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Integrating Efficiency with Health in Commercial Buildings Post-Pandemic

slipstream

Project Manager: Maddie Koolbeck

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EXECUTIVE SUMMARY

The COVID-19 pandemic led to immediate decline in commercial office building occupancy rates and to an increased focus on the connection between how buildings operate and disease transmission. Recommendations around increased ventilation and filtration have become prominent over the last two years and leading public health organizations continue to highlight the importance of building operations on particle spread. But less is known about how building managers implemented these recommendations and even less is known about how they plan to operate their buildings post-pandemic.

This study combines the results of a survey of Xcel Energy customers with a review of the current data around mechanical ventilation and filter use, along with energy analysis, to better understand current market trends and their impacts on energy use.

The objectives of the study were to:

- Determine how customers are operating buildings during the pandemic and how they plan to operate in a post-pandemic future, in relation to best practices and recommendations.
- Identify what other steps customers might take to improve the health impacts of their buildings and what factors they are taking into consideration.
- Quantify magnitude-level energy impacts of key operating decisions being made, in order to understand the magnitude of the intersection between energy and health.
- Identify potential impacts to existing efficiency programs including technical assumptions, new offerings, or modifications to assessment approaches.

Our study found that the majority of building operators did implement at least one change in operations during the pandemic. The most common was filtration updates followed by ventilation increases. Our research showed that most owners did not or were not able implement all of the best practices due to cost or technical challenges. Our research also showed that most respondents anticipated that variable occupancy would persist long-term.

The energy analysis illustrated that filtration updates had a minimal impact on energy use while significant increases in ventilation rates or expanded hours of operation had a much larger impact on energy use. A change in occupancy rates led to slightly lower energy use. Implementation of demand-controlled ventilation was found to have significant savings, and higher percent savings as occupancy dropped or ventilation rates increased.

These findings led to four near-term recommendations. We describe each below.

Encourage and assist customers in implementing measures that have been found to address indoor air quality while not *unnecessarily* penalizing energy.

There are several measures that researchers have identified that have a positive impact on indoor air quality, and a minimal impact on energy use. Some of these measures include MERV 13 filters, air cleaners, smarter ventilation rates and timing, and targeted in-room filtration.

Most notable on the list is MERV13 filters, which have a minimal impact on energy use while providing the same benefits as 100 percent outside air. The other options also have a minimal impact on energy but require more technical knowledge or higher upfront costs to implement.

Promote control-based measures to drive savings with variable occupancy and smart ventilation changes.

This research identified two changes that will impact building energy use long-term: (1) more variable occupancy of office buildings and (2) the potential need for increased ventilation over an extended period of time. Several measures exist that can address these changes and drive further energy savings. The measures include equipment upgrades from pneumatic or dated systems to new systems that allow for controls at a zonal level, and occupancy-based and CO2-based DCV and occupancy-based lighting controls.

In addition to promoting these measures, it will be important for the measure calculations to be updated to reflect the higher savings under new smart ventilation and variable occupancy patterns. More research around the exact baseline assumptions is needed, but this research can serve as a starting point to illustrate the need for updated calculations.

Include health and wellness benefits in marketing of building assessments or related programs.

A building assessment has the potential to improve the health of a building while also identifying energy saving opportunities. One core recommendation from ASHRAE is to ensure proper operation of HVAC systems. The building assessments program could utilize these recommendations to market the program to customers and increase program participation.

Furthermore, the assessments program could train energy auditors and engineers to follow healthy building guidelines and integrate them into a more typical energy assessment evaluation. Many of the healthy building recommendations are directly related to building operations and could be included in the assessment program without formally partnering with health experts.

Consider modifications to baseline energy profiles and measure calculations to reflect new occupancy and ventilation patterns.

As this research identified that variable occupancy and increased ventilation will persist long-term, it will be important to consider modifications to baseline energy profiles both in state technical resource manuals and internal calculations. As the energy analysis in this report illustrated, those changes impact both baseline energy use intensity and the potential savings from measures. More research around the exact baseline assumptions is needed, but this research serves as a starting point in illustrating the need for updated baseline energy profiles.

INTRODUCTION

When the COVID-19 pandemic started, commercial office building occupancy rates dropped to below 20 percent as states implemented stay-at-home orders. The occupancy rates stayed low throughout the pandemic and have still not returned to even half of pre-pandemic levels.[1] During the pandemic, experts also highlighted the influence of building operations on potential disease transmission and leading energy and public health organizations issued recommendations for operational changes to mitigate risks of viral spread. This added to a growing interest among building science professionals (even prior to the pandemic) in the health impacts of buildings.

Recommendations around increased ventilation and filtration have become prominent over the last two years, and leading public health organizations continue to highlight the importance of building operations on particle spread. However, relatively little is known about how building managers implemented these recommendations and even less is known about how they plan to operate their buildings post-pandemic. This study combines the results of a survey of Xcel Energy customers with a review of the current data around mechanical ventilation and filter use and an energy analysis, to better understand current market trends and their impacts on energy.

The objectives of the study were to:

- Determine how customers are operating buildings during the pandemic and how they plan to operate in a post-pandemic future, in relation to best practices and recommendations from organizations like ASHRAE and others.
- Identify what other steps customers might take to improve the health impacts of their buildings and what factors they are taking into consideration.
- Quantify magnitude-level energy impacts of key operating decisions being made, in order to understand the magnitude of the intersection between energy and health.
- Identify potential impacts to existing efficiency programs including technical assumptions, new offerings, or modifications to assessment approaches.

We interviewed Xcel Energy customers in both Colorado and Minnesota to understand building operation practices over the last several years, and also analyzed the energy impact of the changes in Xcel Energy service territory.

The report starts by summarizing the key COVID recommendations around building operations and by providing an overview of the existing research on this subject. We then detail the findings from our building operator interviews with stakeholders in Xcel Energy territory, and present the results of our energy impact analysis. We conclude with recommendations based on the findings of our research.

[1] CBRE Research, "Spring 2022 U.S. Office Occupier Sentiment Survey," April 2022.

BACKGROUND

Over the past decade, there has been growing interest among building operators and professionals on the relation between buildings and occupant health. The pandemic accelerated this interest. At the beginning of the pandemic, several leading organizations issued recommendations for how to operate buildings to mitigate the transmission of COVID-19. The ASHRAE Epidemic Taskforce issued one of the most cited set of recommendations for building operations and updated the recommendations as the pandemic progressed. ASHRAE's early recommendations included using increased outside or 24/7 HVAC operation.

These recommendations have been revised significantly since the first drafts were released, including reductions in the original airflow recommendations.[2] The recommendations for a post-pandemic state are as follows:

- Provide and maintain minimum outdoor airflow rates as required by code and standards (does not need to be 100% outside air)
- Use a combination of filters or air cleaners to achieve MERV 13 or better in recirculated air systems.
- Use air cleaners for which evidence of effectiveness and safety is clear.
- Select control options to provide desired exposure reduction while minimizing energy penalties.
- Promote mixing of air without causing strong air currents within spaces.
- Maintain proper operation of the system, including temperature and humidity design setpoints and equivalent clean air supply required, during all occupied times.
- Flush spaces for a minimum of 3 air-changes of equivalent clean air supply at either pre- or post-occupancy.
- Commission HVAC systems. Conduct a systems evaluation, inspect systems, and perform maintenance.

These recommendations will be referred to throughout the report as we detail the interview results and secondary literature on how the recommendations impact building energy use.

[2] ASHRAE, "Core Recommendations for Reducing Airborne Infectious Aerosol Exposure" (ASHRAE, October 2021).

LITERATURE REVIEW

We examined three topics in depth through a secondary research review: (1) occupancy changes during the pandemic and beyond, (2) implementation of COVID-19 building operation recommendations and impact on energy use and (3) financial benefits from improving indoor air quality.

OCCUPANCY RATES

The COVID-19 pandemic led most businesses to institute remote work policies. At the height of the pandemic, Pew Research found that 71 percent of people who could work from home reported that they were working from home all or most of the time. Over the last year, people started to return to work; yet a survey in January 2022, found that 59 percent of people that could work from home were still working from home most or all of the time and an additional 18 percent were working from home some of the time.[3]

Recent months have led to an uptick in return-to-work policies, but the policies still show a continuation of remote and hybrid work for many companies.[4] A survey from April 2022 found that only 19 percent of respondents expected a full office-based workplace policy in the future.[5] Similarly, another survey found that executives expected only 20 percent of all workers to be back in the office five days a week, down from 50 percent reported in early 2021.[6] Employees also expressed a desire to be able to work home, with 60 percent reporting that they prefer to work from home rather than at the workplace.[7]

Many building types will remain partially occupied for some time to come, though specific levels of occupancy are still unknown.

