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CITIES DRIVING CHANGE

Washington, D.C. Customer Economics Analysis for Building Electrification

Completed December 2020

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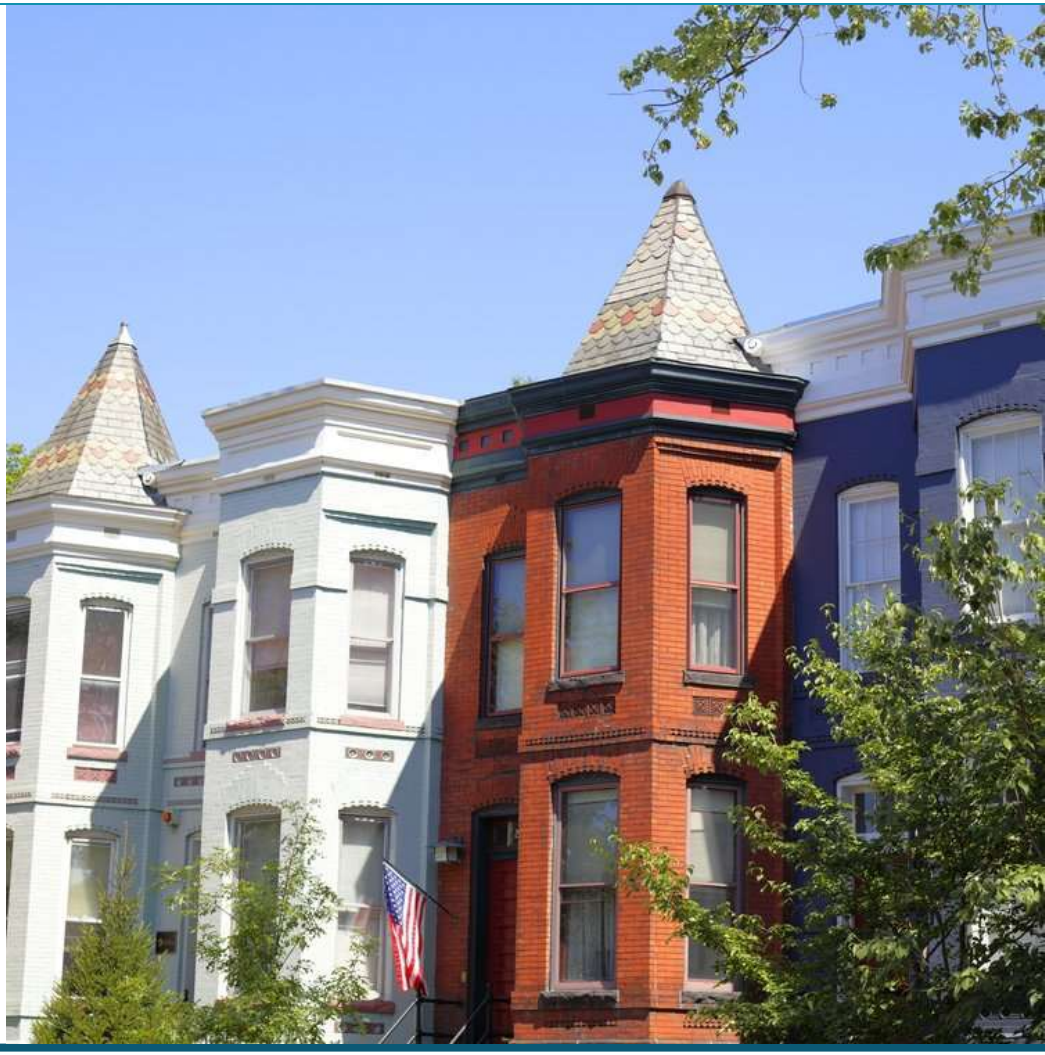
Customer Economics Analysis Background

Background and Summary of Project

Washington, D.C. has committed to reducing greenhouse gas (GHG) emissions by 50% by 2032 and achieving carbon neutrality by 2050. Because three-quarters of D.C.'s GHG emissions come from buildings, and one-third of building-based emissions come from burning fossil fuels on-site, electrifying buildings will be critical to achieving the District's goals.

The Building Electrification Institute (BEI) and its consultants at Steven Winter Associates (SWA) completed this Customer Economics Analysis to assess the economics of all-electric new construction and electrification retrofit scenarios for three common building typologies in the District. This analysis also assesses the difference in impacts for building owners and tenants under several common building energy metering configurations, as well as sensitivities of the results based on potential changes in current gas and electricity rates. The goal of the analysis is to help inform potential new policies and programs in the District by determining when and how the economics of building electrification can benefit building owners and residents.



Objectives of the Customer Economics Analysis

The purpose of the Customer Economics Analysis is to help the D.C. Department of Energy and Environment (DC DOEE) staff:

- Identify the best equipment and retrofit strategies for building electrification
- Understand the benefits and costs to building owners and tenants from building electrification upgrades
- Engage with local utilities and state policymakers on the economics of building electrification

The desired outcomes of the Customer Economics Analysis for DC DOEE are to:

- Share results and solicit input from local stakeholders about building electrification opportunities in D.C.
- Push forward economically sound building electrification policies and programs
- Identify and plan for potential cost impacts to low- and moderate-income tenants and residents
- Inform the design of new electrification incentives
- Inform the broader suite of climate policies and programs in the District

Customer Economics Analysis Process

To complete the customer economics analysis, the BEI project team completed the following process:

Customer Economics Analysis Process

Step 1: Select specific electrification scenarios

Choose baseline buildings, electrification upgrades, and mixed fuel counterfactual upgrades from previous modeling work* for three selected building typologies and identify the common energy metering config-urations to evaluate.

Step 2: Refine model outputs and calculate installed costs

Adjust modeled cost and energy outputs, where appropriate, to reflect real-world energy metering configurations, upgrade strategies, and installation costs for the selected electrification and mixed fuel counter-factual upgrades.

Step 3: Calculate energy costs for owners and tenants

Calculate annual energy costs by end use for each scenario using different selected metering configurations, and allocate relevant costs to owners or tenants to determine paybacks for each scenario.

Step 4: Determine needed incentives

Calculate the gap between current installation costs and those that would be needed to achieve a 10-year payback and to achieve installation cost parity with the mixed fuel counterfactuals.

Step 5: Test sensitivities to energy rate changes

Change the assumed gas and electricity rates to test the sensitivities of the resulting economics to different energy rates.

*Previous energy modeling work was completed in 2020 by Cadmus, a separate BEI consultant. This Customer Economics Analysis refines and builds on this foundational analysis.

Prioritized Electrification Scenarios

The Customer Economics Analysis prioritized several key scenarios for analysis.

Building Typology	Baseline Building	Metering Configurations	Electrification Retrofits	Mixed Fuel Counterfactual(s)
Multifamily New Construction 54-unit, built c. 2020	**Mixed fuel building built to 2020 Energy Code**	**Direct Metered**: Tenants pay for all energy use, causing a landlord-tenant split incentive in which the landlord pays for upgrades, but the tenants will benefit from the energy savings	**1) Lowest All-electric Construction Costs** **2) Low All-electric Construction Costs** **3) High Performance All-electric**	**Mixed fuel building built to 2020 Energy Code** (same as baseline)
Existing Single Family Building Built c. 1965	**1) Mixed fuel with low-efficiency gas boiler/ radiators and window A/C** **2) Mixed fuel with low-efficiency gas furnace and central A/C**	1) **Owner-occupied/Master Metered**: Resident pays all energy bills; no split incentive 2) **Rental/Direct Metered**: Landlord pays for central systems and tenants pay for in-unit systems, causing a landlord-tenant split incentive	**1) Low-cost Displacement*** **2) High Performance All-electric Retrofit** **3) Moderate All-electric Retrofit**	**1) Basic HVAC upgrade** **2) HVAC and DHW upgrade**
Existing Multifamily Building 10-unit, built c. 1955	**Mixed fuel building with a low-efficiency gas furnace and central A/C**	1) **Master Metered**: No split incentive 2) **Central Heat & Hot Water:** Partial split incentive. In a retrofit, converted to: • Central Heat, Hot Water, & Cooling, or • Central Hot Water only 3) **Direct Metered**: Split incentive	**1) Low-cost Displacement*** **2) High Performance All-electric Retrofit** **3) Moderate All-electric Retrofit**	**1) Basic HVAC upgrade** **2) HVAC and DHW upgrade**

*Under the displacement scenario, a high efficiency electric system serves a portion of the heating load, with the existing gas system used as backup.

Multifamily New Construction Analysis

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Multifamily New Construction Analysis | Assumptions

Baseline Building

Conditioned Area (Square Feet)	68,116
Number of Units	54
Number of Rooms per unit	4
Square Footage of Units	950
Year Built	2020

All-electric Construction Scenarios

Scenario 1: Lowest All-electric Construction Costs	**Scenario 2:** Low All-electric Construction Costs	**Scenario 3:** High Performance All-electric
Heating, Ventilation, and Air Conditioning (HVAC): Standard efficiency ductless mini-splits provide all heating and cooling. • *Assumed efficiency: 8.2 HSPF,* 14.5 SEER***	**HVAC:** High efficiency ductless mini-splits provide all heating and cooling. • *Assumed efficiency: 10.5 HSPF,* 23 SEER** (no aux. electric resistance)*	**HVAC:** High efficiency ductless mini-splits provide all heating and cooling. • *Assumed efficiency: 10.5 HSPF,* 23 SEER** (no aux. electric resistance)*
Domestic Hot Water (DHW): Electric resistance water heaters. • *Assumed efficiency: Energy Factor (EF) = 0.92*	**DHW:** Heat pump water heater • *Assumed efficiency: Coefficient of Performance (COP) = 2.0*	**DHW:** Heat pump water heater • *Assumed efficiency: COP = 2.0*
Envelope: Meets 2020 Energy Code (see next slide)	**Envelope**: Meets 2020 Energy Code (see next slide)	**Envelope**: Wall insulation (*R-13 assembly*) and better windows (*Low-e insulated frames*)
Appliances: Electric stove	**Appliances**: Electric stove	**Appliances**: Induction Range

Metering Configuration: All new buildings are assumed to be direct metered. Tenants pay for all of their energy costs, including heating, hot water, and cooling.

*Heating Seasonal Performance Factor
**Seasonal Energy Efficiency Ratio

Multifamily New Construction | Code Comparison

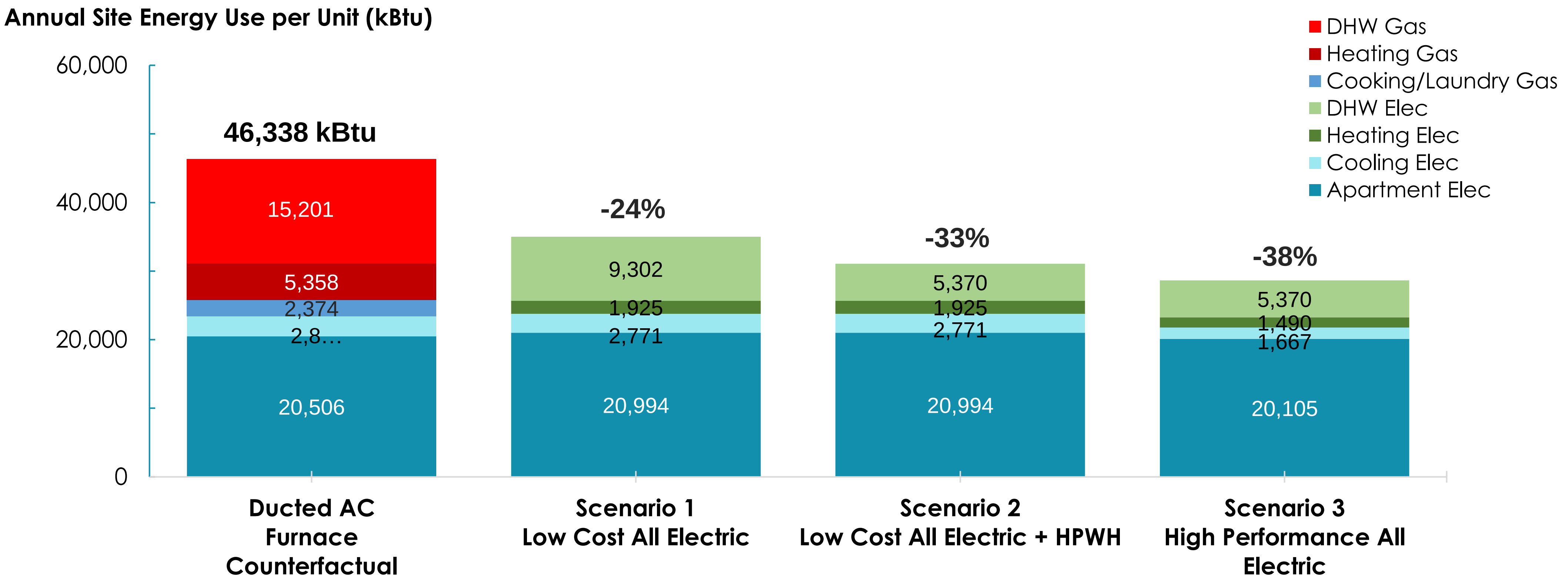
The mixed fuel baseline building roughly meets the 2020 Energy Code.

Building System	2020 Energy Code Requirement	Modeled Mixed Fuel Baseline*	Baseline Comparison to 2020 Energy Code
Roof	R-33 continuous insulation or R-54 for framed	R-49 Batt	Close to 2020 Energy Code (does not exceed)
Wall	R-15 + R-8 continuous	R-20 batt in 2x6 steel studs	Depends on cladding assumption; not exceeding Energy Code, likely meeting it
Windows	U-0.33 non-metal framing	Low-e double pane non-metal framing	Likely meets 2020 Energy Code, but does not exceed it
Basement	R-8 continuous	R-10 continuous	Meets 2020 Energy Code
Heating Efficiency (furnace)	78% Annualized Fuel Utilization Efficiency (AFUE)	92.5% AFUE	Exceeds 2020 Energy Code (could qualify for incentives)
Cooling Efficiency	SEER 13	SEER 15	Meets 2020 Energy Code
Water heating	0.67 EF for gas storage 90% efficiency for central DHW	0.59 EF for gas storage (based on cost estimate text)	Does not meet 2020 Energy Code

*Previous energy modeling work for the mixed fuel baseline was completed in 2020 by Cadmus, a separate BEI consultant.

Multifamily New Construction Results | Energy Use

All-electric multifamily construction could reduce annual on-site energy use by roughly 25-40% per apartment unit when compared to mixed fuel construction.



Multifamily New Construction Results | Installed Costs

All-electric multifamily construction could also reduce construction costs by as much as $5,000 per unit when compared to mixed fuel construction.

Building System	Baseline Mixed Fuel Building		Scenario 1: Lowest Construction Costs		Scenario 2: Lower Construction Costs		Scenario 3: Lowest Operating Costs	
Envelope	Steel stud with insulation DP windows	**$6,932**	Same as baseline	**$6,932**	Same as baseline	**$6,932**	Added wall insulation and better windows	**$9,539**
HVAC	92.5% AFUE gas furnace w/ducts 15 SEER	**$10,965**	Ductless heat pumps	**$7,914**	Ductless heat pumps	**$7,914**	Ductless HE heat pumps	**$8,160**
DHW	Gas water heaters	**$501**	Electric resistance	**$859**	HPWH	**$3,661**	HPWH	**$3,661**
Appliances	Gas Stoves and gas dryer	**$2,270**	Electric stove, electric dryer	**$1,890**	Electric stove, electric dryer	**$1,890**	Induction stove and HP dryer	**$3,194**
Gas distribution piping		**$1,961**		**--**		**--**		**--**
Installation Cost per Unit		**$22,628**		**$17,595** ($5,034 less than the baseline)		**$20,397** ($2,232 less than the baseline)		**$24,554** ($1,925 more than the baseline)

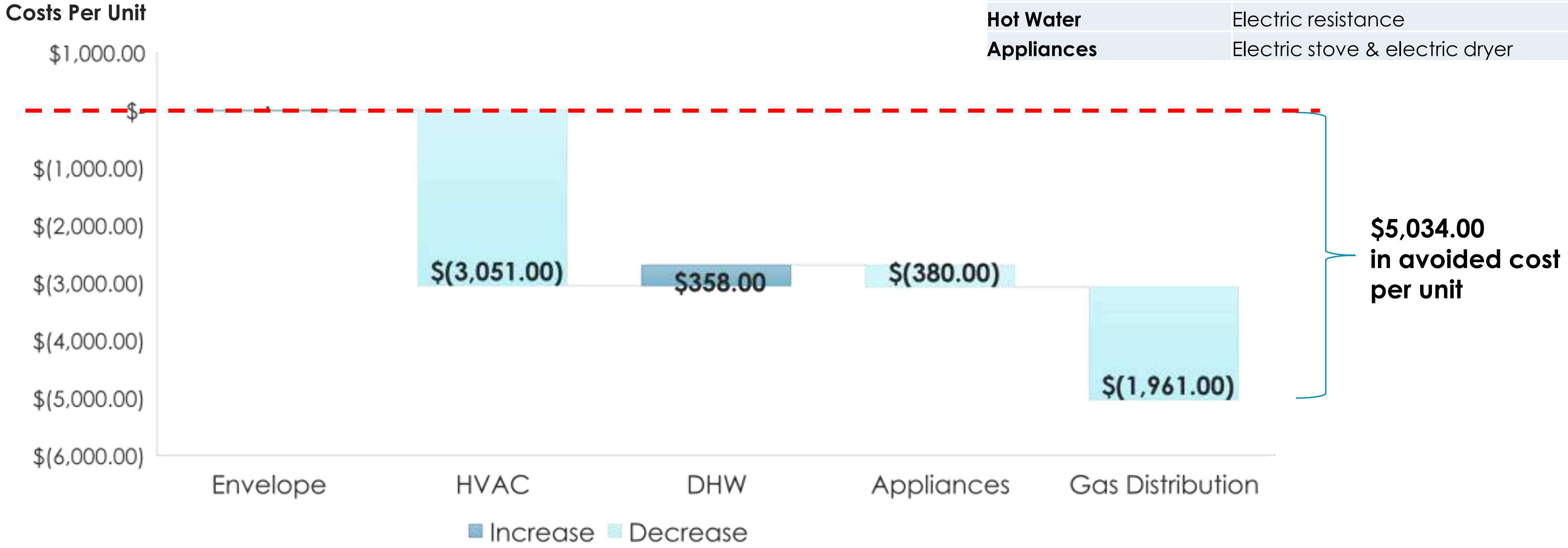
Multifamily New Construction Results | Installed Costs

