We will start in just a few minutes. Tell us…

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The Energy Impacts of COVID-19: HVAC Mitigation Strategies

Monday, February 22, 2021

1:00 – 2:00 pm ET

Mariana Egea-Casalduc

U.S. Department of Energy

U.S. DEPARTMENT OF ENERGY

Agenda & Housekeeping

1. Introduction & Polls
2. Presentation from NREL
3. Q&A

You have joined on a muted line.

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Polls 1 - 6

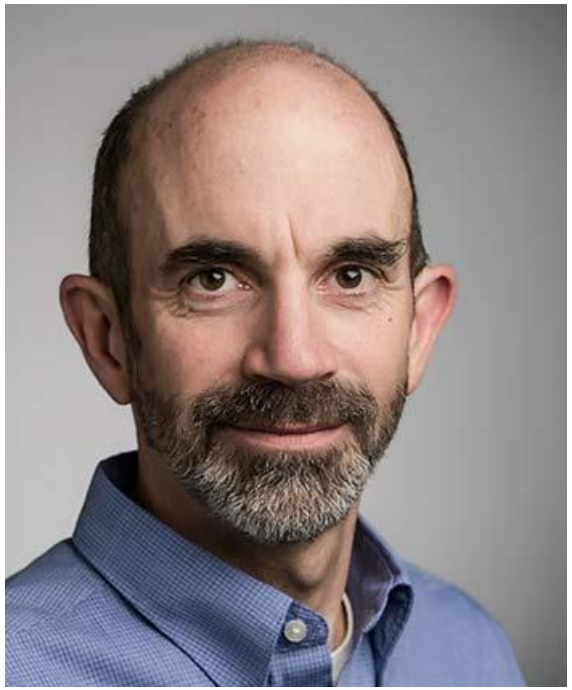
We'd like to hear more about you!

Please go to www.slido.com and enter code **#DOE** to respond

Better Buildings HVAC Technology Research Team at NREL

Marcus Bianchi
Senior Research Engineer

Greg Shoukas
Research Engineer



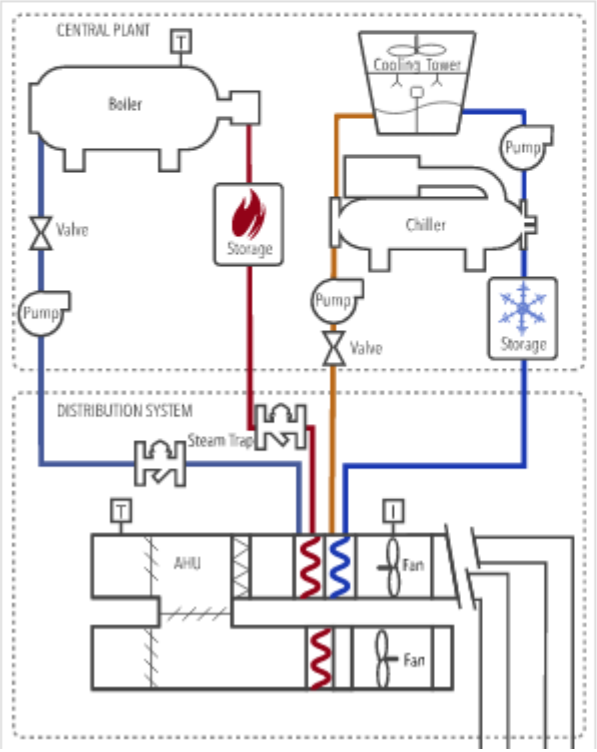
Michael Deru
Senior Research Engineer

HVAC Resource Map

https://hvacresourcemap.net

HVAC Home | Central Plant | Distribution | Space Loads | Contributors

HVAC Resources



What is this resource?

The Central Plant Resource Map is an intuitive graphical interface that provides quick access to a broad array of quality information on operations and maintenance best practices and energy and water efficiency measures. The resources cover the central plant, distribution systems, and zone systems. The primary audiences for this resource are facility managers, operations staff, and design engineers who are looking to improve central plant and distribution efficiency but don't have time to search for these resources.

This Resource Map is not a repetition of guidance provided in codes and standards. It should not be used in lieu of professional engineering services.

Explore HVAC Resources

Use the horizontal navigation above or the interactive diagram to dive into resources on different HVAC components.

The resources listed on this site have been carefully selected to help narrow your search for helpful information.

Today's Presenters

Chris CaraDonna
NREL

Kim Trenbath
NREL

ComStock/COVID19:
U.S. Commercial Building Stock Analysis of COVID-19 Mitigation Strategies

Chris CaraDonna, Lead Researcher
February 22nd, 2021

Project Outcomes

The ASHRAE Epidemic Taskforce (ASHRAE-ETF) has released several COVID-19 mitigation strategies for commercial buildings.

ComStock was used to analyze the impact of select strategies on the existing commercial building stock. Quantities of interest include:

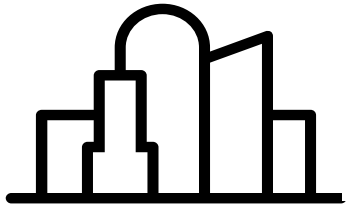
- Energy consumption
- Peak demand
- Indoor air conditions (temperature and humidity)

ComStock Overview

ComStock Overview

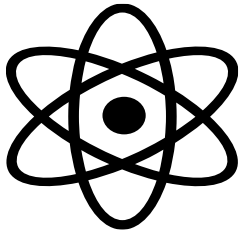
ComStock is a DOE platform, with NREL as the lead developer, that models the U.S. commercial building stock using OpenStudio/EnergyPlus to perform physics-based building energy modeling simulations.

ComStock Overview



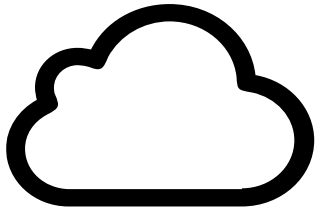
Building stock characteristics database

+



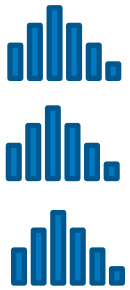
Physics-based computer modeling

+



High-performance computing

Sample characteristics



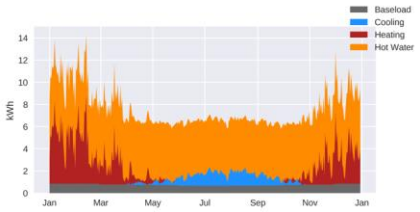
… (100's)

Convert to energy model

OpenStudio

EnergyPlus

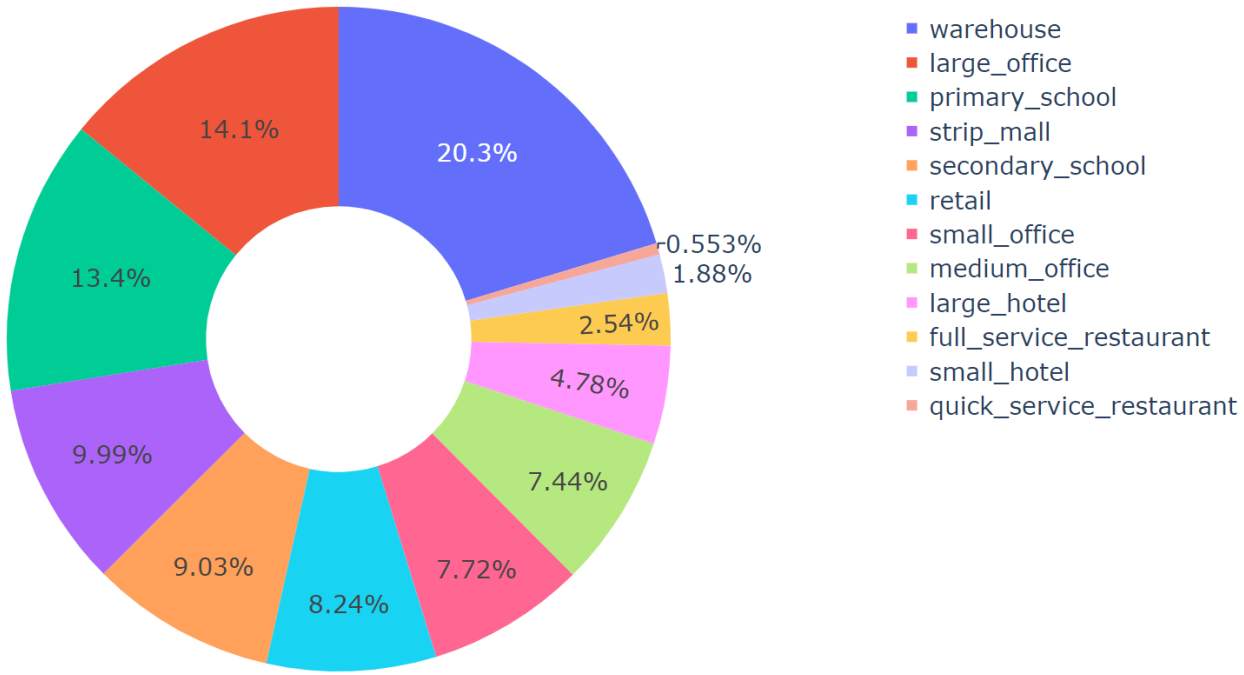
Run energy model



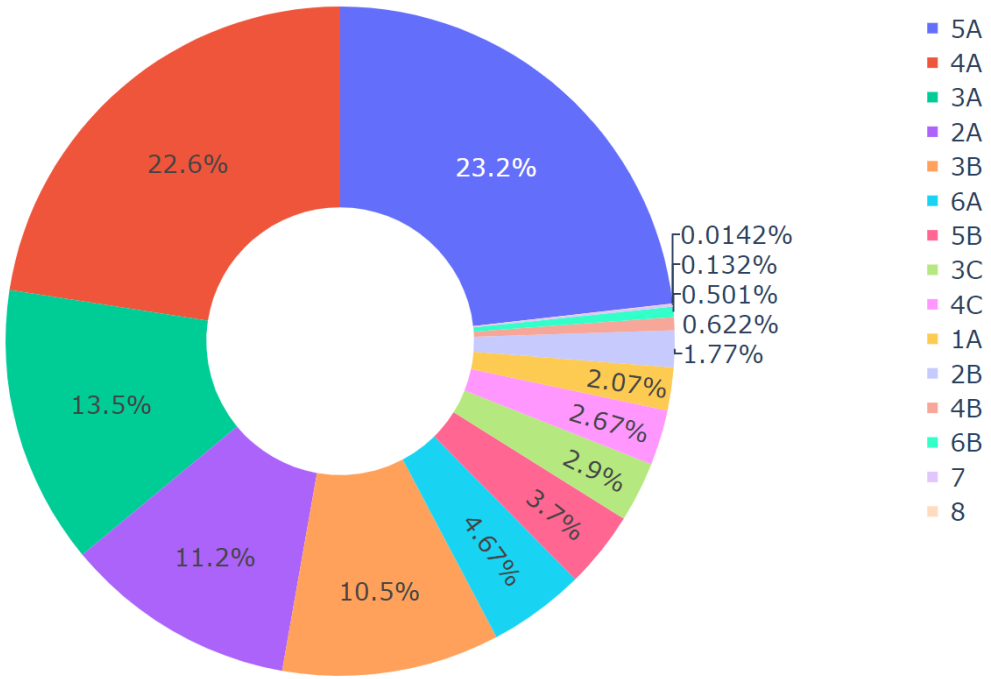
X

~110,000+ models in stock

ComStock – Building Stock Area Composition



Stock Area Percentage by Building Type



Stock Area Percentage by Climate Zone

- This analysis omits health care building types
- Building area scaled on a building type basis using CBECS
- Total stock area modeled = 54.7 billion square feet, which is approximately 65% of the commercial building area in the U.S.

Disclaimer

This project is intended to analyze how specific COVID-19 mitigation strategies recommended by the ASHRAE-ETF impact the energy and indoor air conditions of the U.S. commercial building stock. It does not study the effectiveness of different strategies at decreasing the spread of COVID-19.

This project is analyzing the existing U.S. commercial building stock <u>with no changes to building schedules or occupant behavior</u> as a result of the 2020 COVID-19 pandemic.

COVID-19 Mitigation Strategies

COVID-19 Mitigation Strategies for Analysis

ASHRAE ETF-recommended strategies studied:

- Upgrade to MERV-13 filters
- Disable demand control ventilation (DCV)
- Increase minimum outdoor air to 100%
- HVAC flushing mode operation

Upgrade to MERV-13 Filters

Description: Replace existing HVAC filter with a minimum MERV 13 rating filter on air handling units.

ComStock Implementation & Assumptions:

- Applicable to buildings that constitute about 80% of total building stock by area.
- 0.4” static pressure increase on supply fans of variable air volume (VAV) and constant air volume (CAV) air delivery systems. Actual pressure drops will vary. 0.4” was derived from ASHRAE 90.1: Energy Standard for Buildings Except Low-Rise Residential Buildings.
- Does not affect zone terminal equipment (i.e., PTACs, unit heaters, etc.).
- Only implemented in air handlers that serve zones with people.
- Assumes existing fans can overcome additional pressure drop and have been balanced to maintain design airflows.
- Equipment sizing to remain consistent with base run.

Disable Demand Control Ventilation

Description: Disable existing DCV acting to reduce outdoor air during periods of low occupancy.

ComStock Implementation & Assumptions:

- Applicable to buildings that constitute about 3% of total building stock by area—DCV saturation in ComStock baseline is primarily driven by building energy code requirements.
- DCV is disabled wherever it exists in ComStock baseline (which represents the existing U.S. building stock).
- Equipment sizing to remain consistent with base run.

Increase Minimum Outdoor Air

Description: Increase outdoor air ventilation during occupied hours in air handling units.

ComStock Implementation & Assumptions:

- Applicable to buildings that constitute about 80% of total building stock by area
- 100% minimum outdoor air during occupied hours for VAV and CAV air delivery units.
- Does not affect zone terminal equipment (i.e., PTACs, unit heaters, etc.).
- Only implemented in air handlers that serve zones with people.
- Equipment sizing to remain consistent with base run.

HVAC Flushing Mode Operation

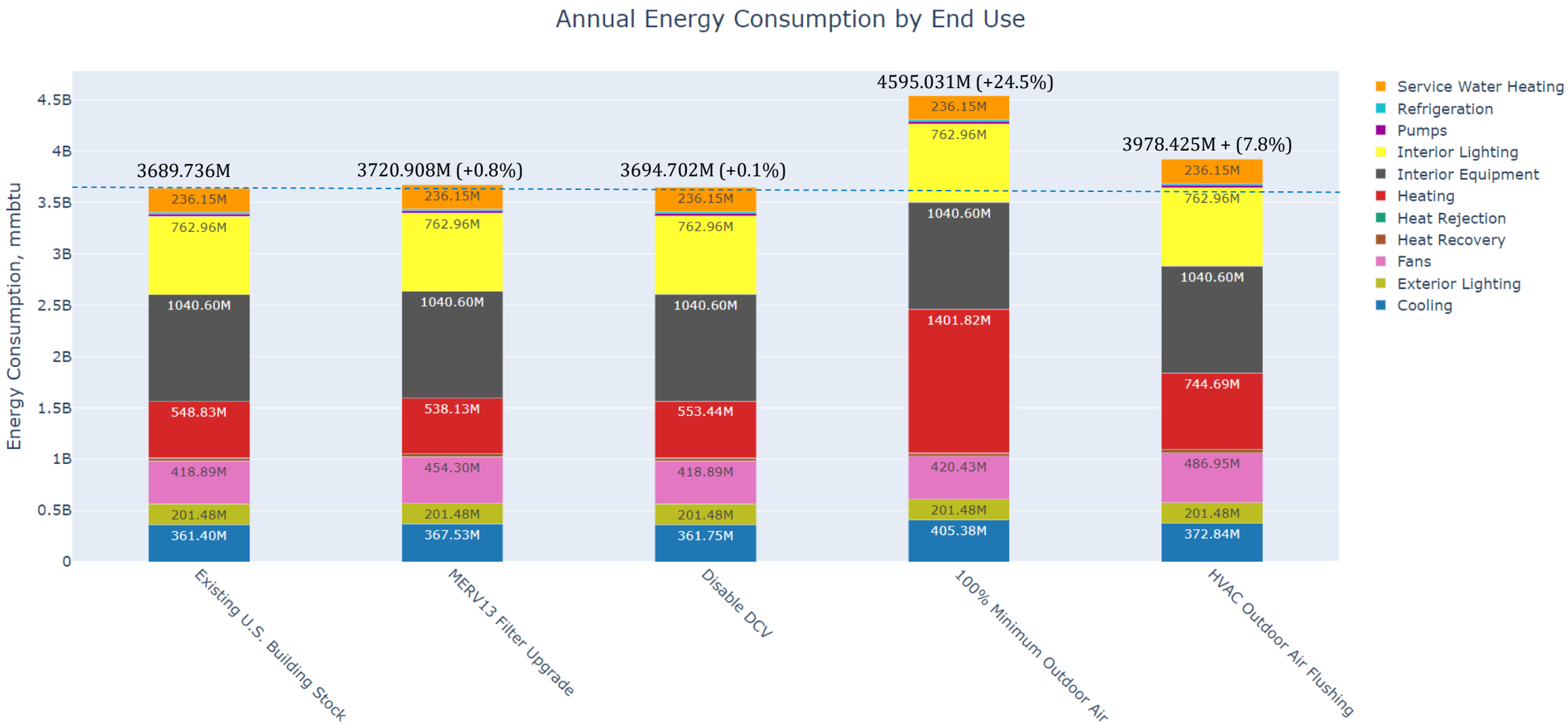
Description: Flush the building pre- and post-occupancy for a period of 2 hours at a rate of at least 3 air changes per hour (ACH) of outdoor air.