COVID-19 BUILDING OPERATION RECOMMENDATIONS IN PRACTICE

The recommendations from ASHRAE and other leading public health organizations have been routinely highlighted as best practice throughout the pandemic. Nevertheless, questions remained around the impact of the recommendations in practice; both on rates of adoption in buildings and how they would impact overall building energy use.

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[3] Kim Parker, Juliana Menasce Horowitz, and Rachel Minkin, "COVID-19 Pandemic Continues To Reshape Work in America," *Pew Research Center's Social & Demographic Trends Project* (blog), February 16, 2022, https://www.pewresearch.org/social-trends/2022/02/16/covid-19-pandemic-continues-to-reshape-work-in-america/.
[4] CBRE Research, "Spring 2022 U.S. Office Occupier Sentiment Survey."
[5] CBRE Research.
[6] Emma Goldberg, "A Full Return to the Office? Does 'Never' Work for You?," *The New York Times*, June 9, 2022, sec. Business, https://www.nytimes.com/2022/06/09/business/return-to-work-office-plans.html.
[7] Parker, Horowitz, and Minkin, "COVID-19 Pandemic Continues To Reshape Work in America."

One survey found that roughly three-fourths of facility managers did reconsider operations practices in the face of the pandemic and around half of the surveyed facility managers reported implementing a change to their HVAC systems.[8]

A second study conducted from April to May 2021 asked 300 respondents more detailed questions about operational changes and found that offices implemented roughly four equipment or operational changes.[9] The respondents cited guidance from CDC and ASHRAE as their motivation to make changes. The strategies with the highest rates of implementation (around 50%) were the ones which included the following: increased airflow, increased outdoor air and upgraded filters. The less frequent changes included: air cleaners, advanced filtration and monitoring. The majority of respondents indicated that increased outdoor air, upgraded filters and more natural ventilation were likely permanent changes while only around a third stated that increased airflow were likely permanent changes.

The recommendations for increased ventilation and improved filtration were both expected to have negative impacts on building energy use. Increased outside air from ventilation increases the need to reheat or cool the air more and thus increases overall HVAC energy consumption. Filtration has an impact on energy use due to increased static pressure drop. A number of studies explored these hypotheses and quantified the impact of recommendations.

Increased ventilation has a significant impact on total energy consumption, especially in cold climates.[10] Significantly increased ventilation rates or expanded hours of operation have the largest impact while implementing extra purges or flushes have a smaller impact. One study found that operating HVAC equipment at 100 percent outside air 24 hours of the day, as initially recommended by ASHRAE, led to an increase in energy costs by roughly 62 percent in cold climates.[11] Reducing the amount of time operating at 100 percent outside air from 24/7 to only typical occupancy periods lowered the energy cost penalty to roughly 25 percent. A nightly purge was estimated to only increase energy use by 8 percent.[12]

Studies have found that MERV-13 filters can provide the same air quality benefits as increased 100% outside air, with a more minimal impact on building energy use.[13] Furthermore, studies have found that MERV-13 filters are at least 85 percent effective at capturing particles between 1 and 3 micrometers[14] and that respiratory droplets that move COVID-19 through the air are typically 1 micrometer or larger. The estimates from the studies illustrate that an upgrade to a MERV-13 filter will increase energy costs by less than one percent and provides equivalent

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[8] Honeywell, "Rethinking Buildings Post COVID," 2021.
[9] Urban Land Institute, "A Transformative Year: Impacts of 2020 on Real Estate."
[10] Nuno D. Cortiços and Carlos C. Duarte, "COVID-19 -The Impact in US High-Rise Office Buildings Energy Efficiency," *Energy and Buildings* 249 (October 15, 2021): 111180.
[11] Michael Risbeck et al., "Airborne Transmission Risk and Energy Impact of HVAC Mitigation Strategies," May 2022.
[12] Chris CaraDonna and Kim Trenbath, "ComStock/COVID19: U.S. Commercial Building Stock Analysis of COVID-19 Mitigation Strategies," February 2021, 69.
[13] CaraDonna and Trenbath; Risbeck et al., "Airborne Transmission Risk and Energy Impact of HVAC Mitigation Strategies"; Cortiços and Duarte, "COVID-19."
[14] "ASHRAE Filtration and Disinfection FAQ," n.d., https://www.ashrae.org/technical-resources/frequently-asked-questions-faq.

outdoor air benefits as increasing ventilation significantly.[15] Upgrades to HEPA or higher MERV-rated filters would provide even more significant health benefits, and still have a relatively small impact on overall energy use.

Researchers also identified that for variable-air-volume (VAV) forced air systems, higher AHU supply temperature setpoint increases the total supply airflow to maintain the temperature setpoint (assuming the same cooling load,) which in turn increases the equivalent outdoor air delivery rates.[16] This provides another way for building operators to address indoor air quality without a large impact on energy use.

There is limited data on the effectiveness and energy impact of air cleaners, including ultraviolet energy, bipolar ionization, or gas-phase (or sorbent) cleaners.

- Gas-phase air cleaners with sorbent beds alone are not typically effective at removing viruses from airstreams.
- UV-C energy is generally effective at inactivating virus particles.
- Bipolar ionization air cleaners have lots of varying reports of efficacy.[17]

General recommendations are for consumers to evaluate the technologies in-depth and only implement cleaners or technologies that have well-documented third-party evaluations showing their effectiveness. The ASHRAE Epidemic Taskforce created a spreadsheet tool to help building operators or owners compare different options by evaluating each option's rate of equivalent outdoor air changes.[18]

There are a variety of approaches to making building operations potentially healthier and their energy impacts differ widely.

INDOOR AIR QUALITY COSTS AND BENEFITS

Even prior to the COVID-19 pandemic, there was an increasing focus on indoor air quality in commercial buildings and the potential impact on productivity and human health. Building science professionals and researchers, as well as, building owners have been interested in these impacts. The most researched benefits include increased productivity and reduced absenteeism from higher ventilation rates. A higher ventilation rate has been linked to reductions in viral particulate spread, carbon dioxide and other indoor-emitted pollutants. These reductions have also been linked to improved cognition abilities. A doubling in minimum

[15] CaraDonna and Trenbath, "ComStock/COVID19: U.S. Commercial Building Stock Analysis of COVID-19 Mitigation Strategies"; Risbeck et al., "Airborne Transmission Risk and Energy Impact of HVAC Mitigation Strategies."
[16] Risbeck et al., "Airborne Transmission Risk and Energy Impact of HVAC Mitigation Strategies."
[17] ASHRAE, "Filtration / Disinfection," ASHRAE, accessed August 2, 2022, https://www.ashrae.org/technical-resources/filtration-disinfection.
[18] "Equivalent Outdoor Air Calculator" (ASHRAE Epidemic Task Force, n.d.), https://docs.google.com/spreadsheets/d/1GUCcjAyhzrTATHD8SQvNcF7JnuWKpadSVT6LA_8SUII/edit#gid=0.

designed ventilation rates has been found to increase cognitive scores by 18 percent[19] and significantly lower absenteeism.[20]

Overall, the research shows that these benefits outweigh the negative environmental and financial impact from higher energy use. In fact, Fisk et al. found that the economic benefits from reduced absenteeism and improved productivity outweigh the financial impact of energy penalties by two orders of magnitude.[21] Another study that considered public health, indoor air quality and energy losses, found that the improved productivity and reduced absenteeism was at least one order of magnitude more valuable than the associated financial and environmental penalty from increased energy use.[22]

Additionally, several studies have examined how utilizing energy recovery ventilation systems, smarter ventilation controls and shifts in the time when mechanical ventilation is used, could limit the energy penalty while still providing indoor air quality benefits.[23] McNaughton et al. show that adding energy recovery ventilation systems can cut the energy cost penalty by over half while still providing similar indoor air quality benefits.[24] Similarly, carbon dioxide-based demand-controlled ventilation (DCV) or more optimized ventilation controls were found to provide indoor air quality benefits while minimizing energy losses.[25] Lastly, a study found a time-shift in ventilation from mid-morning to mid-afternoon can maintain indoor air quality while lowering energy use as temperatures are lower and internal heat gains are higher.

There are value propositions for building impacts on occupant health that are significant enough to have building owners and tenants' attention.

