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Using New Indoor Air Purification Technology to Improve Indoor Air Quality and Reduce Energy Costs

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Abstract

Adequate ventilation is a critical component of design and management practices needed for good indoor air quality. Yet, the energy required to run the heating, ventilation, and air conditioning system constitutes about half of a commercial building's energy cost. Since energy efficiency can reduce operating costs and because the burning of fossil fuels is a major source of greenhouse gases, energy efficiency has become an important concern to the building industry. To this point, the promotion of efficient energy utilization has become a matter of public policy. This paper will examine the relationship between energy use and indoor air quality performance of ventilation systems and how bi-polar ionization, can significantly contribute to the energy efficiency and health of our buildings.

Industrial facilities also stand to gain energy efficiency benefits. Meeting the requirements of the DEP, OSHA and the EPA are of major importance and economic impact to most manufacturing companies, hospitals and industrial facilities. Products such as bi-polar ionization offer solutions for indoor air quality issues and emission issues.

The products evaluated for this paper work on the principal of "bi-polar ionization" or "dual-polarity ionization". This is vastly different from popular consumer type ionization products, which work on the "electrostatic precipitator" principal of generating single polarity ions to charge particles and attract them to an oppositely charged collector cell. Like typical filtration based products, these collector cells (plates) require frequent cleaning. A significant disadvantage of filter based products is the reduction in air flow created by the inherent drag of the filter itself.

The EPA in its report "Energy Cost and IAQ Performance of Ventilation Systems and Controls" has determined that if a building where occupancy averages 7 people per 1000 square feet can reduce its outdoor introduction by 10 cfm per person, this action can result in a 4% to 40% savings in the building's total energy bill. As occupancy becomes more concentrated, the savings become greater.

This is where technology utilizing bi-polar ionization systems can be quite beneficial to both enjoying the productivity gains of improved IAQ and reducing costs by not increasing outdoor air introduction. In a Harvard School of Public Health study of office buildings, much of the productivity losses were due to transmission of airborne illness. Bi-Polar ionization can curtail the spread of these illnesses. This technology can provide these benefits with a minimum of outdoor air introduction thus significantly reducing the energy costs associated with conditioning and moving outside air. This paper will show the impact of IAQ efforts, such as in a Pennsylvania Power and Light (PPL) case study on the benefits of incorporating IAQ into its offices; absenteeism dropped 25%, productivity increased 13.2%, and energy costs declined 69%. The company's up-front investment was paid back in just 69 days.

Ventilation and IAQ

In the design and construction of modern commercial buildings operating efficiency and reduced energy demands have become a prime consideration for the construction industry. Demands to reduce fossil fuel consumption and rising energy costs have prompted the building industry to adapt new construction methods, which result in tighter building envelopes that result in a more energy efficient building. The sacrifice made to tighter construction methods is a degradation of Indoor Air Quality (IAQ). The USEPA has concluded that indoor air is 2 to 5 times worse than outdoor air. They have also stated that most indoor air pollution sources are within the building, furnishings, pesticides, cleaning products and office machines can emit volatile organic compounds (VOC's) which may cause a variety of health related symptoms. Also particulate matter is produced by occupants and poorly filtered outside air. Microbial contaminants such as mold and bacteria also degrade air quality and health. As the buildings are tighter contamination builds up rather than escapes. The term "Sick Building Syndrome" has been coined to describe a building in which 20% or more of its occupants complain of symptoms such as; eye irritation, sore throat, headaches, drowsiness, dizziness, fatigue and nausea to name a few. The person feels relief when the leave the building and the causes for the symptoms are not obvious. When a building is labeled as a "sick building" it will often have serious financial impact on the owner of the building. To help alleviate this, the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) has developed standards for mechanical ventilation to help maintain adequate IAQ and comfort within buildings. The ASHRAE 62 standard which has been modified in 1989, 1999 and 2001 calls for 20 cubic feet per minute (cfm) of outside air ventilation per occupant within office environments. ASHRAE does make some exceptions to this standard, since many buildings, designed and built when lower outside air standards were in practice may not be able to meet the current standard. ASHRAE also offers alternatives to the 20 cfm. per person standard such as the ventilation rate procedure which allows for design of lesser amounts of outside air ventilation when coupled with methods such as; outdoor air pre-treatment and treating re-circulated air with contamination removal equipment.