ComStock Implementation & Assumptions:

- Applicable to buildings that constitute about 77% of total building stock by area.
- Flush period applied to VAV, CAV, and DOAS air delivery units, excluding PIUs, during applicable times at a calculated rate of at least 3 ACH of outdoor air or maximum possible.
- Does not affect zone terminal equipment (i.e., PTACs, unit heaters, etc.).
- Only implemented in air handlers that serve zones with people.
- Equipment sizing to remain consistent with base run.

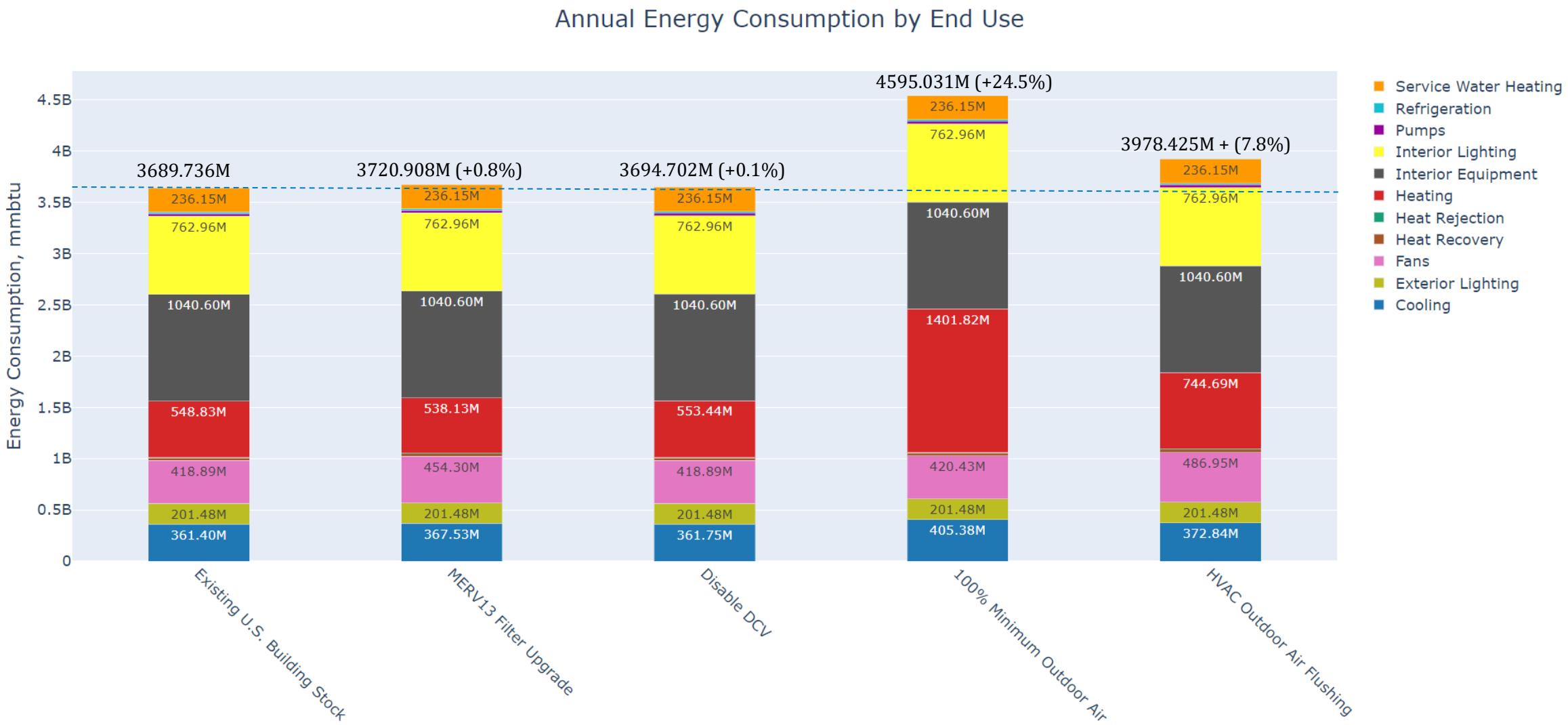
Aggregate Results

Aggregate Results: Energy by End Use



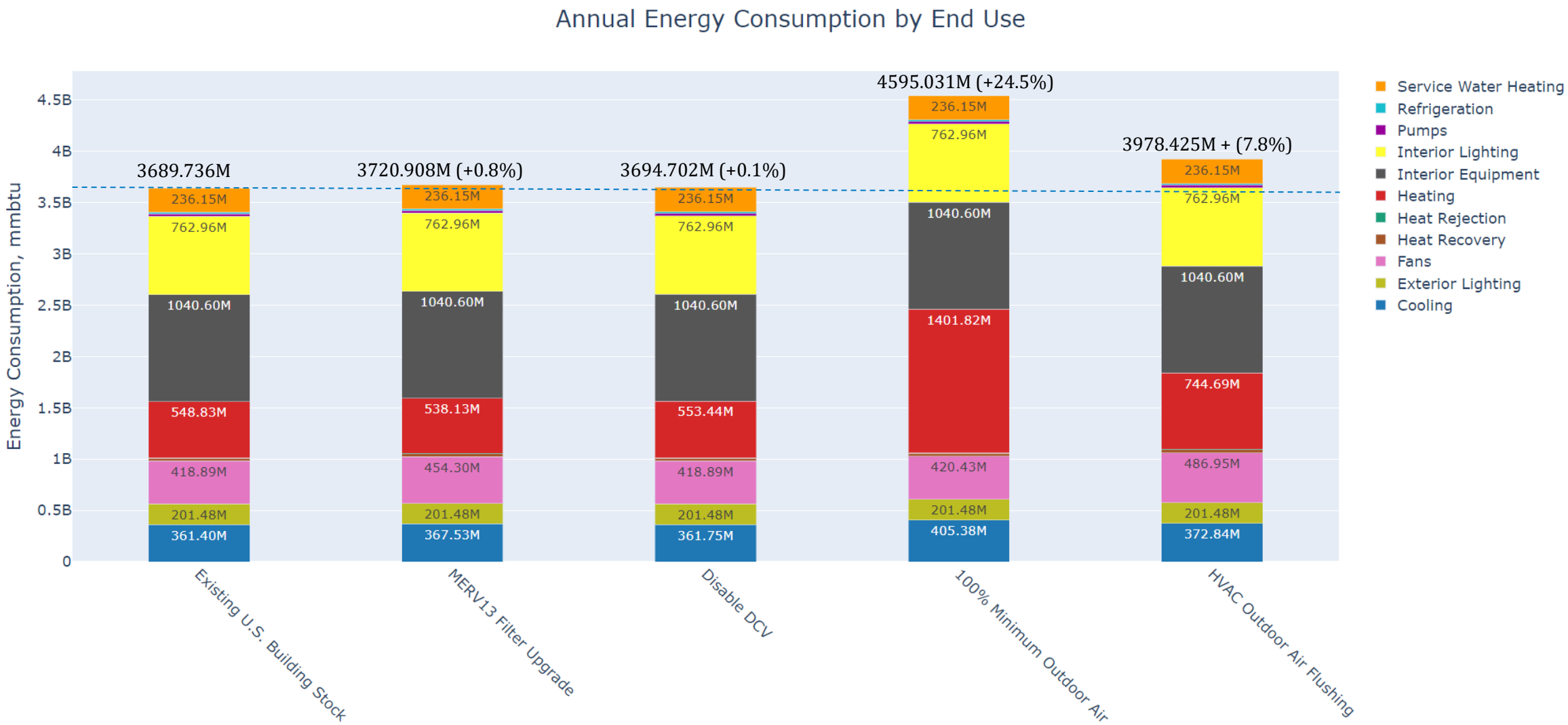
MERV13: Small increase in fan energy due to increased static pressure drop. Small increase in cooling energy and decrease in heating energy due to additional fan waste heat in air stream.

Aggregate Results: Energy by End Use



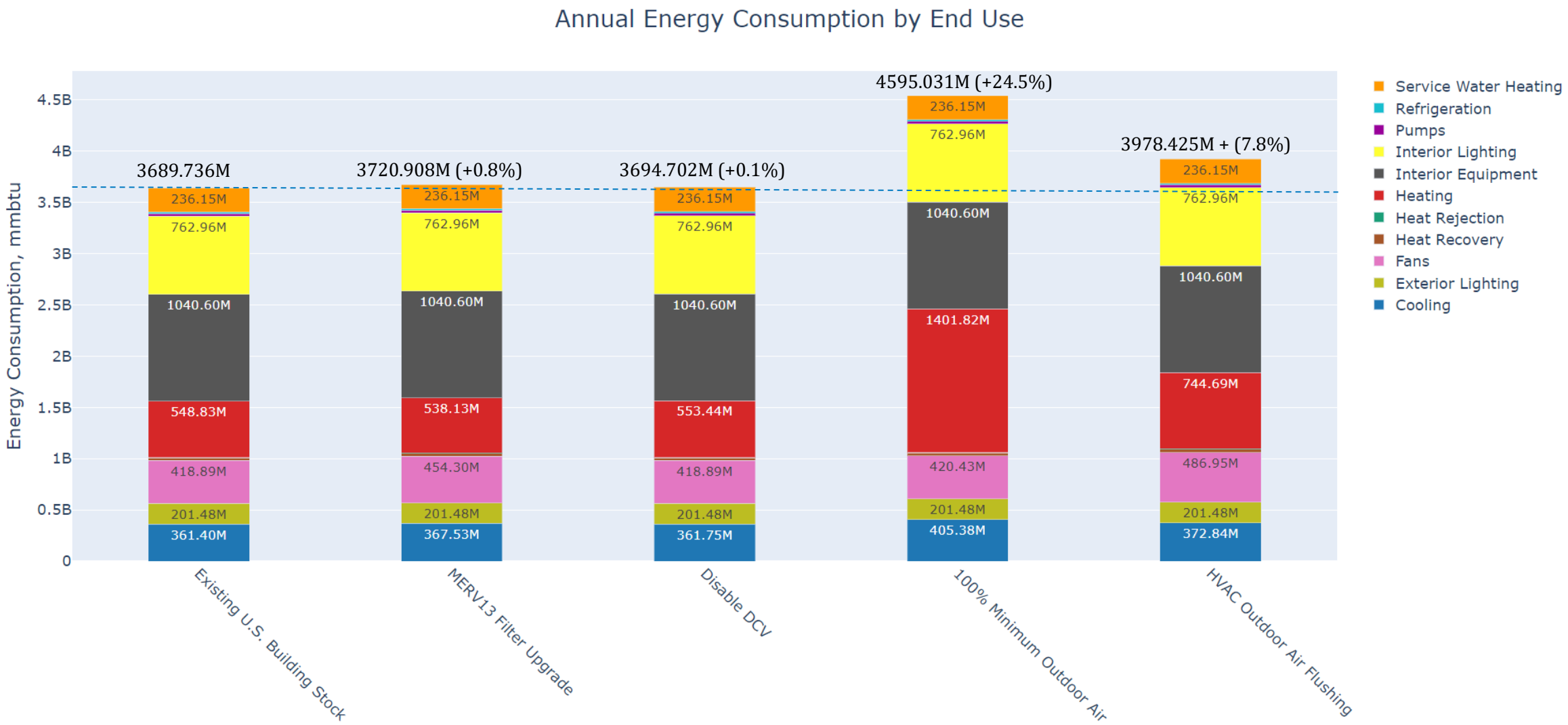
Disable DCV: Minimal impact overall due to low saturation of DCV in the existing building stock. Small increase in heating and cooling energy.

Aggregate Results: Energy by End Use



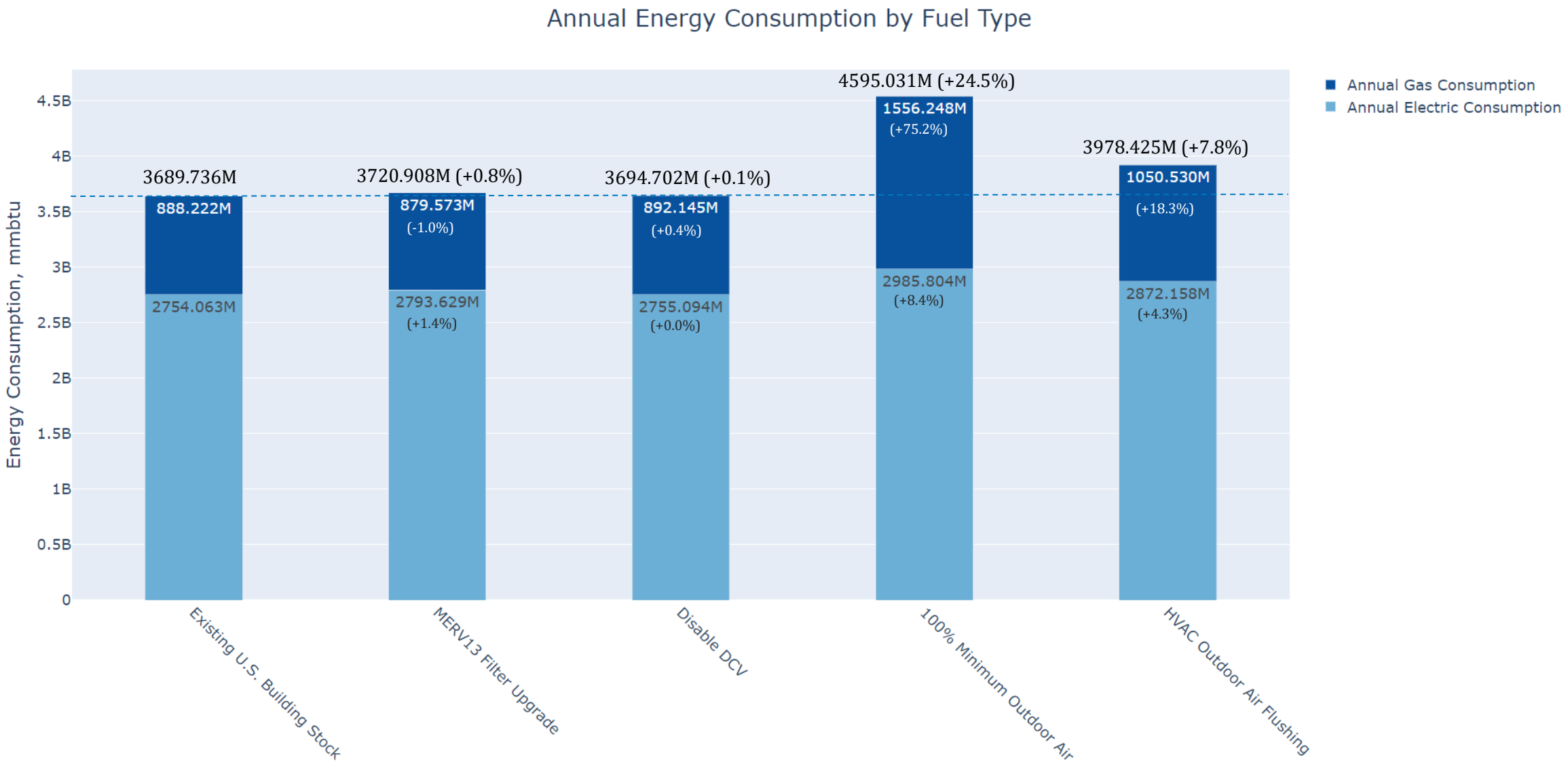
100% Minimum Outdoor Air: Large increase in heating energy and cooling energy due to increased outdoor air requiring conditioning. Heating increase is larger than cooling increase due to the increased temperature delta of outdoor versus indoor air in the heating season versus the cooling season.