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[19] Joseph G. Allen et al., "Associations of Cognitive Function Scores with Carbon Dioxide, Ventilation, and Volatile Organic Compound Exposures in Office Workers: A Controlled Exposure Study of Green and Conventional Office Environments," *Environmental Health Perspectives* 124, no. 6 (June 2016): 805–12.
[20] William J. Fisk, Douglas Black, and Gregory Brunner, "Changing Ventilation Rates in U.S. Offices: Implications for Health, Work Performance, Energy, and Associated Economics," *Building and Environment* 47 (January 2012): 368–72.
[21] Fisk, Black, and Brunner.
[22] A. Rackes, T. Ben-David, and M. S. Waring, "Outcome-based Ventilation: A Framework for Assessing Performance, Health, and Energy Impacts to Inform Office Building Ventilation Decisions," *Indoor Air* 28, no. 4 (July 2018): 585–603.
[23] Tom Ben-David, Adams Rackes, and Michael S. Waring, "Alternative Ventilation Strategies in U.S. Offices: Saving Energy While Enhancing Work Performance, Reducing Absenteeism, and Considering Outdoor Pollutant Exposure Tradeoffs," *Building and Environment* 116 (May 1, 2017): 140–57; Rackes, Ben-David, and Waring, "Outcome-based Ventilation."
[24] Piers MacNaughton et al., "Economic, Environmental and Health Implications of Enhanced Ventilation in Office Buildings," *International Journal of Environmental Research and Public Health* 12, no. 11 (November 18, 2015): 14709–22..
[25] Ben-David, Rackes, and Waring, "Alternative Ventilation Strategies in U.S. Offices."

BUILDING OPERATIONS INTERVIEW RESULTS

We conducted interviews with building and property managers from March 2022 to May 2022 to understand operations changes during the pandemic and to learn about any expected changes in operation post-pandemic. During the interviews, we asked about occupancy changes, ventilation and filtration changes, technology upgrades and how buildings are dealing with variable occupancy. For more detail, the interview guide is provided in Appendix A.

We interviewed 17 organizations in Minnesota and in Colorado. Fourteen interviewees were directly involved in the building management while three were recommissioning or engineering firms that regularly worked with existing buildings. The respondents included a mix of energy managers, property managers, chief engineers, and maintenance managers. Table 1 summarizes the list of interviewees in each state.

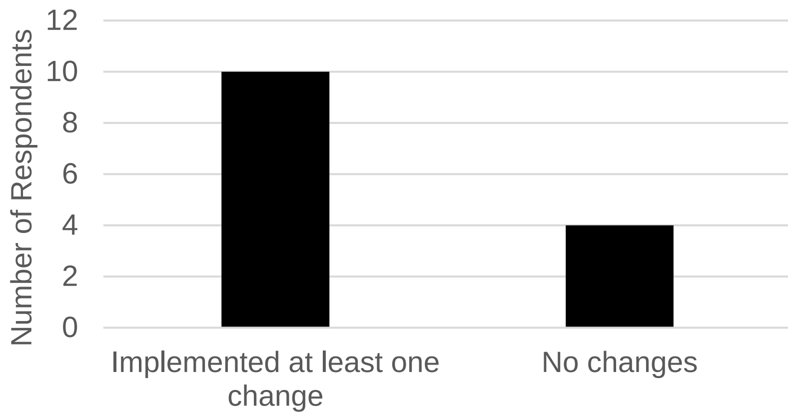
Table 1. Interviewee list.

Minnesota	Colorado
• 6 office owners or managers (represent 35 buildings) • 2 university campuses • 1 recommissioning organization	• 4 office owners or managers (represent 39 buildings) • 2 university or research campuses • 2 recommissioning organizations

All of the building operators we interviewed had either directly looked at the ASHRAE core recommendations or received guidance from their corporate offices based on the ASHRAE core recommendations. A number of the respondents mentioned they reviewed the recommendations early in the pandemic but had not continued to review the guidance as the pandemic continued. The recommissioning firms mentioned that they had received several questions about the ASHRAE recommendations from clients.

Each of the interviewees mentioned that chief engineers, property managers and owners made decisions about implementation of changes together. The universities mentioned that they utilized committees to review recommendations and to decide on implementing changes. Figure 1 summarizes overall adoption of recommendations.

Figure 1. Implementation of ASHRAE COVID-19 taskforce recommendations.



Ten of 14 organizations implemented at least one change. Seven of these ten implemented several changes, while three only implemented one upgrade. Four organizations did not make any significant changes to their operations. The four that did not implement any significant changes said they were constrained by existing building equipment; were already meeting the recommendations or did not have the capability to make upgrades at their building. The following sections detail these changes in more detail.

OCCUPANCY CHANGES

All of the organizations we interviewed reported that occupancy dropped to essential personnel when the pandemic began. Interviewees reported that occupancy rates stayed relatively low through spring 2022, and that return-to-work or hybrid schedules were just starting to be implemented in spring and summer of 2022. Reported occupancy rates were between 5 and 35 percent at the time of the interviews. Seven of the office buildings reported that they expect hybrid schedules and variable occupancy to continue permanently, while another three were unsure of tenants' long-term remote work policy.

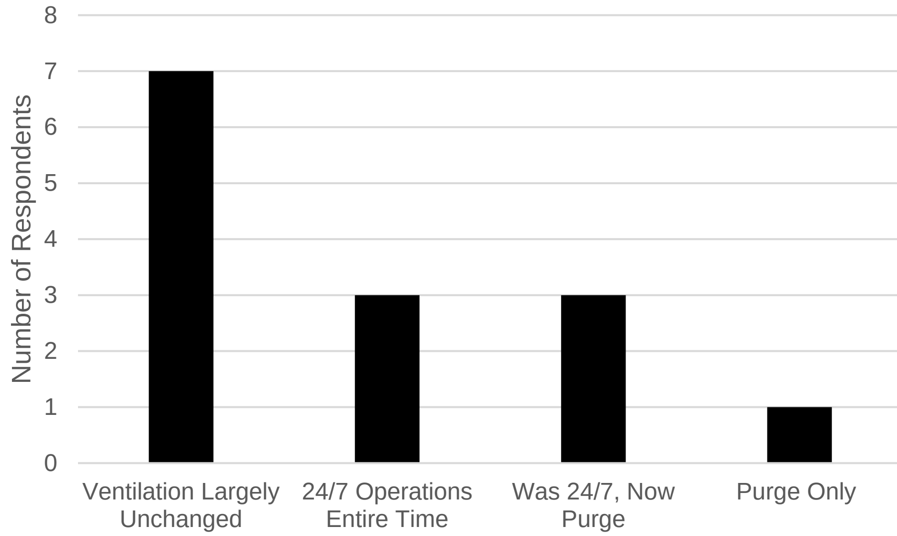
The universities generally had brought people back and returned to in-person classes in fall of 2021 and were operating more normally than the office buildings.

VENTILATION + FILTRATION CHANGES

Ventilation changes varied significantly by organization, with some implementing the most stringent recommendations and others opting to make minimal changes. We asked respondents about what they implemented at the height of the pandemic, how it changed during the pandemic, and what changes they anticipate going forward.

Figure 2 illustrates these changes made throughout the pandemic.

Figure 2. Ventilation changes during the pandemic.



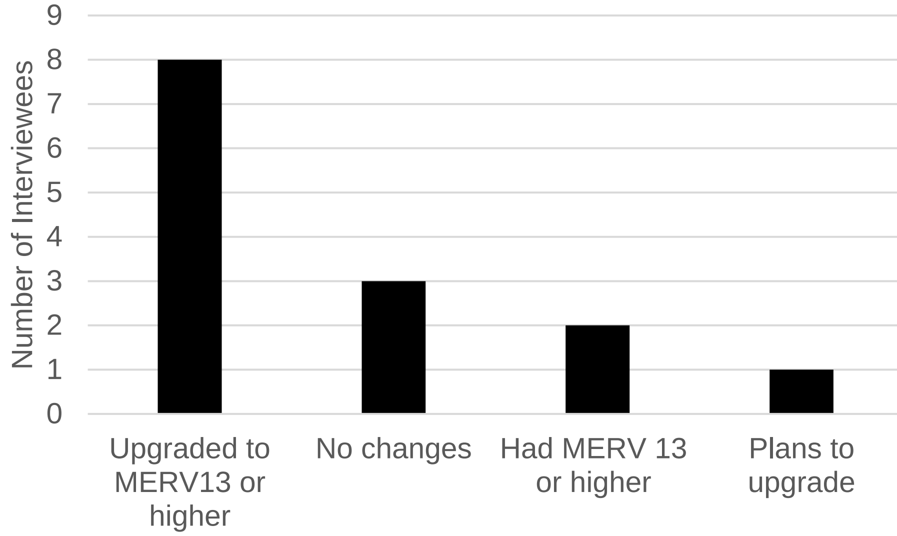
There were 7 buildings that implemented significant ventilation changes – either moving to 24/7 operations or a nightly purge. Three implemented 24/7 operations and are still operating in that way. Three implemented 24/7 operations and have since moved to nightly purges. One building immediately implemented nightly flushing. Of these seven, four were university or research campuses and the other three were office buildings.