There have been many case studies, which show how improved IAQ results in increased productivity and decreased absenteeism by building occupants through providing a healthier environment. Harvard School of Public Health and the Polaroid Corporation conducted a study of 40 buildings owned by Polaroid. In the study they divided buildings into 2 categories: ones with moderate air supply (25 cfm per person) and ones with high air supply (50 cfm per person). The researchers found that occupants in the moderately ventilated areas were 53 percent more likely to be absent due to illness than those in the highly ventilated areas. They also concluded that increasing ventilation may have prevented 35 percent of the absences among occupants in the moderately ventilated areas. In this study, the potentially preventable employee absences cost the company an average of $480 per worker per year. When they extrapolated this data and applied the numbers to the US work force it was estimated that US companies lose as much as 22.8 billion dollars each year to lost productivity resulting from poor IAQ. Many companies have upgraded their interior environments to gain productivity and decrease absenteeism.

Pennsylvania Power & Light upgraded IAQ at it's offices resulting productivity gains of 13.2% absenteeism decreases of 25% and reduced energy costs of 69%. The up-front investment was paid back in just 69 days. The Reno, Nevada Post Office by remodeling and IAQ improvements gained $400,000 to $500,000 a year in productivity, which was enough to pay for the entire renovation in less than a year. The one downside of increasing ventilation to improve IAQ, as the Harvard study found is increased energy costs.

Outside Ventilation and Increased Costs

As outside air is introduced into a building it must be treated to provide a healthy, comfortable environment. This involves heating, cooling, dehumidification and filtration. All of this will increase operating costs. The ability to decease outside air ventilation can result in significant energy savings. See the chart in fig. 1 based on studies conducted by the USEPA:

Fig. 1

Type of Building	Size	Occupant Density	CFM Reduction	Energy Savings
Office	338,633	7 per 1000 ft2	10 cfm	4% approx.
Office	338,633	15 per 1000 ft2	10 cfm	8% approx.
Education	50,600	30 per 1000 ft2	10 cfm	15-32% approx.
Assembly	19,600	60 per 1000 ft2	10 cfm	35-40% approx.

The chart above is an excerpt for the USEPA report Energy Cost and IAQ Performance of Ventilation Systems and Controls Executive Summary which shows the energy savings that can be realized by reducing percentages of outdoor air intake.

Many buildings tend to over ventilate to improve IAQ and comfort. Aircuity Inc. of Newton, MA a manufacturer of IAQ analysis equipment performed a statistical analysis of 276 air-sampling reports. By comparing ambient carbon dioxide (CO2) to indoor CO2 levels, indoor ventilation rates can be determined. By this method, the following was determined:

Elevated Ventilation* – Occupied Hours	54% of Total Reports
Elevated Ventilation* – Unoccupied Hours	76% of Total Reports

Elevated with respect to ASHRAE 62

Even using the more conservative occupied hour percentage as a reference, it is significant to note in this study buildings are 4.5 times more likely to be over ventilated than under ventilated.

Additionally reductions in peak energy demand and HVAC maintenance and repair costs can be realized when treating a larger percentage of re-circulated air. Also outside air needs to be filtered to remove particles, spores and other allergens from entering a building. Filters in typical office building can range from ASHRAE MERV 7 (minimum efficiency reporting value) (25% efficiency) to MERV 15 (95% efficiency). With increased efficiency comes increased cost as detailed in the chart in fig. 2