Aggregate Results: Energy by End Use



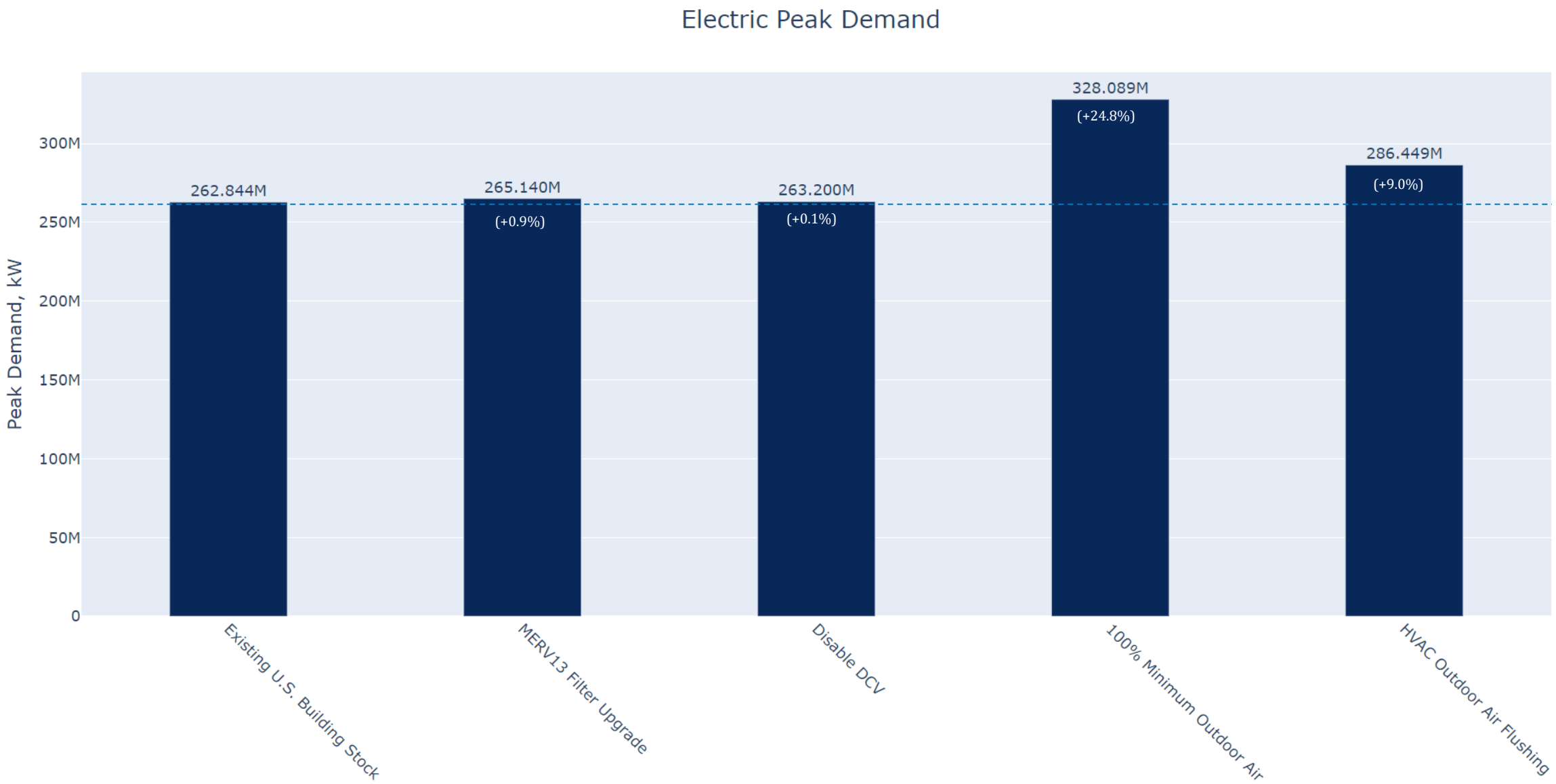
HVAC Flushing: Moderate increase in heating and cooling energy due to increased outdoor air during flush periods which requires additional conditioning. Fan increase is larger than other strategies because the operation hours in which the fan operates is extended.

Aggregate Results: Energy by Fuel Type



The 100% minimum outdoor air strategy is the most impactful to both fuel types, with gas being impacted to a greater extent.

Aggregate Results: Electric Peak Demand (non-coincident)



The 100% minimum outdoor air strategy results in the largest impact on non-coincident peak electric demand.

Temp & Humidity Building-Weighted Bin Concept

- Each hour, a building-area-weighted average temperature or humidity value is determined for the building based on each zone's area, thermostat/humidity set point, and actual temperature/humidity.

  Example:

  Hourly Value = ∑(abs(zone set point - zone temp)*(zone area)) / (building area)

  Zone 1 set point = 70 °F; Zone 1 temp = 67 °F; Zone 1 area = 300 sf

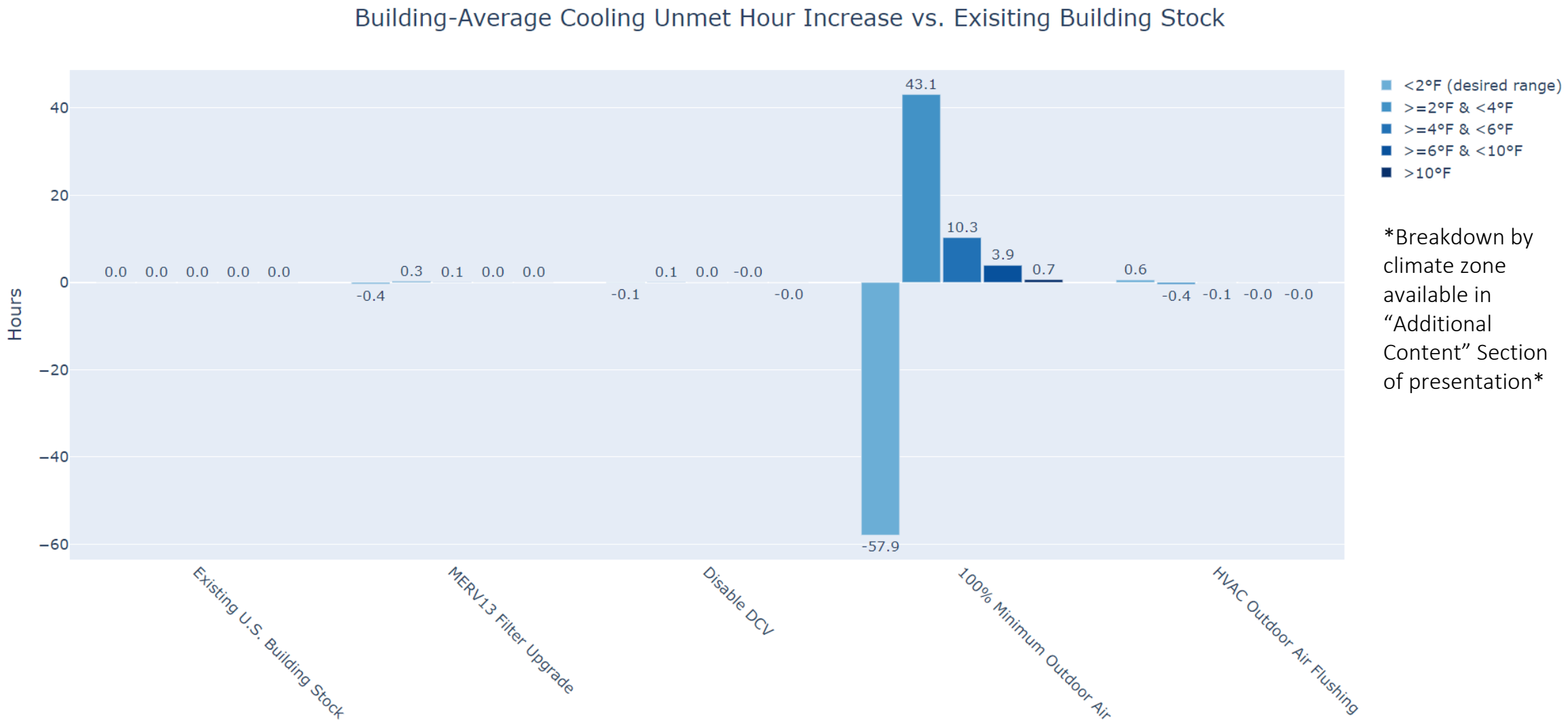
  Zone 2 set point = 70 °F; Zone 2 temp = 65 °F; Zone 2 area = 400 sf

  Hourly Value (heating) = ((70 °F – 67 °F) * (300 sf) + (70 °F – 65 °F) * (100 sf)) / (400 sf)

  Hourly Value (heating) = 3.5 °F = weighted average unmet hour temperature for that hour.

- For analyzing these results over the entire building stock, an equivalent average unmet hour per building was determined by dividing the total number of unmet hours in a bin by the total (scaled) number of buildings used to represent the U.S. building stock.

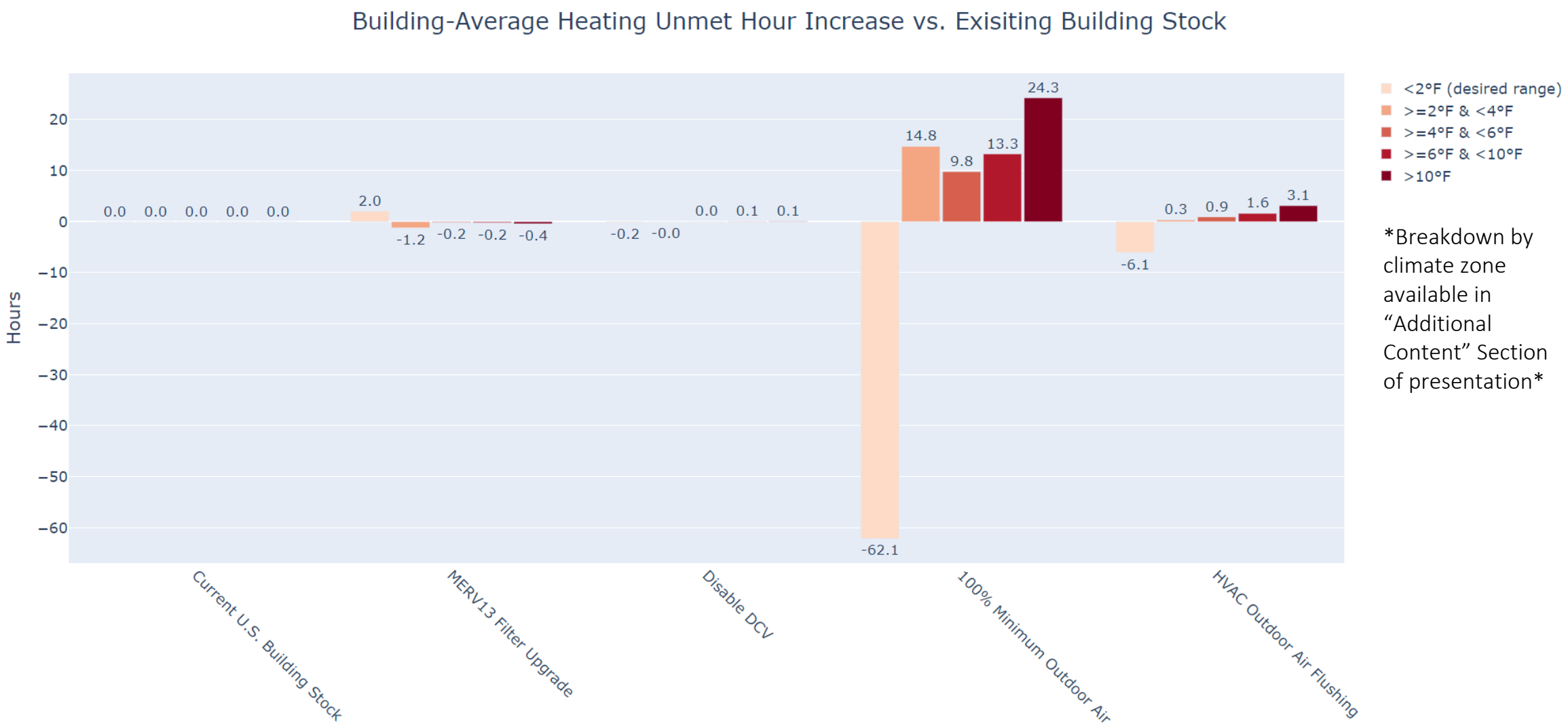
Aggregate Results: Indoor Temperature Conditions



Breakdown by climate zone available in "Additional Content" Section of presentation

100% minimum outdoor air shows the largest increase in unmet hours being shifted to higher violation bins. 57.9 hours were moved from the <2 °F bin to the higher violation bins, on average per building.

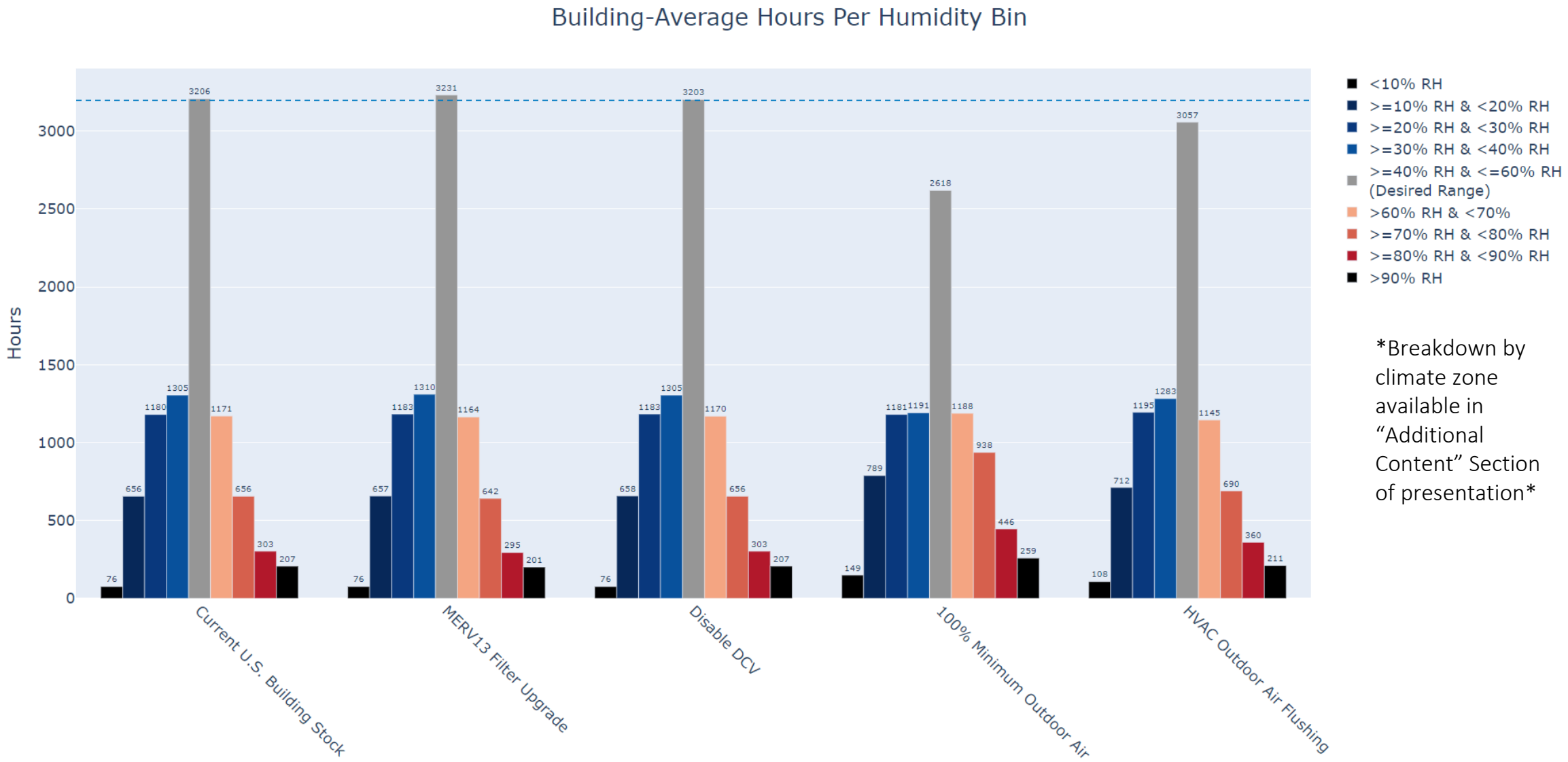
Aggregate Results: Indoor Temperature Conditions



Breakdown by climate zone available in "Additional Content" Section of presentation

100% minimum outdoor air shows the largest increases in unmet hours being shifted to higher violation bins. 62.1 hours were moved from the <2 °F bin to the higher violation bins, on average per building. 24.3 hours per building, on average, are seeing severe (>10 °F) violations annually.