The seven buildings that did not change ventilation, mentioned that they were already bringing in as much outside air as they could, or that they increased outdoor air when temperatures allowed without causing a significant energy impact. Two mentioned using DCV as a way to address ventilation concerns.

Interviewees that implemented 24/7 operations mentioned a plan to return to more normal operations in the coming months. This primarily meant ending 24/7 operations and re-enabling DCV. One of the interviewees had hired a consultant to do a study on how many air changes per unit were needed and planned to make changes based on the results of that study. Several others stated that they wanted to reduce ventilation but there were no defined future plans at the current point in the pandemic. Another mentioned that ventilation rates would decrease but likely stay slightly above pre-pandemic rates. The engineering firms mentioned that only a small number of clients changed ventilation and the 24/7 operations did not last long for many of their clients.

A high percentage of organizations implemented filtration upgrades. Figure 3 details the rates of filtration implementation. Eight of fourteen organizations updated their filters to MERV-13 and two others already had MERV-13 in place. Three made no changes. One tested MERV-13 filters but stated that they threw their building out of balance. Another building has plans to upgrade filters in the next year. The remaining two buildings made no changes and reported having somewhere between MERV8 and MERV11 filters on most air handling units. All of the buildings reported that the filtration changes were permanent.

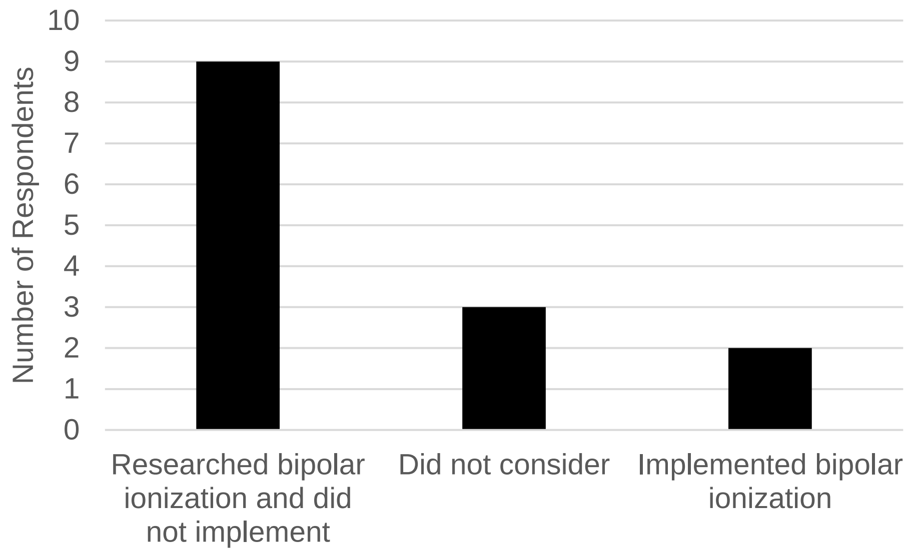
Figure 3. Filtration changes during the pandemic.



AIR CLEANING TECHNOLOGIES

Air cleaning technologies were not widely adopted by commercial offices or universities. Bipolar ionization was the most mentioned technology by respondents. Figure 4 details the responses.

Figure 4. Implementation of bipolar ionization.



Two organizations, one commercial office firm and one university, did implement bipolar ionization in select buildings.

Nine other organizations researched bipolar ionization and decided not to implement. Three of the nine organizations implemented the technology in one air handling unit and decided not to implement as the impact didn't seem large enough. One of these organizations brought in an industrial hygienist to study the impact, and the findings generally showed that it had an impact but not one that was more significant than measures already in place. One of these organizations is still considering the implementation of ultraviolet energy.

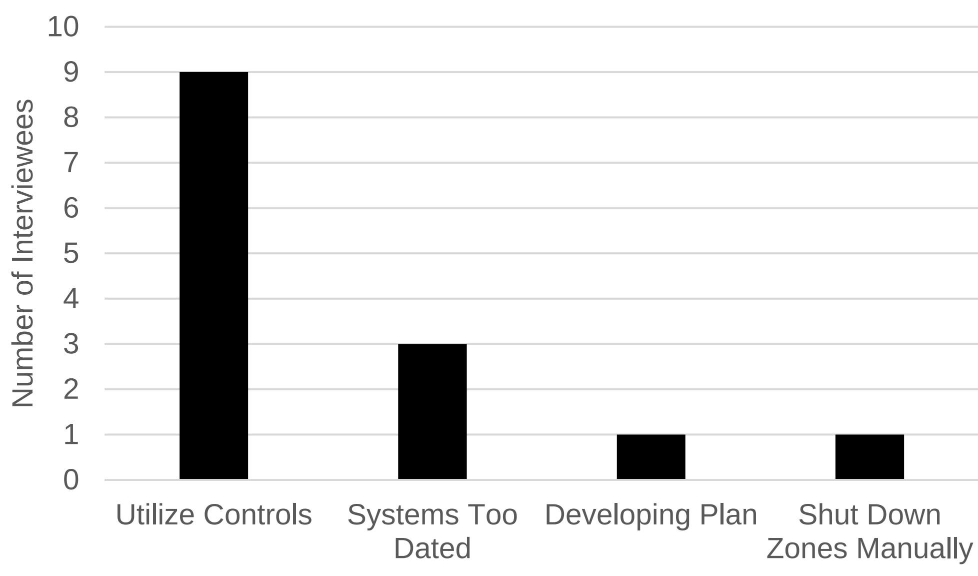
The recommissioning organizations mentioned that they received lots of questions around bipolar ionization as clients were receiving lots of sales pitches from manufacturers at the beginning of the pandemic.

All three universities added HEPA filters or portable air cleaners to certain rooms around campus. They were typically added to areas with high occupancy or older rooms that lacked mechanical ventilation. One university also moved them into rooms if occupants requested them. None of the commercial office spaces added portable air cleaners but did allow tenants to bring in the technology.

VARIABLE OCCUPANCY

Many of the interviewees stated that their tenants were planning on continued flexible or hybrid schedules. We asked about how they planned to deal with variable occupancy in their building operations. Figure 5 illustrates the responses on variable occupancy.

Figure 5. Variable occupancy responses.



Nine of the fourteen interviewees reported utilizing controls to change operations based on occupancy or indoor conditions. Of these nine, five explicitly mentioned that DCV was being used as part of the controls. Two interviewees mentioned that they explored being able to shut down zones completely, but they found that at least one person was typically in the office reducing the ability to fully shut down.

Three interviewees reported that their control systems were too dated to adequately deal with variable occupancy or to utilize zonal controls. One noted that they have primarily been turning off sections of the building that are unoccupied and another is actively developing a plan to deal with changing occupancy.

The retro-commissioning organizations mentioned that there are still lots of pneumatic systems in place which makes it difficult to control building operations at a zonal level or implement any DCV. One also mentioned that building operator knowledge of how to make changes at the zonal level is another barrier to make these changes and adjust for variable occupancy.

ENERGY IMPACT

The majority of interviewees had not quantified the energy impact from the changes in operations, and the estimates they provided varied. Energy use went down for those that had shut down unoccupied zones in their buildings.

Offices that had implemented significant ventilation changes saw an increase in HVAC consumption but a reduction in plug load and lighting use from reduced occupancy. The general feeling was that the two changes result in a net zero impact on energy. Those who had moved to nightly flushing reported a much smaller impact on overall HVAC energy use.

ASSESSMENTS, CERTIFICATIONS, AND MONITORING

The interest in monitoring indoor air quality and pursuing healthy building certifications was relatively low among interviewees. Only one of the interviewees actively monitors indoor air quality and one other mentioned that they were considering options for monitoring. The one interviewee that monitors indoor air quality uses WellStat monitors and tracks particulates, carbon dioxide, and multiple volatile organic compounds (VOCs).

One building was WELL certificated and one interviewee was exploring FitWell certifications for their buildings. Multiple buildings were already LEED certified, which does include optional air quality credits.

Two building owners hired consultants to look specifically at operations during the pandemic – one was focused on identifying needed air changes per unit and the other was focused on ensuring the implemented changes wouldn't have an adverse impact on the HVAC systems. Two other buildings mentioned that assessments are done annually for the building certifications (either WELL or LEED) and that the assessments include spot checks for air quality issues. Others mentioned only bringing in experts if there was a mold or other obvious issues.