Scenario 1 (Lowest Construction Cost) vs. Baseline

Roughly $5,000 in avoided cost per unit

Building Details

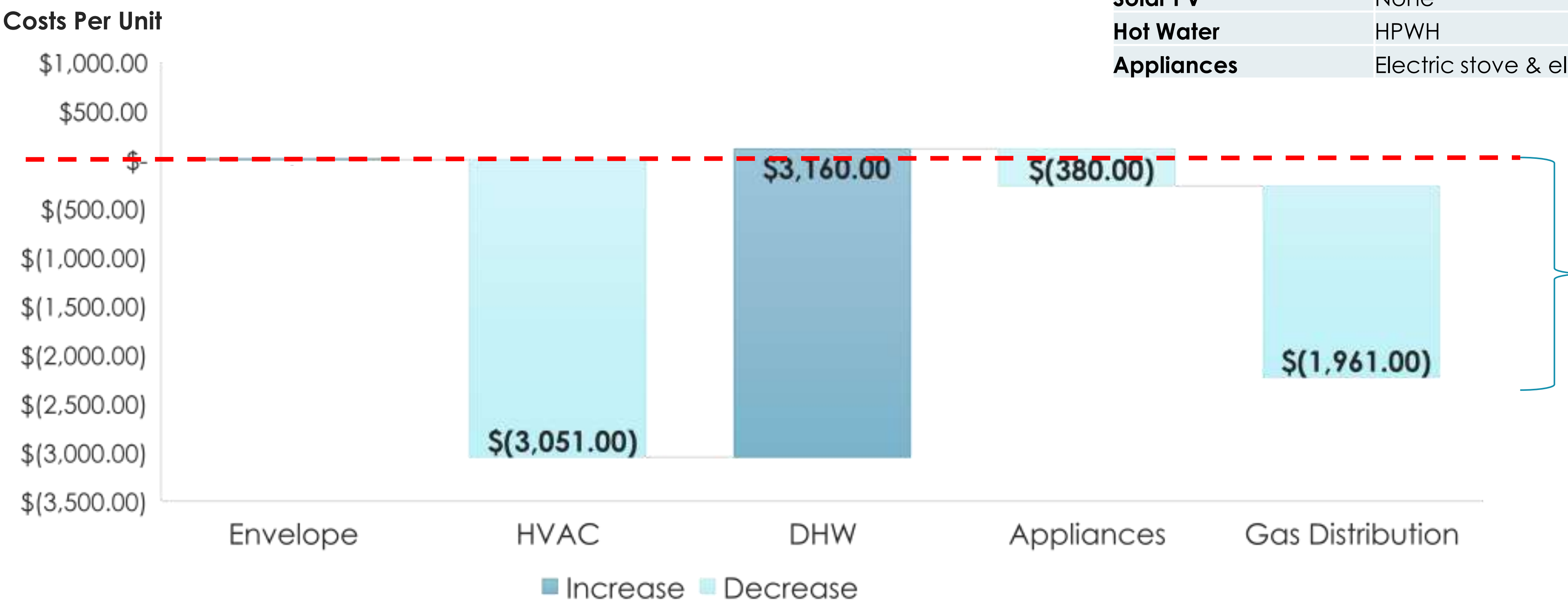
Space Heating/Cooling	Standard efficiency ductless mini-split
Envelope	Same as baseline
Solar PV	None
Hot Water	Electric resistance
Appliances	Electric stove & electric dryer



Multifamily New Construction Results | Installed Costs

Scenario 2 (Low Construction Cost, with HPWH) vs. Baseline

Roughly $2,200 in avoided cost per unit



Building Details

Space Heating/Cooling	High efficiency ductless mini-split
Envelope	Same as baseline
Solar PV	None
Hot Water	HPWH
Appliances	Electric stove & electric dryer

$2,232.00 in avoided cost per unit (not including $1,050 in current incentives available)

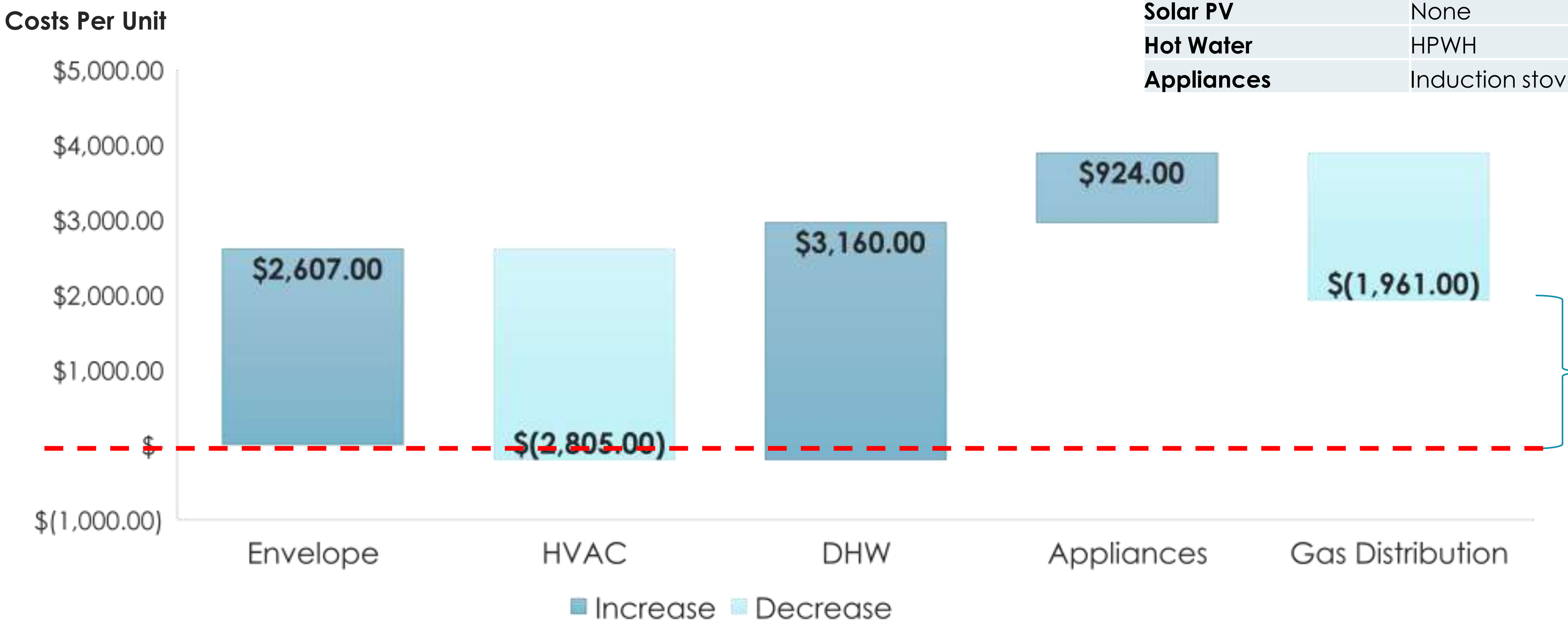
Multifamily New Construction Results | Installed Costs

Scenario 3 (Lowest Operating Costs) vs. Baseline

Roughly $2,000 additional cost per unit

Building Details

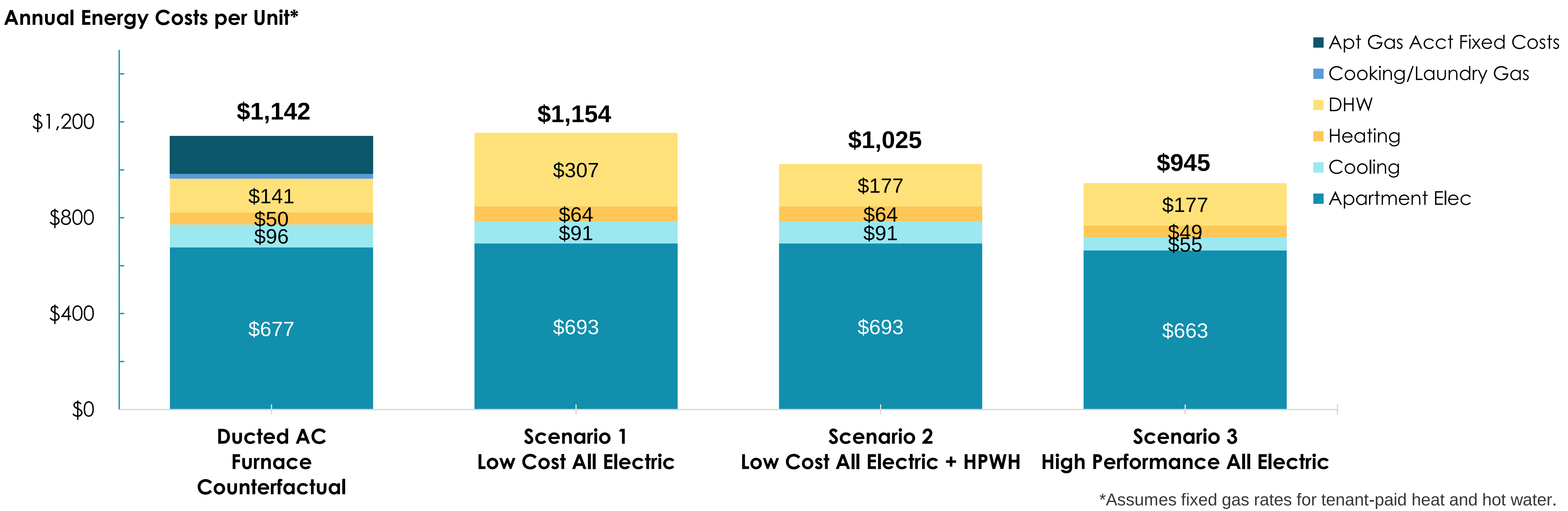
Space Heating/Cooling	High efficiency ductless mini-split
Envelope	Add wall insulation and better windows
Solar PV	None
Hot Water	HPWH
Appliances	Induction stove & heat pump dryer



$1,925.00 in additional cost per unit (not including $1,050 in current incentives available)

Multifamily New Construction Results | Energy Costs

Energy costs for all-electric multifamily construction are roughly equal to or lower than mixed fuel construction, providing the potential for many residents to see savings on their energy bills.



*Assumes fixed gas rates for tenant-paid heat and hot water.

Multifamily New Construction | Current Incentives

DC Sustainable Energy Utility (DC SEU) Incentives for Multifamily New Construction (as of December 2020)

Building System	Gas Equipment Incentives	Scenario 1 Lowest Cost All-Electric	Scenario 2 Low Cost All-electric with HPWH	Scenario 3 Lowest Operating Costs
HVAC	Gas Furnace: $775 Central A/C: $300	1.5 tons $650/unit	1.5 tons $650/unit	1.5 tons $650/unit
Water Heater	$350	$400	$400	$400

Notes:

- There is no federal (ENERGY STAR) heat pump-specific incentive for new construction.
- The federal commercial tax credit 179D may be extended, but this is a performance-based credit with energy cost reduction as a metric, which makes it difficult for heat pumps to qualify more than gas heating.

Multifamily New Construction Results | Installed Costs w/ Incentives

With current incentives, all-electric multifamily construction still has the potential to reduce installation costs, although gas appliance incentives are greater than those for electrification technologies.*

Building System	Baseline Mixed Fuel Building		Scenario 1: Lowest Construction Costs		Scenario 2: Low Construction Costs		Scenario 3: Lowest Operating Costs	
Envelope	Steel stud with insulation Double pane windows	**$6,932**	Same as baseline	**$6,932**	Same as baseline	**$6,932**	Added wall insulation and better windows	**$9,539**
HVAC	92.5% AFUE gas furnace 15 SEER A/C, ducts DC SEU Incentive DC SEU Incentive	**$10,965** **-$775** **-$300**	Ductless heat pumps DC SEU HP incentive	**$7,914** **-$650**	Ductless heat pumps DCSEU HP incentive	**$7,914** **-$650**	Ductless HE heat pumps DC SEU HP incentive	**$8,160** **-$650**
DHW	Gas water heaters DC SEU Gas WH incentive	**$501** **-$350**	Electric resistance	**$859**	HPWH DC SEU HP incentive	**$3,661** **-$400**	HPWH DC SEU HPWH incentive	**$3,661** **-$400**
Appliances	Gas Stoves and gas dryer	**$2,270**	Electric stove + dryer	**$1,890**	Electric stove + dryer	**$1,890**	Induction stove, HP dryer	**$3,194**
Building gas lines		**$1,961**		**--**		**--**		**--**
Cost per Unit		**~~$22,628~~** **$21,253**		**~~$17,595~~** **$16,945** ($4,308 less than the baseline)		**~~$20,397~~** **$19,347** ($1,906 less than the baseline)		**~~$24,554~~** **$23,504** ($2,251 more than the baseline)

*Incentives as of December 2020

Multifamily New Construction | Utility Allowance Impacts

Background on Utility Allowances

- **Utility allowances are the assumed utility bills paid by tenants in government-subsidized affordable housing**, which affordable building owners must deduct from the rents they are allowed to charge to tenants in these buildings.

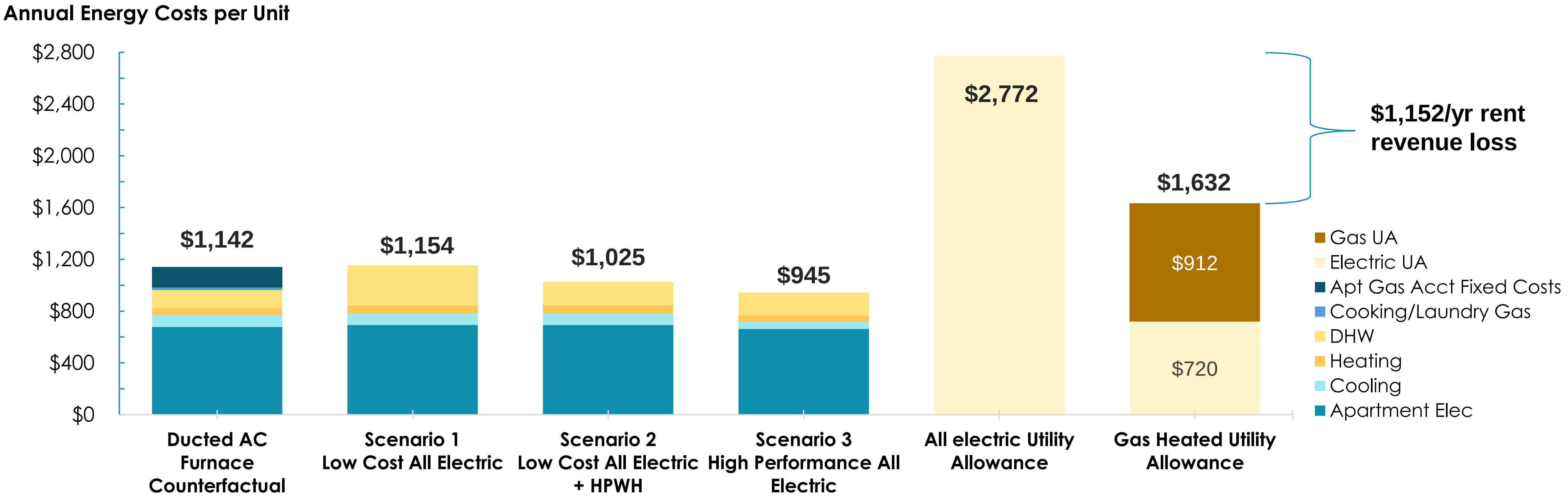
- **There are roughly 53,000 government-subsidized affordable housing units in D.C.**, out of an estimated 207,000 total rental units.* Utility allowances are applied in affordable units where tenants pay directly for any number of end uses, including for electricity, water, and/or heating. Utility allowances are not applied to master-metered buildings, where the owner pays for utilities.

- **To calculate utility allowances, D.C. currently assumes that buildings with electric systems are using electric resistance technology**, which significantly overestimates energy bills compared to heat pump technologies.** Using this assumption reduces owners' revenue in all-electric buildings by significantly reducing the rents they are allowed to charge tenants.

*Source: D.C. Policy Center, *Appraising the District's Rentals*
**Current utility allowances are set by the Department of Housing and Community Development (DHCD)

Multifamily New Construction | Utility Allowance Impacts

Current utility allowances would reduce rent revenue by over $1,100 per unit in a typical government-subsidized affordable building, posing a major barrier for electrification in this housing stock.



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Multifamily New Construction | Key Takeaways

- **All-electric multifamily new construction significantly reduces energy use** compared to mixed fuel multifamily construction built to the 2020 Energy Code, and will substantially reduce GHG emissions over the long term as the grid continues to get cleaner.
- **All-electric multifamily new construction is lower cost to build** than mixed fuel multifamily new construction that is built to the 2020 Energy Code.
- **Energy costs are equal to or lower for all-electric multifamily construction** compared to mixed fuel construction, meaning residents in these buildings will often see their energy bills decrease.
- **Current utility allowances could inhibit these positive economics** for owners of new government-subsidized affordable buildings.

