Building Electrification Institute

CITIES DRIVING CHANGE

Salt Lake City Customer Economics Analysis for Building Electrification

Completed June 2019

Table of Contents

Building Electrification Institute
CITIES DRIVING CHANGE

Customer Economics Analysis | Overview

Background and Summary of Project

Salt Lake City began working with the Building Electrification Institute (BEI) in 2019 to explore opportunities to reduce greenhouse gas (GHG) emissions and air pollution through building electrification.

In 2019, BEI and its consultant, The Cadmus Group, completed this customer economics analysis to assess the costs and potential savings from installing air source heat pumps (ASHPs) and heat pump water heaters (HPWHs) in typical Salt Lake City residential buildings. The goals of these analyses were to identify the electrification upgrades that will reduce costs in Salt Lake City homes today and to help identify strategies that the City or local utilities could implement that will improve the economics of electrification upgrades in these buildings over the long-run.

Customer Economics Analysis | Objectives

The purpose of the Customer Economics Analysis was to:

- Identify building typologies and electrification upgrades with positive customer economics in Salt Lake City under current conditions.
- Help the City or local utilities prioritize strategies to improve customer economics in more building types.
- Serve as a foundation to educate and engage Salt Lake City's building community on increasing heat pump installations.

Key research questions for the Customer Economics Analysis were:

- How do the installation, operating, and lifetime costs of electrification technologies for space heating, cooling, and water heating compare with conventional technologies?
- How long are the paybacks for selected electrification technologies and strategies?

Customer Economics Analysis | Approach

1) Research and validate inputs

First, the BEI team **developed building upgrade scenarios and compiled installation costs for electrification equipment** in typical Salt Lake City buildings and interviewed local contractors to validate these inputs.

2) Model energy use

The team then **modeled energy use for heating, cooling, and water heating** for each scenario using the U.S. Department of Energy's Building Energy Optimization Tool (BEopt).

3) Assess customer economics

The team **used the energy model outputs to assess cash flows** based on the installation costs, predicted energy use, and local energy rates in order to determine lifetime costs of electrification upgrades.

4) Develop recommendations

Based on the results of the analysis, the BEI team developed recommendations for strategies that would help improve the customer economics of electrification upgrades in Salt Lake City buildings.

Notes our approach: *In focusing on costs and savings, this analysis does not directly quantify some of the other benefits of electrification, such as indoor air quality, air pollution, quiet, and comfort. Additionally, while assumptions and inputs were based on extensive research and validation with stakeholders, actual costs and benefits in individual buildings are likely to vary.*

Customer Economics Analysis | Scenarios

	Single family Retrofit ASHP	Single family Retrofit HPWH	Multi-family Retrofit ASHP	Multifamily New Construction - All electric
Building Type	 **Single family detached**	 **Single family detached**	 **4-story, 23-unit building**	 **5-story, 50-unit building**
New/Retrofit	Retrofit (1990s)	Retrofit (1990s)	Retrofit (1980s)	New
Counterfactual Systems	Gas Furnace ***OR*** Electric Baseboard	Gas Water Heater ***OR*** Electric Water Heater	Gas Furnace ***OR*** Electric Baseboard	Gas Appliances
Electrification Technologies	Air source heat pump (ASHP) system: Ductless mini-split ***OR*** Ducted heat pump *(except w/ baseboard)*	Heat pump water heater (HPWH)	ASHP system: Ductless mini-split	Ductless mini-splits, HPWH, ***AND*** Electric range/oven
Installation Type	Displacement*	Replacement	Displacement* ***OR*** Replacement	Whole Home
Cooling Counterfactual Systems	Central A/C ***OR*** No A/C	N/A	Room A/C ***OR*** No A/C	Central A/C
Energy Efficiency/ Envelope	Typical (Base Load) ***OR*** Efficient (Low Load)	N/A	Typical (Base Load) ***OR*** Efficient (Low Load)	Baseline Utah code ***OR*** tighter envelope
Solar PV	No PV ***OR*** With PV	No PV ***OR*** With PV	No PV ***OR*** With PV	No PV ***OR*** With PV

Building Electrification Institute

*Under a ”displacement” scenario, the ASHP is assumed to displace a portion of the existing heating system, rather than fully replacing the system. A displacement strategy can have upsides, including lower total installation cost and redundancy of systems to ensure adequate heat on the coldest days of the year.

Customer Economics Analysis | Common Assumptions

General Inputs

Description	Input	Unit	Notes/Sources
Discount rate	10%	%	Typical customer discount rate
Discount rate	5%	%	Low-end discount rate for sensitivity analysis
Space heating equipment lifetime	18	Years	Varies 15-20 years, selected 18 to simplify analysis
Water heating equipment lifetime	13	Years	BEopt standard input
Fuel cost escalation - electricity	2.5%	Annual % growth	2019 EIA Annual Energy Outlook Reference Case – Mtn. region – nominal
Fuel cost escalation – natural gas	3.5%	Annual % growth	2019 EIA Annual Energy Outlook Reference Case – Mtn. region – nominal

Source: 2014 Building America House Simulation Protocols. NREL, 2014

Natural Gas Rates: GS Rate

Tier	Summer	Winter	Unit	Notes/Sources
Fixed charges	**$6.75**		$/month	*Dominion Energy For new constr. only*
First 45 Dekatherms	**$5.87**	**$7.13**	$/ dekatherm	*Dominion Energy*
Over 45 Dekatherms	**$4.73**	**$5.99**	$/ dekatherm	*Dominion Energy*

Electricity Rates: Residential Service

Tier	Summer	Winter	Unit	Notes/Sources
Fixed charges	**$6.00**		$/month	*Rocky Mountain Power For new constr. only*
First 400 kWh	**¢8.8**	**¢8.8**	¢/kWh	*Rocky Mountain Power*
Next 600 kWh	**¢11.5**	**¢10.7**	¢/kWh	*Rocky Mountain Power*
Above 1,000 kWh	**¢14.5**		¢/kWh	*Rocky Mountain Power*

Notes on rates: Assumes multifamily scenarios are individually metered at residential rates. Electricity pricing in Salt Lake City has since been updated to a two-tiered system.

Table of Contents

Building Electrification Institute
CITIES DRIVING CHANGE

Single Family Retrofit – ASHP Displacement | Assumptions

Building Energy Model Assumptions

Description	Input	Unit	Notes/Sources
Building size *(3 Br, 2 Ba, 2-story, unfinished basement)*	2,000	Sq. ft.	Assumption based on median SF home size in parcel database
Building age*	1941	year	Assumption based on median "effective year" in parcel database
Heating set point	76	°F	2014 Building America House Simulation Protocols
Cooling set point	71	°F	2014 Building America House Simulation Protocols
Water heating set point	125	°F	2014 Building America House Simulation Protocols

*Affects BEopt estimates for typical air infiltration rates, which are based on building age, building size, and local climate.

Additional Information about Building Models:

- Assumptions for typical single-family home size and year built are based on previous BEI analysis of single-family homes in Salt Lake City.
- BEopt software utilizes inputs for building size, vintage, and systems as well as local climate data to model building energy use for a variety of end uses.
- The model also accounts for heat pump performance at different outdoor temperatures.

Single Family Retrofit – ASHP Displacement | Assumptions

Cost and Equipment Assumptions

Input Description	Counterfactual Equipment		Electrification Equipment		Notes/ Sources
	Natural Gas Furnace	Electric Baseboard	Ductless mini-split	Ducted ASHP	
System size	N/A	N/A	1.5 tons (1 ton with EE measures)	2 tons (1.5 tons with EE measures)	Modeled in BEopt
% Heating Load Covered	100%	100%	58%	79%	BEopt output
System efficiency	78% AFUE 20% duct losses	100%	9.6 HSPF, 18 SEER	9.5 HSPF, 19 SEER Assumes same duct losses (20%) as natural gas furnace	BEopt defaults
Capital cost*	N/A	N/A	$4,950 – 1.5 ton $4,380 – 1 ton	$7,000 – 2 ton $6,500 – 1.5 ton	Navigant and Contractor Interviews
Available incentive	N/A	N/A	$1,000 Amount for single zone, only if replacing electric	$750 Amount for a higher efficiency system, only if replacing electric	Rocky Mountain Power

*For all displacement scenarios, there is no capital cost for the counterfactual because existing heating equipment will remain in place. Electrification equipment costs are also therefore presented as total costs (as opposed to incremental costs). Additional assumptions for the capital cost range for the ductless mini-split are included in the Appendix on slide 41.

