The Atmospheric Fund

Improving Indoor Environmental Quality in Multi-Unit Residential Buildings

TAF The Atmospheric Fund

About The Atmospheric Fund

The Atmospheric Fund (TAF) is a regional climate agency that invests in low-carbon solutions for the Greater Toronto and Hamilton Area and helps scale them up for broad implementation. TAF is supported by dedicated endowment funds provided by the City of Toronto (1991) and the Province of Ontario (2016).

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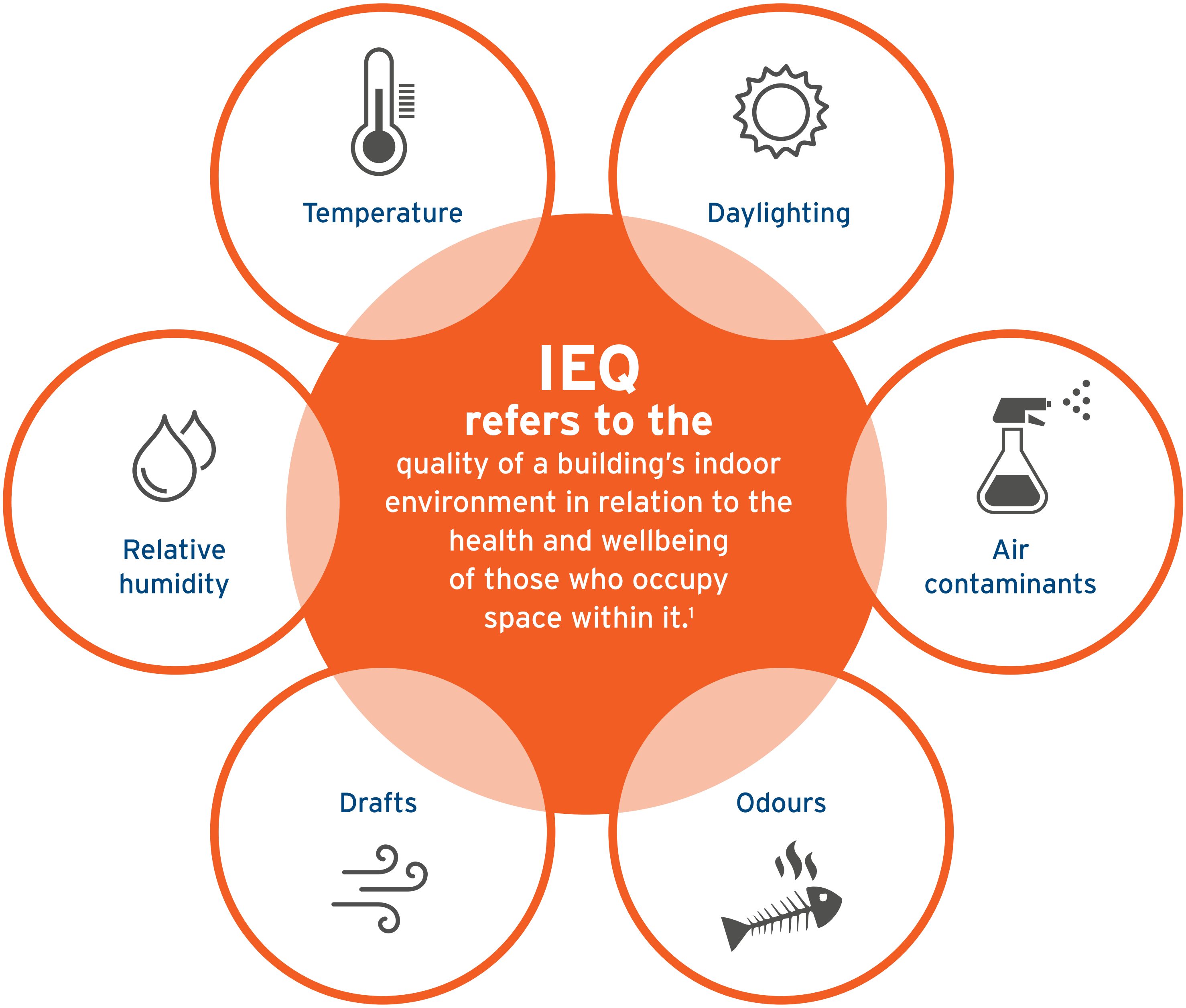
FACTORS INFLUENCING IEQ



Indoor Environmental Quality Impacts Resident Satisfaction

Millions of Canadians live in multi-unit residential buildings, many of which do not meet modern standards for indoor environmental quality.