Fig. 2

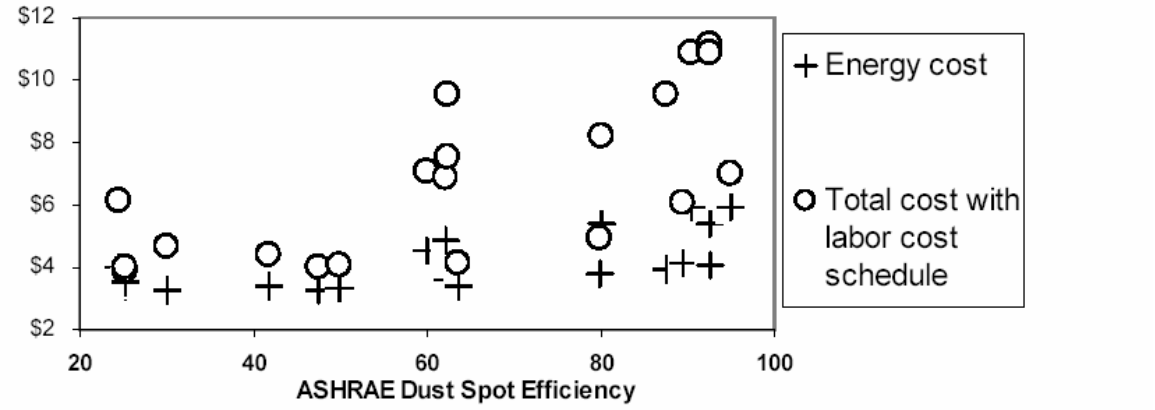


Figure 4. Monthly cost per 1000 ft^3 /min (470 L/s) of supply air for filters with different ASHRAE Dust Spot Efficiency ratings. Total costs include the costs of the filters, labor to remove and replace the filters, and fan energy.

The chart above in figure 2 is an excerpt from the report Performance and Costs of Particle Air Filtration in HVAC Supply Airs Systems Lawrence Berkeley National Laboratory Fisk, WJ. Faulkner,D. Palonen, J. Seppanen, O. Helsinki University of Technology. This shows the costs involved with various degrees of air filtration.

Another factor when considering more efficient filtration to remove particles is air supply. Most buildings' HVAC systems were designed to provide comfort and efficiency. There were not designed with adequate airflow to make higher efficiency filters work to their highest efficiency. The airflow required, would by much greater and would produce an uncomfortable atmosphere and high operating costs.

Demand source ventilation controls and energy recovery ventilator systems are two methods also being used to improve IAQ while reducing ventilation costs. Demand source controls use air monitors located throughout a building and at various supply and return air locations to sample air for conditions such as, temperature, relative humidity, carbon dioxide, and TVOC (Total Volatile Organic Compounds). These controls are integrated into building controls and make adjustments to outside ventilation percentages as readings are controlled to programmed set points. For example, acceptable comfort levels of CO2 according to ASHRAE standards should not exceed 1100 ppm. A demand source ventilation system when seeing CO2 levels rising to this point will automatically increase outside ventilation. As CO2 levels fall the controls will reduce outside ventilation. The same method applies to the various elements of air quality and comfort it is reading. An energy recovery ventilator system is another method used to increase outside ventilation while minimizing energy cost increase. This system introduces outside air, independent of the HVAC system and either pre heats or cools it before introducing it into the desired space. The result is improved IAQ with lower energy cost increases. While these two methods are useful in increasing ventilation they do not provide source

control of contaminants and can be quite costly and complex to integrate into buildings especially older buildings with older HVAC and control systems.

Bi-Polar Ionization Technology

As a method of cleaning air, ionization is not a new concept to the US and other worldwide marketplaces. Sales of IAQ products exceeded 1.4 billion dollars in the US in 2005. Ionization as a means of cleaning air has become quite popular due to the success of the Sharper Image "Ionic Breeze' and other similar products. The majority of these products work on the "electrostatic precipitator" principle, which means to generate a single polarity ion to attract dust or some other particle and to draw it back and collect it to an oppositely charged collector cell.

Bi-polar or dual polarity ionization works on a different principle. Bi-polar systems generate both negative and positive ions. The systems are designed to provide sufficient ionization to the space to be treated and allow the energy imparted by the ions to transform ordinary oxygen into Reactive Oxygen Species, Superoxides, Peroxides, and Hydroxyls. These reactive oxygen species can provide a number of air quality benefits including, particle diffusion, VOC (Volatile Organic Compound) breakdown and microbial (molds, bacteria) reduction. Because of the variety of applications that can benefit from these systems, bi-polar ionization has been used in Europe for many years and is now beginning to be applied in the US marketplace. Studies have shown that these systems are beneficial to improving overall indoor air quality and help to alleviate the factors which cause "Sick Building Syndrome" that can affect the physical and psychological health of building occupants, affecting productivity.

