The Carbon Reduction Potential of ASHRAE Standard 62.1 IAQ Procedure Ventilation Design Method

Comprehensive energy modeling by Performance Systems Development (PSD) shows ASHRAE Standard 62.1 Indoor Air Quality Procedure can reduce annual building carbon emissions by 43.2 $MMTCO_2$/year and annual energy consumption by 0.747 quads/year.

A report by Performance Systems Development (PSD) and enVerid Systems

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Executive Summary

In response to the pressing need to decarbonize buildings, Performance Systems Development (PSD), a leading energy modeling firm, studied the potential building energy savings and carbon reduction that could be achieved if policies, standards, codes, and design practices were updated to encourage the widespread adoption of ASHRAE's existing performance based ventilation design method, the IAQ Procedure (IAQP), which is part of ASHRAE Standard 62.1 Ventilation & Acceptable Indoor Air Quality.

Methods

Energy savings and carbon reduction potential was measured against a baseline case that applied the alternative mechanical ventilation procedure in Standard 62.1, the Ventilation Rate Procedure (VRP). The difference between the VRP and IAQP is summarized in Table 1.

Table 1 – Ventilation Rate Procedure vs. Indoor Air Quality Procedure

VRP	IAQP
A prescriptive procedure in which outdoor air rates are determined based on space type/application, occupancy level, and floor area without any direct control of design compounds. The VRP is fully reliant on outdoor air "dilution ventilation" to maintain IAQ.	A performance-based procedure in which outdoor air rates are determined to maintain defined design compounds below specified limits based on indoor and outdoor contaminant sources and direct source control and removal measures such as air cleaning.

According to Standard 62.1, "Although the intake airflow determined using each of these approaches may differ significantly …any of these approaches is a valid basis for design."[1]

The proposed case, which is based on the IAQP with sorbent air cleaning with a minimum efficiency for formaldehyde of 70%, represents a 75% reduction in outdoor air compared to the VRP baseline case. The outdoor air reduction is derived from a 2020 National Renewable Energy Laboratory (NREL) report that found that up to an 80% reduction in outdoor air is attainable in office buildings while maintaining positive pressure and acceptable indoor air quality (IAQ).[2] 80% from the NREL report was reduced to 75% to account for a broader range of building types covered by this study.

The analysis is based on a large-scale simulation of prototypical building energy models to approximate energy consumption and carbon emission of outdoor air ventilation in the baseline VRP case and the proposed IAQP case in 59.4 billion ft^2 of existing and new construction offices, schools, retails, and warehouse buildings from 2022 through 2030 across all U.S. states. ASHRAE Standard 90.1-2004 was used for the existing building segment, and Standard 90.1-2016 was used for the new construction segment.

The SCOUT software tool was used to conduct the analysis. SCOUT is an open-source software program developed and supported by the U.S. Department of Energy that is used to estimate the impacts of various energy conservation measures (ECMs) across the U.S. residential and commercial building sectors. The simulation consisted of 50 custom SCOUT ECMs and 210 unique OpenStudio/ EnergyPlus "Commercial Prototype" models. The total annual thermal energy was extracted from each of these models.

Key Findings

1. Applying the IAQP with sorbent air cleaning to 59.4 billion ft^2 of office, school, retail, and warehouse buildings in the U.S. has the potential to reduce annual energy consumption by **0.747 quads/year**. This represents a 6% reduction in total building energy consumption, as summarized in Table 2 below. The percentage reduction varies by climate zone and building type.

Table 2 - Average Annual Energy Savings Potential for Existing Building and New Construction Scenarios (2022 – 2030)

Baseline Case (VRP) (Quads / year)	Proposed Case (IAQP) with Sorbent Air Cleaning (Quads / year)	Energy Savings Potential (Quads / year)	Energy Savings Potential %
11.627	10.88	**0.747**	**6%**

2. Applying the IAQP with sorbent air cleaning to the same 59.4 billion ft^2 of buildings has the potential to reduce annual carbon emissions by **43.2 million metric tons of carbon dioxide per year** ($MMTCO_2$/year). This represents a 9% reduction in total building carbon emissions. Using U.S. EPA provided Greenhouse Gas Emissions for Typical Passenger Vehicles, these carbon emission reductions are **equivalent to removing more than 9.3 million non-electric passenger vehicles from the road every year**, which is roughly two-thirds of the total number of automobiles registered in California.

[1] ASHRAE Standard 62.1-2022, Section 6.1

[2] National Renewable Energy Laboratory. Energy Performance Validation of a Gaseous Air Cleaning Technology for Commercial Buildings. February 2020.

As shown in Table 3, 78% of the energy savings and carbon reduction potential is associated with existing buildings. These results align with a simulated floorspace for retrofit of 58.2 billion ft^2, a simulated floorspace for new construction buildings of 1.2 billion ft^2, and 2% of existing floorspace being replaced with new construction each year.

Table 3 - Breakout of Average Annual Energy Savings & Carbon Reduction Potential for Existing Buildings and New Construction (2022 - 2030)

Building Sector	Energy Savings Potential (Quads / year)	% of Total Energy Savings	CO2 Emissions Reduction ($MMTCO_2$/yr)	% of Total CO2 Emissions
Existing Building	0.583	78%	33.7	78%
New Construction	0.164	22%	9.5	22%
Total	**0.747**		**43.2**	

3. Roughly 50% of existing building energy savings and carbon reduction potential comes from 10 states, with each of these states representing 4-8% of the total existing building energy savings and carbon reduction potential. The top 10 states are shown in Figures 1 and 2. States having larger existing building stock - including New York, Ohio, North Carolina, and California – have 2 to 3 times more energy and emissions reduction potential than smaller and less populated states. While potential is lower on an absolute basis in states with a smaller building stock, the savings potential on a percentage basis is comparable to larger states with similar climates.

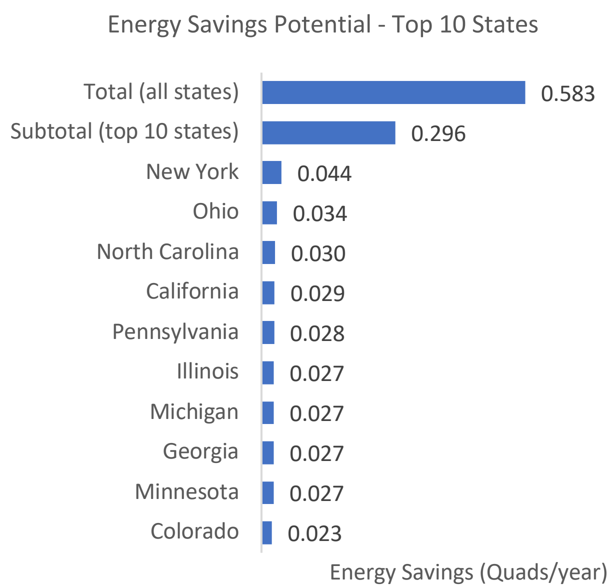

Figure 1 - Energy Savings Potential (Existing Building)

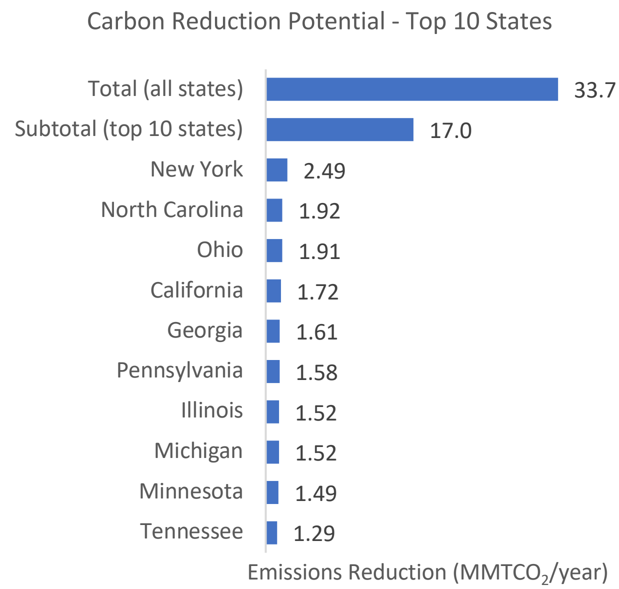

Figure 2 - Carbon Reduction Potential (Existing Building)

4. Annual energy savings potential normalized per 1,000 CFM of outdoor air reduced for each ASHRAE climate zone can be used to quickly understand where the IAQP has the greatest energy savings potential for individual buildings. Figures 3 and 4 summarize the energy savings potential per 1,000 CFM reduction in outdoor air for the retrofit and new construction building sectors, respectively, in reference cities in the states highlighted. These results are comparable in cities and states with similar climates.

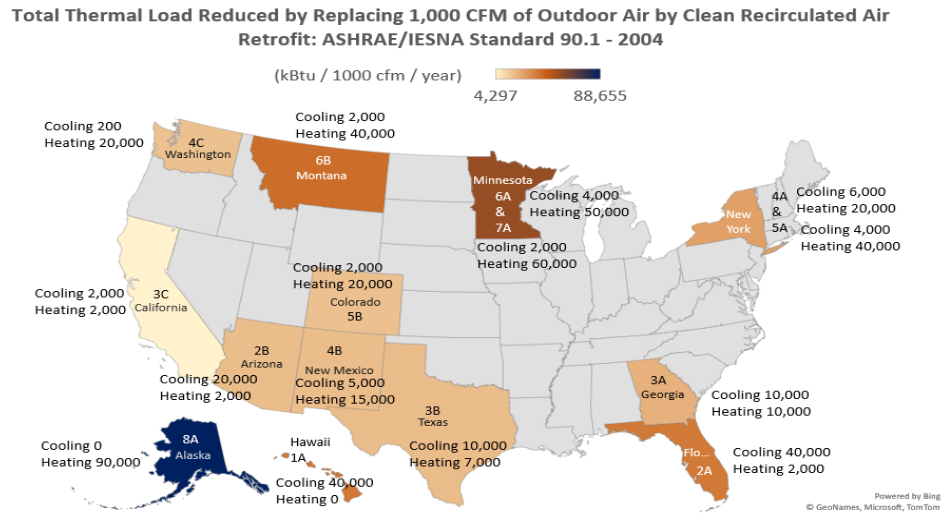

Figure 3 – Average Annual Energy Savings by ASHRAE Climate Zone per 1,000 CFM Reduction in Minimum Outdoor air (Existing Building)

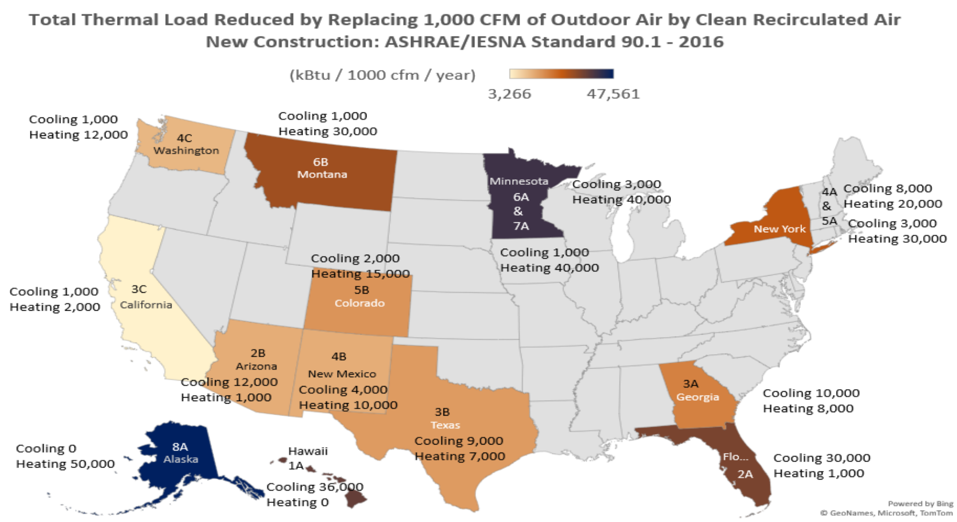

Figure 4 - Average Annual Energy Savings by ASHRAE Climate Zone per 1,000 CFM Reduction in Minimum Outdoor air (New Construction)

5. Both the VRP and IAQP are equivalent with respect to satisfying the requirements of Standard 62.1. Both procedures are also allowed by the International Mechanical Code.[3] But, as the modeling shows, **the IAQP with sorbent air cleaning is more energy efficient** because it allows for cleaned indoor air to offset a significant portion of hot and humid and/or cold outdoor air required by the VRP. As the Standard 62.1 User's Manual says, "The IAQP may allow for a more cost-effective solution to providing good air quality, as all design strategies may be considered and compared…"[4]

Implications

This study shows that widespread adoption of ASHRAE's existing performance-based ventilation design method, the IAQ Procedure, in place of the prescriptive VRP that is used in most buildings today, can deliver immediate and meaningful energy savings and carbon reduction in existing and new commercial buildings. Based on these findings, building policies, standards, codes, and design practices should promote the IAQP as an immediate way to make ventilating buildings more energy efficient without compromising the quality of indoor air.

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[3] See IMC Section 403.2 and the commentary on Section 403.2, which allows for an "engineered system design" using the IAQP.
[4] ASHRAE Standard 62.1-2019 User's Manual: The Definitive Companion to Standard 62.1, published June 2021, pg. 100.

Introduction

The COVID-19 pandemic and Biden administration have focused attention on three key issues relating to buildings – indoor air quality (IAQ), economy-wide decarbonization, and economic stimulus. For example, in December 2021 President Biden signed an executive order directing the federal government to achieve a net-zero emissions building portfolio by 2045,[5] and in March 2022 the Biden Administration announced the Clean Air in Buildings Challenge to help building owners and operators reduce risks from airborne viruses and other contaminants indoors.[6] To support these efforts, the Inflation Reduction Act, signed into law in August 2022, included $50 billion for clean energy technologies and improvements to lower energy bills, make buildings healthier and safer, reduce climate pollution, and prioritize delivery of these benefits to low-income and environmental justice communities.[7] Many states and cities are adopting similar policies, and the push for building decarbonization is now also strong in the private sector.

Commercial buildings are getting so much attention because they contribute 17% of the total U.S. carbon emissions each year.[8] Because heating, ventilating, and air conditioning (HVAC) is responsible for 36% of commercial building energy intensity,[9] improving HVAC efficiency is one of the biggest opportunities for reducing commercial building carbon emissions. HVAC systems are also integral to mitigating the airborne transmission of viruses. According to ASHRAE, "Changes to building operations, including the operation of heating, ventilating, and air-conditioning systems, can reduce airborne exposures."[10] Thus, investments in HVAC should be prioritized to improve indoor air quality <u>and</u> energy efficiency.

In this context, the adoption of ASHRAE's existing performance-based ventilation design method, the IAQ Procedure (IAQP), which is part of ASHRAE Standard 62.1 Ventilation and Acceptable Indoor Air Quality, offers a compelling opportunity to invest in building infrastructure in a way that improves IAQ and decarbonizes buildings at the same time. The key to making this happen is ensuring that building policies, standards, codes, and design practices promote the IAQP as an immediate way to make ventilating buildings more energy efficient while at the same time improving indoor air quality.

Current building standards and codes mandate minimum ventilation rates to maintain IAQ. The purpose of these ventilation rates is to ensure harmful gaseous contaminants generated indoors (e.g., volatile organic compounds from paints, furniture, printers, cleaning agents, etc.) do not reach levels in the air that are harmful to health. Today, most buildings comply with these ventilation requirements by replacing 100% of the air in buildings with "fresh" outdoor air 10-20 times a day. This practice is called "dilution ventilation" and it is energy intensive in many parts of the country because hot, humid, and cold outdoor air needs to be conditioned for comfort before it can be circulated through a building. Additionally, outdoor air is not always fresh, as the recent wildfires highlighted. Therefore, reducing our reliance on dilution ventilation by cleaning and recycling already conditioned indoor air can significantly reduce HVAC energy use, reduce the cost of new, smaller HVAC systems, and make our buildings more resilient to polluted outdoor air.

When operating existing ventilation systems and designing new ventilation systems, building managers and design engineers have two procedures they can follow to calculate minimum mechanical ventilation rates under Standard 62.1 and the local building codes that reference Standard 62.1:

- **Ventilation Rate Procedure (VRP)** – A prescriptive procedure in which outdoor air rates are determined based on space type/application, occupancy level, and floor area without any direct control of contaminants (which are referred to as design compounds in Standard 62.1). The VRP is fully reliant on outdoor air "dilution ventilation" to maintain IAQ.
- **Indoor Air Quality Procedure (IAQP)** – A performance-based procedure in which outdoor air rates are determined to maintain defined design compounds below specified limits based on indoor and outdoor contaminant sources and direct source control and removal measures such as air cleaning. This "hybrid ventilation" approach allows for both outdoor air and air cleaning to achieve the same or better IAQ levels as with the VRP.

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[5] White House. President Biden Signs Executive Order Catalyzing America's Clean Energy Economy Through Federal Sustainability, December 8, 2021.
[6] U.S. EPA. Clean Air in Buildings Challenge. March 2022.
[7] RMI. The Inflation Reduction Act Could Transform the US Buildings Sector. August 31, 2022.
[8] The White House. United Stated Mid-Century Strategy for Deep Decarbonizing. November 2016.
[9] U.S. Energy Information Agency. Annual Energy Outlook 2021. (https://www.eia.gov/outlooks/aeo/pdf/06%20AEO2021%20Buildings.pdf)
[10] ASHRAE Issues Statements on Relationship Between COVID-19 and HVAC in Buildings, April 20, 2020. https://www.ashrae.org/about/news/2020/ashrae-issues-statements-on-relationship-between-covid-19-and-hvac-in-buildings

According to Standard 62.1, "Although the intake airflow determined using each of these approaches may differ significantly…any of these approaches is a valid basis for design."[11]

Using the IAQP, it is possible to maintain IAQ and improve ventilation efficiency by using source-control and removal measures such as sorbent air cleaning to replace a meaningful portion of the outdoor air requirement under the VRP with cleaned indoor air. The IAQP approach with air cleaning reduces the scale of energy-intensive outdoor air heating and cooling and is similar to the approach NASA and the U.S. Navy use in spacecraft and submarines where bringing in outdoor air is impossible. In locations with high levels of pollution, using the IAQP with air cleaning can also improve indoor air quality relative to the VRP by reducing the intake of polluted outdoor air. According to the American Lung Associations 2021 State of the Air Report, "more than 40% of Americans—over 135 million people—are living in places with unhealthy levels of ozone or particle pollution" and "People of color are over three times more likely to be breathing the most polluted air than white people."[12] According to the World Health Organization, "Air pollution is one of the biggest environmental threats to human health, alongside climate change."[13]

Despite the IAQP being an equally acceptable approach for calculating ventilation rates under building codes that follow Standard 62.1, and despite significant cost saving, energy efficiency, and IAQ benefits associated with the IAQP, adoption of the IAQP remains very low. The reason for this was summed up in a 2017 Department of Energy report titled "Energy Savings Potential and RD&D Opportunities for Commercial Building HVAC Systems" that identified "Ventilation Reduction through Advanced Filtration" using the IAQP as having the third largest energy savings potential for technology enhancements for current commercial HVAC systems.[14] According to the report, "Substantially decreasing the amount of outdoor air through use of advanced filters represents a significant change in the building industry. The largest barrier to market adoption is acceptance by building code jurisdictions, HVAC system designers, and customers."[15]

In response to the pressing need to decarbonize buildings, Performance Systems Development (PSD), a leading energy modeling firm, studied the potential building energy savings and carbon reduction that could be achieved if policies, standards, codes, and design practices encouraged the widespread adoption of the IAQP with currently available, field validated sorbent air cleaning technology. The modeling conducted by PSD confirms the very large energy savings and carbon reduction potential of the IAQP. Based on these findings and 2022 updates to Standard 62.1 that make the IAQP more robust and simpler to apply, there should be a focused effort to ensure that all building policies, standards, codes, and design practices encourage adoption of the IAQP.

Study Scope

The scope of this study is the U.S. technical energy consumption (Quads) and carbon dioxide emissions reduction (CO_2e) possible if most existing and new commercial building types applied the IAQP with sorbent air cleaning in place of the VRP. Using the IAQP with sorbent air cleaning technology with the efficiencies identified in Appendix 1, it is possible to replace 75% of the outdoor air requirement under the VRP with cleaned indoor air while maintaining the same or better IAQ levels as are achieved with the VRP.[16]

The cost effectiveness of applying the IAQP with sorbent air cleaning technology is out of scope for this study. However, a 2020 report by the National Renewable Energy Lab showed that the proposed approach is cost effective in many climate zones.[17] This finding is supported by project case studies published by Slipstream[18] and enVerid Systems[19]. The cost-effective use of the IAQP with sorbent air cleaning should be evaluated on a case-by-case basis as results vary by climate zone, building type, ventilation system design, and air cleaning system used.

