of building highly energy-efficient and all-electric homes. Some members of the building community intuitively shared this practice must be more expensive but did not have the extensive experience to support the claim. Further, some builders may actively discourage homebuyers from pursuing efficiency and electric systems in the homes they build because of the real or perceived cost increases. Some builders shared that some organizations actively discourage "green" homes because they fear the homes will be too expensive and will not sell.

Others, who did have extensive experience, were able to share cost data and showed that at times, these types of homes could be more expensive, but often, the difference was less than $5,000. They also shared the following points related to energy efficiency and electrification:

- It is important to prioritize energy efficiency first. For example, one builder noted that all-electric makes the most economic sense (based on load sizing) when the home has a HERS[62] rating of at least 50.
- The current required electrical panel size of 200 amperes is sufficient to support an all-electric home, but panels may need to be upgraded in some cases if electric vehicle charging is added.
- Though not used often, a few general contractors and subcontractors have found that air-to-water heat pumps work more efficiently than air-to-air heat pumps, and many clients prefer in-floor radiant heating and cooling.

All interviewed stakeholders agreed that ductless mini-splits were the less expensive HVAC system to install.

2. We heard that clients typically want gas stoves and fireplaces

While no data suggests that gas stoves are superior to induction cooking, builders shared their experiences indicating that much of the general public assume they are and that they are unwilling to

[62] HERS rating is a scoring system that indicates a home's energy efficient. The lower the score, the more efficient. A score of 100 aligns with the efficiency required by the 2006 IECC, and a score of 0 represents a net-zero home. Homes built to the 2018 IECC typically have a HERS score between 57 and 58.

entertain electric versions. This client preference incentivizes general contractors to facilitate gas connections. However, they also noted that some homebuyers have read articles about the public health impacts of natural gas appliances and are beginning to ask for electric appliances. In general, builders shared that the City may be able to include more advocates for electrification if they focus on electric heating and cooling, while encouraging individual choice for other appliance types.

3. We heard that the City bans, or at a minimum, strongly discourages wood-burning fireplaces

The City does not ban wood-burning stoves or fireplaces. However, this belief incentivizes general contractors to facilitate gas connections in new construction. The City does offer a rebate to help support residents with an older wood stove to replace it with an EPA certified wood stove[63] (applies to existing construction only).

4. We heard that electric heat pumps do not work in cold climates

Not all general contractors nor subcontractors were familiar with ccASHPs. A traditional heat pump may not be able to supply enough heat to meet Flagstaff's heating demand, and even ten years ago, heat pumps were not as effective as they are today at providing heating efficiently at colder temperatures. Some builders continue to feel more comfortable installing backup heat systems or a "hybrid" system – mixed-fuel with electric. Other builders have noted that a backup heating system is not necessary in Flagstaff's climate, and this anecdote is supported by actual projects they have completed themselves. Builders noted that some members of the public also have concerns about heat pumps in cold temperatures.

Today, ample evidence exists in both manufacturer[64,65,66] and NEEP (Northeast Energy Efficiency Partnership) performance and specification sheets. Real-world case studies also support the viability of cold-climate heat pumps in cold climates. Further, a local installer has installed between 400 and 500 ccASHPs in Flagstaff (ducted and ductless mini-split systems) and has not received a single negative report about their ability to meet intended heating and cooling loads. Similarly, a local designer noted that recently, a new all-electric multi-family structure has been constructed, and it's been "very successful".

5. We heard that heat pumps will shut down should a power grid outage occur, while natural gas appliances will still work

Natural gas infrastructure operates using a series of pumps and motors, which are powered by electricity. Should the grid go down, electric and most gas appliances will be equally affected. Though it should be noted that some newer, gas furnaces are available to operate with minimal or no electricity and are labeled as "off-grid" furnaces (such as the Millivolt gas furnace), these are rare and may not meet code due to their poor efficiencies. Some builders emphasized public fears of the grid going down and/or the heat pump not being able to provide enough heat in the winter make homeowners more comfortable with energy efficiency upgrades than installing electric appliances.

6. We heard that electric tankless water heaters should be installed as part of all-electric systems

Tankless water heaters are not preferred due to their high electric demand (and thus, high utility costs) unless the goal is to provide hot water on demand or save space. Generally, electric heat pump water heaters are recommended for installation due to their high efficiency and demonstrated performance in

[63] Home Weatherization and Energy Rebate Program | City of Flagstaff Official Website.
[64] Carrier.
[65] Mitsubishi.
[66] Trane.

Flagstaff. This demonstrates another gap in the adoption of new equipment offerings that could offer many benefits within Flagstaff homes.

7. We heard concern about utility monopolies, particularly APS

Many members of the building community were uncomfortable with the monopoly that APS has as the sole electricity provider in the Flagstaff region, and electrifying homes gives more control to APS.[67] Further, many members of the building community do not see APS as a building advocate, and they may even at times, see them as hindering the process. However, they shared that encouraging more on-site solar generation and battery storage would reduce APS' influence, reduce carbon emissions, and improve self-resilience and energy independence.

8. We heard different viewpoints on whether to adopt stronger energy codes. Some builders would like to keep Flagstaff's current energy code (the 2018 IECC) and apply cost savings from not installing additional energy efficiency features toward home electrification and on-site solar. The 2018 IECC was a big improvement in efficiency standards over previous codes and has been shown to be strong baseline for building performance. Some builders feel that incremental costs to further improving efficiency may not be necessary, and this additional money could be spent on electrifying the homes and buying on-site solar photovoltaic systems. If the money was used to purchase these systems, carbon emissions would be significantly reduced, and the City may be able to reach its carbon goals more quickly. In contrast, we also heard that the only way to increase energy efficiency across the board is increase the minimum energy efficiency standards through updated Building and Fire Codes, including the energy code.

Getting to net-zero without reducing energy consumption first means that a home will have higher utility bills and pay more for a larger solar photovoltaic system than they would if energy consumption were reduced. For example, the optional Net-Zero appendix to the 2024 IECC requires energy use to decrease 31% over the 2018 IECC prior to the installation of solar panels to reduce annual energy use and reduce the size of the solar photovoltaic system.

9. We heard that ideology may influence who builds energy-efficient and all-electric construction

Builders who identified indoor air quality, climate change, and protecting the environment, for example, as their top concerns are more likely to build highly energy-efficient and all-electric homes. Builders who identified costs, the desire to provide customer choice, the desire for the market to dictate building trends, and concerns about APS having a monopoly as their top concerns are more likely to build mixed-fuel homes, even if many of these homes also exceed Flagstaff's current energy-efficiency standards. Builders agreed that support to offset the additional costs of all-electric construction, for example, could help increase the amount of all-electric homes that are built by builders from across the ideological spectrum.

10. We heard that there is a limited pool of subcontractor expertise and how this increases construction costs

A lack of a deep pool of local expertise to install energy efficiency features and heat pumps can lead to builders looking for labor outside of Flagstaff, which requires subcontractors to travel, and increases costs. Builders noted it is already very expensive to build in Flagstaff and that additional requirements such as energy efficiency make building even more unattractive from a financial perspective.

---

[67]Both APS and Unisource are "regulated monopolies," which grant them an exclusive right to serve a particular area without competition in exchange for government oversight. The Arizona Corporation Commission (ACC) regulates public utilities in Arizona, including setting electricity and natural gas rates. Other states have deregulated electricity markets, which means that electricity generation is open to competition (multiple companies can sell electricity). Public utility commissions in these states primarily focus on regulating the distribution of electricity and ensuring customer service standards are met.

11. We heard about other challenges that act as a barrier to highly energy-efficient and all-electric construction

Builders shared several additional barriers that do not fall into any of the categories above:

- It is generally challenging to build in Flagstaff, which makes it harder to meet additional standards, such as building highly energy-efficient and all-electric homes.
- There is a shrinking middle class, and it is becoming more difficult to build higher quality, more expensive homes – they are only available to a few with means.
- Architects noted that even if a house is designed a certain way, ultimate construction decisions are made by the general contractors, who may also be influenced by their subcontractor. If the contractor or subcontractor are not familiar with energy-efficient, all-electric appliances and HVAC systems, they may be more likely to make design decisions in favor of less energy-efficient and/or natural gas-powered equipment.

6. Recommendations

Formal recommendations to advance energy efficiency and beneficial electrification in new construction are included below. These consider stakeholder and City staff feedback, industry best practices, and modeling results.

1. Adopt the 2024 IECC and Appendix RG: 2024 IECC Stretch Code

Advancing energy efficiency is good for the community: it will save operational costs, it is healthier, safer, and cleaner for our planet, and has proven to improve occupant comfort. Several builders noted that the only way to ensure the Flagstaff community realizes these benefits is by requiring it of all new builds through the adoption of new building codes. New building codes include the base 2024 IECC that is projected to save approximately 14% of energy usage and the 2024 IECC Appendix RG: 2024 IECC Stretch Code that is projected to save an additional 10% of energy. Together, national studies project this building code package is projected to reduce energy consumption of new residential buildings by 24% in Flagstaff’s climate zone, though it will vary depending on the measures chosen. The modeled savings in this study showed an approximate reduction of 27% in energy usage.

Improving energy efficiency is a key component of lowering greenhouse gas emissions from the built environment, and can support residents in lowering utility costs by decreasing energy use (and can partially insulate residents from future utility cost increases). The City can support builders in implementing new codes through education, training, and outreach opportunities as noted below.

2. Encourage New Home Construction to Be All-Electric

As with energy efficiency, advancing all-electric homes is also good for the community: with the correct system it has the potential to reach cost parity with traditional, mixed-fuel systems, it will save operational costs, and it is healthier, safer, and cleaner for our planet. The City can advocate and encourage new builds to be all-electric through education, outreach, and incentives.

3. Adopt Appendix RK Electric-Ready Residential Building Provision of the 2024 IECC

Adopting Appendix RK Electric-Ready Residential Building Provision of the 2024 IECC increases resident choice by making it easier and less costly for residents in mixed-fuel homes to switch to electric appliances in the future.

4. Adopt Appendix RB Solar-Ready Provisions – Detached One- and Two-Family Dwellings and Townhouses of the 2024 IECC

Adopting this appendix will make it easier for residents to install on-site photovoltaic panels and battery storage, and will allow them to achieve partial or full energy independence with associated long-term cost savings. Note: Flagstaff adopted the 2018 version of this appendix as part of its current energy code. Building net-zero homes complete with on-site photovoltaic panels and battery storage can mitigate this concern by enabling homeowners to generate and store their own energy and operate with greater independence from the electrical grid.

5. Provide Extensive Education and Outreach to Encourage Energy Efficiency and Beneficial Electrification in New Home Construction

1. Reference "Common Narratives" to inform education and outreach material to potential homebuyers, members of the building community, and local organizations such as the Chamber of Commerce and the Northern Arizona Association of Realtors. This gap in knowledge about ccASHPs – a relatively new but now well-established technology – will hinder Flagstaff's ability to take advantage of electrification benefits without proper outreach.
    a. Emphasize the public health benefits of energy-efficient and all-electric construction.
2. Prioritize building science education and outreach with subcontractors and general contractors, as they may be the most influential member(s) of the homebuilding process.
    a. Consider partnering with Coconino Community College to market and offer building science seminars and an opportunity to build connections with other members of the building community.
        i. Discuss how to model heating and cooling loads and effectively size heat pump equipment. Introduce the most impactful energy saving measures: reduced air infiltration, tight building envelope, and improved insulation (which also align with those measures targeted in the Stretch Code).
    b. Advertise existing seminars, such as those put on by equipment manufacturers, to help train members of the building community. Builders noted that presenting performance facts has been a useful way to build support for these types of homes in the past.
    c. Emphasize the nuances between the cost differences of mixed-fuel and highly energy-efficient, all-electric homes. Explain that this is not straightforward to present nor understand, as demonstrated in this report.
    d. Present case studies showcasing successful, local implementation of all-electric and highly energy-efficient systems, and real-world capital and operational cost data.
    e. Outline what is currently required by code and describe the benefit of installing measures that align with the Stretch Code. This work could help increase the uptake of energy efficiency measures, particularly among contractors who do not see the value of installing energy efficiency measures beyond what is required today.
3. Clarify and conduct public outreach on City policies around wood fireplaces and wood stove rebates.
4. Conduct public and developer-focused outreach on the benefits and implications of APS TOU plans, including the TOU Plus Demand Charge plan.
5. Teach potential homeowners about the benefits of electric heating and cooling equipment – ccASHPs and mini-splits. Heating and cooling equipment has the largest potential to reduce emissions, since these appliances are responsible for the bulk of energy usage.[68] In addition, practitioners stated that consumers are generally more agnostic when it comes to heating and cooling equipment as opposed to cooking appliances and fireplaces.

[68] EIA (Eneryg Information Administration): heating and cooling energy represents more than half of energy usage.

6. Host a Gas Stove vs Induction Stove Cooking Demonstration Exhibit

Demonstrations performed elsewhere have significantly helped improve community support of induction cooking[69]. Consider doing in connection with a Coconino Community College building science seminar. Ensure the exhibit is available to the public and members of the building community.

7. Offer Incentives and Equipment Purchasing Support for Energy Efficiency and/or All-Electric Features to Reduce Upfront Costs

1. Provide monetary incentives, such as up to $3,000 per project, when a general contractor proceeds with an all-electric home. Members of the building community noted that a rebate would significantly help more of these types of homes be built.
2. If incentives are offered for new construction in the future, work to ensure a minimal paperwork burden for the builder, general contractor, and subcontractors when applying for these incentives.

8. Set-up a Heat Pump Co-Operative Program for New Residential Construction

Set up a co-operative for new construction similar to the one that exists for installing solar photovoltaic panels and battery storage on existing homes. Contractors stated they would be willing to share these prices as part of their outreach with clients. It was noted that this approach would be especially useful for multi-family units but would be difficult for custom homes as their home designs will have more design variability.

9. Strengthen Relationships with APS and the Building Community

1. Set up regular working meetings between APS to identify ways in which APS can better support the building community.
    a. Leverage their support for energy efficiency and all-electric and share the information with the building community about APS's ability to accommodate additional electric demand.
2. Leverage this study as an inroad to building stronger relationships with members of the building community.
3. Facilitate peer-to-peer educational opportunities and coalition building through a Builders Association or other means, like a City-sponsored panel.
    a. Enable peers to share best practices and lessons learned directly to one another, e.g., application and results from air-to-water source heat pumps, real-world case studies of heat pump operation at low temperatures, client testimonials, heat load sizing, alternative to gas fireplaces, evolving battery technology, etc.

---

[69] Alida.

Appendix A: Detailed Simulation Methodology and Assumptions

Methodology to Determine Loads for Single-Family Homes

This works aims to emulate the process that a contractor would use to price out heating and cooling equipment. Contractors can use a variety of methods and tools to size equipment; CoolCalc is a popular tool used by contractors and was chosen so we could get the same loads that a contractor might get and therefore, similar pricing estimates. "*CoolCalc Manual J is a web based, ACCA approved MJ8 heating and cooling load calculator that allows you to do accurate load calculations in less time and with less hassle than traditional load calculation software or spreadsheet.*"

Reviewers are encouraged to evaluate high-level cost differentials and trends as noted in the main body of the study, rather than to focus on the detailed inputs as they might be different between members of the building community.

CoolCalc Assumptions and Inputs

All inputs were kept the same for each building scenario excepted where highlighted.

Inputs are based on a single-family home building drawing. Though details will vary by home, inputs are meant to serve as a "representative" home.

Mixed-Fuel Home

- Used generic address of "Flagstaff, AZ" to account for averages.
- Choose Room by room for new construction and to consider mini-split option.
- Assumed earliest a new home could be built would be 2026.
- Assumes:
    - 1 above-grade story.
    - 3 bedrooms.
    - Single-family .
    - No basement.
    - Slab on grade
    - No conditioned "bonus room". (There is an attic, assume that it's not conditioned.)
    - No skylights.
    - No blower door test (new build).
    - Average leakage.
    - 1 fireplace in the living room.
    - Framed walls with exterior siding.
    - Ceiling is under attic (not encapsulated attic).
    - Roofing material includes dark asphalt shingles.
    - Floor is over an enclosed unconditioned crawlspace.
    - Frame construction: 2 x 6.

    - Cavity insulation: R-21 (plans specify R-20 min).
    - No board insulation.
    - Attic vented according to FHA guidelines.
    - No attic fan.
    - No attic radiant barrier.
    - Roof R-38 (plans call for this to be the minimum).
    - Wooden, hollow doors.
    - Crawlspace insulation of R-15 and vented; per County email.
    - No radiant floor heat.
    - R-30 insulation for the floor.
    - Windows are NFRC rated.
    - Windows are low-e with U-value of 0.30 and SHGC of 0.25.
    - Duct insulation R-8.
    - Outside air damper with 60 CFM exhaust
- Room types:
    - Assume garage is not conditioned and therefore, is not included in analysis.
    - Bedroom 1:
        - Avg room height: 9 ft.
        - Exposed wall area
            - Western exposure with 12 feet of exposure and no window and no doors.
            - Northern exposure with 12 feet of exposure and low window area and no doors.
        - Assumes:
            - 1 occupant per room.
            - 0 plants.
            - 0 appliances.
    - Bedroom 2:
        - Avg room height: 9 ft.
        - Exposed wall area
            - Western exposure with 12 feet of exposure and no window and no doors.
            - Southern exposure with 12 feet of exposure and low window area and no doors.
        - Assumes:
            - 1 occupant per room.
            - 0 plants.
            - 0 appliances.
    - Master bedroom:
        - Avg room height: 9 ft.
        - Exposed wall area
            - Northern exposure with 16 feet of exposure and high window and no doors.
        - Assumes:
            - 2 occupant per room.
            - 0 plants.
            - 0 appliances.
    - Living room:

        - Avg room height: vaulted, assume: 12 ft.
        - Exposed wall area
            - Northern exposure with 24 feet of exposure and high window and no doors.
        - Assumes:
            - 4 occupant per room.
            - 4 plants.
            - 1 TV, 1 computer and monitor, 3 100-W light fixtures
    - Den
        - Avg room height: vaulted, assume: 12 ft.
        - Exposed wall area
            - Southern exposure with 7 feet of exposure and medium window and no doors.
        - Assumes:
            - 4 occupant per room.
            - 2 plants.
            - 1 TV, 1 computer and monitor, 3 100-W light fixtures
    - Kitchen
        - Avg room height: vaulted, assume: 12 ft.
        - Exposed wall area
            - Southern exposure with 16 feet of exposure and low window and one door.
        - Assumes:
            - 4 occupant per room.
            - 0 plants.
            - Range with hood, dishwasher, refrigerator with freezer.
    - Laundry
        - Avg room height: 9 feet.
        - Exposed wall area
            - None.
        - Assumes:
            - 0 occupant per room.
            - 0 plants.
            - Clothes washing machine and vented clothes dryer
    - Bathroom
        - Avg room height: 9 feet.
        - Exposed wall area
            - Western exposure with 8 feet with no windows.
        - Assumes:
            - 0 occupant per room.
            - 0 plants.
            - 0 appliances.
    - Master bathroom
        - Avg room height: 9 feet.
        - Exposed wall area
            - Northern exposure with 11 feet with medium windows.
            - Eastern exposure with 15 feet with low windows.
        - Assumes:

        - 0 occupant per room.
        - 0 plants.
        - 0 appliances.
- Assumes:
    - Ducted ccASHP situation:
        - All rooms are served.
        - Provides heating and cooling.
        - Ducted system.
        - Winter indoor T: 70 deg F
        - Summer indoor T: 75 deg F
        - Summer indoor relative humidity: 45%
        - Drawings state "…provide makeup outside air and ventilation as required by IRC 303.4". Assume min ventilation and exhaust rates of 60 CFM for a 3-bedroom home with a floor area between 1,501 and 3,000 SF.
        - Adjust performance data for blower heat.
        - Assume that the home does not have a humidifier without its own heat source.
        - Drawings say "…coordinate with owner and mechanical contractor for location of ductwork." Assume ducts are installed in the crawlspace with R-6.
    - Hot water piping:
        - This section does not need to be completed because the Manual J calculations do not account for heat loss from hot water heating pipes.

Energy Efficient Home

Green text reflects additions made to model highly energy-efficient homes; values come from the 2024 IECC Appendix RG: 2024 IECC Stretch Code.

- Used generic address of "Flagstaff, AZ" to account for averages.
- Choose Room by room for new construction and to consider mini-split option.
- Assumed earliest a new home could be built would be 2026.
- Assumes:
    - 1 above-grade story.
    - Slab on grade.
    - 3 bedrooms.
    - Duplex dwelling type.
    - No basement.
    - No conditioned "bonus room". (There is an attic, assume that it's not conditioned.)
    - No skylights.
    - No blower door test (new build).
    - Tight leakage.
    - 1 fireplace in the living room.
    - Framed walls with exterior siding.
    - Ceiling is under attic (not encapsulated attic).
    - Roofing material includes dark asphalt shingles.
    - Floor is over an enclosed unconditioned crawlspace.
    - Frame construction: 2 x 6.
    - Cavity insulation: R-21 (plans specify R-20 min).
    - No board insulation.