Existing Single Family Building Analysis

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Existing Single Family Home Analysis | Assumptions

Baseline Building

Conditioned Area	1,456
Number of Units	1
Number of Rooms per unit	6
Square Footage of Units	1,456
Effective Year Built	1965

Electrification Retrofits

Retrofit 1: Low-cost Displacement	**Retrofit 2:** High Performance All-electric	**Retrofit 3:** Moderate All-electric
HVAC: High efficiency ductless mini-split provides all cooling, 50% of heating (existing gas system as backup). • *Assumed efficiency: HVAC: 8.2 HSPF, 14.5 SEER*	**HVAC:** High efficiency ductless mini-split provides all heating and cooling. • *Assumed efficiency: HVAC: 8.2 HSPF, 14.5 SEER (no aux. electric resistance)*	**HVAC:** HE ductless mini-split provides all heating and cooling. • *Assumed efficiency: HVAC: 8.2 HSPF, 14.5 SEER (no aux. electric resistance)*
DHW: ---	**DHW:** Heat pump water heater • *Assumed efficiency: COP = 2.0*	**DHW:** Heat pump water heater • *Assumed efficiency: COP = 2.0*
Envelope: ---	**Envelope**: Roof insulation (*R-49*), new windows (*double pane air-filled*), air sealing (*15 ACH50 to 9 ACH50*)*	**Envelope**: Roof insulation (*R-49*)
Appliances: ---	**Appliances**: Induction range	**Appliances**: Electric stove

Metering Configurations

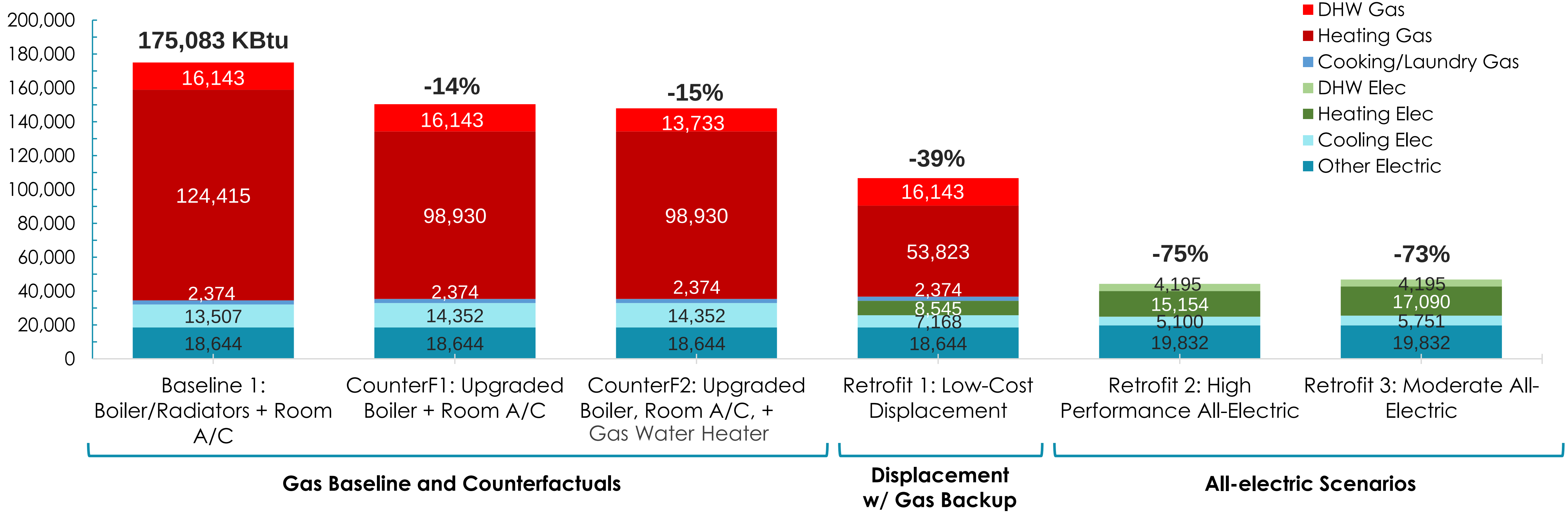
- **Owner-occupied/Master Metered**: Homeowner pays all energy bills; no split incentive
- **Rental/Direct Metered**: Tenant pays for all energy bills, causing a landlord-tenant split incentive

*Air changes per hour at 50 pascals of pressure

Existing Single Family Results | Energy Use

Electrifying a typical single family home in D.C. could reduce on-site energy use by up to 75%.

Baseline 1: Gas boiler + Radiators with Room A/C
Annual Site Energy Use (kBtu)



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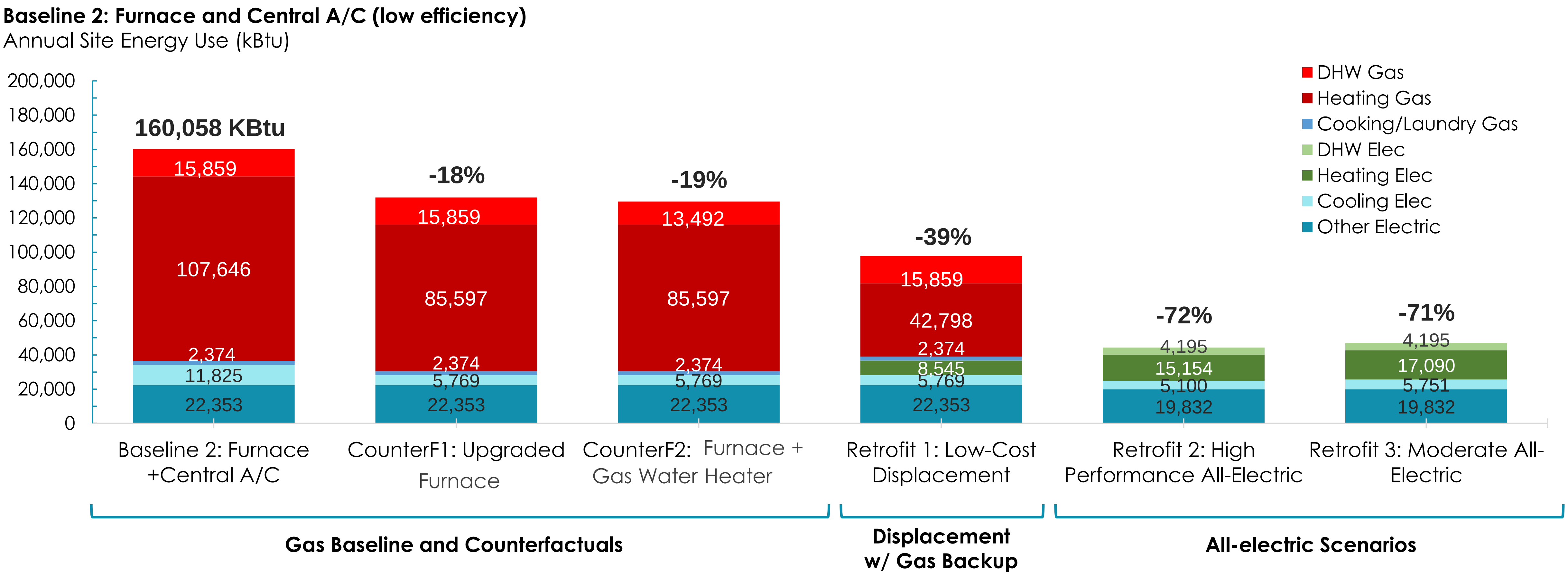
Existing Single Family Results | Energy Use

Electrifying a typical single family home in D.C. could reduce on-site energy use by up to 75%.



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Existing Single Family Results | Installed Costs

Installing a heat pump system that provides both heating and cooling costs less than replacing both a boiler and all room air conditioning units, but heat pump water heaters are more expensive to install than gas water heaters.

Baseline 1: Boiler + Room A/C Retrofit, Installed Costs ($/Home)

Bldg. System	Baseline	Counterfactual 1		Counterfactual 2		Retrofit 1: Low Cost Displacement		Retrofit 2: High Perf. All-electric		Retrofit 3: Moderate All-electric	
Envelope	Uninsulated envelope, single pane metal windows	---	**$0**	---	**$0**	---	**$0**	Roof + basement insulation New Windows Air Sealing	**$19,891**	Roof insulation + moderate air sealing	**$4,213**
HVAC	72% overall efficiency gas boiler, EER 8.5 room A/C with 50% capacity	New boiler (90% eff), EER 9.8 room A/C with 100% cap.	**$7,786**	New boiler (90% eff), EER 9.8 room A/C with 100% cap.	**$7,786**	75% capacity displacement with HE ductless mini-split	**$7,000**	Full replacement with 4 tons HE mini-splits	**$8,804** ($1,018 less than counter-factuals)	Full replacement with 5 tons HE mini-splits	**$8,804** ($1,018 less than counter-factuals)
DHW	Gas water heater	---	**$0**	New gas water heater	**$1,080**	---	**$0**	HPWH	**$1,950** ($870 more than counter-factual)	HPWH	**$1,950** ($870 more than counter-factual)
Appliance	Gas cooking, resistance dryers	---	**$0**	---	**$0**	---	**$0**	Induction stove	**$1,995**	Electric stove	**$745**
$ per Home	**---**		**$7,786**		**$8,866**		**$7,000**		**$32,640**		**$18,051**

Existing Single Family Results | Installed Costs

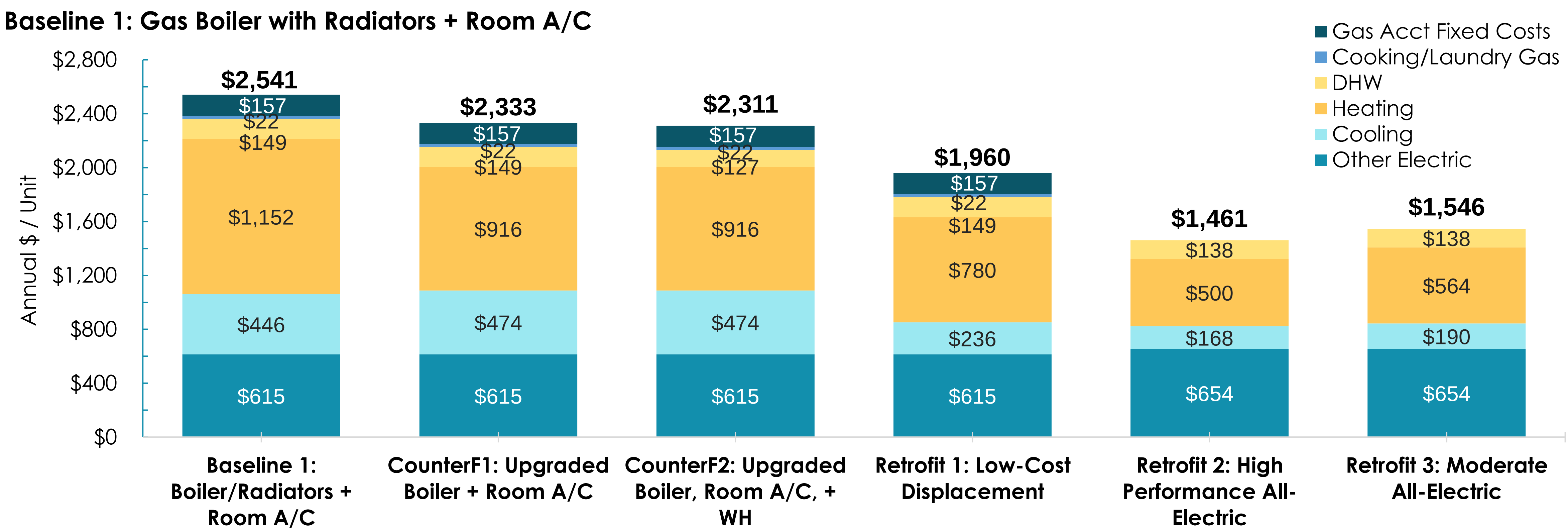
Installing a heat pump system also costs less than replacing both a furnace and a central air conditioning system, but heat pump water heaters are more expensive to install than gas water heaters.

Baseline 2: Furnace + Central A/C Retrofit, Installed Costs ($/Home)

Bldg. System	Baseline	Counterfactual 1		Counterfactual 2		Retrofit 1: Low Cost Displacement		Retrofit 2: High Perf. All-electric		Retrofit 3: Moderate All-electric	
Envelope	Uninsulated envelope, single pane metal windows	---	**$0**	---	**$0**	---	**$0**	Roof + basement insulation New Windows Air Sealing	**$19,891**	Roof insulation + moderate air sealing	**$4,213**
HVAC	72% overall efficiency gas furnace, SEER 10 central A/C with 100% capacity	New furnace (93% eff,) SEER 15 central A/C with 100% cap.	**$12,008**	New furnace (93% eff,) SEER 15 central A/C with 100% cap.	**$12,008**	75% capacity displacement with HE ductless mini-split	**$7,000**	Full replacement with 4 tons HE mini-splits	**$8,804** ($3,204 less than counter-factuals)	Full replacement with 5 tons HE mini-splits	**$11,143** ($865 less than counter-factuals)
DHW	Gas water heater	---	**$0**	New gas water heater	**$1,080**	---	**$0**	HPWH	**$1,950** ($870 more than counter-factuals)	HPWH	**$1,950** ($870 more than counter-factuals)
Appliance	Gas cooking, resistance dryers	---	**$0**	---	**$0**	---	**$0**	Induction stove	**$1,995**	Electric stove	**$745**
$/Home	**---**		**$12,008**		**$13,088**		**$7,000**		**$32,640**		**$18,051**

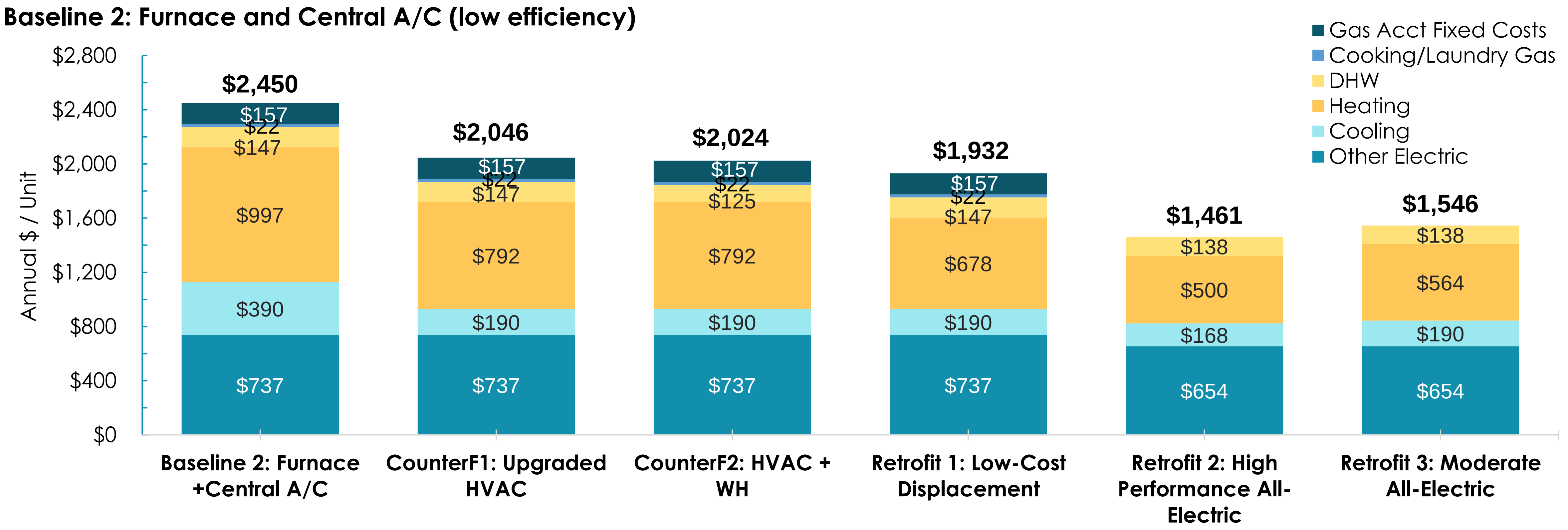
Existing Single Family Results | Energy Costs

When compared to a baseline building with a gas boiler and room air conditioners, electrifying a single family home in D.C. could reduce energy bills for residents by up to $1,000 per year.



Existing Single Family Results | Energy Costs

When compared to a baseline building with a gas furnace and central air conditioning, electrifying a single family home in D.C. could also reduce energy bills by nearly $1,000 per year.



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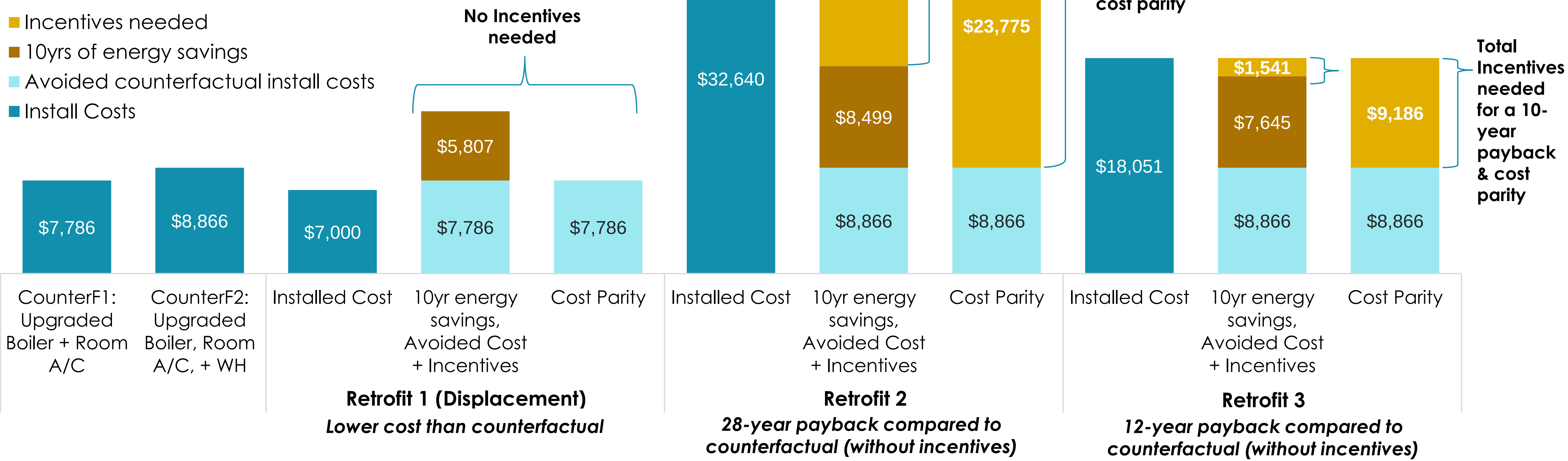
Existing Single Family Results | Needed Incentives

A minimum of $1,500 in incentives are needed to achieve a 10-year payback for an all-electric retrofit in a single family home with a gas boiler and room air conditioners.

