Using Airflow Modelling Software to Predict Airtightness Improvements in a High-Rise Residential Building: A Case Study

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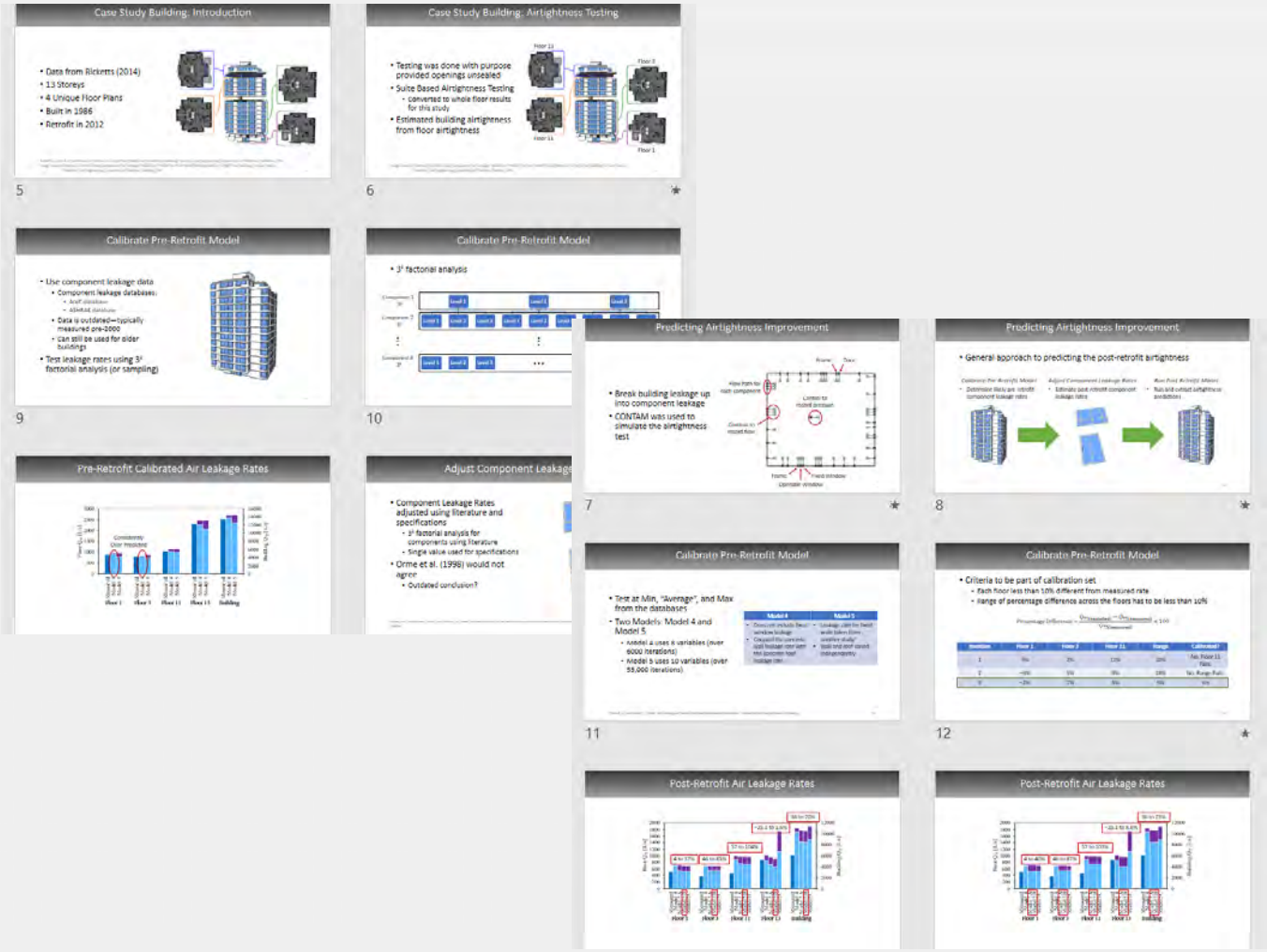
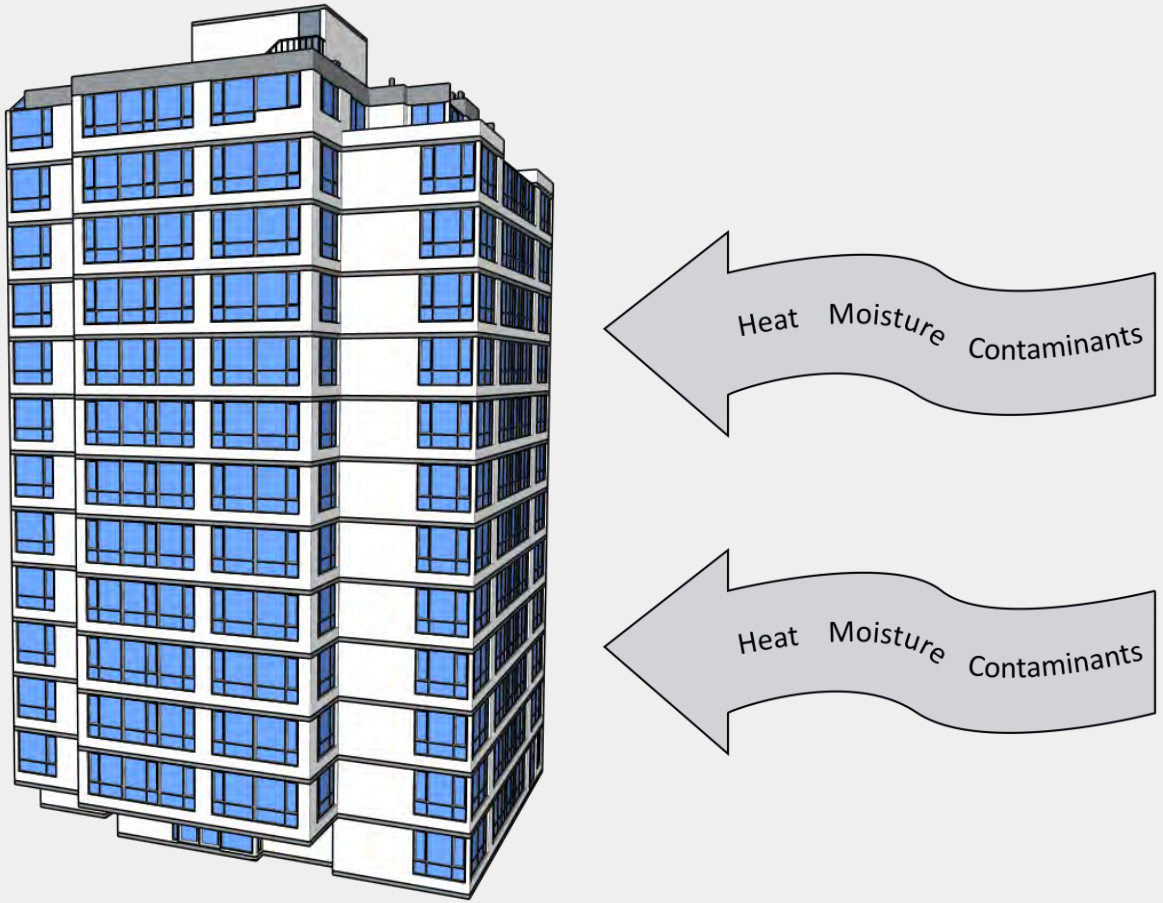
Outline