- Attic vented according to FHA guidelines.
- No attic fan.
- No attic radiant barrier.
- Roof R-50 (ceiling)
  - The 2024 International Energy Conservation Code (IECC) reduces ceiling insulation R-values compared to the 2021 IECC in some climate zones due to a shift in focus towards a performance-based approach, allowing for trade-offs between envelope efficiency and mechanical system efficiency. This means that while ceiling insulation requirements may be lower, the overall energy performance of the building can still be improved by optimizing other factors like HVAC systems and ductwork.
- Wooden, hollow doors.
- Crawlspace insulation of R-19 and sealed/tight.
- No radiant floor heat.
- R-30 insulation for the floor.
- Windows are NFRC rated.
- Windows are low-e with U-value of 0.28 and SHGC of 0.25 (SHGC is not mandated).
- Hot water pipe insulation – R-7 for ¾ pipe
- Extremely well sealed ducts with R-8
- Outside air damper with 60 CFM exhaust
- Drawings state "…provide makeup outside air and ventilation as required by IRC 303.4". Assume min ventilation and exhaust rates of 60 CFM for a 3-bedroom home with a floor area between 1,501 and 3,000 SF.
- In climate zone 6, must have HRV or ERV (Flagstaff is climate zone 5B)
  - Assume ERV: 70% heating and cooling efficiency per: https://www.fpl.com/content/dam/fplgp/us/en/business/save/programs/pdf/erv-primer.pdf
  - Assume latent cooling efficiency of 60% per: https://www.sciencedirect.com/science/article/abs/pii/S1359431123010189

Methodology to Determine Loads for Multi-Family Homes

This works aims to emulate the process that a contractor would use to price out heating and cooling equipment. Contractors can use a variety of methods and tools to size equipment; CoolCalc is a popular tool used by contractors and was chosen so we could get the same loads that a contractor might get and therefore, similar pricing estimates. "*CoolCalc Manual J is a web based, ACCA approved MJ8 heating and cooling load calculator that allows you to do accurate load calculations in less time and with less hassle than traditional load calculation software or spreadsheet.*"

Reviewers are encouraged to evaluate high-level cost differentials and trends as noted in the main body of the study, rather than to focus on the detailed inputs as they might be different between members of the building community.

CoolCalc Assumptions and Inputs

Inputs are based on an multi-family complex drawing. The average outputs from three representative units were used to estimate capital costs of installed equipment. Though details will vary by unit, inputs are meant to serve as a "representative" home.

Mixed-Fuel Home

Representative Top Floor Units

Top-floor, N/W exposure – Unit B (West) on 3rd floor

- SF: 1,079
- Used generic address of "Flagstaff, AZ" to account for averages.
- Choose Room by room for new construction and to consider mini-split option.
- Assumed earliest a new home could be built would be 2026.
- Assumes:
    - 1 above-grade story.
    - 3 bedrooms.
    - Condo.
    - No basement.
    - Slab on grade – chosen as placeholder *but not assigned to rooms.*
    - No conditioned "bonus room".
    - No skylights.
    - No blower door test (new build).
    - Average leakage.
    - No fireplaces.
    - Framed walls with exterior siding.
    - Ceiling is under attic (not encapsulated attic).
    - Roofing material includes dark asphalt shingles.
    - Exterior wall frame construction: 2 x 6 at 16' OC.
    - No radiant floor heating.
    - Cavity insulation: R-21.
    - No board insulation.
    - Attic vented according to FHA guidelines.
    - No attic fan.
    - No attic radiant barrier.
    - Roof R-50 (based on referenced 2018 IECC).
    - Wooden, hollow doors.
    - No radiant floor heat.
    - R-30 insulation for the floor; *ignored floor values.*
    - Windows are NFRC rated.
    - Windows are low-e with U-value of 0.30 and SHGC of 0.25.
    - Ceiling R-50.
- Room types:
    - Bedroom 1:
        - Avg room height: 9 ft.
        - Exposed wall area

        - Northern exposure with 13 feet of exposure and medium window area and no doors.
    - Assumes:
        - 1 occupant per room.
        - 0 plants.
        - 0 appliances.
    - Use a floor area of 0 SF so it doesn't consider contribution to heating and cooling loads.
- Bedroom 2:
    - Avg room height: 9 ft.
    - Exposed wall area
        - Northern exposure with 10 feet of exposure and medium window area and no doors.
    - Assumes:
        - 1 occupant per room.
        - 0 plants.
        - 0 appliances.
    - Use a floor area of 0 SF so it doesn't consider contribution to heating and cooling loads.
- Bedroom 3:
    - Avg room height: 9 ft.
    - Exposed wall area
        - Northern exposure with 11 feet of exposure and medium window area and no doors.
        - Western exposure with 11 feet of exposure and medium window area and no doors.
    - Assumes:
        - 1 occupant per room.
        - 0 plants.
        - 0 appliances.
    - Use a floor area of 0 SF so it doesn't consider contribution to heating and cooling loads.
- Great room:
    - Avg room height: 9 ft.
    - Exposed wall area
        - None.
    - Total area: 324 SF
    - Assumes:
        - 4 occupant per room.
        - 4 plants.
        - 1 TV, 1 computer and monitor, 3 100-W light fixtures
    - Use a floor area of 0 SF so it doesn't consider contribution to heating and cooling loads.
- Kitchen
    - Avg room height: 9 ft.
    - Exposed wall area:
        - None.
    - Total area: 200 SF

        - Assumes:
            - 4 occupant per room.
            - 0 plants.
            - Range with hood, dishwasher, refrigerator with freezer.
        - Use a floor area of 0 SF so it doesn't consider contribution to heating and cooling loads.
    - Bathroom 1
        - Avg room height: 9 feet
        - Exposed wall area
            - None.
        - Total area: 90 SF
        - Assumes:
            - 0 occupant per room.
            - 0 plants.
            - 0 appliances.
        - Use a floor area of 0 SF so it doesn't consider contribution to heating and cooling loads.
    - Bathroom 2
        - Avg room height: 9 feet
        - Exposed wall area
            - Northern exposure with 10 feet of exposure and low window area and no doors.
        - Assumes:
            - 0 occupant per room.
            - 0 plants.
            - 0 appliances.
        - Use a floor area of 0 SF so it doesn't consider contribution to heating and cooling loads.
- Assumes:
    - Ductless ccASHP situation:
        - All rooms are served.
        - Provides heating and cooling.
        - Winter indoor T: 70 deg F
        - Summer indoor T: 75 deg F
        - Summer indoor relative humidity: 45%
        - Outside damper: 60 CFM for ventilation and 0 for exhaust.
        - Adjust performance data for blower heat.
        - Assume that the home does not have a humidifier without its own heat source.
    - Hot water piping:
        - This section does not need to be completed because the Manual J calculations do not account for heat loss from hot water heating pipes.

Representative Middle Floor Units

Middle-floor, S/W exposure – Unit B (West) on 2nd floor

- SF: 1,080.
- Used generic address of "Flagstaff, AZ" to account for averages.

- Choose Room by room for new construction and to consider mini-split option.
- Assumed earliest a new home could be built would be 2026.
- Assumes:
    - 1 above-grade story.
    - 2 bedrooms.
    - Condo.
    - No basement.
    - Slab on grade – chosen as placeholder *but not assigned to rooms.*
    - No conditioned “bonus room”.
    - No skylights.
    - No blower door test (new build).
    - Average leakage.
    - No fireplaces.
    - Framed walls with exterior siding.
    - Ceiling is under attic (not encapsulated attic), *chosen as placeholder, but not assigned to rooms.*
    - Roofing material includes dark asphalt shingles.
    - Exterior wall frame construction: 2 x 6 at 16’ OC.
    - No radiant floor heating.
    - Cavity insulation: R-21.
    - No board insulation.
    - Attic vented according to FHA guidelines.
    - No attic fan.
    - No attic radiant barrier.
    - Roof R-50 (based on referenced 2018 IECC), *chosen as placeholder, but not assigned to rooms.*
    - Wooden, hollow doors.
    - No radiant floor heat.
    - R-30 insulation for the floor; *ignored floor values.*
    - Windows are NFRC rated.
    - Windows are low-e with U-value of 0.30 and SHGC of 0.25.
- Room types:
    - Bedroom 1:
        - Avg room height: 9 ft.
        - Exposed wall area:
            - None.
        - Assumes:
            - 1 occupant per room.
            - 0 plants.
            - 0 appliances.
        - Use a floor and ceiling area of 0 SF so it doesn’t consider contribution to heating and cooling loads.
    - Bedroom 2:
        - Avg room height: 9 ft.
        - Exposed wall area:
            - Southern exposure with 14 feet of exposure and medium window area and no doors.
        - Assumes:

        - 1 occupant per room.
        - 0 plants.
        - 0 appliances.
    - Use a floor and ceiling area of 0 SF so it doesn't consider contribution to heating and cooling loads.
- Great room:
    - Avg room height: 9 ft.
    - Exposed wall area:
        - Western exposure with 15 feet of exposure and medium window area and no doors.
    - Total area: 300 SF
    - Assumes:
        - 4 occupant per room.
        - 4 plants.
        - 1 TV, 1 computer and monitor, 3 100-W light fixtures
    - Use a floor and ceiling area of 0 SF so it doesn't consider contribution to heating and cooling loads.
- Kitchen
    - Avg room height: 9 ft.
    - Exposed wall area:
        - None.
    - Total area: 180 SF
    - Assumes:
        - 4 occupant per room.
        - 0 plants.
        - Range with hood, dishwasher, refrigerator with freezer.
    - Use a floor and ceiling area of 0 SF so it doesn't consider contribution to heating and cooling loads.
- Bathroom 1
    - Avg room height: 9 feet
    - Exposed wall area:
        - None.
    - Total area: 90 SF
    - Assumes:
        - 0 occupant per room.
        - 0 plants.
        - 0 appliances.
    - Use a floor and ceiling area of 0 SF so it doesn't consider contribution to heating and cooling loads.
- Bathroom 2
    - Avg room height: 9 feet
    - Exposed wall area:
        - Southern exposure with 10 feet of exposure and low window area and no doors.
    - Total area: 150 SF
    - Assumes:
        - 0 occupant per room.
        - 0 plants.

      - 0 appliances.
    - Use a floor and ceiling area of 0 SF so it doesn't consider contribution to heating and cooling loads.
- Assumes:
  - Ductless ccASHP situation:
    - All rooms are served.
    - Provides heating and cooling.
    - Winter indoor T: 70 deg F
    - Summer indoor T: 75 deg F
    - Summer indoor relative humidity: 45%
    - Outside damper: 60 CFM for ventilation and 0 for exhaust.
    - Adjust performance data for blower heat.
    - Assume that the home does not have a humidifier without its own heat source.
  - Hot water piping:
    - This section does not need to be completed because the Manual J calculations do not account for heat loss from hot water heating pipes.

Representative Ground Floor Units

First-floor, N/E exposure – Unit A on 1st floor

- SF: 808 SF
- Used generic address of "Flagstaff, AZ" to account for averages.
- Choose Room by room for new construction and to consider mini-split option.
- Assumed earliest a new home could be built would be 2026.
- Assumes:
  - 1 bedroom.
  - Condo.
  - No basement.
  - Slab on grade.
  - No conditioned "bonus room".
  - No skylights.
  - No blower door test (new build).
  - Average leakage.
  - No fireplaces.
  - Framed walls with exterior siding.
  - Ceiling is under attic (not encapsulated attic), *chosen as placeholder, but not assigned to rooms.*
  - Roofing material includes dark asphalt shingles.
  - Exterior wall frame construction: 2 x 6 at 16' OC.
  - No radiant floor heating.
  - Cavity insulation: R-21.
  - No board insulation.
  - Attic vented according to FHA guidelines.
  - No attic fan.
  - No attic radiant barrier.
  - Roof R-50 (based on referenced 2018 IECC), *chosen as placeholder, but not assigned to rooms.*
  - Wooden, hollow doors.

- No radiant floor heat.
- R-30 insulation for the floor.
- Windows are NFRC rated.
- Windows are low-e with U-value of 0.30 and SHGC of 0.25.

- Room types:
  - Bedroom 1:
    - Avg room height: 9 ft.
    - Exposed wall area:
      - Northern exposure with 15 feet of exposure and high window area and no doors.
    - Assumes:
      - 1 occupant per room.
      - 0 plants.
      - 0 appliances.
    - Use a ceiling area of 0 SF so it doesn't consider contribution to heating and cooling loads.
  - Great room:
    - Avg room height: 9 ft.
    - Exposed wall area:
      - Eastern exposure with 15 feet of exposure and medium window area and no doors.
    - Total area: 300 SF.
    - Assumes:
      - 4 occupant per room.
      - 4 plants.
      - 1 TV, 1 computer and monitor, 3 100-W light fixtures
    - Use a ceiling area of 0 SF so it doesn't consider contribution to heating and cooling loads.
  - Kitchen
    - Avg room height: 9 ft.
    - Exposed wall area:
      - None.
    - Total area: 180 SF
    - Assumes:
      - 4 occupant per room.
      - 0 plants.
      - Range with hood, dishwasher, refrigerator with freezer.
    - Use a ceiling area of 0 SF so it doesn't consider contribution to heating and cooling loads.
  - Bathroom 1
    - Avg room height: 9 feet.
    - Exposed wall area:
      - Northern exposure with 15 feet of exposure and low window area and no doors.
    - Total area: 90 SF.
    - Assumes:
      - 0 occupant per room.
      - 0 plants.

                - 0 appliances.
            - Use a ceiling area of 0 SF so it doesn't consider contribution to heating and cooling loads.
- Assumes:
    - Ductless ccASHP situation:
        - All rooms are served.
        - Provides heating and cooling.
        - Winter indoor T: 70 deg F
        - Summer indoor T: 75 deg F
        - Summer indoor relative humidity: 45%
        - Outside damper: 60 CFM for ventilation and 0 for exhaust.
        - Adjust performance data for blower heat.
        - Assume that the home does not have a humidifier without its own heat source.
    - Hot water piping:
        - This section does not need to be completed because the Manual J calculations do not account for heat loss from hot water heating pipes.

Energy Efficient Home

Green text reflects additions made to model highly energy-efficient homes; values come from 2024 IECC Appendix RG: 2024 IECC Stretch Code.

Representative Top Floor Units

Top-floor, N/W exposure – Unit B (West) on 3rd floor

- SF: 1,079
- Used generic address of "Flagstaff, AZ" to account for averages.
- Choose Room by room for new construction and to consider mini-split option.
- Assumed earliest a new home could be built would be 2026.
- Assumes:
    - 1 above-grade story.
    - 3 bedrooms.
    - Condo.
    - No basement.
    - Slab on grade – chosen as placeholder *but not assigned to rooms.*
    - No conditioned "bonus room".
    - No skylights.
    - No blower door test (new build).
    - Tight leakage.
    - No fireplaces.
    - Framed walls with exterior siding.
    - Ceiling is under attic (not encapsulated attic).
    - Roofing material includes dark asphalt shingles.
    - Exterior wall frame construction: 2 x 6 at 16' OC.
    - No radiant floor heating.
    - Cavity insulation: R-21.
    - No board insulation.

- Attic vented according to FHA guidelines.
- No attic fan.
- No attic radiant barrier.
- Roof R-50 (based on referenced 2018 IECC).
- Wooden, hollow doors.
- No radiant floor heat.
- R-30 insulation for the floor; *ignored floor values.*
- Windows are NFRC rated.
- Windows are low-e with U-value of 0.28
- Roof R-50 (ceiling).

- Room types:
  - Bedroom 1:
    - Avg room height: 9 ft.
    - Exposed wall area:
      - Northern exposure with 13 feet of exposure and medium window area and no doors.
    - Assumes:
      - 1 occupant per room.
      - 0 plants.
      - 0 appliances.
    - Use a floor area of 0 SF so it doesn't consider contribution to heating and cooling loads.
  - Bedroom 2:
    - Avg room height: 9 ft.
    - Exposed wall area:
      - Northern exposure with 10 feet of exposure and medium window area and no doors.
    - Assumes:
      - 1 occupant per room.
      - 0 plants.
      - 0 appliances.
    - Use a floor area of 0 SF so it doesn't consider contribution to heating and cooling loads.
  - Bedroom 3:
    - Avg room height: 9 ft.
    - Exposed wall area:
      - Northern exposure with 11 feet of exposure and medium window area and no doors.
      - Western exposure with 11 feet of exposure and medium window area and no doors.
    - Assumes:
      - 1 occupant per room.
      - 0 plants.
      - 0 appliances.
    - Use a floor area of 0 SF so it doesn't consider contribution to heating and cooling loads.
  - Great room:
    - Avg room height: 9 ft.

        - Exposed wall area:
            - None.
        - Total area: 324 SF.
        - Assumes:
            - 4 occupant per room.
            - 4 plants.
            - 1 TV, 1 computer and monitor, 3 100-W light fixtures
        - Use a floor area of 0 SF so it doesn't consider contribution to heating and cooling loads.
    - Kitchen
        - Avg room height: 9 ft.
        - Exposed wall area:
            - None.
        - Total area: 200 SF.
        - Assumes:
            - 4 occupant per room.
            - 0 plants.
            - Range with hood, dishwasher, refrigerator with freezer.
        - Use a floor area of 0 SF so it doesn't consider contribution to heating and cooling loads.
    - Bathroom 1
        - Avg room height: 9 feet.
        - Exposed wall area:
            - None.
        - Total area: 90 SF.
        - Assumes:
            - 0 occupant per room.
            - 0 plants.
            - 0 appliances.
        - Use a floor area of 0 SF so it doesn't consider contribution to heating and cooling loads.
    - Bathroom 2
        - Avg room height: 9 feet.
        - Exposed wall area:
            - Northern exposure with 10 feet of exposure and low window area and no doors.
        - Assumes:
            - 0 occupant per room.
            - 0 plants.
            - 0 appliances.
        - Use a floor area of 0 SF so it doesn't consider contribution to heating and cooling loads.
- Assumes:
    - Ductless ccASHP situation:
        - All rooms are served.
        - Provides heating and cooling.
        - Winter indoor T: 70 deg F
        - Summer indoor T: 75 deg F

        - Summer indoor relative humidity: 45%
        - ERV: 70% heating and cooling efficiency
        - Outside damper: 60 CFM for ventilation and 0 for exhaust.
        - Adjust performance data for blower heat.
        - Assume that the home does not have a humidifier without its own heat source.
    - Hot water piping:
        - This section does not need to be completed because the Manual J calculations do not account for heat loss from hot water heating pipes.

Representative Middle Floor Units

Middle-floor, S/W exposure – Unit B (West) on 2nd floor

- SF: 1,080
- Used generic address of "Flagstaff, AZ" to account for averages.
- Choose Room by room for new construction and to consider mini-split option.
- Assumed earliest a new home could be built would be 2026.
- Assumes:
    - 1 above-grade story.
    - 2 bedrooms.
    - Condo.
    - No basement.
    - Slab on grade – chosen as placeholder *but not assigned to rooms.*
    - No conditioned "bonus room".
    - No skylights.
    - No blower door test (new build).
    - Tight leakage.
    - No fireplaces.
    - Framed walls with exterior siding.
    - Ceiling is under attic (not encapsulated attic), *chosen as placeholder, but not assigned to rooms.*
    - Roofing material includes dark asphalt shingles.
    - Exterior wall frame construction: 2 x 6 at 16' OC.
    - No radiant floor heating.
    - Cavity insulation: R-21.
    - No board insulation.
    - Attic vented according to FHA guidelines.
    - No attic fan.
    - No attic radiant barrier.
    - Roof R-50 (based on referenced 2018 IECC), *chosen as placeholder, but not assigned to rooms.*
    - Wooden, hollow doors.
    - No radiant floor heat.
    - R-30 insulation for the floor; *ignored floor values.*
    - Windows are NFRC rated.
    - Windows are low-e with U-value of 0.28
- Room types:
    - Bedroom 1:
        - Avg room height: 9 ft.