Aggregate Results: Indoor Humidity Conditions



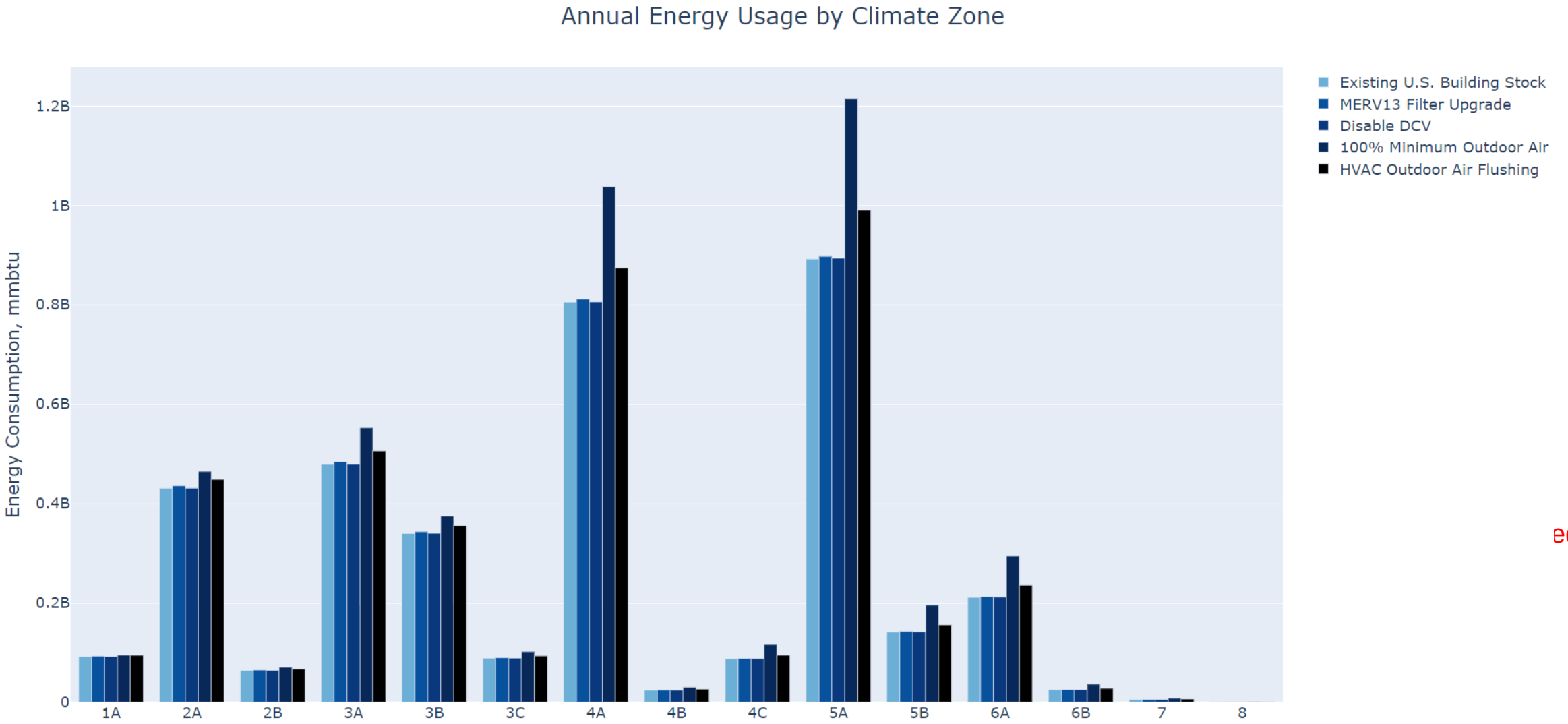
Breakdown by climate zone available in "Additional Content" Section of presentation

All strategies and the existing building stock show hours outside of the recommended humidity range, on average per building. The 100% outdoor air strategy shows the largest shift in hours out of the recommended humidity range to violation bins.

Results By Climate Zone*

*Climate zone reference map can be found in the “Additional Content” section of this document.

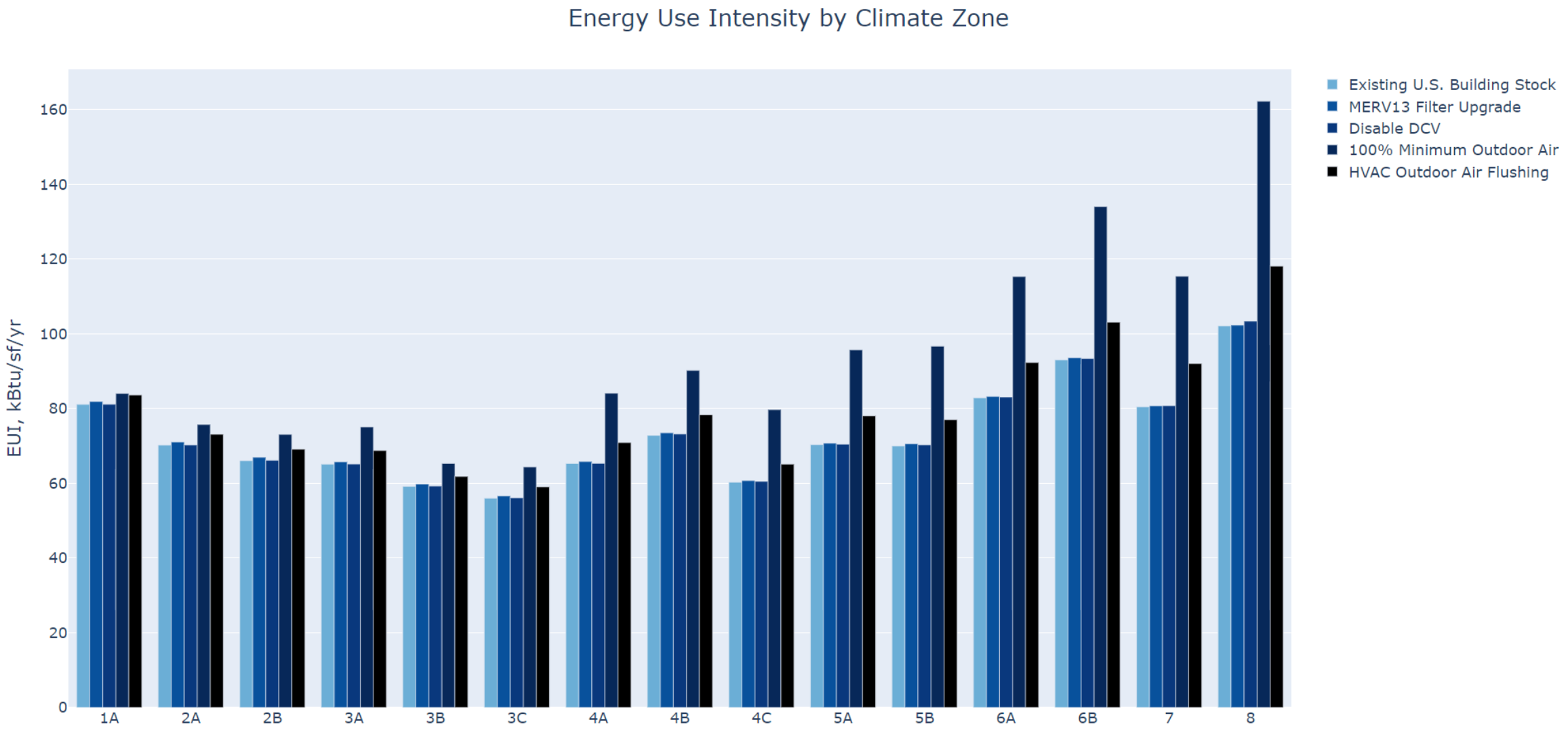
Results by Climate Zone: Total Energy Consumption



ed

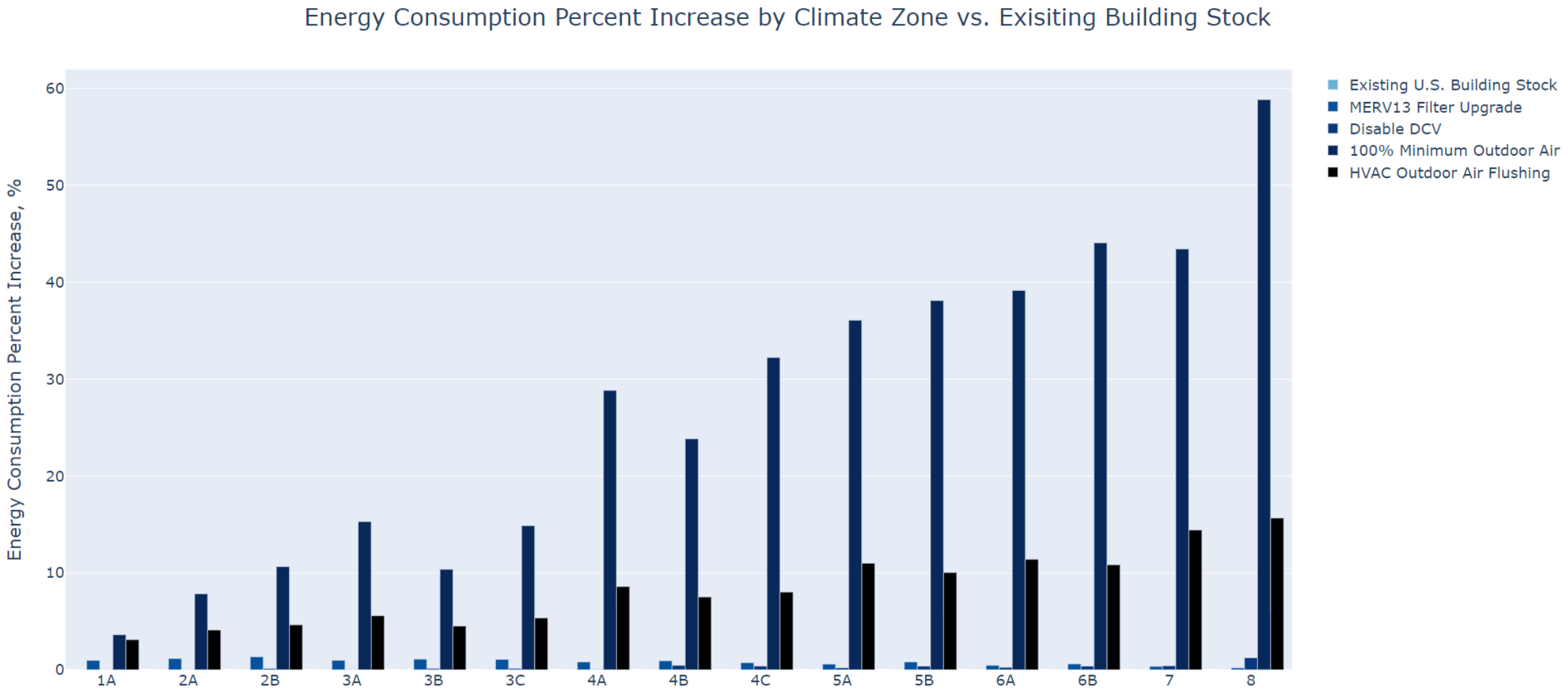
Some climate zones use more energy than others because the total area of buildings per zone varies (as well as differences in weather)—climate zones with higher total building area, and consequently increased energy consumption, typically see larger increases in energy usage as a result of these strategies.

Results by Climate Zone: Energy Use Intensity



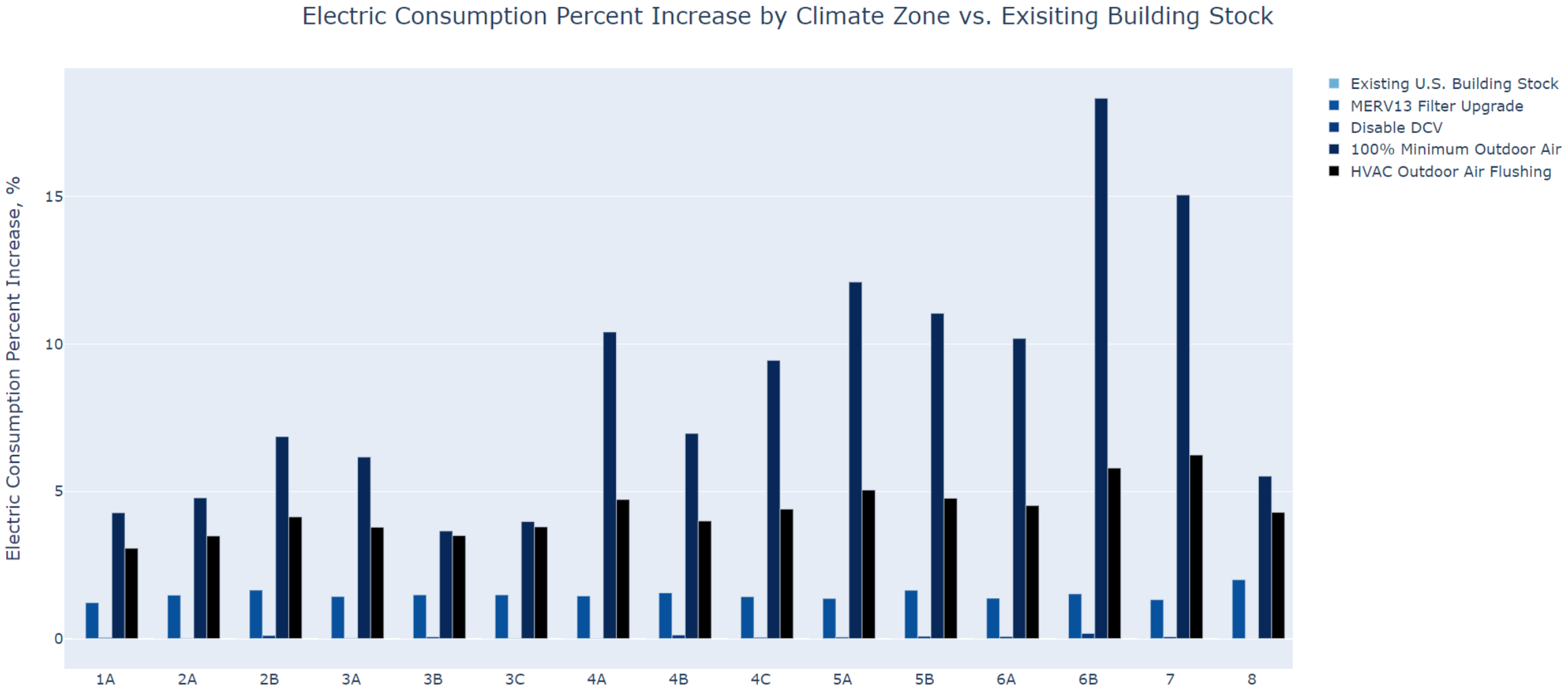
Normalized per sf, colder climate zones show greater increases in energy consumption as a result of the increased ventilation strategies due to the higher heating loads in these climate zones.

Results by Climate Zone: Total Energy % Increase



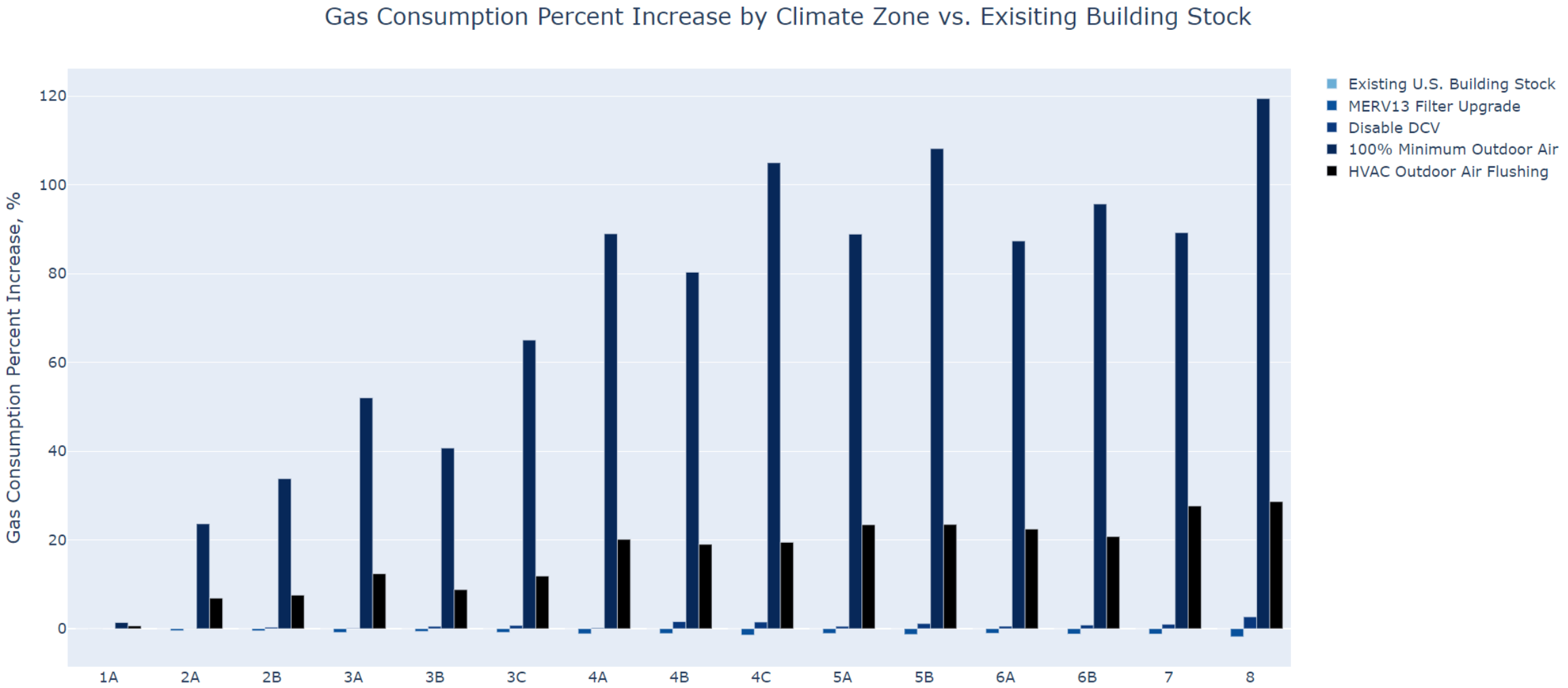
Colder climate zones generally show a higher energy percent increase compared to warmer climate zones for the increased ventilation strategies due to the increased heating load. 100% outdoor air shows the largest percent increase in total energy usage, exceeding 50% in some cases.

