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AIVC Airtightness Workshop

Consideration of Envelope Airtightness in Modelling Commercial Building Energy Consumption

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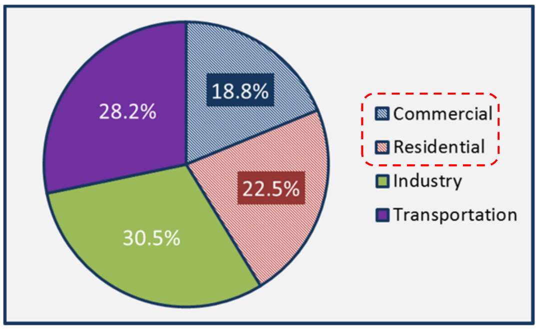
Outline

- Introduction
  - Airflow capabilities of energy simulation software
  - Impacts of improved building envelope airtightness
- Proposed method for more accurately simulating airflow through building envelope using energy software
- Compare results from energy simulation with multizone airflow model results
- Future work

Introduction



Buildings consume 40% of energy in U.S.

- Use of building energy simulation software has increased to investigate energy-saving design options
- One option = improve building envelope airtightness

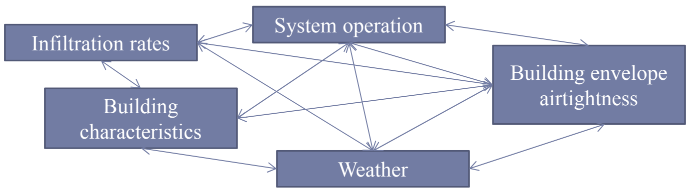
Energy software capabilities

	eQuest	EnergyPlus	TRNSYS	DesignBuilder	Ecotect
Infiltration					
Constant	Y	Y	Y	Y	Y
Wind & stack effects	Y	Y	O	X	Y
Multizone airflow	X	O	O	O	X

Ng et al. (2011), "Airflow & IAQ analyses capabilities of energy simulation software", Proceedings of Indoor Air 2011

Proposed method for more accurate modeling of infiltration in commercial buildings

- Relatively simple to implement yet based on following relationships



- Described for implementation in EnergyPlus, but applicable to many energy simulation software

Infiltration in EnergyPlus

$$\text{Infiltration} = I_{design}\,[A + B|\Delta T| + \cancel{CW_s} + DW_s^2]$$

- A, B, and D are constants. Values based on empirical data for low-rise buildings given in EnergyPlus manual
- **Proposing** a method to calculate A, B, and D based on building height, surface-to-volume ratio and normalized net system flow
  - To apply to other buildings

Proposed method for calculating *A*, *B*, and *D*

$$\text{Infiltration} = I_{design}\,[A + B|\Delta T| + DW_s^{2}]$$

Given I_{design} and weather,
calculate individual *A, B, D* from regression for several buildings

A = *M*(Height) + N(Surface-to-volume ratio) + *P*(normalized net system flow)
Similar equations for B and D

Given *A* and building characteristics
calculate *M, N, P* from regression

Calculate *A, B or D* by knowing building height, surface-to-volume ratio and normalized net system flow

Simulations performed

- 7 commercial reference buildings
  - Restaurant
  - Hospital
  - Large Office
  - Medium Office
  - School
  - Retail
  - Hotel
- Annual simulations using weather data for Chicago
- Assumed building envelope airtightness of 5.27 cm^2/m^2 at 4 Pa (1.8 cfm/ft^2 at 75 Pa)

Ng et al. (2012), " Airflow and Indoor Air Quality Models of DOE Reference Commercial Buildings", Report Number: NIST Technical Note 1734

Equations for *A*, *B*, and *D*

System fan ON

$$A_{on} = 0.0001 \cdot H + 0.0933 \cdot SV + -47 \cdot F_n$$
$$B_{on} = 0.0002 \cdot H + 0.0245 \cdot SV + -5 \cdot F_n$$
$$D_{on} = 0.0008 \cdot H + 0.1312 \cdot SV + -28 \cdot F_n$$

System fan OFF

$$A_{off} = 0$$
$$B_{off} = 0.0002 \cdot H + 0.0430 \cdot SV$$
$$D_{off} = -0.00002 \cdot H + 0.2110 \cdot SV$$

H: height, SV: surface-to-volume ratio, F_n: normalized net system flow

Assume $A = 0$ and *normalized net system flow* = 0 when system is off

Example: Medium Office

Height: 12 m
Surface-to-volume ratio: 0.18 m^2/m^3
Normalized net system flow:
0.56 x 10^{-3} m^3/s-m^2