- Introduction
- Case Study Building
- Predicting Airtightness
  - Approach
  - 3^k factorial analysis
  - Results
- Conclusions



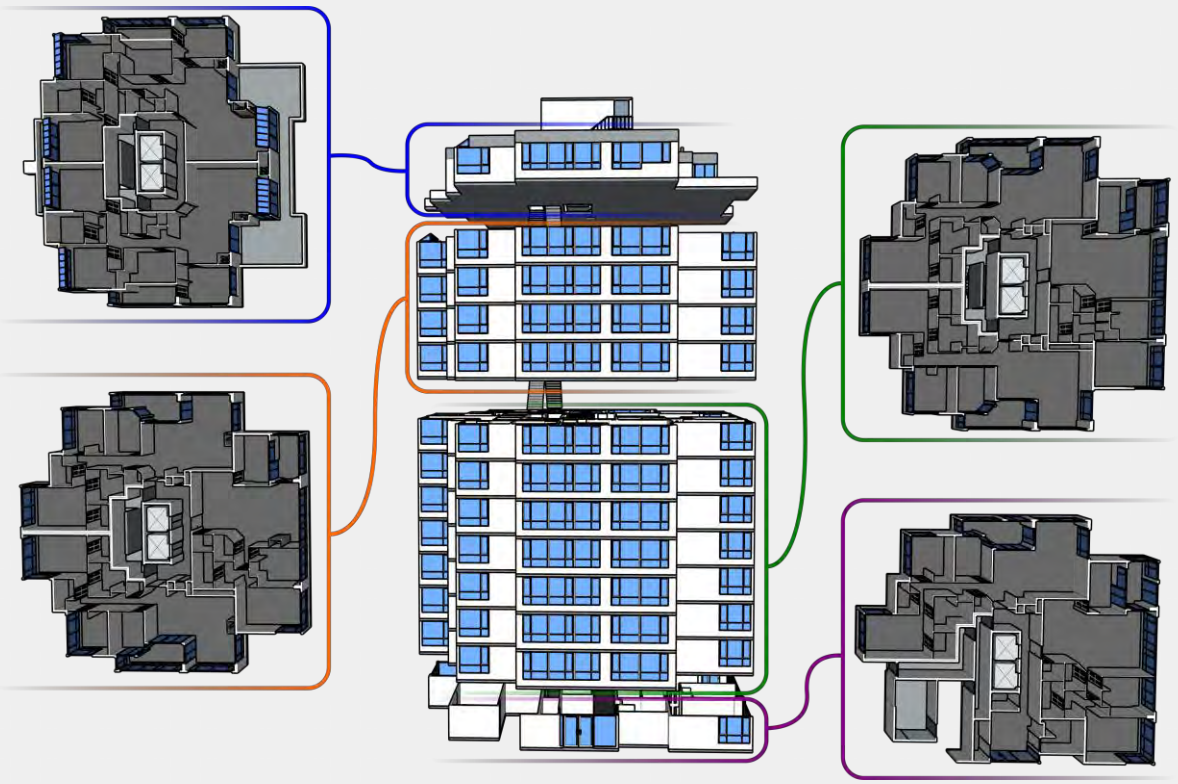
Introduction

- Energy models are used to help designers and estimate savings
- Infiltration accounts for large amount of the heating load
- Current models use defaults or engineering judgment to estimate infiltration
- Need a tool to estimate potential improvements



Case Study Building: Introduction

- Data from Ricketts (2014)
- 13 Storeys
- 4 Unique Floor Plans
- Built in 1986
- Retrofit in 2012
- Retrofit involved:
  - Replacing windows and doors
  - Improving sealing
  - New roof



Ricketts, L. 2014. A Field Study of Airflow in a High-Rise Multi-Unit Residential Building. Masters, Civil Engineering, Univerisity of Waterloo, Waterloo, ON.
Image Source: Stanton, D. 2018. Using Component Air Leakage Models to Predict the Post-Retrofit Airtightness of a High Rise Building: A Case Study. Masters, Civil Engineering, University of Toronto, Toronto, ON.