Single Family Retrofit – ASHP Displacement | Results

Summary of Results

Scenario 1

Gas Furnace Baseline to Ducted ASHP Displacement

- **Installation cost**: $7,000 (full cost)*
- **Operational cost**: Increase of $200 in Year 1
- **Simple Payback**: None

Scenario 2

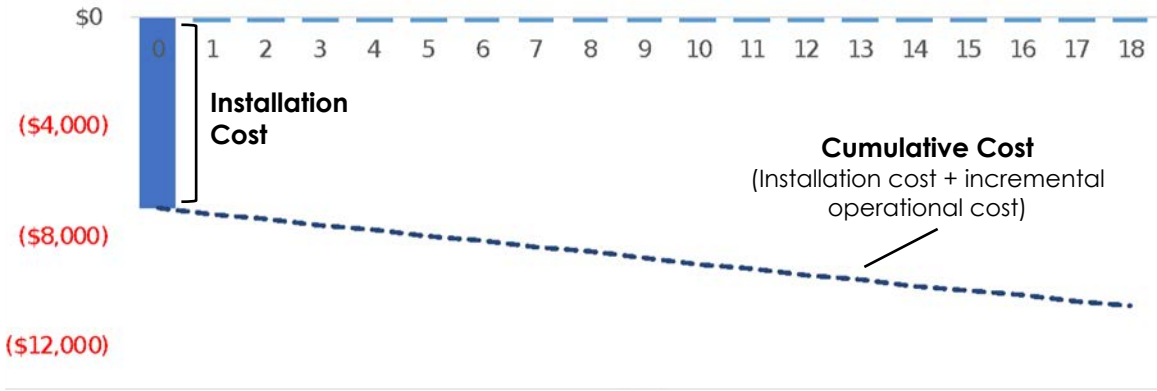
Gas Furnace Baseline to Ductless Mini-split Displacement

- **Installation cost**: $4,950 (full cost)*
- **Operational cost**: Increase of $20 in Year 1
- **Simple Payback**: None

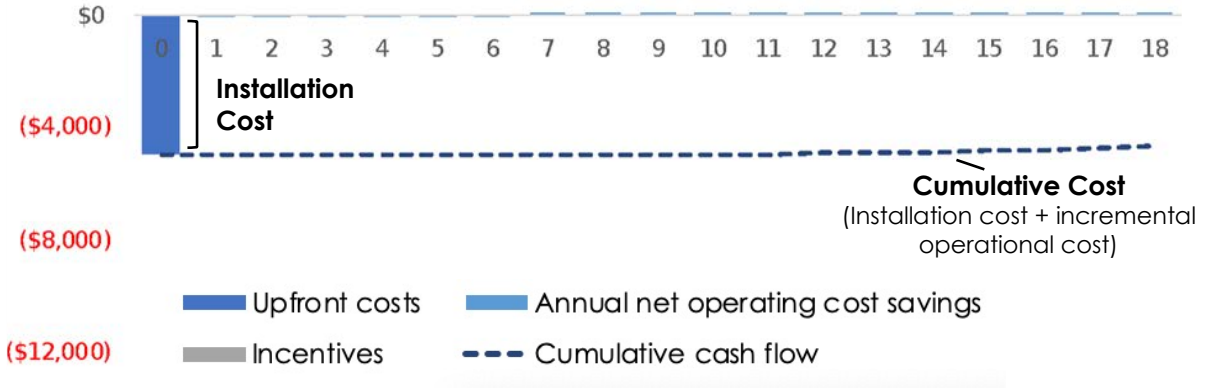
Takeaway: The economics of displacing a gas heating system with an ASHP are challenging in a typical Salt Lake City home when no other measures are included. Energy costs may increase slightly, and the installation costs of the system will not currently pay back.

*All installation costs, savings, and incentives are rounded to the nearest $10.

Scenario 1: Gas Furnace Baseline to Ducted ASHP Displacement
(Total Cost by Year)



Scenario 2: Gas Furnace Baseline to Ductless Mini-split Displacement
(Total Cost by Year)



Building Electrification Institute

Key Assumptions: Baseline building assumes no existing air conditioning, solar PV, or previous envelope improvements. Retrofit scenarios assume displacement of the existing heating load (rather than full replacement), so no counterfactual heating costs are included because the existing system must stay in place. Cash flow charts assume electricity rates increase by 2.5% annually; gas rates increase by 3.5% annually; and include a 3% annual discount rate for the value of future energy savings.

Single Family Retrofit – ASHP Displacement | Results

Summary of Results

Scenario 3

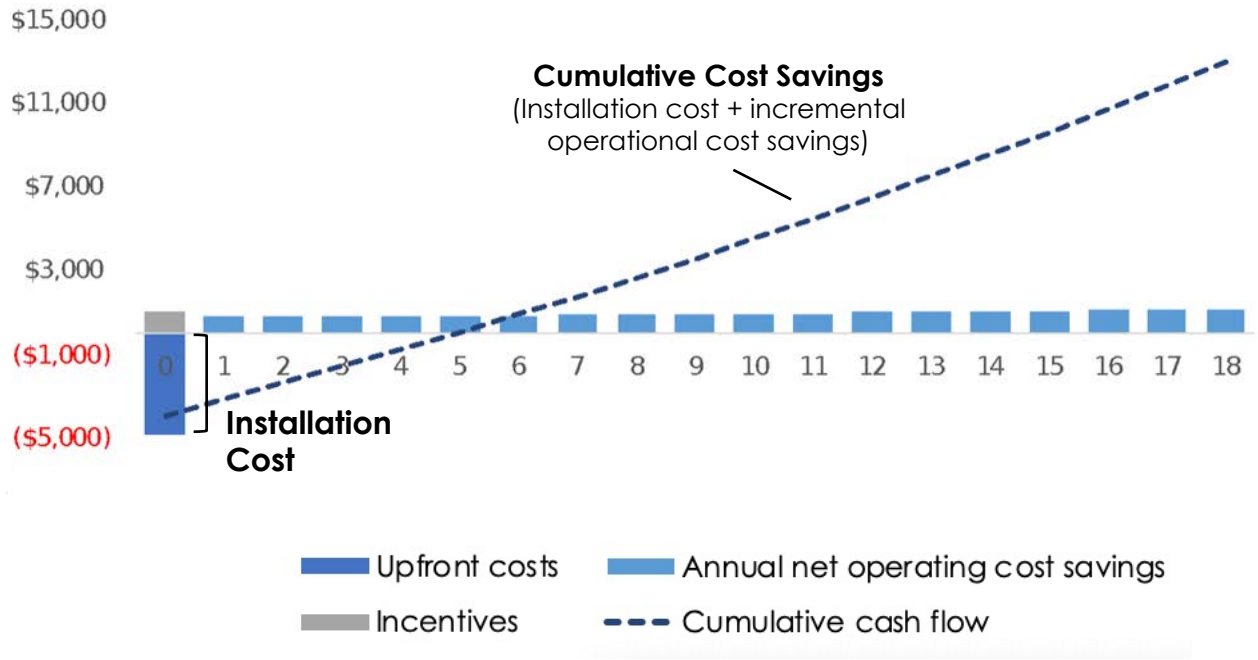
Electric Resistance Baseline to Ductless Mini-split, Displacement

- **Installation cost**: $4,950 (full cost)
  - *Current incentive of $1,000 brings this cost down to $3,950*
- **Operational cost**: Decrease of $760 in Year 1
- **Simple Payback**: 4 years**

Takeaway: The economics of displacing an electric resistance heating system with an ASHP are currently favorable in a typical Salt Lake City home, even without other measures included, and will pay for itself during the lifetime of the system.

*All installation costs, savings, and incentives are rounded to the nearest $10.
**Simple payback does not exactly match chart payback due to rounding and assumed energy price escalations and discount rates included in the charts.

Scenario 3: Electric Resistance Baseline to Ductless Mini-split, Displacement (Total Cost by Year)



Key Assumptions: Baseline building assumes no existing air conditioning, solar PV, or previous envelope improvements. Retrofit scenarios assume displacement of the existing heating load (rather than full replacement), so no counterfactual heating costs are included because the existing system must stay in place. Cash flow charts assume electricity rates increase by 2.5% annually; gas rates increase by 3.5% annually; and include a 3% annual discount rate for the value of future energy savings.

Building Electrification Institute

Single Family Retrofit – ASHP Displacement | Sensitivities

Electric Rates and Heat Pump Efficiencies Needed to Break Even with Gas Furnace

	Gas Furnace	Ductless Mini-Split	Ducted ASHP
Cost per Unit	$0.62/Therm	$0.10/kWh	$0.10/kWh
Cost per MMBTU	$6.15	$29.31	$29.31
Modeled Efficiency*	66%	295%	255%*
Cost per delivered MMBTU	$9.29	$9.93	$11.49
Electricity cost to break even with gas furnace		$0.09/kWh	$0.08/kWh
Efficiency to break even with gas furnace		315%	315%

First Year Operating Cost Comparison to Gas Furnace

Measure		Without Measure	With Measure
Solar PV	Ductless ASHP	+$17	-$673
	Ducted ASHP	+$200	-$490
Air Sealing and Insulation	Ductless ASHP	+$17	-$251
	Ducted ASHP	+$200	-$200
Replacing existing A/C	Ductless ASHP	+$17	-$51
	Ducted ASHP	+$200	+$120

*Ducted system includes duct losses

Note: Analysis holds electricity and natural gas prices constant for simplicity, but new tiered rates will impact the actual comparison.

Adding retrofit measures or changing current conditions could improve the economics for gas-heated single family homes. This could include:

- **Changing utility rates:** Heat pumps result in cost savings compared to gas when electricity is less than **$0.094/kWh** for ductless systems and **$0.081/kWh** for ducted systems (compared to $0.10/kWh today).
- **Increasing heat pump efficiency:** Heat pumps result in cost savings when operating above **315% efficiency**. (Between 250-300% efficient is common today, but newer models may achieve higher levels).
- **Adding solar PV:** Heat pumps paired with solar PV would result in annual cost savings of **$490 – $673** in Salt Lake City, but would increase installed costs.
- **Adding air sealing and insulation:** Heat pumps paired with these energy efficiency measures could result in annual operational savings of **$200 – $251**, but would increase upfront costs.
- **Replacing existing A/C:** If ductless ASHPs are replacing an A/C system in the building, there would be annual cost savings of **$51**. There would not be savings for ducted ASHPs due to their lower efficiencies.

