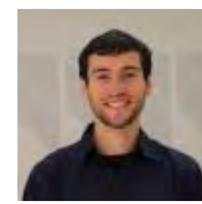
BUILDINGENERGY BOSTON

MARCH 7-9, 2017 • SEAPORT WORLD TRADE CENTER • NESEA.ORG/BE17
Conference + Trade Show of the Northeast Sustainable Energy Association (NESEA)

Spending Through the Roof: Tall Building Energy Wasted Through Passive Vents

Building Energy 2017
A presentation by:
Jamie Kleinberg & Robin Neri



Steven Winter Associates, Inc.
Improving the Built Environment Since 1972

Project Objective:

- Develop and test methods for estimating the savings potential for sealing shaft openings in multifamily buildings using tools common to energy auditors.
- Discuss the benefits of closing the vents to a wide audience of building professionals and provide tools for retrofit implementation.

Project Team:

nyserda
Energy. Innovation. Solutions.

Project funding
Technical review/assistance

urban green | U.S. GREEN BUILDING COUNCIL CHAPTER

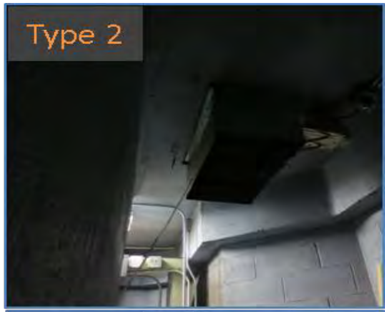
Report co-author and publisher
Website design
Outreach event planning

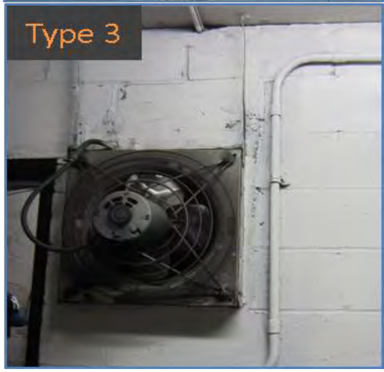
Steven Winter Associates, Inc.
Improving the Built Environment Since 1972

Experimental design
Data collection and analysis
Report co-author

This session will describe:

1. Why there are holes on our roofs
2. Physics Class: full of hot air (the buildings, that is)
3. What worked, what didn't: Test Setups and Data Collection
4. Determining key parameters
5. Making a Retrofit Assistance Tool
6. Outreach to Effect Change





Why there are holes on our roofs

Buildings

2014 Construction Codes
Section 3004.5- Control of smoke and hot gases

Area of vents. The area of vents in the hoistway or the elevator machine room and the smoke hole shall be not less than 3½ percent of the area of the hoistway nor less than 3 square feet (0.28 m^2) for each elevator car, whichever is greater. Such vents shall comply with the following requirements:

2.1. **Open vents.** Of the total required vent area, not less than one-third shall be permanently open or equipped with an openable hinged damper. The smoke hole shall be permanently open.

2.2. **Closed vents.** The two-thirds closed portion of the required vent area either in the hoistway enclosure or in the elevator machine room may consist of windows or skylights glazed with annealed glass not more than 1/8-inch (3.2 mm) thick. A closed damper that opens upon the activation of a smoke detector placed at the top of the hoistway shall be considered closed.

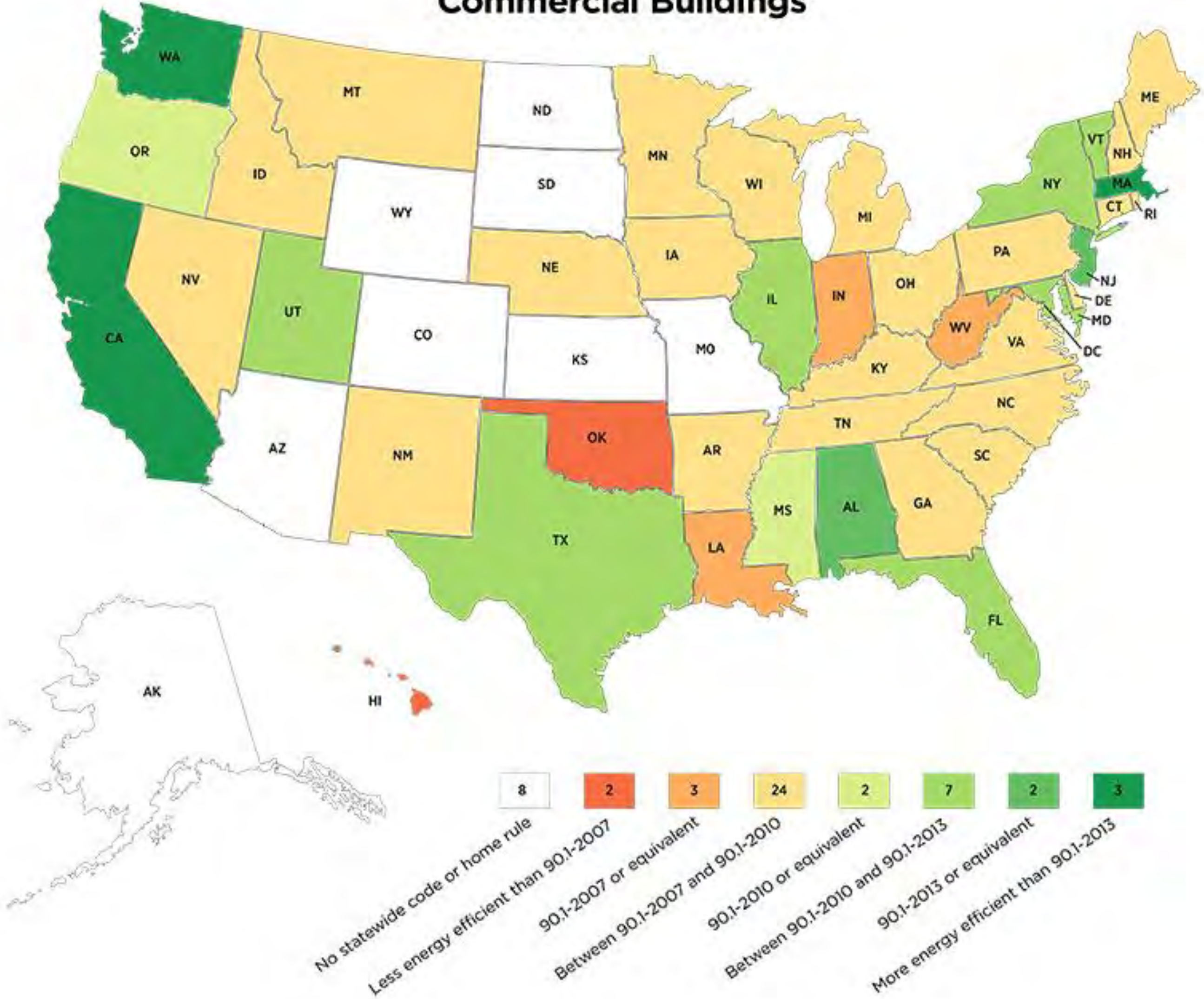
Exception: The total required open vent area shall not be required to be permanently open where all of the vent openings automatically open upon detection of smoke in the elevator lobbies or hoistway, upon power failure (except when provided with a code compliant standby power supply from an approved standby power source) or upon activation of a manual override control. The manual override control shall be capable of opening and closing the vents and shall be located in an approved location.

