Assessing the Ventilation Effectiveness and Indoor Air Quality of a Net-Zero Pilot House for Northern Communities

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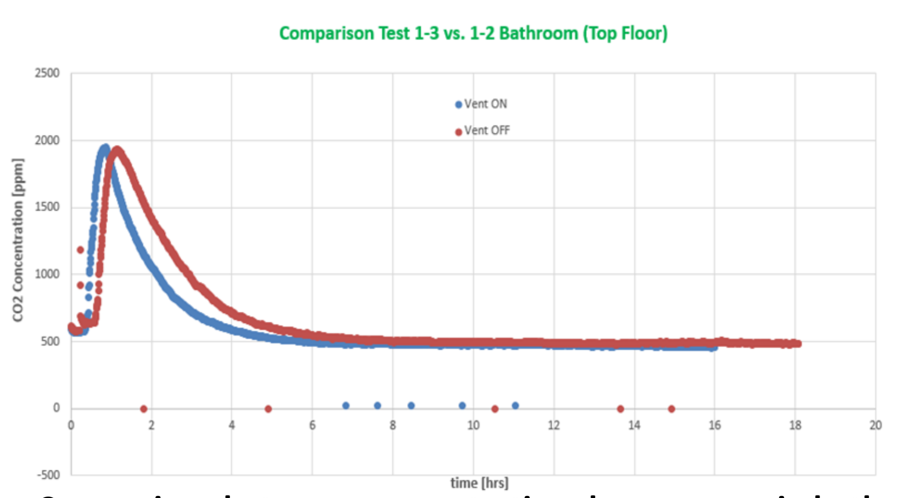
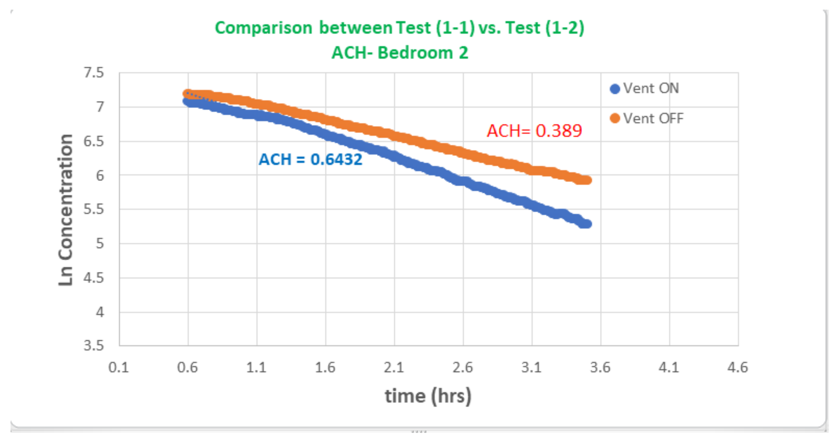
INTRODUCTION

- In cold countries like Canada, inhabitants spend more than 50% of the time in their homes. In certain population groups, this proportion is even exceeding 90%. Maintaining indoor air quality, thermal comfort and adequate ventilation is essential for a healthy and efficient building. Therefore, the ventilation effectiveness is a critical issue that needs to be assessed to avoid unhealthy living conditions.
- In this work, an experimental system is designed and constructed to assess the ventilation adequacy, thermal comfort, envelope infiltration and indoor air quality inside a net-zero pilot house.
- Aiming to achieve a net zero design and an air tight passive house, this house is intended to address the needs for the Northern communities, where indoor humidity has produced famously unhealthy conditions. Hence, ventilation effectiveness is a critical issue that needs to be assessed.
- The house aims to provide a cost-effective design while maintaining high levels of livability and sustainability. It intends to provide this cost effectiveness by using a good building envelope (R30), efficient heat pump, exhaust air energy recovery and smart controls.

