Multifamily Envelope Leakage Model

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Acknowledgements

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Outline/Agenda

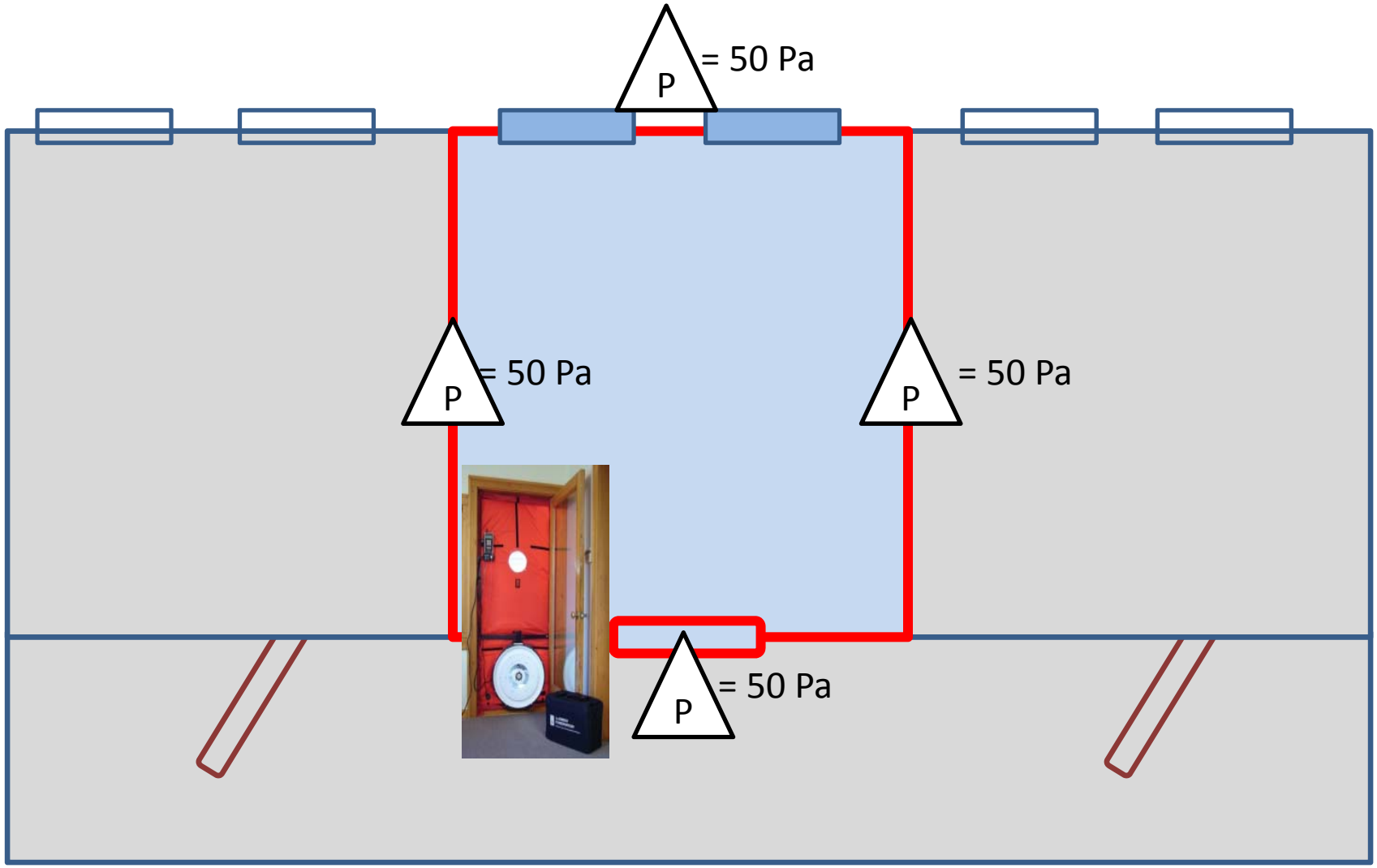
- Introduce multifamily air leakage testing
- Statement of the problem
- Steps taken for a solution
- Model results
- Applying the model
- Benefits of the model

Introduction to multifamily air leakage testing

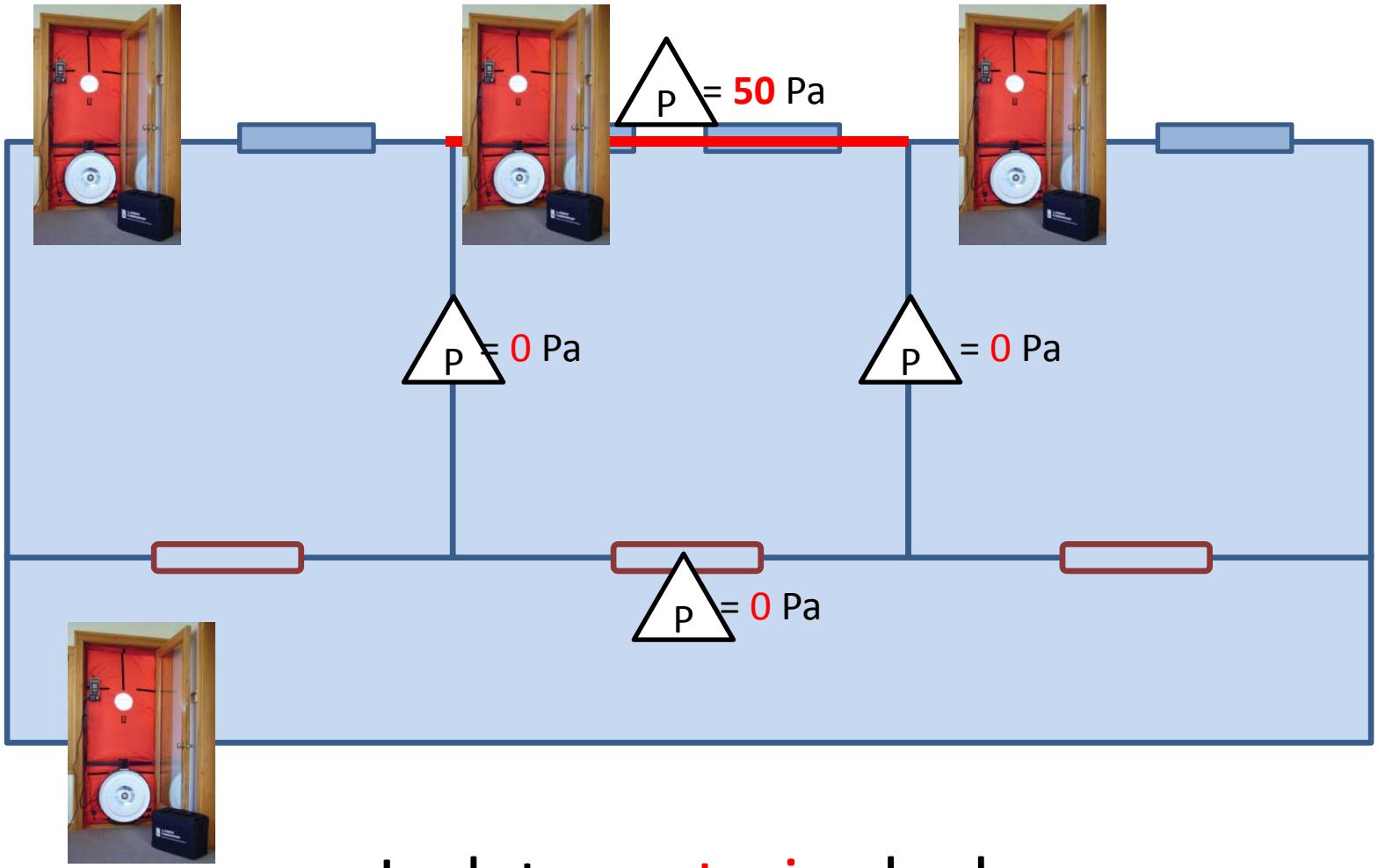
Why do blower door testing?