Results by Climate Zone: Electric % Increase



Electric increases for the 100% minimum outdoor air strategy are generally higher in colder climate zones due to the increased heating load, but this trend is more sporadic due to differing saturations of gas versus electric heat between climate zones. The electric increases from the HVAC outdoor air flushing strategy are more consistent across climate zones since increased fan energy is a key contributor to this strategy, which wouldn't see as much climate zone variation.

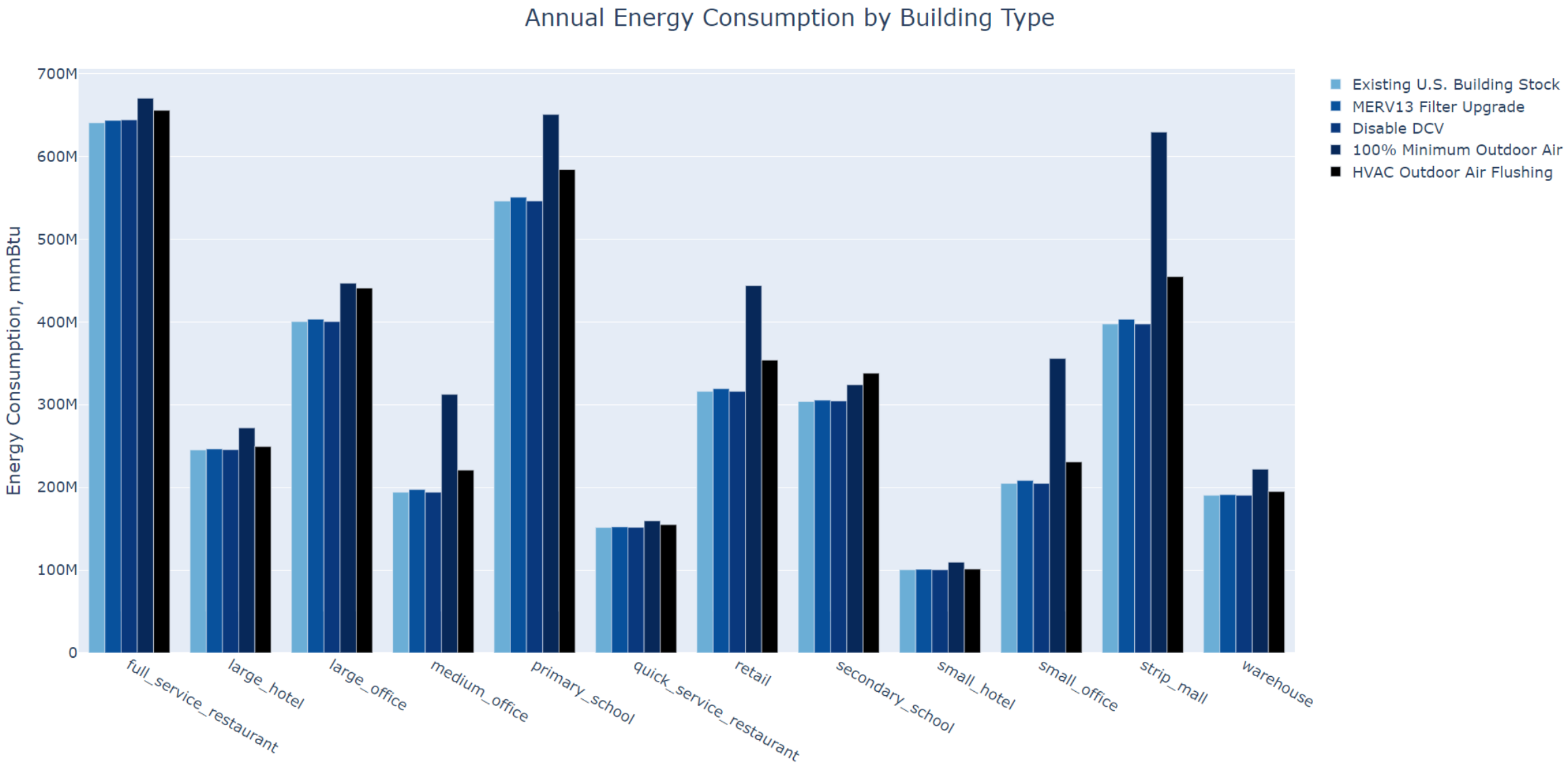
Results by Climate Zone: Gas % Increase



Gas increases from the ventilation strategies are generally higher in colder climate zones due to increased heating load and prevalence of gas-heated systems. Variations in distributions of building types and HVAC system types in a climate zone can skew this trend. The MERV13 filter strategy shows gas savings due to the increased fan heat added to the airstream.

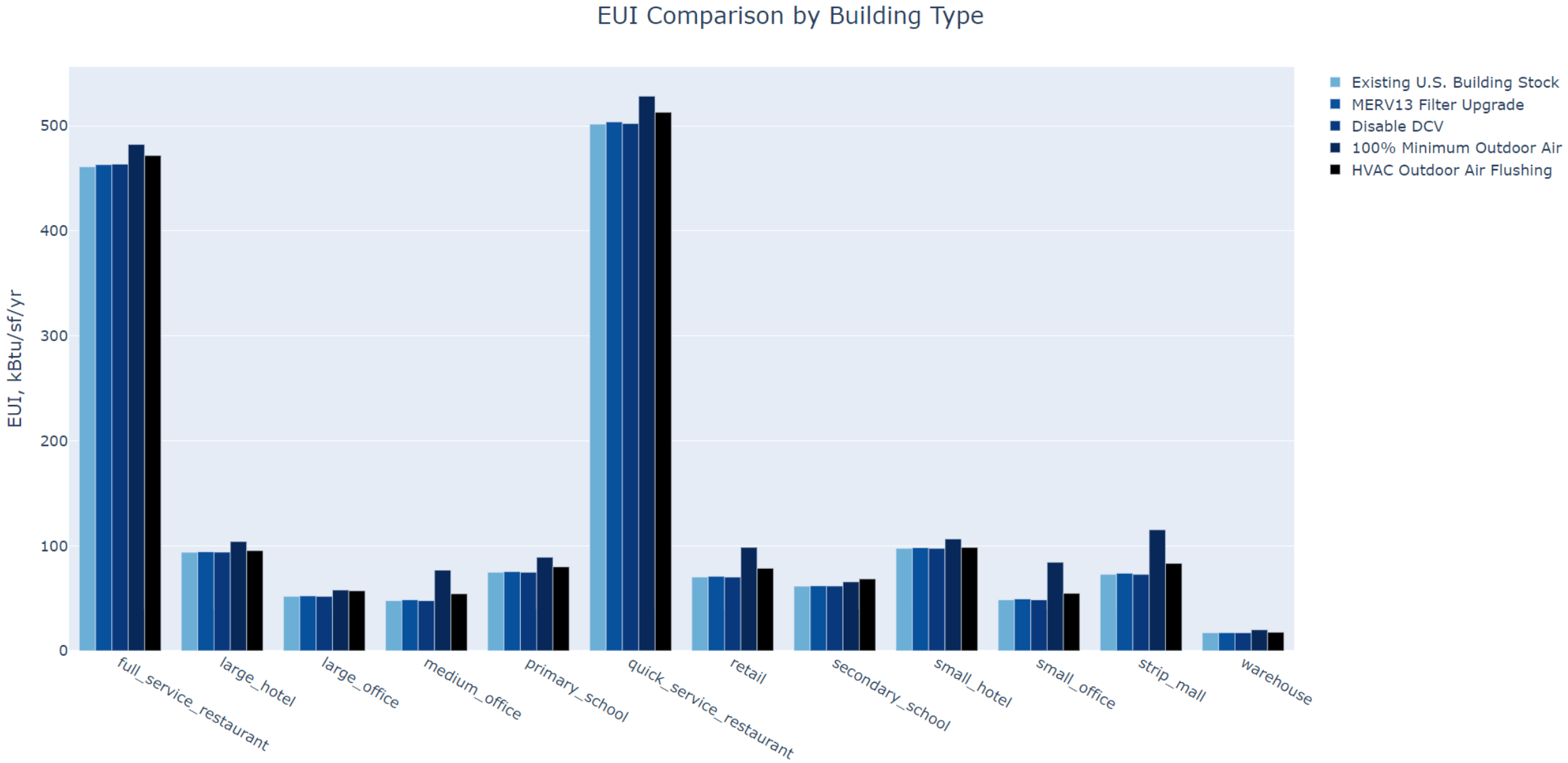
Results By Building Type

Results by Building Type: Total Energy Consumption



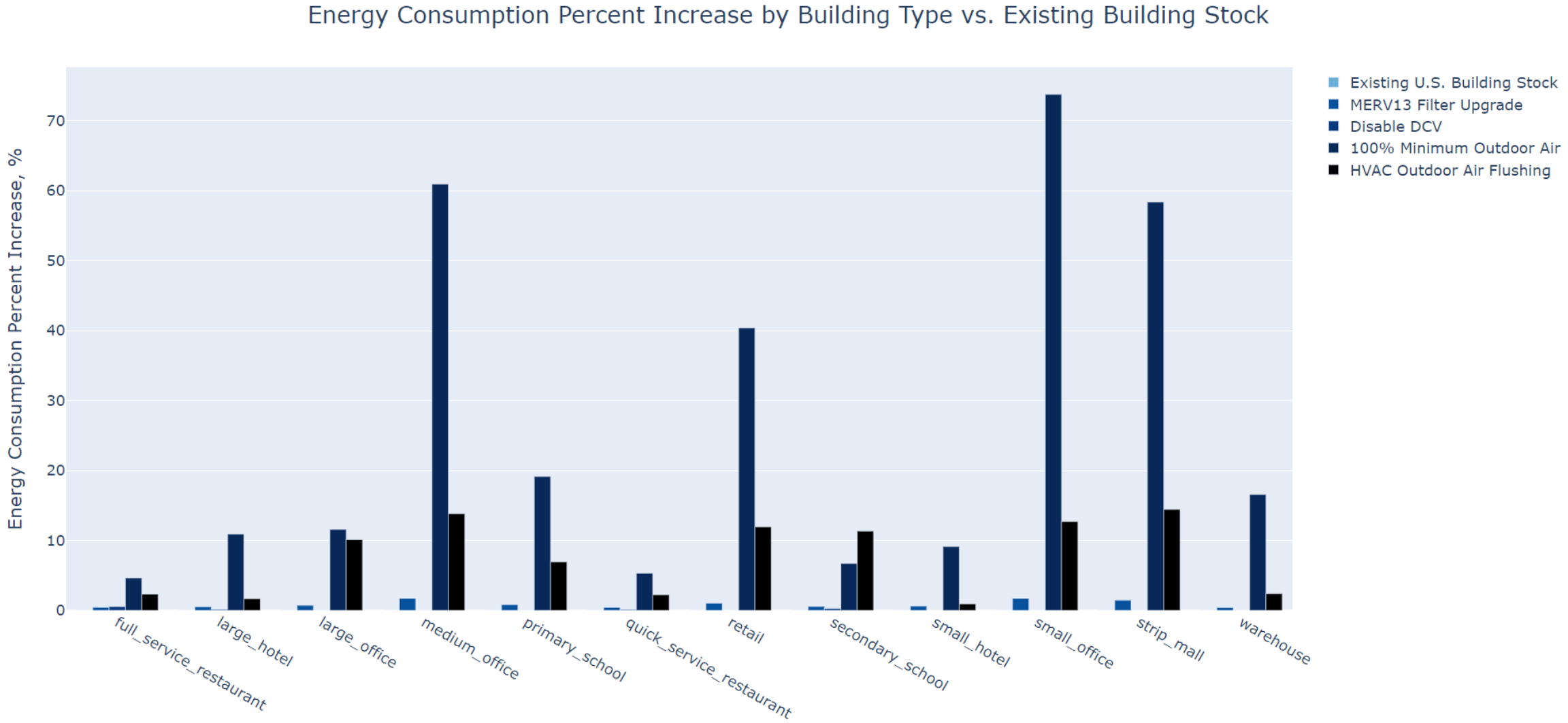
Some building types use more energy than others due to differences in square footage contributions to the total stock, as well as differences in energy as a result of the building's primary activity use. Increases in energy usage as a result of COVID-19 strategies are not necessarily proportional to total energy usage between building types due to differences in system types, loads, schedules, base ventilation rates, etc.

Results by Building Type: Energy Use Intensity



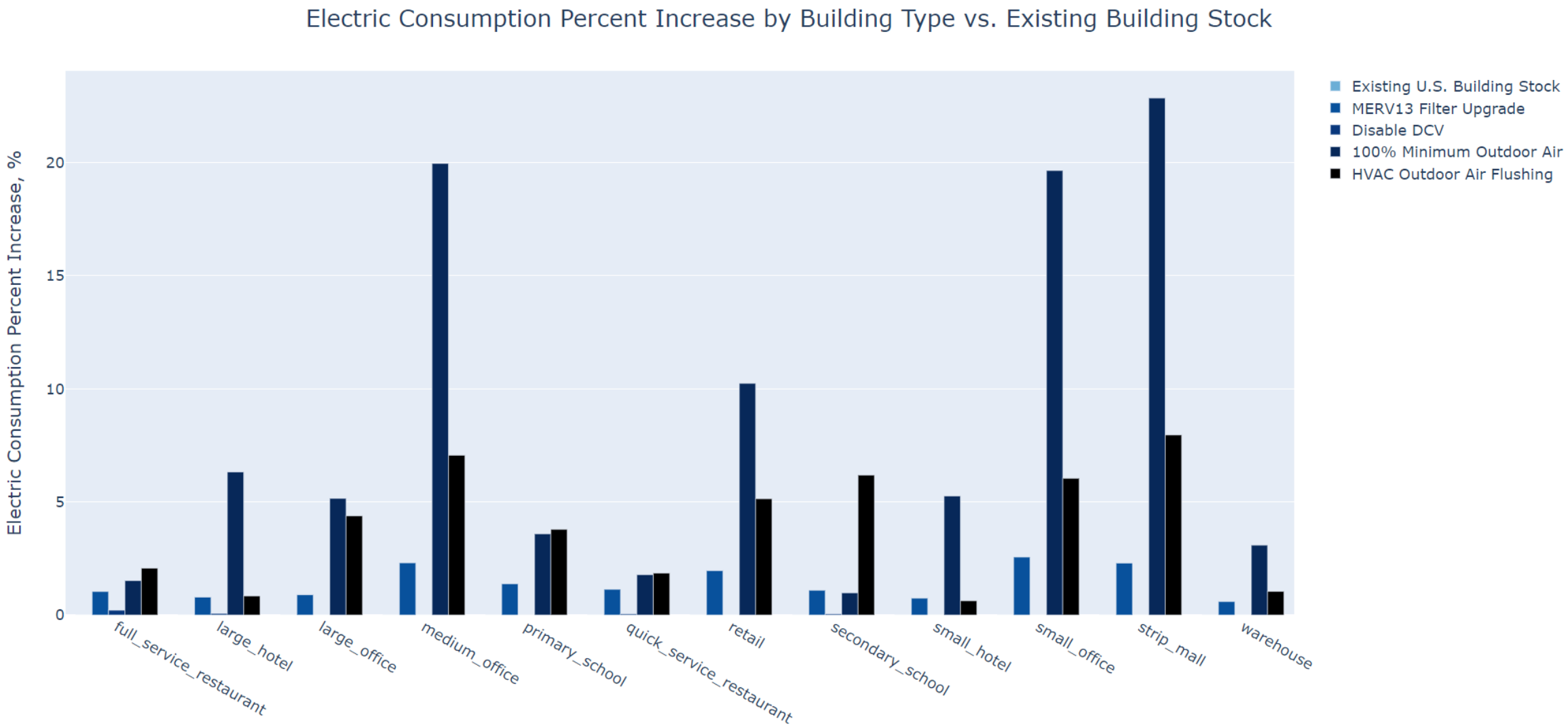
Normalized per square foot, some building types show more energy usage compared to others due to differences in the primary building activity. The energy impacts of the COVID-19 strategies are correlated to the building type characteristics and occupant behavior.