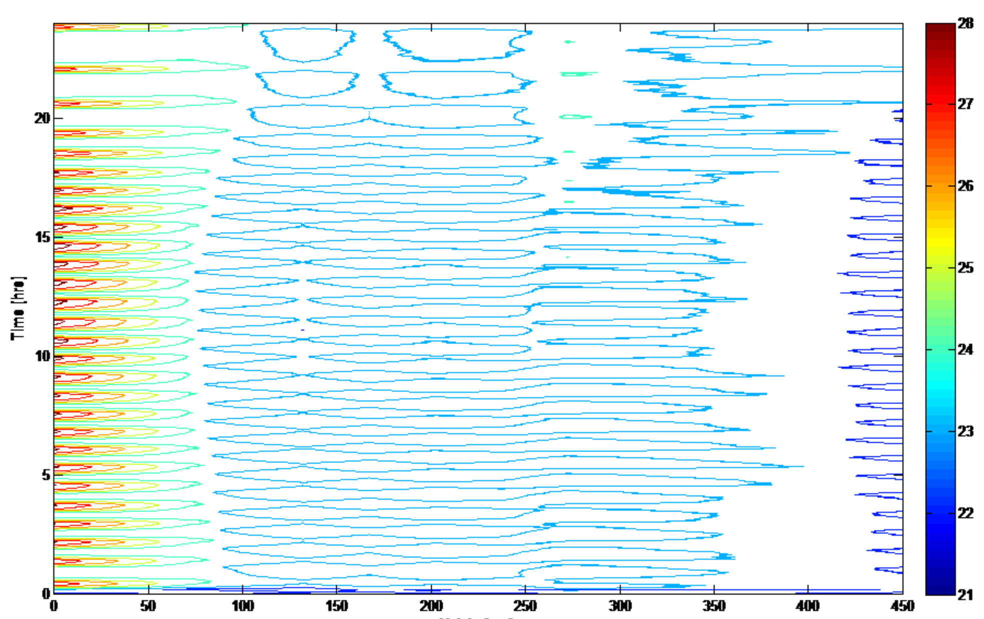
RESULTS



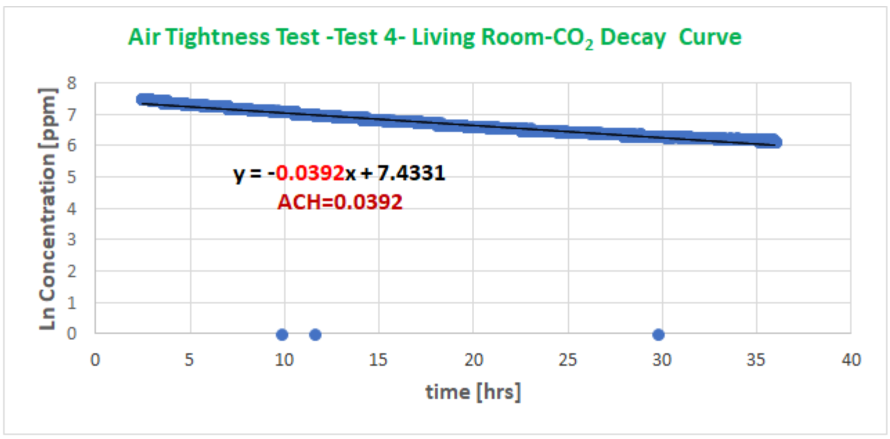
Comparison between concentration decay curves in bathroom



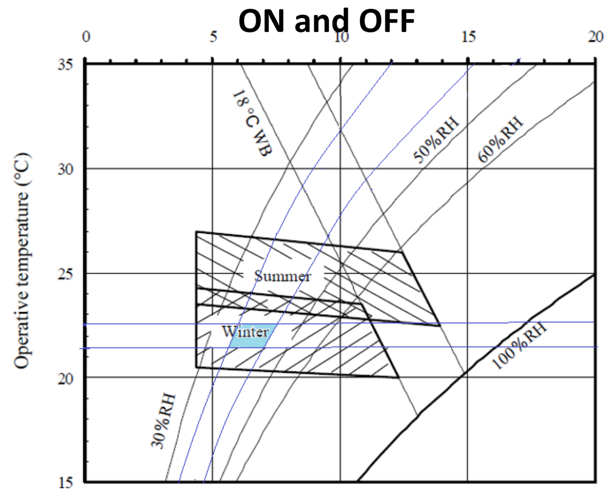
Comparison between ACH in bedroom 2 with vent ON and OFF