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[11] ASHRAE Standard 62.1-2022, Section 6.1
[12] American Lung Association. State of the Air 2021. April 21, 2021
[13] World Health Organization. New WHO Global Air Quality Guidelines aim to save millions of lives from air pollution. September 22, 2021.
[14] Department of Energy. Energy Savings Potential and RD&D Opportunities for Commercial Building HVAC Systems, December 2017.
[15] Ibid, Pg. 44.
[16] 75% is used because it is roughly equal to the minimum outside air under VRP minus exhaust requirements to maintain pressure. Using proven sorbent air cleaning technology available in the market today from vendors such as Daikin, Oxygen8, and enVerid Systems, it is possible to reduce outside air by 75% without impacting indoor air quality. For detailed IAQP calculations, see the ASHRAE Standard 62.1-2019 User's Manual.
[17] National Renewable Energy Laboratory. Energy Performance Validation of a Gaseous Air Cleaning Technology for Commercial Buildings. February 2020.
[18] Morrison, Drew. Adsorbent air cleaning: A new way to think about ventilation. June 2021.
[19] enVerid Systems. Various case studies for office buildings, K-12 schools, and higher education available at https://enverid.com/resources/case-studies/.

Study Methodology

To determine the total potential energy savings and carbon emissions reduction by 2030, PSD developed "Technical Potential" estimates of both energy and CO_2 emissions savings associated with the large-scale adoption of the IAQP with sorbent air cleaning for both new construction and existing ("retrofit") commercial building sectors across the United States, from 2022 – 2030.

Technical Potential is defined as the theoretical "energy savings that could be achieved if all technically suitable installations are replaced with a particular energy-saving technology".[20] The Technical Potential scenario assumes that from 2022, the entire baseline market instantaneously and completely switches to use of the IAQP and that this approach maintaining IAQ remains the standard in subsequent years.

Results from a Technical Potential scenario represent the maximum impact from using the IAQP, limited only by the baseline market size.[21] Unlike a "Maximum Adoption Potential" scenario, accurate analysis of Technical Potential does not require establishing accurate cost or lifetime for an energy conservation measure such as use of the IAQP, which may be difficult to establish for newer technologies.

To establish an analysis workflow for this study, PSD consulted with staff from the National Renewable Energy Laboratory with experience with sorbent air cleaning technologies. PSD also consulted with staff from the Lawrence Berkeley National Laboratory with experience in conducting Technical Potential analysis. PSD reviewed a number of analysis options with the goal of balancing the core principles of repeatability, reproducibility, transparency, credibility, conservativeness, and accuracy. For example, an approach based on bin analysis of published weather data and typical building behavior was considered and rejected based on the limits of accuracy that could be attained with respect to establishing credible baselines.

PSD selected the SCOUT software tool as a basis for establishing both the baseline market size and to accurately determine changes to the baseline market in future years. The SCOUT software tool is an open-source software program developed and supported by the Department of Energy and used to estimate the impacts of various energy conservation measures (ECMs) across the U.S. residential and commercial building sectors. To represent the Technical Potential of the IAQP, 50 custom SCOUT ECMs were used: 5 SCOUT building types x 2 SCOUT building scenarios x 5 SCOUT AIA climate zones. A custom SCOUT ECM is described in Appendix 3.

Fundamentally, the use of the IAQP and sorbent air cleaning technology reduces the annual heating and cooling energy loads served by HVAC systems and thus the site energy consumption of a building. To describe this behavior within a custom SCOUT ECM, PSD developed heating and cooling energy end-use savings that were derived from prototypical whole building energy simulation models. The energy models used were created via a publicly available OpenStudio measure. These models closely resemble the set of OpenStudio/EnergyPlus Standardized Prototype Energy Models used by the ASHRAE 90.1 committee for evaluating the cost-effectiveness of potential changes to the 90.1 standard. These open-source energy models can be easily created and have been previously used by the Department of Energy and ASHRAE to evaluate national level energy savings estimates. Appendix 6 includes instructions for re-creating the OpenStudio/EnergyPlus Prototype models used for this study.

For evaluating the New Construction building market scenario, the workflow uses the same sector and climate weighting factors used as "Progress Indicators" by the ASHRAE 90.1 committee, which use 15 distinct ASHRAE/IECC climate regions. These new construction weighting factors are included in Appendix 8.

For evaluating the existing building Retrofit market scenario, the workflow used recently published data from the 2019 Commercial Building Inventory to develop custom building type and state specific climate weighting factors. These retrofit weighting factors are described in Appendix 9.

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[20] https://www.energy.gov/sites/prod/files/2017/12/f46/bto-DOE-Comm-HVAC-Report-12-21-17.pdf

[21] https://www.energy.gov/sites/default/files/2017/11/f46/2017%20BTO%20Peer%20Review%20Report.pdf

Modeling Results

Total Savings Potential – Existing Building and New Construction by Building Type

Applying the IAQP to approximately 59 billion square feet of office, school, retail, and warehouse buildings in the U.S. has the potential to reduce annual energy consumption by **0.747 quads/year** and reduce carbon emissions by 43.2 **million metric tons of carbon dioxide per year** (MMTCO_2/year)**.**

Using US EPA provided Greenhouse Gas Emissions for Typical Passenger Vehicles, these carbon emission reductions are **equivalent to removing more than 9.3 million non-electric passenger vehicles from the road every year**, which is roughly two-thirds of the total number of automobiles registered in California.[22]

Table 4 - Average Annual Savings Potential for Existing Building and New Construction Scenarios (2022 – 2030), By Building Type

Building Type	Baseline Case with no air cleaning (VRP)		Proposed Case with air cleaning (IAQP)		Savings Potential with IAQP and air cleaning			
	Primary Energy	Total CO_2 Emissions	Primary Energy	Total CO_2 Emissions	Primary Energy	Primary Energy	Total CO_2 Emissions	Total CO_2 Emissions
	(Quads / year)	(MMTCO_2/yr)	(Quads / year)	(MMTCO_2/yr)	(Quads / year)	%	(MMTCO_2/yr)	%
Retail	4.900	194.3	4.631	178.5	0.269	5%	15.8	8%
Warehouse	2.205	85.2	2.188	84.2	0.017	1%	1.0	1%
Office	2.731	105.4	2.533	94.2	0.198	7%	11.2	11%
School	1.790	177.4	1.527	56.9	0.263	15%	15.1	9%
TOTAL	**11.627**	**457.0**	**10.880**	**413.8**	**0.747**	**6%**	**43.2**	**9%**

Primary energy is the "site" or whole-building energy, inclusive of all building energy end uses.

Total Savings Potential – Existing Building and New Construction by AIA Climate Zone and Building Type

The modeled savings from Table 4 are broken out per AIA climate zone in Table 5. These savings represent up to **23% of primary building energy consumption** and **31% of total building carbon emissions,** depending on the climate zone and building type.

Table 5 - Average Annual Savings Potential for Existing Building and New Construction Scenarios for Modeled Building Types, by AIA Climate Zone (2022 – 2030)

AIA Climate Zone	Building Type	Baseline Case with no air cleaning (VRP)		Proposed Case with air cleaning (IAQP)		Savings Potential with IAQP and air cleaning			
		Primary Energy	Total CO2 Emissions	Primary Energy	Total CO2 Emissions	Primary Energy	Primary Energy	Total CO2 Emissions	Total CO2 Emissions
		(Quads / year)	(MMTCO_2/yr)	(Quads / year)	(MMTCO_2/yr)	(Quads / year)	%	(MMTCO_2/yr)	%
(1) Northern states including parts of CO, NV, UT, WA, OR	Retail	0.55	22.3	0.507	19.9	0.043	8%	2.5	11%
	Warehouse	0.316	12.6	0.314	12.5	0.002	1%	0.1	1%
	Office	0.42	16.6	0.389	14.8	0.031	7%	1.7	11%
	School	0.271	11.2	0.224	8.5	0.047	17%	2.7	24%
	Subtotal	**1.557**	**62.7**	**1.434**	**55.6**	**0.123**	**8%**	**7.0**	**11%**
(2) Southern New England to NE, parts of the PNW, CO, NV, UT, NM, AZ	Retail	0.982	40.4	0.897	35.5	0.085	9%	5.0	12%
	Warehouse	0.552	22	0.549	21.8	0.003	1%	0.2	1%
	Office	0.719	28.7	0.657	25.2	0.062	9%	3.5	12%
	School	0.439	18.9	0.338	13.1	0.101	23%	5.8	31%
	Subtotal	**2.692**	**110**	**2.44**	**95.5**	**0.251**	**9%**	**14.5**	**13%**
(3) Mid-Atlantic to KS and parts of OK, NM, CA, and OR	Retail	0.771	31.2	0.72	28.2	0.051	7%	3.0	10%
	Warehouse	0.473	18.2	0.471	18.1	0.002	0%	0.1	1%
	Office	0.536	20.9	0.479	17.7	0.057	11%	3.2	16%
	School	0.277	11.2	0.231	8.7	0.046	17%	2.6	23%
	Subtotal	**2.057**	**81.6**	**1.902**	**72.6**	**0.156**	**8%**	**8.9**	**11%**
(4) Carolinas to AR and parts of OK, TX, NM, AZ, and CA	Retail	0.997	38.6	0.944	35.4	0.053	5%	3.2	8%
	Warehouse	0.535	20.2	0.531	20	0.004	1%	0.3	1%
	Office	0.665	24.8	0.635	23.1	0.030	5%	1.7	7%
	School	0.442	17	0.404	14.9	0.038	9%	2.1	13%
	Subtotal	**2.64**	**100.6**	**2.516**	**93.3**	**0.125**	**5%**	**7.3**	**7%**
(5) Southern US from SC to TX, HI, and parts of CA and AZ	Retail	1.6	61.8	1.563	59.6	0.037	2%	2.2	4%
	Warehouse	0.329	12.2	0.324	11.9	0.005	2%	0.3	3%
	Office	0.391	14.6	0.373	13.5	0.018	5%	1.1	7%
	School	0.361	13.7	0.331	11.8	0.032	8%	1.9	14%
	Subtotal	**2.681**	**102.2**	**2.589**	**96.7**	**0.092**	**3%**	**5.5**	**5%**
Total		**11.627**	**457.1**	**10.881**	**413.7**	**0.747**	**6%**	**43.2**	**9%**

[22] Statista. U.S. automobile registrations in 2019 by state, accessed 1/3/2022.

For individual climate zones, the savings potential (%) is greatest in schools and least in warehouses. This is expected as the baseline ventilation load per ft^2 for schools is about 10 times greater than that for warehouses.

Savings Potential by Building Sector (New Construction vs. Existing Building)

The modeled savings from Table 4 are split across existing building and new construction sectors in Table 6 below.

Table 6 – Breakout of Average Annual Savings Potential for Existing Building and New Construction Scenarios for Modeled Building Types (2022 – 2030)

Building Sector, Building Type		Savings Potential with IAQP and air cleaning	
		Primary Energy (Quads / year)	**Total CO2 Emissions ($MMTCO_2$/yr)**
New Construction	Retail	0.064	3.8
	Warehouse	0.007	0.4
	Office	0.059	3.4
	School	0.034	2.0
	Subtotal	**0.164**	**9.5**
Existing Buildings (Retrofit)	Retail	0.205	12.1
	Warehouse	0.011	**0.6**
	Office	0.138	**7.9**
	School	0.228	**13.1**
	Subtotal	**0.583**	**33.7**
Total		**0.747**	**43.2**

78% of energy savings potential and avoided carbon emissions are associated with the modeled existing building sectors, leaving 22% of energy savings potential and avoided carbon emissions associated with modeled new construction sectors. These estimates align with a modeled floorspace for existing buildings of 58.2 billion ft^2, a modeled floorspace for new construction buildings of 1.2 billion ft^2, and an expectation of 2% of existing floorspace being replaced with new construction, each year.

Savings Potential by State - Existing Buildings (Retrofit)

Table 7 provides a summary of energy savings potential and carbon reduction potential for existing buildings (retrofit), for all modeled commercial building types, broken out by state.

Thermal energy is the heating and cooling energy only, not inclusive of other building energy end uses (i.e., lighting, equipment).

Table 7 - Annual Savings Potential by State, Existing Buildings (Retrofit), All Modeled Building Types (2022 – 2030)

			Baseline Case with no air cleaning (VRP)		Proposed Case with air cleaning (IAQP)		Savings Potential with IAQP and air cleaning	
State	ASHRAE Climate Zone(s)[23]	Population Weighted Degree Days[26] CDD_{65} HDD_{65}	Site Thermal Energy (GWh/year)	Site Thermal Carbon (Kilotonnes CO_2/year)	Site Thermal Energy (GWh/year)	Site Thermal Carbon (Kilotonnes CO_2/year)	Site Thermal Energy (GWh/year)	Site Thermal Carbon (Kilotonnes CO_2/year)
Alabama	3A	2062 2069	5,941	1,444	3,421	921	2,520	523
Alaska	7, 8	N/A	1,149	234	681	145	468	88
Arizona	2B, 3B, 4B, 5B	1687 3058	3,708	916	2,080	577	1,628	339
Arkansas	3A, 4A	1141 2472	2,129	462	1,149	269	980	193
California	2B, 3B, 4B, 5B, 6B, 3C, 4C	479 6633	20,539	4,846	12,020	3,125	8,519	1,721
Colorado	4B, 5B, 6B, 7B	857 5338	16,221	3,300	9,561	2,044	6,660	1,256
Connecticut	5A	1299 3910	5,442	1,104	3,141	670	2,301	435
Delaware	4A	3751 432	1,038	226	541	129	497	97
Florida	1A, 2A	1880 2296	12,408	3,103	6,905	1,862	5,503	1,240
Georgia	2A, 3A	1141 2472	19,453	4,718	11,519	3,107	7,934	1,610

[23] The ASHRAE Climate Zone map can be accessed at https://www.energy.gov/sites/prod/files/2015/10/f27/ba_climate_region_guide_7.3.pdf

[26] For this study, population weighted State degree days for 2020, using a reference temperature of 65°F, are provided for the 48 contiguous states. Source: https://data.globalchange.gov/dataset/noaa-heating-cooling-degree-day-data

			Baseline Case with no air cleaning (VRP)		Proposed Case with air cleaning (IAQP)		Savings Potential with IAQP and air cleaning	
State	**ASHRAE Climate Zone(s)[23]**	**Population Weighted Degree Days[26] CDD_{65} HDD_{65}**	**Site Thermal Energy (GWh/year)**	**Site Thermal Carbon (Kilotonnes CO_2/year)**	**Site Thermal Energy (GWh/year)**	**Site Thermal Carbon (Kilotonnes CO_2/year)**	**Site Thermal Energy (GWh/year)**	**Site Thermal Carbon (Kilotonnes CO_2/year)**
Hawaii	1	N/A	462	114	266	73	196	41
Idaho	5B, 6B	452 6714	3,638	738	2,102	450	1,535	289
Illinois	4A, 5A	981 5693	18,435	3,738	10,399	2,216	8,036	1,522
Indiana	4A, 5A	960 5238	8,334	1,693	4,675	998	3,659	695
Iowa	4A, 5A	862 6575	4,612	934	2,479	528	2,134	406
Kansas	4A, 5A	1390 4662	2,570	558	1,380	326	1,190	232
Kentucky	4A	1244 4023	3,528	768	1,861	441	1,668	327
Louisiana	2A, 3A	2515 1307	6,228	1,506	3,602	961	2,626	545
Maine	6A, 7A	375 7256	2,702	549	1,617	344	1,085	205
Maryland	4A	1310 4038	5,172	1,126	2,949	694	2,224	433
Massachusetts	5A	724 5639	12,772	2,594	6,981	1,498	5,791	1,097
Michigan	5A, 6A	696 6343	16,401	3,314	8,420	1,799	7,981	1,516
Minnesota	6A, 7A	494 8262	17,448	3,551	9,610	2,065	7,838	1,485
Mississippi	2A, 3A	2221 1920	2,101	507	1,255	332	847	175
Missouri	4A, 5A	1219 4784	5,322	1,154	2,927	687	2,395	467
Montana	6B	206 7891	1,400	284	851	182	549	102
Nebraska	5B	1030 5927	2,370	479	1,348	286	1,022	193
Nevada	3B, 5B	1981 3710	4,627	933	2,356	510	2,271	423
New Hampshire	5A, 6A	590 6688	2,165	438	1,262	268	903	171
New Jersey	4A, 5A	1024 4692	10,282	2,166	5,871	1,319	4,411	847
New Mexico	3B, 4B, 5B	1096 4251	1,754	380	946	221	808	159
New York	4A, 5A, 6A	755 5634	26,932	5,665	13,989	3,177	12,943	2,488
North Carolina	3A, 4A, 5A	1574 2843	20,583	5,121	11,745	3,204	8,839	1,917
North Dakota	6A, 7A	424 8695	1,129	229	690	146	439	83
Ohio	4A, 5A	957 5169	20,685	4,199	10,633	2,287	10,051	1,912
Oklahoma	3A, 4B	1712 3456	2,008	498	1,116	311	892	187
Oregon	5B, 4C	250 5261	3,125	675	1,744	405	1,381	269
Pennsylvania	4A, 5A, 6A	925 5162	17,895	3,701	9,645	2,124	8,250	1,576
Rhode Island	5A	774 5143	1,987	402	978	210	1,009	192
South Carolina	3A	1949 2252	7,532	1,841	4,305	1,170	3,226	671
South Dakota	5A, 6A	732 7264	1,155	234	698	149	457	86
Tennessee	3A, 4A	1359 3527	13,869	3,470	8,039	2,179	5,831	1,290
Texas	2A, 3A, 2B, 3B, 4B	2830 1531	14,940	3,689	8,719	2,400	6,220	1,289
Utah	3B, 5B, 6B	639 6662	4,339	880	2,432	518	1,907	362
Vermont	6A	461 7231	1,088	221	615	132	473	90
Virginia	4A	1281 3727	7,644	1,663	4,246	1,000	3,397	663

			Baseline Case with no air cleaning (VRP)		Proposed Case with air cleaning (IAQP)		Savings Potential with IAQP and air cleaning	
State	ASHRAE Climate Zone(s)[23]	Population Weighted Degree Days[26] CDD_{65} HDD_{65}	Site Thermal Energy (GWh/year)	Site Thermal Carbon (Kilotonnes CO_2/year)	Site Thermal Energy (GWh/year)	Site Thermal Carbon (Kilotonnes CO_2/year)	Site Thermal Energy (GWh/year)	Site Thermal Carbon (Kilotonnes CO_2/year)
Washington	5B, 6B, 4C	161 5607	5,795	1,238	3,290	754	2,504	484
West Virginia	4A, 5A	940 4731	1,551	324	849	189	702	136
Wisconsin	6A, 7A	613 7093	14,334	2,907	8,473	1,801	5,861	1,106
Wyoming	6B, 7B	312 7960	687	139	402	85	285	54
TOTAL			387,631	84,977	216,783	51,290	170,848	33,687
TOTAL			**1.32 Quads / Yr**	**84.97 MMTCO2/yr**	**0.740 Quads / Yr**	**51.29MTCO2/yr**	**0.583 Quads / Yr**	**33.68 MMTCO2/yr**

Table 7 suggests that the greatest opportunity for total energy savings and carbon reduction is in states with both a large existing building stock and a high number of combined heating and cooling degree days. States having larger existing building stock - including New York, Ohio, North Carolina, California, and Pennsylvania – have 2 to 3 times more energy and emissions reduction potential than smaller and less populated states. While potential is lower on an absolute basis in states with a smaller building stock, the savings potential on a percentage basis is comparable to larger states of similar climate.

Savings Potential by AIA Climate Zone – New Construction

Table 8 provides a summary of modeled thermal energy savings potential and thermal carbon reduction potential for new construction, for all modeled commercial building types, broken out by AIA climate zone.

Thermal energy is the heating and cooling energy only, not inclusive of other building energy end uses (i.e. lighting, equipment).

Unlike the existing building table above that breaks out results by state, this table breaks out the results by AIA climate zone. This is due to limited sources for estimating new construction floor area at a state-by-state level of granularity for the modeled building types.