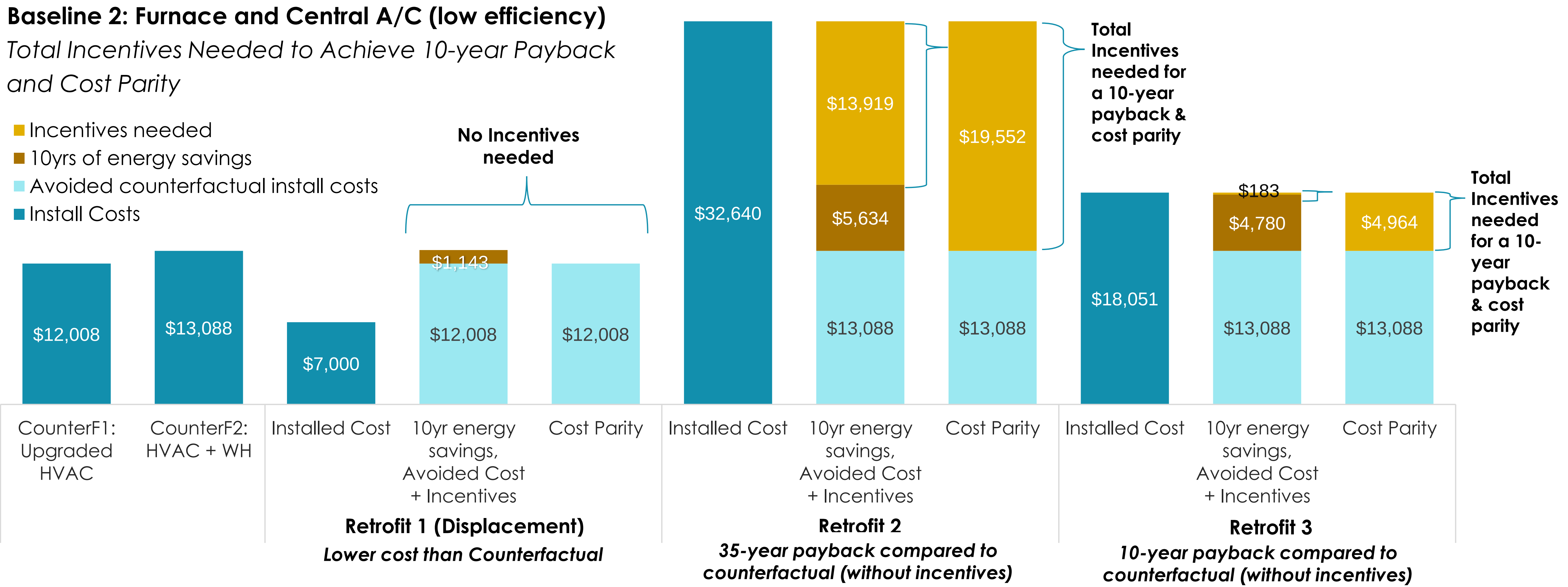
Baseline 1: Gas boiler + Radiators with Room A/C

Total Incentives Needed to Achieve 10-year Payback and Cost Parity



Existing Single Family Results | Needed Incentives

A moderate all-electric retrofit nearly achieves a 10-year payback for a single family home with a gas furnace and central air conditioner, even without incentives.



Existing Single Family Results | Needed Incentives

Total Incentives Needed for Cost Parity and 10-year Payback*

		Retrofit 1		Retrofit 2		Retrofit 3	
	Boiler with Radiators + Room A/C	10-year payback	Cost Parity	10-year payback	Cost Parity	10-year payback	Cost Parity
Owner Pays Utilities	**Total Incentives Needed**	**$0**	**$0**	**$15,297**	**$23,775**	**$1,481**	**$9,186**
	Incentives for HVAC	*$0*	*$0*	*$0*	*$1,018*	*$0*	*$3,358*
	Incentives for DHW	N/A	N/A	*$983*	*$870*	*$983*	*$870*
Tenant Pays Utilities	**Total Incentives Needed**	**$0**	**$0**	**$23,775**	**$23,775**	**$9,186**	**$9,186**
	Incentives for HVAC	*$0*	*$0*	*$1,018*	*$1,018*	*$3,358*	*$3,358*
	Incentives for DHW	N/A	N/A	*$870*	*$870*	*$870*	*$870*
	Furnace + Central A/C	10-year payback	Cost Parity	10-year payback	Cost Parity	10-year payback	Cost Parity
Owner Pays Utilities	**Total Incentives Needed**	**$0**	**$0**	**$13,844**	**$19,552**	**$127**	**$4,964**
	Incentives for HVAC	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
	Incentives for DHW	N/A	N/A	*$983*	*$870*	*$983*	*$870*
Tenant Pays Utilities	**Total Incentives Needed**	**$0**	**$0**	**$19,552**	**$19,552**	**$4,964**	**$4,964**
	Incentives for HVAC	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
	Incentives for DHW	N/A	N/A	*$870*	*$870*	*$870*	*$870*

*Total incentives needed are based on the premium over the cost and savings of the relevant counterfactual scenario, either to achieve the same ten-year cost or the same installation cost (“Cost Parity”). Incentives required for cost parity are the difference in installation costs between the electrification retrofit and the relevant counterfactual scenario. Incentives required for a 10-year payback depend on the energy cost savings to the owner. Where the owner pays for energy, the required incentive is different than if the tenant is paying for energy, because if the owner pays for the equipment and the energy, then the payback is different than if the owner pays for the equipment but the tenant gets the savings.

Existing Single Family Results | Current Incentives

Current heat pump incentives are not sufficient to achieve a 10-year payback for a full electrification retrofit. Gas equipment incentives are also greater than current heat pump incentives, which creates an additional economic barrier to electrification.

Incentives for Existing Single Family Homes (as of December 2020)

	Measure	Amount
Heat Pump Incentives	High Efficiency Ductless Mini-Split Heat Pump ($/home)	DC SEU - $575 Fed. Tax Credit* - $300
	Heat Pump Water Heater ($/home)	DC SEU - $400
Gas Equipment Incentives	High Efficiency Gas Furnace ($/home)	DC SEU - $575
	High Efficiency Central A/C ($/home)	DC SEU - $375
	High Efficiency Gas Water Heater ($/home)	DC SEU - $350

*The federal tax incentive ends at the end of 2020. At the time of this analysis, it is unclear if it will change in 2021.

Total ASHP & HPWH Incentives: $1,275

Total Gas Equipment Incentives: $1,300

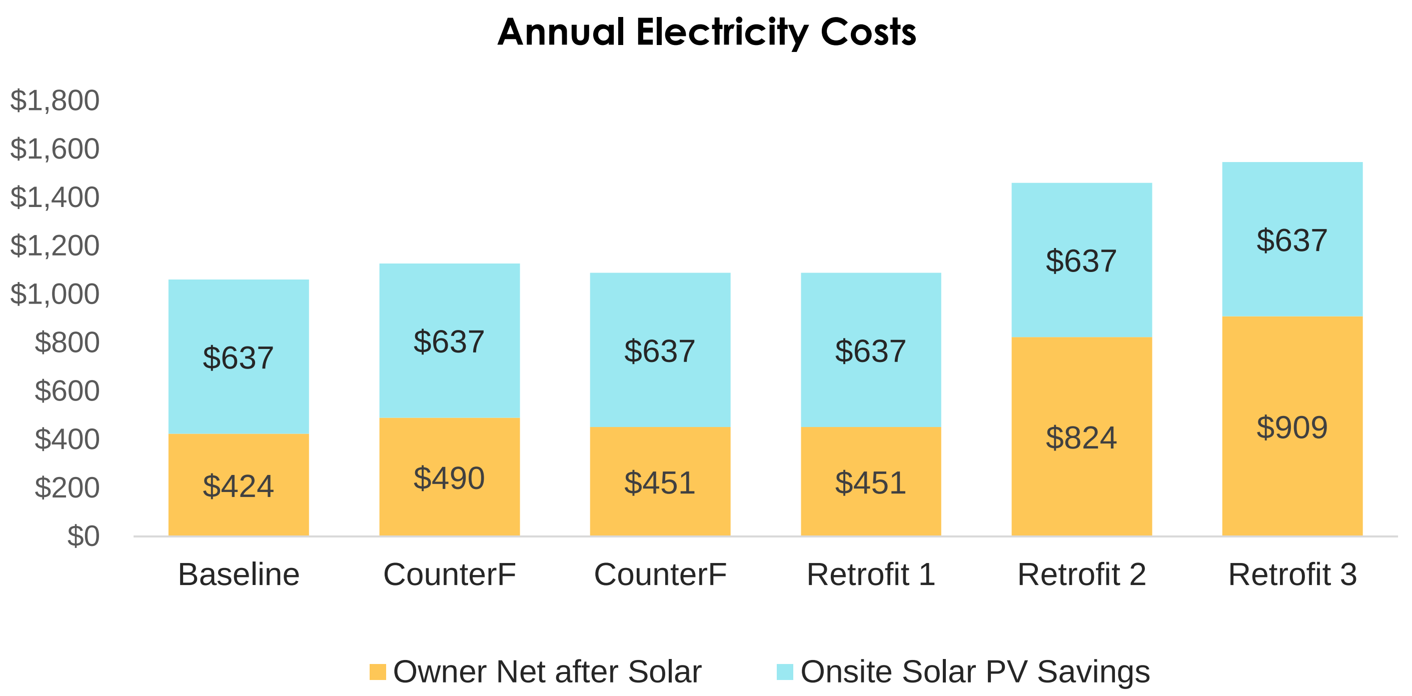
Existing Single Family Results | Impacts of Solar PV

Solar Assumptions

- **On-site Solar PV**
  - Current federal tax credits are set at 22%, but expiring over time.
  - Current Solar Renewable Energy Credits (SRECS) are assumed to be fixed for 3 years.
- **Solar for All**
  - Current program in D.C. for low-income customers that requires $0 for subscription and reduces electricity costs by 50% for tenants.
- **Virtual Net Metering**
  - Virtual net metering is a billing arrangement that allows for a single solar system to offset multiple common area and tenant load(s). This could be an option for a rental building, because the owner could get SRECs and take or share the operational savings.

Existing Single Family Results | Impacts of Solar PV

Impact of On-site Solar for Building Owner
(Saves $637/Year)



Key Takeaways:

- **Cost of Solar PV after SRECs and Federal Investment Tax Credit:** $8,348
- **Operational Savings of Solar PV:** $637/year
- **Simple Payback:** 13 years

On-site Solar Assumptions

Rooftop Solar Installation Cost	5 kW $19,410
Federal Investment Tax Credit @ 22%	-$4270
SRECS: $400/MWh for 3 years*	-$6,792
Discounted Cost of Solar PV after SREC and Federal Investment Tax Credit	$8,348
Annual Electricity Savings	$637

**using 1,132 kWh/kWDC*

SREC Calculations:

Total solar PV Size	5 kW
Total Solar PV Generation / kW for DC	1.132 MWh/kW/yr
Total Solar Generation[1]	5.66 MWh/yr
SREC value[2]	$400 per MWh
Years of SRECS[3]	3 yrs
Total SREC Value (=1*2*3)	**$6,792**

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Existing Single Family Analysis | Key Takeaways

- **Electrification retrofits in single family homes significantly reduce building energy use,** and will substantially reduce GHG emissions over the long term as the grid continues to get cleaner.
- **These retrofits also reduce residents' energy bills, provided that high efficiency equipment is installed.** Weatherization and insulation also help reduce energy bills.
- **Installing a heat pump system can be lower cost than replacing both the existing heating system and the existing cooling system,** although heat pump water heaters are more expensive than gas water heaters.
- **It is possible to achieve a ~10-year payback for a full electrification retrofit** in a typical owner-occupied single family home with a furnace and central air conditioning, even without current incentives. At least $1,500 in incentives are needed for a 10-year payback in a single family home with a boiler and room air conditioners.
- **On-site solar when combined with electrification upgrades can further reduce energy bills,** although it will not substantially reduce overall paybacks.
- **Additional incentives will be needed to bring down electrification retrofit costs in rental buildings** where there is a landlord-tenant split incentive. Ideally, incentives will bring costs to parity with gas alternatives, since paybacks to owners are not possible in these buildings.

Existing Multifamily Building Analysis

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Existing Multifamily Building Analysis | Assumptions

Baseline Building

Conditioned Area	11,284
Number of Units	10
Number of Rooms per unit	4
Square Footage of Units	831
Effective Year Built	1953

Electrification Retrofits

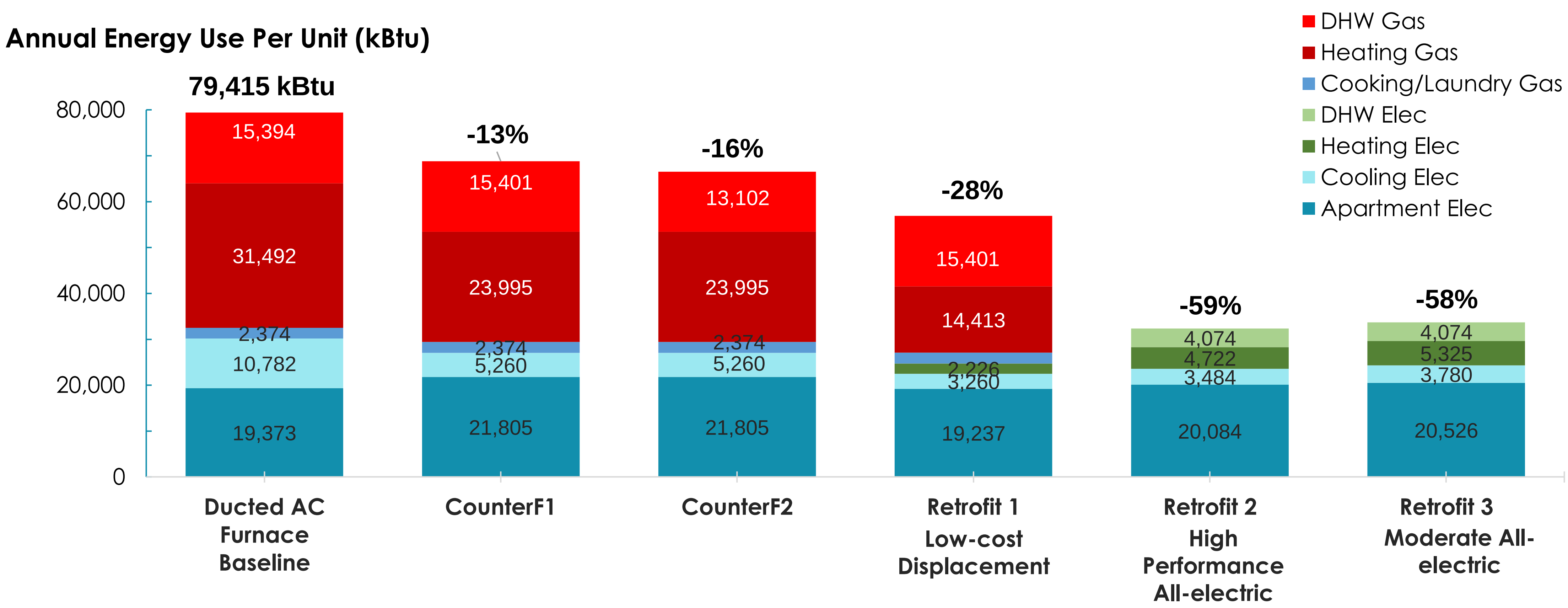
Retrofit 1: Low-cost Displacement	**Retrofit 2:** High Performance All-electric	**Retrofit 3:** Moderate All-electric
HVAC: HE ductless mini-split provides all cooling and some heating (existing gas system as backup) • *Assumed efficiency: 10.5 HSPF, 23 SEER*	**HVAC:** HE ductless mini-split provides all heating and cooling. • *Assumed efficiency: 10.5 HSPF, 23 SEER (no aux. electric resistance)*	**HVAC:** HE ductless mini-split provides all heating and cooling. • *Assumed efficiency: 10.5 HSPF, 23 SEER (no aux. electric resistance)*
DHW: ---	**DHW:** Heat pump water heater • *Assumed efficiency: COP = 2.0*	**DHW:** Heat pump water heater • *Assumed efficiency: COP = 2.0*
Envelope: ---	**Envelope**: Roof insulation (*R-49*), new windows (*double pane air-filled*), air sealing (*15 ACH50 to 9 ACH50*)	**Envelope**: Roof insulation (*R-49*)
Appliances: ---	**Appliances**: Induction range	**Appliances**: Electric stove

Metering Configurations:

- **Master Metered**: Resident pays all energy bills; no split incentive
- **Central Heat & Hot Water**: Landlord pays for central systems and tenants pay for in-unit systems, causing a partial split incentive
- **Direct Metered**: Tenants pay for all energy use, causing a full split incentive

Existing Multifamily Results | Energy Use

Electrifying a typical multifamily building in D.C. could reduce on-site energy use by nearly 60%.