The majority of the interviewees stated that they would be interested in a joint health and energy assessment.

BARRIERS TO IMPLEMENTATION OF CHANGES

The primary barrier for building managers to implement changes to indoor air quality was cost. The costs included upfront costs to implement building upgrades and the potential for increased energy costs if ventilation was increased. Other barriers that were noted included: keeping up to date on the recommended actions and actively communicating the value of those changes to tenants or building owners.

The engineering groups mentioned that air quality concerns do not typically make the top ten list of building priorities for building managers and owners. The engineering groups also highlighted the expense of upgrading building control systems from pneumatic, and how without those updates building operators cannot deal with varying occupancy effectively.

ENERGY IMPACTS

The literature review and interviews illustrated that building operators did make building operation changes during the pandemic and that some of those changes are likely to be permanent. This section explores the impact of those changes on energy use within office buildings in the two large cities in the Xcel Energy service territory. For office buildings in Denver and Minneapolis, the goal was to understand the following:

- The impact of COVID-19 recommendations on energy use.
- The impact of potential permanent ventilation and occupation changes on energy use.
- How savings for DCV may change under new baseline ventilation or occupancy rates.

The following section details the methodology and then the energy impacts for both Minnesota and Colorado.

METHODOLOGY

To understand the impact of potential building operation changes on energy usage, our team developed energy models of a typical existing office building. This prototypical 53,600 square foot, 3 story office building was created in eQUEST and weather normalized. Table 2 details the assumptions for the modeling.

Table 2. Baseline building model assumptions.

Metric	**Value**
Aspect ratio	1.5
Window to Wall Ratio	Evenly Distributed across all four facades, 33%
Floor to floor height	13 ft
Walls	Steel framed (2x4 16IN OC) 0.4 in. Stucco+5/8 in gypsum board + wall Insulation + 5/8 in.
Roofing	Insulation entirely above deck
Glazing	Metal Framing
Foundation	8” concrete slab poured directly on to the earth (slab-on-grade)
Internal Mass	6 inches standard wood (16.6 lb/ft^2)
Skylight	None
Heating Fuel type	Natural Gas
Air-sided system	Packaged VAV with hot water reheat
Cooling system	Direct expansion
Heating system	Boiler

Metric	Value
Dedicated outdoor air system	None
Domestic hot water heater	Natural Gas fired
Occupancy schedule	Follows general office schedule type from ASHRAE (weekdays 9 am to 6 pm)
Daylight controls	Continuous dimming
Heater efficiency	80% at 175 Btu/hr*person
Occupant density	200 ft^2/person
Ventilation rate	17 CFM/person (ASHRAE 62.1 baseline)
Cooling Equipment EER	9.3
Fan Power	1.119 W/CFM
Fan Total Static Pressure	3.5iwg

We started with this baseline model, and then ran a series of trials where we varied filters, ventilation rates and schedules, occupancy rates, and existence of CO_2-based DCV. Table 3 lists the various parameter changes we made across modeling runs.

Table 3. Modeling runs.

COVID-19 Recommendations	Additional Ventilation Changes	Occupancy Changes	Energy Measures
- MERV13 filter - HEPA filter - Night flush - 2x increase in ventilation	- 2x increase in ventilation - 1.6x increase in ventilation - 1.3x increase in ventilation	- 75% occupancy - 50% occupancy - 25% occupancy	- CO_2-based DCV

We started by implementing the ASHRAE core COVID-19 recommendations one at a time to understand the impact of those on energy use. They included filter upgrades, a night flush, and a doubling of baseline ventilation rates. We modeled the night flush by keeping the fans and ventilation for an extra hour after the building closes. The doubling of ventilation rates represents a building that is running close to 100 percent outdoor air.

Then we ran models that represented permanent operational changes as a result of the pandemic. Through the interviews we conducted, we established that the majority of buildings plan to return to more normal ventilation rates as the pandemic moves into the next phase. However, several respondents mentioned that these ventilation rates may be slightly higher than the pre-pandemic rates as there continues to be a large emphasis at the federal government and from industry experts on ventilation. We modeled three different ventilation rate scenarios. The most extreme scenario is a doubling of minimum designed ventilation rates during occupied hours, which represents what is often discussed in the commercial indoor air quality literature. We also included two scenarios that represent requirements to receive indoor air quality credits through LEED or WELL: a 30 percent increase in ventilation rates and a 60 percent increase in ventilation rates during occupied hours.

Next, we varied occupancy at 100%, 75%, 50%, and 25% to represent the likely permanent work-from-home or flexible work policies. Finally, we created trials that included DCV measures to quantify the impact of these changes under the potential new baseline occupancy and ventilation scenarios.

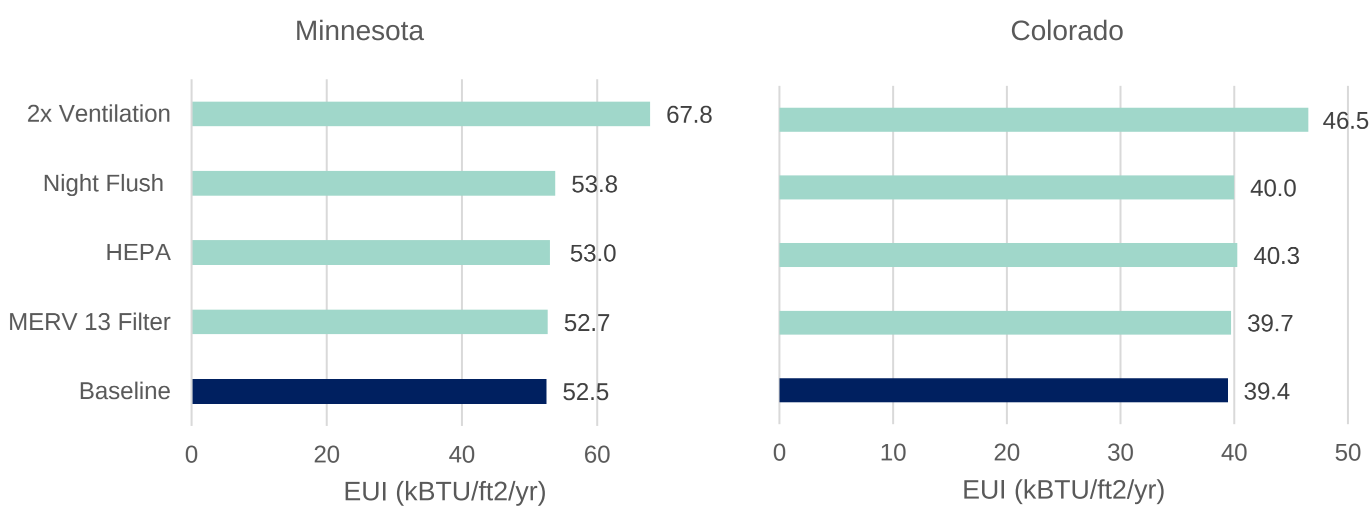
RESULTS

Energy Use and COVID-19 Recommendations

We compared baseline energy use during pre-pandemic operations to recommended ventilation and filtration changes. These included doubling ventilation rates, a night flush, a MERV-13 filter, and an in-unit HEPA filter. Figure 6 shows the results of each of these upgrades.

The results show that filtration upgrades and the one-hour nightly flush have a minimal impact on energy use compared to the impacts from the doubling of ventilation. The MERV-13 filter increases energy use by less than 1 percent and the HEPA filter and night flush increases increase energy by less than 2 percent. The doubling of the ventilation rate, on the other hand, increases energy use by 18 percent in Colorado and 29 percent in Minnesota. In Colorado, there is a smaller impact due to the mild climate. This illustrates the importance of filtration changes and more targeted ventilation changes to reduce impact on energy use.

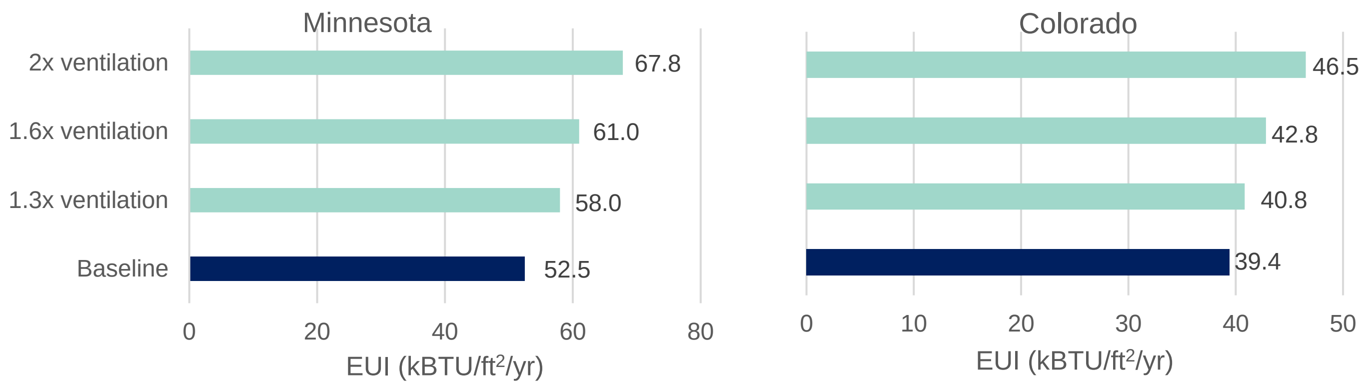
Figure 6. Energy impact of COVID-19 recommendations.