Results by Building Type: Total Energy % Increase



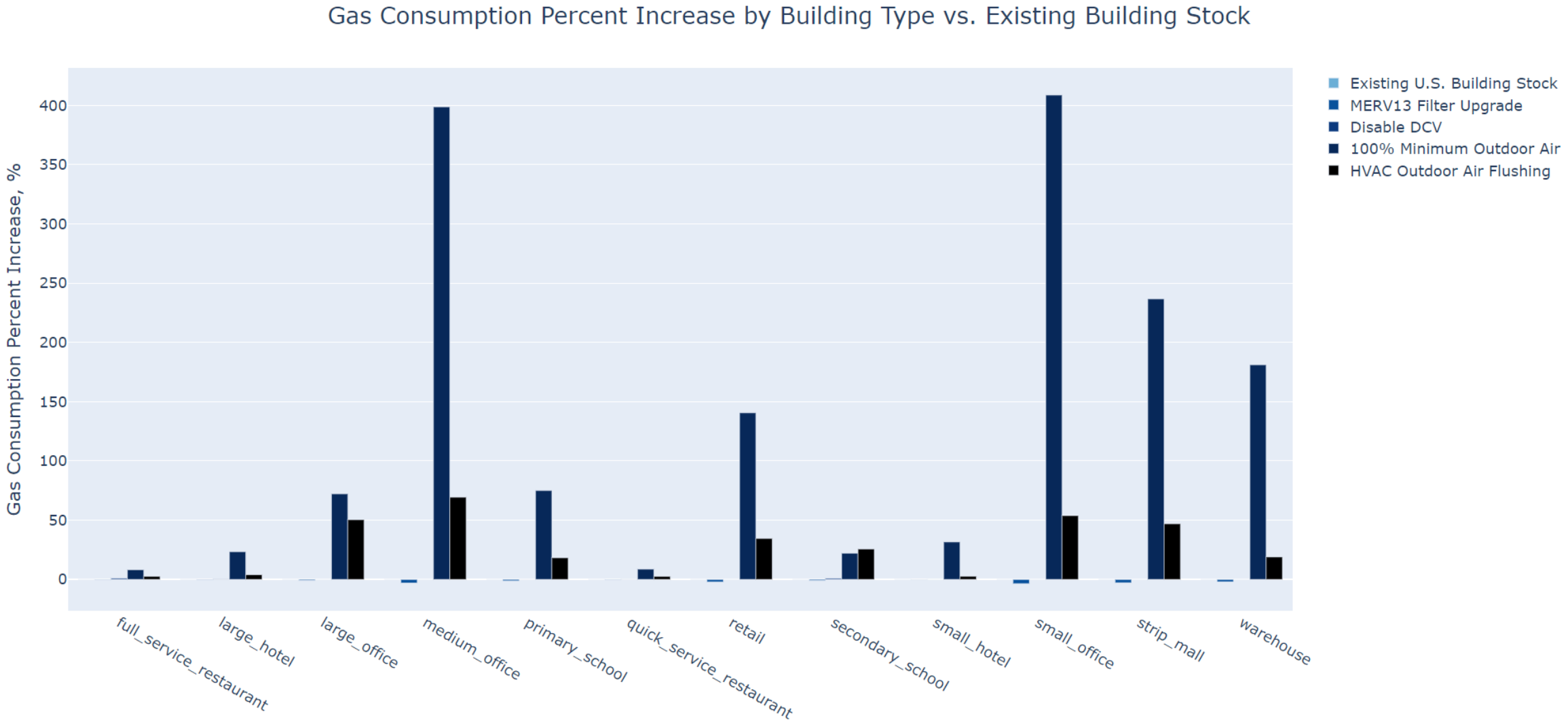
Food service building types are less impacted by the 100% minimum outdoor air strategy due to their already-high outdoor air ventilation fractions, and because much of their load is driven by process equipment (cooking, refrigeration, etc.). Large offices see less impact from the 100% minimum outdoor air strategy compared to small and medium offices in part from differences in applicable HVAC system types for this strategy.

Results by Building Type: Electric % Increase



The impact of the HVAC outdoor air flushing measure can be greater than the impact of the 100% outdoor air measure for some building types. This could be caused by building types having higher default outdoor air fractions (this decreases the impact of raising the minimum outdoor air to 100%), having higher fan power (this increases the impact of increased fan operation hours), and higher equipment/lighting loads (this weighs down the percent increase).

Results by Building Type: Gas % Increase



The 100% minimum outdoor air strategy causes large gas usage increases for several building types. Some factors that can impact these increases are high saturations of applicable HVAC systems types, low design outdoor air fractions, and low usage of other gas equipment in the building. Gas percent increases are higher than electric increases for this strategy because it predominately impacts heating, and heating makes up the majority of gas usage in commercial buildings, whereas electricity is weighed down by several other unaffected end uses.

Q & A

Submit Questions
www.slido.com event code **#DOE**

U.S. DEPARTMENT OF ENERGY

Additional Resources

- COVID-19 Resource Center
  - https://betterbuildingssolutioncenter.energy.gov/covid19
- HVAC Resource Map
  - https://hvacresourcemap.net
- ASHRAE COVID-19 Resources
  - ashrae.org/covid19

Next Webinar in the COVID-19 Webinar Series

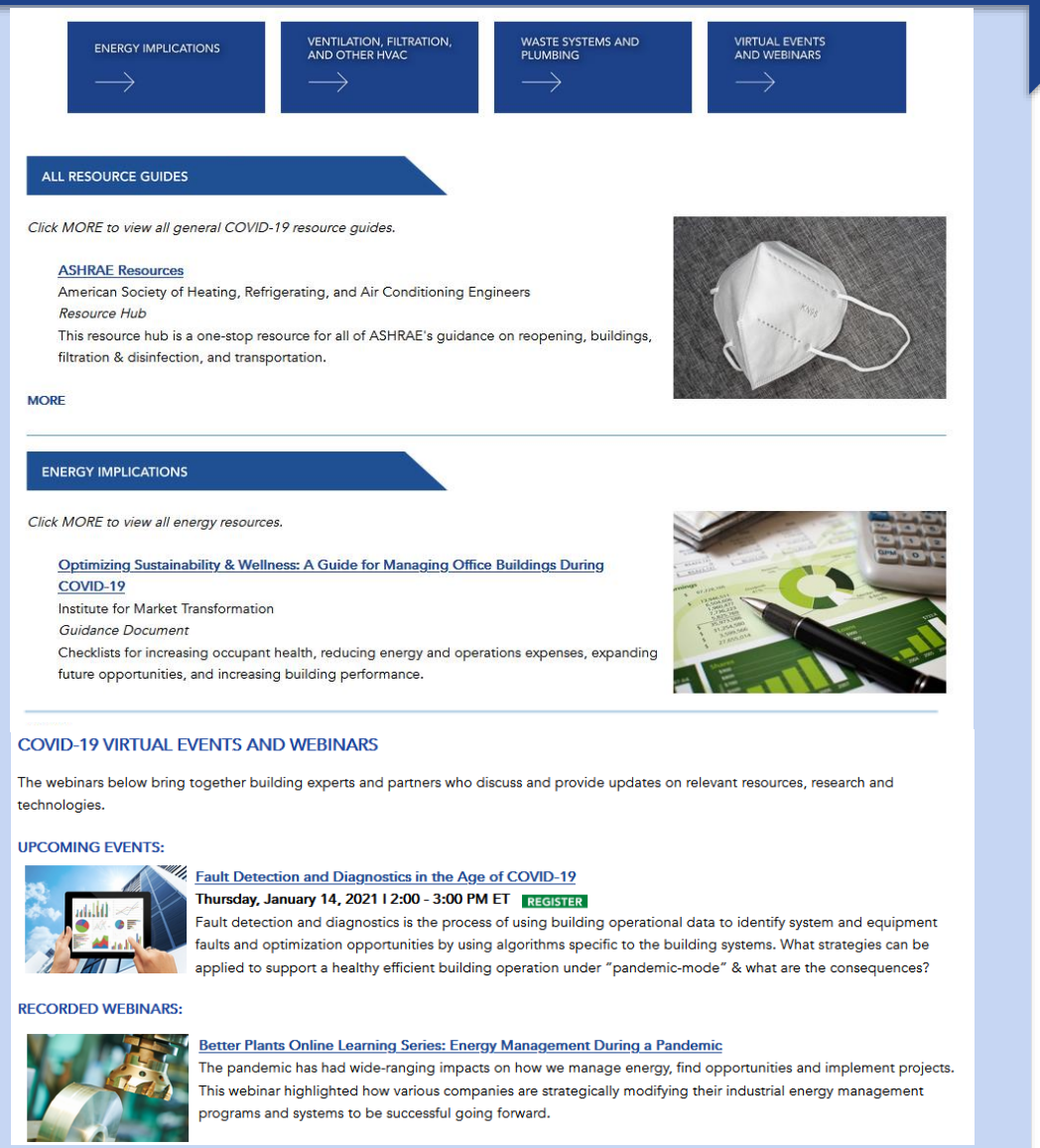
Bipolar Ionization

Monday, March 22, 2021 | 1:00 – 2:00 PM ET

Speakers and details coming soon!

Registration Opening Soon

COVID-19 Resource Center



ENERGY IMPLICATIONS

VENTILATION, FILTRATION, AND OTHER HVAC

WASTE SYSTEMS AND PLUMBING

VIRTUAL EVENTS AND WEBINARS

ALL RESOURCE GUIDES

Click MORE to view all general COVID-19 resource guides.

ASHRAE Resources
American Society of Heating, Refrigerating, and Air Conditioning Engineers
Resource Hub
This resource hub is a one-stop resource for all of ASHRAE's guidance on reopening, buildings, filtration & disinfection, and transportation.

MORE

ENERGY IMPLICATIONS

Click MORE to view all energy resources.

Optimizing Sustainability & Wellness: A Guide for Managing Office Buildings During COVID-19
Institute for Market Transformation
Guidance Document
Checklists for increasing occupant health, reducing energy and operations expenses, expanding future opportunities, and increasing building performance.

COVID-19 VIRTUAL EVENTS AND WEBINARS

The webinars below bring together building experts and partners who discuss and provide updates on relevant resources, research and technologies.

UPCOMING EVENTS:

Fault Detection and Diagnostics in the Age of COVID-19
Thursday, January 14, 2021 I 2:00 - 3:00 PM ET REGISTER
Fault detection and diagnostics is the process of using building operational data to identify system and equipment faults and optimization opportunities by using algorithms specific to the building systems. What strategies can be applied to support a healthy efficient building operation under "pandemic-mode" & what are the consequences?

RECORDED WEBINARS:

Better Plants Online Learning Series: Energy Management During a Pandemic
The pandemic has had wide-ranging impacts on how we manage energy, find opportunities and implement projects. This webinar highlighted how various companies are strategically modifying their industrial energy management programs and systems to be successful going forward.

Explore COVID-19 Resources today.

- **Learn from the experts** with resources from ASHRAE, EPA, DOE, and more…
- **View resources** grouped by technology type
- **Watch webinars** & register for upcoming virtual learning opportunities

Learn more at: https://betterbuildingssolutioncenter.energy.gov/covid19

MAY
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Additional Content

Increase by Better Buildings Sector: Hospitality

Includes DOE Prototype Buildings: Large hotel and small hotel.

Metric	MERV13 Filter Upgrade	Disable DCV	100% Minimum Outdoor Air	HVAC Outdoor Air Flushing
Energy Consumption [Units: Million MMBtu (1012 Btu)]	2.049	0.128	15.809	2.043
Electric Consumption [Units: Million MMBtu (1012 Btu]	2.049	0.128	15.809	2.043
Gas Consumption [Units: Million MMBtu (1012 Btu)]	(0.174)	0.192	18.403	2.730
Peak Electric [Units: GW]	0.072	0.023	3.528	0.867

Increase by Better Buildings Sector: Retail

Includes DOE Prototype Buildings: Retail and strip mall.

Metric	MERV13 Filter Upgrade	Disable DCV	100% Minimum Outdoor Air	HVAC Outdoor Air Flushing
Energy Consumption [Units: Million MMBtu (1012 Btu)]	9.029	-	359.525	95.093
Electric Consumption [Units: Million MMBtu (1012 Btu]	12.356	-	100.499	38.822
Gas Consumption [Units: Million MMBtu (1012 Btu)]	(3.336)	-	258.955	56.244
Peak Electric [Units: GW]	0.591	-	20.755	15.714

Increase by Better Buildings Sector: Commercial Office Spaces

Includes DOE Prototype Buildings: Large office, medium office, and small office.

Metric	MERV13 Filter Upgrade	Disable DCV	100% Minimum Outdoor Air	HVAC Outdoor Air Flushing
Energy Consumption [Units: Million MMBtu (1012 Btu)]	9.743	-	315.691	93.338
Electric Consumption [Units: Million MMBtu (1012 Btu]	11.461	-	86.060	37.388
Gas Consumption [Units: Million MMBtu (1012 Btu)]	(1.886)	-	226.324	48.150
Peak Electric [Units: GW]	0.785	-	26.859	5.966

Percent Increase by Better Buildings Sector: Hospitality

Includes DOE Prototype Buildings: Large hotel and small hotel.

Metric	MERV13 Filter Upgrade	Disable DCV	100% Minimum Outdoor Air	HVAC Outdoor Air Flushing
Energy Consumption [Units: Million MMBtu (1012 Btu)]	0.54%	0.09%	10.39%	1.45%
Electric Consumption [Units: Million MMBtu (1012 Btu]	0.78%	0.05%	5.98%	0.77%
Gas Consumption [Units: Million MMBtu (1012 Btu)]	-0.24%	0.26%	25.01%	3.71%
Peak Electric [Units: GW]	0.45%	0.14%	21.87%	5.37%

Percent Increase by Better Buildings Sector: Retail

Includes DOE Prototype Buildings: Retail and strip mall.

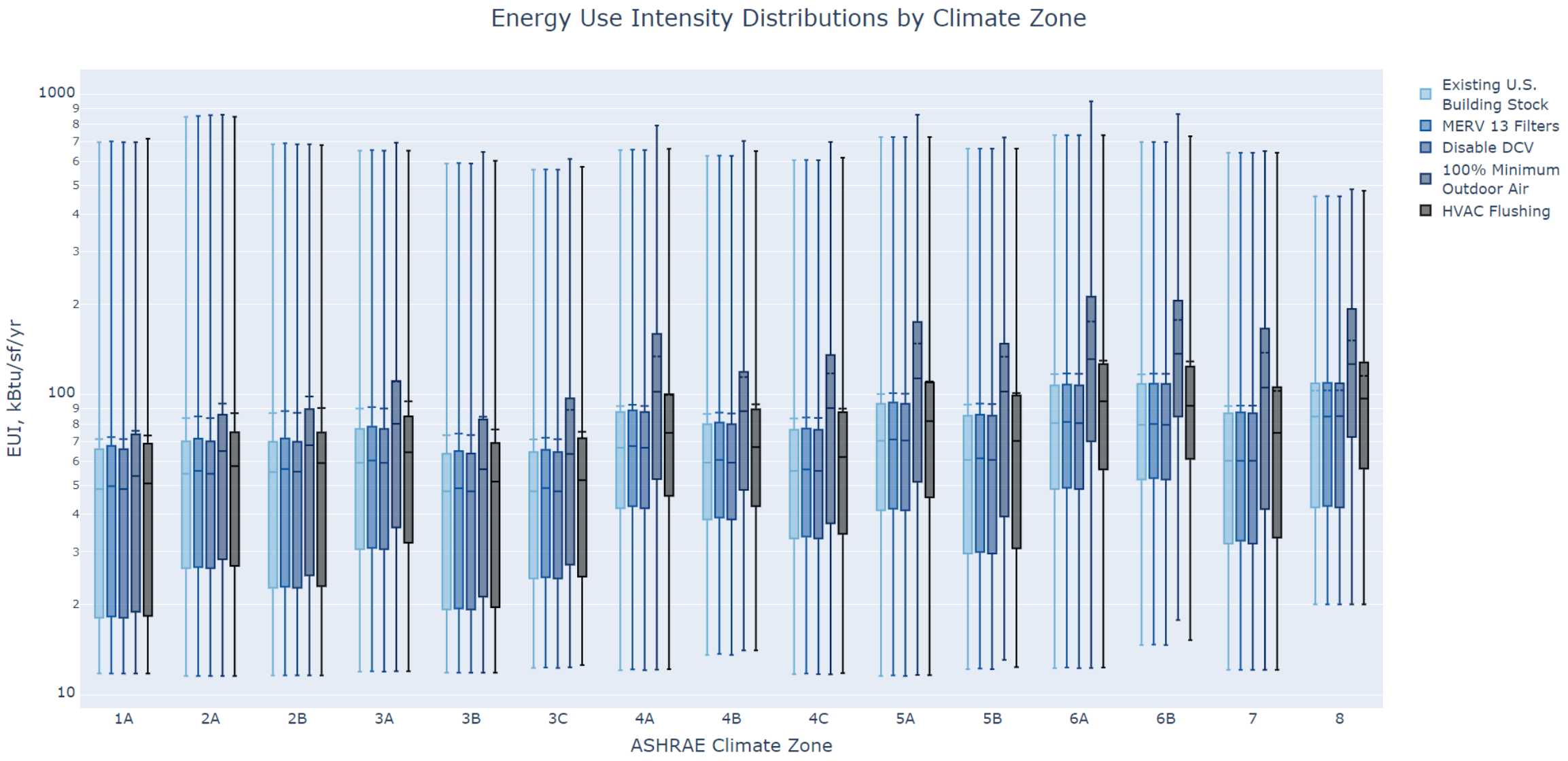
Metric	MERV13 Filter Upgrade	Disable DCV	100% Minimum Outdoor Air	HVAC Outdoor Air Flushing
Energy Consumption [Units: Million MMBtu (1012 Btu)]	1.27%	0.00%	50.41%	13.33%
Electric Consumption [Units: Million MMBtu (1012 Btu]	2.15%	0.00%	17.52%	6.77%
Gas Consumption [Units: Million MMBtu (1012 Btu)]	-2.40%	0.00%	186.24%	40.45%
Peak Electric [Units: GW]	1.01%	0.00%	35.52%	26.89%

Percent Increase by Better Buildings Sector: Commercial Office Spaces

Includes DOE Prototype Buildings: Large office, medium office, and small office.