- Compliance to energy rating standards
- Identify opportunity for reducing energy use
- Identify opportunity for improving IAQ
- Measure implementation verification

Unguarded blower door test



Guarded blower door test

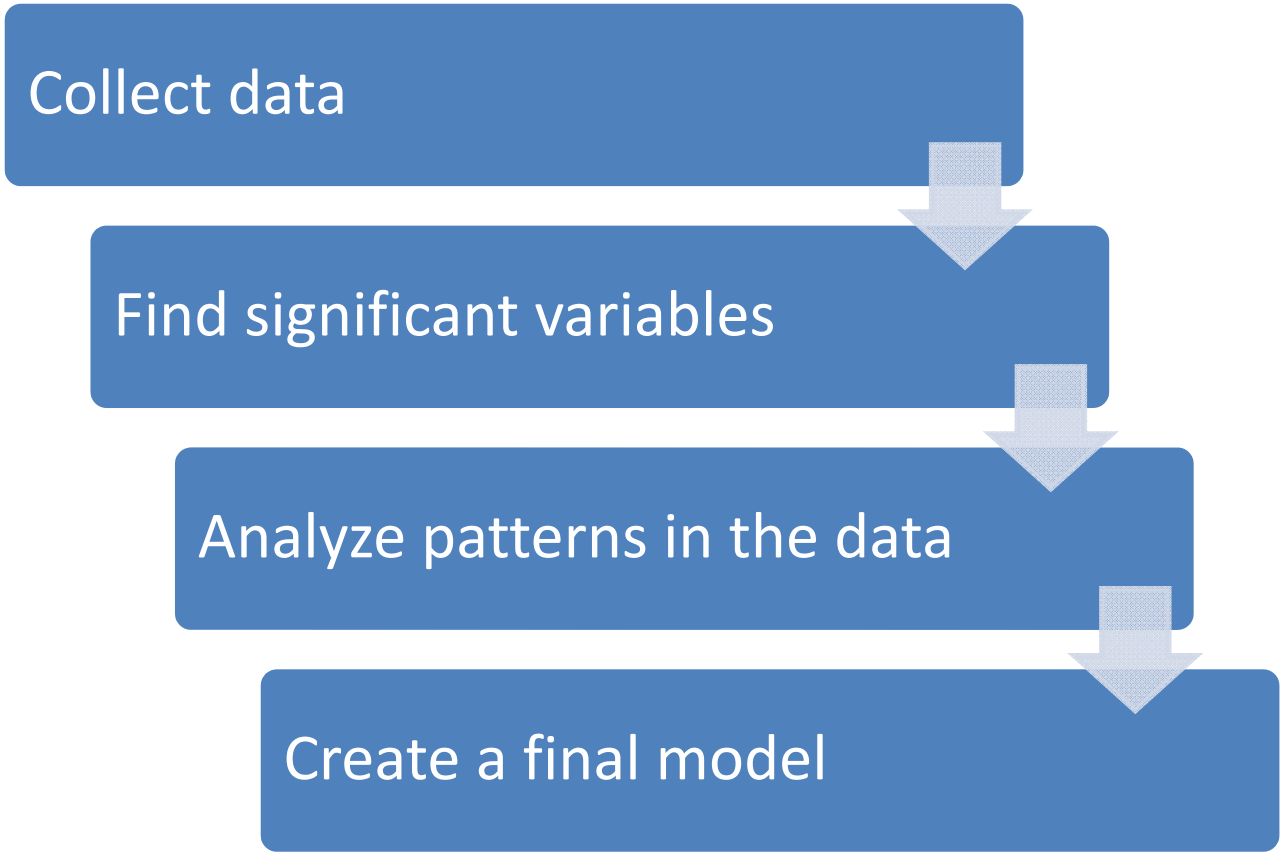


Isolates exterior leakage

What's the big deal?

Guarded	Unguarded/Solo
Time Consuming	Relatively quick
Labor intensive	Less personnel need
More than one blower door equipment are needed	Only one blower door equipment is needed
Generally more cost intensive	Relatively less expensive
Need to coordinate with tenants of multiple units	Dealing with tenant(s) of only one unit
Provide more accurate energy benefits of air sealing	Energy benefits of air sealing is over predicted