Ventilation Changes

We examined the impact of permanent ventilation rate changes on energy use intensity absent any control changes. Figure 7 shows the EUI for each of the ventilation scenarios: baseline (ASHRAE 62.1), 1.3 times the baseline, 1.6 times the baseline, and a doubling of the baseline ventilation rates during occupied hours only.

Figure 7. Comparison of energy use intensity across ventilation rates.



As the ventilation rate increases relative to the baseline, the EUI increases as well. As expected, a doubling of ventilation rates during occupied period has the largest impact while the two options in the LEED standard have a smaller impact. In Minnesota, a doubling of the ventilation rate increases EUI by 29 percent compared to the baseline ventilation scenario, increasing ventilation rates 1.6 times above the baseline increases EUI by 16 percent and increasing the ventilation 1.3 times above baseline increases EUI by 10 percent. In Colorado, the increase in ventilation rate has a smaller impact due to the milder climate. A doubling increases EUI by 14 percent while a ventilation rate 1.6 times higher increases EUI by 8 percent and a ventilation rate 1.3 times higher increases EUI by 3 percent.

As mentioned in the literature review, advanced controls have the ability to decrease the energy impacts while still providing air quality benefits. On the ventilation side, the most significant control measure is DCV. Figure 8 illustrates the same ventilation scenarios with DCV enabled. The results illustrate that increasing ventilation rates by 30 percent with DCV enabled, results in the same EUI as the baseline case. Similarly, the increases in EUI for the 1.6 times and 2 times ventilation with DCV enabled are smaller in magnitude.

Figure 8. Comparison of ventilation scenarios EUIs with DCV.

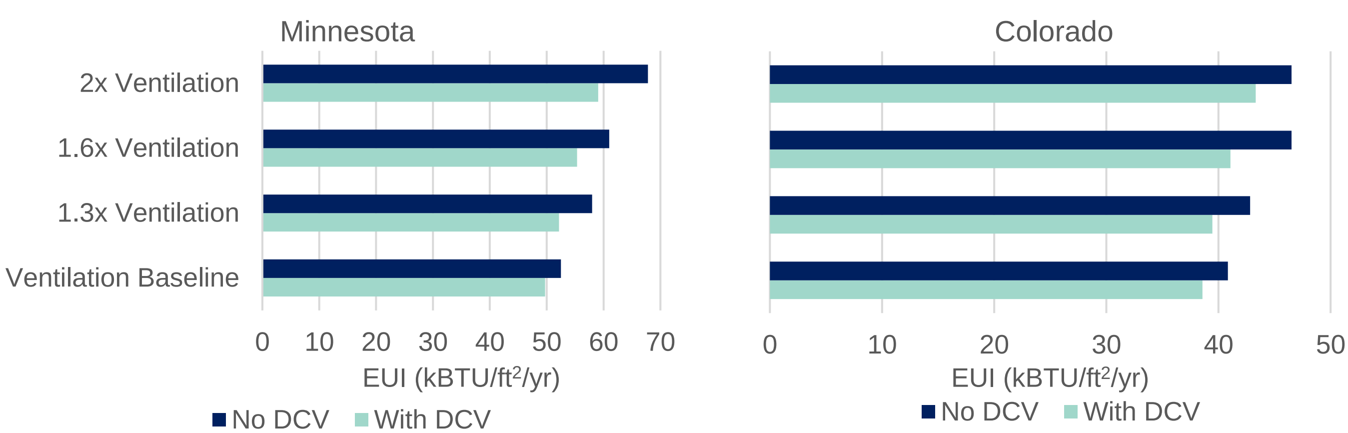
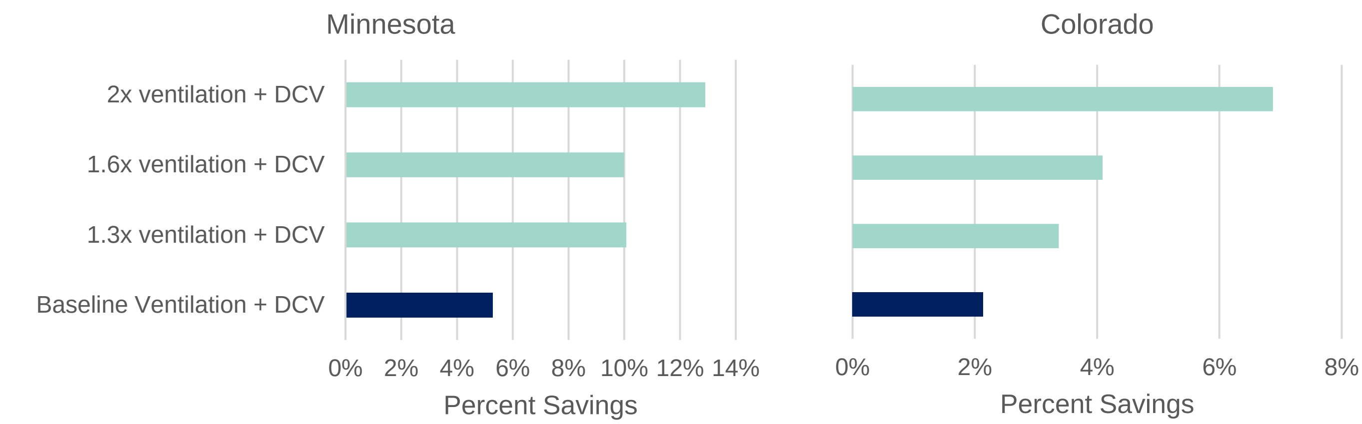


Figure 9 shows the percent savings from the measure as the ventilation rate increases relative to baseline. The percentage savings are based on the difference between the energy use at each ventilation level with and without DCV. The percent savings increase as ventilation increases. This illustrates the importance of DCV implementation across buildings, especially for those deploying higher ventilation rates. The savings across all ventilation rates are higher in Minnesota due to the higher heating and cooling needs that result from increased ventilation.

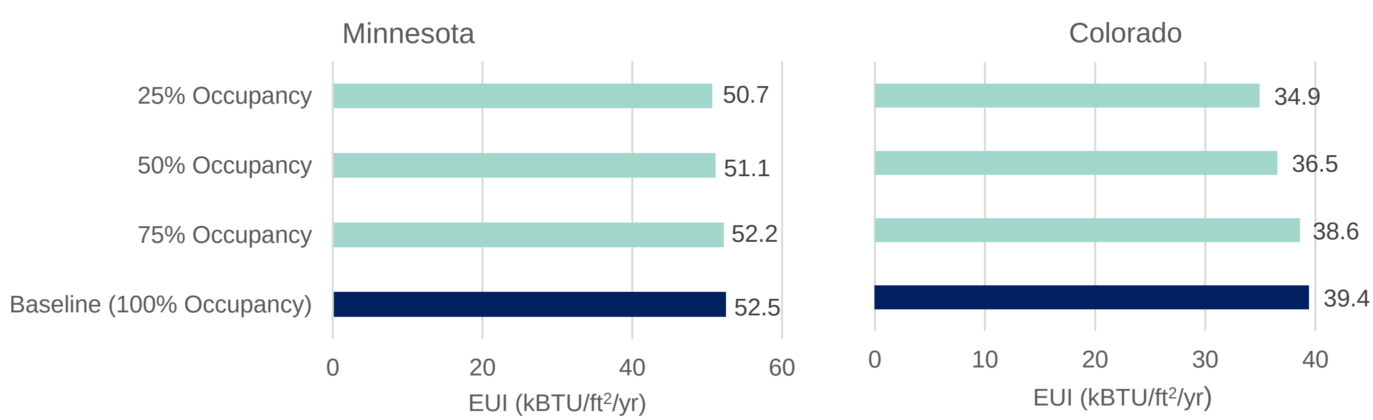
Figure 9. Impact of DCV across ventilation scenarios.