Bi-Polar systems can be an excellent addition to an overall strategy for reduction of energy costs and improvements to IAQ. Bi-Polar systems introduce beneficial air ions into spaces where they can affect the source of contamination. Because they don't rely on bringing air through the return system to the unit to be affected, bi-polar systems don't require increasing airflow or modifying HVAC systems as many filtration based systems do. Also bi-polar systems can be effective on a wider range of IAQ conditions than most other methods. Bi-Polar ionization has a proven effect of particle decay, VOC and odor breakdown and airborne spread of microbial contaminants, such as bacteria and mold. Systems designed to achieve cost efficient ventilation increases may improve IAQ by increasing fresh air volume but do little for source control of contaminants. Bi-Polar ionization can affect sources of contaminants. Also these systems are quite economical to use. Typical bi-polar ion generators use between 5 to 45 watts of power at current draws below 1 amp and affect static pressure within ducts minimally as only small glass tubes are installed into the airflow. The following figures 3-6 illustrate the effectiveness of bi-polar systems:

fig. 3 Testing conducted on particle decay

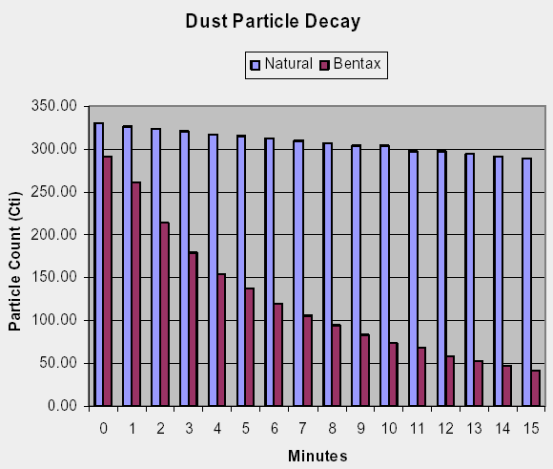
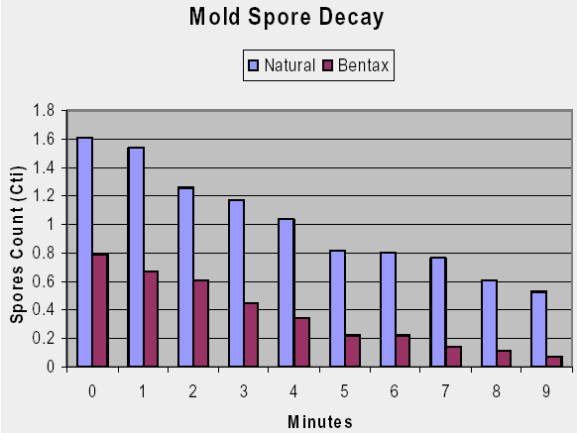
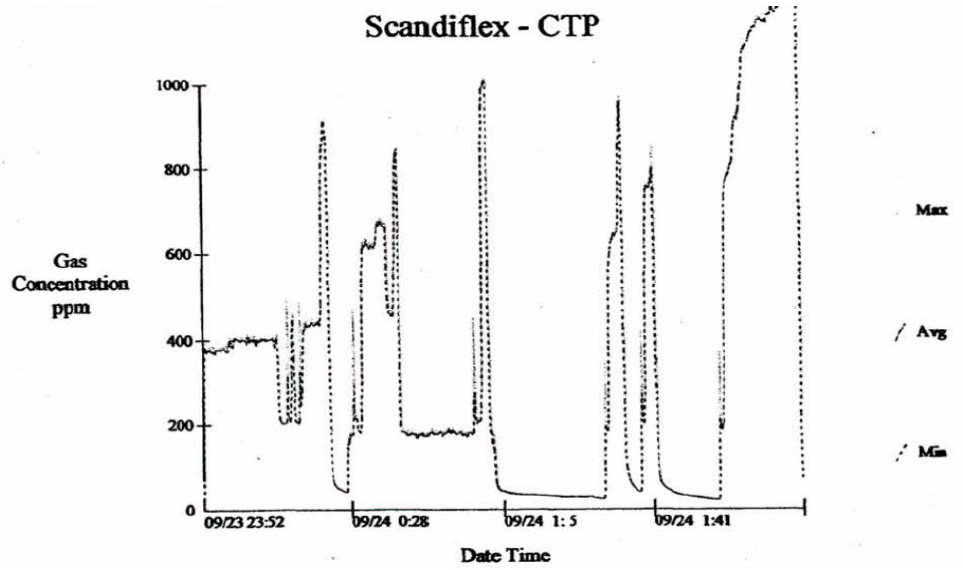