Table 8 - Annual Savings Potential by AIA Climate Zone, New Construction, All Modeled Building Types (2022 – 2030)

AIA Climate Zone	Building Type	Baseline Case with no air cleaning (VRP)		Proposed Case with air cleaning (IAQP)		Savings Potential with IAQP and air cleaning	
		Thermal Energy (Quads / yr)	Thermal Carbon (Kilotonnes CO_2/yr)	Thermal Energy (Quads / yr)	Thermal Carbon (Kilotonnes CO_2/yr)	Thermal Energy	Thermal Carbon (Kilotonnes CO_2/yr)
(1) Northern states including parts of CO, NV, UT, WA, OR	Retail	0.020	1,226	0.011	697	0.009	529
	Warehouse	0.005	310	0.005	271	0.001	39
	Office	0.020	1,223	0.013	841	0.007	382
	School	0.019	1,135	0.013	816	0.006	319
	Subtotal	**0.065**	**3,894**	**0.043**	**2,625**	**0.022**	**1,269**
(2) Southern New England to NE, parts of the PNW, CO, NV, UT, NM, AZ	Retail	0.036	2,167	0.018	1,118	0.018	1,049
	Warehouse	0.008	478	0.007	415	0.001	63
	Office	0.033	1,984	0.018	1,171	0.014	813
	School	0.032	1,930	0.020	1,254	0.012	676
	Subtotal	**0.109**	**6,558**	**0.064**	**3,958**	**0.045**	**2,600**
(3) Mid-Atlantic to KS and parts of OK, NM, CA, and OR	Retail	0.024	1,504	0.012	790	0.012	714
	Warehouse	0.006	361	0.005	318	0.001	43
	Office	0.070	4,447	0.044	3,006	0.025	1,441
	School	0.016	1,054	0.011	714	0.006	340
	Subtotal	**0.115**	**7,366**	**0.072**	**4,828**	**0.044**	**2,537**
(4) Carolinas to AR and parts of OK, TX, NM, AZ, and CA	Retail	0.028	1,875	0.014	1,028	0.014	846
	Warehouse	0.010	693	0.008	595	0.002	98
	Office	0.021	1,503	0.013	1,043	0.008	459
	School	0.020	1,398	0.014	1,045	0.006	353
	Subtotal	**0.078**	**5,469**	**0.049**	**3,712**	**0.030**	**1,757**
(5) Southern US from SC to TX, HI, and parts of CA and AZ	Retail	0.020	1,293	0.009	671	0.011	621
	Warehouse	0.006	427	0.004	282	0.002	144
	Office	0.014	1,048	0.010	749	0.005	299

	School	0.017	1,305	0.013	1,008	0.005	298
	Subtotal	**0.058**	**4,073**	**0.035**	**2,710**	**0.023**	**1,362**
Total		**0.425**	**27,359**	**0.262**	**17,833**	**0.164**	**9,526**

Thermal Load Savings per 1,000 CFM Reduction in Outdoor air

Table 9 and Figure 5 show thermal load savings by replacing 1,000 CFM of outdoor air with cleaned indoor air, broken out by ASHRAE climate zone, for existing buildings. This metric can be used to quickly understand where conditioning outdoor air is the most energy and carbon intensive and to easily extrapolate potential savings for individual existing buildings.

Table 9 - Annual Thermal Load Savings by ASHRAE Climate Zone per 1,000 CFM Reduction in Minimum Outdoor air, All Modeled Existing Buildings

ASHRAE Climate Zone(s)	Reference Location	Annual Heating Load Reduction per 1,000 CFM OA Reduction (kBtu / 1000 cfm / year)	Annual Cooling Load Reduction per 1,000 CFM OA Reduction (kBtu / 1000 cfm / year)	Total Thermal Load Reduction per 1,000 CFM OA Reduction (kBtu / 1000 cfm / year)
1A	Honolulu International Airport, HI	0	38,558	38,558
2A	Tampa-MacDill AFB, FL	1,508	36,186	37,694
2B	Tucson-Davis Monthan AFB, AZ	1,704	17,225	18,929
3A	Atlanta-Hartsfield Jackson International Airport, GA	9,869	12,560	22,429
3B	El Paso International Airport, TX	7,178	12,223	19,401
3C	San Diego-Brown Field Municipal Airport, CA	2,106	2,191	4,297
4A	New York-John F Kennedy International Airport, NY	20,852	6,229	27,081
4B	Albuquerque International Sunport, NM	14,306	4,769	19,074
4C	Seattle Tacoma International Airport, WA	17,589	178	17,767
5A	Buffalo Niagara International Airport, NY	35,623	3,958	39,581
5B	Denver-Aurora-Buckley AFB, CO	15,858	2,162	18,020
6A	Rochester International Airport, MN	52,290	3,936	56,226
6B	Great Falls International Airport, MT	39,512	1,646	41,158
7A	International Falls International Airport, MN	61,618	1,906	63,524
8A	Fairbanks International Airport, AK	88,655	0	88,655

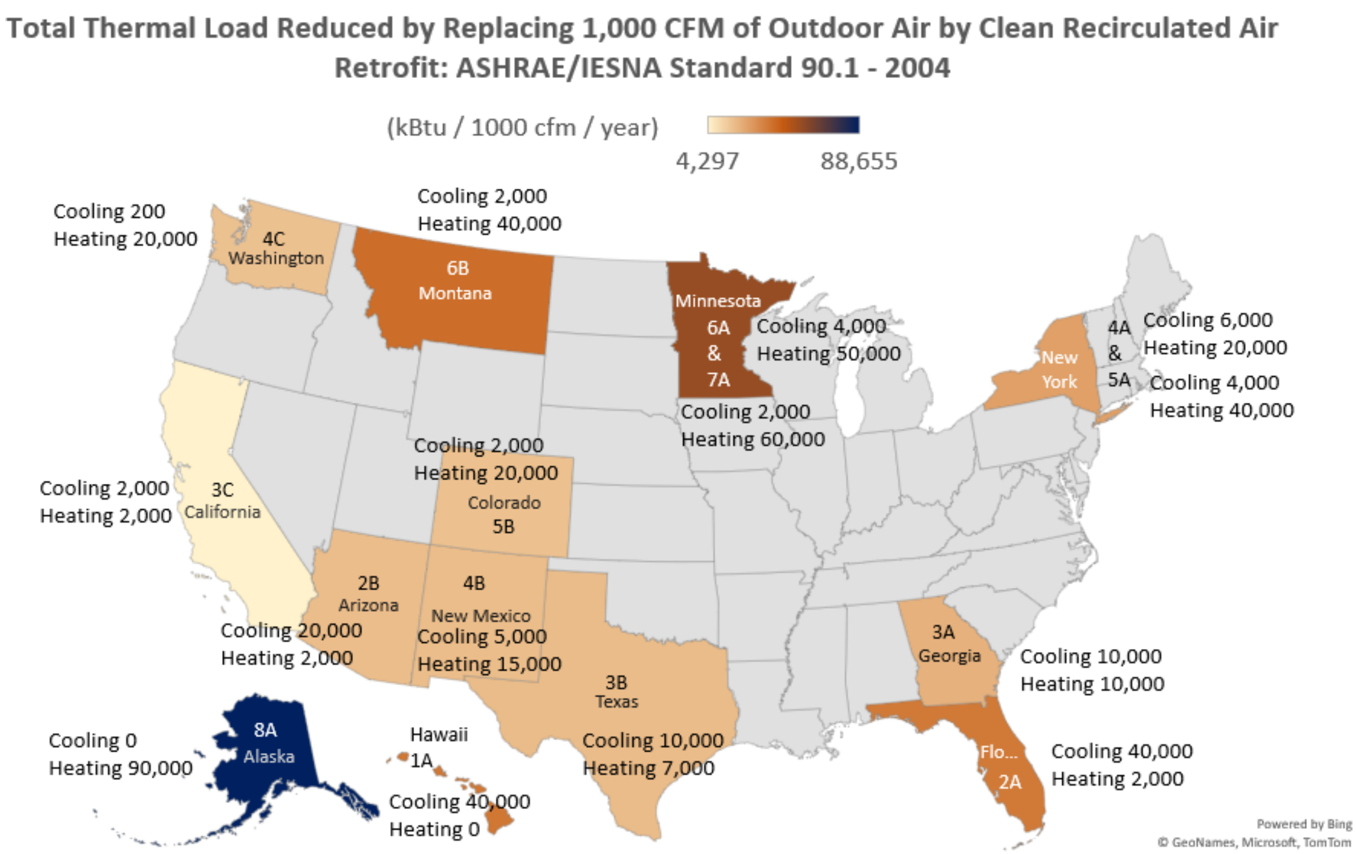


Figure 5 – Average Annual Energy Savings by ASHRAE Climate Zone per 1,000 CFM Reduction in Minimum Outdoor air (Existing Building)

Table 10 and Figure 6 show thermal load savings by replacing 1,000 CFM of outdoor air with cleaned indoor air, broken out by ASHRAE climate zone, for new construction. This metric can be used to quickly understand where conditioning outdoor air is the most energy and carbon intensive and to easily extrapolate potential savings for the design of new buildings.

Table 10 - Annual Thermal Load Savings by ASHRAE Climate Zone per 1,000 CFM Reduction in Minimum Outdoor air, All Modeled New Construction Buildings

ASHRAE Climate Zone(s)	Reference Location	Annual Heating Load Reduction per 1,000 CFM OA Reduction (kBtu / 1000 cfm / year)	Annual Cooling Load Reduction per 1,000 CFM OA Reduction (kBtu / 1000 cfm / year)	Total Thermal Load Reduction per 1,000 CFM OA Reduction (kBtu / 1000 cfm / year)
1A	Honolulu International Airport, HI	0	36,271	36,271
2A	Tampa-MacDill AFB, FL	1,019	32,932	33,950
2B	Tucson-Davis Monthan AFB, AZ	1,063	12,226	13,289
3A	Atlanta-Hartsfield Jackson International Airport, GA	8,496	11,263	19,759
3B	El Paso International Airport, TX	6,543	9,415	15,958
3C	San Diego-Brown Field Municipal Airport, CA	1,894	1,372	3,266
4A	New York-John F Kennedy International Airport, NY	18,011	8,092	26,103
4B	Albuquerque International Sunport, NM	9,631	3,745	13,376
4C	Seattle Tacoma International Airport, WA	11,742	119	11,861
5A	Buffalo Niagara International Airport, NY	28,994	2,867	31,861
5B	Denver-Aurora-Buckley AFB, CO	14,890	2,030	16,920
6A	Rochester International Airport, MN	38,179	2,437	40,616
6B	Great Falls International Airport, MT	28,547	1,189	29,736
7A	International Falls International Airport, MN	39,379	1,218	40,597
8A	Fairbanks International Airport, AK	47,561	0	47,561

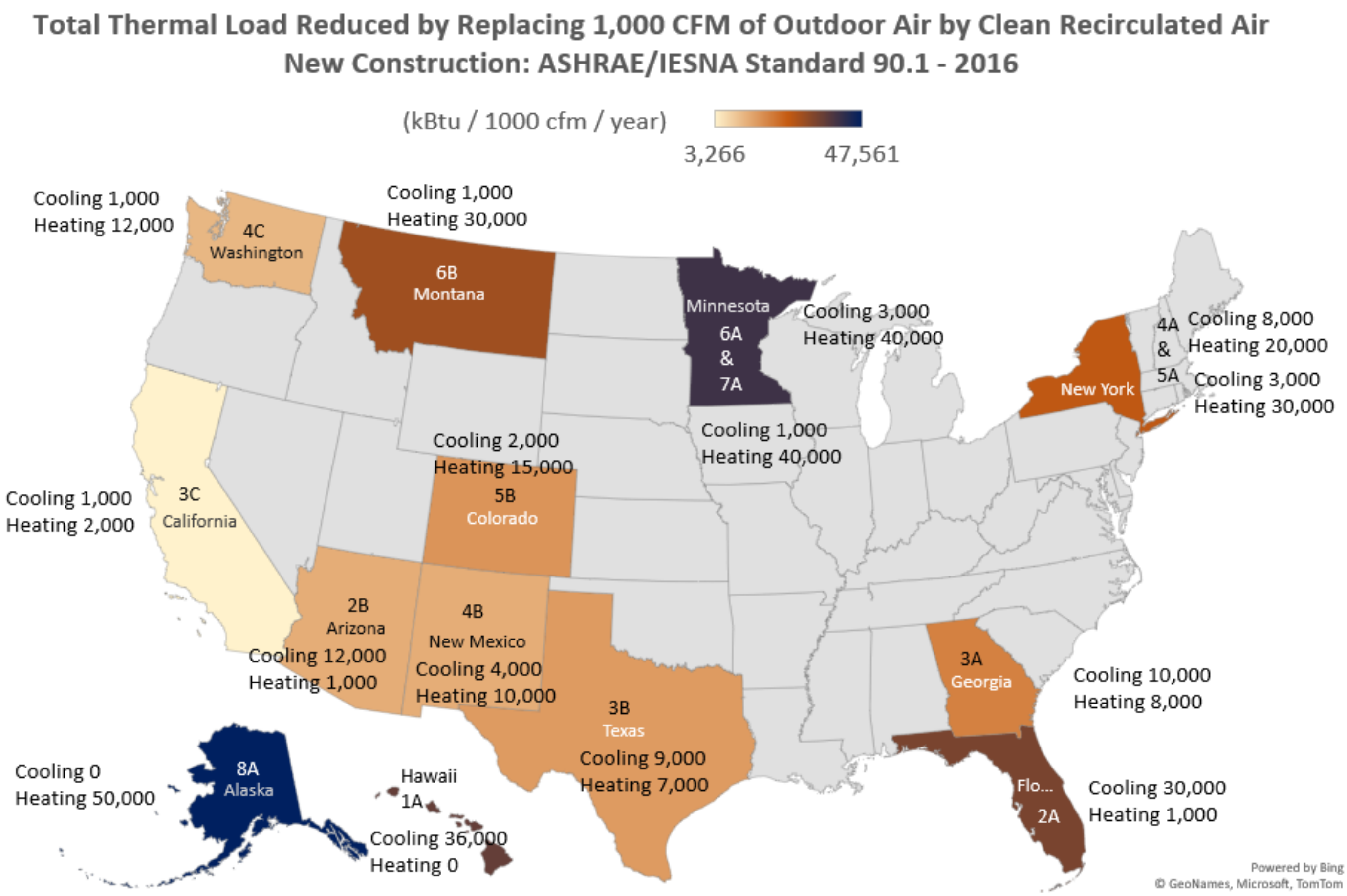


Figure 6 - Average Annual Energy Savings by ASHRAE Climate Zone per 1,000 CFM Reduction in Minimum Outdoor air (New Construction)

Conclusions

Never in our history have the dual goals of better indoor air quality and building decarbonization been more important. Properly designed and operating ventilation and air cleaning systems are critical to the health and wellbeing of our people. At the same time, climate change presents an existential challenge for the globe. As Bill Gates wrote in August of 2020, "To understand the kind of damage that climate change will inflict, look at COVID-19 and spread the pain out over a much longer period." According to Gates, "by 2060, climate change could be just as deadly as COVID-19, and by 2100 it could be five times as deadly."[24]

The good news is that we have many tools at our disposal to address both indoor air quality and climate change. In many cases, we just need to raise awareness and remove barriers to market adoption that result from inertia in slower moving industries such as buildings and HVAC. The use of ASHRAE's existing IAQP and sorbent air cleaning technology is one such example. Multiple studies, including this one, show the significant carbon emissions reduction potential of using the IAQP with sorbent air cleaning technology. The key to driving adoption is removing the roadblocks that exist in many of our current building standards and codes and design practices to allow for the widespread adoption of the IAQP to help us achieve indoor air quality and energy efficiency goals simultaneously.

Based on these findings and 2022 updates to Standard 62.1 that make the IAQP more robust and simpler to apply, there should be a focused effort to ensure that all building policies, standards, codes, and design practices encourage adoption of the IAQP.

[24] Gates, Bill. COVID-19 is awful. Climate change could be worse. August 4, 2020.

Appendix 1: Air Cleaning Efficiencies

This following table lists the air cleaning efficiency for enVerid's sorbent air cleaning technology for contaminants of concern identified in the ASHRAE Standard 62.1-2022. These efficiencies are based on ASHRAE Standard 145.2 and 52.2 tests performed by third-party labs.

Contaminant	Air Cleaning Efficiency	Third-Party Lab	Test Method
Acetaldehyde	99%	RTI International	ASHRAE 145.2
Acetone	99%	RTI International	ASHRAE 145.2
Benzene	87%	RTI International	ASHRAE 145.2
Dichloromethane	54%	RTI International	ASHRAE
Formaldehyde	99%	LMS Technologies	ASHRAE 145.2
Naphthalene	87%	RTI International	ASHRAE 145.2
Phenol	60%	RTI International	ASHRAE 145.2
Tetrachloroethylene	54%	RTI International	ASHRAE 145.2
Toluene	52%	RTI International	ASHRAE 145.2
1,1,1-trichloroethane	54%	RTI International	ASHRAE 145.2
Xylene, total	60%	RTI International	ASHRAE 145.2
Particulate Matter	MERV 11	RTI International	ASHRAE 52.2
Ozone	70%	RTI International	ASHRAE 145.2

Appendix 2: Data Sources and Analysis Tools Used

Data Sources

Several external data sources were used to inform the energy and emissions savings study. Brief descriptions of each source follow.

Name:
"Energy Performance Validation of a Gaseous Air Cleaning Technology for Commercial Buildings"

Location:
https://www.osti.gov/biblio/1600133-energy-performance-validation-gaseous-air-cleaning-technology-commercial-buildings

Description:
This report describes the results from several field validation studies of sorbent air scrubbing technology. The report suggests a 25% ventilation rate (a 75% reduction from the Ventilation Rate Procedure derived OA levels) represents a conservative representation of sorbent ventilation air scrubbing technology. The findings suggest that savings are highly dependent on the ability of existing systems to reduce outdoor air ventilation, HVAC equipment type and efficiency, and the climate in which the building is located.

Name:
"2019 Commercial Building Inventory"

Location:
https://data.openei.org/submissions/906

Description:
This data was used to develop a set of State level (by Building type) weighting factors used for disaggregating Scout Tool derived site energy and CO2 emissions savings for the Existing Building market segment. To accomplish this, the (5) .xlsb Commercial Building Inventory spreadsheets were combined into a single database and merged with data from the "Guide to Determining Climate Regions by County", described below.

The .xlsb files are unique in that they provided the best available estimates of modeled data on commercial buildings (type, vintage, and area) that can be aggregated for each U.S. State.

Name:
"Building America Best Practices Series Volume 7.3 - Guide to Determining Climate Regions by County"

Location: https://www.energy.gov/sites/prod/files/2015/10/f27/ba_climate_region_guide_7.3.pdf

Description:
Data from tables within this publication were used for analyzing the Retrofit Building market segment. The tabular data maps the Building America /AIA Climate Zone regions (used by the Scout Tool) to the ASHRAE / IECC Climate Zone regions (used by the OpenStudio/EnergyPlus models), at the US County level. This information is used to develop weighting factors for each Building Type in the Retrofit Building use-case, aggregated at the State level.

Analysis Tools

A sequential workflow using several open-source analysis tools were used to chained together to conduct the energy and emissions savings study. Brief descriptions of each analysis tool follow.

Name:
OpenStudio Application, Version 1.2

Location:
https://github.com/openstudiocoalition/OpenStudioApplication/releases

Description:
The OpenStudio Application is an open-source graphical user interface for creating, modifying, and simulating OpenStudio energy models. Version 1.2 of the OpenStudio Application uses OpenStudio v3.2 and EnergyPlus v9.5.

For this study, (2 Market Segments x 7 Building Types x 15 ASHRAE/IECC Climate Zones = 210 unique OpenStudio/EnergyPlus "Commercial Prototype" models were constructed. The annual heating and cooling end-use energy were extracted from each of these models and used to determine heating and cooling savings percentages associated with installing Ventilation Air Scrubbing technology. These saving percentages were incorporated in each custom Scout ECM.

Name:
OpenStudio "Create DOE Prototype Building" Measure

Location:
https://github.com/NREL/openstudio-model-articulation-gem/tree/develop/lib/measures/create_DOE_prototype_building

Description:
This OpenStudio measure was used to generate the 210 OpenStudio Commercial Prototype models described above. A Prototype Building model is created when this measure is applied within the OpenStudio Application. The OpenStudio measure requires 3 user-arguments to be provided – Building Type, ASHRAE/IECC Climate Zone and Reference ASHRAE Standard.

Building Type
Seven different types of DOE Prototype Buildings were generated:

1) Small Office
2) Large Office
3) Stand Alone Retail
4) Retail Strip Mall
5) Warehouse
6) Primary School
7) Secondary School

ASHRAE/IECC Climate Zone
The measure supports 15 of the available 16 ASHRAE/IECC Climate Zones (ASHRAE /IECC Climate Zone CZ-5C was not supported)

Reference ASHRAE Standard
ASHRAE Standard 90.1-2004 was used to represent the Existing Building Market Segment. ASHRAE 90.1-2016 was used to represent the New Construction Market Segment.

Name:
OpenStudio "Ideal Air Loads Zone HVAC" Measure

Location:
Available upon request.

Description:
This custom OpenStudio measure was created and used to extract the properties of the HVAC systems serving the 210 OpenStudio/EnergyPlus Commercial Prototype models described. The measure also removes and replaces each modeled HVAC system with an equivalent OpenStudio/EnergyPlus "IdealLoadsAirSystem". This type of HVAC system is used for scenarios where the annual performance of a building's heating and cooling loads need to be understood, without

modeling a fully described HVAC system. The IdealLoadsAirSystem is documented here: https://bigladdersoftware.com/epx/docs/9-5/input-output-reference/group-zone-forced-air-units.html#zonehvacidealloadsairsystem. The measure has no user arguments.

Name:

OpenStudio "variable_rate_procedure_outside_air_levels" Measure

Location:

Available upon request.

Description:

This custom OpenStudio measure was created and used to model the impact of sorbent ventilation technology. In consultation with sorbent ventilation technology design teams and NREL staff, the Ventilation Air Scrubbing technology was represented by reducing the levels of outdoor air (determined using the ASHRAE Standard 62.1 Ventilation Rate Procedure) by 75%, during periods of HVAC system operation.

To determine energy savings, the 210 baseline models were simulated twice – once using the full outdoor air rates and once using the 25% of VRP ventilation rate.