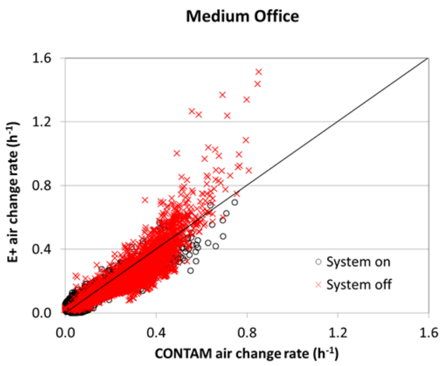
$$A_{on} = 0.0001 \cdot H + 0.0933 \cdot SV + -47 \cdot F_n$$
$$B_{on} = 0.0002 \cdot H + 0.0245 \cdot SV + -5 \cdot F_n$$
$$D_{on} = 0.0008 \cdot H + 0.1312 \cdot SV + -28 \cdot F_n$$

$$A_{off} = 0$$
$$B_{off} = 0.0002 \cdot H + 0.0430 \cdot SV$$
$$D_{off} = -0.00002 \cdot H + 0.2110 \cdot SV$$

$A_{on} = -0.0082$
$B_{on} = 0.0036$
$D_{on} = 0.0177$

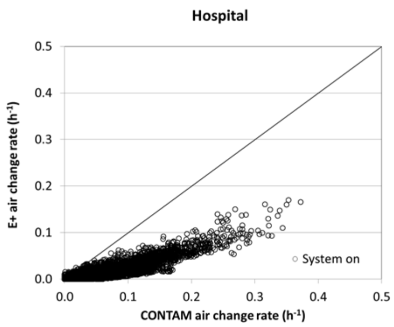
$A_{off} = 0$
$B_{off} = 0.0106$
$D_{off} = 0.0379$

CONTAM & EnergyPlus results



System on	CONTAM mean infiltration rate (h^{-1})	0.11
	EnergyPlus mean infiltration rate (h^{-1})	0.11
	Standard error of EnergyPlus rates (h^{-1})	0.04 (36)
	R^2	0.83
System off	CONTAM mean infiltration rate (h^{-1})	0.27
	EnergyPlus mean infiltration rate (h^{-1})	0.23
	Standard error of EnergyPlus rates (h^{-1})	0.06 (23)
	R^2	0.57

Hospital



System on	CONTAM mean infiltration rate (h^{-1})	0.02
	EnergyPlus mean infiltration rate (h^{-1})	0.01
	Standard error of EnergyPlus rates (h^{-1})	0.02 (130)
	R^2	-0.23

- In general, cases that weren't as successful were ones with relatively low infiltration rates (Hospital, two offices)
  - R^2 were not as good, but absolute errors were also low

Proposed method & other airtightness values

- Proposed method is based on airtightness of 5.27 cm²/m² at 4 Pa (1.8 cfm/ft² at 75 Pa)
- Tested the method using half and double this airtightness
  - In general, for most buildings, using the same equations with different airtightness values resulted in good agreement between CONTAM and EnergyPlus
  - Larger discrepancies for Hospital and Large Office (low infiltration rates)

$$A_{on} = 0.0001 \cdot H + 0.0933 \cdot SV + -47 \cdot F_n$$
$$B_{on} = 0.0002 \cdot H + 0.0245 \cdot SV + -5 \cdot F_n$$
$$D_{on} = 0.0008 \cdot H + 0.1312 \cdot SV + -28 \cdot F_n$$

$$A_{off} = 0$$
$$B_{off} = 0.0002 \cdot H + 0.0430 \cdot SV$$
$$D_{off} = -0.00002 \cdot H + 0.2110 \cdot SV$$

Future work

- Use of the proposed method for other buildings
- Additional weather, system types and operating conditions
- Developing guidance on how to use the proposed strategy
- Proposing modifications to energy simulation software, if needed, that implement the proposed method

Conclusion

- Effects of weather, system operation, and envelope leakage on infiltration are overly simplified in current energy modeling approaches
- Multizone airflow modeling capabilities within energy programs can help, but are often limited or difficult to employ
- Proposed strategy incorporates effects of weather, system operation and envelope leakage on infiltration in a relatively easy manner, and also has good agreement with airflow modeling results

Thank you!

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