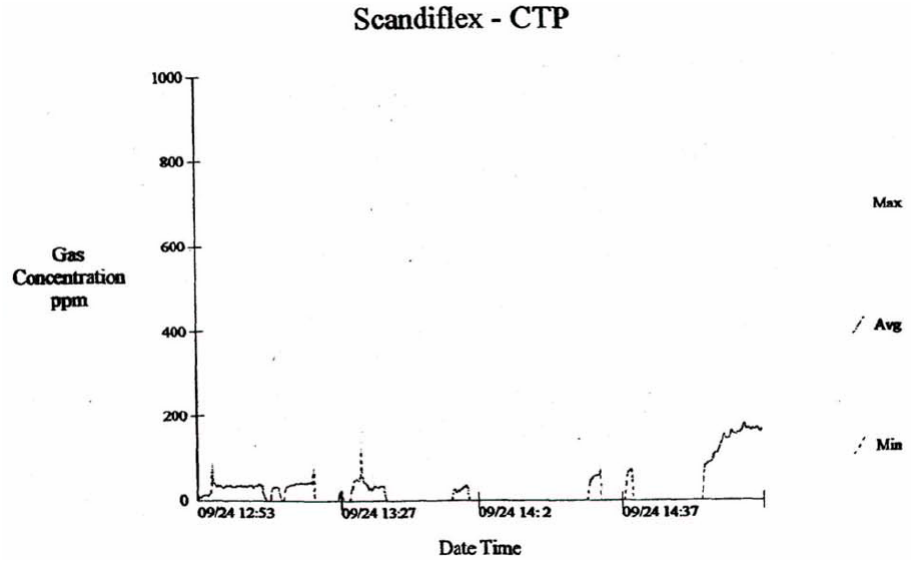
fig. 4 Testing conducted on Mold spores



The graphs in figures 3 and 4 were excerpts of laboratory testing performed on bi-polar ionization equipment by Intertek ETL Semko. The tests show enhanced particle decay effect under ionized conditions.

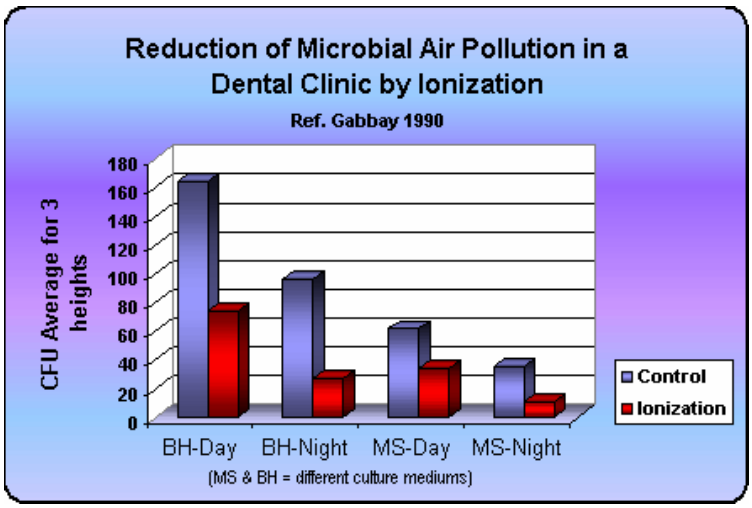
Fig. 5 Before and After testing on Ethanol VOC emissions.



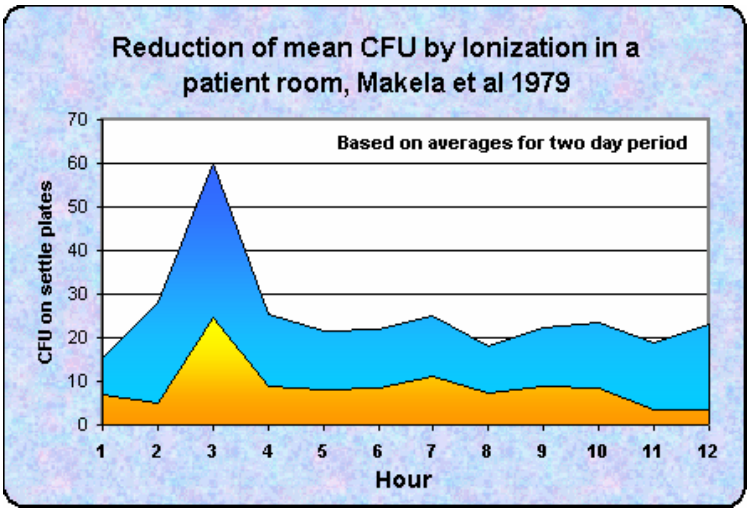


The Graphs in figure 5 were taken from a field analysis of an industrial bi-polar ionization system used to control ethanol exhaust emissions. The analysis was performed by CTP Air Pollution Control in it's Report of Bentax VOC Reduction System at Scandiflex/Lanskinoa Rittsteig, K.