Steps taken for a solution



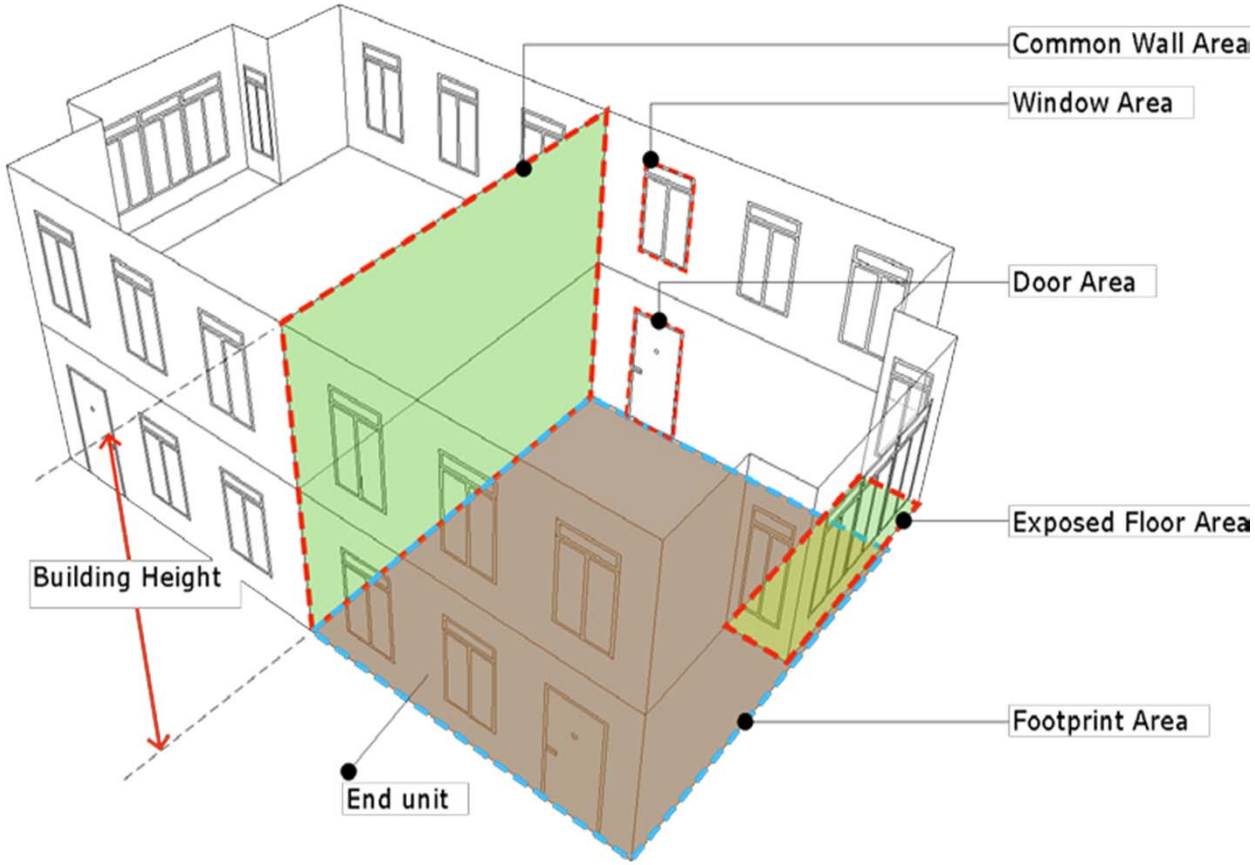
Data Collected

- Data has both guarded and unguarded test results for each unit
- Data consisted of various building specifications for each unit
- Building specifications were used as variables in the predictive model

Data Profile

Category	Value/Range
Number of buildings	17 Buildings
Number of units	236 Units
Climate zones	3, 4, 5, 6
Number of storey	2 and 3
Apartment Types	Apartment or Townhouses

Variables Considered



Variables Considered

- Construction Type
- Guarded Common Area
- Climate Zone
- Unit Level
- Unit Location
- Foundation Type
- Construction Material
- Building Framing Type
- Wall Insulation
- Roof Insulation
- Window Type
- Number of Window Panes
- Window Frame
- Siding
- Common Wall Construction
- Heating System
- Cooling System
- Ductwork Location
- Unit Configuration
- Foot Print Area
- Door Area
- Window Area
- Unit Height
- Common Wall Area
- Exposed Wall Area
- Exposed Floor Area
- Age of building

Set of significant variables

- Climate Zone (3, 4, 5, 6)
- Ductwork Location (None, Condition Space, Unconditioned Space)
- Door Area (ft^2)
- Shared Surface Area (ft^2)
- Envelope Perimeter (ft) = Total Edge Length (ft)
- Age (years)

Model

$$\phi = (0.8610 + \alpha_1 + \alpha_2 - 0.0044X_3 - 0.0002X_4 + 0.0012X_5 + 0.0054X_6) \times \sigma$$

α_1	$X_{1,1}$	ClimateZone_4	-0.2500
	$X_{1,2}$	ClimateZone_5	-0.0423
	$X_{1,3}$	ClimateZone_6	-0.1100
α_2	$X_{2,1}$	DuctworkLocation_conditioned space	0.0511
	$X_{2,2}$	DuctworkLocation_unconditioned space	0.2700

X_3	=	DoorArea (ft^2)
X_4	=	SharedSurfaceArea (ft^2)
X_5	=	Envelope Perimeter(ft)
X_6	=	Age (years)