Occupancy Changes

The pandemic has altered occupancy patterns permanently, potentially more so than ventilation impacts. Next, we will explore how changes in occupancy rates impact energy use, as well as how controls can reduce energy use. Figure 10 shows the impact of decreasing office occupancy versus EUI. As occupancy decreases, we assume that lighting and plug load use decline through both occupancy-controls and fewer people using computers, printers, and other devices in the office. As a result, the graph illustrates that there is a decline in energy use intensity as occupancy decreases.

Figure 10. Comparison of EUI across occupancy rates.



The decline in overall EUI is relatively small in magnitude as occupancy decreases. This is largely because electricity use decreases while natural gas use increases when occupancy decreases. The natural gas increase results from a decline in internal load heating as less people are in the office and fewer computers or lighting is used. Figure 11 illustrates this electricity and natural gas impacts from variable occupancy in both Minnesota and Colorado.

Figure 11. Natural gas and electricity savings across occupancy rates.

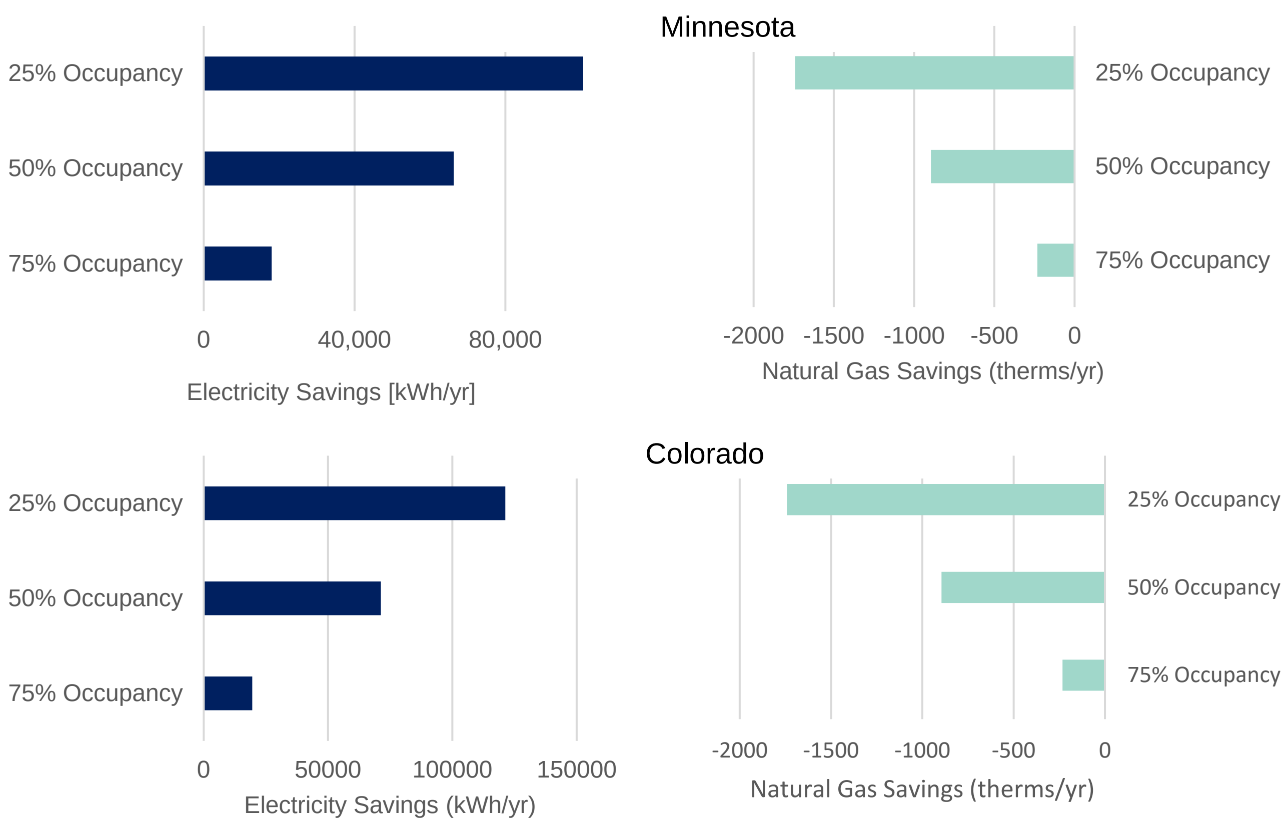
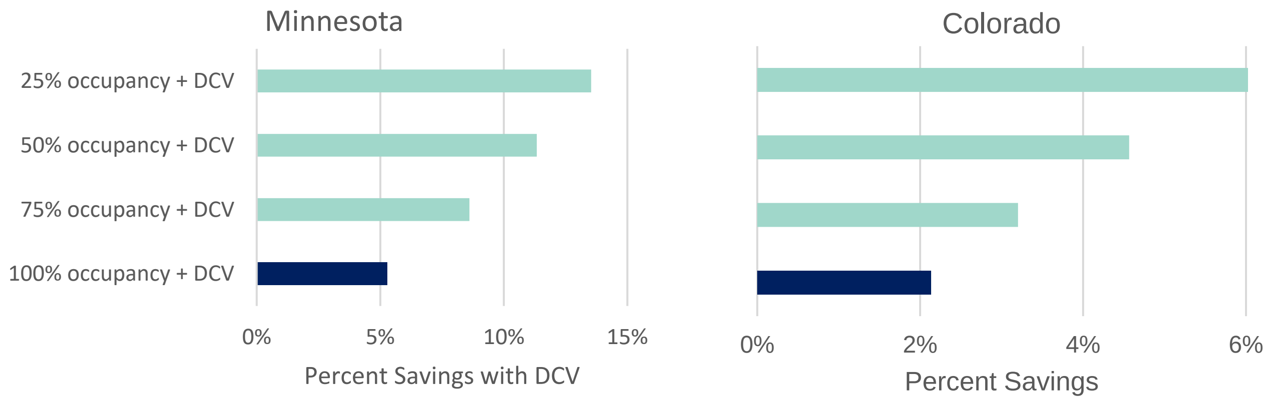


Figure 12 shows increasing savings of DCV as occupancy decreases. In Minnesota, the percent savings increases from 5 percent to 14 percent and from 2 percent to 6 percent as percentage occupancy decreases from 100 percent to 25 percent.

Figure 12. DCV savings across occupancy rates.



CONCLUSIONS

The pandemic resulted in significant shifts in the utilization of commercial office buildings and an increased focus on how building operations impact indoor air quality. With the release of new recommendations for building operations, questions emerged on how building energy use would be impacted and how building operators would implement the recommendations in practice.

Our study found that the majority of building operators did implement at least one change in operations during the pandemic. The most common change was filtration updates followed by ventilation increases. It also showed that most owners did not or were not able implement all of the best practices in regard to indoor air quality due to cost concerns or uncertainty about efficacy of technologies. Most of the respondents anticipated that flexible work policies and variable occupancy would become permanent changes.

These findings led to four near-term recommendations. We describe each of these below.

Encourage and assist customers in implementing measures that have been found to address indoor air quality while not *unnecessarily* penalizing energy.

There are several measures that researchers have identified that have a positive impact on indoor air quality, while minimally impacting overall energy use. The key measures are below:

- MERV 13 filters
- Targeted in-room filtration
- Air cleaners
- Smarter ventilation rates and timing
- Supply air temperature reset

The interviews revealed that operators do not have a clear sense of the exact health impacts versus energy tradeoffs of all the above options. Programs or other interventions could both improve health and reduce energy consumption by helping building operators optimize the set of options at their disposal and prioritize the options above first.

Most notable on the list is MERV13 filters, which have a minimal impact on energy use while providing the same benefits as 100 percent outside air. Similarly, targeted in-room filtration works to eliminate indoor air quality concerns in particular spaces, such as highly occupied rooms, without requiring a whole building ventilation increase. Air cleaners are another option; but there is more uncertainty around efficacy of all options and more technical knowledge is needed to understand which to install.

Two options are less prominent but have the potential to provide benefits while saving energy. Several studies have explored how optimized ventilation strategies based on energy use and indoor air quality can lead to win-win solutions by reducing energy use and improving indoor air quality. The optimized ventilation strategies include occupancy-sensor or CO_2-based DCV and strategic timing of air flushes and ventilation rates based on outdoor temperature and occupancy or pollutant levels. These solutions require additional sensors and more advanced sequencing and might be more difficult to implement. Similarly, AHU supply air temperature increases are discussed in the literature as a way to increase airflow for VAV system and with minimal impacts on energy, but concerns around humidity control and effectiveness in winter limit the applicability.