3D contours of temperature variation with time and height

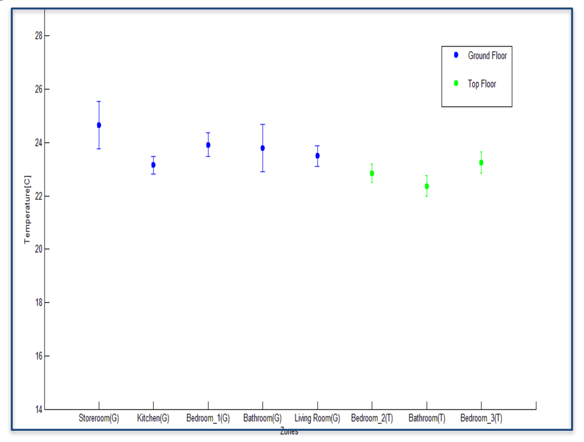


Concentration decay curve- living room for the air tightness test

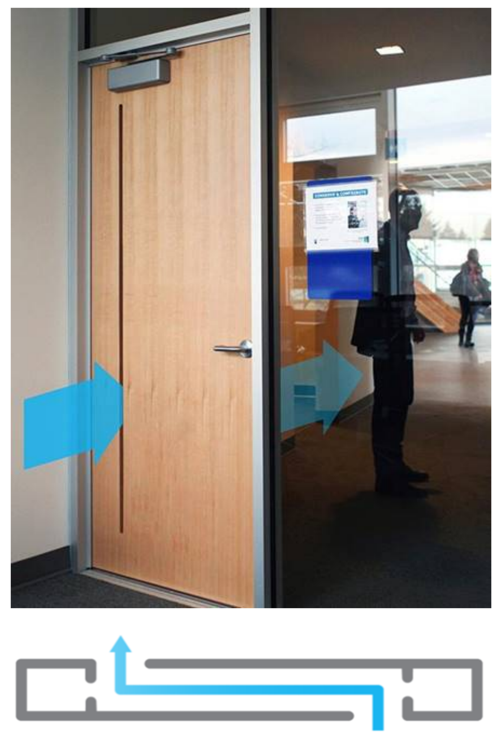


Thermal Comfort Zone in a Psychrometric Chart- ASHRAE Handbook showing the house data as the shaded area.

	Living Room	Kitchen	Bedroom 2	Bathroom (Ground)	Bathroom (Top)
Bathroom Vent ON	0.6134	0.5824	0.6432	0.7244	0.7131
Bathroom Vent OFF	0.4254	0.4352	0.389	0.4948	0.4754
	ASHRAE Standards : ACH for living areas=0.35				



Spatial variation of temperature along different zones in AYO House



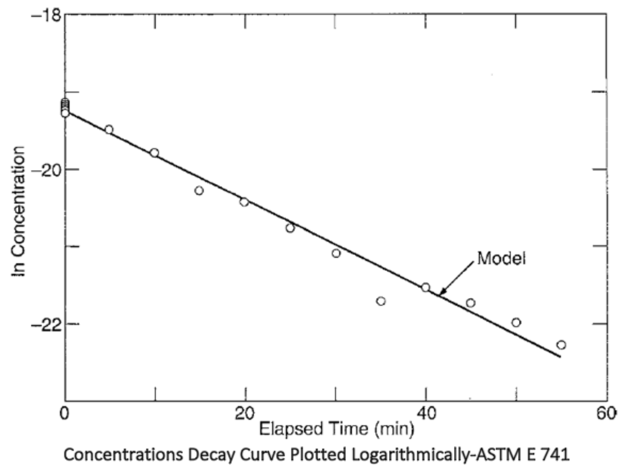
Special designed ventilated internal doors which allow the ventilation while suppressing the noise which avoid the need of using undercut doors.

METHODOLOGY

- **Mathematical Model:**

The air change rate λ, is determined experimentally through the tracer gas technique .This technique consists of introducing a certain quantity of a known gas in the space where the air exchange rate is to be measured—the tracer gas—and measuring the tracer concentration along time. Once the tracer concentration evolution with time is known, using appropriate evaluation algorithms, λ can be calculated from the data obtained:

$$\ln(C_{in}(t) - C_{amb}) = -\lambda t + \ln(C_{in_o} - C_{amb})$$



Concentrations Decay Curve Plotted Logarithmically-ASTM E 741

Following ASTM E-741, and using the regression concentration method dat analysis for the concentration decay technique, the air change rate of a single-zone is evaluated.

Performing a regression of $ln(C_{in}(t) - C_{amb})$ to find the constants a and b in the relationship: $Y = ax + b$. In this case λ corresponds to a, $\ln(C_{in_o} - C_{amb})$ corresponds to b, ln $(C_{in}(t) - C_{amb})$corresponds to Y, and t corresponds to X. Thus, with the best curve fitting, the air change can be then calculated.