Single Family Retrofit – ASHP Displacement | Sensitivities

Summary of Results

Scenario 4

Gas Furnace + Central A/C Baseline to Ducted ASHP Displacement w/ Weatherization

- **Installation cost**: $7,260 (incremental cost)*
- **Operational cost**: Decrease of $300 in Year 1
- **Simple Payback**: 24 years**

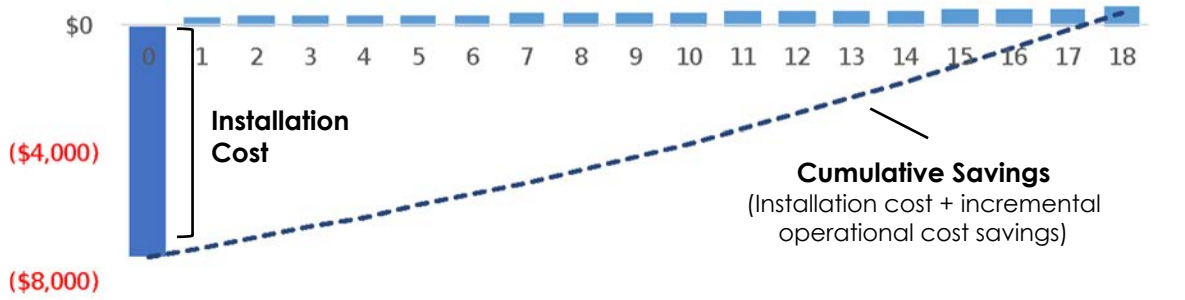
Scenario 5

Gas Furnace + Central A/C Baseline to Ductless Mini-split Displacement w/ Weatherization

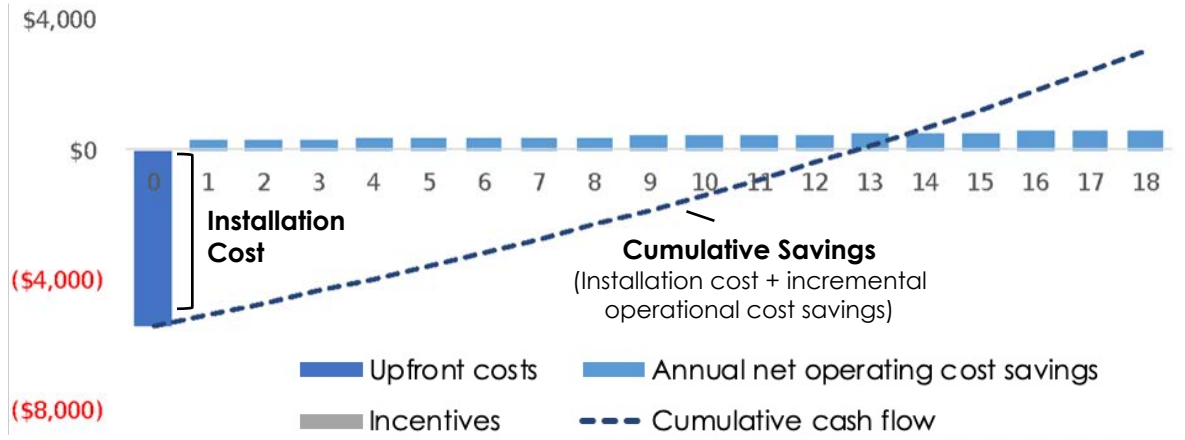
- **Installation cost**: $5,390 (incremental cost)*
- **Operational cost**: Decrease of $340 in Year 1
- **Simple Payback**: 16 years**

Takeaway: The economics of displacing a gas heating system with an ASHP improve significantly in Salt Lake City homes when including cooling system savings and adding weatherization measures.

Scenario 4: Gas Furnace + Central A/C Baseline to Ducted ASHP Displacement w/ Weatherization (Total Cost by Year)



Scenario 2: Gas Furnace + Central A/C Baseline to Ductless Mini-split Displacement w/ Weatherization (Total Cost by Year)



Building Electrification Institute

*All installation costs and savings are rounded to the nearest $10. Incremental costs are included for cooling systems. **Simple payback does not exactly match chart payback due to rounding and assumed energy price escalations and discount rates included in the charts.

Key Assumptions: Cash flow charts assume electricity rates increase by 2.5% annually; gas rates increase by 3.5% annually; and include a 3% annual discount rate for the value of future energy savings.

Single Family Retrofit – ASHP Displacement | Full Results

Results for All Modeled Scenarios (No Incentives)

VARIATIONS					OUTPUTS		
Measures - Space Heating/ Cooling	Counterfactual Heating	Counterfactual Cooling	Efficiency Measures	Solar PV	Installation Cost*	First year net operating savings	Simple Payback period**
Ductless mini-split	Electric baseboard	Central A/C	With Air Sealing/Insulation	With PV	($19,150)	$2,060	9 years
Ductless mini-split	Electric baseboard	Central A/C	With Air Sealing/Insulation	Without PV	($5,390)	$1,370	4 years
Ductless mini-split	Electric baseboard	Central A/C	Without Air Sealing/Insulation	With PV	($14,710)	$1,510	10 years
Ductless mini-split	Electric baseboard	Central A/C	Without Air Sealing/Insulation	Without PV	($950)	$820	1 year
Ductless mini-split	Electric baseboard	No A/C	With Air Sealing/Insulation	With PV	($23,450)	$1,970	12 years
Ductless mini-split	Electric baseboard	No A/C	With Air Sealing/Insulation	Without PV	($9,390)	$1,280	7 years
Ductless mini-split	Electric baseboard	No A/C	Without Air Sealing/Insulation	With PV	($18,710)	$1,450	13 years
Ductless mini-split	Electric baseboard	No A/C	Without Air Sealing/Insulation	Without PV	($4,950)	$760	7 years
Ductless mini-split	Natural gas furnace	Central A/C	Without Air Sealing/Insulation	With PV	($14,710)	$740	20 years
Ductless mini-split	Natural gas furnace	Central A/C	With Air Sealing/Insulation	With PV	($19,150)	$1,030	19 years
Ductless mini-split	Natural gas furnace	Central A/C	Without Air Sealing/Insulation	Without PV	($950)	$50	19 years
Ductless mini-split	Natural gas furnace	Central A/C	With Air Sealing/Insulation	Without PV	($5,390)	$340	16 years
Ducted ASHP	Natural gas furnace	Central A/C	With Air Sealing/Insulation	With PV	($21,020)	$990	21 years
Ducted ASHP	Natural gas furnace	Central A/C	With Air Sealing/Insulation	Without PV	($7,260)	$300	24 years
Ducted ASHP	Natural gas furnace	Central A/C	Without Air Sealing/Insulation	With PV	($16,760)	$570	29 years
Ductless mini-split	Natural gas furnace	No A/C	Without Air Sealing/Insulation	With PV	($18,710)	$670	28 years
Ductless mini-split	Natural gas furnace	No A/C	With Air Sealing/Insulation	With PV	($23,150)	$940	25 years
Ducted ASHP	Natural gas furnace	Central A/C	Without Air Sealing/Insulation	Without PV	($3,000)	($120)	No payback
Ductless mini-split	Natural gas furnace	No A/C	Without Air Sealing/Insulation	Without PV	($4,950)	($20)	No payback
Ductless mini-split	Natural gas furnace	No A/C	With Air Sealing/Insulation	Without PV	($9,390)	$250	38 years
Ducted ASHP	Natural gas furnace	No A/C	With Air Sealing/Insulation	With PV	($25,020)	$890	28 years
Ducted ASHP	Natural gas furnace	No A/C	With Air Sealing/Insulation	Without PV	($11,260)	$200	56 years
Ducted ASHP	Natural gas furnace	No A/C	Without Air Sealing/Insulation	With PV	($20,760)	$490	42 years
Ducted ASHP	Natural gas furnace	No A/C	Without Air Sealing/Insulation	Without PV	($7,000)	($200)	No payback

Building Electrification Institute

*All installation costs and savings are rounded to the nearest $10. Installation costs do not include incentives. Incremental costs for cooling are used when counterfactual includes a new cooling system.

**Average useful life of an ASHP is 20 years, so simple paybacks that are over 20 years will not pay back over the lifespan of the equipment.

Single Family Retrofit – ASHP Displacement | Takeaways

Key Takeaways

- **Displacing a portion of electric resistance heating with a high efficiency ASHP will significantly reduce energy bills for a typical single family home in Salt Lake City**. The operational savings from displacing a portion of the electric resistance heating system will pay back quickly in the lifetime of the equipment (4 years in the scenario presented here).

- **Displacing a portion of a gas heating system with an ASHP in a typical single family home, however, may slightly increase in energy bills, unless other measures included.** The energy costs for high efficiency ductless heat pump systems are closer to breaking even than for ducted heat pump systems.