Why there aren't holes on your roofs

2015 IECC:

- **C403.2.4.3 Shutoff dampers.** Outdoor air intake and exhaust openings and stairway and shaft vents shall be provided with Class I motorized dampers. The dampers shall have an air leakage rate not greater than 4 cfm/ft2 (20.3 L/s · m2) of damper surface area at 1.0 inch water gauge (249 Pa) and shall be labeled by an approved agency when tested in accordance with AMCA 500D for such purpose.
- Outdoor air intake and exhaust dampers shall be installed with automatic controls configured to close when the systems or spaces served are not in use or during unoccupied period warm-up and setback operation, unless the systems served require outdoor or exhaust air in accordance with the *International Mechanical Code* or the dampers are opened to provide intentional economizer cooling.
- **Stairway and shaft vent dampers shall be installed with automatic controls configured to open upon the activation of any fire alarm initiating device of the building's fire alarm system or the interruption of power to the damper.**

Commercial Buildings



Building Physics

NYC buildings are full of hot air, and it's cold outside

Equation for Stack Effect[1]: $\Delta p_T = g * \rho_o * H * \left(\frac{T_o - T_i}{T_i + 459.67}\right)$

Where:

Δp_T = pressure difference in inches of water

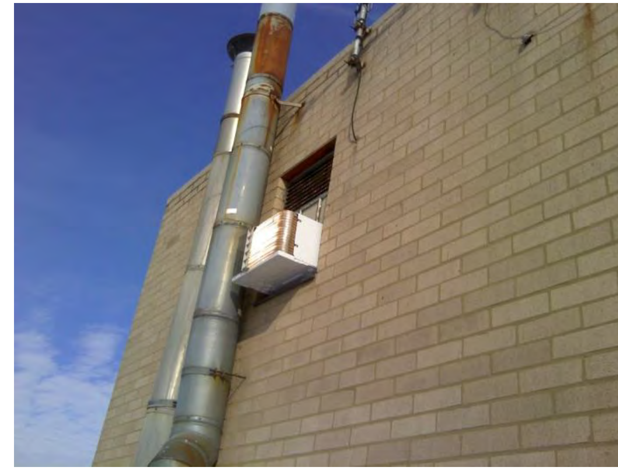
g = gravitational acceleration in ft/s^2

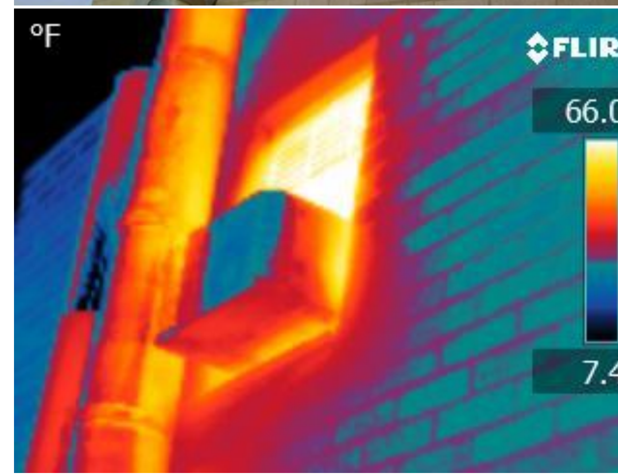
ρ_o = density of air in lbm/ft^3

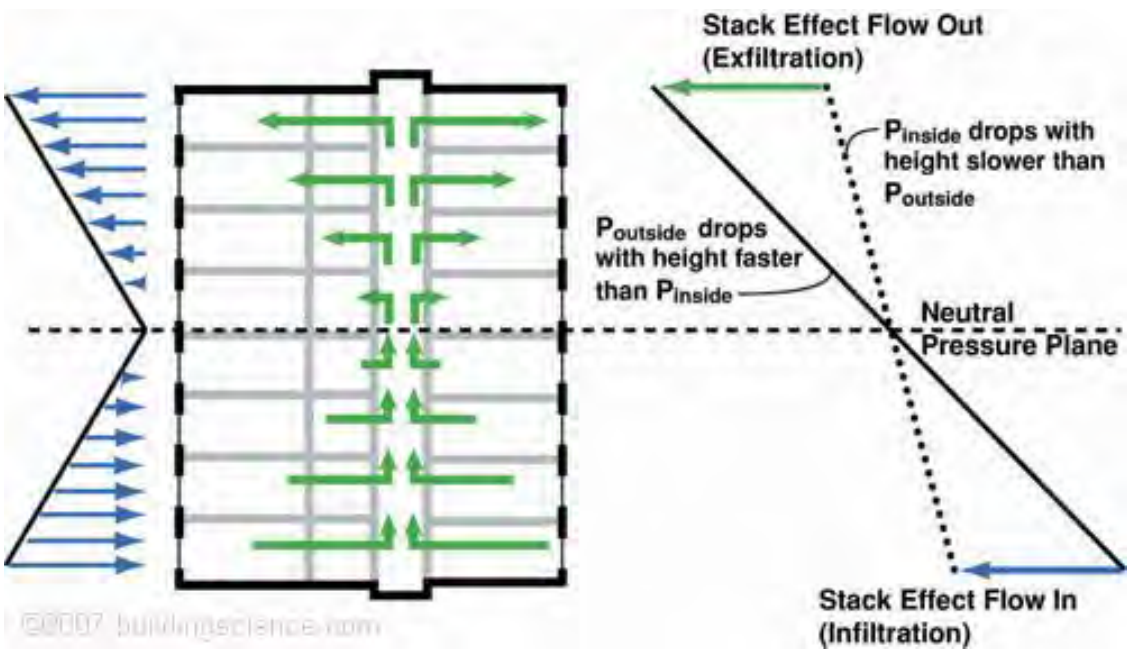
H = stack height **in feet**

T_0 = outdoor temperature in °F

T_i = indoor temperature in °F







Simplifying:

$$\Delta p_T = 3.803 * H * \left(\frac{T_o - T_i}{T_i + 459.67}\right)$$

[1]ASHRAE F.16 (2009), Equation 30

Building Physics

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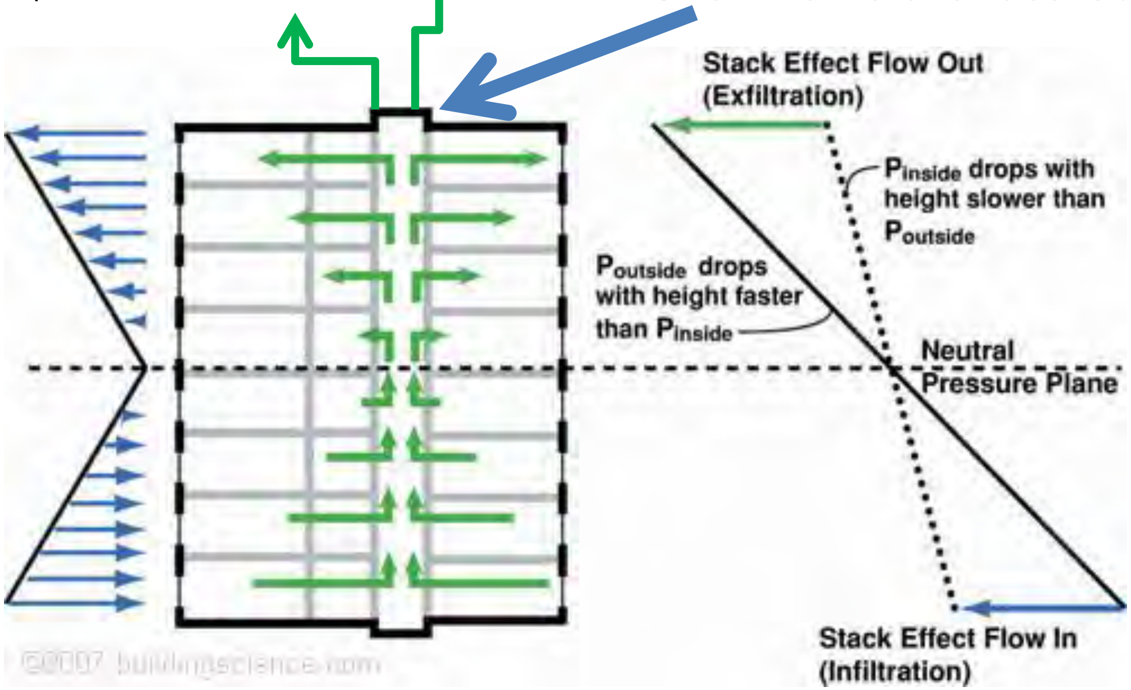
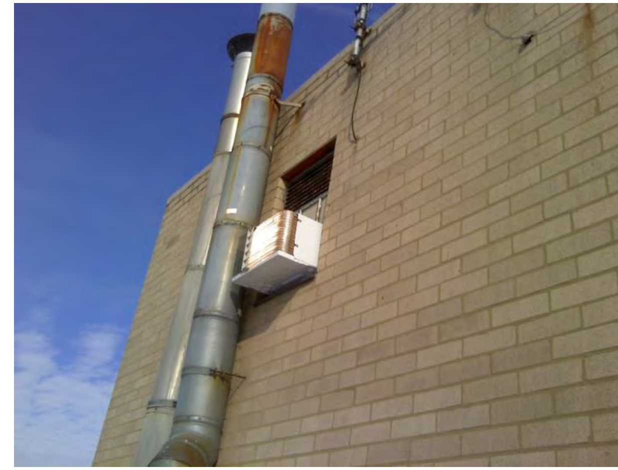
H = stack height **in feet**

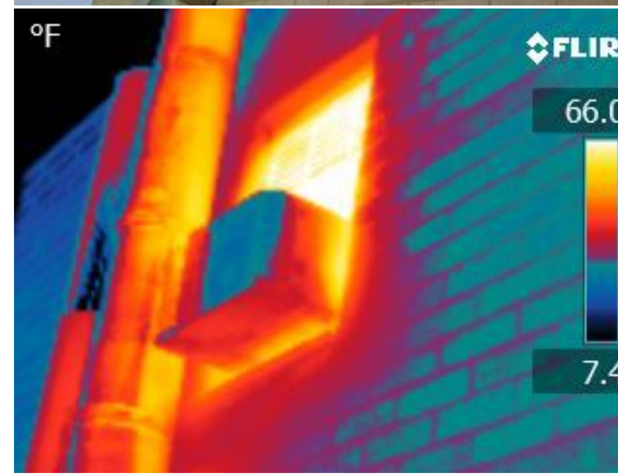
T_0 = outdoor temperature in °F

T_i = indoor temperature in °F

Shaft vents are located here







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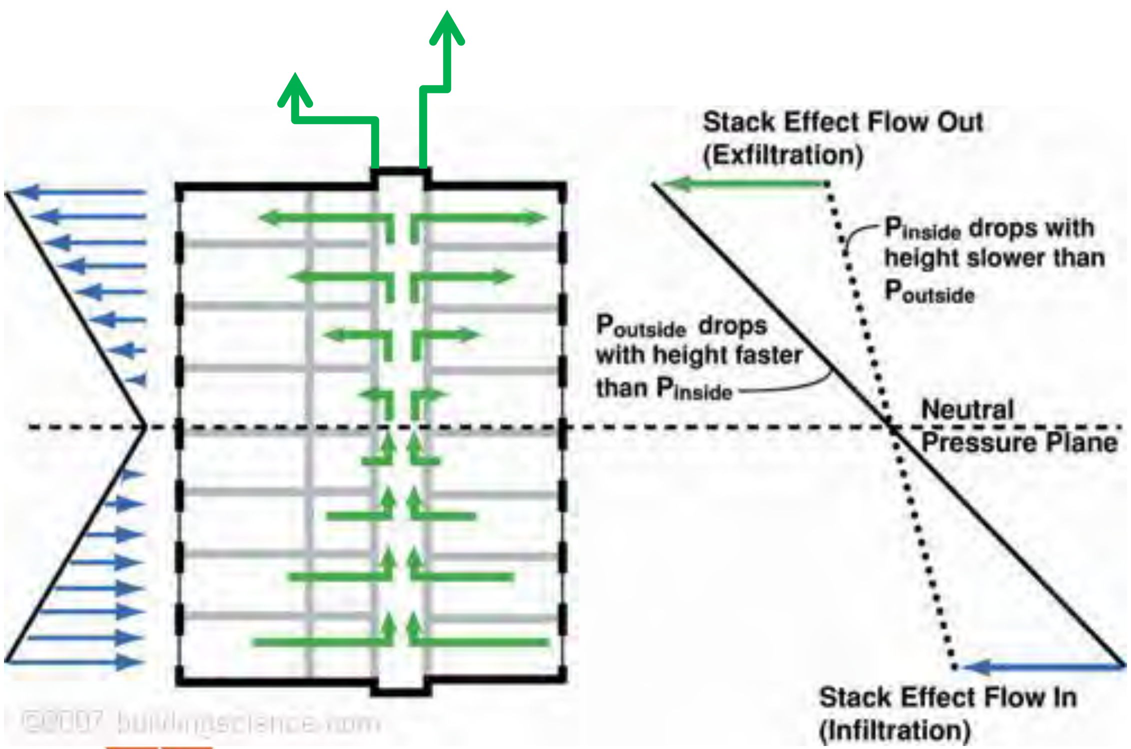
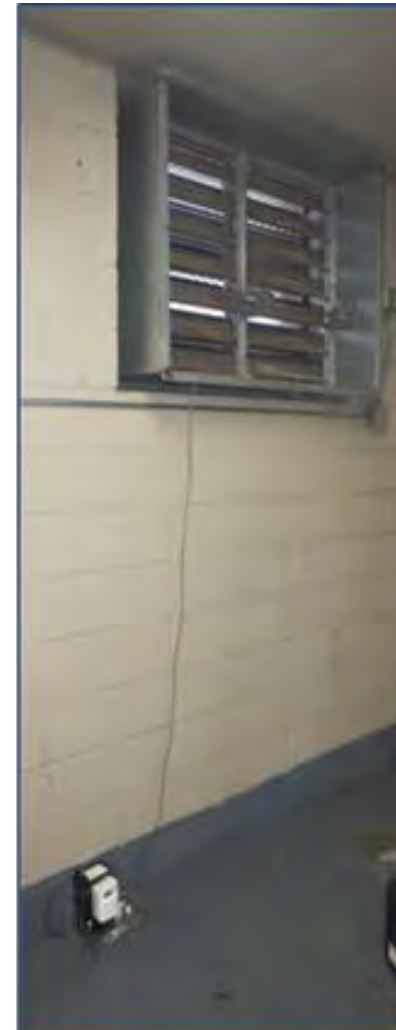
Building Physics