Name:

DOE SCOUT Software Tool

Location:

https://scout.energy.gov/home.html

Description:

The SCOUT software tool is a software program for estimating the national energy and CO2 impacts of building energy efficiency measures in the U.S. residential and commercial building sectors. SCOUT is a project of the U.S. Department of Energy Building Technologies Office (BTO) and is freely available for public use.

This analysis used SCOUT v0.6 (released on July 31, 2020). This version of SCOUT uses the EIA Annual Energy Outlook 2020 "Reference" case (https://www.eia.gov/outlooks/archive/aeo20/) to represent all baseline scenarios. To evaluate the Technical Potential of Ventilation Air Scrubbing technology, (50) custom Scout ECM definitions were created. All custom Scout ECM use a "Market Entry Year" of 2022.

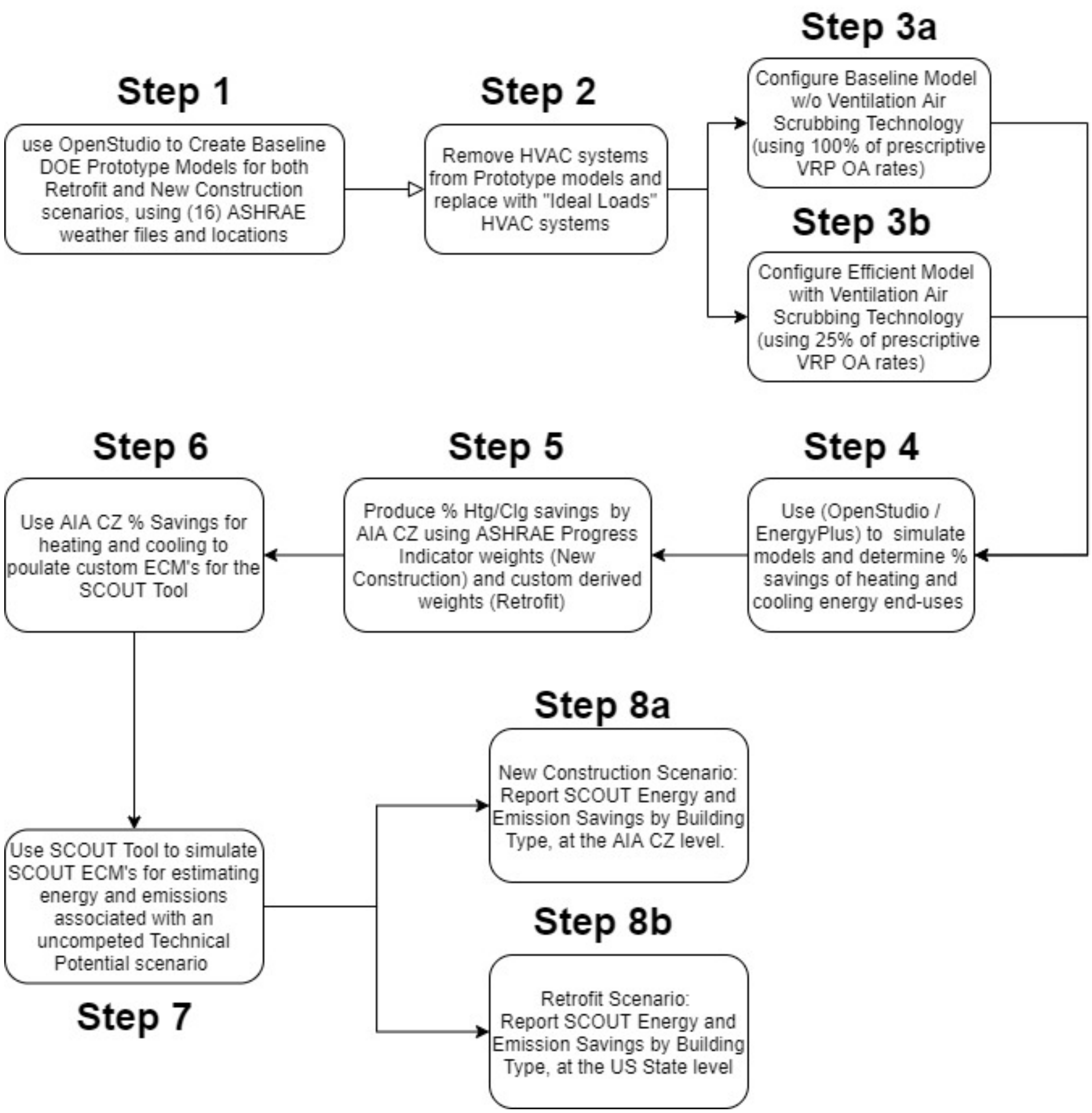
Appendix 3: Methodology Used

Methodology

Separate SCOUT savings analysis were performed for the New Construction Building Type and Retrofit Building Type scenarios.

Overall Workflow

The 8 steps used for the analysis of both the New Construction and Retrofit Scenarios are described below:



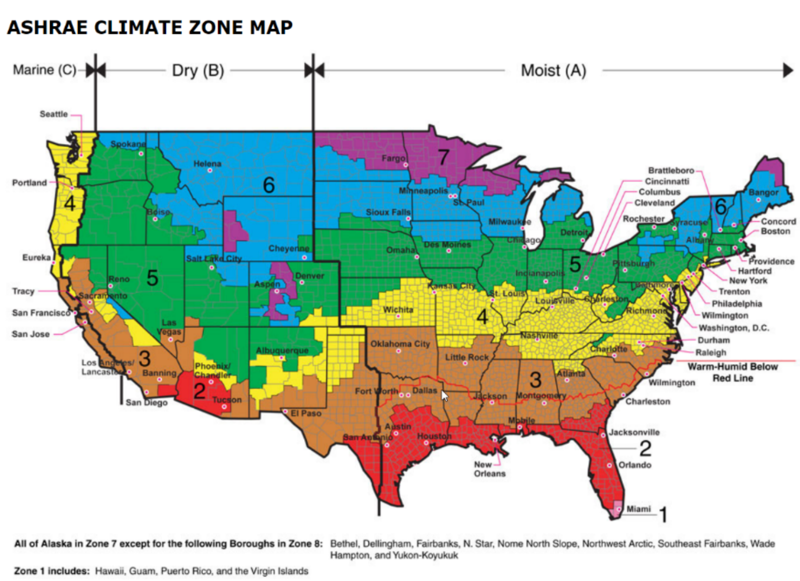
Step 1

In this step, OpenStudio/EnergyPlus models of (7) DOE Prototype Building were created for each of 15 ASHRAE Climate Zones. The (7) DOE Prototype Building Types map to the (5) Scout Commercial Sector Building Types as shown in the table below.

DOE 90.1-2004 Prototype (Retrofit) DOE 90.1-2016 Prototype (New Construction) Building Type	Scout Commercial Sector Represented
Large Office	Large Office
Small Office	Small Office
Stand Alone Retail	Mercantile / Service
Strip Mall	
Secondary School	Education
Primary School	
Refrigerated Warehouse	Warehouse

In situations where more than one DOE Prototype Building is mapped to a Single Scout Commercial Sector (Mercantile/Service and Education), savings percentages from the (2) DOE prototype buildings are averaged.

The "Create DOE Prototype" OpenStudio measure was used to create the set of model prototypes. A description of the inputs used for the DOE "Small Office" Prototype can be found in the Appendix.   Scorecard .xlsx files describing the detailed inputs of the other (6) DOE Commercial Prototypes can be found here: https://www.energycodes.gov/prototype-building-models Site energy usage of the DOE Prototype Buildings were modeled for 15 different ASHRAE/IECC Climate Zones. A map of the 15 ASHRAE Climate Zones and the table of the representative modeled weather sites (TYM3 files) for the climate zones are shown below.



ASHRAE / IECC Climate Zone	Modeled Weather File Location
1A	Honolulu International Airport, HI

2A	Tampa-MacDill AFB, FL
2B	Tucson-Davis Monthan AFB, AZ
3A	Atlanta-Hartsfield Jackson International Airport, GA
3B	El Paso International Airport, TX
3C	San Diego-Brown Field Municipal Airport, CA
4A	New York-John F Kennedy International Airport, NY
4B	Albuquerque International Sunport, NM
4C	Seattle Tacoma International Airport, WA
5A	Buffalo Niagara International Airport, NY
5B	Denver-Aurora-Buckley AFB, CO
6A	Rochester International Airport, MN
6B	Great Falls International Airport, MT
7A	International Falls International Airport, MN
8A	Fairbanks International Airport, AK

For the "New Construction" Scenario, a review of Statewide energy codes was performed using data from https://www.energycodes.gov/status. The results are summarized below. In consultation with sorbent ventilation technology design teams, PSD determined that using ASHRAE 90.1-2016 as the modeling standard for the DOE Prototype New Construction Buildings would be a conservative choice for estimating annual heating and cooling loads.

Referenced Statewide Energy Code to be used for modeling "New Construction" Buildings						
90.1-2019	90.1-2016	90.1-2013	90.1-2010	90.1-2007	90.1-2004	None
CA	FL	AL	DE	AK	KS	AK
	ID	CO	IA	AR		AZ
	IL	CT	KY	IN		MO
	MD	DC	MS	LA		SD
	MN	GA	OH	ME		WY
	MT	HI	TN	ND		
	NJ	MA	WV	NE		
	NM	MI		SC		
	NV	NC				
	OR	NH				
	TX	NY				
	UT	OK				
	WA	PA				
		RI				
		VA				
		VT				
		WI				

For the "Retrofit" Scenario case, PSD determined the regulated performance values (Envelope, Lighting, etc.) prescribed within ASHRAE 90.1-2004 to be a conservative determination of the annual heating and cooling loads.

Subsequent steps involve applying two OpenStudio measures to each DOE Prototype Model, created for each Climate Zone.

Step 2

The first measure removes the Prototype Model's detailed HVAC systems and replaces them with "Ideal" HVAC systems. The Ideal HVAC systems are configured to have infinite heating and cooling capacity, and also include airside economizers for a first stage of cooling. Since it effectively operates as an 100% efficient HVAC system, using Ideal HVAC systems allows us to quantify the ***heating*** and ***cooling*** “load” reductions associated with installing Ventilation Air Scrubbing technology.

Step 3

A second measure is applied twice to the output of Step 2, creating two separate energy models – one representing the baseline (using 100% of the Ventilation Rates prescribed by ASHRAE Standard 62, Variable Rate Procedure) and one defining the improvement (ventilation air scrubbing technology), proxied by reducing the 100% Variable Rate procedure values by 75%.

The table below shows the total modeled ventilation rates used within the DOE Prototype Buildings for the both the New Construction and Retrofit Building Scenarios. Detailed Zone-By-Zone ASHRAE Standard 62 VRP calculations for each Prototype model are documented in the Appendix.

Modeled Outdoor Air - **New Construction** Scenario using ASHRAE Standard 90.1-2016 and ASHRAE Standard 62.1-2016			Total Outdoor air Ventilation (cfm)		Total Outdoor air Ventilation (cfm/ft2)	
Building Type	Area (ft^2)	Total Occupants	VRP Baseline	75% Reduction	VRP Baseline	75% Reduction
Large Office	498,637	2,429	42,061	10,515	0.084	0.021
Secondary School	210,908	6,095	88,399	22,100	0.419	0.105
Primary School	73,966	1,478	26,886	6,721	0.363	0.091
Warehouse	52,050	13	3,187	797	0.061	0.015
Retail Stand Alone	24,695	370	5,281	1,320	0.214	0.053
Retail Strip Mall	22,500	337	5,231	1,308	0.233	0.058
Small Office	5,503	28	468	117	0.085	0.021

Modeled Outdoor Air – **Retrofit** Scenario using ASHRAE Standard 90.1-2004 and ASHRAE Standard 62.1-1999			Total Outdoor air Ventilation (cfm)		Total Outdoor air Ventilation (cfm/ft2)	
Building Type	Area (ft^2)	Total Occupants	VRP Baseline	75% Reduction	VRP Baseline	75% Reduction
Large Office	498,637	2,429	48,572	12,143	0.097	0.024
Secondary School	210,908	6,095	110,728	27,682	0.525	0.131
Primary School	73,966	1,478	30,550	7,638	0.413	0.103
Warehouse	52,050	13	2,730	683	0.052	0.013
Retail Stand Alone	24,695	370	6,795	1,699	0.275	0.069
Retail Strip Mall	22,500	337	6,750	1,687	0.300	0.075
Small Office	5,503	28	550	138	0.100	0.025

Step 4

For each DOE Prototype Building in each ASHRAE Climate zone, the two variants were then simulated using OpenStudio v3.1/EnergyPlus v9.5, and the annual Heating and Cooling energy used by the ideal HVAC systems were used to calculate a Site Energy savings percentage for the heating and cooling energy end-uses.

$$Htg\ Savings\%_{<CZ>,<BuildingType>} = \frac{Annual\ Htg\ Load\ using\ 100\%\ VRP - Annual\ Htg\ Load\ using\ 25\%\ VRP}{Annual\ Htg\ Load\ using\ 100\%\ VRP}$$

$$Clg\ Savings\%_{<CZ>,<BuildingType>} = \frac{Annual\ Clg\ Load\ using\ 100\%\ VRP - Annual\ Clg\ Load\ using\ 25\%\ VRP}{Annual\ Clg\ Load\ using\ 100\%\ VRP}$$

An additional 10% reduction of the calculated heating and cooling savings was applied to to account for the energy (fan and regeneration) consumed by the ventilation air scrubbing technology.

The tables below describe the resulting savings percentages for the DOE Small Office Prototype models, for each simulated ASHRAE Climate Zone, for both the **Retrofit** and **New Construction** Scenarios. In addition to the % savings, the net savings in units of annual Site MMBtu and KBtu/conditioned floor area are also provided.

DOE Prototype New Construction Scenario	ASHRAE / IECC Climate Zone	Annual Heating Load Savings (mmBTU)	Annual Heating Load Savings (KBtu/ft2)	Annual Cooling Load Savings (mmBTU)	Annual Cooling Load Savings (KBtu/ft2)
Small Office	1A	0	0.00	20.91	3.80
Small Office	2A	0.32	0.06	22.51	4.09
Small Office	2B	0.49	0.09	7.48	1.36
Small Office	3A	5.84	1.06	7.77	1.41
Small Office	3B	2.54	0.46	3.32	0.60
Small Office	3C	0.48	0.09	0.63	0.11
Small Office	4A	13.45	2.44	4.91	0.89
Small Office	4B	4.91	0.89	1.5	0.27
Small Office	4C	10.41	1.89	0.1	0.02
Small Office	5A	19.15	3.48	2.15	0.39
Small Office	5B	10.93	1.99	1.37	0.25
Small Office	6A	25.07	4.56	2.11	0.38
Small Office	6B	18.76	3.41	0.65	0.12
Small Office	7	30.4	5.52	1.03	0.19
Small Office	8	41.49	7.54	0.01	0.00

DOE Prototype Retrofit Building Scenario	ASHRAE / IECC Climate Zone	Annual Heating Load Savings (mmBTU)	Annual Heating Load Savings (KBtu/ft2)	Annual Cooling Load Savings (mmBTU)	Annual Cooling Load Savings (KBtu/ft2)
Small Office	1A	0	0.00	25.28	4.59
Small Office	2A	0.57	0.10	27.22	4.95
Small Office	2B	0.78	0.14	8.94	1.62
Small Office	3A	6.03	1.10	9.45	1.72
Small Office	3B	2.12	0.39	4.18	0.76
Small Office	3C	0.46	0.08	0.84	0.15
Small Office	4A	17.24	3.13	5.9	1.07
Small Office	4B	7.56	1.37	1.99	0.36
Small Office	4C	14.15	2.57	0.13	0.02
Small Office	5A	23.71	4.31	2.62	0.48

Small Office	5B	14.35	2.61	1.68	0.31
Small Office	6A	30.5	5.54	2.56	0.47
Small Office	6B	23.48	4.27	0.81	0.15
Small Office	7	37.55	6.82	1.26	0.23
Small Office	8	50.2	9.12	0.01	0.00

Step 5

For the both the New Construction and Retrofit Building Scenarios, these savings percentages were further aggregated up to the AIA Climate Zone Level required by Scout. The New Construction Scenario used published “Progress Indicator” weighting factors used by the ASHRAE 90.1 subcommittee for determining national cost effectiveness. The Retrofit Scenario generated custom weighting based on existing building floorspace developed by merging and analyzing the “2019 Commercial Building Inventory” and “Building America Best Practices Series Volume 7.3 - Guide to Determining Climate Regions by County” documents.

Heating and Cooling Savings % for both the New Construction and Retrofit Scenarios for the “Small Office” sector are shown below. A complete set of the “Progress Indicator” weightings and the weighting factors used for existing buildings can be found in the appendix.

90.1-2016 DOE Prototype New Construction Scenario Building Sector	AIA CZ	Cooling Load % Savings	Heating Load % Savings
Small Office	1	8.78%	33.57%
Small Office	2	7.81%	39.27%
Small Office	3	10.39%	46.7%
Small Office	4	9.87%	48.26%
Small Office	5	13.41%	51.95%

90.1-2004 DOE Prototype Retrofit Scenario Building Sector	AIA CZ	Cooling % Savings	Heating % Savings
Small Office	1	7.64	28.25%
Small Office	2	8.73	29.65
Small Office	3	9.52%	40.43%
Small Office	4	11.58%	41.86%
Small Office	5	10.33%	49.40%

A complete set of the heating and cooling % savings for both the New Construction and Existing Building Scenarios can be found in the appendix. Negative Heating or Cooling Savings from the Ventilation Air Scrubbing technology were ‘zeroed’ out. This is because when installed, the Control Strategy for the Ventilation Air Scrubbing technology is configured to not operate the ventilation air scrubbing equipment under conditions which it would provide a ‘negative’ savings (relative to an ASHRAE VRP based ventilation Baseline).

Custom developed “Weighting Factors” for the Retrofit Scenario are listed in the Appendix.

Step 6

In this step50 Custom Scout ECMs were created – 25 for the New Construction Scenario and 25 for the Existing Building Scenario. These percentages of heating and cooling 'load reduction' values from Step 5 are used directly when creating the Scout Custom ECMs. The Scout Tool has a single category for the "Education" Building sector – to create these Scout ECMs, savings % of the "Primary School" and "Secondary School" Building types were averaged. The Scout Tool has a single category for the "Mercantile/Service" Building sector – to create these Scout ECMs, savings % of the "Stand Alone Retail" and "Retail Strip Mall" Building types were averaged.

An example Scout custom ECM for the Small Office Segment, AIA Climate Zone 1, New Construction Scenario is described below. All Scout ECMs are available for review on the project's GitLab site.