Existing Multifamily Results | Installed Costs

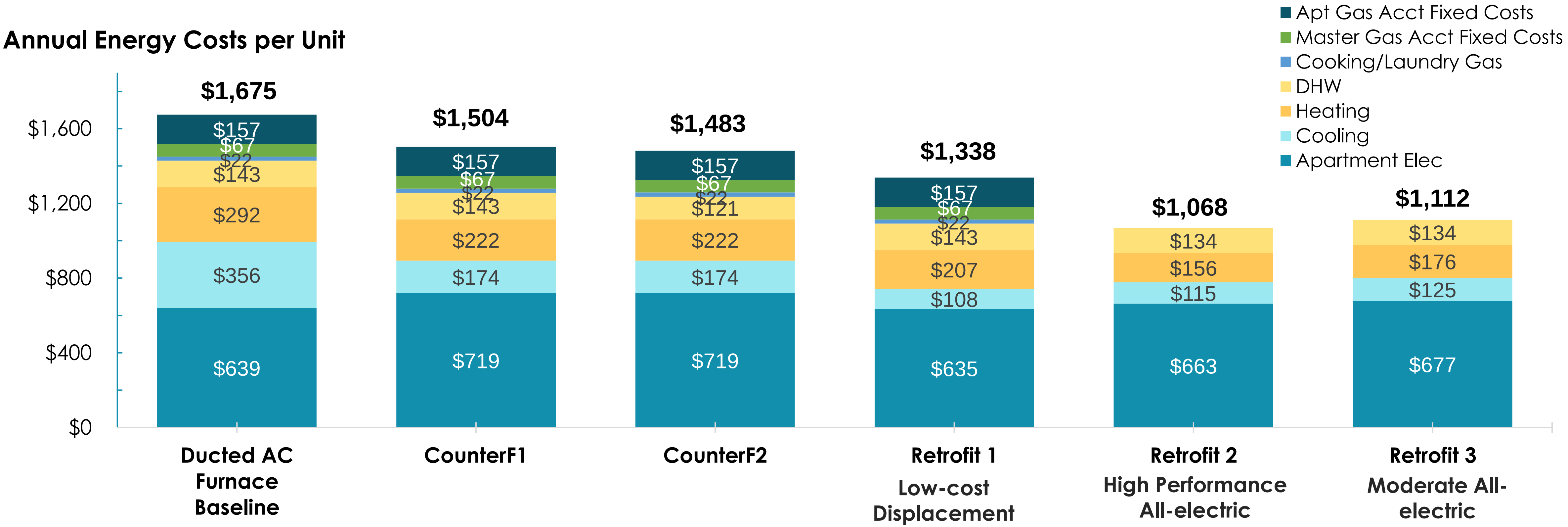
Heat pump systems are more expensive to install than their gas counterparts in typical multifamily buildings in D.C.

Retrofit Installed Costs ($/Unit)

Building System	Baseline	Counterfactual 1		Counterfactual 2		Retrofit 1: Low-cost Displacement		Retrofit 2: High Performance All-electric		Retrofit 3: Moderate All-electric	
Envelope	Uninsulated envelope, single pane metal windows	---	**$0**	**---**	**$0**	---	**$0**	Roof insulation New Windows Air Sealing	**$6,079**	Roof insulation	**$750**
HVAC	Gas furnace, SEER 10 Central A/C	New Gas Furnace, SEER 15 Central A/C	**$6,296**	New Gas Furnace, SEER 15 Central A/C	**$6,296**	75% displacement with HE ductless mini-split	**$8,452** ($2,156 more than counter-factual)	Full replacement with HE mini-splits	**$10,352** ($4,056 more than counter-factual)	Full replacement with HE mini-splits	**$10,352** ($4,056 more than counter-factual)
DHW	Gas water heater	---	**$0**	New gas WH	**$2,113**	---	**$0**	HPWH	**$3,849** ($1,736 more than counter-factual)	HPWH	**$3,849** ($1,736 more than counter-factual)
Appliance	Gas cooking, resistance dryers	---	**$0**		**$0**	---	**$0**	Induction stove	**$1,995**	Electric stove	**$745**
$ per Unit	**---**		**$6,296**		**$8,408**		**$8,452**		**$22,275**		**$15,696**

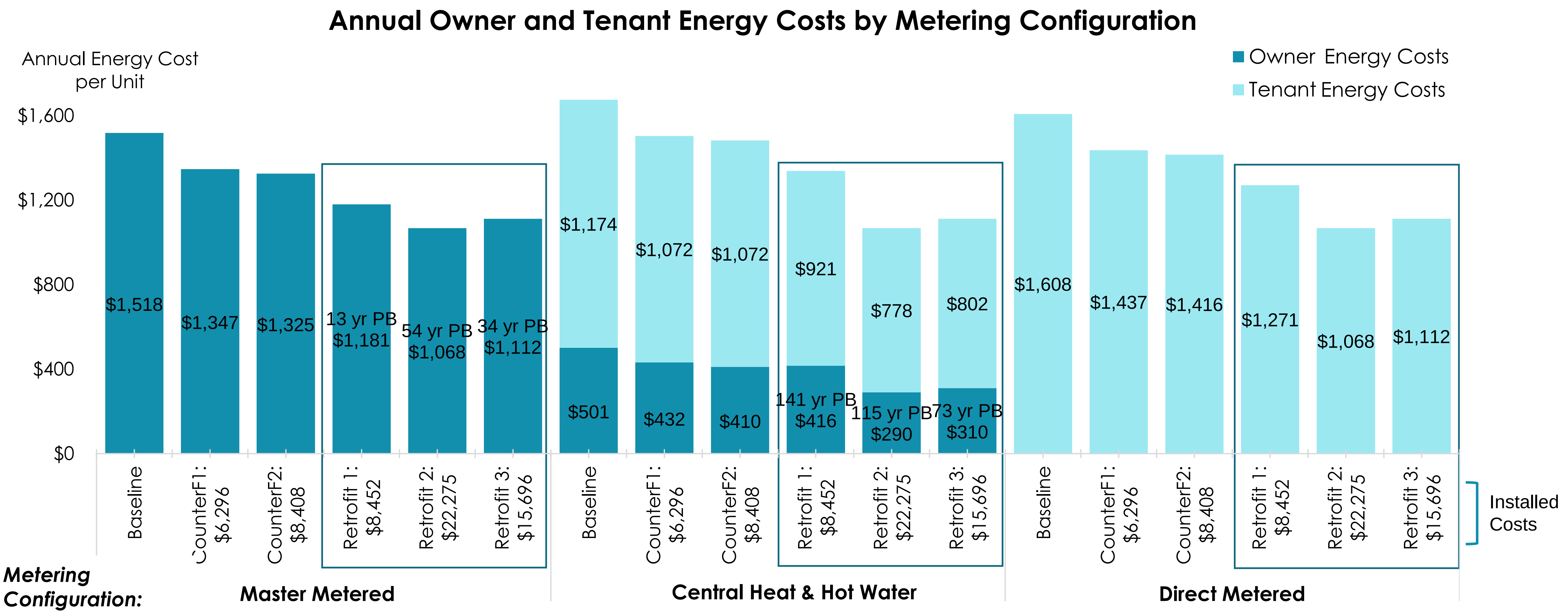
Existing Multifamily Results | Energy Costs

Fully electrifying a multifamily building in D.C. will save $500-$600 in energy costs per unit annually. The savings breakdown for owners vs. tenants will depend on the building's metering configuration.



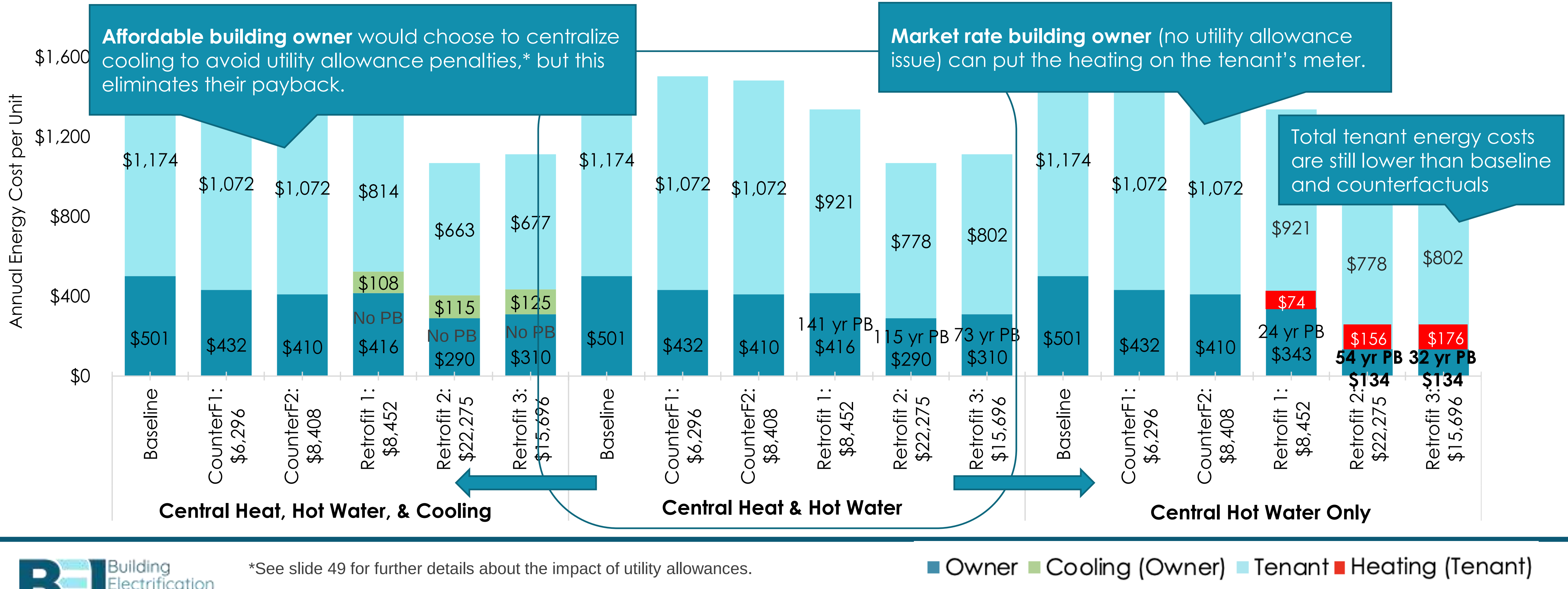
*Uses fixed gas charges for both owner and tenant accounts

Existing Multifamily Results | By Metering Configuration



Existing Multifamily Results | By Metering Configuration

Existing multifamily buildings with centrally-metered heat and hot water would likely convert to either central heat, hot water, and cooling or to central hot water only, which affects the economics and paybacks of electrification retrofits in these buildings.



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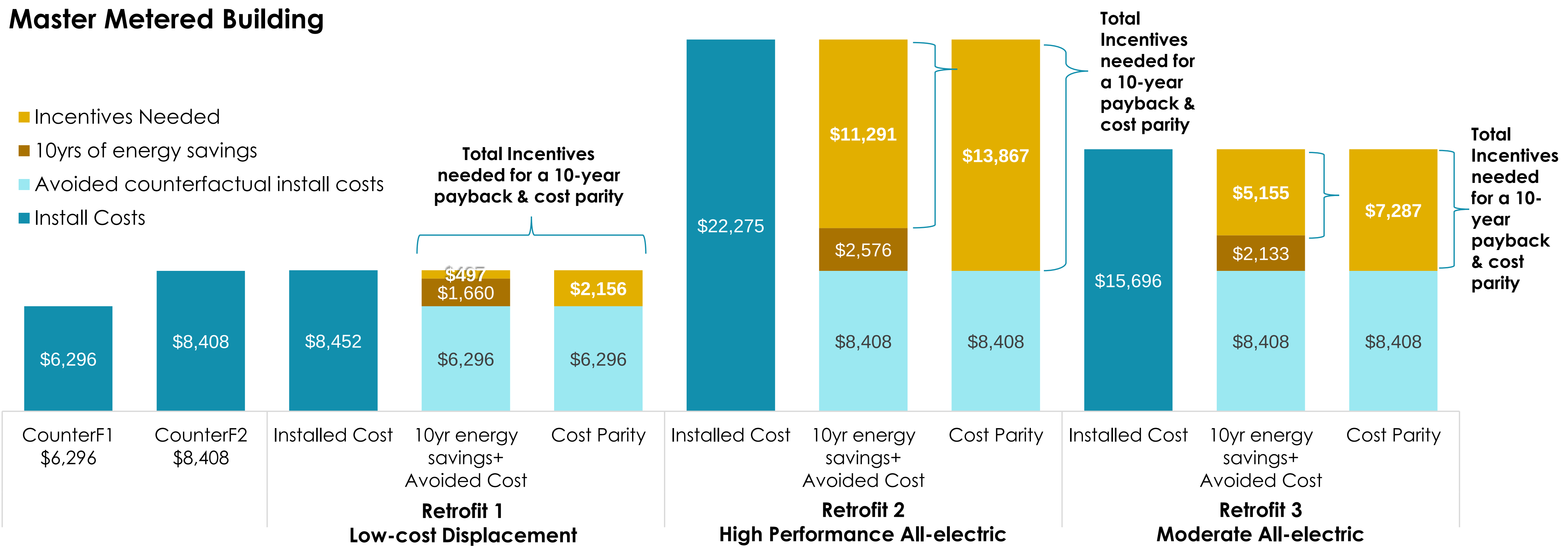
*See slide 49 for further details about the impact of utility allowances.

Existing Multifamily Results | Master-Metered Building

Master-metered multifamily buildings will need at least $5,000 in incentives to achieve a 10-year payback for an all-electric retrofit. Fewer incentives are needed for displacement, but this does not result in full electrification.



13-year payback compared to counterfactual (without incentives)

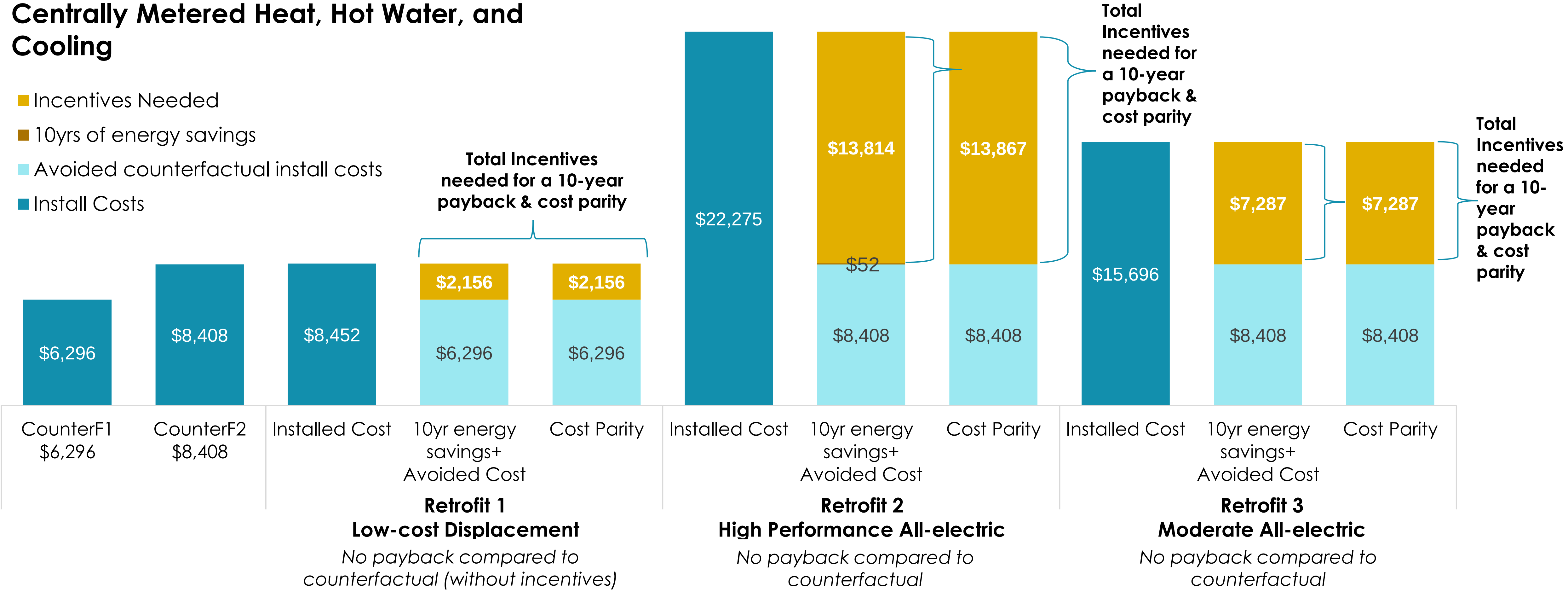
54-year payback compared to counterfactual (without incentives)

34-year payback compared to counterfactual (without incentives)

Existing Multifamily Results | Central Heat/Hot Water/Cooling

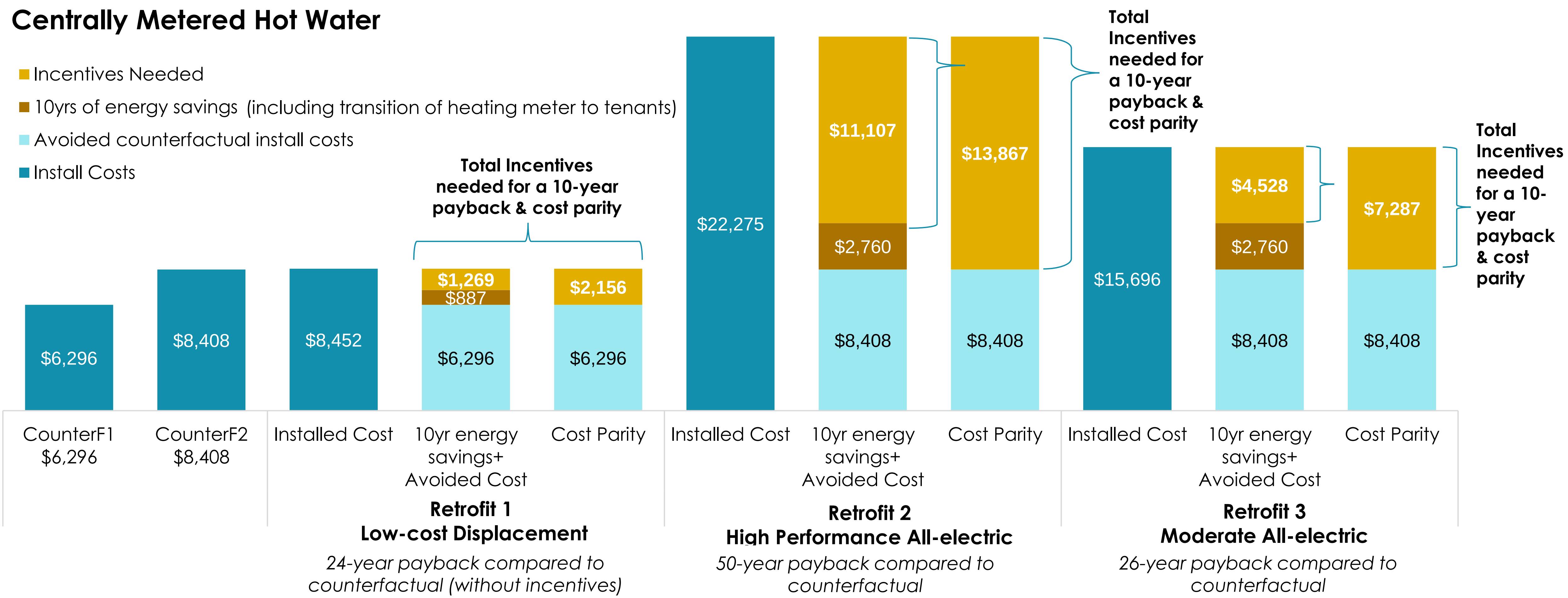
Multifamily buildings that convert to centrally metered heat, hot water, and cooling will not have sufficient energy savings to generate a payback for the owner. Significant incentives would be needed to motivate an owner to act.