$$\Delta p_T = 3.803 * H * \left(\frac{T_o - T_i}{T_i + 459.67}\right)$$

Q = airflow in cubic feet per minute (CFM)
Δp = pressure difference across the opening in inches of water
C_D = coefficient of discharge through an orifice, taken as 0.65 for unidirectional flow
A = free area of the opening in square feet
ρ = density of air in lbm/ft^3

Airflow equation[2]: $Q = 776 * C_D * A * \sqrt{\frac{2\Delta p}{\rho}}$



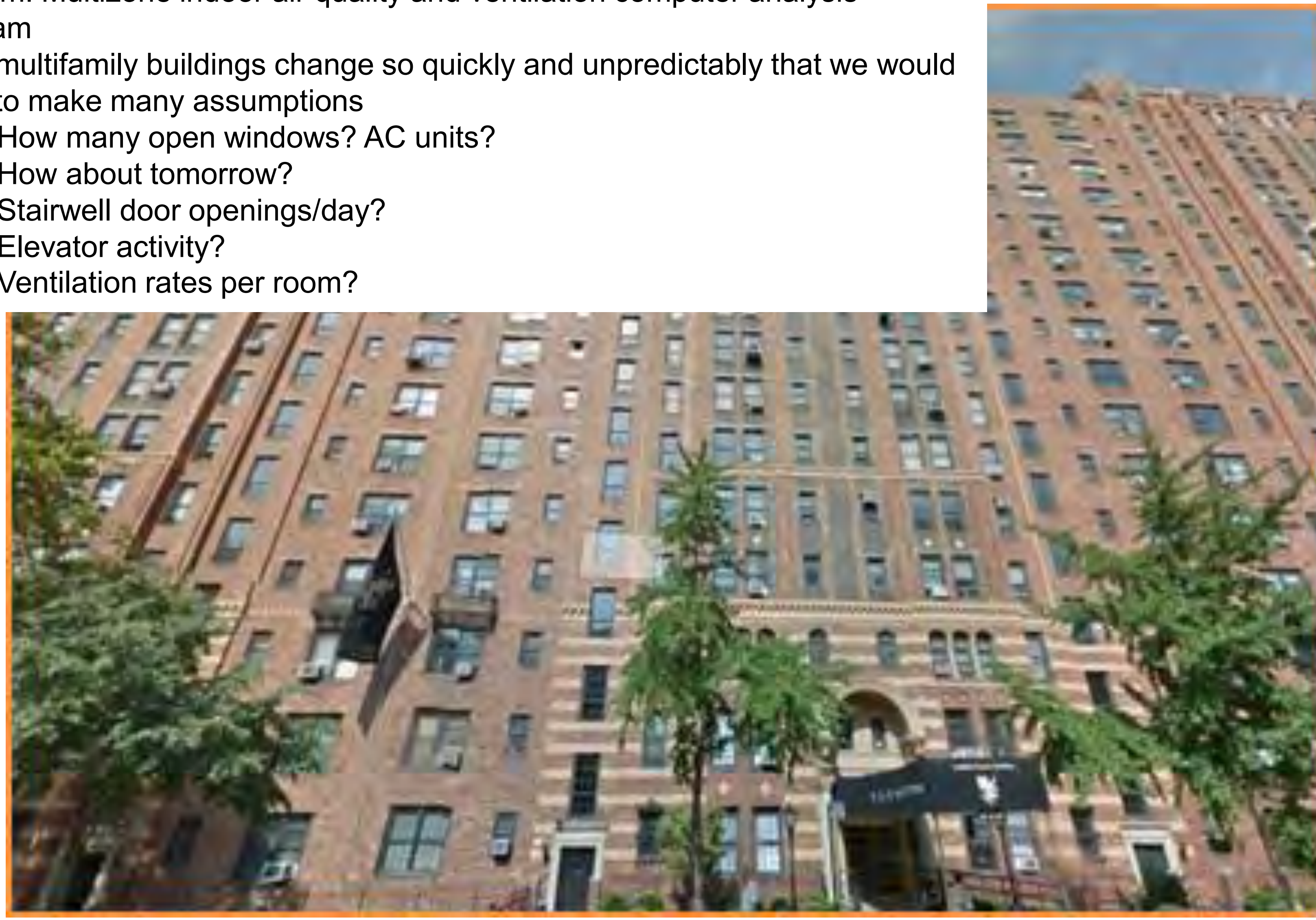


[2]ASHRAE F.16 (2009), Equation 36

Quantifying the Energy Impact

Does airflow modeling get us reliable data?

- Contam: Multizone indoor air quality and ventilation computer analysis program
- But…multifamily buildings change so quickly and unpredictably that we would need to make many assumptions
    - How many open windows? AC units?
    - How about tomorrow?
    - Stairwell door openings/day?
    - Elevator activity?
    - Ventilation rates per room?