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{
  "name": "Small Office CZ1 NC Enverid",
  "climate_zone": "AIA_CZ1",
  "bldg_type": ["small office"],
  "structure_type": "new",
  "end_use": ["heating", "cooling"],
  "fuel_type": "all",
  "technology": "all",
  "market_entry_year": 2022,
  "market_entry_year_source": {
    "notes": "Based on Enverid Business Planning",
    "source_data": null},
  "market_exit_year": null,
  "market_exit_year_source": null,
  "energy_efficiency": {
      "heating": 0.373,
      "cooling": -0.1086},
  "energy_efficiency_units": "relative savings (constant)",
  "energy_efficiency_source": {
    "note": "Based on results from 25% reduction in Design OA values derived from ASHRAE Standard
    62.1-2019 using VRP method, using OpenStudio 90.1-2016 Large Office Prototypical modeling",
    "source_data": [{
      "title": "Energy and Emissions Performance of HLR Technology",
      "author": "Chris Balbach, Emmanuel Omere",
      "organization": "Performance Systems Development of NY, LLC",
      "year": 2021,
      "pages": null,
      "URL": "https://gitlab.com/Balbach/enverid_hlr_savings_analysis"},
      {
      "title": "Energy Performance Validation of a Gaseous Air Cleaning Technology for Commercial
      Buildings",
      "author": "Michael Deru and Jason DeGraw",
      "organization": "National Renewable Energy Lab",
      "year": 2020,
      "pages": [47],
      "URL": "
      https://www.osti.gov/biblio/1600133-energy-performance-validation-gaseous-air-cleaning-technology-c
      ommercial-buildings"}
      ]},
  "installed_cost": 36,
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      "author": "Unknown",
      "organization": "enVerid",
      "year": 2021,
      "pages": null,
      "URL": "http://www.enverid.com"}},
  "product_lifetime": 30,
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  "product_lifetime_source": {
    "notes": "Assumed limited by lifetime of replacement cartridges",
    "source_data": null},
  "measure_type": "add-on",
  "fuel_switch_to": null,
  "market_scaling_fractions": null,
  "market_scaling_fractions_source": null,
  "_description": "S",
  "_notes": null,
  "_added_by": {
    "name": "Chris Balbach",
    "organization": "Performance Systems Development of NY, LLC",
    "email": "cbalbach@psdconsulting.com",
    "timestamp": "2021-08-02 115:44:58 EST"
  },
  "_updated_by": {
    "name": null,
    "organization": null,
    "email": null,
    "timestamp": null
  }
}
```


Step 7

In this step the Scout Tool (v0.6) was used to simulate the 50 Custom Scout ECMs created in Step 6. The Scout Tool analysis generate boteh site energy savings and associated avoided carbon emissions, from a "Market Entrance Year" of 2020, until the year 2050. The analysis of the 540 custom ECMs were run to determine the 'Un-Competed' Technical Potential of Ventilation Air Scrubbing Technologies.

An generic example of the Scout Tool generated Site Thermal CO2 Emissions (in units of Megatons) and Site Thermal Energy savings (in units of Quads) for the New Construction Building Scenario, for the Small Office Sector can be found below.

Site Thermal CO2 Savings (Mt)	**Small Office**	**Small Office**	**Small Office**	**Small Office**	**Small Office**
Climate Zones	AIA CZ1	AIA CZ2	AIA CZ3	AIA CZ4	AIA CZ5
2022 (Mt)	0.117564	0.216342	0.100029	0.147939	0.128441
2023 (Mt)	0.132602	0.244558	0.113063	0.166581	0.142335
2024 (Mt)	0.147144	0.271893	0.125839	0.184931	0.156480
2025 (Mt)	0.160761	0.297494	0.137442	0.201440	0.168716
2026 (Mt)	0.174226	0.322923	0.149556	0.219462	0.183485
2027 (Mt)	0.187191	0.347411	0.160886	0.236094	0.196688
2028 (Mt)	0.200086	0.371781	0.172146	0.252615	0.209919
2029 (Mt)	0.213063	0.396289	0.183391	0.268939	0.223020
2030 (Mt)	0.226061	0.420744	0.194376	0.282577	0.235785

Site Thermal Energy Savings (Quads)	**Small Office**	**Small Office**	**Small Office**	**Small Office**	**Small Office**
Climate Zones	AIA CZ1	AIA CZ2	AIA CZ3	AIA CZ4	AIA CZ5
2022 (Quads)	0.00211	0.00382	0.00171	0.00249	0.00204
2023 (Quads)	0.00239	0.00434	0.00195	0.00283	0.00230
2024 (Quads)	0.00266	0.00483	0.00218	0.00316	0.00254
2025 (Quads)	0.00291	0.00530	0.00240	0.00347	0.00278
2026 (Quads)	0.00315	0.00575	0.00260	0.00376	0.00300
2027 (Quads)	0.00339	0.00619	0.00280	0.00406	0.00323
2028 (Quads)	0.00362	0.00663	0.00300	0.00435	0.00345
2029 (Quads)	0.00386	0.00707	0.00321	0.00465	0.00368
2030 (Quads)	0.00410	0.00752	0.00341	0.00489	0.00391

Step 8

In this step the energy and emissions savings generated by the Scout Tool were post-processed for final presentation. For both the New Construction and Retrofit scenarios, savings of both Site Energy and CO2 Emissions were generated by the Scout Tool at the AIA Climate Zone Level, for each Building Sector.

For the Retrofit scenario, data from the "2019 Commercial Building Survey" were used to further disaggregate the savings to a State Level. For State level Site Energy and CO2 savings, the Scout supported Building Types of "Large Office" and "Small Office" were combined into a single category available in the "2019 Commercial Building Survey" – "Office".

A full set of electronic data files describing the Site Energy and CO2 emissions savings for all Scout Building Sectors, for all Scout AIA Climate Zones sectors and for all US States (Retrofit Building Scenario only) are available from the project repository, upon request.

Appendix 4: Detailed Savings Potential By Scenario, Location and Sector

Savings Potential by Commercial Sectors – Large Office, Year 2022

			Baseline Case		Proposed Case		Savings Potential	
Building Type	**Scenario**	**AIA Climate Zone**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**
Large Office	Retrofit	AIA CZ1	0.051716	3.3048	0.03738	2.4839	0.01434	0.8209
Large Office	Retrofit	AIA CZ2	0.093308	5.9474	0.06435	4.2759	0.02896	1.6715
Large Office	Retrofit	AIA CZ3	0.068915	4.5402	0.04665	3.2582	0.02227	1.2820
Large Office	Retrofit	AIA CZ4	0.042149	3.1434	0.03058	2.4403	0.01157	0.7030
Large Office	Retrofit	AIA CZ5	0.025360	2.0106	0.01960	1.6497	0.00576	0.3609
Large Office	New Construction	AIA CZ1	0.007037	0.449680	0.00455	0.309331	0.002480	0.1403
Large Office	New Construction	AIA CZ2	0.011787	0.751270	0.00658	0.452822	0.005205	0.298448
Large Office	New Construction	AIA CZ3	0.008651	0.569960	0.00513	0.368213	0.003517	0.201747
Large Office	New Construction	AIA CZ4	0.006632	0.494568	0.00384	0.331167	0.002789	0.163401
Large Office	New Construction	AIA CZ5	0.004591	0.363957	0.00329	0.282559	0.001298	0.081397

Savings Potential by Commercial Sectors – Large Office, Year 2022 – 2030

			Baseline Case		Proposed Case		Savings Potential	
Building Type	**Scenario**	**AIA Climate Zone**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**
Large Office	Retrofit	AIA CZ1	0.423275	26.3212	0.306512	19.71041	0.116762	6.610794
Large Office	Retrofit	AIA CZ2	0.76595	47.53701	0.529122	34.02313	0.236828	13.51388
Large Office	Retrofit	AIA CZ3	0.567407	36.15532	0.384957	25.78671	0.18245	10.36861
Large Office	Retrofit	AIA CZ4	0.343008	24.31631	0.249658	18.77006	0.093349	5.54625
Large Office	Retrofit	AIA CZ5	0.206616	15.46001	0.160271	12.63201	0.046346	2.827998
Large Office	New Construction	AIA CZ1	0.095867	5.94405	0.062314	4.064749	0.033552	1.879301
Large Office	New Construction	AIA CZ2	0.161907	10.01908	0.090772	5.986846	0.071135	4.032233
Large Office	New Construction	AIA CZ3	0.120196	7.63064	0.071632	4.883237	0.048564	2.747403
Large Office	New Construction	AIA CZ4	0.091048	6.417301	0.053242	4.243337	0.037806	2.173964
Large Office	New Construction	AIA CZ5	0.061752	4.590366	0.044565	3.542913	0.017187	1.047452

Savings Potential by Commercial Sectors – Small Office, Year 2022

			Baseline Case		Proposed Case		Savings Potential	
Building Type	**Scenario**	**AIA Climate Zone**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**
Small Office	Retrofit	AIA CZ1	0.040352	2.45615	0.029645	1.834366	0.010707	0.6217799
Small Office	Retrofit	AIA CZ2	0.068849	4.21189	0.049556	3.079982	0.019293	1.1319087
Small Office	Retrofit	AIA CZ3	0.028620	1.96584	0.019006	1.373098	0.009614	0.5927407
Small Office	Retrofit	AIA CZ4	0.042882	3.24587	0.029584	2.371015	0.013298	0.8748572
Small Office	Retrofit	AIA CZ5	0.026562	1.99933	0.017375	1.417476	0.009188	0.5818495
Small Office	New Construction	AIA CZ1	0.006345	0.386187	0.004233	0.268623	0.002112	0.117564
Small Office	New Construction	AIA CZ2	0.009689	0.592708	0.005867	0.376366	0.003822	0.216342
Small Office	New Construction	AIA CZ3	0.004294	0.294946	0.002579	0.194917	0.001715	0.100029
Small Office	New Construction	AIA CZ4	0.007300	0.552539	0.004812	0.4046	0.002488	0.147939
Small Office	New Construction	AIA CZ5	0.005115	0.385024	0.003072	0.256583	0.002043	0.128441

Savings Potential by Commercial Sectors – Small Office, Year 2022 - 2030

			Baseline Case		Proposed Case		Savings Potential	
Building Type	**Scenario**	**AIA Climate Zone**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**
Small Office	Retrofit	AIA CZ1	0.326684	19.49973	0.240153	14.53658	0.08653	4.963145
Small Office	Retrofit	AIA CZ2	0.558994	33.54884	0.402574	24.48596	0.15642	9.062873
Small Office	Retrofit	AIA CZ3	0.232713	15.39419	0.154881	10.69957	0.077832	4.694627
Small Office	Retrofit	AIA CZ4	0.346257	24.86434	0.239329	18.05949	0.106928	6.804846
Small Office	Retrofit	AIA CZ5	0.21329	15.26675	0.140085	10.75327	0.073205	4.513472
Small Office	New Construction	AIA CZ1	0.0850070	5.062837	0.056819	3.504139	0.028188	1.558698
Small Office	New Construction	AIA CZ2	0.1308032	7.832909	0.079364	4.943473	0.051439	2.889436
Small Office	New Construction	AIA CZ3	0.0587276	3.868031	0.035458	2.531303	0.023269	1.336728
Small Office	New Construction	AIA CZ4	0.0995797	7.105934	0.065923	5.145355	0.033656	1.960579
Small Office	New Construction	AIA CZ5	0.0680655	4.843496	0.041132	3.198626	0.026933	1.64487

Savings Potential by Commercial Sectors – Mercantile / Service, Year 2022

			Baseline Case		Proposed Case		Savings Potential	
Building Type	**Scenario**	**AIA Climate Zone**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**
Mercantile / Service	Retrofit	AIA CZ1	0.077047	4.718277	0.0428259	2.699285	0.034217	2.0189917

Mercantile / Service	Retrofit	AIA CZ2	0.146444	8.900043	0.0781447	4.867692	0.068300	4.0323509
Mercantile / Service	Retrofit	AIA CZ3	0.085645	5.556656	0.0452017	3.084356	0.040443	2.4722997
Mercantile / Service	Retrofit	AIA CZ4	0.092139	6.490676	0.0500779	3.803099	0.042062	2.6875772
Mercantile / Service	Retrofit	AIA CZ5	0.059697	4.108161	0.0311043	2.347688	0.028594	1.7604735
Mercantile / Service	New Construction	AIA CZ1	0.013788	0.844426	0.0076378	0.482664	0.006150	0.361762
Mercantile / Service	New Construction	AIA CZ2	0.024504	1.489225	0.0123110	0.77357	0.012193	0.715655
Mercantile / Service	New Construction	AIA CZ3	0.016169	1.049091	0.0088262	0.601825	0.007344	0.447266
Mercantile / Service	New Construction	AIA CZ4	0.019139	1.348262	0.0094469	0.754328	0.009693	0.593934
Mercantile / Service	New Construction	AIA CZ5	0.013810	0.950361	0.0064141	0.501391	0.007396	0.448970

Savings Potential by Commercial Sectors – Mercantile / Service, Year 2022 - 2030

			Baseline Case		Proposed Case		Savings Potential	
Building Type	**Scenario**	**AIA Climate Zone**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**
Mercantile / Service	Retrofit	AIA CZ1	0.619022	37.24439	0.344165	21.20645	0.274857	16.03794
Mercantile / Service	Retrofit	AIA CZ2	1.181035	70.61931	0.630202	38.45383	0.550833	32.16548
Mercantile / Service	Retrofit	AIA CZ3	0.689193	43.5832	0.363734	23.98665	0.325458	19.59654
Mercantile / Service	Retrofit	AIA CZ4	0.730704	49.24318	0.397043	28.54388	0.333661	20.69929
Mercantile / Service	Retrofit	AIA CZ5	0.470158	31.10677	0.245491	17.59014	0.224667	13.51663
Mercantile / Service	New Construction	AIA CZ1	0.183761	11.03289	0.1018211	6.270404	0.081940	4.762486
Mercantile / Service	New Construction	AIA CZ2	0.326838	19.50499	0.1642053	10.06527	0.162633	9.439722
Mercantile / Service	New Construction	AIA CZ3	0.214671	13.53399	0.1171834	7.692178	0.097487	5.841813
Mercantile / Service	New Construction	AIA CZ4	0.251731	16.87345	0.1241975	9.255975	0.127534	7.617478
Mercantile / Service	New Construction	AIA CZ5	0.176625	11.63219	0.0823197	6.040021	0.094305	5.592166

Savings Potential by Commercial Sectors – Education, Year 2022

			Baseline Case		Proposed Case		Savings Potential	
Building Type	**Scenario**	**AIA Climate Zone**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**
Education	Retrofit	AIA CZ1	0.074315	4.611334	0.029804	1.999348	0.044511	2.6119862
Education	Retrofit	AIA CZ2	0.138621	8.496765	0.048356	3.226605	0.090265	5.2701602
Education	Retrofit	AIA CZ3	0.066448	4.436945	0.024364	1.913051	0.042084	2.5238932
Education	Retrofit	AIA CZ4	0.070098	5.368812	0.032181	2.934111	0.037917	2.4347007
Education	Retrofit	AIA CZ5	0.054745	4.443033	0.027145	2.588066	0.027600	1.8549668

Education	New Construction	AIA CZ1	0.012427	0.771113	0.008740	0.556880	0.003687	0.214233
Education	New Construction	AIA CZ2	0.021117	1.294340	0.013403	0.846035	0.007714	0.448305
Education	New Construction	AIA CZ3	0.011166	0.745559	0.007171	0.511701	0.003995	0.233858
Education	New Construction	AIA CZ4	0.013520	1.035476	0.009378	0.785370	0.004141	0.250106
Education	New Construction	AIA CZ5	0.012185	0.988922	0.008818	0.772549	0.003367	0.216373

Savings Potential by Commercial Sectors – Education, Year 2022 – 2030

			Baseline Case		**Proposed Case**		**Savings Potential**	
Building Type	**Scenario**	**AIA Climate Zone**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**
Education	Retrofit	AIA CZ1	0.607718	36.82144	0.243686	15.76036	0.364032	21.06108
Education	Retrofit	AIA CZ2	1.135598	68.23236	0.39596	25.52797	0.739638	42.70439
Education	Retrofit	AIA CZ3	0.544795	35.06391	0.199292	14.72673	0.345502	20.33717
Education	Retrofit	AIA CZ4	0.56836	40.99883	0.259829	21.86003	0.308532	19.13881
Education	Retrofit	AIA CZ5	0.44124	33.49272	0.218014	19.09861	0.223225	14.39411
Education	New Construction	AIA CZ1	0.1690550	10.2137	0.118889	7.339588	0.118889	0.050166
Education	New Construction	AIA CZ2	0.2897704	17.36781	0.183894	11.28613	0.183894	0.105877
Education	New Construction	AIA CZ3	0.1479861	9.484682	0.094947	6.429308	0.094947	0.053039
Education	New Construction	AIA CZ4	0.1756519	12.58408	0.121556	9.405388	0.121556	0.054096
Education	New Construction	AIA CZ5	0.1559497	11.74705	0.112634	9.069111	0.112634	0.043316

Savings Potential by Commercial Sectors – Warehouse, Year 2022

			Baseline Case		Proposed Case		Savings Potential	
Building Type	**Scenario**	**AIA Climate Zone**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**
Warehouse	Retrofit	AIA CZ1	0.019566	1.137342	0.0181946	1.061904	0.0013713	0.075438
Warehouse	Retrofit	AIA CZ2	0.030046	1.757835	0.0277180	1.628650	0.0023280	0.129185
Warehouse	Retrofit	AIA CZ3	0.019303	1.302225	0.0177553	1.213875	0.0015474	0.088350
Warehouse	Retrofit	AIA CZ4	0.029560	2.276577	0.0255099	2.020727	0.0040498	0.255850
Warehouse	Retrofit	AIA CZ5	0.018038	1.318228	0.0150036	1.137751	0.0030341	0.180477
Warehouse	New Construction	AIA CZ1	0.003733	0.217027	0.0032450	0.190209	0.000489	0.026819
Warehouse	New Construction	AIA CZ2	0.005661	0.331201	0.0048909	0.288140	0.00077	0.043061
Warehouse	New Construction	AIA CZ3	0.003760	0.253683	0.0032739	0.223659	0.000486	0.030024
Warehouse	New Construction	AIA CZ4	0.006454	0.497092	0.0054133	0.428767	0.001041	0.068325
Warehouse	New Construction	AIA CZ5	0.004331	0.316568	0.0026363	0.211973	0.001695	0.104595

Savings Potential by Commercial Sectors – Warehouse, Year 2022 - 2030

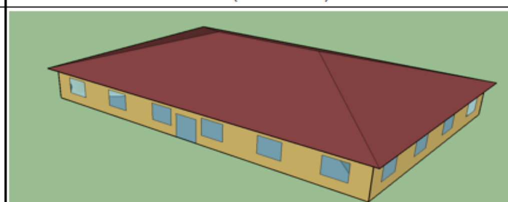