        - Exposed wall area:
            - None.
        - Assumes:
            - 1 occupant per room.
            - 0 plants.
            - 0 appliances.
        - Use a floor and ceiling area of 0 SF so it doesn't consider contribution to heating and cooling loads.
    - Bedroom 2:
        - Avg room height: 9 ft.
        - Exposed wall area:
            - Southern exposure with 14 feet of exposure and medium window area and no doors.
        - Assumes:
            - 1 occupant per room.
            - 0 plants.
            - 0 appliances.
        - Use a floor and ceiling area of 0 SF so it doesn't consider contribution to heating and cooling loads.
    - Great room:
        - Avg room height: 9 ft.
        - Exposed wall area:
            - Western exposure with 15 feet of exposure and medium window area and no doors.
        - Total area: 300 SF
        - Assumes:
            - 4 occupant per room.
            - 4 plants.
            - 1 TV, 1 computer and monitor, 3 100-W light fixtures
        - Use a floor and ceiling area of 0 SF so it doesn't consider contribution to heating and cooling loads.
    - Kitchen
        - Avg room height: 9 ft.
        - Exposed wall area:
            - None.
        - Total area: 180 SF.
        - Assumes:
            - 4 occupant per room.
            - 0 plants.
            - Range with hood, dishwasher, refrigerator with freezer.
        - Use a floor and ceiling area of 0 SF so it doesn't consider contribution to heating and cooling loads.
    - Bathroom 1
        - Avg room height: 9 feet.
        - Exposed wall area:
            - None.
        - Total area: 90 SF
        - Assumes:

            - 0 occupant per room.
            - 0 plants.
            - 0 appliances.
        - Use a floor and ceiling area of 0 SF so it doesn't consider contribution to heating and cooling loads.
    - Bathroom 2
        - Avg room height: 9 feet.
        - Exposed wall area:
            - Southern exposure with 10 feet of exposure and low window area and no doors.
        - Total area: 150 SF.
        - Assumes:
            - 0 occupant per room.
            - 0 plants.
            - 0 appliances.
        - Use a floor and ceiling area of 0 SF so it doesn't consider contribution to heating and cooling loads.
- Assumes:
    - Ductless ccASHP situation:
        - All rooms are served.
        - Provides heating and cooling.
        - Winter indoor T: 70 deg F
        - Summer indoor T: 75 deg F
        - Summer indoor relative humidity: 45%
        - ERV: 70% heating and cooling efficiency
        - Adjust performance data for blower heat.
        - Assume that the home does not have a humidifier without its own heat source.
    - Hot water piping:
        - This section does not need to be completed because the Manual J calculations do not account for heat loss from hot water heating pipes.

Representative Ground Floor Units

First-floor, N/E exposure – Unit A on 1st floor

- SF: 808 SF
- Used generic address of "Flagstaff, AZ" to account for averages.
- Choose Room by room for new construction and to consider mini-split option.
- Assumed earliest a new home could be built would be 2026.
- Assumes:
    - 1 bedroom.
    - Condo.
    - No basement.
    - Slab on grade.
    - No conditioned "bonus room".
    - No skylights.
    - No blower door test (new build).
    - Tight leakage.

- No fireplaces.
- Framed walls with exterior siding.
- Ceiling is under attic (not encapsulated attic), *chosen as placeholder, but not assigned to rooms.*
- Roofing material includes dark asphalt shingles.
- Exterior wall frame construction: 2 x 6 at 16' OC
- No radiant floor heating.
- Cavity insulation: R-21
- No board insulation.
- Attic vented according to FHA guidelines.
- No attic fan.
- No attic radiant barrier.
- Roof R-50 (based on referenced 2018 IECC), *chosen as placeholder, but not assigned to rooms.*
- Wooden, hollow doors.
- No radiant floor heat.
- R-30 insulation for the floor.
- Windows are NFRC rated.
- Windows are low-e with U-value of 0.28

- Room types:
  - Bedroom 1:
    - Avg room height: 9 ft.
    - Exposed wall area:
      - Northern exposure with 15 feet of exposure and high window area and no doors.
    - Assumes:
      - 1 occupant per room.
      - 0 plants.
      - 0 appliances.
    - Use a ceiling area of 0 SF so it doesn't consider contribution to heating and cooling loads.
  - Great room:
    - Avg room height: 9 ft.
    - Exposed wall area:
      - Eastern exposure with 15 feet of exposure and medium window area and no doors.
    - Total area: 300 SF.
    - Assumes:
      - 4 occupant per room.
      - 4 plants.
      - 1 TV, 1 computer and monitor, 3 100-W light fixtures
    - Use a ceiling area of 0 SF so it doesn't consider contribution to heating and cooling loads.
  - Kitchen
    - Avg room height: 9 ft.
    - Exposed wall area:
      - None.
    - Total area: 180 SF

        - Assumes:
            - 4 occupant per room.
            - 0 plants.
            - Range with hood, dishwasher, refrigerator with freezer.
        - Use a ceiling area of 0 SF so it doesn't consider contribution to heating and cooling loads.
    - Bathroom 1
        - Avg room height: 9 feet
        - Exposed wall area:
            - Northern exposure with 15 feet of exposure and low window area and no doors.
        - Total area: 90 SF.
        - Assumes:
            - 0 occupant per room.
            - 0 plants.
            - 0 appliances.
        - Use a ceiling area of 0 SF so it doesn't consider contribution to heating and cooling loads.
- Assumes:
    - Ductless ccASHP situation:
        - All rooms are served.
        - Provides heating and cooling.
        - Winter indoor T: 70 deg F
        - Summer indoor T: 75 deg F
        - Summer indoor relative humidity: 45%
        - ERV: 70% heating and cooling efficiency
        - Adjust performance data for blower heat.
        - Assume that the home does not have a humidifier without its own heat source.
    - Hot water piping:
        - This section does not need to be completed because the Manual J calculations do not account for heat loss from hot water heating pipes.

Methodology to Determine Operational Costs for Single-Family Homes

The Building Energy Optimization Tool (BEopt) was chosen to simulate energy usage throughout the year and outputs were translated into energy costs based on APS's three different utility rates: fixed, TOU, and TOU plus demand.

"*The BEopt™ (Building Energy Optimization Tool) software provides capabilities to evaluate residential building designs and identify cost-optimal efficiency packages at various levels of whole-house energy savings along the path to zero net energy*." BEopt was created by NREL and is a commonly used tool among building science professionals.

Reviewers are encouraged to evaluate high-level cost differentials and trends as noted in the main body of the study, rather than to focus on the detailed inputs as they might be different between members of the building community.

BEopt Assumptions and Inputs

All inputs were kept the same for each building scenario excepted where highlighted.

Mixed-Fuel Home

- General:
  - Assumed 2,530 SF home based on provided drawings.
  - Wall height of 9 ft.
  - Choose Flagstaff, AZ Pulliam AP weather station.
  - Terrain: suburban.
  - Use default economic inputs: only interest in energy usage.
- Building:
  - Assume building is facing South; input as building orientation.
  - No neighbors.
- Walls:
  - Wood stud, 2x6, R-21, fiberglass batts (insulation type not specified in plans).
  - Wall sheathing: OSB.
  - Exterior finish: medium/dark vinyl siding.
  - Interzonal walls: 2x6, R-21, fiberglass batts (insulation type not specified in plans).
- Ceiling/roofs:
  - No attic radiant barrier.
  - Roof, R-49, cellulose, vented (insulation type not specified in plans).
  - Dark asphalt shingles.
- Foundation/floors:
  - Under slab, 2 ft, R10 XPS, plans specify: Slab floors 2’ R-10, rigid foam 24” slab.
  - Assume 60% carpeted; not specified on plans.
- Thermal mass:
  - Exterior wall mass: ½ inch drywall.
  - Partition wall mass: ½ inch drywall (not specified).
  - Ceiling mass: ½ inch drywall (plans allow for ½ or 5/8 inch).
- Windows and doors:
  - North: 50% windows to wall.
  - East: 15% windows to wall.
  - South: 15% windows to wall.
  - West: 0% windows to wall.
  - Meaning: F15 B50 L15 R0; closet match is F10 B30 L10 R10.
  - Window type:
    - 0.3-U windows; low-e double, insulated.
  - Assume: sheer curtain; 0.7 and 0.7 for heating and cooling shade multiplier.
  - Opaque door area: 40 SF (two exterior doors).
  - Assume: fiberglass doors.
  - Assume: 2 feet eaves.
  - Assume: 2 feet first story overhang all windows.

- Airflow:
  - Assume: 4ACH50.
  - Assume: exhaust system in accordance with IRC 303.4.
  - Assume: natural ventilation cooling months, 7 days/week.
- Space conditioning:
  - Single stage SEER2 14.3 air conditioner; 1.5 tons.
  - No room air conditioner.
  - Gas, 92.5% efficient furnace; 35 kbtuh.
  - No boiler.
  - No electric baseboard.
  - No ccASHP.
  - No mini splits.
  - No ground source heat pumps.
  - Ducts: assume 7.5% leakage at R-8, outside conditioned space.
  - No ceiling fan.
  - No dehumidifier.
- Space conditioning schedules:
  - Heating and cooling seasons.
  - Cooling setpoint of 75 deg F.
  - Heating setpoint of 68 deg F.
  - No humidity setpoint.
- Water heating:
  - Gas, UEF: 0.66.
  - Insulated copper.
  - No solar water heating.
- Water heating schedules:
  - 125 deg F.
- Lighting:
  - 100% LEDs.
  - Standard lighting schedule.
- Appliances:
  - Bottom freezer @ 669 kWh/hr (std usage), assume lowest EF value of 15.9.
  - Gas cooking range (std usage).
  - Dishwasher 270 kWh (std usage).
  - Clothes washer @ 105 kWh/yr (std usage), assume IMEF of 2.06.
  - Clothes dryer @ 835 kWh/yr (std usage), assume electric and CEF equal to 3.73.
  - Assume 1.0 for hot water fixtures.
- Appliances and fixtures schedules:
  - All std schedules.
- Miscellaneous
  - 1.0 for plug loads.
  - None for everything else.
- Miscellaneous schedules
  - Std for all.
- Power generation and storage
  - None for all.

Mixed-Fuel, Energy-Efficient Home

Turquoise text reflects additions made to model highly energy-efficient homes; values informed by additional efficiency required from 2024 IECC Appendix RG: 2024 IECC Stretch Code.

- General:
  - Assumed 30' x 60' rectangular home based on provided drawings.
  - Wall height of 9 ft.
  - Choose Flagstaff, AZ Pulliam AP weather station.
  - Terrain: suburban.
  - Use default economic inputs: only interest in energy usage.
- Building:
  - Assume building is facing South; input as building orientation.
  - No neighbors.
- Walls:
  - Wood stud, 2x6, R-20 and R-5ci, fiberglass batts.
  - Exterior finish: medium/dark vinyl siding.
  - Interzonal walls: 2x6, R-20 and R-5ci, fiberglass batts.
- Ceiling/roofs:
  - No attic radiant barrier.
  - Roof, R-49, cellulose, vented.
  - Dark asphalt shingles.
- Foundation/floors:
  - Under slab, 3 ft, R10 XPS
  - Assume 60% carpeted.
- Thermal mass:
  - Exterior wall mass: ½ inch drywall.
  - Partition wall mass: ½ inch drywall (not specified).
  - Ceiling mass: ½ inch drywall (plans allow for ½ or 5/8 inch).
- Windows and doors:
  - North: 50% windows to wall.
  - East: 15% windows to wall.
  - South: 15% windows to wall.
  - West: 0% windows to wall.
  - Meaning: F15 B50 L15 R0; closet match is F10 B30 L10 R10.
  - Window type:
    - 0.3-U windows; low-e double, insulated.
  - Assume: sheer curtain; 0.7 and 0.7 for heating and cooling shade multiplier.
  - Opaque door area: 40 SF (two exterior doors).
  - Assume: fiberglass doors.
  - Assume: 2 feet eaves.
  - Assume: 2 feet first story overhang all windows.
- Airflow:
  - Assume: 3ACH50.
  - Assume: ERV, 60%.
- Space conditioning:
  - Single stage SEER2 14.3 air conditioner; 1.5 tons.
  - No room air conditioner.

  - Gas, 95% efficient furnace.
  - No boiler.
  - No electric baseboard.
  - No ccASHP.
  - No mini splits.
  - No ground source heat pumps.
  - Ducts: assume 4CFM per 100ft2, R-8, 90% in conditioned space.
  - No ceiling fan.
  - No dehumidifier.
- Space conditioning schedules:
  - Heating and cooling seasons.
  - Cooling setpoint of 75 deg F.
  - Heating setpoint of 68 deg F.
  - No humidity setpoint.
- Water heating:
  - Gas, UEF: 0.83.
  - Insulated copper.
  - No solar water heating.
- Water heating schedules:
  - 125 deg F.
- Lighting:
  - 100% LEDs.
  - Standard lighting schedule.
- Appliances:
  - Bottom freezer EF = 21.3.
  - Gas cooking range (std usage).
  - Dishwasher 270 kWh (std usage).
  - Clothes washer @ 105 kWh/yr (std usage), assume IMEF of 2.06.
  - Clothes dryer @ 835 kWh/yr (std usage), assume electric and CEF equal to 3.93.
  - Assume 1.0 for hot water fixtures.
- Appliances and fixtures schedules:
  - All std schedules.
- Miscellaneous
  - 1.0 for plug loads.
  - None for everything else.
- Miscellaneous schedules
  - Std for all.
- Power generation and storage
  - None for all.

Ducted All-Electric Home

Green text reflects additions made to model all-electric homes using 2018 IECC requirements.

- General:
  - Assumed 30’ x 60’ rectangular home based on provided drawings.
  - Wall height of 9 ft.
  - Choose Flagstaff, AZ Pulliam AP weather station.
  - Terrain: suburban.

- Use default economic inputs: only interest in energy usage.
- Building:
  - Assume building is facing South; input as building orientation.
  - No neighbors.
- Walls:
  - Wood stud, 2x6, R-21, fiberglass batts (insulation type not specified in plans).
  - Wall sheathing: OSB.
  - Exterior finish: medium/dark vinyl siding.
  - Interzonal walls: 2x6, R-21, fiberglass batts (insulation type not specified in plans).
- Ceiling/roofs:
  - No attic radiant barrier.
  - Roof, R-49, fiberglass, vented (attic vented according to FHA guidelines, per plans).
  - Dark asphalt shingles.
- Foundation/floors:
  - Under slab, 2 ft, R10 XPS, plans specify: Slab floors 2' R-10, rigid foam 24" slab.
  - Assume 60% carpeted; not specified on plans.
- Thermal mass:
  - Exterior wall mass: ½ inch drywall.
  - Partition wall mass: ½ inch drywall (not specified).
  - Ceiling mass: ½ inch drywall (plans allow for ½ or 5/8 inch).
- Windows and doors:
  - North: 50% windows to wall.
  - East: 15% windows to wall.
  - South: 15% windows to wall.
  - West: 0% windows to wall.
  - Meaning: F15 B50 L15 R0; closet match is F10 B30 L10 R10.
  - Window type:
    - 0.3-U windows; low-e double, insulated.
  - Assume: sheer curtain; 0.7 and 0.7 for heating and cooling shade multiplier.
  - Opaque door area: 40 SF (two exterior doors).
  - Assume: fiberglass doors.
  - Assume: 2 feet eaves.
  - Assume: 2 feet first story overhang all windows.
- Airflow:
  - Assume: 4ACH50.
  - Assume: exhaust system in accordance with IRC 303.4.
  - Assume: natural ventilation cooling months, 7 days/week.
- Space conditioning:
  - No central air conditioner.
  - No room air conditioner.
  - No gas furnace.
  - No boiler.
  - No electric baseboard.
  - ccASHP: 1.5 tons of cooling capacity, 35 kbtuh heating capacity, HSPF2 8.9 and SEER2 20.9, with variable speed with autosize supplemental heating output capacity.
  - No mini splits.
  - No ground source heat pumps.
  - Ducts: assume 7.5% leakage at R-8, outside conditioned space.

- No ceiling fan.
- No dehumidifier.

- Space conditioning schedules:
  - Heating and cooling seasons.
  - Cooling setpoint of 75 deg F.
  - Heating setpoint of 68 deg F
  - No humidity setpoint
- Water heating:
  - Electric UEF = 3.5, 80 gal.
  - Insulated copper.
  - No solar water heating.
- Water heating schedules:
  - 125 deg F.
- Lighting:
  - 100% LEDs.
  - Standard lighting schedule.
- Appliances:
  - Bottom freezer @ 669 kWh/hr (std usage), assume lowest EF value of 15.9.
  - Electric induction.
  - Dishwasher 270 kWh (std usage).
  - Clothes washer @ 105 kWh/yr (std usage), assume IMEF of 2.06.
  - Clothes dryer @ 835 kWh/yr (std usage), assume electric and CEF equal to 3.73.
  - Assume 1.0 for hot water fixtures.
- Appliances and fixtures schedules:
  - All std schedules.
- Miscellaneous
  - 1.0 for plug loads.
  - None for everything else.
- Miscellaneous schedules
  - Std for all.
- Power generation and storage
  - None for all .

Ductless All-Electric Home

Pink text reflects additions made to model ductless all-electric homes.

- General:
  - Assumed 30’ x 60’ rectangular home based on provided drawings.
  - Wall height of 9 ft.
  - Choose Flagstaff, AZ Pulliam AP weather station.
  - Terrain: suburban.
  - Use default economic inputs: only interest in energy usage.
- Building:
  - Assume building is facing South; input as building orientation.
  - No neighbors.
- Walls:
  - Wood stud, 2x6, R-21, fiberglass batts (insulation type not specified in plans).

    - Wall sheathing: OSB.
    - Exterior finish: medium/dark vinyl siding.
    - Interzonal walls: 2x6, R-21, fiberglass batts (insulation type not specified in plans).
- Ceiling/roofs:
    - No attic radiant barrier.
    - Roof, R-49, fiberglass, vented (attic vented according to FHA guidelines, per plans).
    - Dark asphalt shingles.
- Foundation/floors:
    - Under slab, 2 ft, R10 XPS, plans specify: Slab floors 2' R-10, rigid foam 24" slab.
    - Assume 60% carpeted; not specified on plans.
- Thermal mass:
    - Exterior wall mass: ½ inch drywall.
    - Partition wall mass: ½ inch drywall (not specified).
    - Ceiling mass: ½ inch drywall (plans allow for ½ or 5/8 inch).
- Windows and doors:
    - North: 50% windows to wall.
    - East: 15% windows to wall.
    - South: 15% windows to wall.
    - West: 0% windows to wall.
    - Meaning: F15 B50 L15 R0; closet match is F10 B30 L10 R10.
    - Window type:
        - 0.3-U windows; low-e double, insulated.
    - Assume: sheer curtain; 0.7 and 0.7 for heating and cooling shade multiplier.
    - Opaque door area: 40 SF (two exterior doors).
    - Assume: fiberglass doors.
    - Assume: 2 feet eaves.
    - Assume: 2 feet first story overhang all windows.
- Airflow:
    - Assume: 4ACH50.
    - Assume: exhaust system in accordance with IRC 303.4.
    - Assume: natural ventilation cooling months, 7 days/week.
- Space conditioning:
    - No central air conditioner.
    - No room air conditioner.
    - No gas furnace.
    - No boiler.
    - No electric baseboard.
    - No air source heat pump.
    - Mini-split: SEER2 26 HSPF2 11.3.
    - No ground source heat pumps.
    - No ducts.
    - No ceiling fan.
    - No dehumidifier.
- Space conditioning schedules:
    - Heating and cooling seasons.
    - Cooling setpoint of 75 deg F.
    - Heating setpoint of 68 deg F
    - No humidity setpoint

- Water heating:
  - Electric UEF = 3.5, 80 gal.
  - Insulated copper.
  - No solar water heating.
- Water heating schedules:
  - 125 deg F.
- Lighting:
  - 100% LEDs.
  - Standard lighting schedule.
- Appliances:
  - Bottom freezer @ 669 kWh/hr (std usage), assume lowest EF value of 15.9.
  - Electric induction.
  - Dishwasher 270 kWh (std usage).
  - Clothes washer @ 105 kWh/yr (std usage), assume IMEF of 2.06.
  - Clothes dryer @ 835 kWh/yr (std usage), assume electric and CEF equal to 3.73.
  - Assume 1.0 for hot water fixtures.
- Appliances and fixtures schedules:
  - All std schedules.
- Miscellaneous:
  - 1.0 for plug loads.
  - None for everything else.
- Miscellaneous schedules:
  - Std for all.
- Power generation and storage:
  - None for all.

Ducted All-Electric with Efficiency

Turquoise text reflects additions made to model highly energy-efficient homes; values informed by additional efficiency required from 2024 IECC Appendix RG: 2024 IECC Stretch Code.

- General:
  - Assumed rectangular home based on provided drawings.
  - 1800 SF and 2500 SF variations.
  - Wall height of 9 ft.
  - Choose Flagstaff, AZ Pulliam AP weather station.
  - Terrain: suburban.
  - Use default economic inputs: only interest in energy usage.
- Building:
  - Assume building is facing South; input as building orientation.
  - No neighbors.
- Walls:
  - Wood stud, 2x6, R-20 and R-5ci, fiberglass batts.
  - Exterior finish: medium/dark vinyl siding.
  - Interzonal walls: 2x6, R-20 and R-5ci, fiberglass batts.
- Ceiling/roofs:
  - No attic radiant barrier.
  - Ceiling, R-49 cellulose, vented.
  - Dark asphalt shingles.