The quality of residents' indoor environment has a major impact on their health and wellbeing, and it is often the most vulnerable who suffer the highest exposure. For example, exposure to sustained indoor temperatures over 26°C is known to significantly increase the risk of early mortality and morbidity, yet such temperatures are common in older multi-unit residential buildings (MURBs).[2] Stale air has been shown to negatively impact cognitive functioning and alertness,[3,4] yet the majority of older buildings have no system to deliver fresh air directly to the suites.

These discomforts translate into resident complaints, increased energy use, and increased costs. And yet, they are rarely addressed, even when older buildings are being renovated. Simply put, there is limited awareness of the problems and too little incentive to fix them.

Energy Efficiency Retrofits Save Money and Provide Co-Benefits

We know that achieving the Greater Toronto and Hamilton Area's (GTHA's) 2050 climate targets requires deep carbon reductions across the multi-residential building stock. This can only be done through energy efficiency retrofits, such as heating and ventilation system upgrades, lighting upgrades, and better building controls.

Improved indoor environmental quality (IEQ) is one co-benefit of energy efficiency retrofits. Capturing this benefit means taking a holistic approach to the retrofit, and incorporating improved IEQ as a project goal from the outset. Increasing resident comfort can even lead residents to more energy-efficient behaviours, such as limiting window opening in winter and reducing use of supplemental heating and cooling devices.

Energy efficiency retrofits also present a good opportunity for local job creation by engaging the local trades in new projects. And of course, lowering energy use also results in utility cost savings (see the business case on page 11).

THE CASE FOR COMPREHENSIVE ENERGY AND IEQ RETROFITS

Building energy use is a major source of carbon emissions in Canada, and accounts for 44 per cent of emissions within the GTHA.[5] Achieving local climate goals will require major retrofits in the majority of existing buildings. The building systems that need upgrading to address climate change are the very same systems responsible for IEQ.

44%

of the GTHA's carbon emissions come from buildings

High indoor temperatures due to overheating lead to wasted energy and uncomfortable residents. Introducing comprehensive energy efficiency measures, including condensing boilers with high modulation and in-suite smart thermostats, can help address both overheating and poor thermal comfort. When residents feel uncomfortable, they are also more likely to open hallway doors or windows, or use energy consuming devices like space heaters, fans, and air conditioners. Improving thermal comfort leads to less reliance on these types of controls, thereby reducing energy use.

Ventilation improvements are also important. High humidity levels can lead to mould growth and respiratory issues; low levels can lead to dry skin and throat irritation. By increasing ventilation rates and ensuring air ducts are kept clean it is possible to manage humidity levels indoors. Introducing variable frequency drives allows for an increase in ventilation rates during peak hours, such as in the evening, while decreasing them during hours of low occupancy. This reduces energy use and related costs.

Odour can be a sign of poor ventilation, and in multi-unit buildings it is most likely caused by inadequate pressurization of corridors. In the pre-retrofit survey, residents revealed a number of concerns with odours, particularly around smoke from neighbouring suites entering their homes. Drafts can be caused by air infiltration, convection currents near external surfaces such as windows, and stack effect. They can cause residents to feel cold and uncomfortable.

Energy efficiency retrofits provide a valuable opportunity to improve IEQ while generating a return on investment through utility cost savings. The very same upgrades that save energy can also be designed to deeply improve resident satisfaction, health, and comfort. However, achieving both outcomes requires a conscious effort during the retrofit design, construction, and commissioning processes. If IEQ is ignored or undervalued, retrofits can actually reduce health and comfort for residents.

Case Study Overview

The Atmospheric Fund (TAF) recently completed comprehensive energy and IEQ retrofits in seven multi-unit residential buildings, home to 1,212 low-income households. We did this to lower energy costs, reduce carbon emissions, and improve comfort and air quality for residents – while making a return on investment.

An important project goal was to assess the relationship between energy efficiency improvements and resident comfort and health. We tracked indoor air temperature, relative humidity, and carbon dioxide levels. This monitoring helped prioritize the energy retrofit measures and enabled a comparison between conditions before and after the improvements. We also surveyed residents before and after the retrofits to understand their experiences and perceptions of IEQ.

3 years
of data

320
resident surveys

31 million
data points

Spotlight on local job creation

We worked with Building Up on this project. Building Up connects housing providers with skilled labourers from the local community to improve Toronto's environmental efficiency and affordable housing stock, and create a real pathway for individuals experiencing barriers to enter apprenticeships and careers in the trades.

buildingup.ca

KEY IEQ-RELATED RETROFIT MEASURES

Ventilation system upgraded

Prior to the retrofit, the fresh air supply provided to the buildings was 43-50 per cent below modern code standards, and ventilation ducts were choked with dust and dirt. As part of the retrofit, ventilation systems were replaced and ventilation ducts were thoroughly cleaned.