Promote control-based measures to drive savings with variable occupancy and smart ventilation changes.

This research identified two changes that will impact building energy use long-term: (1) more variable occupancy of office buildings and (2) the potential need for increased ventilation over an extended period of time. The data shows that the majority of commercial businesses expect hybrid or flexible schedules moving forward. There is more uncertainty around how long and to what magnitude ventilation changes will persist into the future. However, with increased focus from building experts and the federal government it is likely that some buildings will continue to utilize increased ventilation rates well into the future. [26]

Several measures exist that can address these changes and drive further energy savings. The measures are all control-based.

The first measure is to promote equipment upgrades from pneumatic or dated systems to new systems that allow for controls at a zonal level. Several respondents mentioned that the high upfront cost for the upgrade from pneumatic systems inhibited their ability to upgrade and implement HVAC controls. Additionally, the recommissioning firms mentioned that a number of buildings still have pneumatic controls and that current rebates often aren't high enough to encourage upgrades to new control systems.

Two additional measures utilities could promote are both occupancy-based and CO2-based DCV and occupancy-based lighting controls. As the modeling showed, DCV has the potential to provide more significant percent savings under new occupancy and ventilation baselines. Additionally, as occupancy decreases, occupancy-based lighting sensors lead to significant savings. This makes it important to emphasize occupancy sensors for any buildings without existing controls.

Include health and wellness benefits in marketing of building assessments or related programs.

A building assessment has the potential to improve the health of a building while also identifying energy saving opportunities. One core recommendation from ASHRAE is to ensure proper

[26] White House, "FACT SHEET: Biden Administration Launches Effort to Improve Ventilation and Reduce the Spread of COVID-19 in Buildings," The White House, March 17, 2022, https://www.whitehouse.gov/briefing-room/statements-releases/2022/03/17/fact-sheet-biden-administration-launches-effort-to-improve-ventilation-and-reduce-the-spread-of-covid-19-in-buildings/.

operation of HVAC systems. It is also recommended to perform recommissioning when buildings fully reopen to ensure all systems are operating correctly. The building assessments program could utilize these recommendations to market the program to customers and increase program participation.

Furthermore, the assessments program could train energy auditors and engineers to follow healthy building guidelines and integrate them into a more typical energy assessment evaluation. Many of the healthy building recommendations are directly related to building operations and could be included in the assessment program without formally partnering with health experts.

There are several measures that could be included in the energy assessments program to address health and energy together without adding significant time to the existing process. These include:

- **Filters:** The team could easily add a step to review current filtration and recommend MERV-13 or higher filters where applicable. MERV-13 filters can have a significant impact on health without increasing energy use. This would alleviate any concerns for building owners around whether the new filters work with the current HVAC system.
- **Smarter ventilation strategies:** The energy assessment team could recommend smarter ventilation strategies that go beyond minimum ventilation requirements to address both health and energy. The optimized ventilation strategies could include strategic timing of air flushes and ventilation rates based on outdoor temperature and occupancy or pollutant levels, or incorporation of DCV.
- **Economizer assessments:** Economizers commonly have issues that reduce their effectiveness. A small addition to the assessment could be an in-depth review of economizers. This could result in recommendations that both save energy and allow for increased ventilation to improve health.
- **Supply air temperature reset:** As part of the assessment, the team could also provide details on supply air temperature For VAV forced air systems, higher AHU supply temperature setpoint increases the total supply airflow to maintain the temperature setpoint, which in turn increases the equivalent outdoor air delivery rates. This could be recommended to customers as a way to address indoor air quality.

Another consideration for the assessment program is to include or recommend the measurement and monitoring of indoor criteria pollutants using cost-effective and reliable sensors. Measurement of indoor air quality is the best way to identify air quality concerns.

Consider modifications to baseline energy profiles and measure calculations to reflect new occupancy and ventilation patterns.

As this research identified that variable occupancy and increased ventilation will persist long-term, it will be important to consider modifications to baseline energy profiles both in state technical resource manuals and internal calculations. As the energy analysis in this report illustrated, those changes impact both baseline energy use intensity and the potential savings from measures. More research around the exact baseline assumptions is needed, but this research serves as a starting point in illustrating the need for updated baseline energy profiles.

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APPENDIX A: INTERVIEW GUIDE

Introduction

Thanks again for being willing to talk with us today. We are conducting a study on behalf of Xcel Energy Energy to help them understand building operation practices in their territory during the pandemic, and operation policies for a post-pandemic state. The survey will ask questions about HVAC and building operation practices, and general thoughts on indoor air quality and occupant health within buildings. The data collected will help Xcel Energy Energy develop program approaches that better serve their customers.

All of the information shared today will be anonymized before being shared with Xcel Energy or anybody else.

Do you have any questions for us before we begin?

Introductory Questions

1. To start, I want to ask a few basic questions about your role and the building:
2. What is your role at your organization?
3. How many buildings do you manage?
4. What is the primary function of your facility or facilities? Or functions, if there are multiple.
5. What were the primary operating hours and days prior to March 2020?
6. What were typical daily occupancy rates prior to March 2020?
7. What changes to building operation schedules have been made throughout the pandemic?
    a. [If needed] Did your facility revise operating hours or allowed occupancy rate? Describe the timing and nature of major changes.
8. How did the rate of actual occupancy fluctuate in response to these changes in operation? (e.g. as the building opened more, did occupants return proportionately?)
    a. [If needed] Does your facility have any future timelines for further reopening or other changes?

Building Operation Questions

Now, I have some specific questions about building and HVAC operations and upgrades, with specific focus on the last few years:

1. Who at your organization makes the decisions about building operation practices and HVAC upgrades?
2. What resources or guides do you rely on for understanding and maintaining good indoor air quality with your facility management processes?
3. How did your ventilation and filtration change throughout the pandemic? [Note: Listen for other strategies beyond filtration and ventilation, including ‘system tune-up’]

4. How did ventilation rates change throughout the pandemic? What is your current ventilation rate?
    a. Do you utilize any pre-occupancy or post-occupancy flushing? Is demand controlled ventilation used?
5. What filters are used? Did this change as a result of the pandemic?
6. Do you have any plans to adjust the ventilation, filtration, or humidity controls as the pandemic progresses to its next stage (endemic)?
    a. [If yes]: What are those plans? What is your timeline for implementation?
7. Are you currently utilizing or planning to add any air cleaning devices at your facility/facilities? [if needed: examples include bipolar ionization, in-room air purifiers, or ultraviolet air treatment]
8. Did you install, or do you have any plans to install, any other new technologies in your facility/facilities as a result of the pandemic?
    a. [If yes] What are the technologies?
9. The pandemic has led to significantly varying occupancy in most buildings. How has your facility handled, or how does it plan to handle, variable occupancy as a result of changing schedules?
    a. Probe on: shutting down zones; certain days of occupancy, other strategies to save energy such as demand-controlled ventilation
10. Did you see an energy impact from any of these changes? [probe on magnitude of impact]

General Thoughts on IAQ

Next, I want to turn to a few more general questions about future operations and thoughts on indoor air quality:

1. Prior to the pandemic, did your organization place specific value on the impact of your building spaces on the occupants' health or productivity?
    a. [If yes]: what actions did your organization take to reflect that value? [e.g. operational changes, monitoring, etc.]
2. Looking forward, do you or your organization have plan to focus on occupant health or productivity in the future?
    a. If yes:
        i. What are the plans?
        ii. Do they address additional health and safety concerns outside of IAQ? [if needed: mold control, lighting, etc.]
        iii. What factors contributed to these decisions? [probe on: productivity, wellness, comfort, spread of disease]
        iv. Who is the primary champion in leadership of the organization behind these plans?
3. What are some of the challenges facing the operators of buildings trying to promote occupant health? [Probe on: funding, behavioral change management, energy concerns, lack of data to track indoor air quality]

Monitoring and Assessment (only ask if time)

Lastly, we have some questions about monitoring and assessment of health impacts.

1. Does your facility utilize any monitoring equipment or data tracking to evaluate either IAQ or occupant health on an ongoing basis? [beyond CO2 sensors for demand controlled ventilation]
    a. If yes, what tracking do you do?
    b. How do you use that to inform operations?
    c. Does your organization have any desires or plans to add more measurement?
2. Have you had an assessment of the health impacts of your facility operations? When?
    a. If your local utility subsidized the cost of an assessment down to a small nominal fee, do you think your org would have one conducted?
    b. If the utility offered such an assessment bundled with its more typical energy assessment, would your organization value and trust in that for making health-related decisions?
3. How could utility programs assist with improving IAQ and health in your building? [probe on financial or technical assistance]