- Foundation/floors:
  - Under slab, 3 ft, R10 XPS
  - Assume 60% carpeted; not specified on plans.
- Thermal mass:
  - Exterior wall mass: ½ inch drywall .
  - Partition wall mass: ½ inch drywall (not specified).
  - Ceiling mass: ½ inch drywall (plans allow for ½ or 5/8 inch).
- Windows and doors:
  - North: 50% windows to wall.
  - East: 15% windows to wall.
  - South: 15% windows to wall.
  - West: 0% windows to wall.
  - Meaning: F15 B50 L15 R0; closet match is F10 B30 L10 R10.
  - Window type:
    - 0.3-U windows; low-e double, insulated.
  - Assume: sheer curtain; 0.7 and 0.7 for heating and cooling shade multiplier.
  - Opaque door area: 40 SF (two exterior doors).
  - Assume: fiberglass doors.
  - Assume: 2 feet eaves.
  - Assume: 2 feet first story overhang all windows.
- Airflow:
  - Assume: 3ACH50.
  - Assume: ERV, 60%.
  - Assume: natural ventilation cooling months, 7 days/week.
- Space conditioning:
  - No central air conditioner.
  - No room air conditioner.
  - No gas furnace.
  - No boiler.
  - No electric baseboard.
  - ccASHP: 1.5 tons of cooling capacity, 30 kbtuh heating capacity, HSPF 8.9 and SEER2 20.9, with variable speed with autosize supplemental heating output capacity.
  - No mini splits.
  - No ground source heat pumps.
  - Ducts: assume 4CFM25 per 100ft2, R-8, 90% in conditioned space.
  - No ceiling fan.
  - No dehumidifier.
- Space conditioning schedules:
  - Heating and cooling seasons.
  - Cooling setpoint of 75 deg F.
  - Heating setpoint of 68 deg F
  - No humidity setpoint
- Water heating:
  - Electric UEF = 3.5, 80 gal.
  - Insulated copper.
  - No solar water heating.
- Water heating schedules:
  - 125 deg F.

- Lighting:
  - 100% LEDs.
  - Standard lighting schedule.
- Appliances:
  - Bottom freezer EF = 21.3.
  - Electric induction.
  - Dishwasher 270 kWh (std usage).
  - Clothes washer @ 105 kWh/yr (std usage), assume IMEF of 2.06.
  - Clothes dryer @ 835 kWh/yr (std usage), assume electric and CEF equal to 3.93.
  - Assume 1.0 for hot water fixtures.
- Appliances and fixtures schedules:
  - All std schedules.
- Miscellaneous:
  - 1.0 for plug loads.
  - None for everything else.
- Miscellaneous schedules:
  - Std for all.
- Power generation and storage:
  - None for all.

Ductless All-Electric with Efficiency

Turquoise text reflects additions made to model highly energy-efficient homes; values informed by additional efficiency required from 2024 IECC Appendix RG: 2024 IECC Stretch Code.

- General:
  - Assumed 30’ x 60’ rectangular home based on provided drawings.
  - Wall height of 9 ft.
  - Choose Flagstaff, AZ Pulliam AP weather station.
  - Terrain: suburban.
  - Use default economic inputs: only interest in energy usage.
- Building:
  - Assume building is facing South; input as building orientation.
  - No neighbors.
- Walls:
  - Wood stud, 2x6, R-20 and R-5ci, fiberglass batts.
  - Exterior finish: medium/dark vinyl siding.
  - Interzonal walls: 2x6, R-20 and R-5ci, fiberglass batts.
- Ceiling/roofs:
  - No attic radiant barrier.
  - Ceiling, R-49 cellulose, vented.
  - Dark asphalt shingles.
- Foundation/floors:
  - Under slab, 3 ft, R10 XPS
  - Assume 60% carpeted; not specified on plans.
- Thermal mass:
  - Exterior wall mass: ½ inch drywall.
  - Partition wall mass: ½ inch drywall (not specified).
  - Ceiling mass: ½ inch drywall (plans allow for ½ or 5/8 inch).

- Windows and doors:
  - North: 50% windows to wall.
  - East: 15% windows to wall.
  - South: 15% windows to wall.
  - West: 0% windows to wall.
  - Meaning: F15 B50 L15 R0; closet match is F10 B30 L10 R10.
  - Window type:
    - 0.3-U windows; low-e double, insulated.
  - Assume: sheer curtain; 0.7 and 0.7 for heating and cooling shade multiplier.
  - Opaque door area: 40 SF (two exterior doors).
  - Assume: fiberglass doors.
  - Assume: 2 feet eaves.
  - Assume: 2 feet first story overhang all windows.
- Airflow:
  - Assume: 3ACH50.
  - Assume: ERV, 60%.
  - Assume: natural ventilation cooling months, 7 days/week.
- Space conditioning:
  - No central air conditioner.
  - No room air conditioner.
  - No gas furnace.
  - No boiler.
  - No electric baseboard.
  - No air source heat pump.
  - Mini-split: SEER2 26 HSPF2 11.3.
  - No ground source heat pumps.
  - No ducts.
  - No ceiling fan.
  - No dehumidifier.
- Space conditioning schedules:
  - Heating and cooling seasons.
  - Cooling setpoint of 75 deg F.
  - Heating setpoint of 68 deg F.
  - No humidity setpoint.
- Water heating:
  - Electric UEF = 3.5, 80 gal.
  - Insulated copper.
  - No solar water heating.
- Water heating schedules:
  - 125 deg F.
- Lighting:
  - 100% LEDs.
  - Standard lighting schedule.
- Appliances:
  - Bottom freezer EF = 21.3.
  - Electric induction.
  - Dishwasher 270 kWh (std usage).
  - Clothes washer @ 105 kWh/yr (std usage), assume IMEF of 2.06.

    - Clothes dryer @ 835 kWh/yr (std usage), assume electric and CEF equal to 3.93.
    - Assume 1.0 for hot water fixtures.
- Appliances and fixtures schedules:
    - All std schedules.
- Miscellaneous:
    - 1.0 for plug loads.
    - None for everything else.
- Miscellaneous schedules:
    - Std for all.
- Power generation and storage
    - None for all

Methodology to Determine Operational Costs for Multi-Family Homes

The Building Energy Optimization Tool (BEopt) was chosen to simulate energy usage throughout the year and in a separate spreadsheet, outputs were translated into energy costs based on APS's three different utility rates: fixed, TOU, and TOU plus demand. Multi-family homes were modeled as individual units, and the outputs were based on an average of three representative units.

"The BEopt™ (Building Energy Optimization Tool) software provides capabilities to evaluate residential building designs and identify cost-optimal efficiency packages at various levels of whole-house energy savings along the path to zero net energy."

BEopt was created by NREL and is a commonly used tool among building science professionals.

Reviewers are encouraged to evaluate high-level cost differentials and trends as noted in the main body of the study, rather than to focus on the detailed inputs as they might be different between members of the building community.

BEopt Assumptions and Inputs

All inputs were kept the same for each building scenario excepted where highlighted.

Representative Top Floor Units: Mixed-Fuel

Top-floor, N/W exposure – Unit E on 3rd floor;

Inputs are based on building drawings approved by Coconino County

- SF: 1,085
    - Set bottom floor as shared heating boundary floors.
- General:
    - Assumed MFU heated boundary where other units attach.
    - Wall height of 9 ft
    - Choose Flagstaff, AZ Pulliam AP weather station.
    - Terrain: suburban.

- Use default economic inputs: only interest in energy usage.
- Building:
  - Assume condo is facing North; input as building orientation.
  - Left and front neighbors.
- Walls:
  - Wood stud, 2x6, R-21, fiberglass batts.
  - Wall sheathing: OSB
  - Exterior finish: medium/dark vinyl siding
  - Interzonal walls: wood stud, 2x6, R-21, fiberglass batts.
- Ceilings/roofs:
  - Roof, R-49, cellulose, vented.
  - Roofing material includes dark asphalt shingles.
  - No attic radiant barrier.
- Foundation/floors:
  - Interzonal floors: R-19 fiberglass.
  - 80% carpet.
- Thermal mass:
  - Wood surface.
  - Exterior: ½" drywall
  - Partition wall: ½" drywall
  - Ceiling mass: ½" drywall
- Windows and doors:
  - Though not totally representative, the "least bad" option to represent window placement was chosen to be F15B15L15R15.
  - "Window distributions were assigned using BEopt presets; this required allocating some glazing to non-exposed façades. Energy use may therefore modestly understate heating demand and overstate cooling demand."
  - Windows 0.3-U windows; low-e double, insulated.
  - Interior shading: summer = 0.7, winter = 0.7
  - No exterior doors.
  - 2 ft eaves
  - 0 ft overhang
- Airflow:
  - Assume: 4ACH50
  - Assume: exhaust system in accordance with IRC 303.4
  - Assume: natural ventilation cooling months, 7 days/week
- Space conditioning:
  - Single stage SEER2 14.3 air conditioner; 1.0 tons
  - No room air conditioner
  - Gas, 92.5% efficient furnace; autosize
  - No boiler
  - No electric baseboard
  - No ccASHP
  - No mini splits
  - No ground source heat pumps
  - Ducts: assume 7.5% leakage at R-8
  - No ceiling fan.
  - No dehumidifier.

- Space conditioning schedules:
  - Heating and cooling seasons.
  - Cooling setpoint of 75 deg F.
  - Heating setpoint of 68 deg F
  - No humidity setpoint
- Water heating:
  - Gas, UEF: 0.66.
  - Insulated copper
  - No solar water heating
- Water heating schedules:
  - 125 deg F
- Lighting:
  - 100% LEDs
  - Standard lighting schedule
- Appliances:
  - Bottom freezer @ 669 kWh/hr (std usage), assume lowest EF value of 15.9
  - Gas stove
  - Dishwasher 270 kWh (std usage)
  - Clothes washer @ 105 kWh/yr (std usage), assume IMEF of 2.06
  - Clothes dryer @ 835 kWh/yr (std usage), assume electric and CEF equal to 3.73
  - Assume 1.0 for hot water fixtures
- Appliances and fixtures schedules:
  - All std schedules
- Miscellaneous
  - 1.0 for plug loads
  - None for everything else
- Miscellaneous schedules
  - Std for all
- Power generation and storage
  - None for all

Representative Middle Floor Units: Mixed-Fuel

Middle-floor, S/W exposure – Unit B West on 2nd floor.

- SF: 1,080
  - Set top floor and bottom floors as shared heating boundary ceiling and floors.
- General:
  - Assumed MFU heated boundary where other units attach.
  - Wall height of 8 ft
  - Choose Flagstaff, AZ Pulliam AP weather station.
  - Terrain: suburban.
  - Use default economic inputs: only interest in energy usage.
- Building:
  - Assume condo is facing South; input as building orientation.
  - Left and front neighbors.
- Walls:
  - Wood stud, 2x6, R-21, fiberglass batts.

- Wall sheathing: OSB
- Exterior finish: medium/dark vinyl siding
- Interzonal walls: 2x6, R-21, fiberglass batts

- Ceilings/roofs:
  - None
  - Roofing material includes dark asphalt shingles.
  - No attic radiant barrier.
- Foundation/floors:
  - Interzonal floor: R19 fiberglass batt
  - 80% carpet
- Thermal mass:
  - Wood surface.
  - Exterior: ½" drywall
  - Partition wall: ½" drywall
  - Ceiling mass: ½" drywall
- Windows and doors:
  - Though not totally representative, the "least bad" option to represent window placement was chosen to be F15B15L15R15.
  - "Window distributions were assigned using BEopt presets; this required allocating some glazing to non-exposed façades. Energy use may therefore modestly understate heating demand and overstate cooling demand."
  - Windows 0.3-U windows; low-e double, insulated.
  - Interior shading: summer = 0.7, winter = 0.7
  - No exterior doors.
  - 2 ft eaves
  - 0 ft overhang
- Airflow:
  - Assume: 4ACH50
  - Assume: exhaust system in accordance with IRC 303.4
  - Assume: natural ventilation cooling months, 7 days/week
- Space conditioning:
  - Single stage SEER2 14.3 air conditioner; autosize
  - No room air conditioner
  - Gas, 92.5% efficient furnace; autosize
  - No boiler
  - No electric baseboard
  - No ccASHP
  - No mini splits
  - No ground source heat pumps
  - Ducts: assume 7.5% leakage at R-8
  - No ceiling fan.
  - No dehumidifier.
- Space conditioning schedules:
  - Heating and cooling seasons.
  - Cooling setpoint of 75 deg F.
  - Heating setpoint of 68 deg F
  - No humidity setpoint
- Water heating:

    - Gas, UEF: 0.66.
    - Insulated copper
    - No solar water heating
- Water heating schedules:
    - 125 deg F
- Lighting:
    - 100% LEDs
    - Standard lighting schedule
- Appliances:
    - Bottom freezer @ 669 kWh/hr (std usage), assume lowest EF value of 15.9
    - Gas stove
    - Dishwasher 270 kWh (std usage)
    - Clothes washer @ 105 kWh/yr (std usage), assume IMEF of 2.06
    - Clothes dryer @ 835 kWh/yr (std usage), assume electric and CEF equal to 3.73
    - Assume 1.0 for hot water fixtures
- Appliances and fixtures schedules:
    - All std schedules
- Miscellaneous
    - 1.0 for plug loads
    - None for everything else
- Miscellaneous schedules
    - Std for all
- Power generation and storage
    - None for all

Representative Ground Floor Units: Mixed-Fuel

Ground-floor, S/W exposure – Unit B West on 1st floor.

- SF: 810 sf
    - Set top floor as shared heating boundary ceiling.
- General:
    - Assumed MFU heated boundary where other units attach.
    - Wall height of 9 ft
    - Choose Flagstaff, AZ Pulliam AP weather station.
    - Terrain: suburban.
    - Use default economic inputs: only interest in energy usage.
- Building:
    - Assume condo is facing South; input as building orientation.
    - Right and back neighbors.
- Walls:
    - Wood stud, 2x6, R-21, fiberglass batts.
    - Wall sheathing: OSB
    - Exterior finish: medium/dark vinyl siding
    - Interzonal walls: 2x6, R-21, fiberglass batts
- Ceilings/roofs:
    - Under slab 2 ft R10 XPS
    - Roofing material includes dark asphalt shingles.

    - No attic radiant barrier.
- Foundation/floors:
    - Interzonal floor: R19 fiberglass batt
    - 80% carpet
- Thermal mass:
    - Wood surface.
    - Exterior: ½" drywall
    - Partition wall: ½" drywall
    - Ceiling mass: ½" drywall
- Windows and doors:
    - Though not totally representative, the "least bad" option to represent window placement was chosen to be F15B15L15R15.
    - "Window distributions were assigned using BEopt presets; this required allocating some glazing to non-exposed façades. Energy use may therefore modestly understate heating demand and overstate cooling demand."
    - Windows 0.3-U windows; low-e double, insulated.
    - Interior shading: summer = 0.7, winter = 0.7
    - No exterior doors.
    - 2 ft eaves
    - 0 ft overhang
- Airflow:
    - Assume: 4ACH50
    - Assume: exhaust system in accordance with IRC 303.4
    - Assume: natural ventilation cooling months, 7 days/week
- Space conditioning:
    - Single stage SEER2 14.3 air conditioner; autosize
    - No room air conditioner
    - Gas, 92.5% efficient furnace; autosize
    - No boiler
    - No electric baseboard
    - No ccASHP
    - No mini splits
    - No ground source heat pumps
    - Ducts: assume 7.5% leakage at R-8
    - No ceiling fan.
    - No dehumidifier.
- Space conditioning schedules:
    - Heating and cooling seasons.
    - Cooling setpoint of 75 deg F.
    - Heating setpoint of 68 deg F
    - No humidity setpoint
- Water heating:
    - Gas, UEF: 0.66.
    - Insulated copper
    - No solar water heating
- Water heating schedules:
    - 125 deg F
- Lighting:

  - 100% LEDs
  - Standard lighting schedule
- Appliances:
  - Bottom freezer @ 669 kWh/hr (std usage), assume lowest EF value of 15.9
  - Gas stove
  - Dishwasher 270 kWh (std usage)
  - Clothes washer @ 105 kWh/yr (std usage), assume IMEF of 2.06
  - Clothes dryer @ 835 kWh/yr (std usage), assume electric and CEF equal to 3.73
  - Assume 1.0 for hot water fixtures
- Appliances and fixtures schedules:
  - All std schedules
- Miscellaneous
  - 1.0 for plug loads
  - None for everything else
- Miscellaneous schedules
  - Std for all
- Power generation and storage
  - None for all

Representative Top Floor Units: All-Electric

- SF: 1,085
  - Set bottom floor as shared heating boundary floors.
- General:
  - Assumed MFU heated boundary where other units attach.
  - Wall height of 9 ft
  - Choose Flagstaff, AZ Pulliam AP weather station.
  - Terrain: suburban.
  - Use default economic inputs: only interest in energy usage.
- Building:
  - Assume condo is facing North; input as building orientation.
  - No neighbors.
- Walls:
  - Wood stud, 2x6, R-21, fiberglass batts.
  - Wall sheathing: OSB
  - Exterior finish: medium/dark vinyl siding
  - Interzonal walls: 2x6, R-21, fiberglass batts
- Ceilings/roofs:
  - Ceiling, vented R-49, cellulose
  - Roofing material includes dark asphalt shingles.
  - No attic radiant barrier.
- Foundation/floors:
  - Interzonal floor: R19 fiberglass batt
  - 80% carpet
- Thermal mass:
  - Wood surface.
  - Exterior: ½” drywall
  - Partition wall: ½” drywall

- Ceiling mass: ½" drywall
- Windows and doors:
  - Though not totally representative, the "least bad" option to represent window placement was chosen to be F15B15L15R15.
    - "Window distributions were assigned using BEopt presets; this required allocating some glazing to non-exposed façades. Energy use may therefore modestly understate heating demand and overstate cooling demand."
  - Windows are low-e with U-value of 0.30 and SHGC of 0.25; l-gain
  - Interior shading: summer = 0.7, winter = 0.7
  - No exterior doors.
  - 2 ft eaves
  - 0 ft overhang
- Airflow:
  - Assume: 4ACH50
  - Assume: exhaust system in accordance with IRC 303.4
  - Assume: natural ventilation cooling months, 7 days/week
- Space conditioning:
  - No central air conditioner.
  - No room air conditioner
  - No gas furnace.
  - No boiler
  - No electric baseboard
  - No ccASHP
  - Mini-split: SEER2 26 HSPF2 11.3.
  - No ground source heat pumps
  - No ducts.
  - No ceiling fan.
  - No dehumidifier.
- Space conditioning schedules:
  - Heating and cooling seasons.
  - Cooling setpoint of 75 deg F.
  - Heating setpoint of 68 deg F
  - No humidity setpoint
- Water heating:

  Electric HPWH; UEF=3.5, 50 gal
  - Insulated copper
  - No solar water heating
- Water heating schedules:
  - 125 deg F
- Lighting:
  - 90% LEDs
  - Standard lighting schedule
- Appliances:
  - Bottom freezer @ 669 kWh/hr (std usage), assume lowest EF value of 15.9
  - Electric induction
  - Dishwasher 270 kWh (std usage)
  - Clothes washer @ 105 kWh/yr (std usage), assume IMEF of 2.06
  - Clothes dryer @ 835 kWh/yr (std usage), assume electric and CEF equal to 3.73

    - Assume 1.0 for hot water fixtures
- Appliances and fixtures schedules:
    - All std schedules
- Miscellaneous
    - 1.0 for plug loads
    - None for everything else
- Miscellaneous schedules
    - Std for all
- Power generation and storage
    - None for all

Representative Middle Floor Units: All-Electric

- SF: 1,080
    - Set top floor and bottom floors as shared heating boundary ceiling and floors.
- General:
    - Assumed MFU heated boundary where other units attach.
    - Wall height of 9 ft
    - Choose Flagstaff, AZ Pulliam AP weather station.
    - Terrain: suburban.
    - Use default economic inputs: only interest in energy usage.
- Building:
    - Assume condo is facing South; input as building orientation.
    - Left and front neighbors.
- Walls:
    - Wood stud, 2x6, R-21, fiberglass batts.
    - Wall sheathing: OSB
    - Exterior finish: medium/dark vinyl siding
    - Interzonal walls: 2x6, R-21, fiberglass batts
- Ceilings/roofs:
    - None
    - Roofing material includes dark asphalt shingles.
    - No attic radiant barrier.
- Foundation/floors:
    - Interzonal floor: R19 fiberglass batt
    - 80% carpet
- Thermal mass:
    - Wood surface.
    - Exterior: ½" drywall
    - Partition wall: ½" drywall
    - Ceiling mass: ½" drywall
- Windows and doors:
    - Though not totally representative, the "least bad" option to represent window placement was chosen to be F15B15L15R15.
    - "Window distributions were assigned using BEopt presets; this required allocating some glazing to non-exposed façades. Energy use may therefore modestly understate heating demand and overstate cooling demand."
    - Windows are low-e with U-value of 0.30 and SHGC of 0.25; l-gain
    - Interior shading: summer = 0.7, winter = 0.7

- No exterior doors.
- 2 ft eaves
- 0 ft overhang

- Airflow:
  - Assume: 3ACH50
  - Assume: exhaust system in accordance with IRC 303.4
  - Assume: natural ventilation cooling months, 7 days/week
- Space conditioning:
  - No central air conditioner.
  - No room air conditioner
  - No gas furnace.
  - No boiler
  - No electric baseboard
  - No ccASHP
  - Mini-split: SEER2 26 HSPF2 11.3.
  - No ground source heat pumps
  - No ducts.
  - No ceiling fan.
  - No dehumidifier.
- Space conditioning schedules:
  - Heating and cooling seasons.
  - Cooling setpoint of 75 deg F.
  - Heating setpoint of 68 deg F
  - No humidity setpoint
- Water heating:

  Electric HPWH; UEF=3.5, 50 gal
  - Insulated copper
  - No solar water heating
- Water heating schedules:
  - 125 deg F
- Lighting:
  - 90% LEDs
  - Standard lighting schedule
- Appliances:
  - Bottom freezer @ 669 kWh/hr (std usage), assume lowest EF value of 15.9
  - Electric induction
  - Dishwasher 270 kWh (std usage)
  - Clothes washer @ 105 kWh/yr (std usage), assume IMEF of 2.06
  - Clothes dryer @ 835 kWh/yr (std usage), assume electric and CEF equal to 3.73
  - Assume 1.0 for hot water fixtures
- Appliances and fixtures schedules:
  - All std schedules
- Miscellaneous
  - 1.0 for plug loads
  - None for everything else
- Miscellaneous schedules
  - Std for all
- Power generation and storage

- None for all

Representative Ground Floor Units: All-Electric

- SF: 810 sf
  - Set top floor as shared heating boundary ceiling.
- General:
  - Assumed MFU heated boundary where other units attach.
  - Wall height of 9 ft
  - Choose Flagstaff, AZ Pulliam AP weather station.
  - Terrain: suburban.
  - Use default economic inputs: only interest in energy usage.
- Building:
  - Assume condo is facing South; input as building orientation.
  - Right and back neighbors.
- Walls:
  - Wood stud, 2x6, R-21, fiberglass batts.
  - Wall sheathing: OSB
  - Exterior finish: medium/dark vinyl siding
  - Interzonal walls: 2x6, R-21, fiberglass batts
- Ceilings/roofs:
  - Under slab 2 ft R10 XPS
  - Roofing material includes dark asphalt shingles.
  - No attic radiant barrier.
- Foundation/floors:
  - Interzonal floor: R19 fiberglass batt
  - 80% carpet
- Thermal mass:
  - Wood surface.
  - Exterior: ½” drywall
  - Partition wall: ½” drywall
  - Ceiling mass: ½” drywall
- Windows and doors:
  - Though not totally representative, the “least bad” option to represent window placement was chosen to be F15B15L15R15.
  - “Window distributions were assigned using BEopt presets; this required allocating some glazing to non-exposed façades. Energy use may therefore modestly understate heating demand and overstate cooling demand.”
  - Windows 0.3-U windows; low-e double, insulated.
  - Interior shading: summer = 0.7, winter = 0.7
  - No exterior doors.
  - 2 ft eaves
  - 0 ft overhang
- Airflow:
  - Assume: 4ACH50
  - Assume: exhaust system in accordance with IRC 303.4
  - Assume: natural ventilation cooling months, 7 days/week
- Space conditioning:

- No central air conditioner.
- No room air conditioner
- No gas furnace.
- No boiler
- No electric baseboard
- No ccASHP
- Mini-split: SEER2 26 HSPF2 11.3.
- No ground source heat pumps
- No ducts.
- No ceiling fan.
- No dehumidifier.