In-suite heating controls installed

Prior to the retrofits, residents had no control over their indoor temperatures, other than by opening their windows. This, combined with oversized and poorly controlled boilers, led to indoor temperatures averaging between 25.2°C and 28.2°C throughout the heating season with the highest temperatures in the shoulder months. As a result, 81 per cent of residents opened their windows throughout the winter. Smart thermostats were installed to give residents control over heat in their home, while boilers and controls were replaced and optimized.

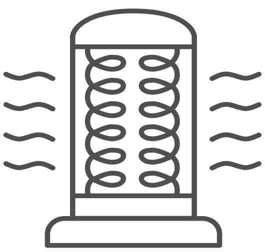
New ventilation system

Two of the buildings housed seniors, a group at high risk from extreme heat. These buildings also had the most extreme summertime temperatures, with suite temperatures over 26°C for 88 per cent of the time. A new heat recovery ventilation system with active cooling capability was installed.

Findings

COMPREHENSIVE ENERGY AND IEQ RETROFITS IMPROVE RESIDENT SATISFACTION AND LOWER ENERGY COSTS

Thermal Comfort Impacts



44%

reduction in exposure to extreme indoor temperatures (≥26°C) in winter

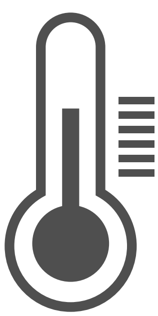
16%

improvement in comfort[i]

54%

reduction in residents feeling "too hot"[ii]

Less Reliance on Supplemental In-Suite Controls



39%

reduction in window opening in winter

69%

reduction in use of portable heaters in winter

[i] Based on ASHRAE 55 comfort model.

[ii] Though some residents reported under-heating post-retrofit, 63 per cent of those who felt "too cold" in winter also opened their windows on a regular basis, likely for ventilation rather than cooling; ventilation is another key factor in resident comfort.

Relative Humidity Impacts

35%
reduction in residents reporting condensation issues in winter

36%
reduction in reported daily dryness in winter

Decrease in Odours and Drafts

31%
reduction in odours from neighbouring suites

28%
reduction in lingering cooking odours

20%
reduction in exposure to odours from outdoors

18%
reduction in reported drafts

Study Limitations: A large portion of this research is based on the reported experience from resident surveys and is subject to some inaccuracy. Moreover, due to more extensive resident engagement, it is possible that more positive responses were received as a result of the rapport created between residents and the project team. That said, the survey results were confirmed by monitoring packages installed in a smaller number of suites, along with monitoring of heating and ventilation systems.

OTHER IEQ FACTORS EXAMINED

Carbon Dioxide

In order to examine the duct cleaning and make-up air unit upgrades, carbon dioxide (CO_2) levels were monitored before and after retrofit. Pre-retrofit CO_2 levels were above 950 ppm between two and 14 per cent of the time, on average. Post-retrofit CO_2 levels were above 950 ppm slightly more often, between six and 17 per cent of the time.

Although fresh air supply to the hallways was doubled, a number of studies reveal that pressurized corridor ventilation systems are not adequate as they do not evenly distribute ventilation air throughout the building. In some cases, upper floors may be over-ventilated while lower floors are under-ventilated, partially due to the stack effect.[6] Moreover, as the reduction in over-heating led residents to open their windows less often, fresh air infiltration into the suites also decreased. Suite-based ventilation measures may be needed to achieve better ventilation levels in older buildings such as these.

Although CO_2 concentrations found in our study do not reach levels which pose significant health risks, CO_2 levels are an indicator of overall ventilation quality.

Indoor CO_2 concentrations above 950 ppm may cause occupants to feel lethargic.

Formaldehyde

Formaldehyde is a common volatile organic compound, or chemical found in off-gassing from certain products such as new furniture or carpeting.[7] Prolonged exposure to formaldehyde can have health effects such as eye, nose, and throat irritation, and can cause certain types of cancers.[8]

Health Canada provides a formaldehyde concentration guideline of 50 mg/m^3 (over eight hours).[9] Pre-retrofit only one suite exceeded the guideline. Post-retrofit monitoring revealed a similar trend, with only two suites above the guideline. Overall, the energy efficiency retrofits did not impact formaldehyde concentrations.