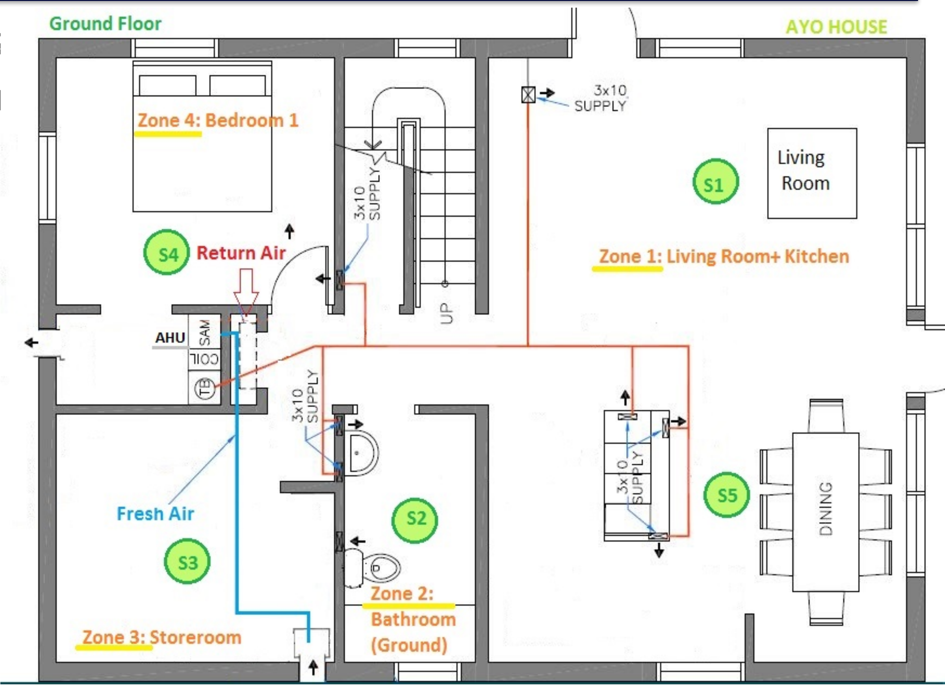
- **The tracer gas:**

The gas used in this work is CO_2. The advantages of using CO_2 as tracer gas are that; It is cheap, it is easily available, it is easily detectable and it has relatively high PEL (5000 ppm)

EXPERIMENTAL SETUP

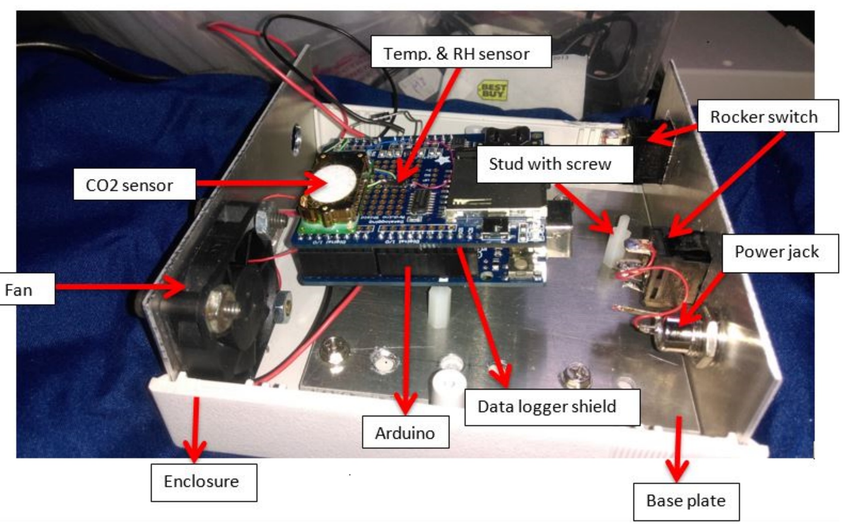
- The sublimated dry ice is placed in the return air duct, this ensures well mixing of the tracer gas with the supply air and even distribution into all zones.

Tracer gas tests experimental setup at the AYO house



Schematic of ground floor zones and sensors locations

- The tracer gas concentration is logged using multiple CO_2 sensors The **temperature** and **relative humidity** are recorded over time for the thermal comforts assessment using T and RH sensors.
- For the ease of **DAQ**, sensor packages are built to combine all the sensors in an **Arduino** UNO board coupled with Arduino data logging shield for DAQ .
- Ground and top floors are divided into 8 different zones



The sensor package components

A-Tracer gas tests:
9 different tracer gas tests are designed with different internal doors, HVAC and bathroom vent arrangements.

B-Air tightness tests:
HVAC system is turned off and all doors and windows are closed.

C-Thermal Comfort Tests:
Three thermal comforts tests are designed: **First test:** T and RH are logged over time and the results are compared with ASHRAE standards for thermal comfort zones. **Second test :** The temperature is recorded with time and along different heights. **Third test:** The spatial variation of temperature is logged with time in different zones.

CONCLUSIONS

- Results show that the house has high **ACH**, higher than ASHRAE standards recommendations, which means that the ventilation is adequate without the need of opening any external windows or doors.
- By comparing the ventilation with and without the bathroom vent, results show that the ventilation is better when the bathroom vent is ON. Thus, it is recommended to always open both bathroom vents in the top and ground floors.
- Air tightness test results give very slow decay of the tracer gas concentration i.e. very low air change rate, which proves that the building envelope is air tight.
- 3D contours of temperature show that there are no major cold or hot spots in the living areas.
- There are also no swings in temperature with time and temperature fluctuations band is within the thermal comfort band in living areas recommended by ASHRAE.
- Results show that there is no spatial changes in temperature along different rooms which means adequate mixing of supply air with the room air.

ACKNOWLEDGMENT

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NSERC CRSNG AYO smart home