- Space conditioning schedules:
  - Heating and cooling seasons.
  - Cooling setpoint of 75 deg F.
  - Heating setpoint of 68 deg F
  - No humidity setpoint
- Water heating:
  - Electric HPWH; UEF=3.5, 50 gal
  - Insulated copper
  - No solar water heating
- Water heating schedules:
  - 125 deg F
- Lighting:
  - 90% LEDs
  - Standard lighting schedule
- Appliances:
  - Bottom freezer @ 669 kWh/hr (std usage), assume lowest EF value of 15.9
  - Electric induction
  - Dishwasher 270 kWh (std usage)
  - Clothes washer @ 105 kWh/yr (std usage), assume IMEF of 2.06
  - Clothes dryer @ 835 kWh/yr (std usage), assume electric and CEF equal to 3.73
  - Assume 1.0 for hot water fixtures
- Appliances and fixtures schedules:
  - All std schedules
- Miscellaneous
  - 1.0 for plug loads
  - None for everything else
- Miscellaneous schedules
  - Std for all
- Power generation and storage
  - None for all

Representative Top Floor Units: Mixed-Fuel, Highly Energy-Efficient

Pink text reflects additions made to model highly energy-efficient homes; values informed by additional efficiency required from 2024 IECC Appendix RG: 2024 IECC Stretch Code.

Top-floor, N/W exposure – Unit E on 3rd floor;

Inputs are based on building drawings approved by Coconino County

- SF: 1,085
  - Set bottom floor as shared heating boundary floors.
- General:
  - Assumed MFU heated boundary where other units attach.
  - Wall height of 9 ft
  - Choose Flagstaff, AZ Pulliam AP weather station.
  - Terrain: suburban.
  - Use default economic inputs: only interest in energy usage.
- Building:
  - Assume condo is facing North; input as building orientation.
  - Left and front neighbors.
- Walls:
  - Wood stud, 2x6, R-20 and R-5ci, fiberglass batts.
  - Wall sheathing: OSB
  - Exterior finish: medium/dark vinyl siding
  - Interzonal walls: 2x6, R-20 and R-5ci, fiberglass batts.
- Ceilings/roofs:
  - Roof, R-49, cellulose, vented.
  - Roofing material includes dark asphalt shingles.
  - No attic radiant barrier.
- Foundation/floors:
  - Interzonal floors: R-19 fiberglass.
  - 80% carpet.
- Thermal mass:
  - Wood surface.
  - Exterior: ½" drywall
  - Partition wall: ½" drywall
  - Ceiling mass: ½" drywall
- Windows and doors:
  - Though not totally representative, the "least bad" option to represent window placement was chosen to be F15B15L15R15.
  - "Window distributions were assigned using BEopt presets; this required allocating some glazing to non-exposed façades. Energy use may therefore modestly understate heating demand and overstate cooling demand."
  - Windows 0.3-U windows; low-e double, insulated.
  - Interior shading: summer = 0.7, winter = 0.7
  - No exterior doors.
  - 2 ft eaves
  - 0 ft overhang
- Airflow:
  - Assume: 3ACH50
  - Assume: ERV 60%
- Space conditioning:
  - Single stage SEER2 14.3 air conditioner; 1.0 tons

- No room air conditioner
- Gas, 95% efficient furnace; autosize
- No boiler
- No electric baseboard
- No ccASHP
- No mini splits
- No ground source heat pumps
- Ducts: assume 4CFM per 100ft2, R-8, 90% in conditioned space.
- No ceiling fan.
- No dehumidifier.

- Space conditioning schedules:
  - Heating and cooling seasons.
  - Cooling setpoint of 75 deg F.
  - Heating setpoint of 68 deg F
  - No humidity setpoint
- Water heating:
  - Gas, UEF: 0.83.
  - Insulated copper
  - No solar water heating
- Water heating schedules:
  - 125 deg F
- Lighting:
  - 100% LEDs
  - Standard lighting schedule
- Appliances:
  - Bottom freezer EF = 21.3.
  - Gas stove
  - Dishwasher 270 kWh (std usage)
  - Clothes washer @ 105 kWh/yr (std usage), assume IMEF of 2.06
  - Clothes dryer @ 835 kWh/yr (std usage), assume electric and CEF equal to 3.93
  - Assume 1.0 for hot water fixtures
- Appliances and fixtures schedules:
  - All std schedules
- Miscellaneous
  - 1.0 for plug loads
  - None for everything else
- Miscellaneous schedules
  - Std for all
- Power generation and storage
  - None for all

Representative Middle Floor Units: Mixed-Fuel, Highly Energy-Efficient

Top-floor, S/W exposure – Unit B West on 2nd floor.

- SF: 1,080
  - Set top floor and bottom floors as shared heating boundary ceiling and floors.
- General:

- Assumed MFU heated boundary where other units attach.
  - Wall height of 9 ft
  - Choose Flagstaff, AZ Pulliam AP weather station.
  - Terrain: suburban.
  - Use default economic inputs: only interest in energy usage.
- Building:
  - Assume condo is facing South; input as building orientation.
  - Left and front neighbors.
- Walls:
  - Wood stud, 2x6, R-20 and R-5ci, fiberglass batts.
  - Wall sheathing: OSB
  - Exterior finish: medium/dark vinyl siding
  - Interzonal walls: 2x6, R-20 and R-5ci, fiberglass batts.
- Ceilings/roofs:
  - None
  - Roofing material includes dark asphalt shingles.
  - No attic radiant barrier.
- Foundation/floors:
  - Interzonal floor: R19 fiberglass batt
  - 80% carpet
- Thermal mass:
  - Wood surface.
  - Exterior: ½” drywall
  - Partition wall: ½” drywall
  - Ceiling mass: ½” drywall
- Windows and doors:
  - Though not totally representative, the “least bad” option to represent window placement was chosen to be F15B15L15R15.
  - “Window distributions were assigned using BEopt presets; this required allocating some glazing to non-exposed façades. Energy use may therefore modestly understate heating demand and overstate cooling demand.”
  - Windows 0.3-U windows; low-e double, insulated.
  - Interior shading: summer = 0.7, winter = 0.7
  - No exterior doors.
  - 2 ft eaves
  - 0 ft overhang
- Airflow:
  - Assume: 3ACH50
  - Assume: ERV 60%
- Space conditioning:
  - Single stage SEER2 14.3 air conditioner; autosize
  - No room air conditioner
  - Gas, 95% efficient furnace; autosize
  - No boiler
  - No electric baseboard
  - No ccASHP
  - No mini splits
  - No ground source heat pumps

- Ducts: in finished space
- No ceiling fan.
- No dehumidifier.

- Space conditioning schedules:
  - Heating and cooling seasons.
  - Cooling setpoint of 75 deg F.
  - Heating setpoint of 68 deg F
  - No humidity setpoint
- Water heating:
  - Gas, UEF: 0.83.
  - Insulated copper
  - No solar water heating
- Water heating schedules:
  - 125 deg F
- Lighting:
  - 100% LEDs
  - Standard lighting schedule
- Appliances:
  - Bottom freezer @ 669 kWh/hr (std usage), assume lowest EF value of 21.3
  - Gas stove
  - Dishwasher 270 kWh (std usage)
  - Clothes washer @ 105 kWh/yr (std usage), assume IMEF of 2.06
  - Clothes dryer @ 835 kWh/yr (std usage), assume electric and CEF equal to 3.93
  - Assume 1.0 for hot water fixtures
- Appliances and fixtures schedules:
  - All std schedules
- Miscellaneous
  - 1.0 for plug loads
  - None for everything else
- Miscellaneous schedules
  - Std for all
- Power generation and storage
  - None for all

Representative Ground Floor Units: Mixed-Fuel, Highly Energy-Efficient

Ground-floor, S/W exposure – Unit B West on 1st floor.

- SF: 810 sf
  - Set top floor as shared heating boundary ceiling.
- General:
  - Assumed MFU heated boundary where other units attach.
  - Wall height of 9 ft
  - Choose Flagstaff, AZ Pulliam AP weather station.
  - Terrain: suburban.
  - Use default economic inputs: only interest in energy usage.
- Building:
  - Assume condo is facing South; input as building orientation.
  - Right and back neighbors.

- Wood stud, 2x6, R-20 and R-5ci, fiberglass batts.
- Exterior finish: medium/dark vinyl siding.
- Interzonal walls: 2x6, R-20 and R-5ci, fiberglass batts.

- Ceilings/roofs:
  - Ceiling, R-49 cellulose, vented
  - Roofing material includes dark asphalt shingles.
  - No attic radiant barrier.
- Foundation/floors:
  - Interzonal floor: R19 fiberglass batt
  - 80% carpet
  - Under Slab 3ft R10 XPS
- Thermal mass:
  - Wood surface.
  - Exterior: ½" drywall
  - Partition wall: ½" drywall
  - Ceiling mass: ½" drywall
- Windows and doors:
  - Though not totally representative, the "least bad" option to represent window placement was chosen to be F15B15L15R15.
  - "Window distributions were assigned using BEopt presets; this required allocating some glazing to non-exposed façades. Energy use may therefore modestly understate heating demand and overstate cooling demand."
  - Windows 0.3-U windows; low-e double, insulated.
  - Interior shading: summer = 0.7, winter = 0.7
  - No exterior doors.
  - 2 ft eaves
  - 0 ft overhang
- Airflow:
  - Assume: 3ACH50
  - Assume: 60% ERV.
- Space conditioning:
  - Single stage SEER2 14.3 air conditioner; autosize
  - No room air conditioner
  - Gas, 95% efficient furnace; autosize
  - No boiler
  - No electric baseboard
  - No ccASHP
  - No mini splits
  - No ground source heat pumps
  - Ducts: in finished space
  - No ceiling fan.
  - No dehumidifier.
- Space conditioning schedules:
  - Heating and cooling seasons.
  - Cooling setpoint of 75 deg F.
  - Heating setpoint of 68 deg F
  - No humidity setpoint
- Water heating:

    - Gas, UEF: 0.83.
    - Insulated copper
    - No solar water heating
- Water heating schedules:
    - 125 deg F
- Lighting:
    - 100% LEDs
    - Standard lighting schedule
- Appliances:
    - Bottom freezer @ 669 kWh/hr (std usage), assume lowest EF value of 21.3
    - Gas stove
    - Dishwasher 270 kWh (std usage)
    - Clothes washer @ 105 kWh/yr (std usage), assume IMEF of 2.06
    - Clothes dryer @ 835 kWh/yr (std usage), assume electric and CEF equal to 3.93
    - Assume 1.0 for hot water fixtures
- Appliances and fixtures schedules:
    - All std schedules
- Miscellaneous
    - 1.0 for plug loads
    - None for everything else
- Miscellaneous schedules
    - Std for all
- Power generation and storage
    - None for all

Representative All-Electric, Highly Energy Efficient

Areas in pink are updated to reflect highly energy-efficient homes; values informed by additional efficiency required from 2024 IECC Appendix RG: 2024 IECC Stretch Code.

- General:
    - Assumed MFU heated boundary where other units attach.
    - Wall height of 8 ft
    - Choose Flagstaff, AZ Pulliam AP weather station.
    - Terrain: suburban.
    - Use default economic inputs: only interest in energy usage.
- Building:
    - Assume condo is facing North; input as building orientation.
    - No neighbors.
- Walls:
    - Wood stud, 2x6, R-20 and R-5ci, fiberglass batts.
    - Exterior finish: medium/dark vinyl siding.
    - Interzonal walls: 2x6, R-20 and R-5ci, fiberglass batts.
- Ceilings/roofs:
    - Ceiling, R-49 cellulose, vented
    - Roofing material includes dark asphalt shingles.
    - No attic radiant barrier.

- Foundation/floors:
    - Interzonal floor: R19 fiberglass batt
    - 80% carpet
    - Under Slab 3ft R10 XPS
- Thermal mass:
    - Wood surface.
    - Exterior: ½" drywall
    - Partition wall: ½" drywall
    - Ceiling mass: ½" drywall
- Windows and doors:
    - Though not totally representative, the "least bad" option to represent window placement was chosen to be F15B15L15R15.
        - "Window distributions were assigned using BEopt presets; this required allocating some glazing to non-exposed façades. Energy use may therefore modestly understate heating demand and overstate cooling demand."
    - 0.3-U windows; low-e double, insulated.
    - Interior shading: summer = 0.7, winter = 0.7
    - No exterior doors.
    - 2 ft eaves
    - 0 ft overhang
- Airflow:
    - Assume: 3ACH50
    - Assume: ERV, 60%
- Space conditioning:
    - No central air conditioner.
    - No room air conditioner
    - No gas furnace.
    - No boiler
    - No electric baseboard
    - No ccASHP
    - Mini-split: SEER2 26 HSPF2 11.3.
    - No ground source heat pumps
    - No ducts.
    - No ceiling fan.
    - No dehumidifier.
- Space conditioning schedules:
    - Heating and cooling seasons.
    - Cooling setpoint of 75 deg F.
    - Heating setpoint of 68 deg F
    - No humidity setpoint
- Water heating:

    Electric HPWH; UEF=3.5, 50 gal
    - Insulated copper
    - No solar water heating
- Water heating schedules:
    - 125 deg F
- Lighting:
    - 100% LEDs

- Standard lighting schedule

- Appliances:
    - Bottom freezer EF = 21.3
    - Electric induction
    - Dishwasher 270 kWh (std usage)
    - Clothes washer @ 105 kWh/yr (std usage), assume IMEF of 2.06
    - Clothes dryer @ 835 kWh/yr (std usage), assume electric and CEF equal to 3.93
    - Assume 1.0 for hot water fixtures
- Appliances and fixtures schedules:
    - All std schedules
- Miscellaneous
    - 1.0 for plug loads
    - None for everything else
- Miscellaneous schedules
    - Std for all
- Power generation and storage
    - None for all

City Council Presentation

December 9, 2025

Analysis of the Costs, Benefits, and Barriers to Building New Highly Energy-Efficient and All-Electric Residential Homes in Flagstaff, Arizona

Filling the Data Gap

Noverra Collective

Study Goals

- Fill a **critical data gap**
  - LASS/CAP identified general costs of electrification and energy efficiency
  - National studies identified all-electric homes can achieve cost-parity with mixed-fuel homes and bring other benefits to residents
  - Need local data on costs, barriers, and benefits

- Develop **defensible, locally grounded cost** insights that reflect Flagstaff's real-world construction practices

- **Inform City decisions** about how to reduce energy use and emissions in the built environment while prioritizing long-term affordability
  - Feeds into broader code change discussions (Zoning, Building codes)
  - Informs future policy and programming
  - Ensure programs that support electrification bring co-benefits to residents (affordability, health, etc.)

Flagstaff Carbon Neutrality Plan

- In 2023, **55%** of Flagstaff's **greenhouse gas emissions came from building energy use**

- **Reducing emissions** from the built environment is critical to carbon neutrality.

CNP focuses on:

- **Energy efficiency**: reducing all energy use from buildings.
- **Beneficial electrification**: when and where residents benefit from switching to electric appliances (retrofits).

Key Takeaways: City of Flagstaff Staff Perspective

- Very **nuanced topic**
- Building energy systems are **complex**
- **Costs and benefits vary across multiple factors**
- We now have a **better understanding** of home electrification and energy efficiency
- We've **learned so much** from builders, contractors, sub-contractors, designers, building scientists, and other professionals
- Staff can set up 1:1 meetings with Councilmembers to discuss further

Consultant Introduction

Emily Artale, PE

- Professional engineer and sustainability professional with 20 years of consulting and teaching experience
- Founder and Principal Engineer of Noverra Collective, LLC
- Consulted with 100 organizations on energy efficiency, energy performance contracting, sustainability, and building electrification
    - Local and state governments, non-profit organizations, Fortune 500 companies, and small, private ventures

Agenda

1. Introduction
2. Methodology
3. Key Findings
4. Recommendations
5. Next Steps

Introduction

Background and Purpose

- Numerous studies have been published that show the impacts of building code adoption and construction of all-electric homes.

- However, experience has shown that these studies do not always match local conditions, potentially setting us up for failure.

- The City commissioned a **cost and benefit analysis that considered local conditions**.

Study Goals & Outcome

- Determine **key costs, barriers, and benefits** to building new all-electric and highly energy-efficient single- and multi-family homes.
- Identify ways to **overcome** these barriers.
- Increase dialogue with members of the building community and **build connections**.
- Use findings to **inform decisions** about policies and programming to advance energy efficiency and beneficial electrification.

Methodology

Study Components

- **Modeling** to determine capital and operational costs for single-family and multifamily homes (natural gas/electric and all-electric)
- **Professional feedback – 13 local builders**
  - Provide a nuanced perspectives on the costs, barriers, and benefits of all-electric and energy efficiency
  - Inform modeling

Modeling: Single-Family Homes

- Base case and scenarios 1-2: meet **Flagstaff's current energy code**
- Scenarios 3-5: **24% improvement in energy efficiency**

Single-Family Home Scenarios		**Fuel type**	**Air distribution**	**Highly efficient?**
Base case	Mixed-fuel (electricity and natural gas)	🔥 ⚡	▦	
1	Ducted, all-electric	⚡	▦	
2	Ductless, all-electric	⚡	💨	
3	Mixed-fuel, highly energy-efficient (HEE)	🔥 ⚡	▦	✓
4	Ducted, all-electric, HEE	⚡	▦	✓
5	Ductless, all-electric, HEE	⚡	💨	✓

Key: 🔥 = gas ⚡ = Electric ▦ = Ducted 💨 = Ductless

Modeling: Multi-family Homes

- **Compare capital and operational costs**
  - Base Case and scenario 1: Flagstaff's current energy code
  - Scenarios 2-3 modeled: 20% improvement in energy efficiency

Multi-Family Home Scenarios		Fuel type	Air distribution	Highly efficient?
Base case	Mixed-fuel (electricity and natural gas)	gas, Electric	Ducted	
1	Ductless, all-electric	Electric	Ductless	
2	Mixed-fuel, HEE	gas, Electric	Ducted	✓
3	Ductless, all-electric, HEE	Electric	Ductless	✓

Key: (flame) = gas (lightning) = Electric (grid) = Ducted (air) = Ductless

The multi-family home was assumed to be three stories and fall under the Residential IECC

Local Builder Engagement

- **13 individual virtual interviews** with developers, builders, architects, general contractors, and subcontractors.
  - Goal to determine common narratives, barriers, and solutions.
- Virtual **focus group** to review and get feedback on draft findings.
- **Aggregated feedback** into costs and a list of barriers and benefits to all-electric and highly energy-efficient new homes.
- Used feedback to **inform final study recommendations** and common narratives.