The Empirical Strikes Back

Pressure is simple to measure and can be logged over various weather and building conditions

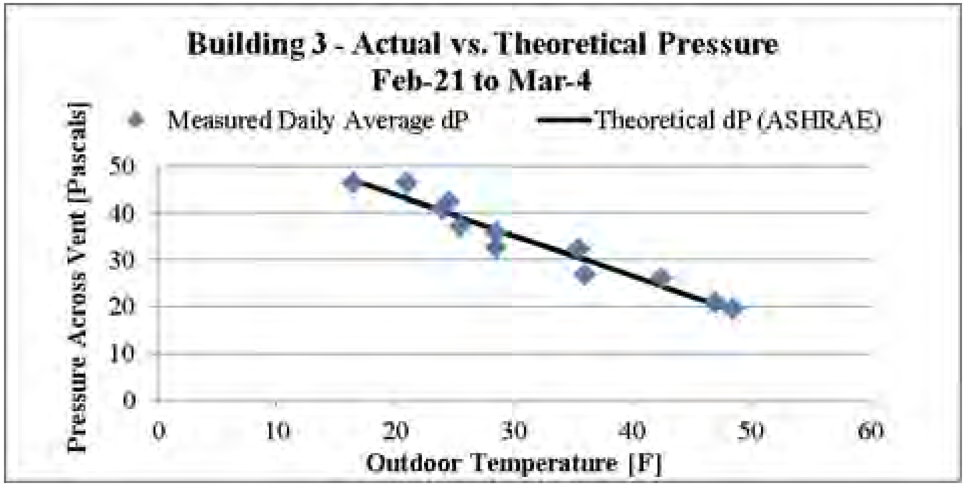
- Measure vent area, take airflow spot measurement
- Differential pressure sensors logging pressure across the vent
- 1-4 weeks pressure monitoring

Sample Population	Units	Sample Population (per building)
Average shaft temperature	°F	71
Median Building Height	feet	225
Average VPF = Actual/Total Stack at Vent	Ratio	0.28
Average stack effect pressure	IWC	0.072
Elevator vent free area per building	in^2	466
Stairwell vent net free area per building	in^2	195
Elevator vent airflow	CFM	2295
Stairwell vent airflow	CFM	720

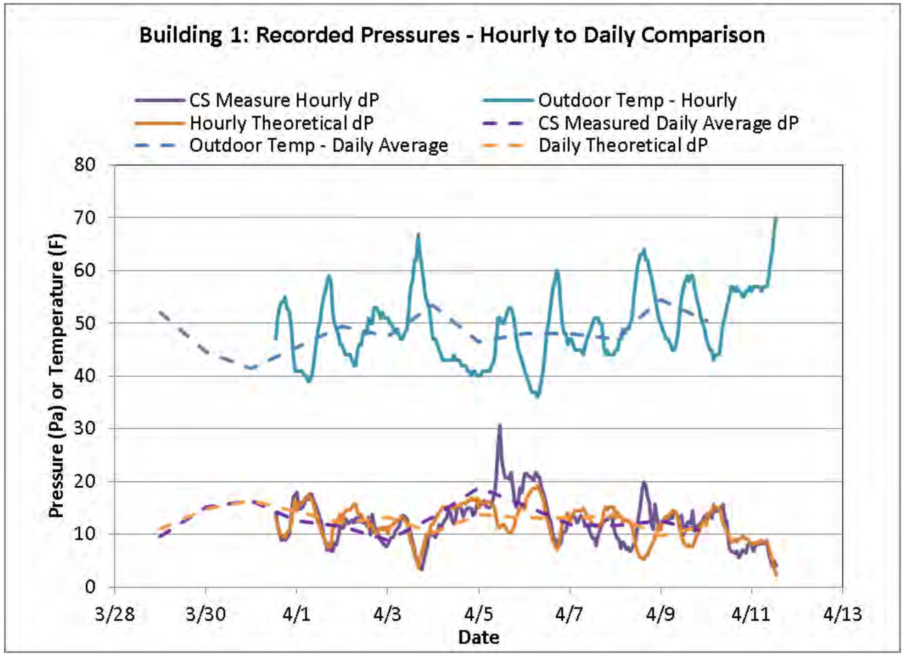
Data Analysis

Daily Energy Flow[3]: $q_s\left(\frac{BTU}{day}\right) = 60 * 24 * Q * \rho * c_p * \Delta T$

$$q_{s,season} = q_{s,test} * \frac{HDD_{season}}{HDD_{test}}$$

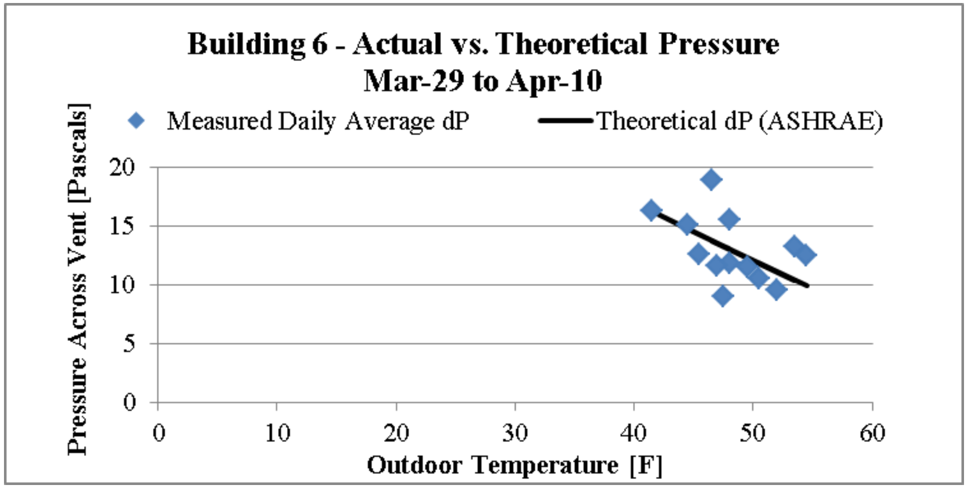


Pressure averaged daily and did not introduce unreasonable error over hourly pressures