ϕ	=	predicted fully guarded value
σ	=	measured solo test value

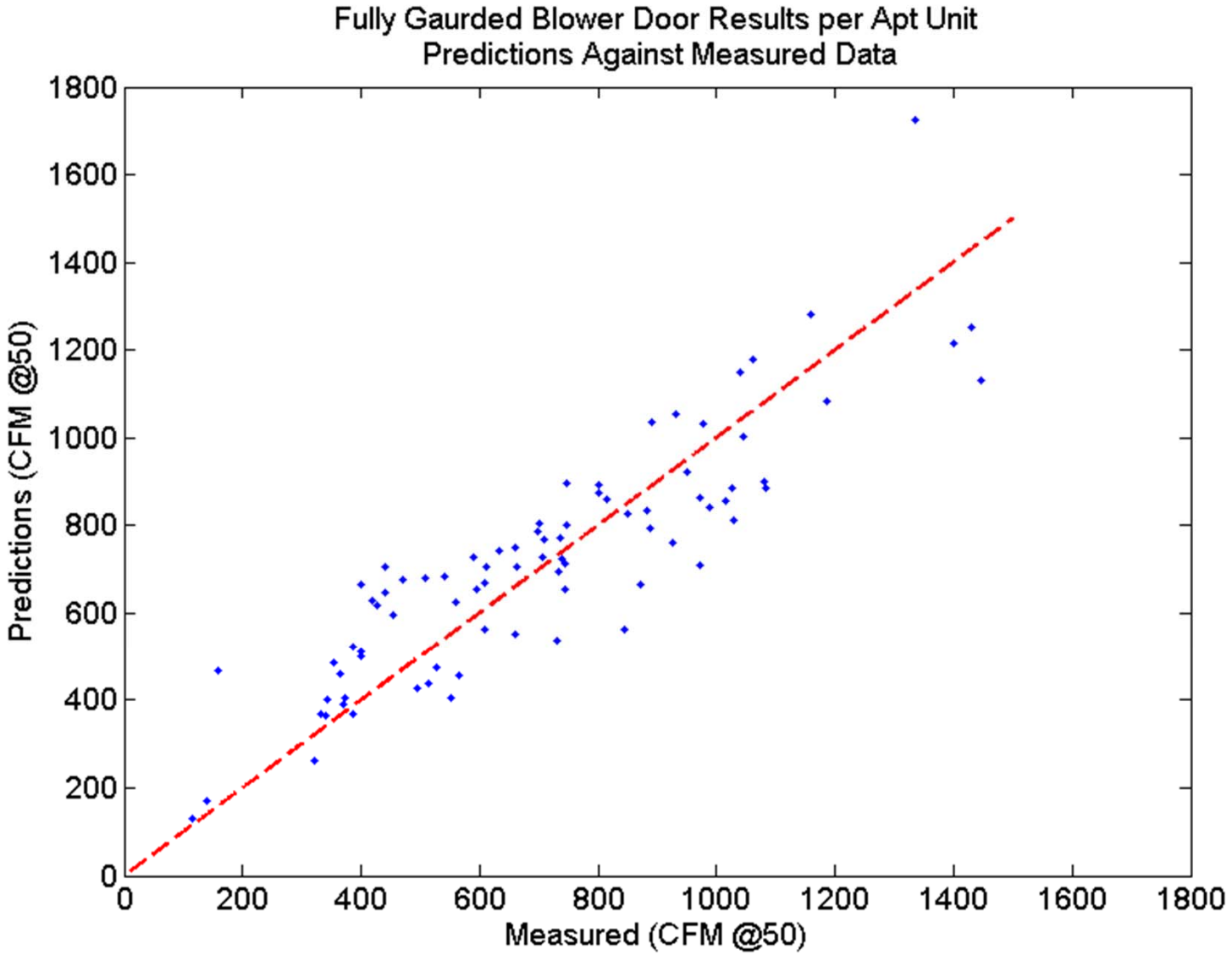
Applying the Model

$$\phi = (0.8610 + \alpha_1 + \alpha_2 - 0.0044X_3 - 0.0002X_4 + 0.0012X_5 + 0.0054X_6) \times \sigma$$

Predictor Variables (X)		Coefficients (α)		Unit 1		
				Unit Info.	Calculations	
X_0	Intercept	α_0	8.61E-01	1	1 x 8.61E-01	0.861
$X_{1,1}$	Climate Zone_4	α_1	-2.50E-01	1	1 x -2.50E-01	-0.250
$X_{2,1}$	Ductwork Location_ conditioned space	α_2	5.11E-02	1	1 x 5.11E-02	0.051
X_3	Door Area (ft²)	α_3	-4.43E-03	18	18 x -4.43E-03	-0.080
X_4	Shared Surface Area (ft²)	α_4	-1.59E-04	1,052	1,052 x -1.59E-04	-0.167
X_5	Envelope Perimeter (ft)	α_5	1.23E-03	396	369 x 1.23E-03	0.454
X_6	Age (years)	α_6	-5.39E-03	43	43 x -5.39E-03	-0.232
ρ_{fs}	Ratio of ϕ to σ					**0.637**

$$\phi = \rho_{fs} \times \sigma = 0.637 \times 842 = 536\ CFM$$

Predicted Versus Measured



Benefits of Model

- Saves time and **$ $ $ MONEY**
- Less personnel needed
- Overall **CONVENIENT!**

Conclusions and Future Work

- Model saves a lot of time and money used in performing guarded blower tests
- Model can be employed in rating software like REM, TREAT, EQUIP to better predict energy saving potential
- Model could use more validation
- Model could use more data to improve it

Bibliography

- Persily, A. 1982. "Repeatability and accuracy of pressurization testing." Proceedings of the ASHRAE/DOE Conference Thermal Performance of the Exterior Envelopes of Buildings II, Las Vegas, NY, December 6-9.
- Kim, A.K. and Shaw, C. Y. 1986. “Seasonal Variation In Airtightness of Two Detached Housed,” Measued Air Leakage of Bulildings, ASTM STP 904, H.R. Trechel and P.L. Lagis, Eds., American Society for Testing and Matrials, Philadelphia. 17-32.

Questions?