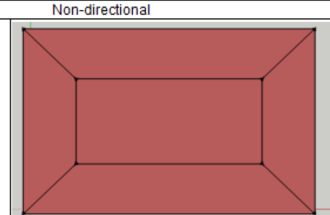
			Baseline Case		Proposed Case		Savings Potential	
Building Type	**Scenario**	**AIA Climate Zone**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**	**Energy (Quad)**	**Carbon ($MMTCO_2e$)**
Warehouse	Retrofit	AIA CZ1	0.157065	8.987309	0.146057	8.385484	0.011008	0.601826
Warehouse	Retrofit	AIA CZ2	0.242136	13.93096	0.223369	12.89714	0.018767	1.033821
Warehouse	Retrofit	AIA CZ3	0.155196	10.07868	0.142777	9.377851	0.012419	0.700825
Warehouse	Retrofit	AIA CZ4	0.234698	17.07757	0.202582	15.10356	0.032116	1.974013
Warehouse	Retrofit	AIA CZ5	0.142756	9.949963	0.118864	8.552239	0.023891	1.397724
Warehouse	New Construction	AIA CZ1	0.048852	2.790249	0.042460	2.441629	0.006392	0.348620
Warehouse	New Construction	AIA CZ2	0.074896	4.300512	0.064703	3.736154	0.010193	0.564359
Warehouse	New Construction	AIA CZ3	0.050254	3.248935	0.043762	2.858995	0.006492	0.389940
Warehouse	New Construction	AIA CZ4	0.086313	6.235942	0.072408	5.357083	0.013905	0.878860
Warehouse	New Construction	AIA CZ5	0.055387	3.839282	0.033816	2.541232	0.021571	1.298050

Appendix 5: Descriptions of Prototype Models

Details for “Small Office” model can be found below. Details of additional Prototype Models used can be found here: https://www.energy.gov/eere/buildings/commercial-reference-buildings

Prototype Building Modeling Specifications

Pacific Northwest National Laboratory, updated on October 18, 2018

Item	Descriptions	Data Source
Program		
Vintage	**NEW CONSTRUCTION**	
Location (Representing 8 Climate Zones)	Zone 1A: Honolulu, Hawaii (very hot, humid) Zone 1B: New Delhi, India (very hot, dry) Zone 2A: Tampa, Florida (hot, humid) Zone 2B: Tucson, Arizona (hot, dry) Zone 3A: Atlanta, Georgia (warm, humid) Zone 3B: El Paso, Texas (warm, dry) Zone 3C: San Diego, California (warm, marine) Zone 4A: New York, New York (mixed, humid) Zone 4B: Albuquerque, New Mexico (mixed, dry) Zone 4C: Seattle, Washington (mixed, marine) Zone 5A: Buffalo, NY (cool, humid) Zone 5B: Denver, Colorado (cool, dry) Zone 5C: Port Angeles, Washington (cool, marine) Zone 6A: Rochester, Minnesota (cold, humid) Zone 6B: Great Falls, Montana (cold, dry) Zone 7: International Falls, Minnesota (very cold) Zone 8: Fairbanks, Alaska (subarctic	Selection of representative climates based on ASHRAE Standard 169-2013
Available fuel types	Gas, electricity	
Building Type (Principal Building	**Office**	
Building Prototype	**Small Office**	
Form		
Total Floor Area (sq feet)	5500 (90.8 ft x 60.5ft)	
Building shape		
Aspect Ratio	1.5	
Number of Floors	1	
Window Fraction (Window-to-Wall Ratio)	24.4% for South and 19.8% for the other three orientations (Window Dimensions: 6.0 ft x 5.0 ft punch windows for all façades)	2003 CBECS Data and PNNL's CBECS Study 2007.
Window Locations	Evenly distributed along four façades	
Shading Geometry	None	
Azimuth	Non-directional	
Thermal Zoning	Perimeter zone depth: 16.4 ft. Four perimeter zones, one core zone and an attic zone. Percentages of floor area: perimeter 70%, core 30% 	
Floor to floor height (feet)	10	
Floor to ceiling height (feet)	10	
Glazing sill height (feet)	3 (top of the window is 8 ft high with 5 ft high glass)	

Architecture			
Exterior walls			
	Construction	Wood-frame walls (2X4 16 in o.c.) 1in. Stucco + 5/8 in. gypsum board + wall Insulation+ 5/8 in. gypsum board	Construction type: 2003 CBECS Data and PNNL's CBECS Study 2007. Base assembly from 90.1 Appendix A.
	U-factor (Btu / h * ft^2 * °F) and/or R-value (h * ft^2 * °F / Btu)	Requirements in codes or standards Nonresidential; walls, above-grade, wood-framed	Applicable codes or standards
	Dimensions	Based on floor area and aspect ratio	
	Tilts and orientations	Vertical	
Roof			
	Construction	Attic roof with wood joist: Roof insulation + 5/8 in. gypsum board	Construction type: 2003 CBECS Data and PNNL's CBECS Study 2007. Base assembly from 90.1 Appendix A.
	U-factor (Btu / h * ft^2 * °F) and/or R-value (h * ft^2 * °F / Btu)	Requirements in codes or standards Nonresidential; roofs, attic	Applicable codes or standards
	Dimensions	Based on floor area and aspect ratio	
	Tilts and orientations	Hipped roof: 10.76 ft attic ridge height, 2 ft overhang-soffit	
Window			
	Dimensions	Based on window fraction, location, glazing sill height, floor area and aspect ratio	
	Glass-Type and frame	Hypothetical window with weighted U-factor and SHGC	
	U-factor (Btu / h * ft^2 * °F) SHGC (all)	Requirements in codes or standards Nonresidential; Vertical Glazing	Applicable codes or standards
	Visible transmittance	Same as above requirements	
	Operable area	0	Ducker Fenestration Market Data provided by the 90.1 Envelope Subcommittee
Skylight			
	Dimensions	Not modeled	
	Glass-Type and frame U-factor (Btu / h * ft^2 * °F) SHGC (all) Visible transmittance	NA	
Foundation			
	Foundation Type	Slab-on-grade floors (unheated)	
	Construction	8" concrete slab poured directly on to the earth	
	Thermal properties for ground level floor U-factor (Btu / h * ft2 * °F) and/or R-value (h * ft2 * °F / Btu)	Requirements in codes or standards Nonresidential; slab-on-grade floors, unheated	Applicable codes or standards
	Thermal properties for basement	NA	
	Dimensions	Based on floor area and aspect ratio	
Interior Partitions			
	Construction	2 x 4 uninsulated stud wall	
	Dimensions	Based on floor plan and floor-to-floor height	
Internal Mass		6 inches standard wood (16.6 lb/ft²)	
Air Barrier System			
	Infiltration	Peak: 0.2016 cfm/sf of above grade exterior wall surface area, adjusted by wind (when fans turn off) Off Peak: 25% of peak infiltration rate (when fans turn on) Additional infiltration through building entrance	Reference: PNNL-18898. *Infiltration Modeling Guidelines for Commercial Building Energy Analysis*. PNNL-20026. *Energy*

HVAC			
System Type			
Heating type	Air-source heat pump with gas furnace as back up	2003 CBECS Data, PNNL's CBECS Study 2006, and 90.1 Mechanical Subcommittee input.	
Cooling type	Air-source heat pump		
Distribution and terminal units	Single zone, constant air volume air distribution, one unit per occupied thermal zone		
HVAC Sizing			
Air Conditioning	Autosized to design day		
Heating	Autosized to design day		
HVAC Efficiency			
Air Conditioning	Requirements in codes or standards Minimum equipment efficiency for packaged heat pumps	Applicable codes or standards	
Heating	Requirements in codes or standards Minimum equipment efficiency for packaged heat pumps and warm air furnaces	Applicable codes or standards	
HVAC Control			
Thermostat Setpoint	75°F Cooling/70°F Heating		
Thermostat Setback	85°F Cooling/60°F Heating		
Supply air temperature	Maximum 104F, Minimum 55F		
Chilled water supply temperatures	NA		
Hot water supply temperatures	NA		
Economizers	Requirements in codes or standards	Applicable codes or standards	
Ventilation	ASHRAE Standard 62.1 or International Mechanical Code See under **Outdoor Air**.	Applicable codes or standards	
Demand Control Ventilation	Requirements in codes or standards	Applicable codes or standards	
Energy Recovery	Requirements in codes or standards	Applicable codes or standards	
Supply Fan			
Fan schedules	See under **Schedules**		
Supply Fan Total Efficiency (%)	Depending on the fan motor size and requirements in codes or standards	Requirements in applicable codes or standards for motor efficiency and fan power	
Supply Fan Pressure Drop	Depending on the fan supply air cfm		
Pump			
Pump Type	NA		
Rated Pump Head	NA		
Pump Power	NA		
Cooling Tower			
Cooling Tower Type	NA		
Cooling Tower Efficiency	NA		
Service Water			
SWH type	Storage tank		
Fuel type	Electric	Reference: *PNNL 2014. Enhancements to ASHRAE Standard 90.1 Prototype Building Models*	
Thermal efficiency (%)	Requirements in codes or standards	Applicable codes or standards	
Tank Volume (gal)	40		
Water temperature setpoint	140 F		
Water consumption	See under **Schedules**		

Internal Loads & Schedules		
Lighting		
Average power density (W/ft^2)	Requirements in codes or standards See **Zone Summary**	Applicable codes or standards
Schedule	See under **Schedules**	
Daylighting Controls	Requirements in codes or standards	Applicable codes or standards
Occupancy Sensors	Requirements in codes or standards	Applicable codes or standards
Plug load		
Average power density (W/ft^2)	See under **Zone Summary**	User's Manual for ASHRAE Standard 90.1-2004 (Appendix G)
Schedule	See under **Schedules**	
Occupancy		
Average people	See under **Zone Summary**	ASHRAE Standard 62.1
Schedule	See under **Schedules**	
Misc.		
Elevator		
Quantity	NA	Reference: DOE Commercial Reference Building Models of the National Building Stock
Motor type	NA	
Peak Motor Power (W/elevator)	NA	
Heat Gain to Building	NA	
Peak Fan/lights Power (W/elevator)	NA	
Motor and fan/lights Schedules	NA	
Exterior Lighting		
Peak Power (W)	Based on design assumptions for façade, parking lot, entrance, etc. and requirements in codes or standards	Applicable codes or standards
Schedule	See under **Schedules** and control requirements in codes or standards	Applicable codes or standards

References

ASHRAE 2013. ANSI/ASHRAE Standard 169-2013. Climatic Data for Building Design Standards. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, Georgia. Relevant information available as Annex 1 in

PNNL's CBECS Study. 2007. *Analysis of Building Envelope Construction in 2003 CBECS Buildings.* Dave Winiarski, Mark Halverson, and Wei Jiang. Pacific Northwest National Laboratory. March 2007.

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Gowri K, DW Winiarski, and RE Jarnagin. 2009. Infiltration modeling guidelines for commercial building energy analysis . PNNL-18898, Pacific Northwest National Laboratory, Richland, WA. http://www.pnl.gov/main/publications/external/technical_reports/PNNL-18898.pdf

Goel S, M Rosenberg, R Athalye, Y Xie, W Wang, R Hart, J Zhang, V Mendon. 2014. Enhancements to ASHRAE Standard 90.1 Prototype Building Models. PNNL-23269, Pacific Northwest National Laboratory, Richland, Washington. http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23269.pdf

Appendix 6: DOE Prototype Models – Detailed Ventilation Descriptions

DOE Large Office Prototype Building Minimum Outdoor Ventilation Air Requirements – Retrofit Use Case using ASHRAE Standard 90.1-2004 and ASHRAE Standard 62.1-1999							Total OSA Ventilation (cfm/zone)		Total OSA Ventilation (cfm/ft2)	
Zone Name	**Zone Multipliers**	**Zone Area (ft^2)**	**Total Occupants**	**Assumed Space Type**	**VRP OA CFM / ft2**	**VRP OA CFM / Person**	**VRP Baseline**	**75% Reduction**	**VRP Baseline**	**75% Reduction**
BASEMENT	1	29920	150	Office space	0.0	20.0	2,993	748	0.100	0.025
CORE_BOTTOM	1	26871	134	Office space	0.0	20.0	2,688	672	0.100	0.025
CORE_MID	10	26871	134	Office space	0.0	20.0	2,688	672	0.100	0.025
CORE_TOP	1	26871	134	Office space	0.0	20.0	2,688	672	0.100	0.025
PERIMETER_BOT_ZN_3	1	3374	17	Office space	0.0	20.0	338	84	0.100	0.025
PERIMETER_BOT_ZN_2	1	2174	11	Office space	0.0	20.0	218	54	0.100	0.025
PERIMETER_BOT_ZN_1	1	3374	17	Office space	0.0	20.0	338	84	0.100	0.025
PERIMETER_BOT_ZN_4	1	2174	11	Office space	0.0	20.0	218	54	0.100	0.025
PERIMETER_MID_ZN_3	10	3374	17	Office space	0.0	20.0	338	84	0.100	0.025
PERIMETER_MID_ZN_2	10	2174	11	Office space	0.0	20.0	218	54	0.100	0.025
PERIMETER_MID_ZN_1	10	3374	17	Office space	0.0	20.0	338	84	0.100	0.025
PERIMETER_MID_ZN_4	10	2174	11	Office space	0.0	20.0	218	54	0.100	0.025
PERIMETER_TOP_ZN_3	1	3374	17	Office space	0.0	20.0	338	84	0.100	0.025
PERIMETER_TOP_ZN_2	1	2174	11	Office space	0.0	20.0	218	54	0.100	0.025
PERIMETER_TOP_ZN_1	1	3374	17	Office space	0.0	20.0	338	84	0.100	0.025
PERIMETER_TOP_ZN_4	1	2174	11	Office space	0.0	20.0	218	54	0.100	0.025
DATACENTER_BOT_ZN_6	1	390	0	IT Closet	0.0	20.0	0	0	0.000	0.000
DATACENTER_MID_ZN_6	10	390	0	IT Closet	0.0	20.0	0	0	0.000	0.000
DATACENTER_TOP_ZN_6	1	390	0	IT Closet	0.0	20.0	0	0	0.000	0.000
DATACENTER_BASEMENT_ZN_6	1	8436	0	Datacenter	0.0	20.0	0	0	0.000	0.000
TOTAL		**498,637**	**2,429**				**48,572**	**12,143**	**0.097**	**0.024**

DOE Large Office Prototype Building Minimum Outdoor Ventilation Air Requirements – New Construction Use Case using ASHRAE Standard 90.1-2016 and ASHRAE Standard 62.1-2013							Total OSA Ventilation (cfm/zone)		Total OSA Ventilation (cfm/ft2)	
Zone Name	**Zone Multipliers**	**Zone Area (ft^2)**	**Total Occupants**	**Assumed Space Type**	**VRP OA CFM / ft2**	VRP OA CFM / Person	VRP Baseline	**75% Reduction**	**VRP Baseline**	**75% Reduction**
BASEMENT	1	29920	150	Office space	0.06	5.00	2,543	2,543	0.085	0.021
CORE_BOTTOM	1	26871	134	Office space	0.06	5.00	2,284	2,284	0.085	0.021
CORE_MID	10	26871	134	Office space	0.06	5.00	2,284	2,284	0.085	0.021
CORE_TOP	1	26871	134	Office space	0.06	5.00	2,284	2,284	0.085	0.021
PERIMETER_BOT_ZN_3	1	3374	17	Office space	0.06	5.00	287	287	0.085	0.021
PERIMETER_BOT_ZN_2	1	2174	11	Office space	0.06	5.00	185	185	0.085	0.021
PERIMETER_BOT_ZN_1	1	3374	17	Office space	0.06	5.00	287	287	0.085	0.021
PERIMETER_BOT_ZN_4	1	2174	11	Office space	0.06	5.00	185	185	0.085	0.021
PERIMETER_MID_ZN_3	10	3374	17	Office space	0.06	5.00	287	287	0.085	0.021
PERIMETER_MID_ZN_2	10	2174	11	Office space	0.06	5.00	185	185	0.085	0.021
PERIMETER_MID_ZN_1	10	3374	17	Office space	0.06	5.00	287	287	0.085	0.021
PERIMETER_MID_ZN_4	10	2174	11	Office space	0.06	5.00	185	185	0.085	0.021
PERIMETER_TOP_ZN_3	1	3374	17	Office space	0.06	5.00	287	287	0.085	0.021
PERIMETER_TOP_ZN_2	1	2174	11	Office space	0.06	5.00	185	185	0.085	0.021
PERIMETER_TOP_ZN_1	1	3374	17	Office space	0.06	5.00	287	287	0.085	0.021
PERIMETER_TOP_ZN_4	1	2174	11	Office space	0.06	5.00	185	185	0.085	0.021
DATACENTER_BOT_ZN_6	1	390	0	IT Closet	0.06	5.00	23	23	0.060	0.015
DATACENTER_MID_ZN_6	10	390	0	IT Closet	0.06	5.00	23	23	0.060	0.015
DATACENTER_TOP_ZN_6	1	390	0	IT Closet	0.06	5.00	23	23	0.060	0.015
DATACENTER_BASEMENT_ZN_6	1	8436	0	Datacenter	0.06	5.00	506	506	0.060	0.015
TOTAL		**498,637**	**2,429**				**42,061**	**10,515**	**0.084**	**0.021**

DOE Small Office Prototype Building Minimum Outdoor Ventilation Air Requirements – Retrofit Use Case using ASHRAE Standard 90.1-2004 and ASHRAE Standard 62.1-1999							Total OSA Ventilation (cfm/zone)		Total OSA Ventilation (cfm/ft2)	
Zone Name	**Zone Multipliers**	**Zone Area (ft²)**	**Total Occupants**	**Assumed Space Type**	**VRP OA CFM / ft2**	VRP OA CFM / Person	VRP Baseline	**75% Reduction**	**VRP Baseline**	**75% Reduction**
CORE_ZN	1	1611	8	Office space	0.0	20.0	161	40	0.100	0.025
PERIMETER_ZN_1	1	1221	6	Office space	0.0	20.0	122	31	0.100	0.025
PERIMETER_ZN_2	1	724	4	Office space	0.0	20.0	72	18	0.100	0.025
PERIMETER_ZN_3	1	1221	6	Office space	0.0	20.0	122	31	0.100	0.025
PERIMETER_ZN_4	1	724	4	Office space	0.0	20.0	72	18	0.100	0.025
TOTAL		**5,503**	**28**				**550**	**138**	**0.100**	**0.025**

DOE Small Office Prototype Building Minimum Outdoor Ventilation Air Requirements – New Construction Use Case using ASHRAE Standard 90.1-2016 and ASHRAE Standard 62.1-2013							Total OSA Ventilation (cfm/zone)		Total OSA Ventilation (cfm/ft2)	
Zone Name	**Zone Multipliers**	**Zone Area (ft²)**	**Total Occupants**	**Assumed Space Type**	**VRP OA CFM / ft2**	VRP OA CFM / Person	VRP Baseline	**75% Reduction**	**VRP Baseline**	**75% Reduction**
CORE_ZN	1	1611	8	Office space	0.06	5.00	137	34	0.085	0.021
PERIMETER_ZN_1	1	1221	6	Office space	0.06	5.00	104	26	0.085	0.021
PERIMETER_ZN_2	1	724	4	Office space	0.06	5.00	62	15	0.085	0.021
PERIMETER_ZN_3	1	1221	6	Office space	0.06	5.00	104	26	0.085	0.021
PERIMETER_ZN_4	1	724	4	Office space	0.06	5.00	62	15	0.085	0.021
TOTAL		**5,503**	**28**				**468**	**117**	**0.085**	**0.021**