Measured data was closer to theoretical during colder weather

This is likely due to occupants starting to open windows

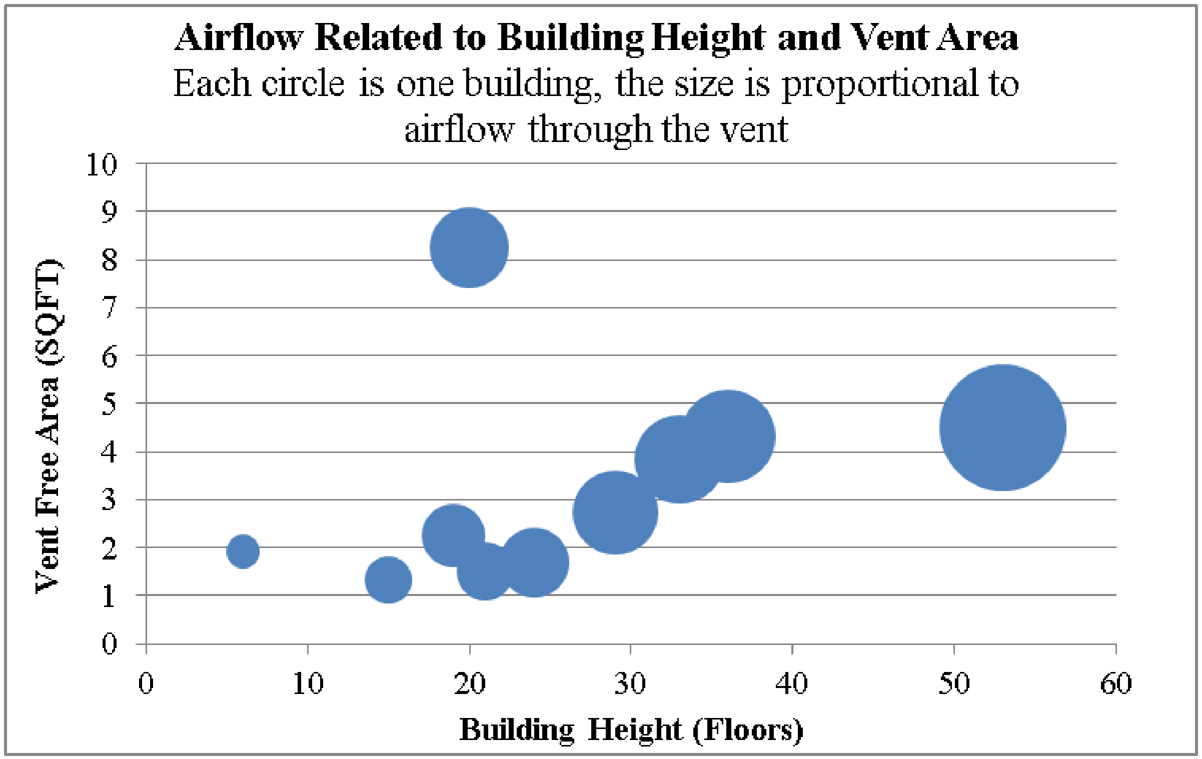


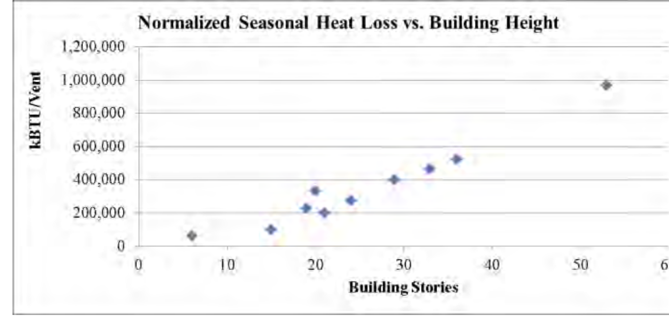
[3]ASHRAE F.16 (2009), Equation 33

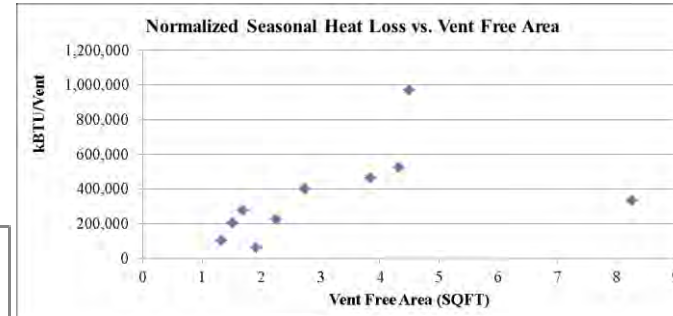
Results

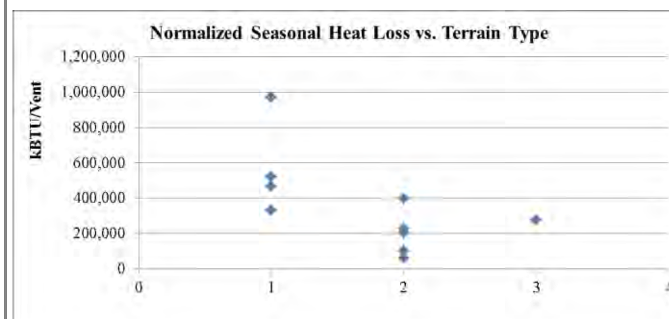
Correlation analysis on building characteristics

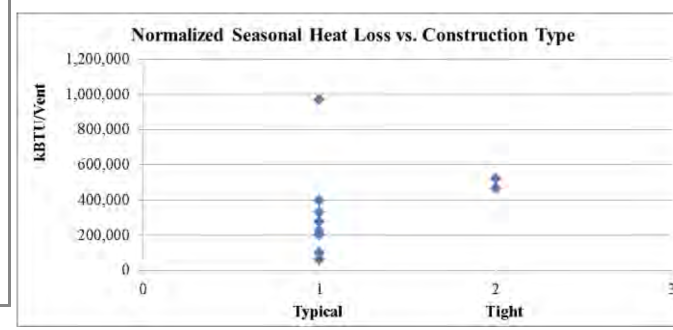
1. Height: 0.91
2. Vent Free Area: 0.69
3. Exposure: 0.83
4. Envelope type: 0.29











Results

Correlation analysis on building characteristics

1. Height: 0.91
2. Vent Free Area: 0.69
3. Exposure (ASHRAE terrain type): 0.83
4. Envelope type: 0.29

For elevator vents, the following calculation can be used as a tool:

$$Energy\ Savings\left(\frac{MMBTU}{year}\right) = H * A * ES_{VENT}$$

ES_{VENT} MMBTU/ (SqFt Vent F.A.* # Floors)		Terrain Classification (ASHRAE)		
		1-City Center	2-Urban	3-Suburban
Wall Construction	Typical	1.7	3.7	4.8
	Tight (Curtain wall)	2.5	5.4[a]	6.9[a]

Stairwell vents use the same equation but multiplied by 80%, as measurements indicated lower pressure buildup in stairwell shafts