Key Concepts

Beneficial Electrification

- The process of **strategically replacing natural gas-powered equipment** with electric-powered equipment.
- Brings the most **benefits to the consumer** through:
  - Improving indoor air quality
  - Optimizing energy use
  - Providing the potential for lower monthly energy costs
  - Reducing carbon emissions
  - Improving electrical grid management.
- **Does not include installing inefficient electric appliances**, such as electric-resistance furnaces.

Mixed-Fuel and All-Electric Features

Mixed-Fuel Home

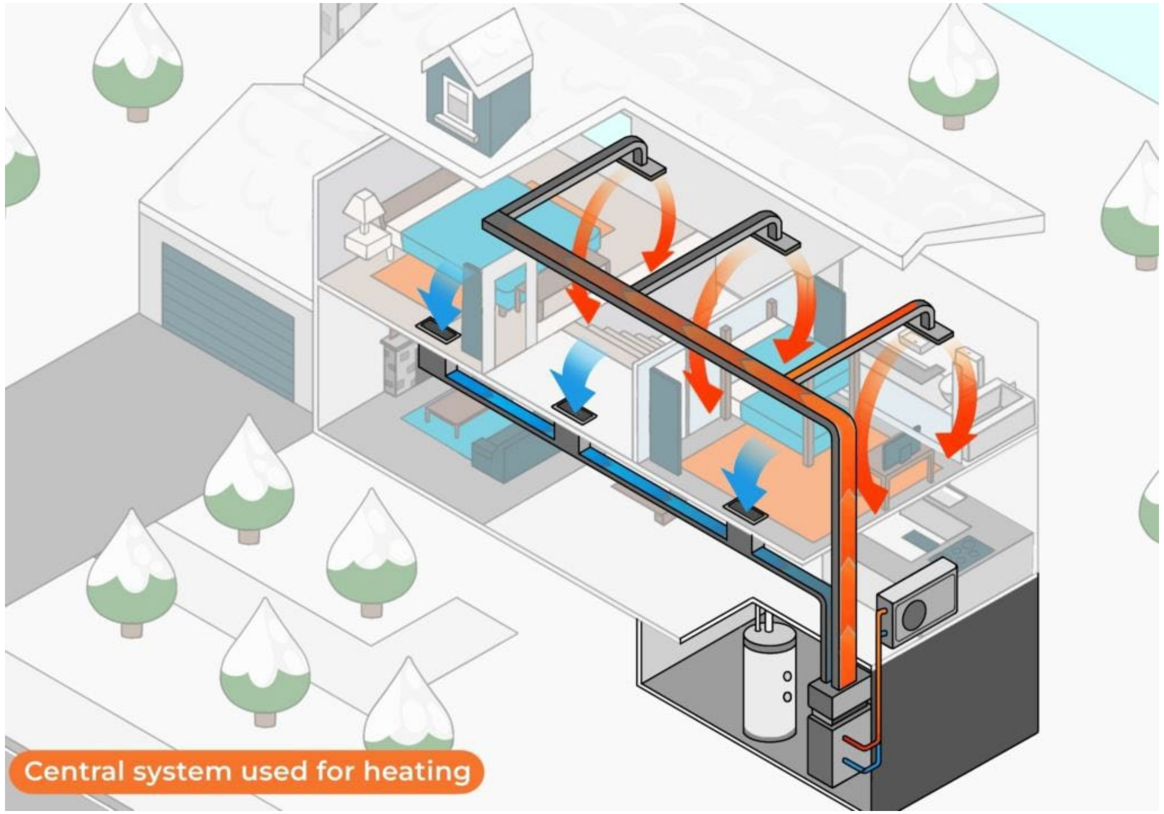
- Gas furnace and air conditioning (ducted system)
- Gas water heater
- Gas stove

All-Electric Home

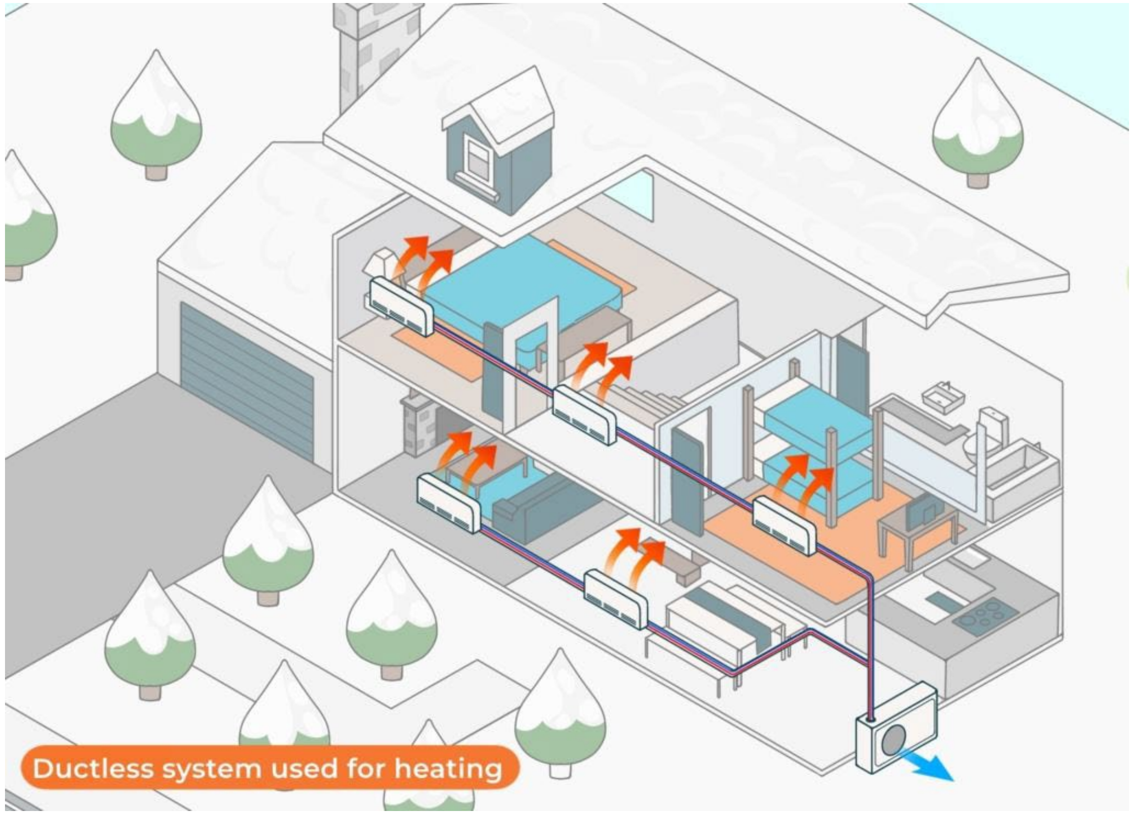
- Cold climate air source heat pump (ducted or ductless)
- Heat pump water heater
- Induction stove

Ducted vs. Ductless Heat Pumps

Ducted (central) system



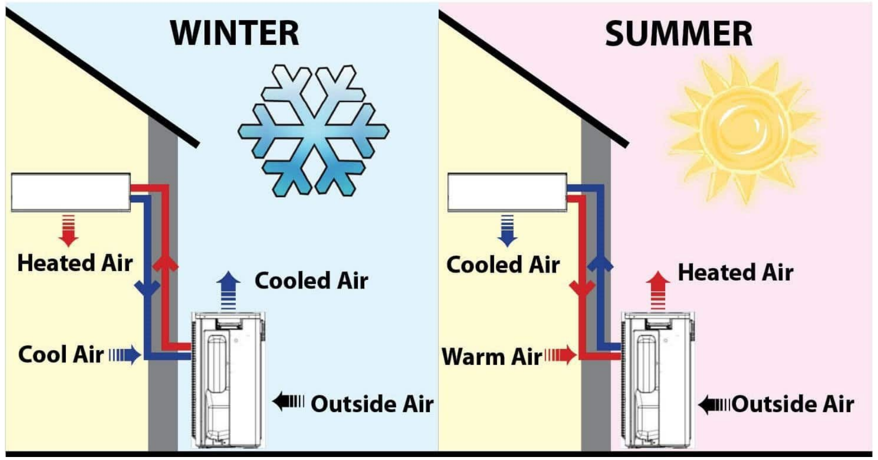
Ductless (mini-split) system



Air Source Heat Pump

Air Source Heat Pump (ASHP)

- Provide heating and cooling (AC in the summer and heating in the winter).
- 300-400% more efficient at heating than a gas or electric resistance furnace.
- Ducted or ductless (mini-split) systems.



Cold Climate Air Source Heat Pump

- Air-source heat pumps designed to operate efficiently at very low temperatures.
- Designed to provide heating for **cold climates**, such as Flagstaff's.
- cASHPs can operate effectively at temperatures as low as **-22 deg F** without a backup heating system.

APS Residential Electricity Plans

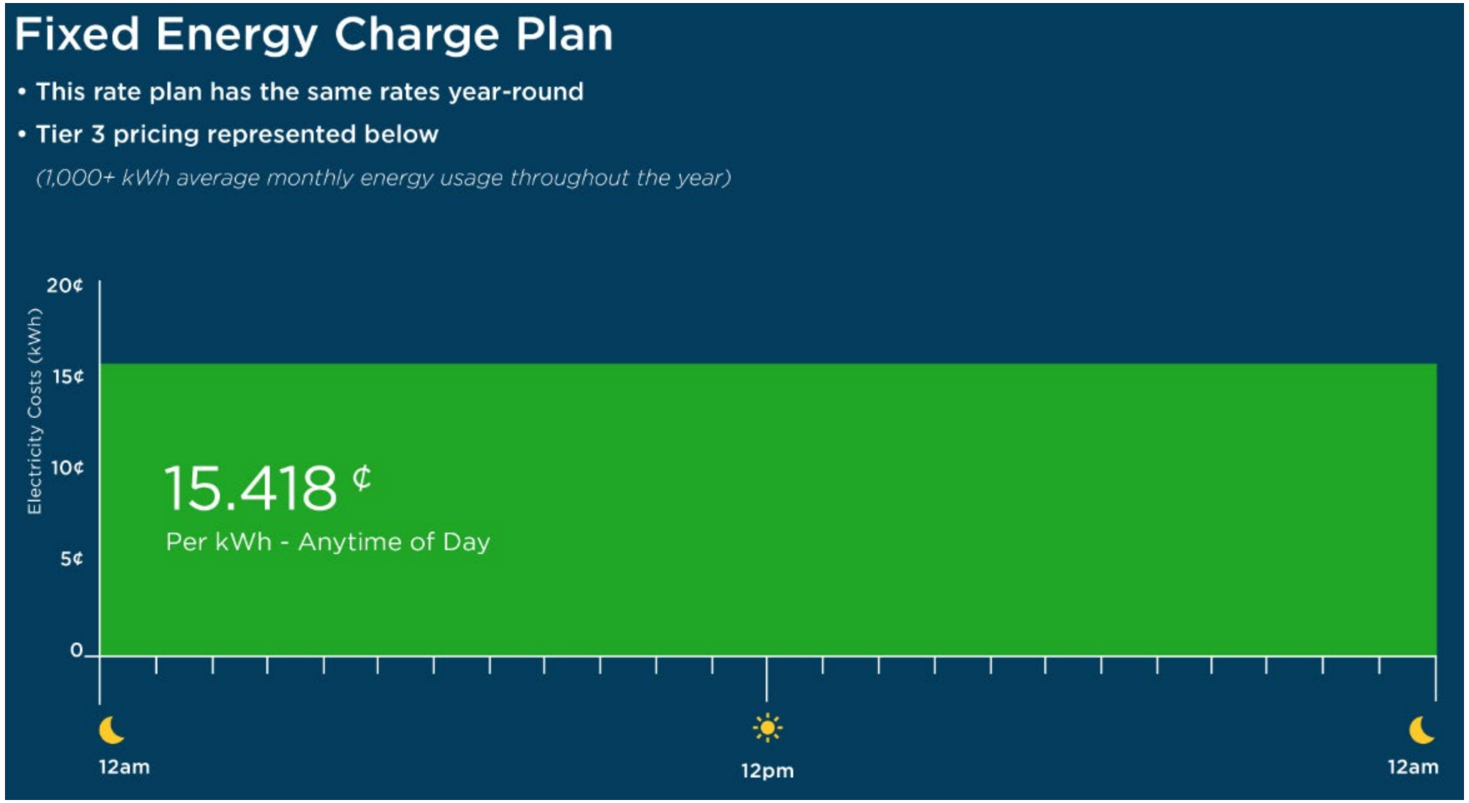
- Arizona Public Service (APS) provides electricity to Flagstaff and offers several residential electricity plans.
- **Rates vary** by plan and time of day.

- **Fixed Energy Plan:**
  - 3 tiers (small, medium, large) based on residents' average monthly electricity usage
  - Rates increase as usage increases.

APS Fixed Energy Charge Electricity Plan

Electricity costs:

- Tier 1 **(Small):** 12.925¢ per kilowatt hour (kWh)
- Tier 2 **(Medium):** 14.052¢
- Tier 3 **(Large):** 15.418¢



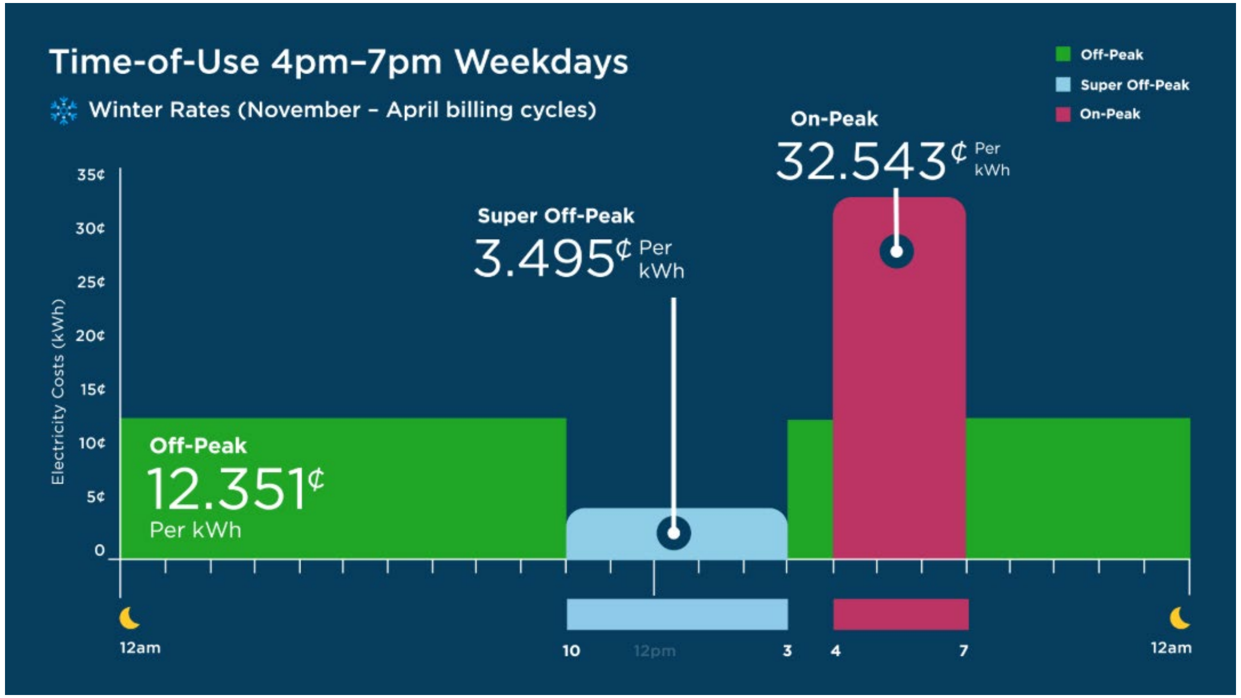
Shows rates per kWh for Tier 3 (Large).

APS Residential Electricity Plans

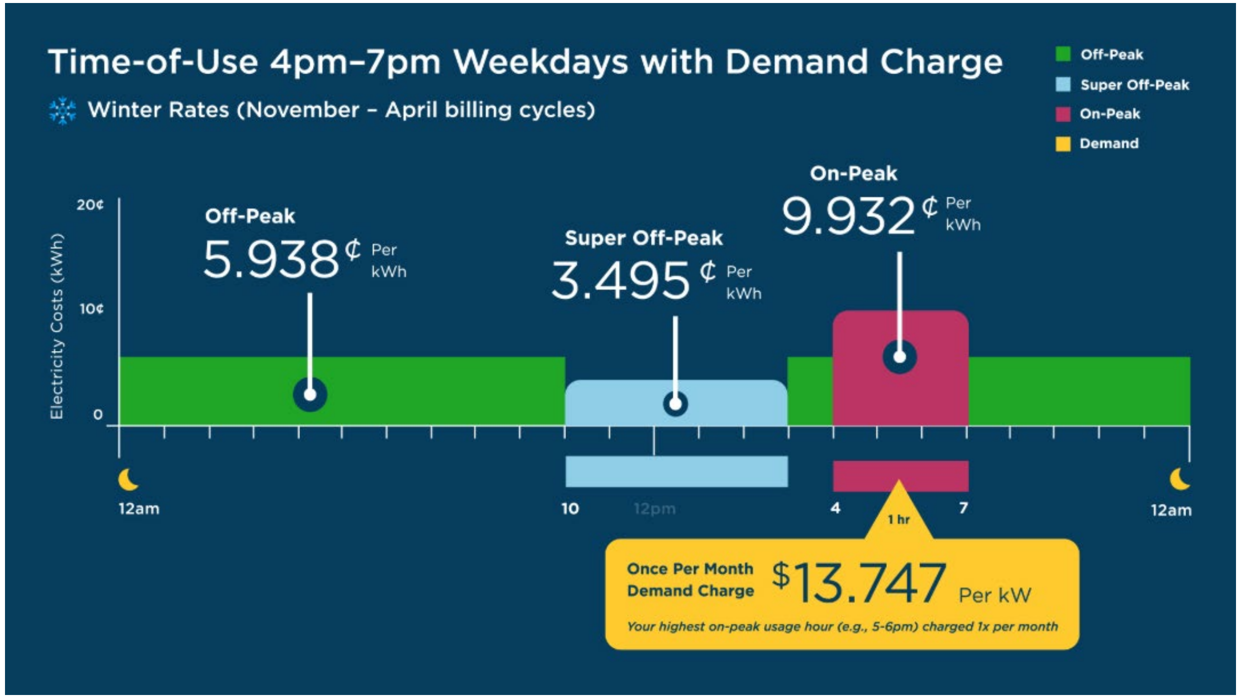
- **Time of Use (TOU) Plan** and **TOU + Demand Charge Plan**
  - Higher rates: “on-peak” hours (4-7 pm weekdays).
  - Lower rates: “off-peak” hours (all other times).
  - Lowest rates: “super off-peak” hours (10am – 3pm M-F, November – April).
- TOU + Demand Charge Plan has the lowest rates, but higher costs for using electricity during “on-peak” hours.
- **Both plans incentivize residents to minimize electricity use during “on-peak” hours.**

APS Time of Use Electricity Plans

Time of Use



Time of Use + Demand Charge



Winter rates are lower than summer rates; winter is when Flagstaff residents tend to use the most energy (to heat their homes).

Key Findings

Capital Costs: Single-Family **Mixed-Fuel**

Capital costs for a new 2,500 sf single-family home

System	Average Capital Cost	Cost Breakdown	Cost Range	Notes
Mixed-fuel	$12,500 - **$14,500**	Mixed-fuel: $11,500 Natural gas hookup: $3,000 Potential UniSource rebate: $2,000*	$8,500 - $18,500 (+/- $4,000)	Equipment costs, ductwork, gas connection

**It is likely that UniSource's rebate is not available to all builders.*
Presented costs are estimates and may vary depending on the exact system chosen. Findings are meant to serve as an order-of-magnitude estimate when evaluating the first costs associated with different building scenarios.

Capital Costs: Single-Family **All-Electric Ducted**

Capital costs for a new 2,500 sf single-family home

System	Average Capital Cost	Cost Breakdown	Cost Range	Notes
All-electric, ducted ccASHP	**$17,000**	All-electric ducted : $17,000 Additional electrical panel capacity: $0	$14,000 - $20,000 (+/- $3,000)	Slightly higher cost; includes ductwork

Presented costs are estimates and may vary depending on the exact system chosen. Findings are meant to serve as an order-of-magnitude estimate when evaluating the first costs associated with different building scenarios.