- **There are many options to improve the economics of ASHPs in Salt Lake City's single family homes**, including changing energy rates to be more favorable for electrification, increasing the heat pump system efficiency, adding on-site solar PV, increasing air sealing and/or insulation within a home, and replacing the existing air conditioning system at the time of the retrofit.

Table of Contents

Building Electrification Institute
CITIES DRIVING CHANGE

Single Family Retrofit – HPWH Replacement | Assumptions

Building Energy Model Assumptions

Description	Input	Unit	Notes/Sources
Building size *(3 Br, 2 Ba, 2-story, unfinished basement)*	2,000	Sq. ft.	Assumption based on median SF home size in parcel database
Building age*	1941	year	Assumption based on median "effective year" in parcel database
Heating set point	76	°F	2014 Building America House Simulation Protocols
Cooling set point	71	°F	2014 Building America House Simulation Protocols
Water heating set point	125	°F	2014 Building America House Simulation Protocols

*Affects BEopt estimates for typical air infiltration rates, which are based on building age, building size, and local climate.

Additional Information about Building Models

(Note: There are same assumptions as the single-family ASHP retrofit models)

- Assumptions for typical single-family home size and year built are based on previous BEI analysis of single-family homes in Salt Lake City.
- BEopt software utilizes inputs for building size, vintage, and systems as well as local climate data to model building energy use for a variety of end uses.
- The model also accounts for heat pump performance at different outdoor temperatures.

Single Family Retrofit – HPWH Replacement | Assumptions

Cost and Equipment Assumptions

	Counterfactual Equipment		Electrification	Notes/ Sources
Input Description	**Gas water heater**	**Electric water heater**	**Heat pump water heater**	
System size	40 gallon	50 gallon	50 gallon	BEopt defaults
System efficiency	0.59 EF *(existing)* 0.67 EF *(new)*	0.9 EF *(existing)* 0.95 EF *(new)*	3.69 EF	BEopt defaults, Rheem Professional Prestige Hybrid Electric
Capital cost*	$1,000 ($500 – equip., $500 – labor, DNV GL)	$1,000 ($959 – Xcel TRM)	Low: $1,800 Mid: $2,000 High: $2,800	Renewable Heating and Cooling in Boulder report (DNV GL), Interviewees
Available incentives	N/A	N/A	$400 – tier 1 $550 – tier 2 (for electric water heating customers only)	Rocky Mountain Power

* Electrification equipment costs are presented here as total costs (as opposed to incremental costs).

Notes on Cost Assumptions:

- HPWH costs include estimated labor costs ($800-$1,800) based on local interviewees and recent research in Boulder.
- Electric panel upgrade costs are not included, as interviewees suggest they are not often needed in Salt Lake City homes.

Single Family Retrofit – HPWH Replacement | Results

Summary of Results

Scenario 1

Gas Water Heater Baseline to HPWH

- **Installation cost:** $1,000 (incremental cost)*
- **Operational cost**: Increase of $100 in Year 1
- **Simple Payback:** None

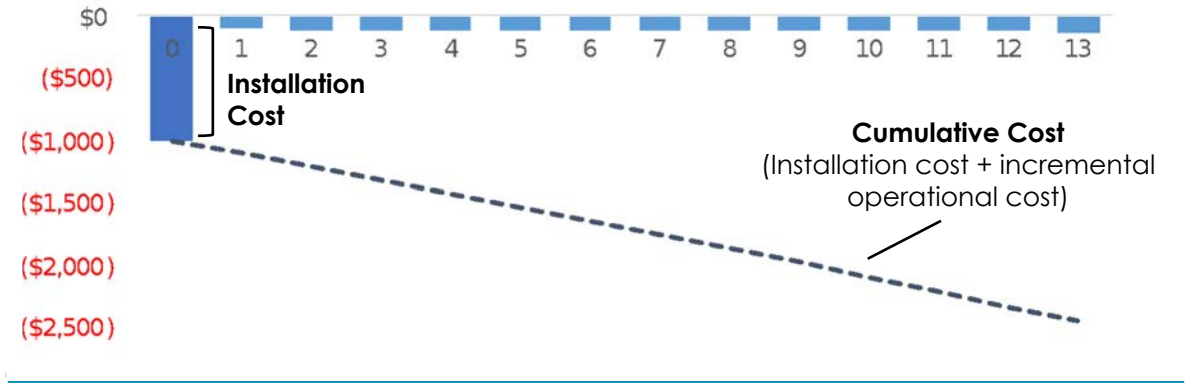
Scenario 2

Electric Resistance Water Heater Baseline to HPWH

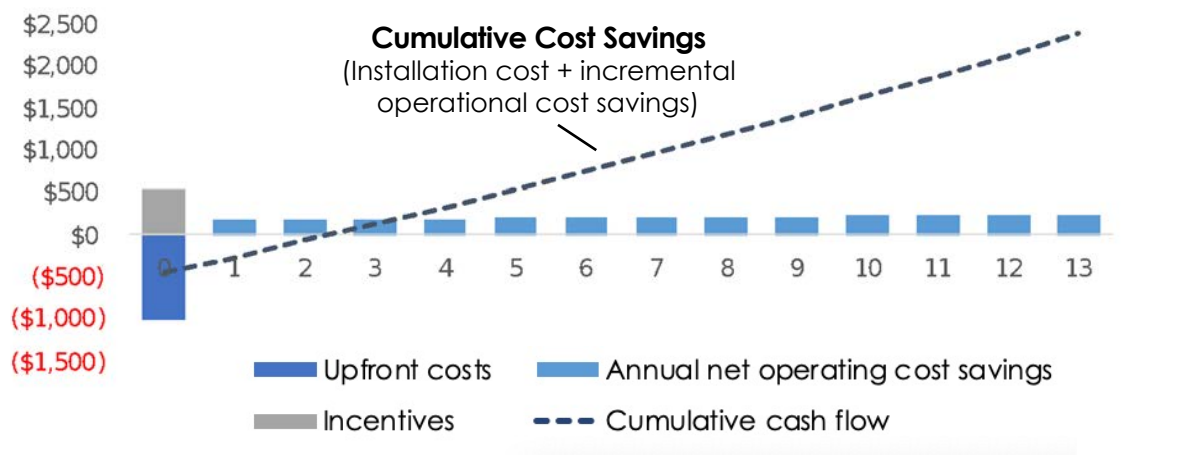
- **Installation cost:** $1,000 (incremental cost)*
  - *Current incentive of $500 brings this cost down to $500*
- **Operational cost:** Decrease of $190 in Year 1
- **Simple Payback with Incentive:** 3 years**

Takeaway: The economics of replacing a gas water heater with a HPWH are challenging in Salt Lake City homes, but the economics of replacing an electric resistance water heater with a HPWH are favorable.

Scenario 1: Gas Water Heater Baseline to HPWH (Total Cost by Year)



Scenario 2: Electric Resistance Water Heater Baseline to HPWH (Total Cost by Year)



Building Electrification Institute

*All installation costs and savings are rounded to the nearest $10.
**Simple payback does not exactly match chart payback due to rounding and assumed energy price escalations and discount rates.

Key Assumptions: Baseline building assumes no solar PV. Cash flow charts assume electricity rates increase by 2.5% annually; gas rates increase by 3.5% annually; and include a 3% annual discount rate for the value of future energy savings.

Single Family Retrofit – HPWH Replacement | Full Results

Results for All Modeled Scenarios (No Incentives)

Counterfactual	Solar PV	HPWH Cost*	Incremental installed cost**	First year net operating savings	Simple Payback Period***
Electric resistance	Without PV	Low	($800)	$190	4 years
Electric resistance	Without PV	Mid	($1,000)	$190	5 years
Electric resistance	Without PV	High	($1,800)	$190	9 years
Natural gas	Without PV	Low	($800)	($100)	No payback
Natural gas	Without PV	Mid	($1,000)	($100)	No payback
Electric resistance	With PV	Low	($14,560)	$880	17 years
Electric resistance	With PV	Mid	($14,760)	$880	17 years
Natural gas	Without PV	High	($1,800)	($100)	No payback
Electric resistance	With PV	High	($15,560)	$880	18 years
Natural gas	With PV	Low	($14,560)	$590	25 years
Natural gas	With PV	Mid	($14,760)	$590	25 years
Natural gas	With PV	High	($15,560)	$590	26 years

*High, medium, and low cost estimates for HWPHs were included given the variability found in the Salt Lake City market.
**All installation costs and savings are rounded to the nearest $10. Installation costs do not include incentives. Incremental costs are calculated against a counterfactual water heating system.
***Average useful life of a HPWH is 15 years, so simple paybacks over 15 years will not pay back over the lifespan of the equipment.

Single Family Retrofit – HPWH Replacement | Takeaways

Key Takeaways

- **Replacing an electric resistance water heater with a high efficiency HPWH will significantly reduce residents' energy bills** for a typical single family home in Salt Lake City. The operational savings from replacing an electric resistance water heater will pay back quickly (3 years in the scenario presented here).

- **Replacing a gas heating system with a high efficiency HPWH, however, will slightly increase energy bills for water heating under current conditions** in a typical single family home in Salt Lake City, although there are opportunities to improve these economics.

- **There are many options to improve the economics of HPWHs in Salt Lake City's single family homes**, which include changing energy rates to be more favorable to electrification, increasing HPWH system efficiency, adding on-site solar PV, and/or including a HPWH as part of a broader package of measures.