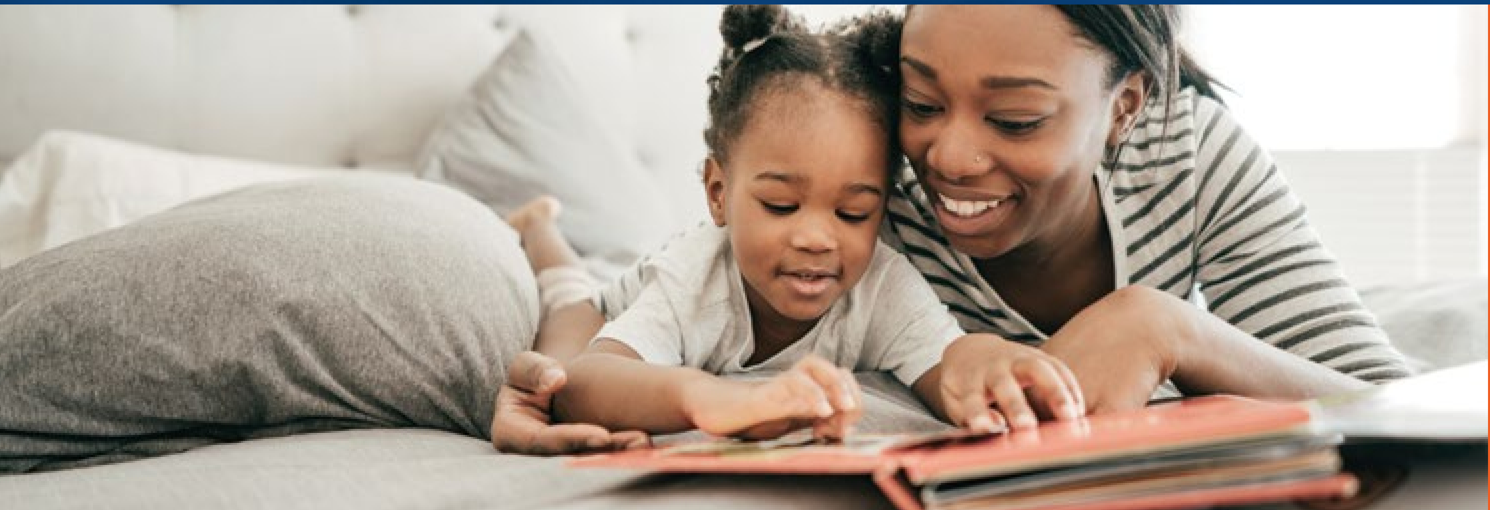
Fine Particulate Matter

Particulate matter (PM) is a commonly used indicator for indoor and outdoor air quality. $PM_{2.5}$ particles, which are smaller than 2.5 micrometers in diameter, consist of sulfates, nitrates, ammonia, sodium chloride, and mineral dust that are small enough to enter the lungs and cause damage.[10] Pre-retrofit monitoring results indicated a large variation in $PM_{2.5}$ count across the test suites; however, $PM_{2.5}$ concentrations were slightly higher in suites where residents smoked. Post-retrofit, $PM_{2.5}$ levels revealed a similar trend. Retrofit measures did not have an impact on $PM_{2.5}$ levels.

TAF financed the energy efficiency retrofits through an Energy Savings Performance Agreement™. This is a non-debt agreement where energy savings are used to cover the retrofit capital costs. This approach helps to address the financial barriers to undertaking efficiency retrofits by allowing building owners to implement energy and water saving measures without the usual upfront capital cost requirements.

Project Performance | 25 year project lifetime

$502,000 annual cost savings	**364%** return on investment
$6,830,000 net present value (4% discount rate)	**14.9%** internal rate of return
7.9 Year simple payback	**22%** reduction in emissions



Recommendations

Improving IEQ not only improves resident satisfaction; it saves energy, too.

We recommend building owners:

- Consult with residents to understand concerns (like "too hot", "too cold" and "poor ventilation") and prioritize energy efficiency measures that will also tackle these concerns. Communicating with residents about retrofit measures and their benefits is integral to a program's success.
- Limit over-heating. Implementing smart thermostats as well as heating system upgrades with a properly sized boiler can help ensure heating supply is in line with the actual demand.
- Reduce the need for supplemental controls. When residents feel more comfortable they are less likely to rely on space heaters and air conditioners, which require additional energy. This is especially important for buildings without sub-metering.
- Perform regular preventative maintenance, like duct cleaning to improve ventilation.
- Think holistically when considering energy efficiency – consider resident health and comfort to make the most impactful changes.
- Understand the relationship between different measures, as solutions may have unintended impacts. When residents' thermal comfort is improved, they may open the windows less. However, this can then reduce ventilation slightly.
- Encourage government and utility programs that support energy efficiency retrofits to also promote and provide resources for IEQ improvements. These measures include in-suite smart thermostats and suite-based ventilation.

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