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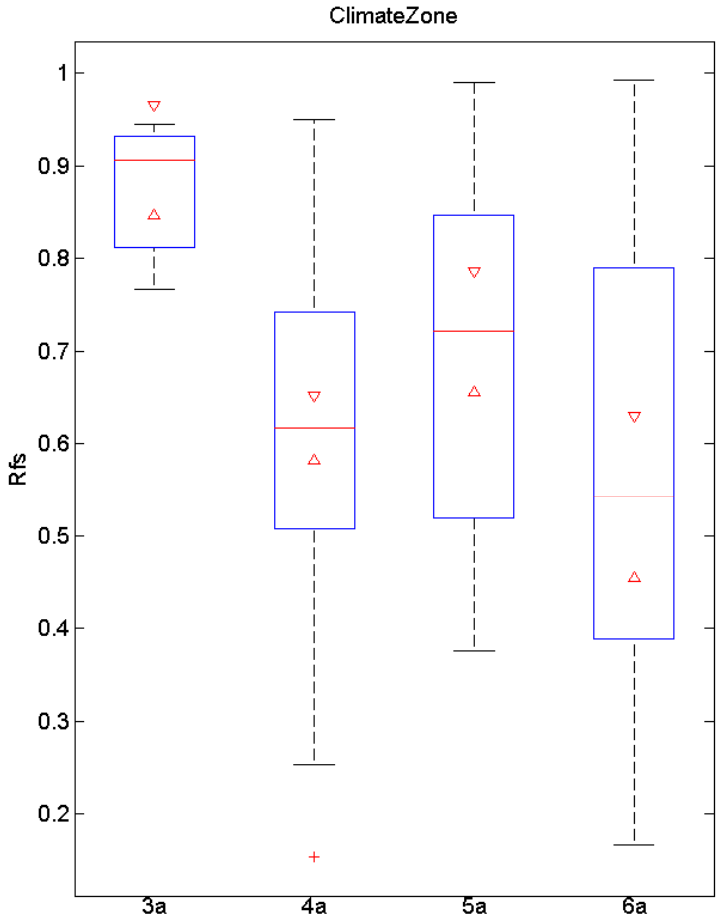
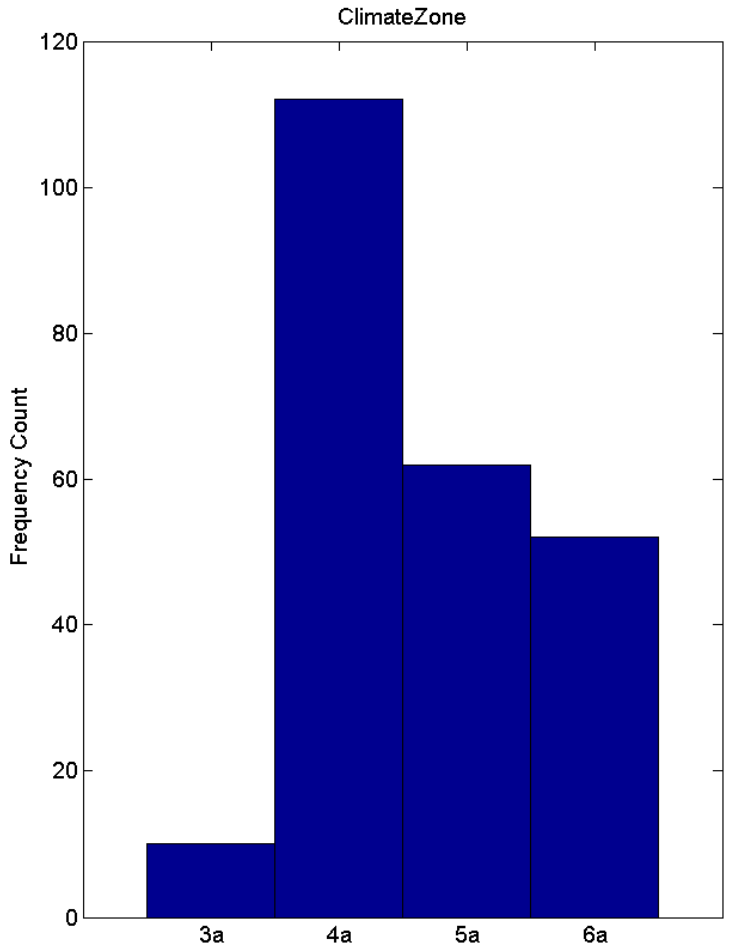
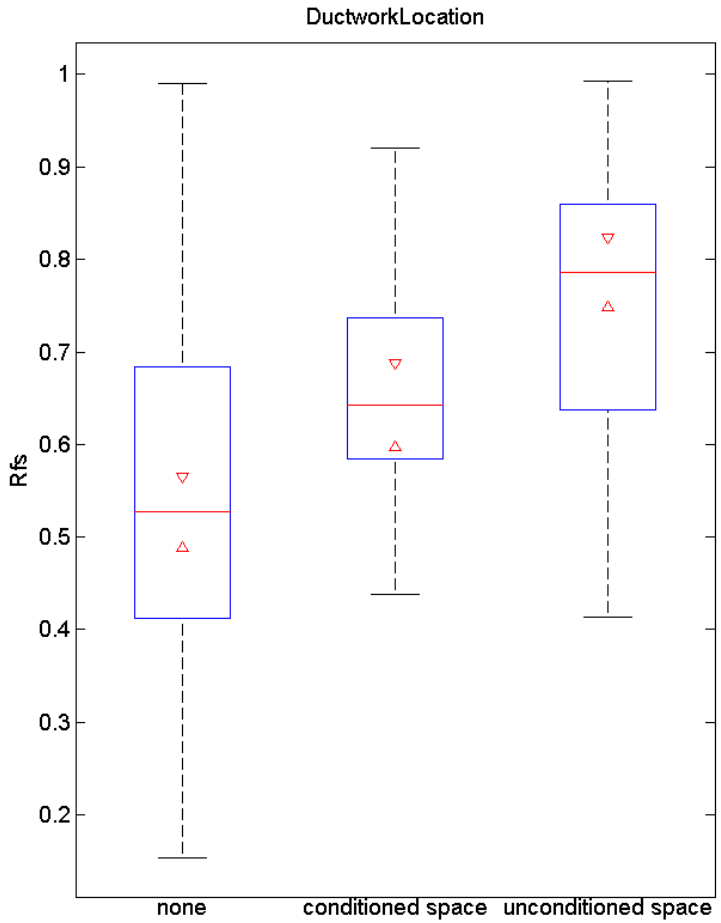
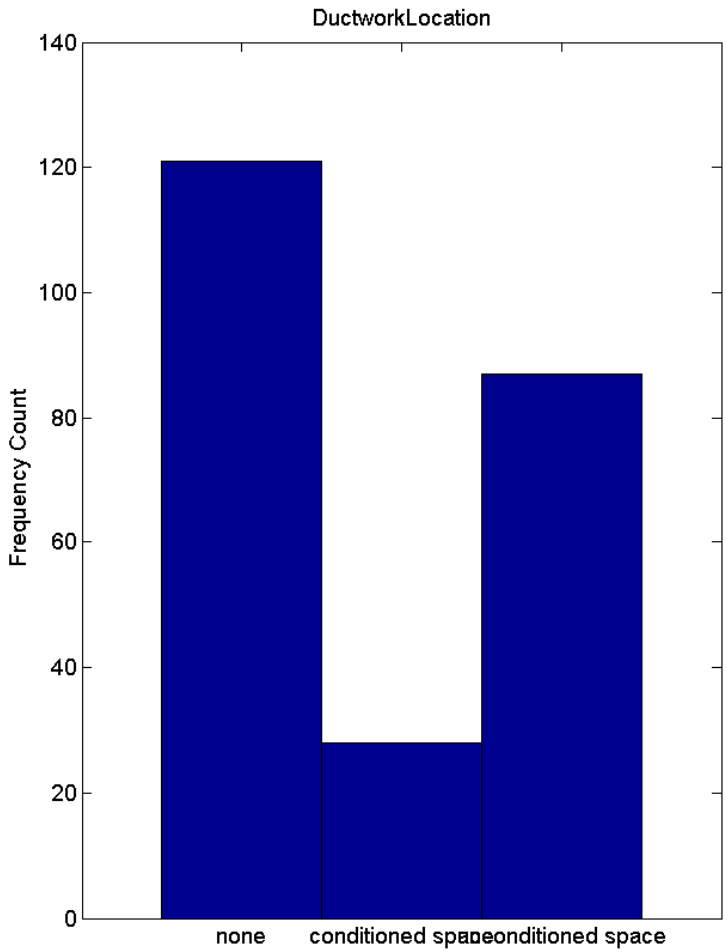
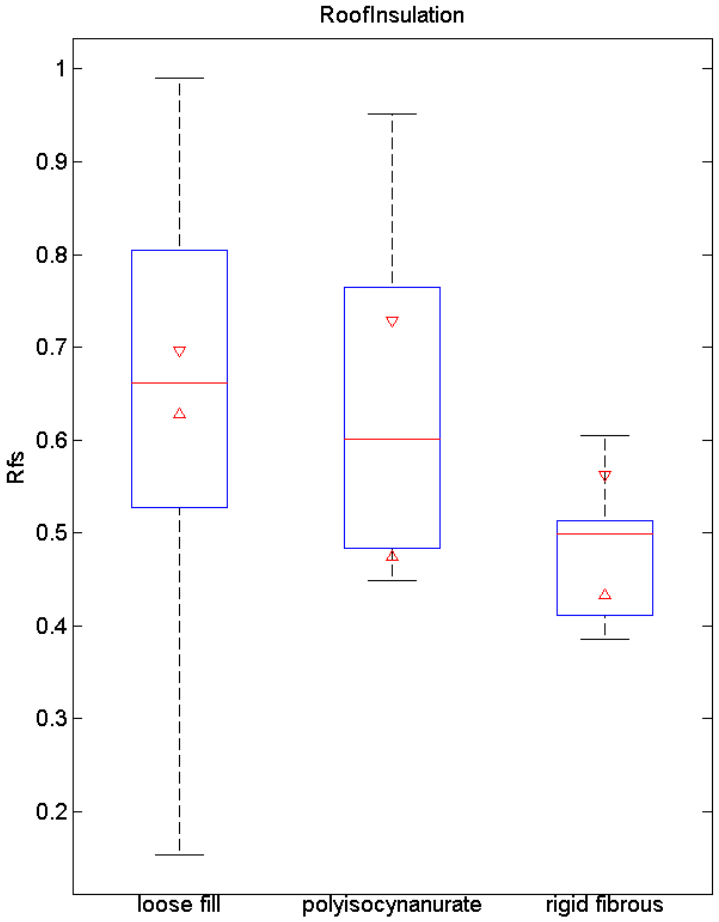
Supplementary Slides