Guidance for Retrofits

1. Locate the vent and identify the vent type.

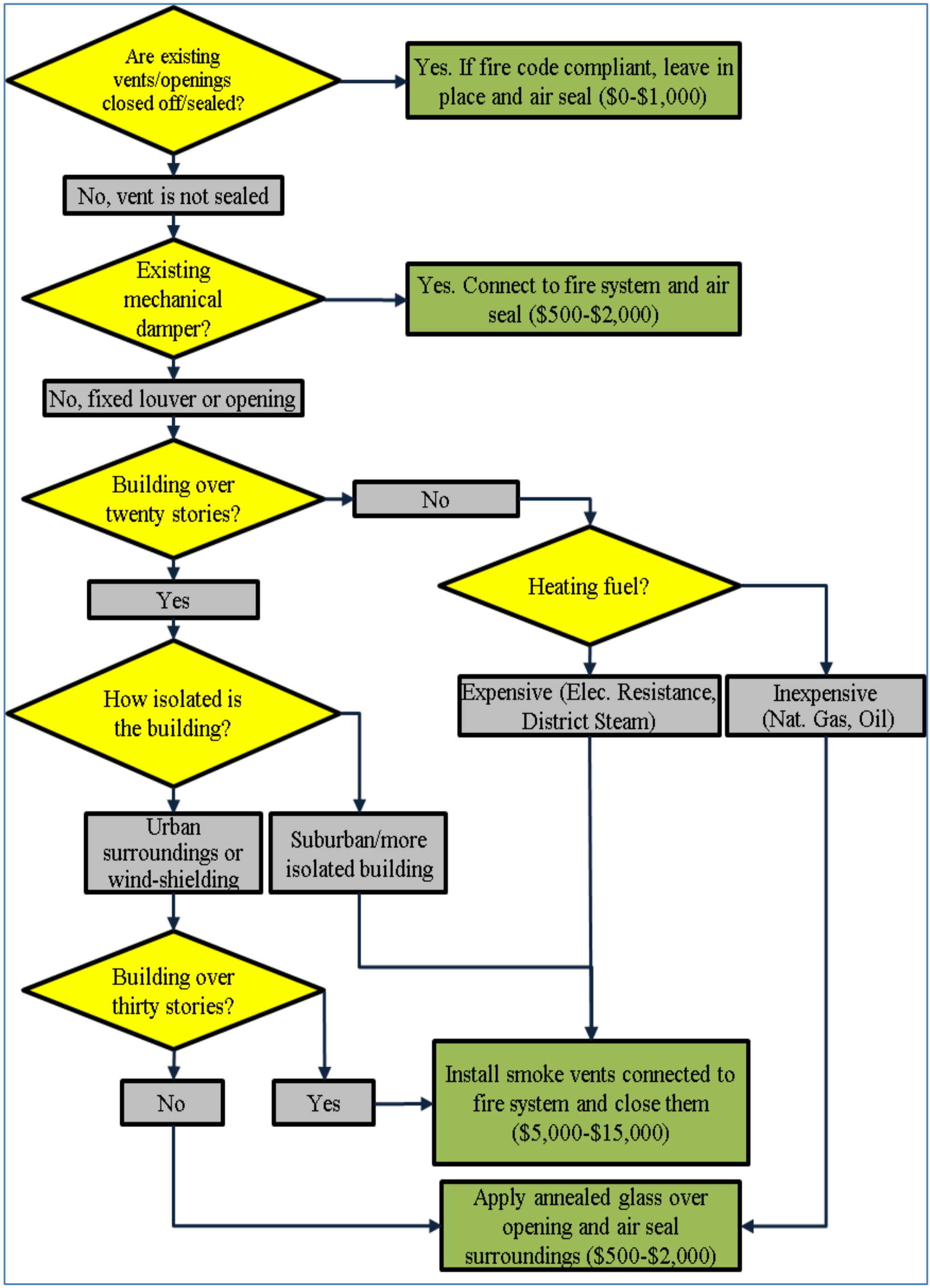
- Vent located in the elevator MER?
- Vent located in the side wall of the shaft?
- Mechanically vented? Ducted?

2. Determine the appropriate retrofit.

- Close 2/3 of the vent opening with glass
- Close the entire opening with a smoke-activated damper
- Close stairwell vents down to 1 SF opening (up for debate)

3. Execute the retrofit.

- Use in-house staff? Cost effective option for glass retrofit.
- Hire a contractor? Best option for bigger buildings or where elevator shaft airflow concerns are greatest.



New Construction

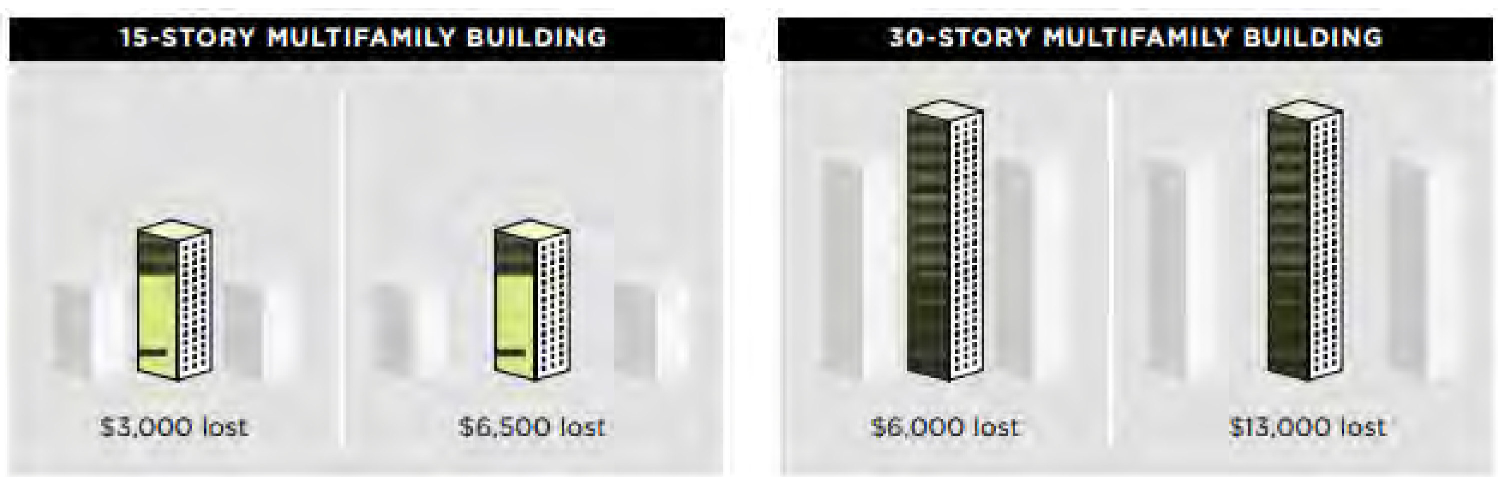
Energy Codes

Existing Buildings

???

Citywide Potential Savings

Factors		**PLUTO Database Fields**
Building Height	→	Number of Floors
Envelope Construction	→	Year Built (before or after 2000)
Exposure	→	Borough
Size of Vent Opening	→	?



$11,000,000/year

80,000 barrels of oil

30,000 metric tons CO2e

New York Times Coverage

Environmental Report Details Heat's Costly Escape Through Elevator Shafts

By LISA W. FODERARO MARCH 17, 2015

David Davenport, principal of Urban Greenfit, and a hole that had been closed above an elevator shaft. Sealing such cracks and holes, he said, "is critical because the biggest problem is air leakage from buildings."
Hiroko Masuike/The New York Times

RELATED COVERAGE

Building Toward a Goal of Reducing Emissions in New York City by 80 Percent
DEC. 19, 2014

Public Event: Panel Discussion

How-to Guide for Auditors

STEP 1: ASSESSING YOUR BUILDING

To assess your building's potential energy savings using the worksheet on p. 14, you need to provide information on five basic characteristics:

1. Building Height

Tall buildings lose more heat. You'll enter the height of your building in number of floors. The guide that follows assumes 10 feet per floor, an average height for tall buildings.

2. Wind Exposure

The more exposed a building is to the wind, the greater the loss of warm air through the roof. Select which **terrain class** best fits your building: 1—large city center with nearby buildings 80 feet tall or higher; 2—urban or suburban areas with nearby buildings 20 to 80 feet high; 3—suburban areas with nearby buildings below 20 feet in height.