Table of Contents

Building Electrification Institute
CITIES DRIVING CHANGE

Multifamily ASHP Displacement & Replacement | Assumptions

Building Energy Model Assumptions

Description	Input	Unit	Notes/Sources
Building size (23 units, 4 stories)	33,700, ~950 ft^2 per unit	Sq. ft.	DOE Midrise Apartment Reference Building
Building age*	1970	years	Assumption, based on Census data
Heating set point	76	°F	2014 Building America Housing Simulation Protocols
Cooling set point	71	°F	2014 Building America Housing Simulation Protocols
Water heating set point	125	°F	2014 Building America House Simulation Protocols

*Affects BEopt estimates for typical air infiltration rates, which are based on building age, building size, and local climate.

Additional Information about Building Models:

- Assumptions for typical multifamily size and year built are based on previous BEI analysis of multifamily buildings in Salt Lake City.
  - *Most existing multifamily buildings in Salt Lake City were built between 1960 and 1999 and are a range of different sizes.*
- BEopt software utilizes inputs for building size, vintage, and systems as well as local climate data to model building energy use for a variety of end uses.
- The model also accounts for heat pump performance at different outdoor temperatures.

Multifamily ASHP Displacement & Replacement | Assumptions

Cost and Equipment Assumptions

	Counterfactual Equipment		Electrification Equipment		
Input Description	**Gas Furnace**	**Electric Baseboard**	**Ductless mini-split – 1 zone displacement**	**Ductless mini-split – multi-zone full replacement**	**Notes/Sources**
System size	N/A	*N/A*	1.25 ton 1 ton – w envelope measures	1.5 ton 1.25 ton – w envelope measures	Modeled in BEopt
Heating load coverage	100%	100%	80% (Displacement)	100% (Full Replacement)	BEopt outputs
System efficiency	78% AFUE	100%	9.6 HSPF, 18 SEER (non-cold climate)	10.3 HSPF, 20 SEER *(cold climate)*	BEopt defaults
Capital cost*	$1,934/unit For replacement variation	(Doesn't model costs in replacement variation, not typically replaced)	$3,957 – 1.25 ton $3,860 – 1 ton (single zone, non-cold climate)	$5,577 – 1.5 ton $4,989 – 1.25 ton (multi-zone, cold climate)	Navigant report, unable to verify with local contractors
Available incentive	N/A	N/A	$0.25/kWh (up to 70% of total project costs, market rate) $0.30/kWh (up to 100% total project costs, low income)		Rocky Mountain Power

* Electrification equipment costs are presented as total costs (as opposed to incremental costs). Heat pump cost assumptions do not currently assume any economies of scale for installation costs, which may be possible in multi-family settings.

Multifamily ASHP Displacement & Replacement | Results

Summary of Results

Scenario 1

Gas Furnace Baseline to Ductless Mini-split, Displacement

- **Installation cost:** $3,960/unit (full cost)*
- **Operational cost:** Increase of $10/unit in Year 1
- **Simple Payback:** None

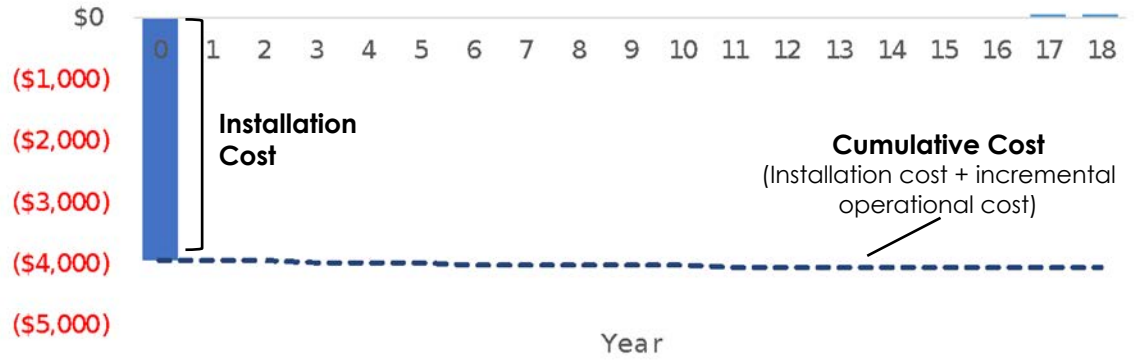
Scenario 2

Gas Furnace Baseline to Ductless Mini-split, Full Replacement

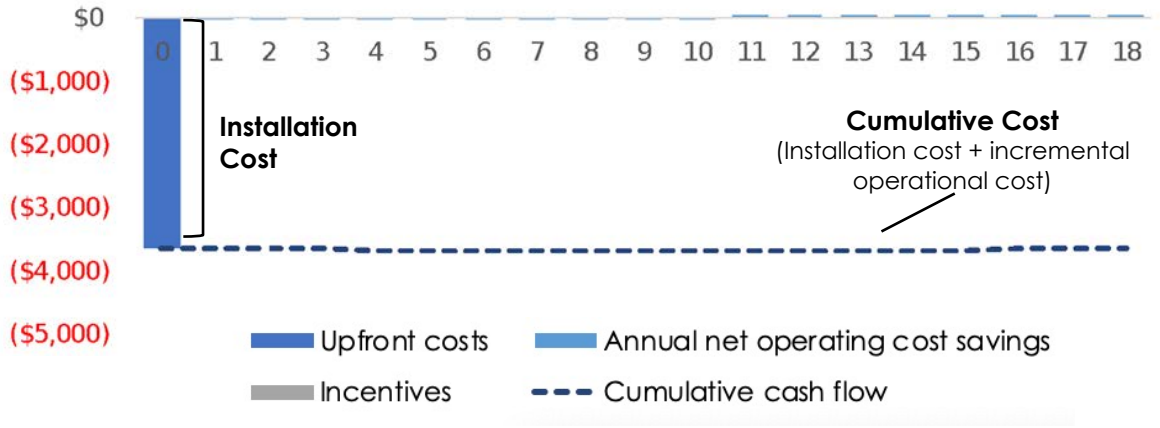
- **Installation cost:** $3,640/unit (incremental cost)*
- **Operational cost:** Increase of $10/unit in Year 1
- **Simple Payback:** None

Takeaway: Displacing or replacing a gas heating system with an ASHP could result in breakeven or slightly increased energy costs in a typical multifamily building if no other measures are included.

Scenario 1: Gas Furnace Baseline to Ductless Mini-split, Displacement (Total Cost by Year)



Scenario 2: Gas Furnace Baseline to Ductless Mini-split, Full Replacement (Total Cost by Year)



Building Electrification Institute

*All installation costs and savings are rounded to the nearest $10.

Key Assumptions: Baseline building assumes no existing air conditioning, previous envelope improvements, or solar PV. Cash flow charts assume electricity rates increase by 2.5% annually; gas rates increase by 3.5% annually; and include a 3% annual discount rate for the value of future energy savings.

Multifamily ASHP Displacement & Replacement | Results

Summary of Results

Scenario 3

Gas Furnace + Room A/C Baseline to Ductless Mini-split, Displacement

- **Installation cost:** $3,460/unit (full cost)*
- **Operational cost:** Decrease of $100/unit in Year 1
- **Simple Payback:** 35 years**

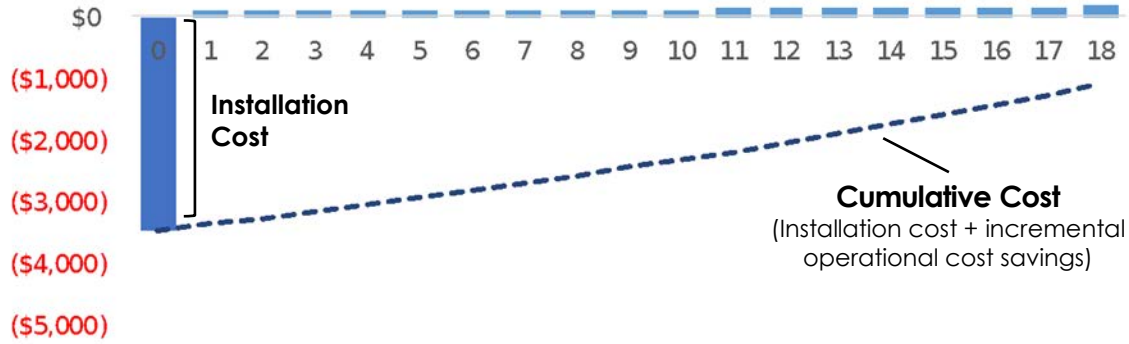
Scenario 4

Gas Furnace + Room A/C Baseline to Ductless Mini-split, Full Replacement

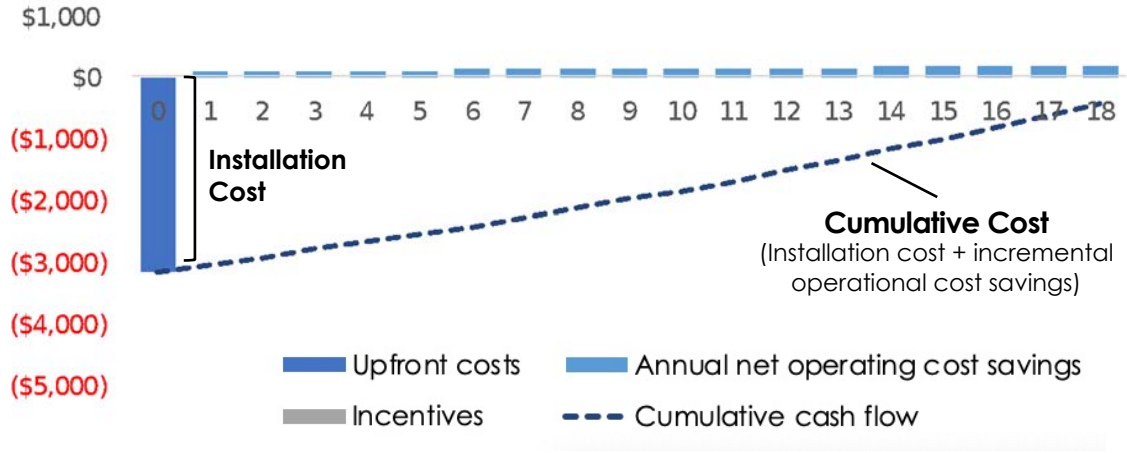
- **Installation cost:** $3,140/unit (incremental cost)*
- **Operational cost:** Decrease of $110/unit in Year 1
- **Simple Payback:** 29 years**