Centrally Metered Heat, Hot Water, and Cooling



Existing Multifamily Results | Central Hot Water

Multifamily buildings that convert to centrally metered hot water will need at least $4,500 in incentives for a 10-year payback from an all-electric retrofit. Fewer incentives are needed for displacement.



Existing Multifamily Results | Total Incentives Needed

Total Incentives Needed for Cost Parity and 10-year Payback*

		Retrofit 1		Retrofit 2		Retrofit 3	
		10-year payback	Cost Parity	10-year payback	Cost Parity	10-year payback	Cost Parity
Master Metered Building	**Total Incentives Needed**	**$497**	**$2,156**	**$11,291**	**$13,867**	**$5,155**	**$7,287**
	Incentives for HVAC	*$497*	*$2,156*	*$3,739*	*$4,056*	*$3,500*	*$4,056*
	Incentives DHW	*N/A*	*N/A*	*$1,654*	*$1,736*	*$1,654*	*$1,736*
Central Heat, Hot Water, & Cooling	**Total Incentives Needed**	**$2,156**	**$2,156**	**$13,814**	**$13,867**	**$7,287**	**$7,287**
	Incentives for HVAC	*$2,156*	*$2,156*	*$4,004*	*$4,056*	*$5,633*	*$4,056*
	Incentives DHW	*N/A*	*N/A*	*$1,654*	*$1,736*	*$1,654*	*$1,736*
Central Hot Water	**Total Incentives Needed**	**$1,269**	**$2,156**	**$11,107**	**$13,867**	**$4,528**	**$7,287**
	Incentives for HVAC	*$1,269*	*$2,156*	*$1,950*	*$4,056*	*$1,950*	*$4,056*
	Incentives DHW	*N/A*	*N/A*	*$1,654*	*$1,736*	*$1,654*	*$1,736*
Direct Metered Building	**Total Incentives Needed**	**$2,156**	**$2,156**	**$13,867**	**$13,867**	**$7,287**	**$7,287**
	Incentives for HVAC	*$2,156*	*$2,156*	*$4,056*	*$4,056*	*$4,056*	*$4,056*
	Incentives DHW	*N/A*	*N/A*	*$1,736*	*$1,736*	*$1,736*	*$1,736*

*Paybacks are calculated against a central heat/hot water baseline.

Existing Multifamily Results | Current Incentives

Current heat pump incentives are not sufficient to achieve a 10-year payback for a full electrification retrofit in a multifamily building. Gas equipment incentives are also greater than heat pump incentives, creating an additional economic barrier to electrification.

Incentives for Existing Multifamily Buildings (as of December 2020)

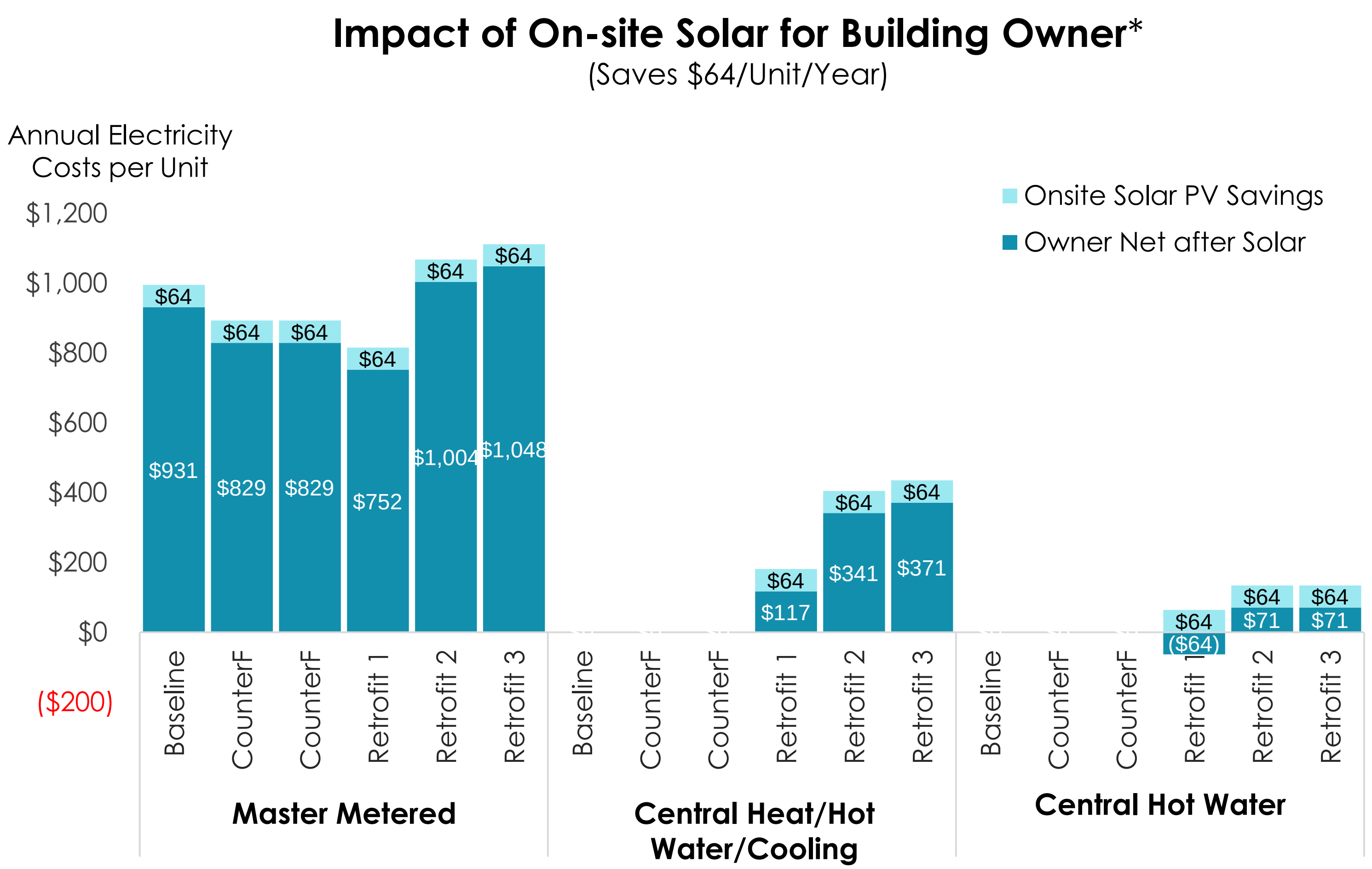
	Measure	Amount
Heat Pump Incentives	High Efficiency Ductless Mini-Split Heat Pump ($/unit)	DC SEU - $1,050 Fed. Tax Credit* - $900
	Heat Pump Water Heater ($/unit)	DC SEU - $400
Gas Equipment Incentives	High Efficiency Gas Furnace ($/unit)	DC SEU - $775
	High Efficiency Central A/C ($/unit)	DC SEU - $300
	High Efficiency Gas Water Heater ($/unit)	DC SEU - $350

ASHP & HPWH Incentives: $1,075-1,750

Total Gas Equipment Incentives: $1,425

*The federal tax incentive ends at the end of 2020, and it is unclear if it will increase or decrease in 2021.

Existing Multifamily Results | Impacts of Solar PV



Key Takeaways:

- **Cost of Solar PV/Unit after SRECs and Federal Investment Tax Credit:** $835
- **Operational Savings of Solar PV/Unit:** $64
- **Simple Payback: 13** years

On-site Solar Assumptions

Rooftop Solar Installation Cost per Unit	5 kW -> 0.5kWDC / Unit $19,410 -> **$1,941 / Unit**
Federal Investment Tax Credit @ 22%	-$427 / Unit
SRECS: $400/MWh for 3 years*	-$679 / Unit
Discounted Cost of Solar PV / Unit after SREC and Federal Investment Tax Credit	$835
Annual Electricity Savings / Unit	$64

**using 1,132 kWh/kWDC*

SREC Calculations:

Total solar PV Size	5 kW
Total Solar PV Generation / kW (given for DC)	1.132 MWh/kW/yr
Total Solar Generation[1]	5.66 MWh/yr
SREC value[2]	$400 per MWh
Years of SRECS[3]	3 yrs
Total SREC Value (=1*2*3)	**$6,792 for 10 units**

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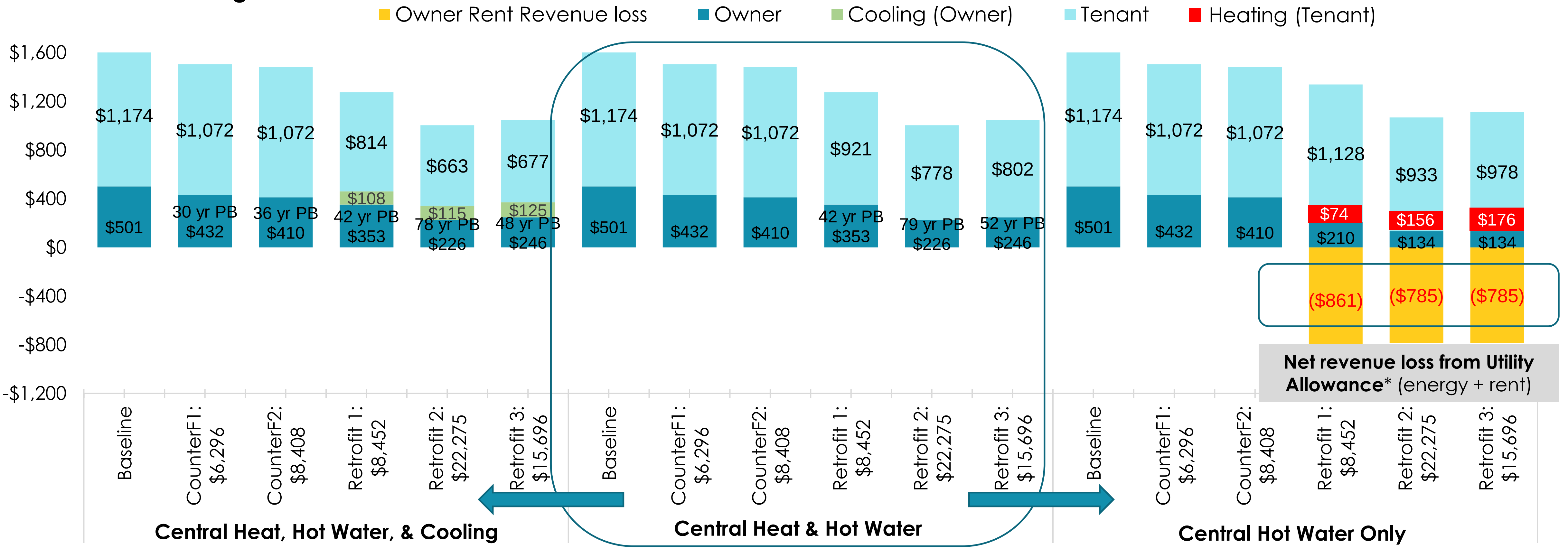
*Direct metered was not included because the owner does not have energy costs in that scenario. Direct metered tenant electricity costs would be the same as the "Master Metered" scenario on this chart.

Existing Multifamily Results | Impact of Utility Allowances

In subsidized affordable multifamily buildings with centrally-metered heat and hot water, current utility allowances would reduce an owner's rent revenue by up to $860, unless cooling is added to the owner's meter.

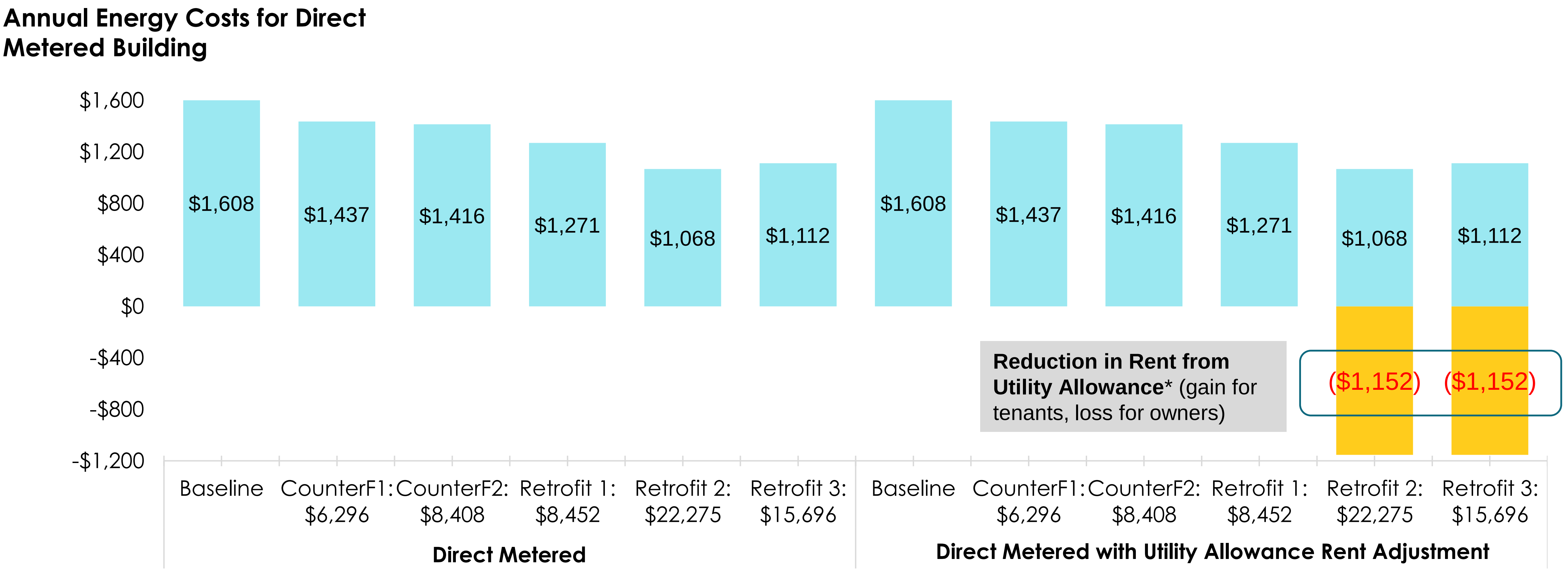
Annual Energy Costs for Central Heat & Hot Water Building



*Current utility allowance amount for a two-bedroom apartment, net of owner savings from baseline

Existing Multifamily Results | Impact of Utility Allowances

In subsidized affordable multifamily buildings that are direct-metered for energy (where the tenant pays all energy bills), current utility allowances would reduce an owner's rent revenue by over $1,100, posing a major barrier for electrification in subsidized affordable housing with this metering configuration.



*Current utility allowance amount for a two-bedroom apartment, net of owner savings from baseline

Existing Multifamily Analysis | Key Takeaways

- **Electrification retrofits in multifamily buildings significantly reduce building energy use,** and will reduce GHG emissions over the long term as the grid continues to get cleaner.
- **These retrofits also reduce residents' energy bills, provided that high efficiency equipment is installed**. Weatherization also helps reduce energy bills.
- **Installation costs are often too high to achieve reasonable paybacks** for building owners, despite the energy cost savings. Direct metered buildings offer no paybacks to owners, creating a landlord-tenant split incentive.
- **Market rate building owners with central systems will likely transfer heating costs to tenants**, **although tenants will still see reductions in their energy bills from electrification.** Protections may be necessary to ensure this is true in all cases.
- **Current incentives can help overcome the challenging economics, but additional incentives will be needed to motivate all building owners**. In direct metered buildings, incentives would likely need to achieve cost parity with gas alternatives to overcome the landlord-tenant split incentive.
- **On-site solar paired with electrification can help improve the economics** in buildings where owners pay some or all of the energy costs.
- **Current utility allowances inhibit the economics of electrification retrofits** in government-subsidized affordable buildings by substantially reducing rent revenue for owners.