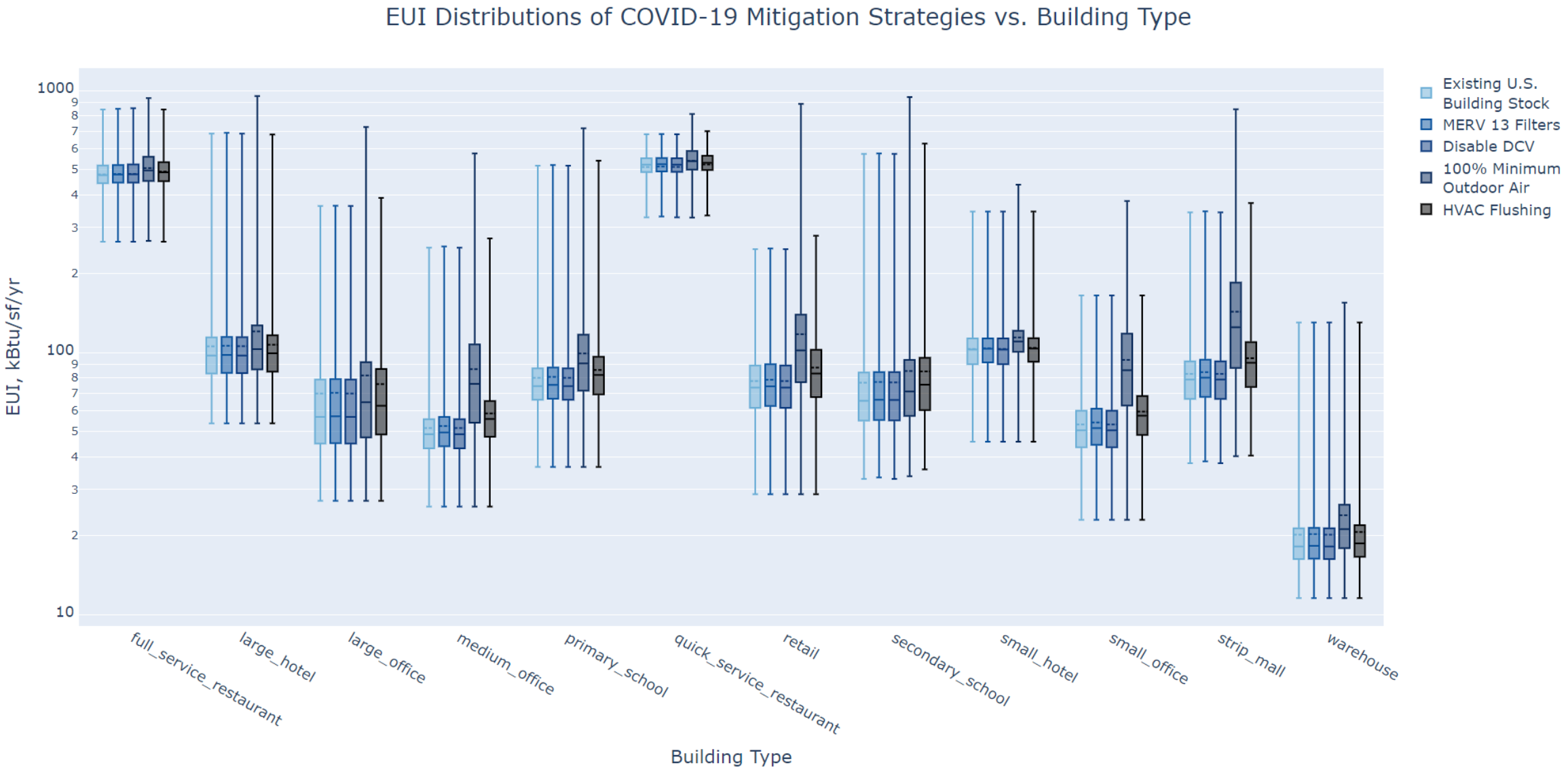
Metric	MERV13 Filter Upgrade	Disable DCV	100% Minimum Outdoor Air	HVAC Outdoor Air Flushing
Energy Consumption [Units: Million MMBtu (1012 Btu)]	-1.22%	0.00%	-39.51%	-11.68%
Electric Consumption [Units: Million MMBtu (1012 Btu]	1.68%	0.00%	12.63%	5.49%
Gas Consumption [Units: Million MMBtu (1012 Btu)]	-2.20%	0.00%	264.24%	56.22%
Peak Electric [Units: GW]	1.08%	0.00%	36.80%	8.17%

Results by Climate Zone: EUI Distributions



Log scale used on Y-Axes

Results by Building Type: EUI Distributions



Log scale used on Y-Axes

Results by Building Type: Energy Consumption

Building Type	Current U.S. Building Stock	MERV13 Filter Upgrade	Disable DCV	100% Minimum Outdoor Air	HVAC Outdoor Air Flushing
Full-Service Restaurant	640.468	643.294	643.995	670.082	655.416
Large Hotel	245.163	246.424	245.48	271.904	249.242
Large Office	400.214	403.099	400.214	446.582	440.704
Medium Office	194.055	197.395	194.055	312.323	220.886
Primary School	545.918	550.457	546.029	650.484	583.812
Quick Service Restaurant	151.591	152.244	151.769	159.64	154.981
Retail	315.971	319.229	315.971	443.589	353.713
Secondary School	303.559	305.298	304.389	323.962	337.992
Small Hotel	100.387	101.005	100.391	109.552	101.322
Small Office	204.771	208.289	204.771	355.826	230.788
Strip Mall	397.256	403.027	397.256	629.163	454.607
Warehouse	190.383	191.145	190.383	221.923	194.961
Total	3689.736	3720.908	3694.702	4595.031	3978.425

Units: Million MMBtu (10^{12} Btu)

Results by Building Type: Electric Consumption

Building Type	Current U.S. Building Stock	MERV13 Filter Upgrade	Disable DCV	100% Minimum Outdoor Air	HVAC Outdoor Air Flushing
Full-Service Restaurant	341.257	344.803	341.992	346.451	348.322
Large Hotel	178.832	180.245	178.957	190.143	180.338
Large Office	333.712	336.704	333.712	350.927	348.344
Medium Office	171.563	175.519	171.563	205.81	183.679
Primary School	426.491	432.387	426.515	441.795	442.634
Quick Service Restaurant	74.158	75	74.196	75.481	75.534
Retail	242.707	247.463	242.707	267.561	255.179
Secondary School	216.939	219.313	217.047	219.067	230.359
Small Hotel	85.496	86.132	85.499	89.994	86.033
Small Office	176.062	180.575	176.062	210.66	186.702
Strip Mall	331.027	338.627	331.027	406.672	357.377
Warehouse	175.818	176.86	175.818	181.244	177.656
Total	2754.063	2793.629	2755.094	2985.804	2872.158

Units: Million MMBtu (10^{12} Btu)

Results by Building Type: Gas Consumption

Building Type	Current U.S. Building Stock	MERV13 Filter Upgrade	Disable DCV	100% Minimum Outdoor Air	HVAC Outdoor Air Flushing
Full-Service Restaurant	298.17	297.439	300.957	322.567	306.011
Large Hotel	58.851	58.695	59.042	72.589	61.183
Large Office	36.158	35.898	36.158	62.269	54.384
Medium Office	21.011	20.384	21.011	104.802	35.589
Primary School	118.797	117.428	118.884	207.916	140.526
Quick Service Restaurant	77.377	77.187	77.518	84.103	79.391
Retail	73.07	71.569	73.07	175.817	98.332
Secondary School	81.179	80.496	81.895	99.171	102.041
Small Hotel	14.735	14.717	14.736	19.4	15.133
Small Office	28.482	27.483	28.482	144.904	43.828
Strip Mall	65.975	64.14	65.975	222.183	96.957
Warehouse	14.417	14.136	14.417	40.528	17.155
Total	888.222	879.573	892.145	1556.248	1050.53

Units: Million MMBtu (10^{12} Btu)

Results by Building Type: Peak Electric

Building Type	Current U.S. Building Stock	MERV13 Filter Upgrade	Disable DCV	100% Minimum Outdoor Air	HVAC Outdoor Air Flushing
Full-Service Restaurant	23.366	23.504	23.614	25.599	23.504
Large Hotel	11.444	11.494	11.467	13.476	11.983
Large Office	33.242	33.526	33.242	38.502	34.832
Medium Office	19.646	19.876	19.646	30.495	22.301
Primary School	45.117	45.527	45.138	53.017	45.532
Quick Service Restaurant	4.911	4.944	4.923	5.479	4.933
Retail	22.479	22.703	22.479	27.293	26.671
Secondary School	27.203	27.412	27.255	28.769	27.511
Small Hotel	4.689	4.711	4.689	6.185	5.017
Small Office	20.091	20.362	20.091	30.841	21.812
Strip Mall	35.96	36.327	35.96	51.901	47.482
Warehouse	14.696	14.754	14.696	16.532	14.873
Total	262.844	265.14	263.2	328.089	286.449

Units: GW

Results by Climate Zone: Energy Consumption

Climate Zone	Current U.S. Building Stock	MERV13 Filter Upgrade	Disable DCV	100% Minimum Outdoor Air	HVAC Outdoor Air Flushing
1A	91.913	92.802	91.941	95.238	94.769
2A	430.833	435.863	430.94	464.655	448.519
2B	64.038	64.901	64.126	70.858	67.009
3A	479.05	483.709	479.264	552.364	505.787
3B	339.816	343.564	340.306	375.054	355.17
3C	88.977	89.929	89.106	102.22	93.74
4A	805.094	811.686	805.54	1037.342	874.279
4B	24.762	24.994	24.877	30.67	26.624
4C	87.902	88.55	88.244	116.243	94.956
5A	892.202	897.459	894.008	1214.213	990.37
5B	141.63	142.791	142.168	195.619	155.846
6A	211.438	212.404	211.971	294.251	235.551
6B	25.488	25.642	25.586	36.724	28.252
7	5.798	5.818	5.822	8.317	6.635
8	0.795	0.796	0.805	1.263	0.919
Total	3689.736	3720.908	3694.702	4595.031	3978.425

Units: Million MMBtu (10^{12} Btu)

Results by Climate Zone: Electric Consumption

Climate Zone	Current U.S. Building Stock	MERV13 Filter Upgrade	Disable DCV	100% Minimum Outdoor Air	HVAC Outdoor Air Flushing
1A	72.435	73.319	72.462	75.529	74.656
2A	354.324	359.552	354.39	371.248	366.667
2B	54.825	55.728	54.882	58.585	57.089
3A	378.819	384.224	378.895	402.162	393.141
3B	275.734	279.827	275.893	285.807	285.377
3C	72.5	73.576	72.512	75.379	75.25
4A	601.63	610.342	601.716	664.257	630.033
4B	18.841	19.134	18.864	20.154	19.593
4C	66.595	67.543	66.622	72.885	69.521
5A	604.962	613.212	605.259	678.185	635.462
5B	101.427	103.094	101.505	112.629	106.259
6A	131.104	132.901	131.196	144.46	137.026
6B	16.875	17.131	16.905	19.971	17.852
7	3.575	3.622	3.578	4.114	3.798
8	0.416	0.424	0.416	0.438	0.433
Total	2754.063	2793.629	2755.094	2985.804	2872.158

Units: Million MMBtu (10^{12} Btu)

Results by Climate Zone: Gas Consumption

Climate Zone	Current U.S. Building Stock	MERV13 Filter Upgrade	Disable DCV	100% Minimum Outdoor Air	HVAC Outdoor Air Flushing
1A	16.555	16.55	16.556	16.786	16.658
2A	67.139	66.85	67.175	83.003	71.753
2B	9.027	8.985	9.058	12.08	9.71
3A	94.3	93.5	94.435	143.341	105.988
3B	61.724	61.357	62.056	86.849	67.149
3C	15.956	15.825	16.073	26.33	17.849
4A	188.547	186.383	188.903	356.285	226.488
4B	5.715	5.652	5.806	10.304	6.801
4C	20.997	20.696	21.312	43.036	25.083
5A	278.345	275.336	279.853	525.757	343.563
5B	39.498	38.988	39.956	82.217	48.773
6A	79.327	78.496	79.769	148.61	97.137
6B	8.5	8.398	8.568	16.633	10.265
7	2.22	2.193	2.241	4.2	2.834
8	0.373	0.366	0.382	0.817	0.479
Total	888.222	879.573	892.145	1556.248	1050.53

Units: Million MMBtu (10^{12} Btu)

Results by Climate Zone: Peak Electric

Climate Zone	Current U.S. Building Stock	MERV13 Filter Upgrade	Disable DCV	100% Minimum Outdoor Air	HVAC Outdoor Air Flushing
1A	4.996	5.046	4.997	5.432	5.141
2A	29.68	29.965	29.692	34.683	31.117
2B	4.753	4.808	4.759	5.537	4.978
3A	36.147	36.407	36.186	45.082	38.646
3B	24.193	24.455	24.257	29.005	25.625
3C	6.493	6.56	6.501	8.461	6.999
4A	62.036	62.528	62.065	79.352	68.758
4B	1.714	1.731	1.724	2.229	1.861
4C	6.485	6.544	6.499	8.693	7.17
5A	60.979	61.495	61.084	76.935	68.361
5B	10.177	10.273	10.206	13.739	11.183
6A	12.958	13.076	12.987	15.81	14.123
6B	1.823	1.836	1.831	2.606	2.039
7	0.378	0.381	0.378	0.48	0.415
8	0.033	0.034	0.033	0.043	0.034
Total	262.844	265.14	263.2	328.089	286.449

Units: GW

Results by Climate Zone: Delta Temp Binned Hours Averaged Per Building versus Existing Stock

Strategy: MERV 13 Filters

Climate Zone	cool: <2°F (Desired Range)	cool: >=2°F & <4°F	cool: >=4°F & <6°F	cool: >=6°F & <10°F	cool: >10°F	heat: <2°F (Desired Range)	heat: >=2°F & <4°F	heat: >=4°F & <6°F	heat: >=6°F & <10°F	heat: >10°F
1A	-1.1	0.8	0.2	0.1	0	0.1	-0.1	0	0	0
2A	-1.2	0.9	0.2	0.1	0	1.2	-0.8	-0.2	-0.2	-0.1
2B	-0.9	0.5	0.2	0.1	0.1	0.5	-0.4	-0.1	-0.1	0
3A	-0.5	0.4	0.1	0	0	2.1	-1	-0.2	-0.4	-0.5
3B	-0.1	0.1	0	0	0	1.5	-0.8	-0.3	-0.3	-0.1
3C	0	0	0	0	0	2.8	-1.6	-0.6	-0.5	-0.1
4A	-0.3	0.2	0.1	0	0	2.3	-1.2	-0.2	-0.3	-0.6
4B	-0.2	0.1	0	0	0	2	-1.2	-0.2	-0.3	-0.2
4C	0	0	0	0	0	4.2	-1.8	-0.5	-0.9	-0.9
5A	-0.1	0.1	0	0	0	2.5	-1.7	-0.1	-0.1	-0.5
5B	-0.1	0.1	0	0	0	1.7	-0.9	-0.1	-0.2	-0.5
6A	0	0	0	0	0	1.9	-1.6	0	0	-0.3
6B	0	0	0	0	0	1.7	-1.1	0	-0.1	-0.5
7	0	0	0	0	0	6.1	-3.4	-0.4	-0.1	-2.3
8	0	0	0	0	0	0.1	-0.1	0	0	0

Note: Values in table are weighted by climate zone, so the sum of each column across climate zones will not equal the weighted stock-wide total.