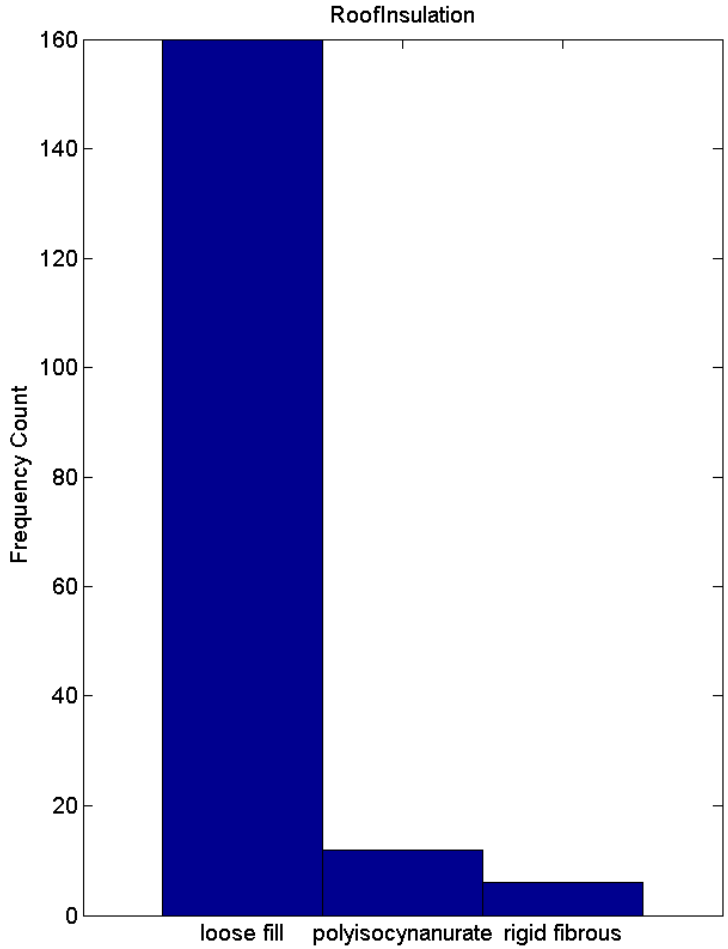

ClimateZone
Rfs
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
3a
4a
5a
6a