Capital Costs: Single-Family **All-Electric Ductless**

Capital costs for a new 2,500 sf single-family home

System	Average Capital Cost	Cost Breakdown	Cost Range	Notes
All-electric, ductless mini-spilt	**$14,000**	All-electric ducted : $14,000 Additional electrical panel capacity: $0	$12,000 - $16,000 (+/- $2,000)	Lower cost; no ductwork needed; minimal heat loss

Presented costs are estimates and may vary depending on the exact system chosen. Findings are meant to serve as an order-of-magnitude estimate when evaluating the first costs associated with different building scenarios.

Capital Costs: Single-Family
Energy Efficiency Upgrades

Capital costs for a new 2,500 sf single-family home

System	Average Capital Cost	Cost Breakdown	Cost Range	Notes
Highly energy-efficient (HEE) upgrades	**$8,500**	Energy efficiency measures: $7,000 ERV: $1,500	$4,000 - $13,000 (+/- $4,500)	Some builders already exceed code, incl ERVs

Presented costs are estimates and may vary depending on the exact system chosen. Findings are meant to serve as an order-of-magnitude estimate when evaluating the first costs associated with different building scenarios.

Summary of Capital Costs: Single-Family

Scenario	Total Cost	Range	Cost Difference (vs. Base Case)
Base case: mixed-fuel	$12,500 - $14,500	$8,500 - $18,500	--
1: All-electric ducted	$17,000	$14,000 - $20,000	+$2,500
2: All-electric ductless	$14,000	$12,000 - $16,000	-$500
3: Mixed-fuel, HEE	$23,000	$15,500 - $30,500	+$8,500
4: All-electric ducted, HEE	$25,500	$19,000 - $32,000	+$11,000
5: All-electric ductless, HEE	$22,500	$17,000 - $28,000	+$8,000

Green shading indicates that costs are less than the mixed-fuel base case; orange shading indicates costs are greater.

Capital Costs: Multi-Family **Mixed-Fuel**

Capital costs for a new 990 sf multi-family home

System	Average Capital Cost	Cost Breakdown	Cost Range	Notes
Mixed-fuel	**$12,500**	Mixed-fuel: $11,000 Gas hookup: $1,500	$8,300 - $15,800 (+/- $3,300)	Equipment costs, ductwork, gas connection

Presented costs are estimates and may vary depending on the exact system chosen. Findings are meant to serve as an order-of-magnitude estimate when evaluating the first costs associated with different building scenarios.

Capital Costs: Multi-Family **All-Electric Ductless**

Capital costs for a new 1,000 sf multi-family home

System	Average Capital Cost	Cost Breakdown	Cost Range	Notes
All-electric, ductless mini-spilt	**$11,300**	All-electric ducted : $11,300 Additional electrical panel capacity: $0	$7,000 - $15,300	Lower cost; no ductwork needed; minimal heat loss

Presented costs are estimates and may vary depending on the exact system chosen. Findings are meant to serve as an order-of-magnitude estimate when evaluating the first costs associated with different building scenarios.

Capital Costs: Multi-Family
Energy Efficiency Upgrades

Capital costs for a new 1,000 sf multi-family home

System	Average Capital Cost	Cost Breakdown	Cost Range	Notes
Energy efficiency upgrades	**$6,500**	Energy efficiency: $5,000 ERV: $1,500	$4,000 - $12,000 (ERV: +/- $500 Energy efficiency: - $2,000 / + $5,000)	Some builders already exceed code, incl ERVs

Presented costs are estimates and may vary depending on the exact system chosen. Findings are meant to serve as an order-of-magnitude estimate when evaluating the first costs associated with different building scenarios.

Summary of Capital Costs: Multi-Family

Scenario	All-in cost	Range	Cost difference vs. base case
Base case: Mixed-fuel	$12,500	$8,300 - $15,800	--
1: All-electric, ductless	$11,300	+/- $4,000	-$1,200
2: Mixed-fuel, HEE	$19,000	$13,200 - $27,800	+$6,500
3: All-electric, ductless, HEE	$17,800	$11,300 - $27,300	+$5,300

Green shading indicates that costs are less than mixed-fuel base case; orange shading indicates costs are greater.

Important Notes on Capital Costs

- Many builders already build **“beyond code”**.
- **Gas connection fees** are complicated.
- Current **electrical panel size** is most likely sufficient to accommodate electric loads for all-electric homes.
- Estimated SFU building costs were collected during builder interviews; costs ranged from **$160/sf to $850/sf**.
- Average additional cost of:
  - Energy efficiency upgrades ($8,500) is **less than 2.2%** of construction costs.
  - All-electric ducted system ($3,500) **is less than 0.9%**.

Key Capital Cost Takeaways

- All-electric ductless systems had the **lowest capital costs** in all home types.
- **All-electric ducted systems are likely to be more expensive** than mixed-fuel systems.
- Adding **energy efficiency** measures increases capital costs.
- Capital costs will likely **vary by home size and energy type**.

Given each home's unique nature, it is difficult to accurately pinpoint an exact cost for each system. *These **values should be considered illustrative.***

Operational Costs: Single-Family

Monthly energy costs for a new 2,500 sf single-family home on different APS electricity plans

Scenario	Fixed Rate (Medium)	TOU	TOU plus demand
Base case: Mixed-fuel	$159	$158	$138
1: All-electric, ducted	$182	$172	$129
2: All-electric, ductless	$131	$127	$97
3: Mixed-fuel, HEE	$138	$137	$116
4: All-electric, ducted, HEE	$141	$137	$103
5: All-electric, ductless, HEE	$128	$124	$95

Green shading indicates all-electric costs are less than mixed-fuel base case; orange shading indicates all-electric costs are greater.

Operational Costs: Multi-Family

Monthly energy costs for a new 990 sf multi-family home on different APS electricity plans

Scenario	Fixed rate (small)	TOU	TOU plus demand
Base case: Mixed-Fuel	$77	$82	$71
1: All-electric, ductless	$63	$69	$55
2: Mixed-fuel, HEE	$72	$77	$65
3: All-electric, ductless, HEE	$61	$68	$54

Green shading indicates all-electric costs are less than mixed-fuel base case.
No all-electric costs exceed the mixed-fuel base case.

Energy Efficiency Improvements vs. Cost Savings

Energy efficiency and utility costs savings for the highly energy efficient (HEE) homes varied by home and fuel type compared to Flagstaff's current energy code.

Home Type	Scenario	Modeled Energy Efficiency Improvement	Actual Energy Cost Savings
Single-family homes	3: Mixed-fuel, HEE	27%	13-16%
	4. All-electric, ducted, HEE	27%	19-22%
	3: All-electric, ductless, HEE	3%	2-3%
Multi-family homes	2: Mixed-fuel, HEE	21%	3 -11%
	3: All-electric, ductless, HEE	3%	2-3%

Key Operational Cost Takeaways: Single- and Multi-Family Homes

All-electric and highly energy-efficient homes have the potential to offer lower operational costs.

The **lowest operational costs** can be achieved through:

- Energy efficiency.
- Switching to the APS TOU plus demand plan.
- All-electric ductless systems.

Return on Investment: Single-Family Homes

Scenario	Capital Cost Differential		First Year Utility Cost Savings Compared to Mixed-Fuel Base Case*	Return on Investment
	Stakeholder Provided Estimate	Market Research Provided Estimate		
1: All-electric, ducted	+$2,500	+$3,000	$130	<15 years
2: All-electric, ductless	-$500	---	$500	Immediate
3: Mixed-fuel, HEE	+$8,500	+$6,500	$270	<18 years
4: All-electric, ducted, HEE	+$11,000	+$9,500	$430	<17 years
5: All-electric, ductless, HEE	+$8,000	+$6,500	$520	<11 years

*Based on the APS TOU plus demand charge plan

Return on Investment: Multi-Family Homes

Scenario	Capital Cost Differential		First Year Utility Cost Savings Compared to Mixed-Fuel Base Case	Return on Investment *
	Stakeholder Provided Estimate	Market Research Provided Estimate		
1: All-electric, ductless	-$1,200	-$2,000	$200	Immediate
2: Mixed-fuel, HEE	+$6,500	+$4,000	Up to $100	<30 years
3: All-electric, ductless, HEE	+$5,300	+$4,000	$200	<15 years

*Based on the APS TOU plus demand charge plan

Key Takeaways: Return on Investment

- The **useful life** of heating and cooling equipment is ~ 20 years. The ROI of most scenarios will be met within this timeframe.
- Rebates, not included here, will **improve all ROIs**.
- Efficient all-electric homes **pay for themselves** through lower utility bills.
- All-electric ductless mini-split systems have an **immediate payback**.

Additional Benefits of All-Electric Homes

- Better **indoor air quality.**
- Lower greenhouse gas (GHG) **emissions.**
  - All-electric ductless home will emit 60% fewer GHG emissions than a mixed-fuel home in 2030.
- Improved **safety.**
- Improved **resilience**.

Reduced Greenhouse Gas (GHG) Emissions

Scenario	Difference in Cumulative Carbon Emissions (present through 2050) Compared to Mixed-Fuel Base Case	
	Single-Family Homes	Multi-Family Homes
1: All-electric, ducted	-38%	Not applicable
2: All-electric, ductless	-56%	-43%
3: Mixed-fuel, HEE	-25%	-18%
4: All-electric, ducted, HEE	-53%	Not applicable
5: All-electric, ductless, HEE	-58%	-45%

Practitioner Feedback: Narratives and Barriers

This is what we heard:

1. Highly energy-efficient and all-electric homes are too costly to install and operate.
2. Clients typically want gas stoves and fireplaces.
3. The City bans, or at a minimum, strongly discourages wood-burning fireplaces.
4. Electric heat pumps do not work in cold climates.
5. Heat pumps will shut down should a grid outage occur, while natural gas appliances will still work.

However, this study found:

1. All-electric & energy-efficiency can, but don't always, cost more to build. Residents benefit from lower utility bills that help recoup costs.
2. Some builders say clients want gas stoves and fireplaces; others say clients choose electric options to improve air quality.
3. The City does not ban wood-burning stoves or fireplaces. Instead, it offers a rebate to replace an older model with an EPA certified wood stove.
4. Heat pumps work effectively in cold climates. A local contractor has installed 400-500 ccASHPs in Flagstaff.
5. Should the grid go down, most gas appliances will be equally affected.

Practitioner Feedback: Narratives and Barriers

This is what we heard:

5. Electric tankless water heaters should be installed as part of all-electric systems.
6. APS has a monopoly and do not want to build all-electric homes (support APS).
7. Conflicting viewpoints on whether the City should advance the energy code. Some builders recommended keeping the 2018 IECC + installing solar to get to net-zero, others say energy efficiency should be advanced with stronger energy codes.

However, this study found:

5. Heat pump water heaters are more efficient.
6. Some builders were supportive of energy efficiency, renewable energy, and battery storage to reduce reliance on APS.
7. Net-zero homes minimize energy use as much as possible (reduces the amount of renewable energy needed to offset energy use). Homes will have higher utility bills if energy consumption is not reduced.

Practitioner Feedback

Lessons Learned

- Ultimate construction decisions made by general contractors.
- Prioritize energy efficiency first!
- 2018 IECC requirements create such tight houses that ERVs are required.
- Some builders feel more comfortable building hybrid systems – though a backup heating system is likely not necessary in Flagstaff's climate.
- Typical panel size of 200 A is sufficient for all-electric homes.
- Several builders are not familiar with air-to-water heat pumps, and clients like in-floor radiant heating.
- Initial design and construction are paramount.

Recommendations for the City

1. Adopt the 2024 **International Energy Conservation Code** (IECC) and Appendix RG: 2024 IECC **Stretch Code**
    a. Improve energy efficiency by 24% to 27% over Flagstaff's current code.

2. Encourage new homes to be electric and adopt 2024 IECC Appendix RK **Electric-Ready** Residential Building Provisions

3. Adopt 2024 IECC Appendix RB **Solar-Ready Provisions**

4. Provide extensive **education and outreach**.

Recommendations for the City

5. Host a gas stove vs **induction stove cooking demonstration.**

6. Offer **incentives and equipment purchasing support**.
   a. Provide monetary incentives to support all-electric construction.

7. Set-up a **heat pump co-op program** to support bulk pricing and reduce capital costs.

8. Strengthen relationships with APS and members of the building community.

Thank you for your time!

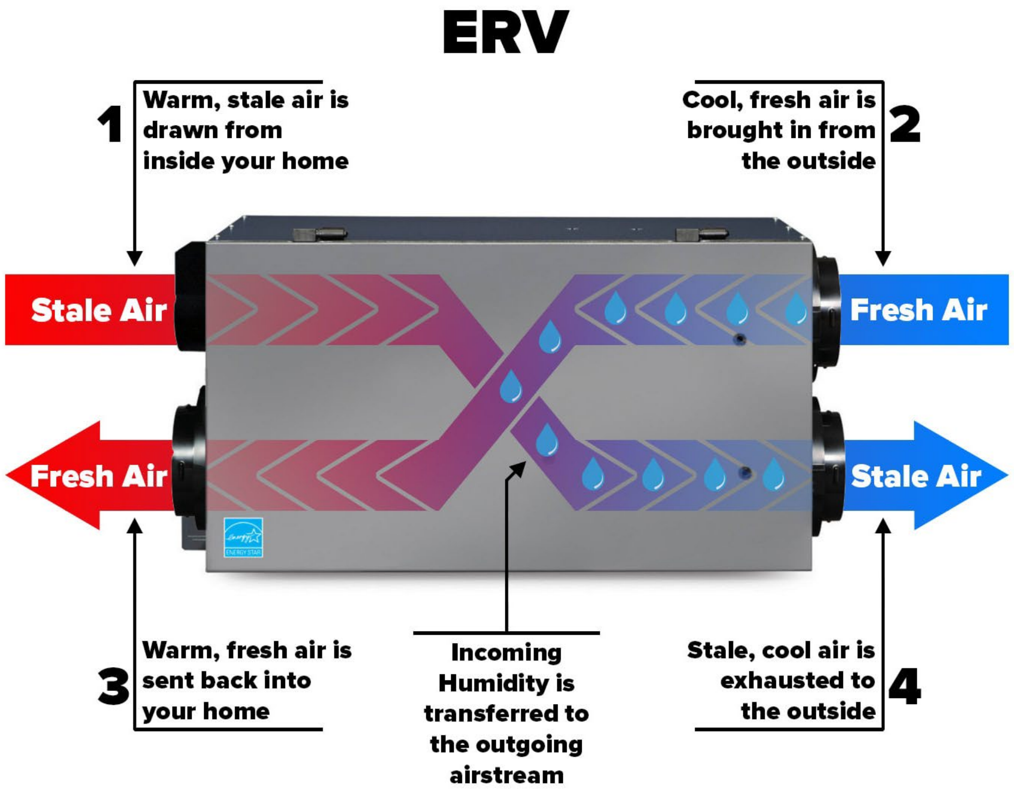
Questions?

Modeling Approach

- **Determine capital costs:**
  - Estimated heating and cooling loads for HVAC systems using CoolCalc.
  - Sizing informed feedback on costs from local construction professionals.

- **Determine operational costs:**
  - Estimated annual energy usage for each scenario in BeOPT modeling software under current energy rates
  - Used outputs to estimate energy costs based on different APS electricity plans
  - Used future utility cost projections to estimate return on investment Plans

Energy Recovery Ventilator (ERV)



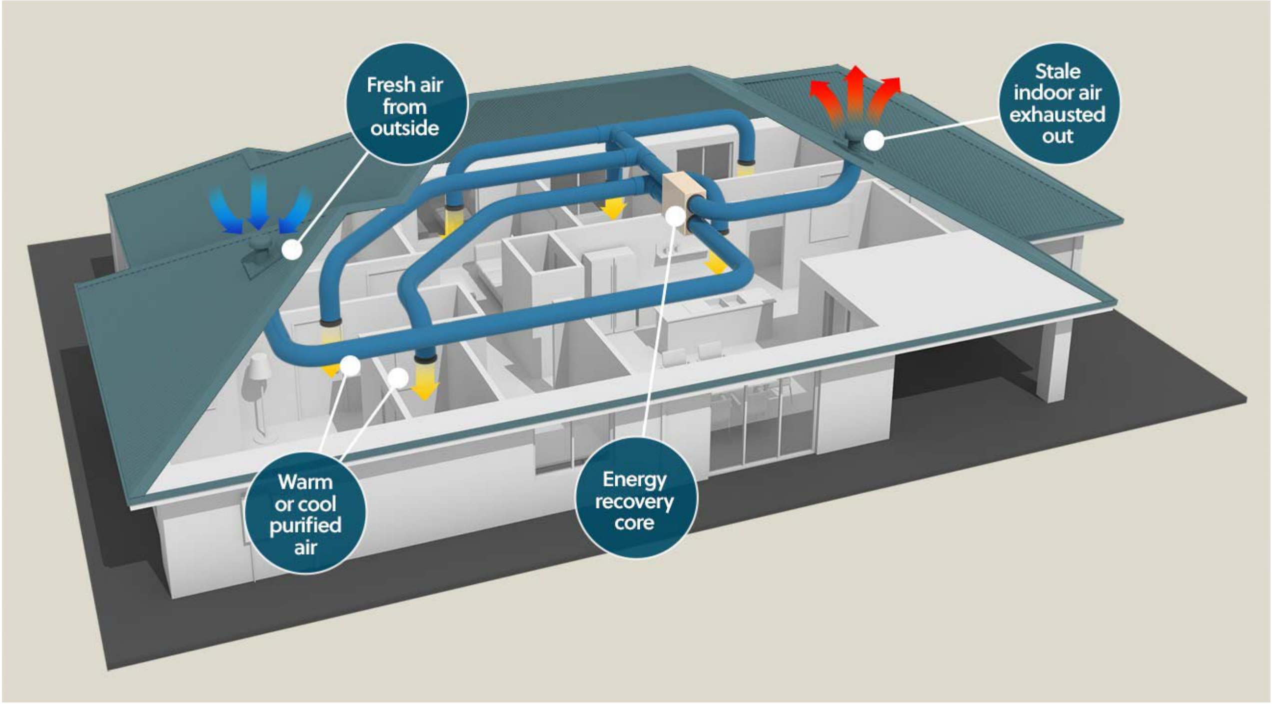


Image sources:
https://www.homevent.com.au/products/energy-recovery-ventilation/
https://westlandhvac.com/commercial-hvac/heat-energy-recovery-ventilators/

Analysis of the Costs, Benefits, and Barriers to Building Highly Energy-Efficient and All-Electric Residential Homes in Flagstaff, Arizona

Filling the Data Gap

Submitted to the City of Flagstaff | November 2025

Prepared by Noverra Collective, LLC

Executive Summary

The City of Flagstaff (the City) is committed to advancing its climate and housing goals, while maintaining a high quality of life for residents. A key strategy for reducing greenhouse gas (GHG) emissions and monthly utility costs is the expansion of energy efficiency[1] and beneficial electrification[2] in new residential construction. While several national studies provide evidence suggesting energy efficiency and electrification can bring health, economic, and other benefits to residents of cold-climate Western cities,[3] industry experience has shown that national studies may not always reflect local construction realities.

Recognizing this disparity, the City commissioned a study to evaluate the capital and operational costs and barriers, as well as the opportunities of building highly energy-efficient and all-electric new single- and multi-family homes. The intent of this analysis is to fill a critical data gap and inform City decisions about how to reduce energy use and emissions in the built environment while prioritizing long-term affordability.

Through this work, the City seeks to develop defensible, locally-grounded cost insights that reflect Flagstaff's real-world construction practices, while highlighting both the economic and non-economic benefits of energy-efficient, all-electric development.

Conclusions

This analysis finds that building all-electric, highly energy-efficient (HEE) homes is both technically and financially feasible in Flagstaff. A key takeaway is that building energy systems are complex and require nuanced considerations: costs and benefits vary with the degree of builder's familiarity with building systems and technology, available rate plans, heating and cooling system types, and other external factors. Energy usage and energy costs determined in this study are illustrative and will vary in practice.

Stakeholder and market research supported significant new findings on the cost of building electric, highly energy-efficient homes in Flagstaff. Among the many conclusions, we find:

- **For single-family homes**: It is less costly to construct an all-electric ductless single-family home, compared to a mixed-fuel single-family home in most cases, while it costs more to construct an all-electric ducted home compared to a mixed-fuel home. It costs less to operate an all-electric ductless home than a mixed-fuel home on all Arizona Public Service (APS) electricity plans. For all-electric ducted homes, the picture is mixed: using APS' Time-of-Use (TOU) Plus Demand Charge plan reduces costs versus a mixed-fuel home; on all other APS plans, it is more costly to operate an all-electric ducted home[4].

[1] For the purposes of this work, "energy efficient" and "highly energy-efficient" are defined as those measures that align with the 2024 International Energy Conservation Code (IECC) Appendix RG: 2024 IECC Stretch Code.
[2] Beneficial electrification is the process of strategically replacing natural gas-powered equipment with electric-powered equipment that brings the most benefits to the consumer through improving indoor air quality, optimizing energy use, providing the potential for lower monthly energy costs, reducing carbon emissions, and improving grid management. All references to "electrification" made in this report refer to "beneficial electrification".
[3] See RMI's The New Economics of Electrifying Buildings, NREL's Field Application of Air-Source Heat Pumps for Cold Climates, Government of Canada's Cold-Climate Air Source Heat Pumps, Joule's Coming in from the Cold: Heat Pump Efficiency at Low Temps
[4] APS offers several different electricity plans that residents can choose from. These plans offer different electricity rates, depending on the amount of energy used and the time of day and are discussed in detail in the Definitions and Assumptions section of this report. Also see APS rate plans.