Lower Hour Count ← → Higher Hour Count

Results by Climate Zone: Delta Temp Binned Hours Averaged Per Building versus Existing Stock

Strategy: Disable DCV

Climate Zone	cool: <2°F (Desired Range)	cool: >=2°F & <4°F	cool: >=4°F & <6°F	cool: >=6°F & <10°F	cool: >10°F	heat: <2°F (Desired Range)	heat: >=2°F & <4°F	heat: >=4°F & <6°F	heat: >=6°F & <10°F	heat: >10°F
1A	-0.2	0.2	0	0	0	0	0	0	0	0
2A	-0.2	0.2	0	0	0	0	0	0	0	0
2B	-1.2	1	0.2	0	0	0	0	0	0	0
3A	-0.1	0.1	0	0	0	-0.2	-0.1	0	0.1	0.2
3B	-0.2	0.2	0	0	0	0	0	0	0	0
3C	0	0	0	0	0	0	0	0	0	0
4A	0	0	0	0	0	0	0	0	0	0.1
4B	0	0	0	0	0	0	0	0	0	0
4C	0.1	0	0	0	0	0	0	-0.1	-0.1	0.2
5A	0	0	0	0	0	-0.3	0	0.1	0.1	0.1
5B	0	0.1	0	-0.1	-0.1	0	-0.1	0	0	0.2
6A	0	0	0	0	0	-0.7	0.1	0.1	0.2	0.2
6B	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	-10.8	-1.3	6.1	4	1.9
8	0	0	0	0	0	0	0	0	0	0

Note: Values in table are weighted by climate zone, so the sum of each column across climate zones will not equal the weighted stock-wide total.

Lower Hour Count ← → Higher Hour Count

Results by Climate Zone: Delta Temp Binned Hours Averaged Per Building versus Existing Stock

Strategy: 100% Minimum Outdoor Air

Climate Zone	cool: <2°F (Desired Range)	cool: >=2°F & <4°F	cool: >=4°F & <6°F	cool: >=6°F & <10°F	cool: >10°F	heat: <2°F (Desired Range)	heat: >=2°F & <4°F	heat: >=4°F & <6°F	heat: >=6°F & <10°F	heat: >10°F
1A	-127.8	110	16	1.8	0	-2.1	0.9	0.6	0.5	0.1
2A	-173.6	140.7	27.8	4.9	0	-13.7	3.1	2.5	3.9	4.2
2B	-337.5	157	83.6	76.7	20.3	-8.6	1.9	1.5	3.1	2
3A	-83.4	67.4	13.4	2.5	0.1	-34	5.6	3.6	6.6	18.2
3B	-73.4	38.2	18.1	13.9	3.2	-25.5	5.2	4.9	8.3	7.1
3C	-2.4	1.7	0.5	0.2	0	-59.7	11.1	12.2	21.9	14.6
4A	-33.8	27.7	5.1	0.9	0	-63.9	13.9	8.5	11.5	30
4B	-38.1	23.6	8	5	1.5	-37.8	8.5	5	9.1	15.1
4C	-3.7	2.9	0.7	0.1	0	-62.8	3.6	3.5	15.3	40.3
5A	-8	6.8	1	0.1	0	-103.9	27.6	17.7	21.2	37.3
5B	-19.7	14.5	4.6	1.1	-0.4	-82.6	21.1	12.6	15.4	33.5
6A	-2.9	2.6	0.3	0	0	-134.1	38.7	25.9	31.4	38.1
6B	-2.6	2.4	0.3	0	-0.1	-131.4	35.8	23.9	26.9	44.8
7	0.2	-0.1	-0.1	0	0	-202.5	39.2	32	33.2	98.1
8	0	0	0	0	0	-40.3	22	9.2	7	2.1

Note: Values in table are weighted by climate zone, so the sum of each column across climate zones will not equal the weighted stock-wide total.

Lower Hour Count ← → Higher Hour Count

Results by Climate Zone: Delta Temp Binned Hours Averaged Per Building versus Existing Stock

Strategy: HVAC Outdoor Air Flushing

Climate Zone	cool: <2°F (Desired Range)	cool: >=2°F & <4°F	cool: >=4°F & <6°F	cool: >=6°F & <10°F	cool: >10°F	heat: <2°F (Desired Range)	heat: >=2°F & <4°F	heat: >=4°F & <6°F	heat: >=6°F & <10°F	heat: >10°F
1A	2.1	-1.8	-0.3	0	0	-0.4	0.2	0.1	0.1	0
2A	0.7	-0.4	-0.2	-0.1	-0.1	-2.8	0.5	0.7	0.8	0.8
2B	2.3	-2.1	-0.2	0	0	-0.9	-0.1	0.1	0.6	0.3
3A	0.5	-0.4	-0.1	0	0	-7.3	1.2	1	1.9	3.3
3B	0.3	-0.3	0	0	0	-5	0.8	1.3	1.9	1.1
3C	0	0	0	0	0	-8.2	1.3	2.2	3.6	1.2
4A	0.8	-0.6	-0.1	0	-0.1	-7.1	0.4	0.7	1.8	4.3
4B	0.7	-0.6	-0.1	0	0	-4.2	-0.9	0.3	2	2.8
4C	0.2	-0.1	0	0	0	-13	0.6	1.7	4.6	6
5A	0.4	-0.3	0	0	0	-7.2	0.2	1.1	1.5	4.5
5B	0.4	-0.3	0	0	0	-7.3	1.6	0.4	1.4	3.8
6A	0.3	-0.2	0	0	0	-1	-3.3	0.8	1	2.5
6B	0.3	-0.3	0	0	0	1.2	-4.5	-0.1	0	3.3
7	0	0	0	0	0	-38.5	5.1	4.4	6.9	22.1
8	0	0	0	0	0	2.3	-2.6	0.3	0	0

Note: Values in table are weighted by climate zone, so the sum of each column across climate zones will not equal the weighted stock-wide total.

Lower Hour Count ← → Higher Hour Count

Results by Climate Zone: Humidity Binned Hours Averaged per Building

Strategy: Existing U.S. Commercial Building Stock

Climate Zone	<10% RH	>=10% RH & <20% RH	>=20% RH & <30% RH	>=30% RH & <40% RH	>=40% RH & <=60% RH (Desired Range)	>60% RH & <70%	>=70% RH & <80% RH	>=80% RH & <90% RH	>90% RH
1A	0	0	22	211	2836	2349	1791	902	649
2A	0	61	337	597	3060	1986	1441	722	556
2B	41	1373	2209	1823	2539	429	191	90	65
3A	15	357	904	1098	3327	1509	876	403	271
3B	24	496	958	1432	4189	1021	376	162	102
3C	1	20	239	1067	5639	1155	391	157	92
4A	96	775	1332	1284	3117	1130	593	258	175
4B	84	1835	2140	1762	2299	405	156	59	19
4C	1	87	427	2027	5161	629	230	122	77
5A	132	937	1495	1427	2911	987	510	225	136
5B	99	1488	2786	2478	1589	178	81	38	23
6A	265	1081	1545	1462	2723	904	470	201	108
6B	173	1445	2760	2573	1562	161	62	22	3
7	63	488	1857	2667	2841	499	167	88	89
8	87	561	1570	2142	2552	782	435	301	330

Note: Values in table are weighted by climate zone, so the sum of each column across climate zones will not equal the weighted stock-wide total.

Lower Hour Count ← → Higher Hour Count

Results by Climate Zone: Humidity Binned Hours Averaged per Building

Strategy: MERV 13 Filters

Climate Zone	<10% RH	>=10% RH & <20% RH	>=20% RH & <30% RH	>=30% RH & <40% RH	>=40% RH & <=60% RH (Desired Range)	>60% RH & <70%	>=70% RH & <80% RH	>=80% RH & <90% RH	>90% RH
1A	0	0	22	214	2903	2360	1756	872	633
2A	0	61	339	600	3118	1991	1414	698	539
2B	42	1377	2210	1828	2541	423	187	88	64
3A	15	357	907	1103	3366	1503	855	391	263
3B	24	498	959	1440	4203	1004	370	160	101
3C	1	20	241	1079	5651	1137	385	156	91
4A	96	777	1335	1289	3145	1119	578	251	170
4B	85	1839	2143	1767	2297	399	154	58	19
4C	1	88	430	2046	5151	620	227	121	77
5A	132	939	1498	1431	2928	979	500	220	133
5B	100	1492	2791	2482	1577	176	81	38	23
6A	265	1083	1548	1466	2738	897	460	197	106
6B	173	1448	2766	2577	1549	160	62	22	3
7	63	488	1865	2672	2838	491	166	87	89
8	87	562	1577	2145	2550	776	434	299	329

Note: Values in table are weighted by climate zone, so the sum of each column across climate zones will not equal the weighted stock-wide total.

Lower Hour Count ← → Higher Hour Count

Results by Climate Zone: Humidity Binned Hours Averaged per Building

Strategy: Disable DCV

Climate Zone	<10% RH	>=10% RH & <20% RH	>=20% RH & <30% RH	>=30% RH & <40% RH	>=40% RH & <=60% RH (Desired Range)	>60% RH & <70%	>=70% RH & <80% RH	>=80% RH & <90% RH	>90% RH
1A	0	0	22	211	2836	2346	1791	903	649
2A	0	61	337	597	3060	1983	1441	723	557
2B	41	1378	2220	1818	2527	429	192	90	65
3A	15	357	905	1098	3326	1507	877	403	271
3B	24	498	962	1433	4184	1020	375	161	101
3C	1	20	239	1069	5641	1154	390	156	91
4A	96	776	1333	1284	3115	1129	593	258	175
4B	84	1842	2156	1757	2291	401	154	58	18
4C	1	88	429	2036	5158	626	227	119	77
5A	132	940	1499	1426	2905	986	511	225	136
5B	100	1493	2801	2474	1577	175	80	37	23
6A	265	1085	1547	1462	2718	904	470	201	108
6B	173	1453	2773	2569	1548	158	61	22	3
7	63	489	1861	2671	2839	498	165	86	89
8	87	563	1578	2136	2550	780	434	301	330

Note: Values in table are weighted by climate zone, so the sum of each column across climate zones will not equal the weighted stock-wide total.

Lower Hour Count ← → Higher Hour Count

Results by Climate Zone: Humidity Binned Hours Averaged per Building

Strategy: 100% Minimum Outdoor Air

Climate Zone	<10% RH	>=10% RH & <20% RH	>=20% RH & <30% RH	>=30% RH & <40% RH	>=40% RH & <=60% RH (Desired Range)	>60% RH & <70%	>=70% RH & <80% RH	>=80% RH & <90% RH	>90% RH
1A	0	1	35	200	1879	2009	2458	1345	833
2A	1	97	381	561	2081	1641	2103	1156	738
2B	139	1890	2072	1598	2039	568	273	109	71
3A	48	462	951	1004	2437	1530	1366	612	351
3B	67	655	980	1340	3793	1214	434	176	102
3C	1	33	290	1027	5391	1319	442	165	92
4A	185	906	1308	1150	2445	1205	925	413	223
4B	240	2218	2005	1496	2093	454	172	63	19
4C	2	129	567	2089	4860	685	238	118	72
5A	252	1072	1452	1311	2479	1058	676	301	159
5B	243	1908	2774	2072	1447	182	78	35	21
6A	411	1199	1520	1332	2387	948	590	252	120
6B	324	1784	2793	2216	1407	155	57	20	3
7	149	682	2190	2278	2617	512	161	85	87
8	169	689	1755	1840	2405	831	435	307	329

Note: Values in table are weighted by climate zone, so the sum of each column across climate zones will not equal the weighted stock-wide total.

Lower Hour Count ← → Higher Hour Count

Results by Climate Zone: Humidity Binned Hours Averaged per Building

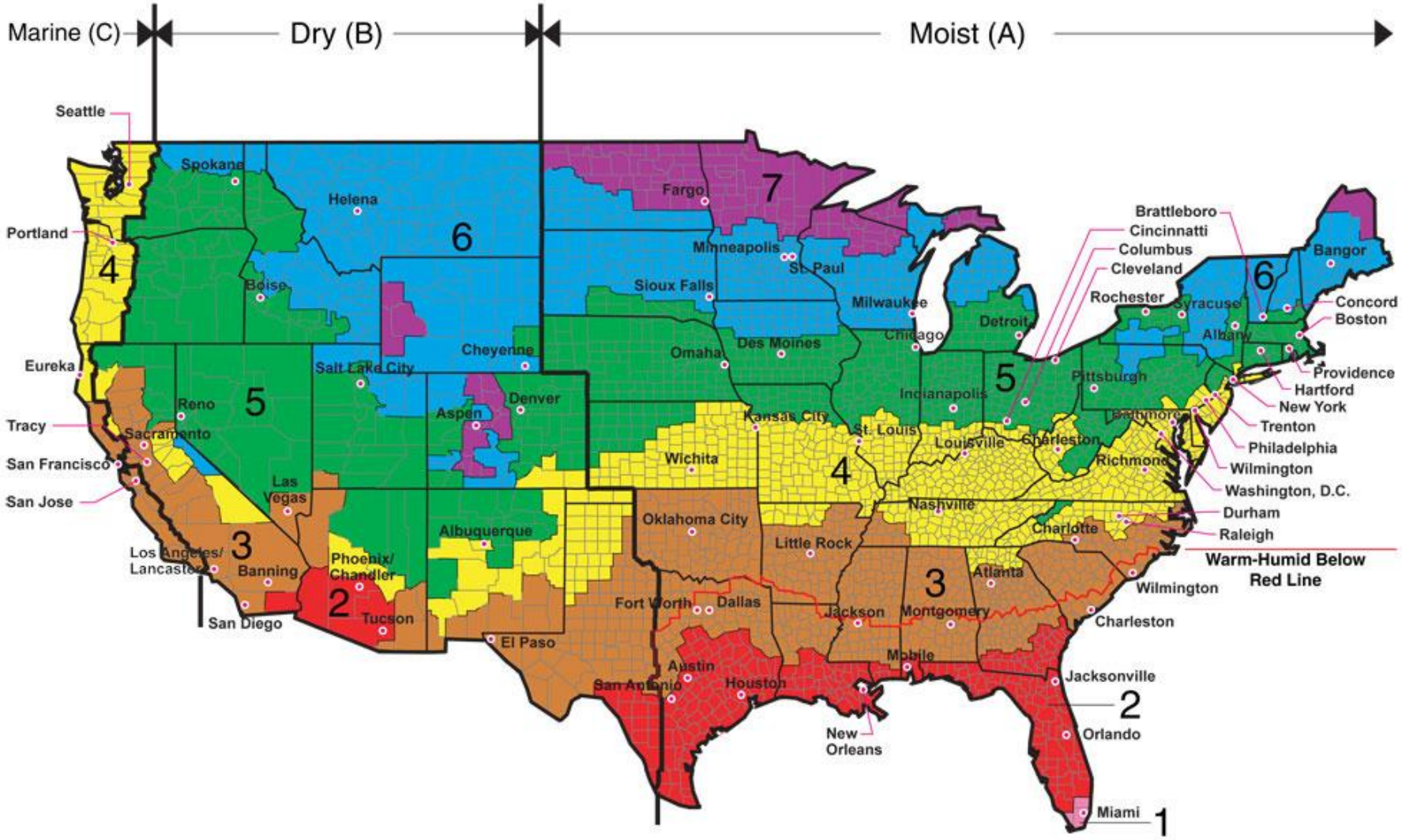
Strategy: HVAC Outdoor Air Flushing

Climate Zone	<10% RH	>=10% RH & <20% RH	>=20% RH & <30% RH	>=30% RH & <40% RH	>=40% RH & <=60% RH (Desired Range)	>60% RH & <70%	>=70% RH & <80% RH	>=80% RH & <90% RH	>90% RH
1A	0	0	25	203	2721	2194	1793	1084	739
2A	0	70	356	592	2872	1797	1460	927	685
2B	56	1491	2245	1828	2420	408	173	84	56
3A	23	401	928	1088	3093	1460	962	520	285
3B	40	552	993	1409	4110	1110	392	114	40
3C	1	27	268	1100	5624	1236	364	95	44
4A	127	833	1335	1247	2914	1124	667	337	175
4B	133	1994	2124	1712	2212	400	142	38	4
4C	1	111	476	2049	5195	643	165	65	54
5A	191	1008	1498	1393	2774	987	544	250	114
5B	171	1635	2779	2429	1544	130	40	16	18
6A	348	1142	1558	1443	2607	901	487	199	74
6B	261	1575	2788	2535	1488	91	16	4	0
7	127	593	2064	2569	2730	462	110	48	56
8	150	644	1709	2033	2538	738	384	262	303

Note: Values in table are weighted by climate zone, so the sum of each column across climate zones will not equal the weighted stock-wide total.

Lower Hour Count ← → Higher Hour Count

ASHRAE Climate Zones (for reference)



All of Alaska in Zone 7 except for the following Boroughs in Zone 8: Bethel, Dellingham, Fairbanks, N. Star, Nome North Slope, Northwest Arctic, Southeast Fairbanks, Wade Hampton, and Yukon-Koyukuk

Zone 1 includes: Hawaii, Guam, Puerto Rico, and the Virgin Islands

Source: iaqsource.com

Other Project Contributors

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