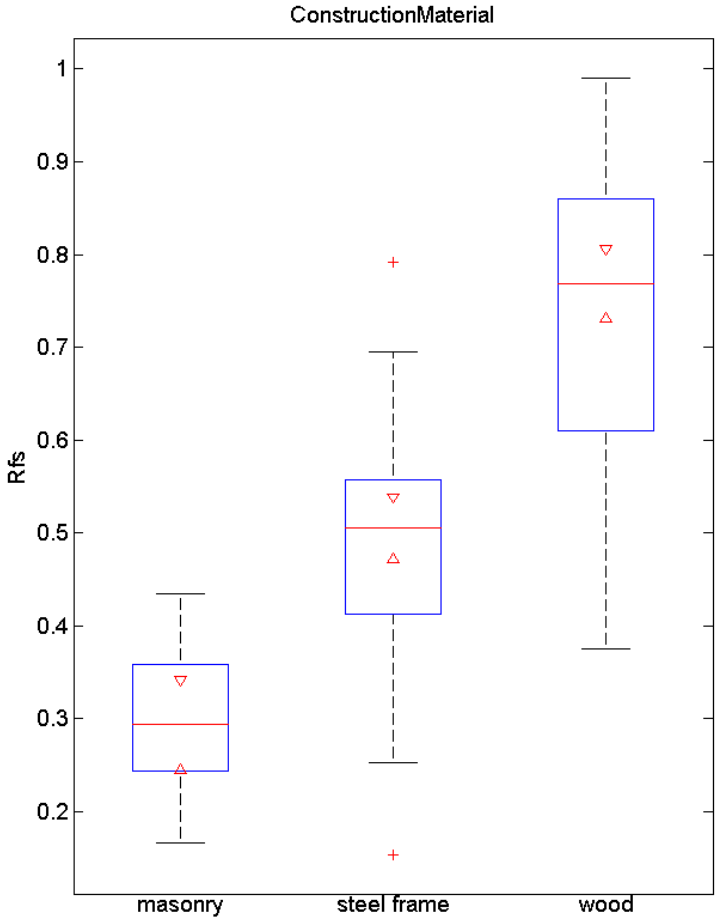

ClimateZone
Frequency Count
120
100
80
60
40
20
0
3a
4a
5a
6a

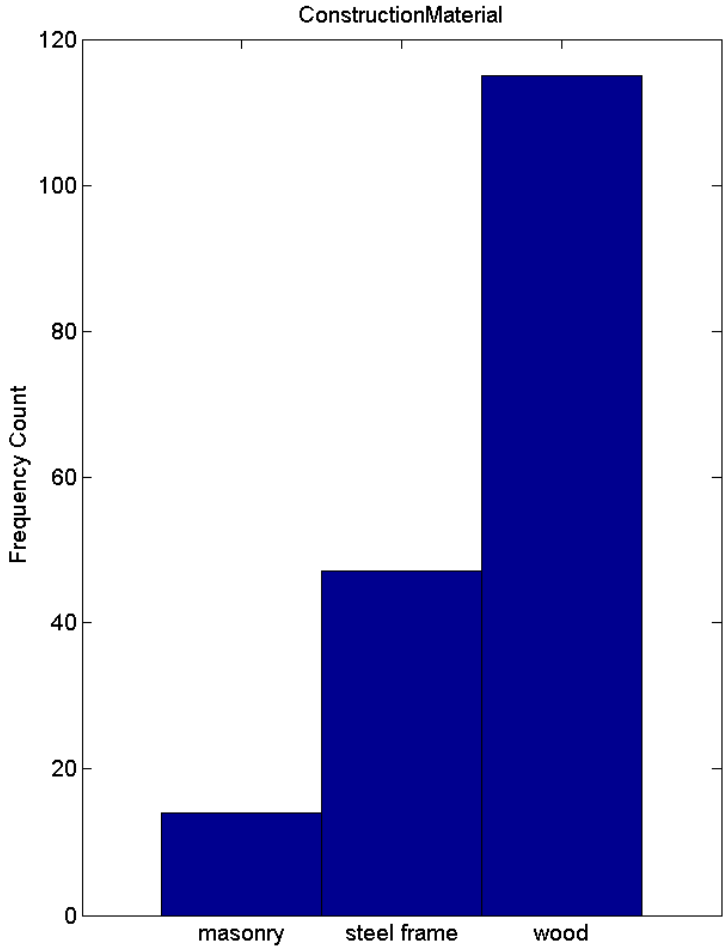

DuctworkLocation
Rfs
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
none
conditioned space
unconditioned space

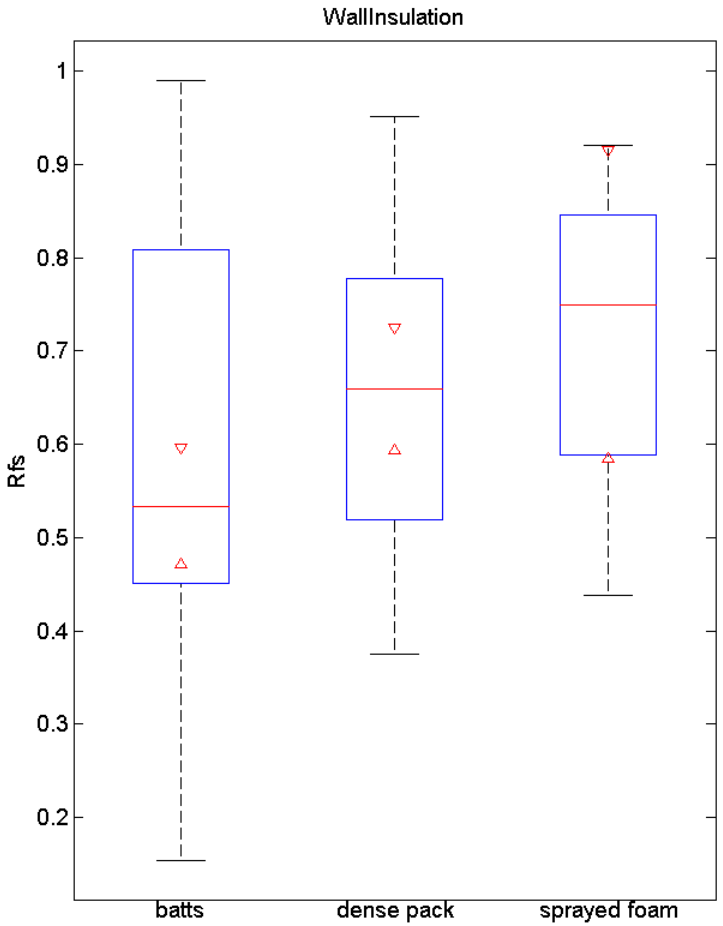

DuctworkLocation
Frequency Count
140
120
100
80
60
40
20
0
none
conditioned space
unconditioned space