Interactive Calculator

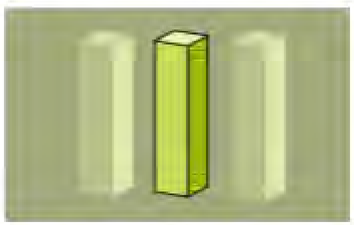
http://urbangreencouncil.org/spending

1. HOW TALL IS YOUR BUILDING?

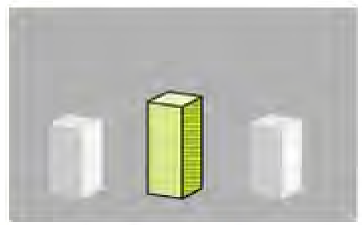
6

6 FLOORS — 100 FLOORS

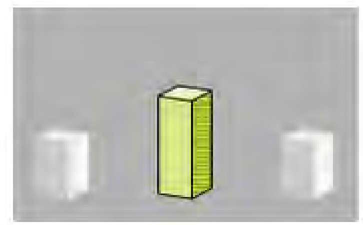
2. HOW WOULD YOU DESCRIBE YOUR BUILDING'S SURROUNDINGS?



DENSE CITY CENTER
Nearby buildings 80 feet or taller

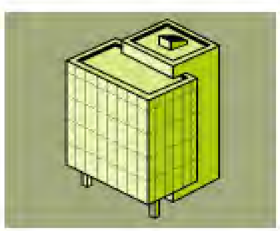


URBAN/SUBURBAN
Nearby buildings 20-80 feet tall

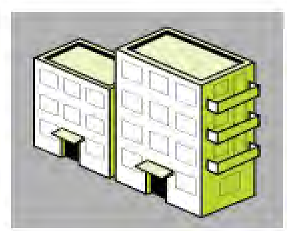


SUBURBAN
Nearby buildings below 20 feet

3. IS YOUR BUILDING TIGHT OR TYPICAL?



TIGHT (WELL-SEALED)
No major penetrations through majority of walls (usually constructed 2000 or later)



TYPICAL (DRAFTY)
Walls have openings for AC units, ventilation, etc., that are not well sealed (usually constructed before 2000)

4. SELECT YOUR LOCATION

NY - New York

5. BUILDING OPERATION DETAILS

- [ ] I don't think I know these, use the default values.
- [x] I know my details, I'll enter them below (improves result accuracy).

A. HOW MANY ELEVATOR SHAFT VENTS DOES YOUR BUILDING HAVE?

1

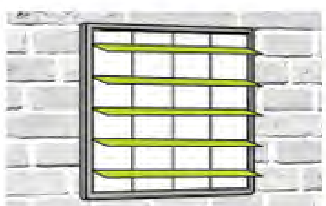
1 — 10

B. WHAT IS THE AREA OF EACH VENT (ASSUME ALL VENTS ARE EQUAL SIZE)?

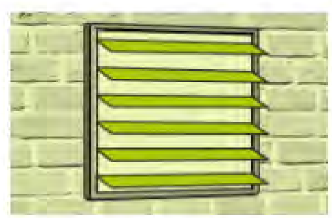
6

1 SQUARE FT. — 50 SQUARE FT.

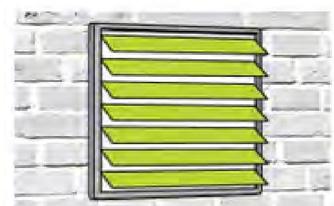
C. WHAT IS THE PERCENT OF OPEN SPACE FOR EACH VENT?



75% FREE AREA



50% FREE AREA



25% FREE AREA

D. WHAT IS THE PRIMARY FUEL FOR YOUR HEATING SYSTEM?

- [ ] Oil
- [ ] Steam
- [x] I don't know
- [ ] Natural gas
- [ ] Electric heat

YOUR SAVINGS

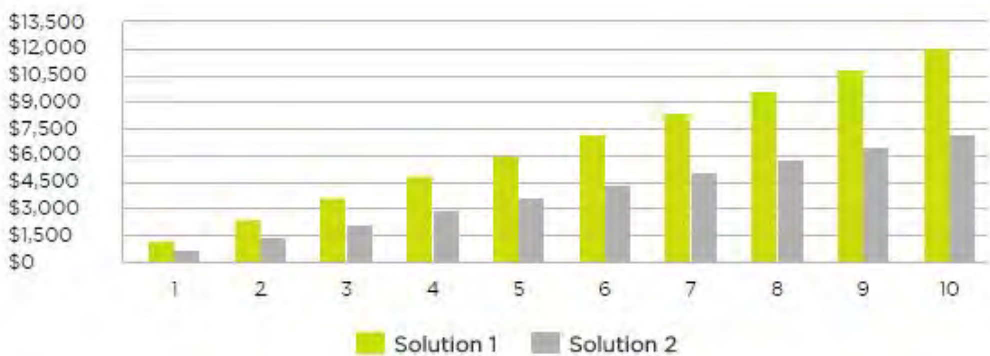
Toggle back and forth between solution one and two to compare.

SOLUTION ONE
FULLY CLOSING VENT WITH ELECTRIC LOUVERS

$1,200
AFTER 1 YEAR

$12,000
AFTER 10 YEARS

9 YEARS
TIME TO PAY BACK INITIAL COST OF $10,000



Each situation is unique, so your energy savings and payback period may be higher or lower than calculated here.

Developed in partnership with **Steven Winter Associates**

One City Built to Last

Technical Working Group Report

TRANSFORMING NEW YORK CITY BUILDINGS FOR A LOW-CARBON FUTURE

The City will take the following steps:

- **Require owners of large and mid-sized buildings to repair and improve heating distribution systems, including specific requirements for steam systems, within the next 10 years.**
- **Require owners of mid-sized buildings to upgrade lighting in non-residential areas to meet current Energy Code standards by 2025.**
- **Require owners of large and mid-sized buildings to assess deep energy retrofit strategies as part of the Local Law 87 energy audit through a simple template developed by the City.**
- **Require implementation of efficiency measures in existing buildings by incorporating low- and medium-difficulty measures into the codes or as standalone mandates. The City will begin with requiring digital burner controls for boilers, restrictions on open refrigerators in retail stores, thermal de-stratification fans in heated industrial spaces, sealed roof vents in elevator shafts, and upgrades of exterior lighting to current Energy Code standards.**

Thank you!

NYC Code
MA Stretch Energy Code:
502.4.5 Outdoor Air Intakes and Exhaust Openings. Stair and elevator shaft vents and other outdoor air intakes and exhaust openings integral to the building envelope shall be equipped with not less than a Class I motorized, leakage-rated damper with a maximum leakage rate of 4 cfm per square foot (6.8 L/s · C m2) at 1.0 inch water gauge (w.g.) (1250 Pa) when tested in accordance with AMCA 500D. These air tight, operable dampers shall be installed when the air barrier is penetrated by:

1. Fixed open louvers such as in elevator shafts and machine rooms.
2. Mechanical system components which allow infiltration or exfiltration of air when the systems are inactive, such as atrium smoke exhaust systems, elevator shaft smoke relief openings, and other similar elements. Such dampers shall be set in the closed position and automatically open upon:

1. the activation of any fire alarm initiating device of the building's fire alarm system;
2. the interruption of power to the damper.

Exceptions: Gravity (nonmotorized) dampers are permitted to be used in buildings less than three stories in height above grade plane.