Takeaway: When displacing or replacing a gas heating system with an ASHP, including cooling system savings can generate energy cost savings, although may not be sufficient to pay back over the lifetime of the equipment.

Scenario 3: Gas Furnace + Room A/C Baseline to Ductless Mini-split, Displacement (Total Cost by Year)



Scenario 4: Gas Furnace + Room A/C Baseline to Ductless Mini-split, Full Replacement (Total Cost by Year)



Building Electrification Institute

*All installation costs and savings are rounded to the nearest $10.
**Simple payback does not exactly match chart payback due to rounding and assumed energy price escalations and discount rates. Average useful life of an ASHP is 20 years, so paybacks over 20 years will not pay back over the lifespan of the equipment.

Key Assumptions: Baseline building assumes no previous envelope improvements or solar PV. Cash flow charts assume electricity rates increase by 2.5% annually; gas rates increase by 3.5% annually; and include a 3% annual discount rate for the value of future energy savings.

Multifamily ASHP Displacement & Replacement | Results

Summary of Results

Scenario 5

Electric Resistance to Ductless Mini-split, Displacement

- **Installation cost**: $3,960/unit (full cost)*
  - *Current incentive of $840 brings cost to $3,120*
- **Operational cost**: Decrease of $190/unit in Year 1
- **Simple Payback with Incentive**: 16 years**

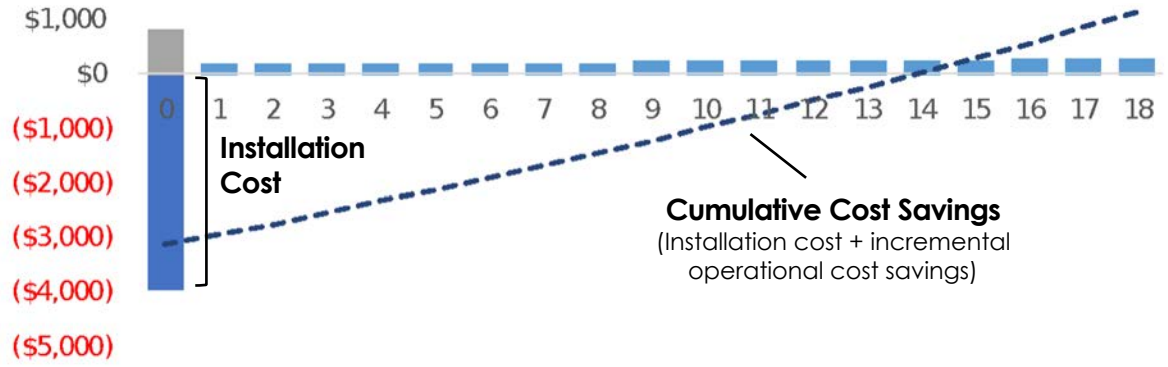
Scenario 6

Electric Resistance to Ductless Mini-split, Full Replacement

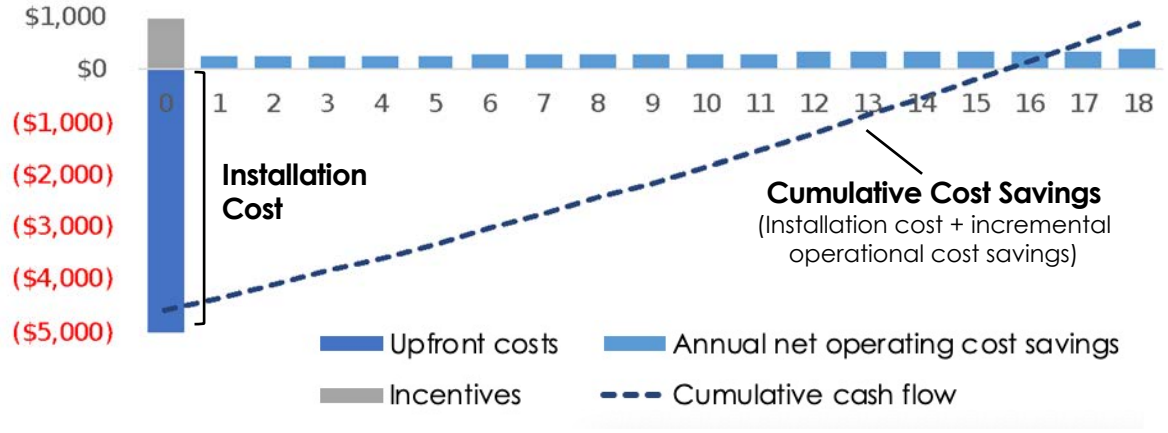
- **Installation cost**: $5,570/unit (incremental cost)*
  - *Current incentive of $960 brings cost to $4,610*
- **Operational cost**: Decrease of $250/unit in Year 1
- **Simple Payback**: 18 years**

Takeaway: Displacing or replacing an electric resistance heating system with an ASHP will result in significant cost savings in a typical multifamily building, even with no other measures included.

Scenario 5: Electric Resistance to Ductless Mini-split, Displacement (Total Cost by Year)



Scenario 6: Electric Resistance to Ductless Mini-split, Full Replacement (Total Cost by Year)



Building Electrification Institute

*All installation costs and savings are rounded to the nearest $10. Displacement scenarios use full installation cost because the existing system must stay in place.
** Simple payback does not exactly match chart payback due to rounding and assumed energy price escalations and discount rates.

Key Assumptions: Baseline building assumes no existing air conditioning, previous envelope improvements, or solar PV. Cash flow charts assume electricity rates increase by 2.5% annually; gas rates increase by 3.5% annually; and include a 3% annual discount rate for the value of future energy savings.

Multifamily ASHP Displacement & Replacement | Full Results

Results for All Modeled Scenarios (Including Current Incentives)

Measures - Space Heating/ Cooling	Counterfactual: Space Heating	Counterfactual: Space Cooling	Efficiency Measures	Solar PV	Incremental installed costs (w/ incentive)*	First year net operating savings	Simple Payback Period**
Displacement DMSHP	Electric baseboard	Room A/C	Without EE	Without PV	($2,770)	$300	9 years
Replacement DMSHP	Electric baseboard	Room A/C	Without EE	Without PV	($4,240)	$370	11 years
Displacement DMSHP	Electric baseboard	Room A/C	With EE	Without PV	($4,780)	$390	12 years
Replacement DMSHP	Electric baseboard	Room A/C	With EE	Without PV	($5,820)	$430	14 years
Displacement DMSHP	Electric baseboard	No A/C	Without EE	Without PV	($3,120)	$190	16 years
Replacement DMSHP	Electric baseboard	No A/C	Without EE	Without PV	($4,610)	$250	18 years
Displacement DMSHP	Electric baseboard	No A/C	With EE	Without PV	($5,140)	$270	19 years
Displacement DMSHP	Electric baseboard	Room A/C	Without EE	With PV	($2,770)	$150	18 years
Replacement DMSHP	Electric baseboard	Room A/C	Without EE	With PV	($4,240)	$220	19 years
Displacement DMSHP	Electric baseboard	Room A/C	With EE	With PV	($4,780)	$240	20 years
Replacement DMSHP	Electric baseboard	No A/C	With EE	Without PV	($6,210)	$300	21 years
Replacement DMSHP	Electric baseboard	Room A/C	With EE	With PV	($5,820)	$280	21 years
Replacement DMSHP	Gas furnace	Room A/C	Without EE	Without PV	($3,140)	$110	29 years
Replacement DMSHP	Gas furnace	Room A/C	With EE	Without PV	($4,860)	$170	29 years
Displacement DMSHP	Gas furnace	Room A/C	Without EE	Without PV	($3,460)	$100	35 years
Displacement DMSHP	Gas furnace	Room A/C	With EE	Without PV	($5,660)	$160	35 years
Replacement DMSHP	Electric baseboard	No A/C	With EE	With PV	($6,210)	$160	39 years
Displacement DMSHP	Electric baseboard	No A/C	With EE	With PV	($5,140)	$130	40 years
Replacement DMSHP	Electric baseboard	No A/C	Without EE	With PV	($4,610)	$100	46 years
Displacement DMSHP	Electric baseboard	No A/C	Without EE	With PV	($3,120)	$40	78 years
Replacement DMSHP	Gas furnace	No A/C	With EE	Without PV	($5,360)	$40	134 years
Displacement DMSHP	Gas furnace	No A/C	With EE	Without PV	($6,160)	$40	154 years
Replacement DMSHP	Gas furnace	Room A/C	With EE	With PV	($4,860)	$20	243 years
Displacement DMSHP	Gas furnace	Room A/C	With EE	With PV	($5,660)	$10	566 years
Replacement DMSHP	Gas furnace	Room A/C	Without EE	With PV	($3,140)	($40)	No Payback
Displacement DMSHP	Gas furnace	Room A/C	Without EE	With PV	($3,460)	($50)	No Payback
Replacement DMSHP	Gas furnace	No A/C	Without EE	Without PV	($3,640)	($10)	No Payback
Displacement DMSHP	Gas furnace	No A/C	Without EE	Without PV	($3,960)	($10)	No Payback
Replacement DMSHP	Gas furnace	No A/C	Without EE	With PV	($3,640)	($160)	No Payback
Displacement DMSHP	Gas furnace	No A/C	Without EE	With PV	($3,960)	($160)	No Payback
Replacement DMSHP	Gas furnace	No A/C	With EE	With PV	($5,360)	($100)	No Payback
Displacement DMSHP	Gas furnace	No A/C	With EE	With PV	($6,160)	($100)	No Payback