DOE Stand Alone Retail Prototype Building Minimum Outdoor Ventilation Air Requirements – Retrofit Use Case using ASHRAE Standard 90.1-2004 and ASHRAE Standard 62.1-1999							Total OSA Ventilation (cfm/zone)		Total OSA Ventilation (cfm/ft2)	
Zone Name	**Zone Multipliers**	**Zone Area (ft^2)**	**Total Occupants**	**Assumed Space Type**	**VRP OA CFM / ft2**	VRP OA CFM / Person	VRP Baseline	**75% Reduction**	**VRP Baseline**	**75% Reduction**
BACK_SPACE	1	4089.5	61	Storage rooms	0.15	0.0	613	153	0.150	0.038
CORE_RETAIL	1	17229.0	258	Sales (except as below)	0.30	0.0	5,169	1,292	0.300	0.075
POINT_OF_SALE	1	1623.5	24	Sales (except as below)	0.30	0.0	487	122	0.300	0.075
FRONT_RETAIL	1	1623.5	24	Sales (except as below)	0.30	0.0	487	122	0.300	0.075
FRONT_ENTRY2.	1	129.2	2	Sales (except as below)	0.30	0.0	39	10	0.300	0.075
TOTAL		**24,695**	**370**				**6,795**	**1,699**	**0.275**	**0.069**

DOE Stand Alone Retail Prototype Building Minimum Outdoor Ventilation Air Requirements – New Construction Use Case using ASHRAE Standard 90.1-2016 and ASHRAE Standard 62.1-2013							Total OSA Ventilation (cfm/zone)		Total OSA Ventilation (cfm/ft2)	
Zone Name	**Zone Multipliers**	**Zone Area (ft^2)**	**Total Occupants**	**Assumed Space Type**	**VRP OA CFM / ft2**	VRP OA CFM / Person	VRP Baseline	**75% Reduction**	**VRP Baseline**	**75% Reduction**
BACK_SPACE	1	4089.5	61	Storage rooms	0.12	0.0	491	123	0.120	0.030
CORE_RETAIL	1	17229.0	258	Sales (except as below)	0.12	7.5	4006	1001	0.233	0.058
POINT_OF_SALE	1	1623.5	24	Sales (except as below)	0.12	7.5	377	94	0.233	0.058
FRONT_RETAIL	1	1623.5	24	Sales (except as below)	0.12	7.5	377	94	0.233	0.058
FRONT_ENTRY2.	1	129.2	2	Sales (except as below)	0.12	7.5	30	8	0.233	0.058
TOTAL		**24,695**	**370**				**5,281**	**1,320**	**0.214**	**0.053**

DOE Retail Strip Mall Prototype Buildings Minimum Outdoor Ventilation Air Requirements – Retrofit Use Case using ASHRAE Standard 90.1-2004 and ASHRAE Standard 62.1-1999							Total OSA Ventilation (cfm/zone)		Total OSA Ventilation (cfm/ft2)	
Zone Name	**Zone Multipliers**	**Zone Area (ft^2)**	**Total Occupants**	**Assumed Space Type**	**VRP OA CFM / ft2**	**VRP OA CFM / Person**	**VRP Baseline**	**75% Reduction**	**VRP Baseline**	**75% Reduction**
LGSTORE1	1	3750	56	Sales (except as below)	0.30	0.0	1,125	281	0.300	0.075
SMSTORE1	1	1875	28	Sales (except as below)	0.30	0.0	562	141	0.300	0.075
SMSTORE2	1	1875	28	Sales (except as below)	0.30	0.0	562	141	0.300	0.075
SMSTORE3	1	1875	28	Sales (except as below)	0.30	0.0	562	141	0.300	0.075
SMSTORE4	1	1875	28	Sales (except as below)	0.30	0.0	562	141	0.300	0.075
LGSTORE2	1	3750	56	Sales (except as below)	0.30	0.0	1,125	281	0.300	0.075
SMSTORE5	1	1875	28	Sales (except as below)	0.30	0.0	562	141	0.300	0.075
SMSTORE6	1	1875	28	Sales (except as below)	0.30	0.0	562	141	0.300	0.075
SMSTORE7	1	1875	28	Sales (except as below)	0.30	0.0	562	141	0.300	0.075
SMSTORE8	1	1875	28	Sales (except as below)	0.30	0.0	562	141	0.300	0.075
TOTAL		**22,500**	**337**				**6,750**	**1.687**	**0.300**	**0.075**

DOE Retail Strip Mall Prototype Buildings Minimum Outdoor Ventilation Air Requirements – New Construction Use Case using ASHRAE Standard 90.1-2016 and ASHRAE Standard 62.1-2013							Total OSA Ventilation (cfm/zone)		Total OSA Ventilation (cfm/ft2)	
Zone Name	**Zone Multipliers**	**Zone Area (ft^2)**	**Total Occupants**	**Assumed Space Type**	**VRP OA CFM / ft2**	**VRP OA CFM / Person**	**VRP Baseline**	**75% Reduction**	**VRP Baseline**	**75% Reduction**
LGSTORE1	1	3750	56	Sales (except as below)	0.12	7.5	872	218	0.233	0.058
SMSTORE1	1	1875	28	Sales (except as below)	0.12	7.5	436	109	0.233	0.058
SMSTORE2	1	1875	28	Sales (except as below)	0.12	7.5	436	109	0.233	0.058
SMSTORE3	1	1875	28	Sales (except as below)	0.12	7.5	436	109	0.233	0.058
SMSTORE4	1	1875	28	Sales (except as below)	0.12	7.5	436	109	0.233	0.058
LGSTORE2	1	3750	56	Sales (except as below)	0.12	7.5	872	218	0.233	0.058
SMSTORE5	1	1875	28	Sales (except as below)	0.12	7.5	436	109	0.233	0.058
SMSTORE6	1	1875	28	Sales (except as below)	0.12	7.5	436	109	0.233	0.058
SMSTORE7	1	1875	28	Sales (except as below)	0.12	7.5	436	109	0.233	0.058
SMSTORE8	1	1875	28	Sales (except as below)	0.12	7.5	436	109	0.233	0.058
TOTAL		**1875**	**28**				**5,231**	**1,308**	**0.233**	**0.058**

DOE Primary School Prototype Building Minimum Outdoor Ventilation Air Requirements – Retrofit Use Case using ASHRAE Standard 90.1-2004 and ASHRAE Standard 62.1-1999							Total OSA Ventilation (cfm/zone)		Total OSA Ventilation (cfm/ft2)	
Zone Name	**Zone Multipliers**	**Zone Area (ft^2)**	**Total Occupants**	**Assumed Space Type**	**VRP OA CFM / ft2**	**VRP OA CFM / Person**	**VRP Baseline**	**75% Reduction**	**VRP Baseline**	**75% Reduction**
CORNER_CLASS_1_POD_1_ZN_1_FLR_1	1	1,066	27	Classrooms (ages 5-8)	0.00	15.0	399.65	100	0.375	0.094
MULT_CLASS_1_POD_1_ZN_1_FLR_1	1	5,135	128	Classrooms (ages 5-8)	0.00	15.0	1,925.589	481	0.375	0.094
CORRIDOR_POD_1_ZN_1_FLR_1	1	2,067	0	Corridors (school)	0.10	0.0	206.69	52	0.100	0.025
CORNER_CLASS_2_POD_1_ZN_1_FLR_1	1	1,066	27	Classrooms (ages 5-8)	0.0	15.0	400	100	0.375	0.094
MULT_CLASS_2_POD_1_ZN_1_FLR_1	1	5,135	128	Classrooms (ages 5-8)	0.0	15.0	1,926	481	0.375	0.094
CORNER_CLASS_1_POD_2_ZN_1_FLR_1	1	1,066	27	Classrooms (ages 5-8)	0.0	15.0	400	100	0.375	0.094
MULT_CLASS_1_POD_2_ZN_1_FLR_1	1	5,135	128	Classrooms (ages 5-8)	0.0	15.0	1,926	481	0.375	0.094
CORRIDOR_POD_2_ZN_1_FLR_1	1	2,067	0	Corridors (school)	0.1	0.0	207	52	0.100	0.025
CORNER_CLASS_2_POD_2_ZN_1_FLR_1	1	1,066	27	Classrooms (ages 5-8)	0.0	15.0	400	100	0.375	0.094
MULT_CLASS_2_POD_2_ZN_1_FLR_1	1	5,135	128	Classrooms (ages 5-8)	0.0	15.0	1,926	481	0.375	0.094
CORNER_CLASS_1_POD_3_ZN_1_FLR_1	1	1,066	27	Classrooms (ages 5-8)	0.0	15.0	400	100	0.375	0.094
MULT_CLASS_1_POD_3_ZN_1_FLR_1	1	5,135	128	Classrooms (ages 5-8)	0.0	15.0	1,926	481	0.375	0.094
CORRIDOR_POD_3_ZN_1_FLR_1	1	2,067	0	Corridors (school)	0.1	0.0	207	52	0.100	0.025
CORNER_CLASS_2_POD_3_ZN_1_FLR_1	1	1,066	27	Classrooms (ages 5-8)	0.0	15.0	400	100	0.375	0.094
MULT_CLASS_2_POD_3_ZN_1_FLR_1	1	3,391	85	Classrooms (ages 5-8)	0.0	15.0	1,272	318	0.375	0.094
COMPUTER_CLASS_ZN_1_FLR_1	1	1,744	44	Computer Lab.	0.0	15.0	654	163	0.375	0.094
MAIN_CORRIDOR_ZN_1_FLR_1	1	5,878	0	Corridors (school)	0.1	0.0	588	147	0.100	0.025
LOBBY_ZN_1_FLR_1	1	1,841	0	Corridors (school)	0.1	0.0	184	46	0.100	0.025
MECH_ZN_1_FLR_1	1	2,713	0	--	0.0	0.0	NA	NA	NA	NA
BATH_ZN_1_FLR_11.	1	2,045	0	Restroom	0.0	0.0	0	0	0.000	0.000
OFFICES_ZN_1_FLR_1	1	4,747	24	Office space	0.0	20.0	475	119	0.100	0.025
GYM_ZN_1_FLR_1	1	3,843	115	Gym, stadium (play area)	0.0	20	2,306	577	0.600	0.150
KITCHEN_ZN_1_FLR_1	1	1,809	27	Kitchen	0.0	15	5,000	1,250	2.765	0.691
CAFETERIA_ZN_1_FLR_1	1	3,391	339	Cafeteria / fast food dining	0.0	20	6,782	1,695	2.000	0.500
LIBRARY_MEDIA_CENTER_ZN_1_FLR_1	1	4,295	43	Libraries	0.0	15.0	644	161	0.150	0.038
TOTAL		**73,966**	**1,478**				**30,550**	**7,638**	**0.413**	**0.103**

DOE Primary School Prototype Building Minimum Outdoor Ventilation Air Requirements – New Construction Use Case using ASHRAE Standard 90.1-2016 and ASHRAE Standard 62.1-2013							Total OSA Ventilation (cfm/zone)		Total OSA Ventilation (cfm/ft2)	
Zone Name	**Zone Multipliers**	**Zone Area (ft^2)**	**Total Occupants**	**Assumed Space Type**	**VRP OA CFM / ft2**	**VRP OA CFM / Person**	**VRP Baseline**	**75% Reduction**	**VRP Baseline**	**75% Reduction**
CORNER_CLASS_1_POD_1_ZN_1_FLR_1	1	1,066	27	Classrooms (ages 5-8)	0.12	10.0	394	99	0.370	0.093
MULT_CLASS_1_POD_1_ZN_1_FLR_1	1	5,135	128	Classrooms (ages 5-8)	0.12	10.0	1900	475	0.370	0.093
CORRIDOR_POD_1_ZN_1_FLR_1	1	2,067	0	Corridors (school)	0.06	0.0	124	31	0.060	0.015
CORNER_CLASS_2_POD_1_ZN_1_FLR_1	1	1,066	27	Classrooms (ages 5-8)	0.12	10.0	394	99	0.370	0.093
MULT_CLASS_2_POD_1_ZN_1_FLR_1	1	5,135	128	Classrooms (ages 5-8)	0.12	10.0	1900	475	0.370	0.093
CORNER_CLASS_1_POD_2_ZN_1_FLR_1	1	1,066	27	Classrooms (ages 5-8)	0.12	10.0	394	99	0.370	0.093
MULT_CLASS_1_POD_2_ZN_1_FLR_1	1	5,135	128	Classrooms (ages 5-8)	0.12	10.0	1900	475	0.370	0.093
CORRIDOR_POD_2_ZN_1_FLR_1	1	2,067	0	Corridors (school)	0.06	0.0	124	31	0.060	0.015
CORNER_CLASS_2_POD_2_ZN_1_FLR_1	1	1,066	27	Classrooms (ages 5-8)	0.12	10.0	394	99	0.370	0.093
MULT_CLASS_2_POD_2_ZN_1_FLR_1	1	5,135	128	Classrooms (ages 5-8)	0.12	10.0	1900	475	0.370	0.093
CORNER_CLASS_1_POD_3_ZN_1_FLR_1	1	1,066	27	Classrooms (ages 5-8)	0.12	10.0	394	99	0.370	0.093
MULT_CLASS_1_POD_3_ZN_1_FLR_1	1	5,135	128	Classrooms (ages 5-8)	0.12	10.0	1900	475	0.370	0.093
CORRIDOR_POD_3_ZN_1_FLR_1	1	2,067	0	Corridors (school)	0.06	0.0	124	31	0.060	0.015
CORNER_CLASS_2_POD_3_ZN_1_FLR_1	1	1,066	27	Classrooms (ages 5-8)	0.12	10.0	394	99	0.370	0.093
MULT_CLASS_2_POD_3_ZN_1_FLR_1	1	3,391	85	Classrooms (ages 5-8)	0.12	10.0	1255	314	0.370	0.093
COMPUTER_CLASS_ZN_1_FLR_1	1	1,744	44	Computer Lab.	0.12	10.0	645	161	0.370	0.093
MAIN_CORRIDOR_ZN_1_FLR_1	1	5,878	0	Corridors (school)	0.06	0.0	353	88	0.060	0.015
LOBBY_ZN_1_FLR_1	1	1,841	0	Corridors (school)	0.06	0.0	110	28	0.060	0.015
MECH_ZN_1_FLR_1	1	2,713	0	--	0.00	0.0	NA	NA	NA	NA
BATH_ZN_1_FLR_11.	1	2,045	0	Restroom	0.00	0.0	0	0	0.000	0.000
OFFICES_ZN_1_FLR_1	1	4,747	24	Office space	0.06	5.00	404	101	0.085	0.021
GYM_ZN_1_FLR_1	1	3,843	115	Gym, stadium (play area)	0.18	20	2,998	749	0.780	0.195
KITCHEN_ZN_1_FLR_1	1	1,809	27	Kitchen	0.12	7.5	5000	1250	2.765	0.691
CAFETERIA_ZN_1_FLR_1	1	3,391	339	Cafeteria / fast food dining	0.18	7.5	3154	788	0.930	0.233
LIBRARY_MEDIA_CENTER_ZN_1_FLR_1	1	4,295	43	Libraries	0.12	5.0	730	183	0.170	0.043
TOTAL		**73,966**	**1,478**				**26,886**	**6,721**	**0.363**	**0.091**

DOE Secondary School Prototype Building Minimum Outdoor Ventilation Air Requirements – Retrofit Use Case using ASHRAE Standard 90.1-2004 and ASHRAE Standard 62.1-1999							Total OSA Ventilation (cfm/zone)		Total OSA Ventilation (cfm/ft2)	
Zone Name	**Zone Multipliers**	**Zone Area (ft^2)**	**Total Occupants**	**Assumed Space Type**	**VRP OA CFM / ft2**	**VRP OA CFM / Person**	**VRP Baseline**	**75% Reduction**	**VRP Baseline**	**75% Reduction**
CORNER_CLASS_1_POD_1_ZN_1_FLR_1	1	1,066	37	Classrooms (age 9 plus)	0.00	15.0	559.49	140	0.525	0.131
CORNER_CLASS_1_POD_1_ZN_1_FLR_2	1	1,066	37	Classrooms (age 9 plus)	0.00	15.0	559.493	140	0.525	0.131
MULT_CLASS_1_POD_1_ZN_1_FLR_1	1	5,135	180	Classrooms (age 9 plus)	0.00	15.0	2,695.82	674	0.525	0.131
MULT_CLASS_1_POD_1_ZN_1_FLR_2	1	5,135	180	Classrooms (age 9 plus)	0.00	15.0	2,696	674	0.525	0.131
CORRIDOR_POD_1_ZN_1_FLR_1	1	3,445	0	Corridors (school)	0.10	0.0	344	86	0.100	0.025
CORRIDOR_POD_1_ZN_1_FLR_2	1	3,445	0	Corridors (school)	0.10	0.0	344	86	0.100	0.025
CORNER_CLASS_2_POD_1_ZN_1_FLR_1	1	1,066	37	Classrooms (age 9 plus)	0.00	15.0	559	140	0.525	0.131
CORNER_CLASS_2_POD_1_ZN_1_FLR_2	1	1,066	37	Classrooms (age 9 plus)	0.00	15.0	559	140	0.525	0.131
MULT_CLASS_2_POD_1_ZN_1_FLR_1	1	5,135	180	Classrooms (age 9 plus)	0.00	15.0	2,696	674	0.525	0.131
MULT_CLASS_2_POD_1_ZN_1_FLR_2	1	5,135	180	Classrooms (age 9 plus)	0.00	15.0	2,696	674	0.525	0.131
CORNER_CLASS_1_POD_2_ZN_1_FLR_1	1	1,066	37	Classrooms (age 9 plus)	0.00	15.0	559	140	0.525	0.131
CORNER_CLASS_1_POD_2_ZN_1_FLR_2	1	1,066	37	Classrooms (age 9 plus)	0.00	15.0	559	140	0.525	0.131
MULT_CLASS_1_POD_2_ZN_1_FLR_1	1	5,135	180	Classrooms (age 9 plus)	0.00	15.0	2,696	674	0.525	0.131
MULT_CLASS_1_POD_2_ZN_1_FLR_2	1	5,135	180	Classrooms (age 9 plus)	0.00	15.0	2,696	674	0.525	0.131
CORRIDOR_POD_2_ZN_1_FLR_1	1	3,445	0	Corridors (school)	0.10	0.0	344	86	0.100	0.025
CORRIDOR_POD_2_ZN_1_FLR_2	1	3,445	0	Corridors (school)	0.10	0.0	344	86	0.100	0.025
CORNER_CLASS_2_POD_2_ZN_1_FLR_1	1	1,066	37	Classrooms (age 9 plus)	0.00	15.0	559	140	0.525	0.131
CORNER_CLASS_2_POD_2_ZN_1_FLR_2	1	1,066	37	Classrooms (age 9 plus)	0.00	15.0	559	140	0.525	0.131
MULT_CLASS_2_POD_2_ZN_1_FLR_1	1	5,135	180	Classrooms (age 9 plus)	0.00	15.0	2,696	674	0.525	0.131
MULT_CLASS_2_POD_2_ZN_1_FLR_2	1	5,135	180	Classrooms (age 9 plus)	0.00	15.0	2,696	674	0.525	0.131
CORNER_CLASS_1_POD_3_ZN_1_FLR_1	1	1,066	37	Classrooms (age 9 plus)	0.00	15.0	559	140	0.525	0.131
CORNER_CLASS_1_POD_3_ZN_1_FLR_2	1	1,066	37	Classrooms (age 9 plus)	0.00	15.0	559	140	0.525	0.131
MULT_CLASS_1_POD_3_ZN_1_FLR_1	1	5,135	180	Classrooms (age 9 plus)	0.00	15.0	2,696	674	0.525	0.131
MULT_CLASS_1_POD_3_ZN_1_FLR_2	1	5,135	180	Classrooms (age 9 plus)	0.00	15.0	2,696	674	0.525	0.131
CORRIDOR_POD_3_ZN_1_FLR_1	1	3,445	0	Corridors (school)	0.10	0.0	344	86	0.100	0.025
CORRIDOR_POD_3_ZN_1_FLR_2	1	3,445	0	Corridors (school)	0.10	0.0	344	86	0.100	0.025
CORNER_CLASS_2_POD_3_ZN_1_FLR_1	1	1,066	37	Classrooms (age 9 plus)	0.00	15.0	559	140	0.525	0.131
CORNER_CLASS_2_POD_3_ZN_1_FLR_2	1	1,066	37	Classrooms (age 9 plus)	0.00	15.0	559	140	0.525	0.131
MULT_CLASS_2_POD_3_ZN_1_FLR_1	1	5,135	180	Classrooms (age 9 plus)	0.00	15.0	2,696	674	0.525	0.131
MULT_CLASS_2_POD_3_ZN_1_FLR_2	1	5,135	180	Classrooms (age 9 plus)	0.00	15.0	2,696	674	0.525	0.131
MAIN_CORRIDOR_ZN_1_FLR_1	1	12,272	0	Corridors (school)	0.10	0.0	1,227	307	0.100	0.025
MAIN_CORRIDOR_ZN_1_FLR_2	1	12,272	0	Corridors (school)	0.10	0.0	1,227	307	0.100	0.025
LOBBY_ZN_1_FLR_1	1	2,261	0	Corridors (school)	0.10	0.0	226	57	0.100	0.025
LOBBY_ZN_1_FLR_2	1	2,261	0	Corridors (school)	0.10	0.0	226	57	0.100	0.025
BATHROOMS_ZN_1_FLR_1	1	2,261	0	Restroom	0.0	0.0	0	0	0.000	0.000
BATHROOMS_ZN_1_FLR_2	1	2,261	0	Restroom	0.0	0.0	0	0	0.000	0.000
OFFICES_ZN_1_FLR_1	1	5,727	29	Office space	0.0	20.0	573	143	0.100	0.025
OFFICES_ZN_1_FLR_2	1	5,727	29	Office space	0.0	20.0	573	143	0.100	0.025
GYM_ZN_1_FLR_1	1	21,272	638	Gym, stadium (play area)	0.0	20	12,763	3,191	0.600	0.150

AUX_GYM_ZN_1_FLR_1	1	13,435	403	Gym, stadium (play area)	0.0	20	8,061	2,015	0.600	0.150
AUDITORIUM_ZN_1_FLR_1	1	10,636	1,595	Auditorium seating area	0.0	15.0	23,931	5,983	2.250	0.563
KITCHEN_ZN_1_FLR_1	1	2,325	35	Kitchen	0.0	15	6,000	1,500	2.580	0.645
LIBRARY_MEDIA_CENTER_ZN_1_FLR_2	1	9,043	90	Libraries	0.0	15.0	1,356	339	0.150	0.038
CAFETERIA_ZN_1_FLR_1	1	6,717	672	Cafeteria / fast food dining	0.0	20	13,435	3,359	2.000	0.500
MECH_ZN_1_FLR_1	1	3,682	0	--	0.0	0.0	NA	NA	NA	NA
MECH_ZN_1_FLR_2	1	3,682	0	--	0.0	0.0	NA	NA	NA	NA
TOTAL		**210,908**	**6,095**				**110,728**	**27,682**	**0.525**	**0.131**

DOE Secondary School Prototype Building Minimum Outdoor Ventilation Air Requirements – New Construction Use Case using ASHRAE Standard 90.1-2016 and ASHRAE Standard 62.1-2013							Total OSA Ventilation (cfm/zone)		Total OSA Ventilation (cfm/ft2)	
Zone Name	**Zone Multipliers**	**Zone Area (ft²)**	**Total Occupants**	**Assumed Space Type**	**VRP OA CFM / ft2**	**VRP OA CFM / Person**	**VRP Baseline**	**75% Reduction**	**VRP Baseline**	**75% Reduction**
CORNER_CLASS_1_POD_1_ZN_1_FLR_1	1	1,066	37	Classrooms (age 9 plus)	0.12	10.0	501	125	0.470	0.118
CORNER_CLASS_1_POD_1_ZN_1_FLR_2	1	1,066	37	Classrooms (age 9 plus)	0.12	10.0	501	125	0.470	0.118
MULT_CLASS_1_POD_1_ZN_1_FLR_1	1	5,135	180	Classrooms (age 9 plus)	0.12	10.0	2413	603	0.470	0.118
MULT_CLASS_1_POD_1_ZN_1_FLR_2	1	5,135	180	Classrooms (age 9 plus)	0.12	10.0	2413	603	0.470	0.118
CORRIDOR_POD_1_ZN_1_FLR_1	1	3,445	0	Corridors (school)	0.06	0.0	207	52	0.060	0.015
CORRIDOR_POD_1_ZN_1_FLR_2	1	3,445	0	Corridors (school)	0.06	0.0	207	52	0.060	0.015
CORNER_CLASS_2_POD_1_ZN_1_FLR_1	1	1,066	37	Classrooms (age 9 plus)	0.12	10.0	501	125	0.470	0.118
CORNER_CLASS_2_POD_1_ZN_1_FLR_2	1	1,066	37	Classrooms (age 9 plus)	0.12	10.0	501	125	0.470	0.118
MULT_CLASS_2_POD_1_ZN_1_FLR_1	1	5,135	180	Classrooms (age 9 plus)	0.12	10.0	2413	603	0.470	0.118
MULT_CLASS_2_POD_1_ZN_1_FLR_2	1	5,135	180	Classrooms (age 9 plus)	0.12	10.0	2413	603	0.470	0.118