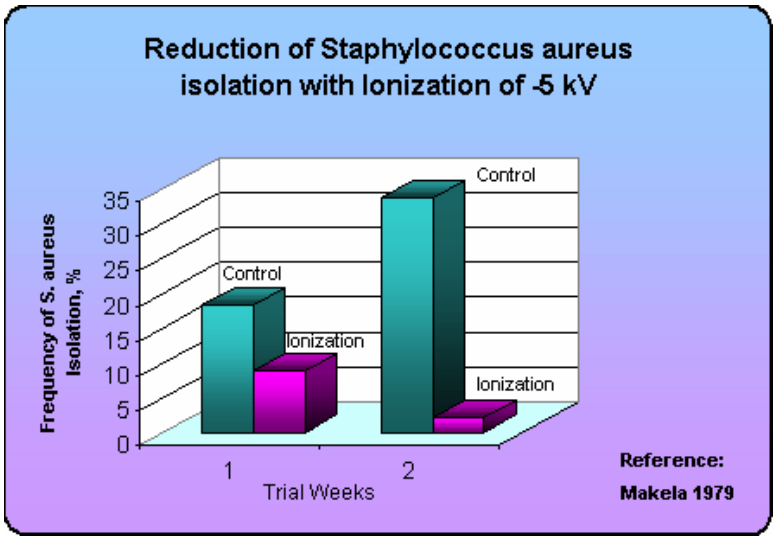
Fig 6 Studies conducted on ionization's effect of airborne bacteria



This chart in figure 6 was presented by the Penn State Department of Architectural Engineering paper on Negative Air Ionization. It demonstrates the levels of colony forming units (CFU) in a dental clinic with and without ionization. Airborne ionization levels were reduced by 32-52% with ionization. The study was performed by Gabby, J. "Effect of ionization on microbial air pollution in the dental clinic" (1990)



This chart in figure 6 was presented by the Penn State Department of Architectural Engineering paper on Negative Air Ionization. This chart summarizes results of studies of bacterial aerosol levels in patient rooms in a burn and plastic surgery unit. The blue color represents CFU levels without ionization and the amber color represents CFU levels with ionization. The study was performed by Makela, P., Ojajarvi, et al. "Studies on the effects of ionization on bacterial aerosols in a burns and plastic surgery unit" (1979)



The chart above in figure 6 was presented by the Penn State Department of Architectural Engineering paper on Negative Air Ionization. This chart summarizes results of studies of Staphylococcus aureus levels in patient rooms in a burn and plastic surgery unit. The averages of two days of monitoring showed a definite reduction in airborne levels with ionization. The study was performed by Makela, P., Ojajarvi, et al. "Studies on the effects of ionization on bacterial aerosols in a burns and plastic surgery unit" (1979)

Summary

In the effort to provide energy cost savings strategies in commercial buildings, indoor air quality and comfort can often be compromised resulting in buildings where occupants' productivity is diminished and absenteeism rates go up. In order to improve the indoor environment, many times outside air ventilation rates are increased to address some of the issues that degrade indoor air quality. While this can be an effective strategy especially when combined with enhanced filtration, demand source ventilation controls, air monitors and systems such as energy recovery ventilators, these methods can be quite costly to implement and increase energy costs. Also they lack the ability to significantly affect the source of typical building contaminants. An emerging method to provide an improved air quality in the U.S. is bi-polar ionization systems. Bi-Polar ionization can go the source of contamination and reduce common contaminants such as particles, VOC's and airborne microbes (bacteria, molds). With these systems the need for costly outside ventilation is decreased. Re-circulated air is purified and contamination sources are diminished. Bi-Polar systems are also easy to integrate into new and existing building mechanical systems and use very little energy. In a strategy directed to decrease energy consumption and peak demand usage, these systems will contribute towards achieving that goal.

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