Energy Rate Sensitivity Analysis

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Overview of Energy Rate Sensitivity Analysis

Local Energy Rate Assumptions

Electricity Rates*

This analysis assumes a blended average from Pepco's 2019 rates:

- Multifamily Owner : $0.113/kWh
- Single Family + Multifamily Tenants: $0.116/kWh

Gas Rates**

This analysis assumes a blended average from Washington Gas 2019 rates:

- All scenarios: $0.93/therm

Sensitivity Analysis

Electricity Rates

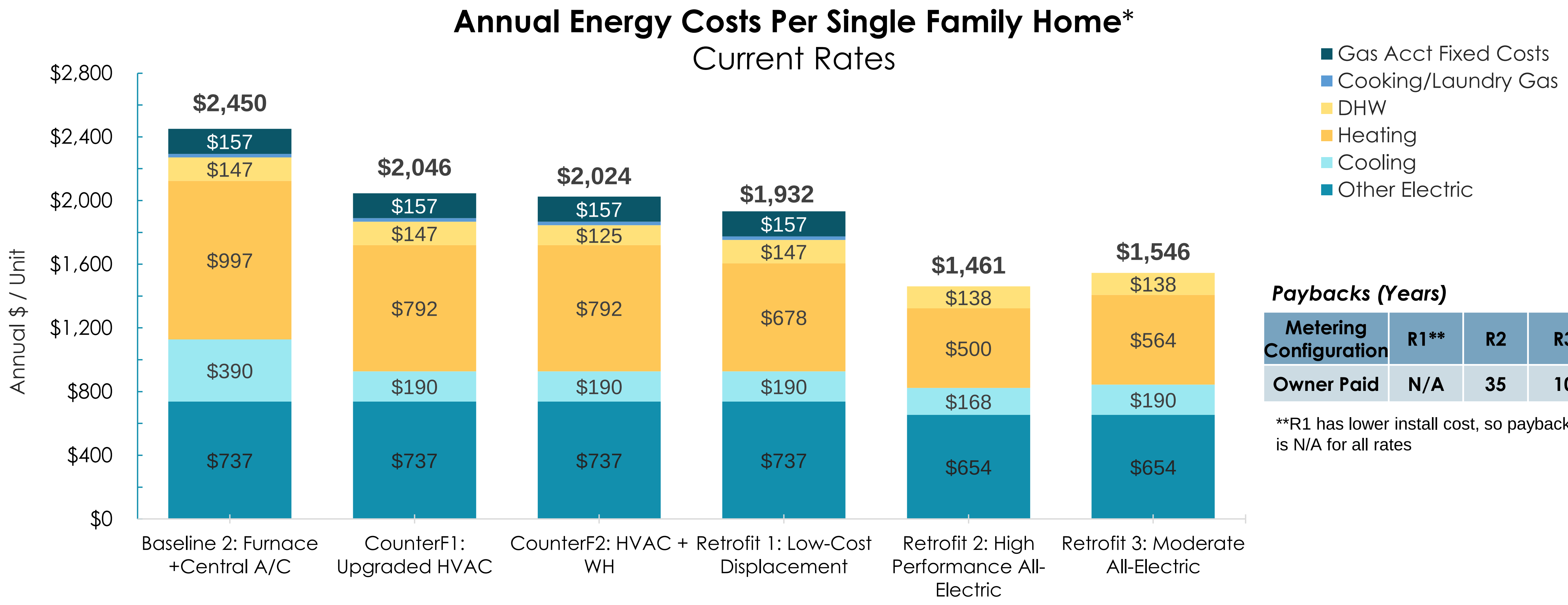
BEI selected an electric rate decrease of 30% to test the sensitivity of the analysis results to electric rate changes. This does not represent a projection of future rates in D.C.

Gas Rates

BEI selected a gas rate increase of 40% to test the sensitivity of the analysis results to gas rate changes. This does not represent a projection of future rates in the District, although there have been recent spikes in gas prices close to this rate.

*Multifamily Owner meter uses PECO's rate class "MMA". Single Family + Multifamily Tenant meters use rate class "R." (Link to source).
**Washington Gas rates for Rate 1 and Rate 2 are $0.95/therm and $0.93/therm, respectively. Because of the similarity, one rate was used across all scenarios. (Link to source).

Existing Single Family Homes | Energy Costs



Paybacks (Years)

Metering Configuration	R1**	R2	R3
Owner Paid	N/A	35	10

**R1 has lower install cost, so payback is N/A for all rates

*Results shown for Existing Single Family Baseline 2 only (Furnace and Central A/C)

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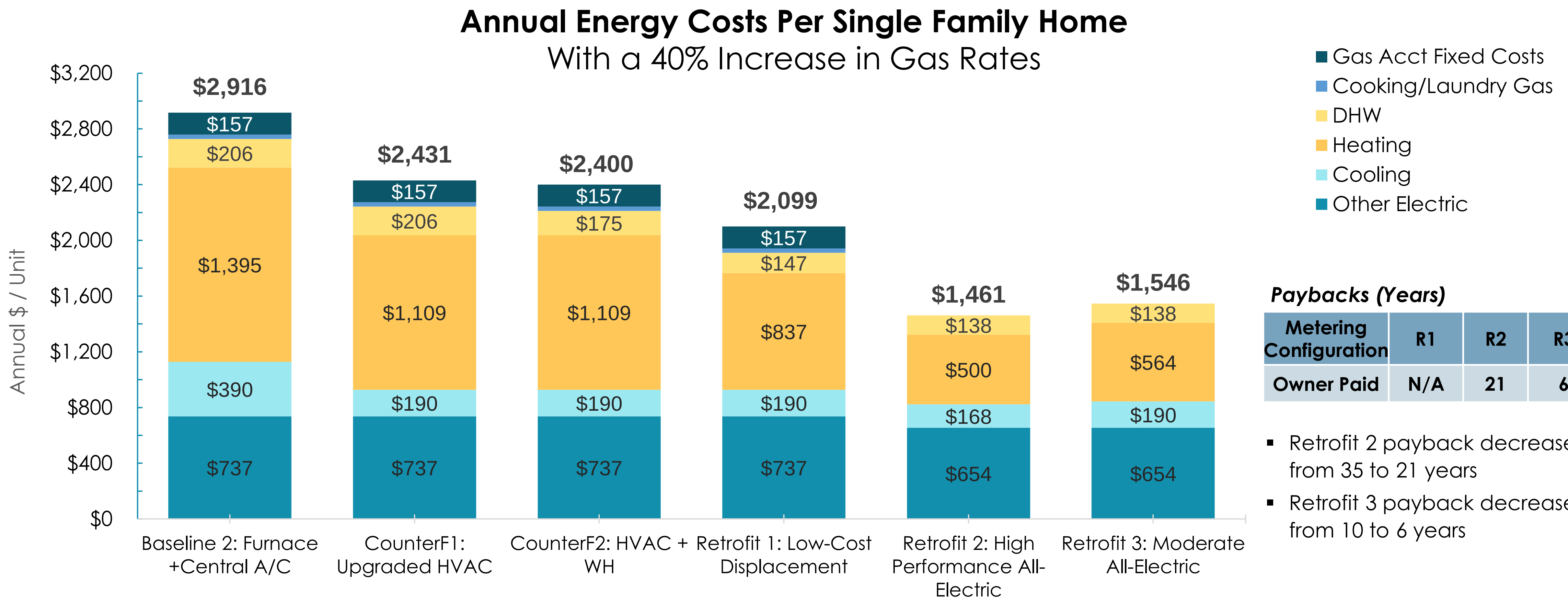
Existing Single Family Homes | Gas Rate Change



Paybacks (Years)

Metering Configuration	R1	R2	R3
Owner Paid	N/A	21	6

- Retrofit 2 payback decreases from 35 to 21 years
- Retrofit 3 payback decreases from 10 to 6 years

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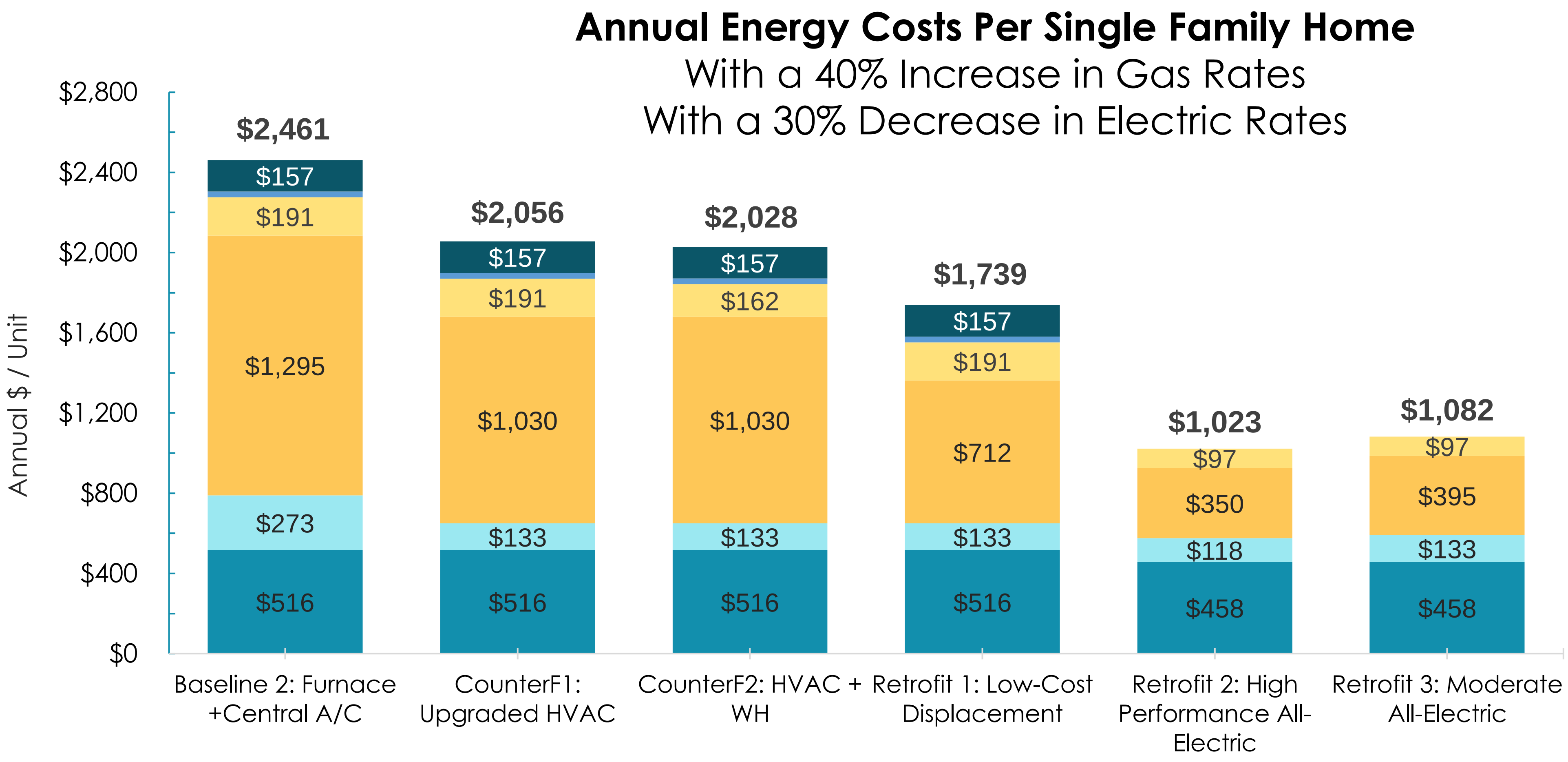
Existing Single Family Homes | Gas & Electric Rate Change



Paybacks (Years)

Metering Configuration	R1	R2	R3
Owner Paid	N/A	18	5

- Retrofit 2 payback decreases from 35 to 18 years
- Retrofit 3 payback decreases from 10 to 5 years

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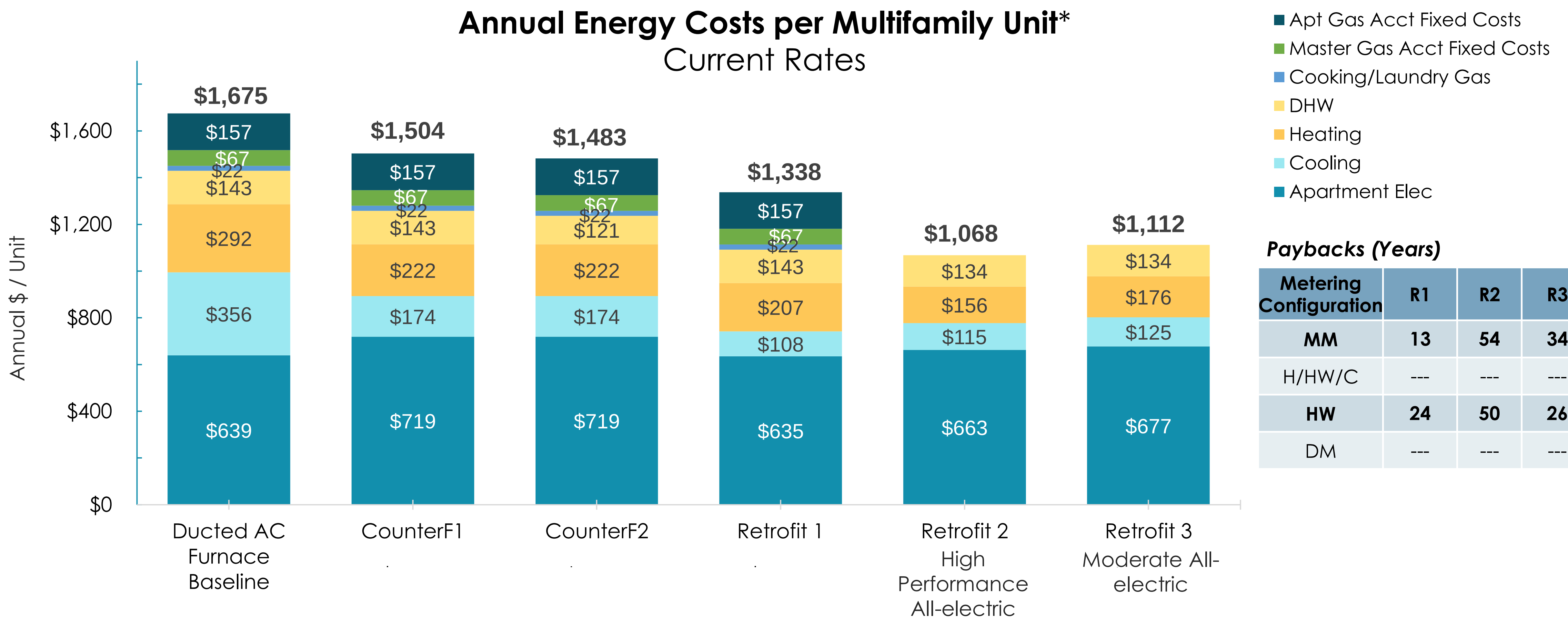
*Note: Gas increase and electricity decrease amount was selected to demonstrate the impacts of utility changes for this sensitivity analysis, this is just a projection selected by BEI.

Existing Multifamily Building | Energy Costs



Paybacks (Years)

Metering Configuration	R1	R2	R3
MM	**13**	**54**	**34**
H/HW/C	---	---	---
HW	**24**	**50**	**26**
DM	---	---	---

*Uses fixed gas charges for both owner and tenant accounts

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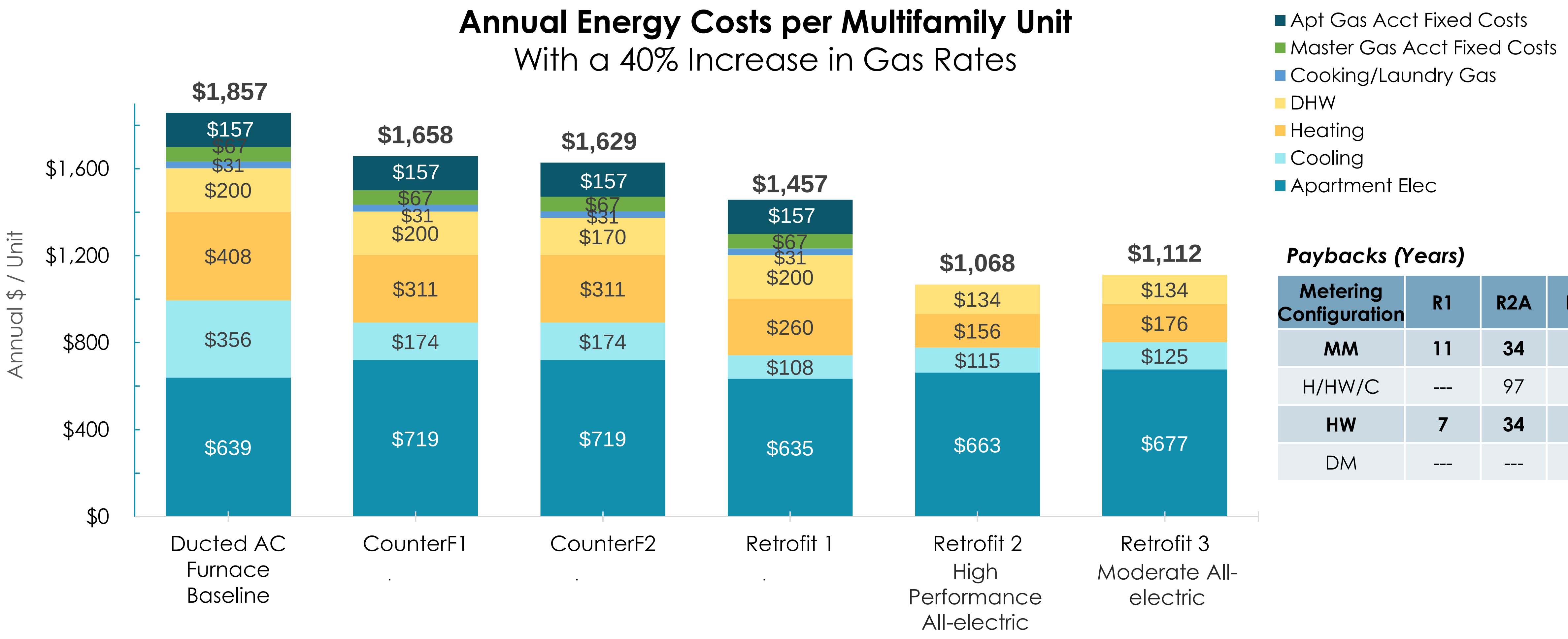
Existing Multifamily Building | Gas Rate Changes



Paybacks (Years)

Metering Configuration	R1	R2A	R3A
MM	**11**	**34**	**20**
H/HW/C	---	97	65
HW	**7**	**34**	**18**
DM	---	---	---

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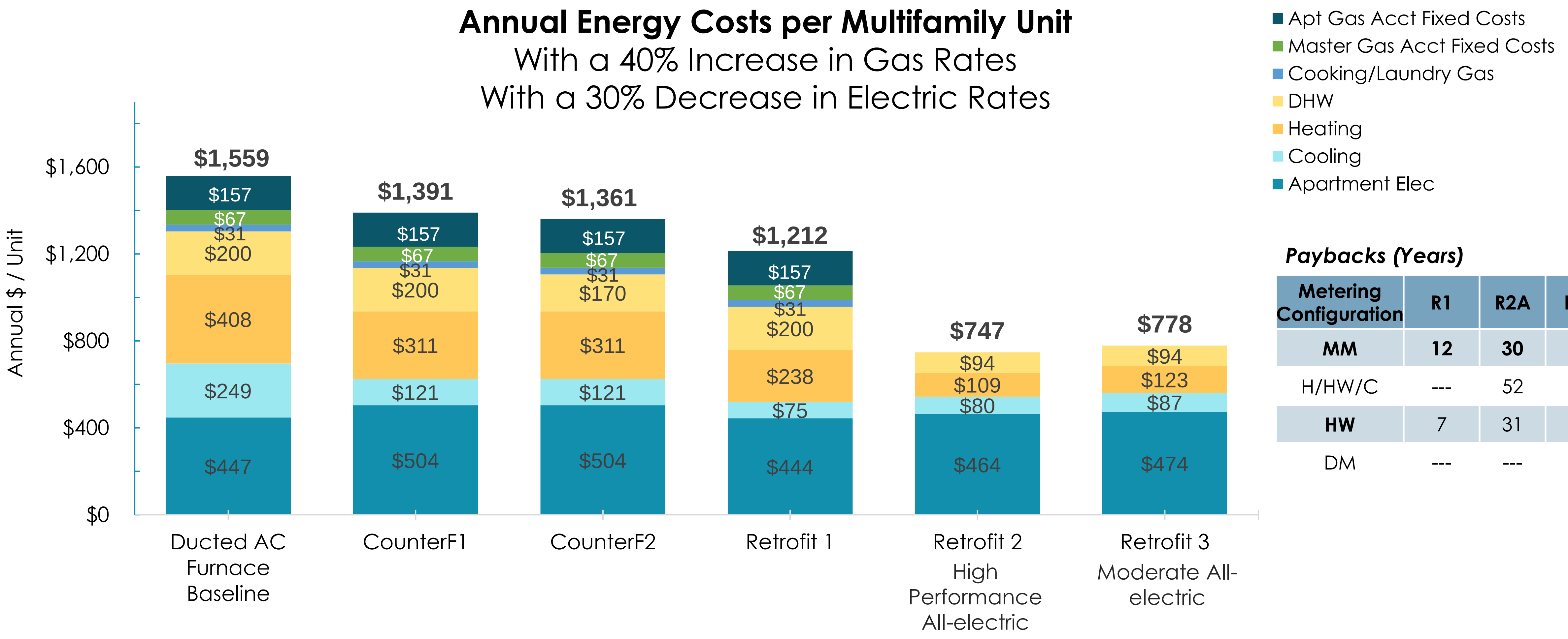
Existing Multifamily Building | Electric & Gas Rate Changes



Paybacks (Years)

Metering Configuration	R1	R2A	R3A
MM	**12**	**30**	**17**
H/HW/C	---	52	30
HW	7	31	16
DM	---	---	---

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Time of Use Rates

Background on Time of Use Rates

- **Time of use rates increase or lower energy rates at certain times of the day or the year and can signal to customers to adopt energy use profiles that are more favorable to utilities.** Typically, this means using less energy when there is significant demand on the grid, and using more energy when there is excess capacity on the grid.