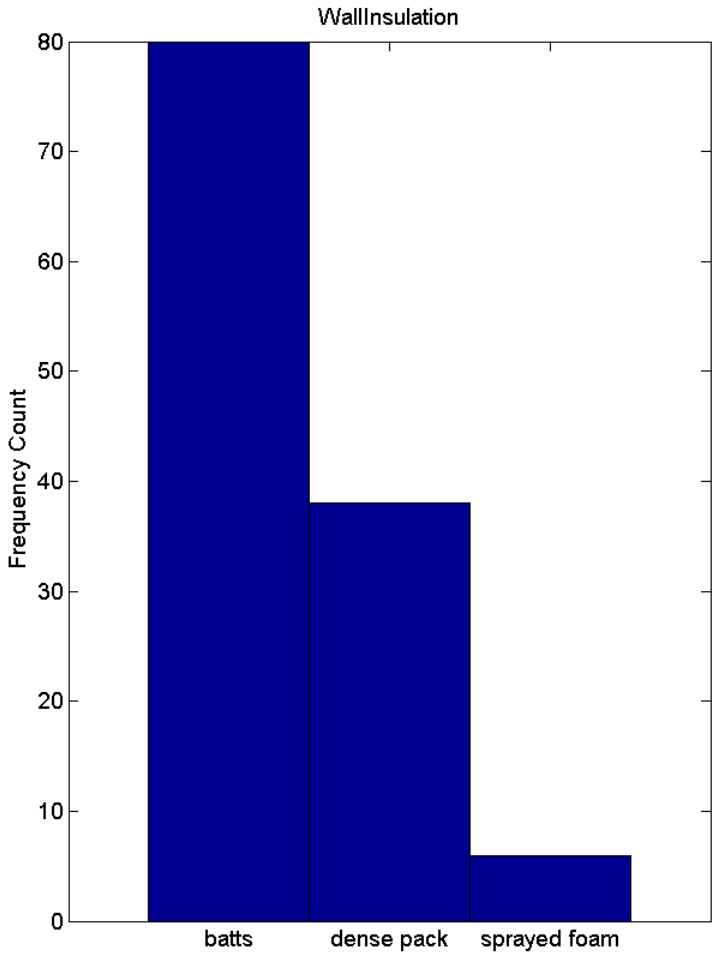

RoofInsulation
Rfs
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
loose fill
polyisocynanurate
rigid fibrous

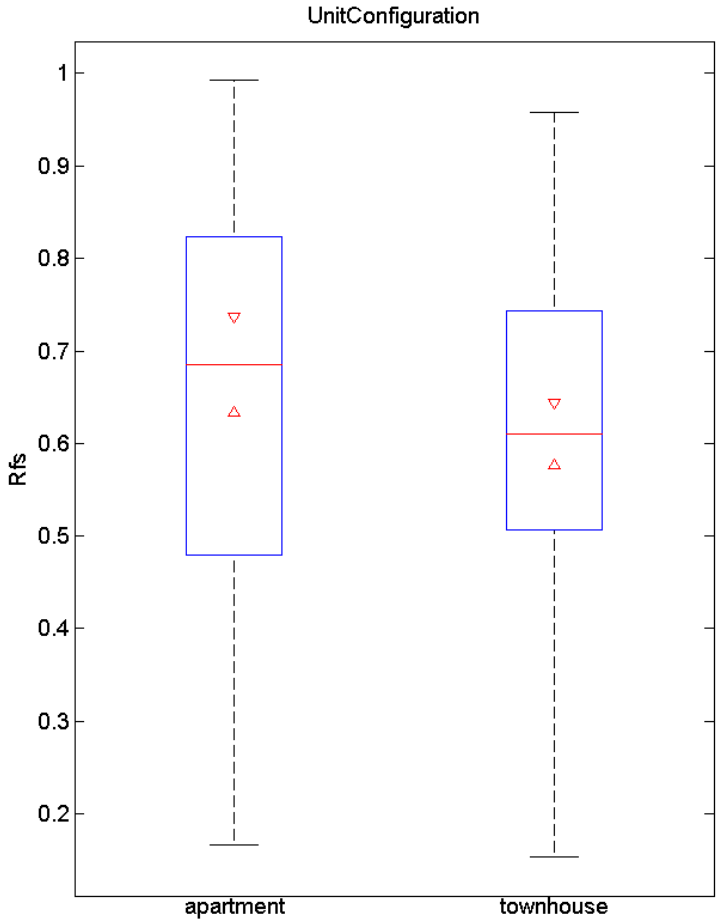

RoofInsulation
Frequency Count
160
140
120
100
80
60
40
20
0
loose fill
polyisocynanurate
rigid fibrous

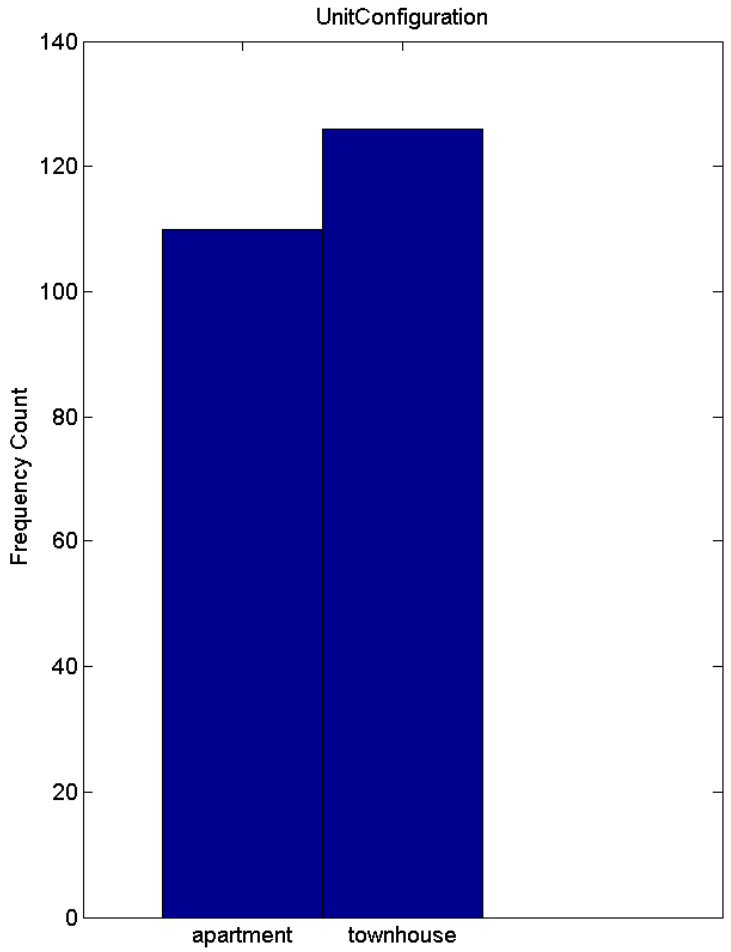

ConstructionMaterial
Rfs
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
masonry
steel frame
wood


ConstructionMaterial
Frequency Count
120
100
80
60
40
20
0
masonry
steel frame
wood


WallInsulation
Rfs
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
batts
dense pack
sprayed foam


WallInsulation
Frequency Count
80
70
60
50
40
30
20
10
0
batts
dense pack
sprayed foam


UnitConfiguration
Rfs
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
apartment
townhouse


UnitConfiguration
Frequency Count
140
120
100
80
60
40
20
0
apartment
townhouse