- **For multi-family homes:** It is less expensive to construct an all-electric ductless multi-family home than a mixed-fuel home in Flagstaff. It also costs less to operate all-electric multi-family home than a mixed-fuel home on all APS rate plans.

Advancing highly energy-efficient and all-electric systems is not a straightforward process, but with City intervention at key points, particularly through education and outreach, these homes can be built more cost effectively. Highly energy-efficient, electric homes are worth pursuing as these homes produce cleaner air and fewer carbon emissions and provide resilience against a changing climate. The City can help address misconceptions and concerns through targeted outreach, while increasing builder and homeowner confidence in highly energy-efficient and all-electric homes.

Methodology

To reflect local realities, thirteen local practitioners – architects, builders, general contractors, and subcontractors – provided feedback on estimated capital costs, modeled operational costs, barriers, lessons learned, and recommendations that the City can consider to advance its climate and housing goals.

Practitioner feedback was complemented by modeling to explore capital costs, and the impacts that different APS electricity plans have on operational costs. Capital costs are "all-in" and include all required equipment for each modeling scenario. The base case and ducted and ductless scenarios were modeled to Flagstaff's current energy code (the 2018 International Energy Conservation Code— 2018 [IECC]) and Flagstaff's weather. The highly energy-efficient scenarios were modeled to the 2024 IECC and accompanying appendix -- Appendix RG: 2024 IECC Stretch Code (Stretch Code). The 2024 IECC and Stretch Code are estimated to provide a 24% improvement in energy efficiency over Flagstaff's current energy code[5]. Table ES-1 presents the modeled single- and multi-family scenarios.

Table ES-1. Modeled Single- and Multi-Family Scenarios

Scenarios Modeled	
Single-family home (2,500 sf)	**Multi-family home (990 sf)**
Base case: Mixed-fuel (electricity and natural gas)	Base case: Mixed-fuel (electricity and natural gas)
Scenario 1: Ducted all-electric[6]	Scenario 1: Ductless, all-electric
Scenario 2: Ductless all-electric	Scenario 2: Mixed-fuel, HEE
Scenario 3: Mixed-fuel, highly energy-efficient (HEE)	Scenario 3: Ductless all-electric, HEE
Scenario 4: Ducted all-electric, HEE	
Scenario 5: Ductless all-electric, HEE	

[5] Per the Department of Energy (DOE), Pacific Northwest National Laboratory (PNNL), and the International Code Council (ICC). 2024 IECC base code: DOE report. PNNL report. Stretch code improvements: DOE report and NAHB.

[6] Ducted systems may also be referred to as "heat pumps" or more specifically cold-climate air-source heat pumps (ccASHPs) and ductless systems may also be referred to as "mini-split heat pumps" or simply "mini-splits".

Findings

This analysis indicates that **building highly energy-efficient, all-electric homes is feasible and can bring health benefits and cost savings to Flagstaff residents, in addition to reducing greenhouse gas emissions from the built environment**[7]**.** However, the development picture is nuanced, and the actual costs and cost savings vary by system type and APS's electric rate plan.

Capital Cost Findings: Single-Family Homes

1. **All-electric ductless single-family homes cost less to construct than a mixed-fuel home.** Costs for ductless systems (mini-split systems) are lower because these systems do not require ductwork, as is required with a mixed-fuel and ducted all-electric system. All-electric homes also avoid costs associated with natural gas connections and plumbing.
2. **All-electric ducted homes cost slightly more to construct than a mixed-fuel home,** when both are built to Flagstaff's current energy code.
3. **Energy efficiency features add to construction costs for all home types.** However, many builders already build beyond the current code and capital cost estimates shared during this study may be overstated for some builders. Further, though a ducted all-electric, highly energy-efficient single-family home may cost the most to build, its additional costs are likely to be no more than 3% of total building costs based on estimates of building costs provided by practitioners.

Table ES-2: Capital cost comparison for single-family homes

Scenario	Total Cost	Range	Cost Difference (vs. Base Case)
Base case: mixed-fuel	$14,500*	$8,500 - $18,500	--
1: All-electric, ducted	$17,000	$14,000 - $20,000	+$2,500
2: All-electric, ductless	$14,000	$12,000 - $16,000	-$500
3: Mixed-fuel, HEE	$23,000*	$15,000 - $30,500	+$8,500
4: All-electric, ducted, HEE	$25,500	$19,000 - $32,000	+$11,000
5: All-electric, ductless HEE	$22,500	$17,000 - $28,000	+$8,000

Green = Costs are lower than the mixed-fuel base case. Orange = Costs are higher than the mixed-fuel base case.

**A $2,000 UniSource natural gas connection rebate may not be available for all projects, so the average capital cost of mixed-fuel homes is calculated without the rebate.*

Operational Cost Findings: Single-Family Homes

1. Utilizing APS' **TOU Plus Demand Charge plan provided the greatest electricity cost savings** across all scenarios when compared to the APS Fixed Energy Charge or TOU rate plan.
2. **Highly energy-efficient homes have lower utility costs than homes built to Flagstaff's current code because the** energy efficiency features reduce the amount of energy used by the consumer.

[7] The ranges for capital cost estimates are large and vary by the practitioner's familiarity with the technology, design of the home, equipment manufacturer, and other construction features. *The values presented here are illustrative.*

3. **It costs less to operate an all-electric ducted home on the APS TOU Plus Demand Charge Plan, compared to a mixed-fuel home.** On all other APS plans, it is more costly to operate an all-electric ducted home than a mixed-fuel home.
4. **It costs less to operate an all-electric ductless home than a mixed-fuel home** on all APS electricity plans. These systems provide targeted heating and cooling and eliminate the need for ductwork. Also, shifting heating to electric heat pump systems is a much more efficient use of energy.
5. **Utility cost savings from energy efficiency improvements were greater for all-electric homes than for mixed-fuel homes.** Per unit, electricity is more expensive on the APS fixed rate plans than natural gas, although the picture is nuanced on APS TOU plans. Therefore, reducing natural gas usage will typically yield lower cost savings than reducing electricity usage by the same amount. In addition to use-based rates, energy costs include fixed fees, which are not reduced as energy usage decreases.
6. **Utility cost savings from energy efficiency improvements were greater for all-electric ducted homes than for all-electric ductless homes.** Because ducted systems use more electricity than ductless systems, energy efficiency improvements had a bigger impact on utility costs.

Table ES-3: Monthly energy cost comparison for single-family homes

Scenario	Fixed Rate (Medium)	TOU	TOU plus demand
Base case: Mixed-fuel	$159	$158	$138
1: All-electric, ducted	$182	$172	$128
2: All-electric, ductless	$131	$127	$97
3: Mixed-fuel, HEE	$138	$137	$116
4: All-electric, ducted, HEE	$141	$136	$103
5: All-electric, ductless, HEE	$128	$124	$95

Green = Costs are lower than the mixed-fuel base case. Orange = Costs are higher than the mixed-fuel base case.

Capital Cost Findings - Multi-family Homes

1. **It costs less to construct an all-electric ductless multi-family home than a mixed-fuel home.** Costs for ductless mini-split systems are lower because these systems do not require ductwork, which is required with both mixed-fuel and ducted heat pump systems. Though at times, installers may choose slim-duct systems, which may slightly increase costs compared to a ductless system[8]. All-electric homes also avoid costs associated with natural gas connections and plumbing.
2. **Energy efficiency features add construction costs for all home types.** However, many builders already build beyond the current code, and the additional capital cost estimates of energy efficiency features shared during this study may be overstated for some builders.

[8] Slim-ducts are commonly used in condos because they take up less space than traditional ductwork. They are smaller, shorter, and typically installed within conditioned spaces.

Table ES-4: Capital cost comparison for multi-family homes

Scenario	All-in cost	Range	Cost difference vs. base case
Base case: Mixed-fuel	$12,500	$8,300 - $15,800	--
1: All-electric, ductless	$11,300	+/- $4,000	-$1,200
2: Mixed-fuel, HEE	$19,000	$13,200 - $27,800	+$6,500
3: All-electric, ductless, HEE	$17,800	$11,300 - $27,300	+$5,300

Green = Costs are lower than the mixed-fuel base case. Orange = Costs are higher than the mixed-fuel base case.

Operational Cost Findings - Multi-family Homes

1. **It costs less to operate an all-electric, ductless multi-family home than a mixed-fuel home on all APS plans.**
2. **It is least expensive to operate a highly energy-efficient, all-electric ductless multi-family home -** with the lowest utility costs occurring under the TOU Plus Demand Charge plan.
3. **Energy efficiency improvements reduce energy use at varying rates, depending on the location of each multi-family unit in the building.** Units on the top floor experienced the greatest reduction in energy use, followed by units on the middle and bottom floors.
4. **The cost savings from energy efficiency improvements were higher for mixed-fuel homes than for ductless all-electric homes.** Mixed-fuel homes start with lower-efficiency heating and cooling equipment, so efficiency upgrades reduce a larger share of their total energy use. In contrast, all-electric cold-climate heat pumps already operate at very high efficiency, leaving less opportunity for additional savings.

Table ES-5: Monthly energy cost comparison for multi-family homes

Scenario	Fixed rate (small)	TOU	TOU plus demand
Base case: Mixed-Fuel	$77	$82	$71
1: All-electric, ductless	$63	$69	$55
2: Mixed-fuel, HEE	$71	$76	$65
3: All-electric, ductless, HEE	$61	$68	$54

Green = Costs are lower than the mixed-fuel base case. No all-electric costs exceed the mixed-fuel base case.

Energy Efficiency Improvements and Utility Cost Savings in Single-Family and Multi-Family Homes

1. **Energy efficiency improvements in the HEE homes reduced energy use by 3-27%** over homes built to Flagstaff's current energy code. This is a wide range compared to the national estimates of a 24% for Flagstaff's climate zone. However, actual energy cost savings varied by home and fuel type, and were impacted by the chosen energy efficiency measures.

Table ES-6: Energy efficiency improvements vs. utility cost savings for single- and multi-family homes

	Scenario	Modeled Energy Efficiency Improvement	Actual Energy Cost Savings
Single-family homes	3: Mixed-fuel, HEE	27%	13-16%
	4. All-electric, ducted, HEE	27%	19-22%
	5: All-electric, ductless, HEE	3%	2-3%
Multi-family homes	2: Mixed-fuel, HEE	21%	7-9%
	3: All-electric, ductless, HEE	3%	2-3%

Return on Investment: Single-Family and Multi-family Homes

1. **The return on investment (ROI) for single-family homes varied from 0 - 18 years, and for multi-family homes from 0-30 years[9].** This is the amount of time it could take utility cost savings to offset the additional capital cost of all-electric and energy-efficiency features on the TOU Plus Demand Charge Plan. While the presented return on investment is relatively long, they may be conservative given the large variability of capital costs needed to improve home efficiency. Further, capital costs exclude any potential rebates or incentives, which could significantly offset first costs and shorten the ROI.
2. **All-electric ductless single- and multi-family homes had the shortest payback period; mixed-fuel, highly energy-efficient homes had the longest payback period.**

Table ES-7: Maximum expected ROI for all-electric and highly energy-efficient systems in single-family homes

Scenario	Capital Cost Differential		First Year Utility Cost Savings Compared to Mixed-Fuel Base Case*	Return on Investment [10]
	Stakeholder Provided Estimate	Market Research Provided Estimate		
1: All-electric, ducted	+$2,500	+$3,000	$130	<15 years
2: All-electric, ductless	-$500	---	$500	Immediate
3: Mixed-fuel, HEE	+$8,500	+$6,500	$270	<18 years
4: All-electric, ducted, HEE	+$11,000	+$9,500	$430	<17 years
5: All-electric, ductless, HEE	+$8,000	+$6,500	$520	<11 years

Green = ROI is shorter than the mixed-fuel base case. Orange = ROI is longer than the mixed-fuel base case.
**Based on TOU plus demand rates and projected energy rate escalation.*

[9] ROI was calculated using the simple payback period, which focus on the upfront costs and utility cost savings only. It does not include mortgage costs or potential impacts of higher upfront construction costs on monthly rent.
[10] Utility cost increases are based on Energy Information Administration (EIA) projects and industry best practice, and assume that electricity rates increase by 3.5% and natural gas rates increase by 5% in 2026. Thereafter, both energy rates are projected to increase by 3%.

Table ES-8. Maximum expected ROI for all-electric and highly energy-efficient systems in multi-family homes

Scenario	Capital Cost Differential		First Year Utility Cost Savings Compared to Mixed-Fuel Base Case*	Return on Investment[11,*]
	Stakeholder Provided Estimate	Market Research Provided Estimate		
1: All-electric, ductless	-$1,200	-$2,000	$200	Immediate
2: Mixed-fuel, HEE	+$6,500	+$4,000	Up to $100	<30 years
3: All-electric, ductless, HEE	+$5,300	+$4,000	$200	<15 years

Green = ROI is shorter than the mixed-fuel base case. Orange = ROI is longer than the mixed-fuel base case.
**Based on TOU plus demand rates and projected energy rate escalation.*

Co-Benefits of All-Electric Homes

While the financial impacts of building highly energy-efficient and all-electric homes are subject to a variety of conditions, the ancillary benefits are clear, especially when compared to mixed-fuel homes.

Co-benefits are the additional advantages to the community beyond cost savings that improve health, reduce emissions, and improve resiliency. These include the following:

- **Healthier indoor air:** All-electric homes eliminate gas combustion indoors, improving air quality and reducing pollutants linked to asthma and other respiratory illness.[12]
- **Improved safety:** All-electric homes are safer to operate than mixed-fuel homes because they do not burn natural gas, avoiding the associated risks of carbon monoxide poisoning from malfunctioning natural gas appliances and explosions from natural gas leaks.
- **Homeowner pride.** Some builders shared that homeowners take a great deal of pride in highly energy-efficient and all-electric homes, and that pride extends to a greater sense of pride in their neighborhood and community.
- **Potential to support market evolution.** Some builders shared that building energy-efficient, all-electric homes in Flagstaff can support the local labor pool by creating a common approach to installing electric systems and participating in the market evolution towards all-electric homes.
- **Lower carbon emissions:** APS's grid was 51% carbon-free in 2024**.** Using electricity produces fewer greenhouse gas (GHG) emissions than burning natural gas in the home, especially as the grid adds renewables. By 2050, highly energy-efficient, all-electric ductless homes will emit approximately 58% fewer greenhouse gas emissions annually than a mixed-fuel home built to Flagstaff's current code. A high-efficiency mixed-fuel home will emit approximately 25% fewer emissions.

[11] Ibid.
[12] International Journal of Environmental Research and Public Health.

Table ES-9. Greenhouse gas emissions savings compared to mixed-fuel base case

Scenario	Difference in Cumulative Carbon Emissions (present through 2050) Compared to Mixed-Fuel Base Case*	
	Single-Family Homes	Multi-Family Homes
1: All-electric, ducted	-38%	Not applicable
2: All-electric, ductless	-56%	-43%
3: Mixed-fuel, HEE	-25%	-18%
4: All-electric, ducted, HEE	-53%	Not applicable
5: All-electric, ductless, HEE	-58%	-45%

Green = reduction in emissions compared to the mixed-fuel base case (no scenarios produced more emissions than the mixed-fuel base case).

**It should be noted that the modeled parameters chosen to represent "high efficiency" affect the way that savings are experienced. For instance, ductless systems start with a better baseline of energy performance (and lower carbon emissions) due to a variety of factors, such as lower distribution losses, and may not be as affected by the measures chosen to represent "high efficiency".*

Barriers to Energy Efficiency and Electrification

Thirteen members of the building community shared narratives that may serve as barriers to building energy-efficient and all-electric homes. These narratives reflect impressions that the building community may have and are presented with additional context, including information gathered from this study.

1. **We heard that highly energy-efficient and all-electric homes are too costly to install and operate.** Our report shows that there is often an additional capital expenditure for electric homes, though at times it's nominal, and that all-electric ductless systems are less expensive to build than mixed-fuel systems.
2. **We heard that clients typically want gas stoves and fireplaces.** While no data suggests that gas stoves are superior to induction cooking, much of the general public assumes that they are, resulting in a preference for the "experience" of gas cooking and gas fireplaces. As a result, these are the types of appliances that contractors typically sell and install.
3. **We heard that the City bans, or at a minimum, strongly discourages wood-burning fireplaces.** The City does not ban wood-burning stoves or fireplaces. However, this belief incentivizes general contractors to plan for gas connections in new construction. The City offers a rebate for replacing an older wood stove with an EPA-certified wood stove.
4. **We heard that electric heat pumps do not work in cold climates.** Ample evidence shows that heat pumps work effectively in cold climates such as Flagstaff's(see product information from Carrier, Mitsubishi and Trane). Further, a local installer has installed up to 500 cold-climate air-source heat pumps (ccASHP) in Flagstaff and has not received a single negative report about their ability to meet heating and cooling loads.
5. **We heard that heat pumps will shut down should a power grid outage occur.** Should the grid go down, most gas appliances will be equally affected.

6. **We heard that electric tankless water heaters should be installed as part of all-electric systems.** Generally, electric heat pump water heaters are preferred due to their high efficiency and demonstrated performance within Flagstaff.
7. **We heard different viewpoints on whether to adopt stronger energy codes.** Some builders would like to keep Flagstaff's current energy code (the 2018 IECC) and apply cost savings from not installing additional energy efficiency features toward home electrification and on-site solar. However, getting to net-zero without reducing energy consumption first means that a home will have higher utility bills and pay more for a larger solar photovoltaic system than they would if energy consumption were reduced. In contrast, we also heard that the only way to increase energy efficiency across the board is increase the minimum energy efficiency standards through updated Building and Fire Codes, including the energy code.
8. **We heard that ideology may influence who builds energy-efficient and all-electric construction.** Incentives or rebates to offset the additional costs of all-electric construction, for example, could help increase the amount of all-electric homes that are built by builders from across the ideological spectrum.
9. **We heard that there is a limited pool of subcontractor expertise and how this increases construction costs.** A lack of a deep pool of local expertise to install energy efficiency features and heat pumps can lead builders to seek labor from outside of Flagstaff, which requires subcontractors to travel and increases costs.

Recommendations

To support practitioners' concerns while advancing highly energy-efficient and all-electric homes, we make the following recommendations for the City's consideration:

1. **Adopt the 2024 IECC and Appendix RG: 2024 IECC Stretch Code** to advance energy efficiency by an average of 24% - 27% over Flagstaff's current energy code. Advancing energy efficiency is good for the community: it will save operational costs, it is healthier, safer, and cleaner for our planet, and has proven to improve occupant comfort. Several builders noted that the only way to ensure that Flagstaff's community realizes these benefits is by requiring it of all new builds through the adoption of new building codes. This is particularly important for Flagstaff's low-income residents, who are disproportionately burdened with high energy costs.
2. **Encourage new home construction to be all-electric.** The City can advocate for and encourage new builds to be all-electric through education, outreach, and incentives.
3. **Adopt Appendix RK Electric-Ready Residential Building Provision of the 2024 IECC.** This appendix will make it easier and less costly for residents living in mixed-fuel homes to switch from natural gas to electric appliances in the future.
4. **Adopt Appendix RB Solar-Ready Provisions – Detached One- and Two-Family Dwellings and Townhouses of the 2024 IECC.** This appendix will make it easier for residents to install on-site photovoltaic panels and battery storage and will allow them to achieve partial or full energy independence with associated long-term cost savings. Note: Flagstaff adopted the 2018 version of this appendix as part of its current energy code.
5. **Provide extensive education and outreach to encourage energy efficiency and beneficial electrification in new home construction.** Reference the barriers in outreach materials, prioritize building science training with subcontractors and general contractors, provide informational materials on cost savings from switching to APS TOU plans, conduct outreach on gas stoves and fireplaces, and focus outreach on electric heating and cooling equipment, since these appliances are responsible for the bulk of energy usage.

6. **Host a gas stove vs induction stove cooking demonstration exhibit for the public and members of the building community.** Providing in-person demonstrations of induction (electric) cook stoves will likely build support and encourage residents to move away from natural gas cook stoves and towards electric ones.
7. **Set-up a heat pump co-operative program for new residential construction.** Set up a co-operative for new construction similar to the one that exists for installing solar photovoltaic panels and battery storage on existing homes. Contractors stated they would be willing to share these prices as part of their outreach with clients.
8. **Offer incentives and equipment purchasing support.** Provide monetary incentives, such as up to $3,000 per project, when a general contractor proceeds with an all-electric home. Members of the building community noted that rebates could significantly help more electric homes be built.
9. **Strengthen relationships with APS and the building community.** Set up regular working meetings between APS to identify ways in which APS can better support the building community, leverage this study as an in-roads to building stronger relationships with members of the building community, and facilitate peer-to-peer educational opportunities and coalition building through a Builders Association or other means like a City-sponsored panel.