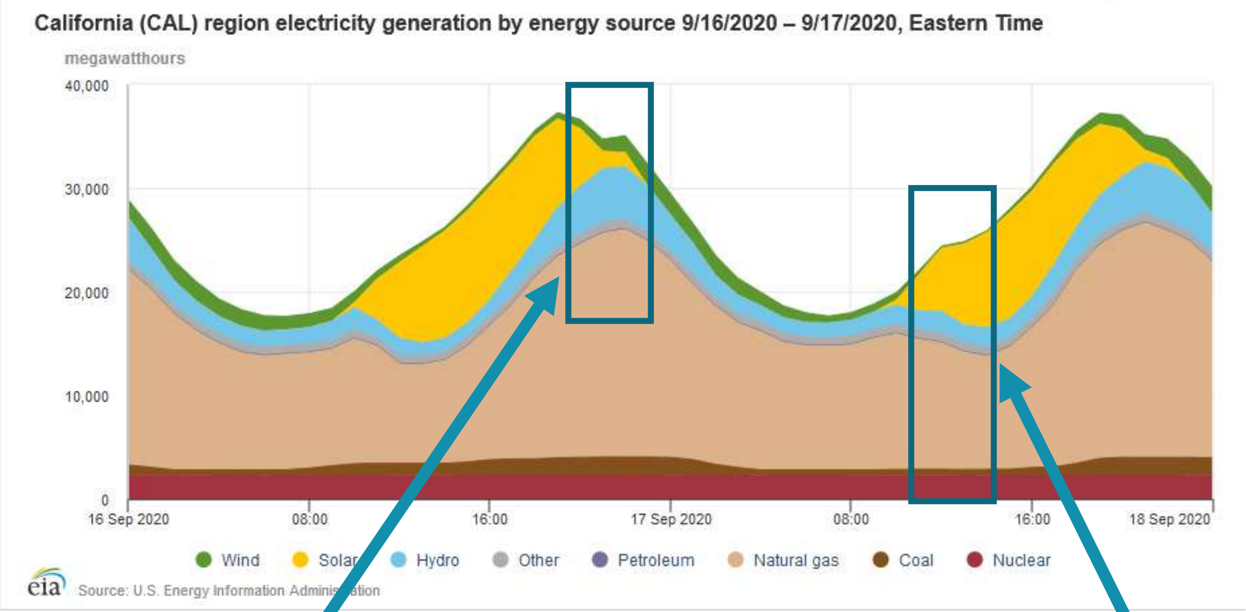
- **Time of use rates can be designed to be favorable to building electrification** while presenting an opportunity to adjust rates to help manage electric grid loads.

- **When time of use rates are adopted, smart management of electric equipment is needed to reduce a customer's overall electricity rate.** An example of a smart energy management strategy is thermal energy storage, which entails heating water during periods of lower electric demand and storing this water in a tank for later use. Heat pump water heaters allow for thermal energy storage.

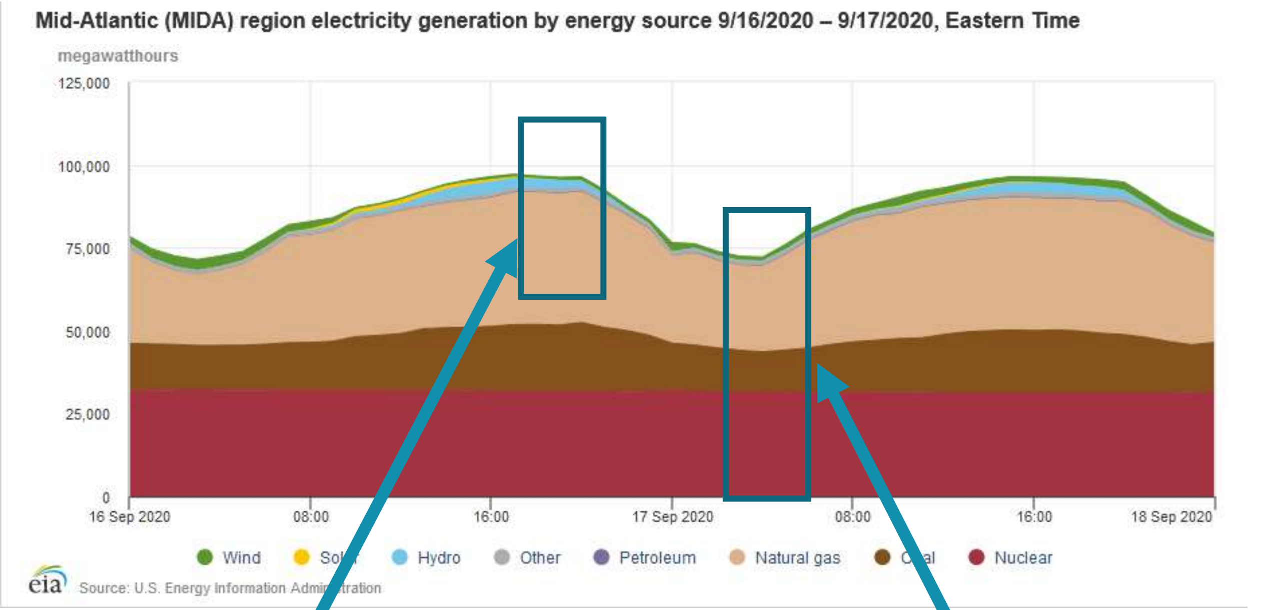
Time of Use Rates

Examples of Daily Loads in California and the Mid-Atlantic Region

California Example – Daily Loads



Mid-Atlantic Region – Daily Loads



4-9pm: Utility and residential solar generation decreases when home electricity use increases, causing a strain on the electric grid – electricity prices are highest to reflect this strain

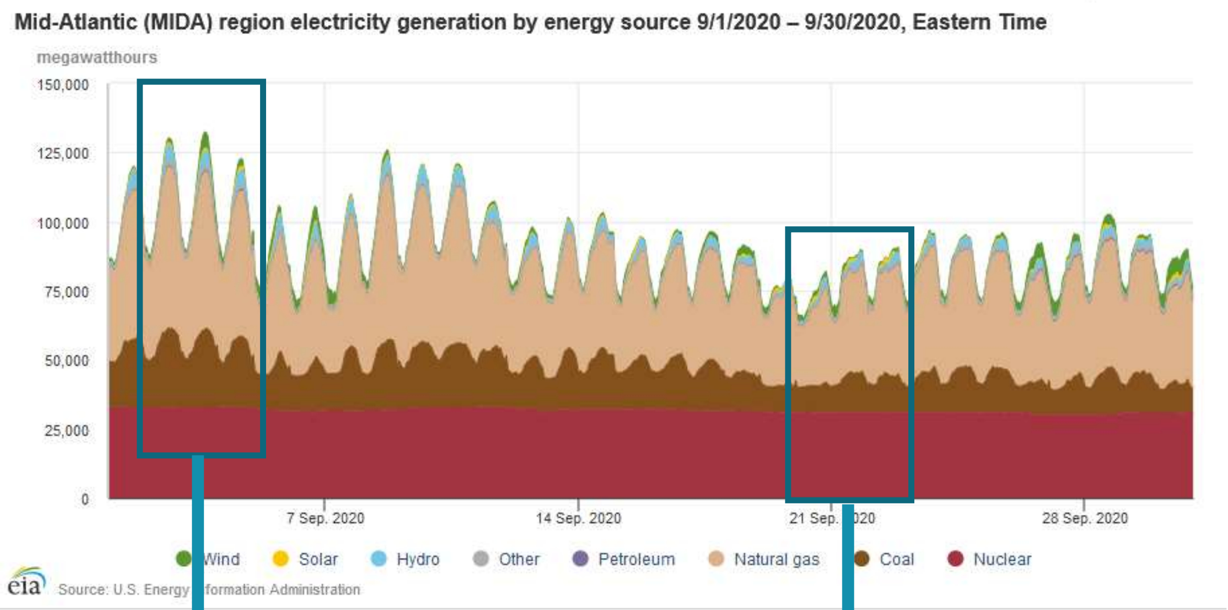
12-2pm: Maximum solar generation, but low usage (best time for energy storage) – electricity is cheapest to reflect this surplus

Similar daily trough and peak that California experiences, indicating a potential for building-level energy/thermal storage to reduce electricity costs.

Time of Use Rates

Examples of Seasonal Loads in the Mid-Atlantic Region

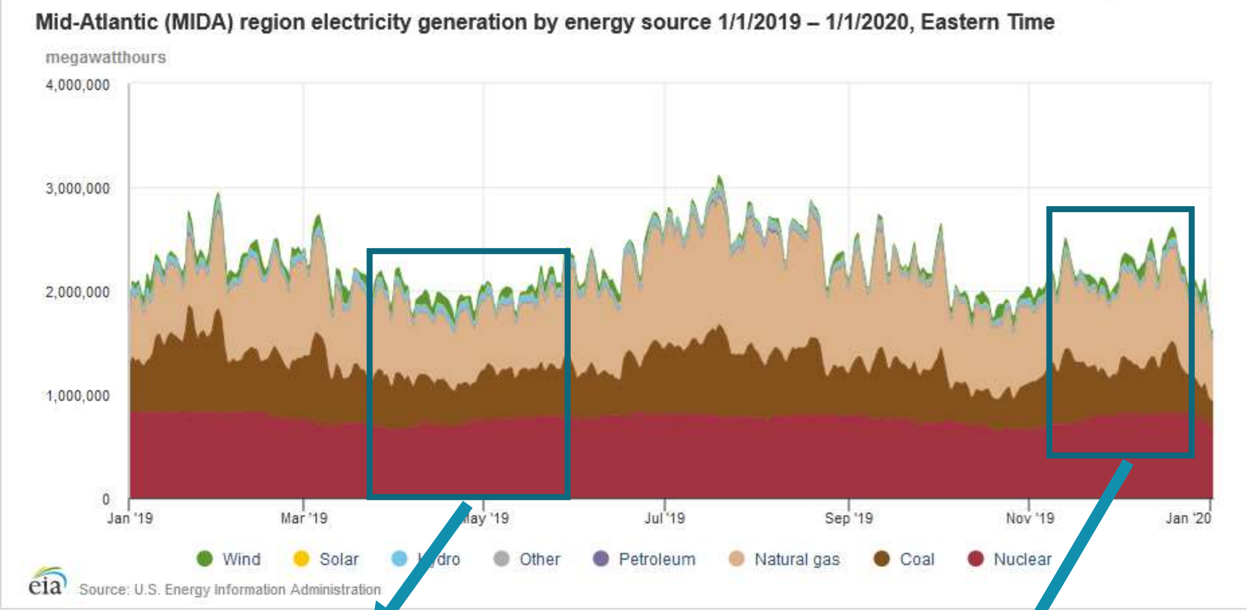
Mid-Atlantic – Seasonal Loads (Sept.)



Warm at the beginning of Sept: high cooling loads

Cooler at the end of Sept: lower cooling loads

Mid-Atlantic – Seasonal Loads (Annual)



Shoulder seasons have lowest electric loads, so prices could be lowest

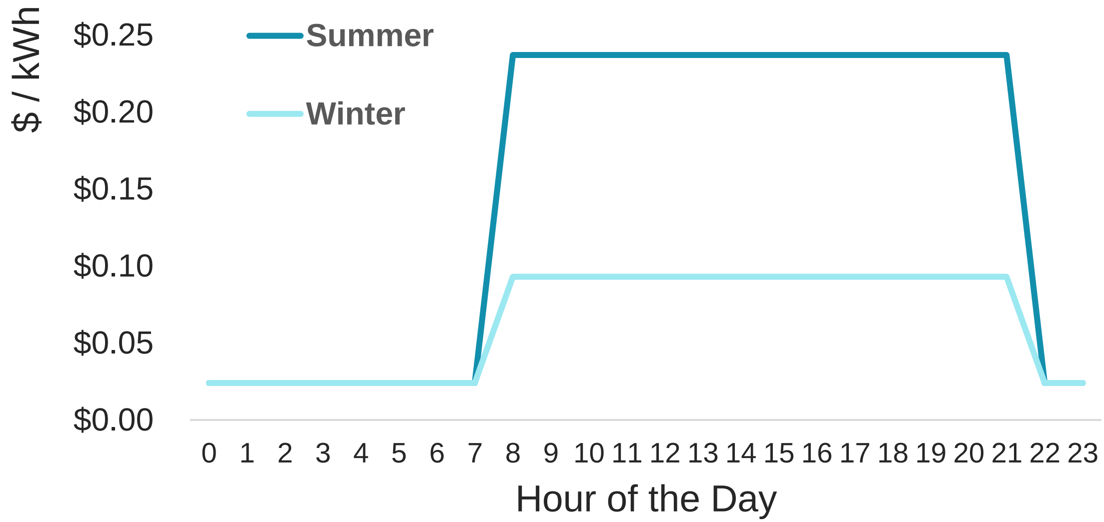
Winter electric loads are higher but do not reach summer peaks, indicating potential for lower rates

Time of Use Rates

New York City Commercial Building TOU Rate Example

- In New York City, peak time is summer daytime, when businesses are occupied and using electricity for cooling, straining the grid to supply enough energy from regional power plants

NYC Commercial Building TOU Rate Example
(distribution costs only, not supply)



Commercial TOU Rate	$/kWh
Summer M-F 8am-10pm	$0.237
Summer nights/weekends	$0.024
Non-summer M-F 8am-10pm	$0.093
Non-Summer nights/ weekends	$0.024

Expensive summer daytime rates to curb peak cooling use

Much less at night and on weekends (no office contribution)

Less expensive during non-summer months

Customer Economics Analysis: Final Takeaways

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Final Takeaways

- **Building electrification significantly reduces energy use in existing multifamily, existing single family, and new multifamily buildings in Washington, D.C.** and will reduce GHG emissions over the long term.
- **Building electrification will also typically reduce residents' energy bills, provided that high efficiency equipment is installed**, even if owners transition heating costs to tenants. Weatherization also helps reduce energy bills.
- **All-electric multifamily new construction is lower cost to build** than new mixed fuel multifamily buildings that are built to the 2020 Energy Code.
- **Installation costs for all-electric retrofits are often higher than gas alternatives, although these costs are lower when replacing both the existing heating and cooling system in single family homes.**
- **Additional incentives will be needed to improve the economics for building owners and motivate action.** For direct-metered buildings where there is a landlord-tenant split incentive, incentives may need to reach cost parity with gas alternatives to motivate owners.
- **Changes to rate design and on-site solar are options to improve the economics of electrification**.
- **The District can start taking action now to improve the economics of building electrification** to accelerate the associated cost, health, and climate benefits for its residents.

Potential Next Steps

Based on the findings of this analysis, potential next steps in D.C. include:

- **Develop an all-electric new construction code for implementation in the District** beginning in 2023 or 2026.
- **Update current DC SEU and other incentive programs** to buy down the installation costs of electrification retrofits and help streamline the retrofit process.
  - *Specific changes could include, for example: Increasing ASHP/HPWH incentives and sizing them to cost parity; removing incentives for new gas equipment; creating incentives for envelope improvements; and providing technical assistance to simplify the electrification retrofit process.*
- **Update the Building Energy Performance Standard (BEPS) policy** to encourage electrification and discourage the installation of new gas equipment to meet the standard.
- **Consider implementing electric and gas rate changes** to encourage electrification upgrades.
  - *Specific rate changes could include, for example: Heat pump-specific rates; Time of Use (TOU) rates; low-income utility rates; or rate changes that reflect the social cost of carbon (which would increase gas rates/decrease electric rates).*
- **Develop a heat pump-specific utility allowance** to ensure financial viability of all-electric construction and retrofits in government-subsidized affordable housing.
- **Expand access to solar programs** to provide combined electrification and solar benefits to more residents.

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