*All installation cost and savings are rounded to the nearest $10. Full replacement scenarios include incremental costs against counterfactual heating and cooling systems. Displacement scenarios include full installation costs because the existing system must stay in place. Costs include Rocky Mountain Power and Dominion incentives current to the tie of this analysis, although these incentives have likely since changed.
**Average useful life of an ASHP is 20 years, so simple paybacks that are over 20 years will not pay back over the lifespan of the equipment.

Multifamily ASHP Displacement & Replacement | Takeaways

Key Takeaways

- **Displacing or replacing an electric resistance heating system with a high efficiency ASHP system will result in significant energy cost savings** that will pay back over the lifetime of the equipment in a typical Salt Lake City multifamily building.
- **Displacing or replacing both a gas heating system and room air conditioning with a high efficiency ASHP will result in energy cost savings** that can come close to paying back over the lifetime of the equipment in a typical multifamily building.
- **Displacing or replacing a gas heating system alone, without addressing cooling, may result in a slight energy cost increase** in a typical multifamily building, although it is close to breaking even. However, providing reliable cooling will become increasingly important as temperatures rise due to climate change, making ASHP systems even more attractive as a strategy for improving health and resiliency.
- **There are many options to improve the economics of installing an ASHP system in Salt Lake City multifamily buildings**, which include changing energy rates to be more favorable to electrification, increasing the heat pump system efficiency, adding solar PV, and increasing air sealing and/or insulation.

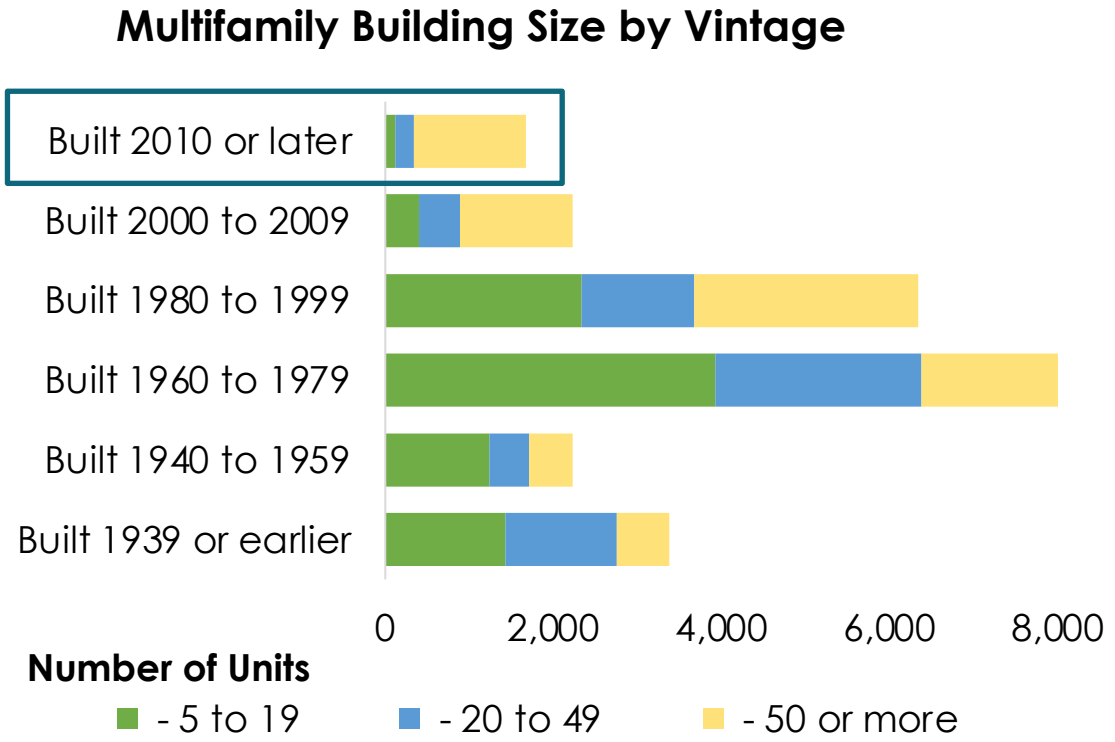
Table of Contents

Building Electrification Institute
CITIES DRIVING CHANGE

Multifamily All-electric New Construction | Assumptions

Relevant Findings from BEI's Building and Housing Stock Analysis for Salt Lake City

- Salt Lake City is experiencing an increase in multifamily new construction.
- Many of these buildings are larger than Salt Lake City's average multifamily building size.
- Nearly 80% of the multifamily buildings constructed after 2010 had more than 50 units.



Multifamily All-electric New Construction | Assumptions

Building Energy Model Assumptions

Description	Input	Unit	Notes/Sources
Building size (50 units (1 BR), 5 stories)	47,500, ~950 ft^2 per unit	Sq. ft.	Modeled in BEopt
Heating set point	76	°F	2014 Building America Housing Simulation Protocols
Cooling set point	71	°F	2014 Building America Housing Simulation Protocols
Water heating set point	125	°F	2014 Building America House Simulation Protocols

Additional Information about Building Models:

- Assumptions for typical new multifamily building are based on previous BEI analysis of multifamily buildings in Salt Lake City.
- BEopt software utilizes inputs for building size, vintage, and systems as well as local climate data to model building energy use for a variety of end uses.
- The model also accounts for heat pump performance at different outdoor temperatures.

Multifamily All-electric New Construction | Assumptions

Heating & Cooling Equipment and Cost Assumptions

	Counterfactual Equipment			Electrification Equipment		Notes/ Sources
Input Description	**Gas Furnace**	**Central A/C**	**Air Exchange**	**Ductless mini-split**	**Air Exchange**	
System info	10 kbtu	0.6 ton	Air exchange - Air King BFQ80	0.75 ton 0.5 ton – w envelope measures	Panasonic FV-08VKS3 Exhaust Fan	BEopt outputs
System efficiency	80% AFUE	14 SEER		12 HSPF, 22 SEER (cold climate)		BEopt defaults
Capital cost	$7,995		$60	$7,115	$130	Local Developer
Available incentive	N/A	N/A	N/A	$0.25/kWh (up to 70% of total project costs – market rate) $0.30/kWh (up to 100% total project costs – low income)	N/A	Rocky Mountain Power

Rationale for selecting Ductless Mini-splits:
These systems can require less space than ducted central systems, which is a consideration for developers.

For additional information on all-electric construction from Giv Group/Pragmatists for Clean Air: https://pragmatistsforcleanair.org/resources/item/40-case-study-diamond-rail-all-electric-vs-typical

Multifamily All-electric New Construction | Assumptions

Water Heating Equipment and Cost Assumptions

	Counterfactual Equipment	Electrification Equipment	Notes/ Sources
Input Description	**Gas water heater**	**Heat pump water heater**	
System size	40 gallon	50 gallon	BEopt defaults
System efficiency	0.61 EF	3.55 UEF	BEopt defaults
Capital cost	$625	$1870 total $1300 equipment $220 louvered doors $350 additional installation labor and parts cost	Local Developers

Notes on Assumptions:

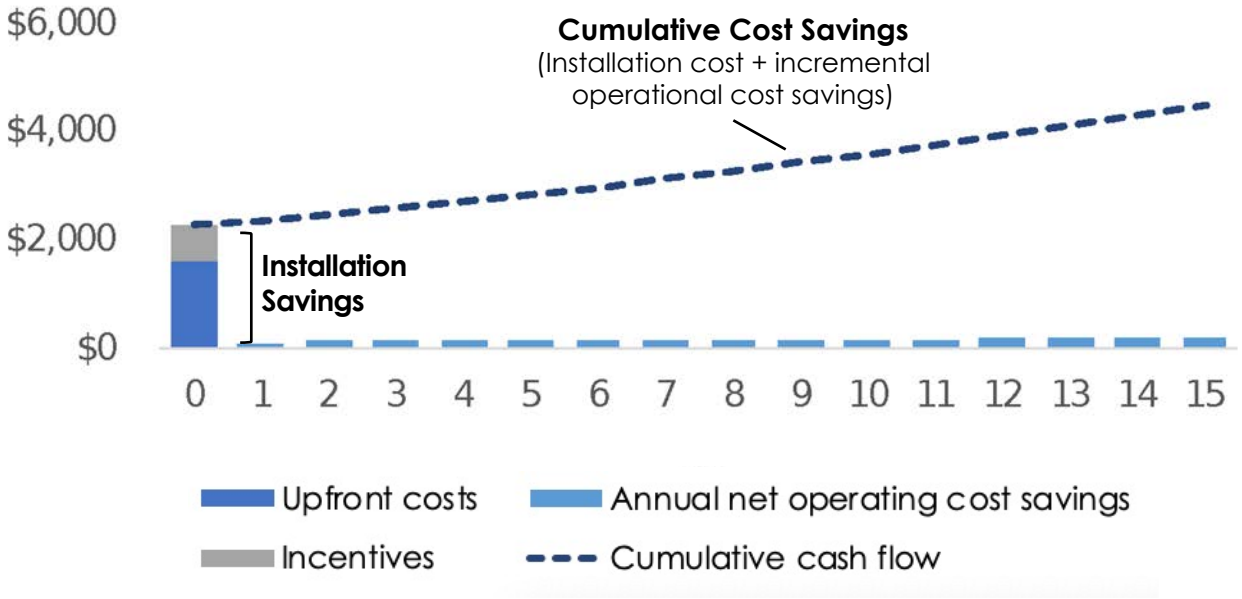
- This analysis uses retail costs for equipment and factors in additional installation costs for HPWH based on local interviews.
- HPWHs were selected over electric tankless water heaters because they have higher efficiencies and lower peak demand.
- HPWHs can have long recovery times, which often requires larger storage compared to gas water heaters.

Multifamily All-electric New Construction | Results

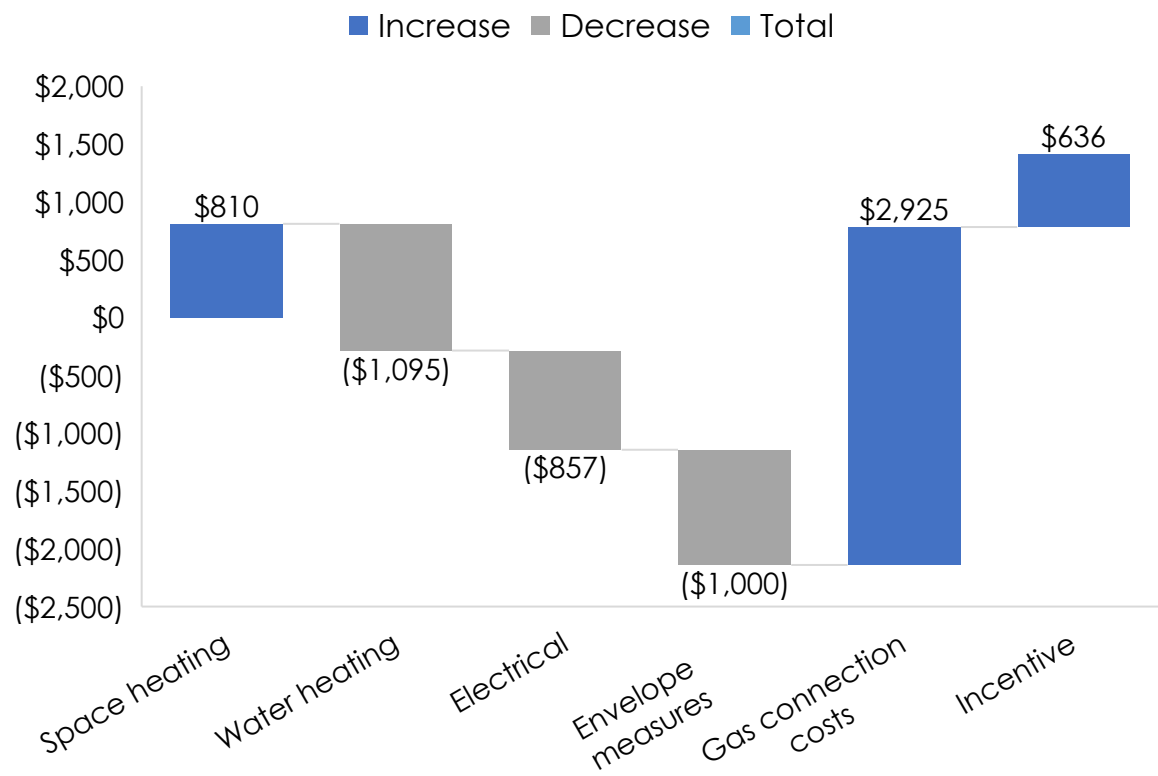
Results

- **All-electric new construction avoids $1,600 per unit** compared to mixed fuel new construction.
- **All-electric new construction also results in $100 in operational cost-savings** in Year 1.

New Construction with Ductless Mini-split + HPWH (Savings by Year)



Net upfront cost savings by cost type for Baseline Variation
(Per unit. Positive = savings in all-electric case)



Multifamily All-electric New Construction | Takeaways

Key Takeaways

- **There has been a rapid increase in new construction on the Wasatch Front**, and all-electric new construction will be critical to lowering emissions, improving air quality, and preventing future gas infrastructure build-out in the coming years.

- **Multifamily all-electric new construction in Salt Lake City has lower installed costs compared to a mixed fuel building** today. This is a result of avoided gas infrastructure costs as well as cost-savings come from only installing one heating and cooling system instead of two.

- **Multifamily all-electric new construction also has lower operating costs compared to a mixed fuel building** today, which is largely the result of avoided monthly fixed costs for gas service in all-electric multifamily construction.

Table of Contents

Building Electrification Institute
CITIES DRIVING CHANGE

Final Takeaways

- **All-electric multifamily new construction has both lower installed costs and lower operating costs** in Salt Lake City compared to a mixed fuel building today. Building all-electric will also avoid the build-out of additional gas infrastructure across the city.
- **Replacing or displacing electric resistance technologies with ASHP and HPWH systems is currently very cost-effective** for typical single family and multifamily buildings in Salt Lake City.
- **The results for replacing or displacing gas appliances with ASHP and HPWH systems are more mixed.** Some scenarios reduce energy costs or are close to breaking even, particularly when replacing both the heating and cooling system at the same time. However, other retrofit scenarios can result in slight increases in energy costs under today's conditions for both single family and multifamily buildings.
- **There are many options that would help improve the economics of electrification upgrades in Salt Lake City,** including changing energy rates to be more favorable for electrification, increasing the heat pump system efficiency, adding solar PV, increasing air sealing and/or insulation within a home, and replacing the existing air conditioning system at the time of the retrofit.

Appendix

- Abbreviations
- Additional Cost Assumptions

Abbreviations

- AFUE: Annual Fuel Utilization Efficiency
- A/C: Air Conditioner
- ASHP: Air-source heat pump
- BEOpt: Building Energy Optimization Tool
- BR: Bedroom
- DMSHP: Ductless mini-split heat pump
- DOE: US Department of Energy
- EE: Energy Efficiency
- EER: Energy Efficiency Ratio
- EF: Efficiency Rating
- GS Rate: General Service Rate
- HH: Household
- HPWH: Heat Pump Water Heater
- HVAC: Heating, Ventilation, and Air Conditioning
- ICAST: International Center for Appropriate & Sustainable Technologies
- PV: Photovoltaic (Solar)
- RMP: Rocky Mountain Power
- SEER: Seasonal Energy Efficiency Ratio
- SF: Single Family Home
- UEF: Uniform Energy Factor

Single Family Retrofit – ASHP Displacement | Additional Assumptions

Additional Cost Assumptions for Ductless Mini-splits

Cost element	Cost
Cost elements	
Non-equipment (labor, materials, other)	$1,751
Typical contractor equipment mark-up	$875
Potential additional costs	
Each additional zone	$887-974
Exterior wall-mounted	$1,000
Roof-mounted	$400
Brick exterior wall	$260
Electric panel upgrade	$1,000-$3,800
Sample ranges of total Installed costs	
Single zone	$3,643 - $5,256

Background on Additional Cost Assumptions:

- In 2018, Navigant conducted an extensive study via contractor surveys and web scraping on ductless ASHP costs in MA that estimated non-equipment costs and equipment costs by efficiency level.
- Costs vary substantially by size, number of zones, efficiency level, whether it is a cold climate heat pump, as well as building type and installation context.
- Electric panel cost range quoted from Building Decarbonization Coalition, though are not included in the analysis based on local interviews suggesting they are not typically needed in Salt Lake City homes.
- Costs were validated with local contractors to be in a similar range for a 1.5 ton single zone ductless system: $4,500-$5,400.

Source: Navigant Consulting. 2018. Ductless Mini-Split Heat Pump Cost Study (RES 28). Prepared for the Electric Program Administrators of Massachusetts. Boulder, CO: Navigant Consulting.


BEI
Building
Electrification
Institute
CITIES DRIVING CHANGE