CORNER_CLASS_1_POD_2_ZN_1_FLR_1	1	1,066	37	Classrooms (age 9 plus)	0.12	10.0	501	125	0.470	0.118
CORNER_CLASS_1_POD_2_ZN_1_FLR_2	1	1,066	37	Classrooms (age 9 plus)	0.12	10.0	501	125	0.470	0.118
MULT_CLASS_1_POD_2_ZN_1_FLR_1	1	5,135	180	Classrooms (age 9 plus)	0.12	10.0	2413	603	0.470	0.118
MULT_CLASS_1_POD_2_ZN_1_FLR_2	1	5,135	180	Classrooms (age 9 plus)	0.12	10.0	2413	603	0.470	0.118
CORRIDOR_POD_2_ZN_1_FLR_1	1	3,445	0	Corridors (school)	0.06	0.0	207	52	0.060	0.015
CORRIDOR_POD_2_ZN_1_FLR_2	1	3,445	0	Corridors (school)	0.06	0.0	207	52	0.060	0.015
CORNER_CLASS_2_POD_2_ZN_1_FLR_1	1	1,066	37	Classrooms (age 9 plus)	0.12	10.0	501	125	0.470	0.118
CORNER_CLASS_2_POD_2_ZN_1_FLR_2	1	1,066	37	Classrooms (age 9 plus)	0.12	10.0	501	125	0.470	0.118
MULT_CLASS_2_POD_2_ZN_1_FLR_1	1	5,135	180	Classrooms (age 9 plus)	0.12	10.0	2413	603	0.470	0.118
MULT_CLASS_2_POD_2_ZN_1_FLR_2	1	5,135	180	Classrooms (age 9 plus)	0.12	10.0	2413	603	0.470	0.118
CORNER_CLASS_1_POD_3_ZN_1_FLR_1	1	1,066	37	Classrooms (age 9 plus)	0.12	10.0	501	125	0.470	0.118
CORNER_CLASS_1_POD_3_ZN_1_FLR_2	1	1,066	37	Classrooms (age 9 plus)	0.12	10.0	501	125	0.470	0.118
MULT_CLASS_1_POD_3_ZN_1_FLR_1	1	5,135	180	Classrooms (age 9 plus)	0.12	10.0	2413	603	0.470	0.118
MULT_CLASS_1_POD_3_ZN_1_FLR_2	1	5,135	180	Classrooms (age 9 plus)	0.12	10.0	2413	603	0.470	0.118
CORRIDOR_POD_3_ZN_1_FLR_1	1	3,445	0	Corridors (school)	0.06	0.0	207	52	0.060	0.015
CORRIDOR_POD_3_ZN_1_FLR_2	1	3,445	0	Corridors (school)	0.06	0.0	207	52	0.060	0.015
CORNER_CLASS_2_POD_3_ZN_1_FLR_1	1	1,066	37	Classrooms (age 9 plus)	0.12	10.0	501	125	0.470	0.118
CORNER_CLASS_2_POD_3_ZN_1_FLR_2	1	1,066	37	Classrooms (age 9 plus)	0.12	10.0	501	125	0.470	0.118
MULT_CLASS_2_POD_3_ZN_1_FLR_1	1	5,135	180	Classrooms (age 9 plus)	0.12	10.0	2413	603	0.470	0.118
MULT_CLASS_2_POD_3_ZN_1_FLR_2	1	5,135	180	Classrooms (age 9 plus)	0.12	10.0	2413	603	0.470	0.118
MAIN_CORRIDOR_ZN_1_FLR_1	1	12,272	0	Corridors (school)	0.06	0.0	736	184	0.060	0.015
MAIN_CORRIDOR_ZN_1_FLR_2	1	12,272	0	Corridors (school)	0.06	0.0	736	184	0.060	0.015
LOBBY_ZN_1_FLR_1	1	2,261	0	Corridors (school)	0.06	0.0	136	34	0.060	0.015
LOBBY_ZN_1_FLR_2	1	2,261	0	Corridors (school)	0.06	0.0	136	34	0.060	0.015
BATHROOMS_ZN_1_FLR_1	1	2,261	0	Restroom	0.00	0.0	0	0	0.000	0.000
BATHROOMS_ZN_1_FLR_2	1	2,261	0	Restroom	0.00	0.0	0	0	0.000	0.000
OFFICES_ZN_1_FLR_1	1	5,727	29	Office space	0.06	5.00	487	122	0.085	0.021
OFFICES_ZN_1_FLR_2	1	5,727	29	Office space	0.06	5.00	487	122	0.085	0.021

GYM_ZN_1_FLR_1	1	21,272	638	Gym, stadium (play area)	0.18	20	16592	4148	0.780	0.195
AUX_GYM_ZN_1_FLR_1	1	13,435	403	Gym, stadium (play area)	0.18	20	10479	2620	0.780	0.195
AUDITORIUM_ZN_1_FLR_1	1	10,636	1,595	Auditorium seating area	0.06	5.0	8615	2154	0.810	0.203
KITCHEN_ZN_1_FLR_1	1	2,325	35	Kitchen	0.12	7.5	6000	1500	2.580	0.645
LIBRARY_MEDIA_CENTER_ZN_1_FLR_2	1	9,043	90	Libraries	0.12	5.0	1537	384	0.170	0.043
CAFETERIA_ZN_1_FLR_1	1	6,717	672	Cafeteria / fast food dining	0.18	7.5	6247	1562	0.930	0.233
MECH_ZN_1_FLR_1	1	3,682	0	--	0.00	0.0	NA	NA	NA	NA
MECH_ZN_1_FLR_2	1	3,682	0	--	0.00	0.0	NA	NA	NA	NA
TOTAL		**210,908**	**6,095**				**88,399**	**22,100**	**0.419**	**0.105**

Appendix 7: Aggregated (Weighted) Savings from DOE Prototype Models as SCOUT inputs

DOE Prototype New Construction Building Sector	AIA CZ	Cooling % Savings	Heating % Savings
Large Office	1	4.15	37.3
Large Office	2	4.03	51.06
Large Office	3	5.86	49.54
Large Office	4	5.98	57.06
Large Office	5	8.46	41.88
Primary School	1	3.96	30.13
Primary School	2	4.07	36.29
Primary School	3	6.25	42.2
Primary School	4	5.91	43.84
Primary School	5	8.11	45.76
Retail Standalone	1	7.36	32.15
Retail Standalone	2	8.21	36.34
Retail Standalone	3	10.42	39.48
Retail Standalone	4	9.84	47.28
Retail Standalone	5	13.95	51.17
Retail Stripmall	1	13.88	52.61
Retail Stripmall	2	14.5	57.46
Retail Stripmall	3	18.85	61.12
Retail Stripmall	4	17.62	70.91
Retail Stripmall	5	21.72	71.1
Secondary School	1	1.1	28.07
Secondary School	2	0	36.15
Secondary School	3	2.88	36.04
Secondary School	4	3.18	42.3
Secondary School	5	4.64	38.42
Small Office	1	8.78	33.57
Small Office	2	7.81	39.27
Small Office	3	10.39	46.71
Small Office	4	9.87	48.26
Small Office	5	13.41	51.95
Warehouse	1	0	12.58
Warehouse	2	0	12.94
Warehouse	3	1.13	13.35
Warehouse	4	2.53	20.05
Warehouse	5	9.1	47.1

DOE Prototype Retrofit Building Sector	AIA CZ	Cooling % Savings	Heating % Savings
Large Office	1	3.79	32.18
Large Office	2	4.47	35.61
Large Office	3	5.34	39.2
Large Office	4	6.7	39.53
Large Office	5	6.33	37.53
Primary School	1	15.32	60.49
Primary School	2	15.07	65.48
Primary School	3	19.77	71.77
Primary School	4	21.33	74.59
Primary School	5	20.07	77.88
Retail Standalone	1	14.69	46.62
Retail Standalone	2	17.2	47.89
Retail Standalone	3	18.14	49.89
Retail Standalone	4	22.19	53.05
Retail Standalone	5	21.33	52.58
Retail Stripmall	1	13.53	46.76
Retail Stripmall	2	16.36	49.06
Retail Stripmall	3	17.78	54.14
Retail Stripmall	4	21.08	57.59
Retail Stripmall	5	19.74	66.19
Secondary School	1	12.04	68.57
Secondary School	2	6.58	73.36
Secondary School	3	14.02	77.4
Secondary School	4	16.78	80.12
Secondary School	5	17.8	81
Small Office	1	7.64	28.25
Small Office	2	8.73	29.65
Small Office	3	9.52	40.43
Small Office	4	11.58	41.86
Small Office	5	10.33	49.4
Warehouse	1	0.00	7.47
Warehouse	2	0.00	8.26
Warehouse	3	0.00	10.14
Warehouse	4	2.7	11.57
Warehouse	5	2.37	23.59

Appendix 8: New Construction: ASHRAE 90.1 Progress Indicator Weightings and Mappings

ASHRAE Progress Indicator Weightings: DOE NC Prototypes: Large Office Buildings

AIA CZ	1A	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8	Total
1													0.08		0.01	0	0.09
2									0.08	0.44	0.12	0					0.64
3							1.05	0	0.08								1.13
4				0.49	0.28	0.12											0.89
5	0.13	0.39	0.06														0.58

ASHRAE Progress Indicator Weightings: DOE NC Prototypes: Primary School Buildings

AIA CZ	1A	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8	Total
1													0.12	0.03	0.02		0.17
2									0.05	0.82	0.23						1.1
3							0.87	0.03	0.05								0.95
4				0.96	0.45	0.05											1.46
5	0.16	0.99	0.16														1.31

ASHRAE Progress Indicator Weightings: DOE NC Prototypes: Secondary School Buildings

AIA CZ	1A	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8	Total
1													0.3	0.06	0.05	0.01	0.42
2									0.12	2.15	0.45	0.01					2.73
3							1.97	0.06	0.12								2.15
4				1.99	0.82	0.11											2.92
5	0.32	1.59	0.23														2.14

ASHRAE Progress Indicator Weightings: DOE NC Prototypes: Small Office Buildings

AIA CZ	1A	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8	Total
1													0.18	0.03	0.02	0	0.23
2									0.06	0.89	0.32	0.01					1.28
3							0.84	0.06	0.06								0.96
4				1.02	0.47	0.08											1.57
5	0.17	1.13	0.29														1.59

ASHRAE Progress Indicator Weightings: DOE NC Prototypes: Stand Alone Retail Buildings																	
AIA CZ	**1A**	**2A**	**2B**	**3A**	**3B**	**3C**	**4A**	**4B**	**4C**	**5A**	**5B**	**5C**	**6A**	**6B**	**7**	**8**	**Total**
1													0.69	0.08	0.06	0.01	0.84
2									0.21	3.36	0.79	0.02					4.38
3							2.44	0.13	0.21								2.78
4				2.57	1.25	0.19											4.01
5	0.41	2.33	0.51														3.25

ASHRAE Progress Indicator Weightings: DOE NC Prototypes: Retail Strip Mall																	
AIA CZ	**1A**	**2A**	**2B**	**3A**	**3B**	**3C**	**4A**	**4B**	**4C**	**5A**	**5B**	**5C**	**6A**	**6B**	**7**	**8**	**Total**
1													0.09	0.01	0	0	0.1
2									0.06	0.96	0.2	0					1.22
3							0.89	0.02	0.06								0.97
4				1.11	0.63	0.1											1.84
5	0.2	1.08	0.25														1.53

ASHRAE Progress Indicator Weightings: DOE NC Prototypes: Non-Refrigerated Warehouse																	
AIA CZ	**1A**	**2A**	**2B**	**3A**	**3B**	**3C**	**4A**	**4B**	**4C**	**5A**	**5B**	**5C**	**6A**	**6B**	**7**	**8**	**Total**
1													0.29	0.03	0.03	0	0.35
2									0.22	3.01	0.7	0					3.93
3							2.64	0.08	0.22								2.94
4				2.7	2.3	0.15											5.15
5	0.51	3.07	0.58														4.16

Appendix 9: Retrofit Scenario: Custom Developed Weighting Factors and Mappings

2019 Commercial Building Inventory Derived Weighing Factors: DOE Retrofit Prototypes: Large Office

AIA CZ	1A	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	6A	6B	7	8	Total
1											0.090	0.168	0.013	0.015		0.287
2					0.004					0.245	0.016					0.266
3				0.005		0.048	0.262	0.003	0.035							0.353
4		0.017		0.139	0.001		0.072	0.002								0.230
5	0.017	0.086	0.015	0.052	0.075											0.245

2019 Commercial Building Inventory Derived Weighing Factors: DOE Retrofit Prototypes: Primary School

AIA CZ	1A	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	6A	6B	7	8	Total
1								0			0.0043	0.0121	0.0005	0.0009		0.0178
2					0.001					0.0197	0.0009					0.0216
3				0.0004	0	0.0014	0.0184	0.0002	0.0016							0.022
4		0.0008		0.0089	0		0.0057	0.0001								0.0155
5	0.0007	0.0052	0.0011	0.0029	0.0029			0								0.0128

2019 Commercial Building Inventory Derived Weighing Factors: DOE Retrofit Prototypes: Secondary School

AIA CZ	1A	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	6A	6B	7	8	Total
1											0.0043	0.0121	0.0005	0.0009		0.0178
2					0.001					0.0197	0.0009					0.0216
3				0.0004		0.0014	0.0184	0.0002	0.0016							0.022
4		0.0008		0.0089			0.0057	0.0001								0.0155
5	0.0007	0.0052	0.0011	0.0029	0.0029											0.0128

2019 Commercial Building Inventory Derived Weighing Factors: DOE Retrofit Prototypes: Small Office

AIA CZ	1A	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	6A	6B	7	8	Total
1								0.0001			0.0899	0.1683	0.0134	0.0148	0.0003	0.2868
2					0.0043					0.2448	0.0163		0.0001			0.2655
3				0.0047	0.0003	0.0481	0.2622	0.003	0.0349							0.3532
4		0.0166		0.139	0.0011		0.0715	0.0022								0.2304
5	0.0168	0.0862	0.0152	0.0517	0.0751			0.0004								0.2454

2019 Commercial Building Inventory Derived Weighing Factors: DOE Retrofit Prototypes: Retail Stand Alone

AIA CZ	1A	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	6A	6B	7	8	Total
1								0.0004			0.0702	0.1902	0.0227	0.0243	0.000 8	0.3086
2					0.007					0.2282	0.0203		0.0002			0.2557
3				0.0086	0.0008	0.023	0.168	0.0041	0.0276							0.2321
4		0.0266		0.164	0.0028		0.0861	0.0047								0.2842
5	0.0165	0.1079	0.0189	0.0578	0.0772			0.0009								0.2792

2019 Commercial Building Inventory Derived Weighing Factors: DOE Retrofit Prototypes: Retail Strip Mall															
AIA CZ	**1A**	**2A**	**2B**	**3A**	**3B**	**3C**	**4A**	**4B**	**4C**	**5A**	**5B**	**6A**	**6B**	**7**	**8**	**Total**
1											0.0107	0.0218	0.0029	0.0032	0.0001	0.0387
2					0.0013					0.0266	0.002					0.0299
3				0.001	0.0001	0.0035	0.0246	0.0003	0.0029							0.0324
4		0.0021		0.0167	0.0002		0.008	0.0005								0.0275
5	0.0025	0.009	0.0015	0.0062	0.0105			0.0001								0.0298

2019 Commercial Building Inventory Derived Weighing Factors: DOE Retrofit Prototypes: Warehouse															
AIA CZ	**1A**	**2A**	**2B**	**3A**	**3B**	**3C**	**4A**	**4B**	**4C**	**5A**	**5B**	**6A**	**6B**	**7**	**8**	**Total**
1								0.0001			0.0951	0.2218	0.0148	0.016	0.0004	0.3482
2					0.0104					0.3882	0.0288					0.4274
3				0.0089	0.0004	0.0371	0.2656	0.0032	0.0453							0.3605
4		0.0208		0.2926	0.0015		0.1234	0.0042								0.4425
5	0.028	0.1286	0.0257	0.0864	0.1637			0.0005								0.4329

Appendix 10: Retrofit Building Scenario – Floor Space Weighting Factors

Retrofit BuildingType	Office AIA CZ 1	Education AIA CZ 1	Warehouse AIA CZ 1	Mercantile/Service AIA CZ 1
AK	0.0054	0.0002	0.0048	0.0068
AL				
AR				
AZ				
CA				
CO	0.0798	0.0039	0.0795	0.0677
CT				
DC				
DE				
FL				
GA				
HI				
IA	0.0027	0.0003	0.0057	0.0072
ID	0.0143	0.0008	0.0189	0.0215
IL				
IN				
KS				
KY				
LA				
MA				
MD				
ME	0.0127	0.0004	0.0117	0.0172
MI	0.0037	0.0003	0.005	0.013
MN	0.0659	0.0062	0.073	0.0673
MO				
MS				
MT	0.0066	0.0001	0.006	0.0109
NC				
ND	0.005	0.0001	0.0064	0.0085
NE				
NH	0.0033	0.0001	0.0037	0.006
NJ				
NM				
NV				
NY	0.0139	0.0016	0.0182	0.0244
OH				
OK				
OR				
PA	0.0011	0	0.0021	0.003
RI				
SC				
SD	0.0052	0.0001	0.0036	0.0083
TN				
TX				
UT	0.0013	0.0001	0.0025	0.0032
VA				
VT	0.0047	0.0003	0.0032	0.0053
WA				
WI	0.0591	0.0033	0.1002	0.0715
WV				
WY	0.0023	0.0001	0.0036	0.0056

Retrofit BuildingType	Office AIA CZ 2	Education AIA CZ 2	Warehouse AIA CZ 2	Mercantile/Service AIA CZ 2
AK				
AL				
AR				
AZ	0.0002		0.0003	0.0008
CA	0.0003		0.0003	0.0004
CO				
CT	0.0158	0.0005	0.0134	0.0131
DC				
DE				
FL				
GA				
HI				
IA	0.0068	0.0006	0.0112	0.0089
ID				
IL	0.0426	0.0024	0.0792	0.0392
IN	0.015	0.0009	0.0354	0.0217
KS	0.0001			0.0004
KY				
LA				
MA	0.0355	0.0022	0.0262	0.0203
MD				0.0001
ME				
MI	0.025	0.0033	0.045	0.0321
MN				
MO	0.0004		0.0006	0.0011
MS				
MT				
NC	0.0001	0	0.0003	0.0004
ND				
NE	0.0056	0.0002	0.007	0.0073
NH	0.0034	0.0001	0.0041	0.0042
NJ	0.0152	0.0005	0.0172	0.0102
NM	0.001	0.0001	0.0007	0.0018
NV	0.0063	0.001	0.0182	0.0114
NY	0.0172	0.0019	0.0227	0.0211
OH	0.0313	0.0043	0.0717	0.0403
OK				
OR	0.0007	0	0.0012	0.0015
PA	0.0256	0.0021	0.0495	0.0278
RI	0.0035	0.0005	0.0031	0.0037
SC				
SD	0.0002	0	0.0002	0.0002
TN				
TX				
UT	0.0089	0.0005	0.0146	0.0094
VA				
VT				
WA	0.0033	0.0001	0.004	0.0056
WI				
WV	0.0015	0.0001	0.0013	0.0028
WY				

Retrofit BuildingType	Office AIA CZ 3	Education AIA CZ 3	Warehouse AIA CZ 3	Mercantile/Service AIA CZ 3
AK				
AL				
AR	0.0068	0.0005	0.0118	0.0124
AZ				
CA	0.0486	0.0014	0.0377	0.0277
CO				
CT				
DC	0.015	0.0007	0.0009	0.0014
DE	0.0042	0.0004	0.0041	0.0041
FL				
GA				
HI				
IA				
ID				
IL	0.0016	0.0001	0.0045	0.0042
IN	0.0025	0.0001	0.0063	0.0047
KS	0.0092	0.0008	0.0152	0.0113
KY	0.0097	0.0013	0.0254	0.0165
LA				
MA				
MD	0.0301	0.001	0.0274	0.0206
ME				
MI				
MN				
MO	0.0208	0.0014	0.0332	0.0231
MS				
MT				
NC				
ND				
NE				
NH				
NJ	0.0215	0.0016	0.0467	0.0203
NM	0.003	0.0002	0.0032	0.0043
NV				
NY	0.0724	0.0063	0.029	0.0255
OH	0.0062	0.0005	0.008	0.0052
OK	0	0	0	0.0001
OR	0.012	0.0007	0.0182	0.0127
PA	0.0237	0.0022	0.0253	0.015
RI				
SC				
SD				
TN				
TX				
UT				
VA	0.0402	0.0017	0.0329	0.0335
VT				
WA	0.0227	0.0009	0.0268	0.0174
WI				
WV	0.0031	0.0001	0.004	0.0043
WY				

Retrofit BuildingType	Office AIA CZ 4	Education AIA CZ 4	Warehouse AIA CZ 4	Mercantile/Service AIA CZ 4
AK				
AL	0.0163	0.0009	0.0248	0.0263
AR				
AZ	0.0005	0	0.0006	0.0017
CA				
CO				
CT				
DC				
DE				
FL				
GA	0.0671	0.0035	0.1342	0.0703
HI				
IA				
ID				
IL				
IN				
KS				
KY				
LA	0.0196	0.0009	0.0256	0.0355
MA				
MD				
ME				
MI				
MN				
MO				
MS	0.0031	0.0001	0.0187	0.0102
MT				
NC	0.0618	0.0054	0.1045	0.0741
ND				
NE				
NH				
NJ				
NM	0.0011	0	0.0015	0.003
NV				
NY				
OH				
OK				
OR				
PA				
RI				
SC	0.0176	0.0015	0.0416	0.0306
SD				
TN	0.0417	0.0032	0.0872	0.0565
TX	0.0017	0	0.0036	0.0034
UT				
VA				
VT				
WA				
WI				
WV				
WY				

Retrofit BuildingType	Office AIA CZ 5	Education AIA CZ 5	Warehouse AIA CZ 5	Mercantile/Service AIA CZ 5
AK				
AL	0.0029	0.0002	0.0051	0.0064
AR				
AZ	0.015	0.0011	0.0237	0.0198
CA	0.0711	0.0027	0.1552	0.0796
CO				
CT				
DC				
DE				
FL	0.0535	0.0042	0.0813	0.0728
GA	0.0022	0.0001	0.0091	0.0065
HI	0.0025	0.0001	0.0036	0.0033
IA				
ID				
IL				
IN				
KS				
KY				
LA	0	0	0	0.0001
MA				
MD				
ME				
MI				
MN				
MO				
MS	0.0022	0.0001	0.0033	0.0054
MT				
NC	0.0016	0.0001	0.0014	0.0027
ND				
NE				
NH				
NJ				
NM				
NV				
NY				
OH				
OK	0.0084	0.0006	0.0126	0.0138
OR				
PA				
RI				
SC	0.0034	0.0003	0.0056	0.0057
SD				
TN				
TX	0.0825	0.0032	0.1317	0.0923
UT	0.0002	0	0.0004	0.0006
VA				
VT				
WA				
WI				
WV				
WY				

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