Case Study Building: Airtightness Testing

- Testing was done with purpose provided openings *un*sealed
- Suite Based Airtightness Testing
  - Converted to whole floor results for this study
- Estimated building airtightness from floor airtightness

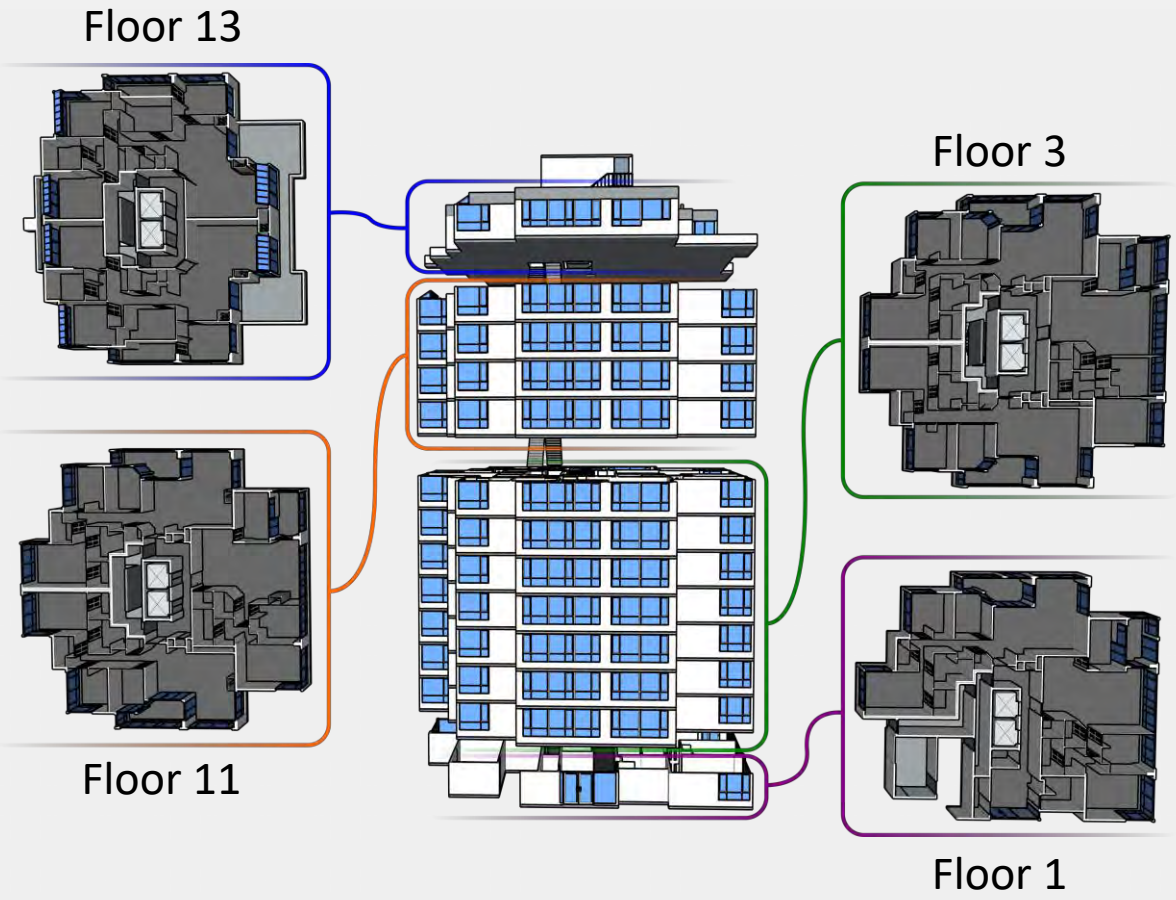
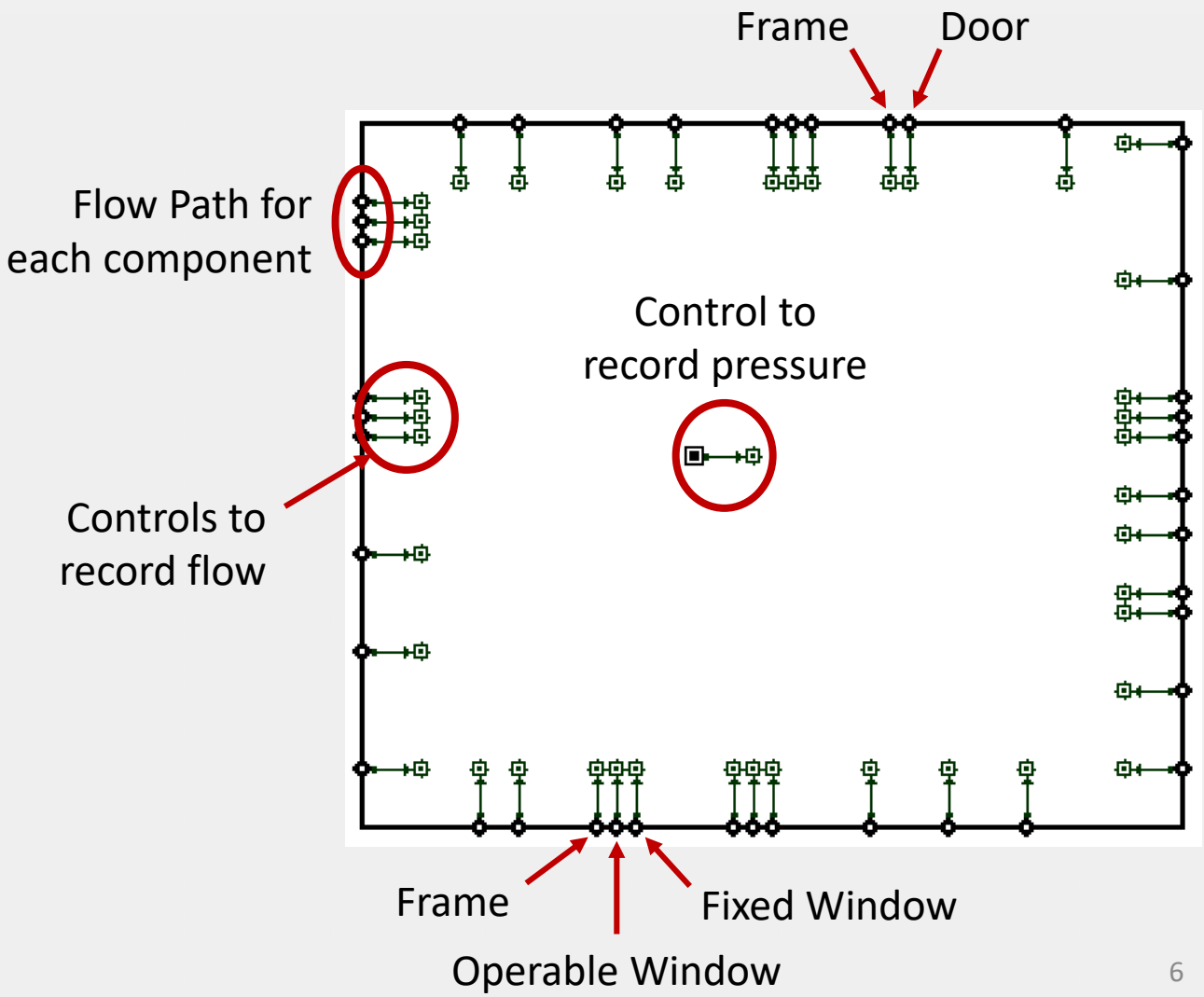


Image Source: Stanton, D. 2018. Using Component Air Leakage Models to Predict the Post-Retrofit Airtightness of a High Rise Building: A Case Study. Masters, Civil Engineering, University of Toronto, Toronto, ON.

Predicting Airtightness Improvement

- Break building leakage up into component leakage
- CONTAM was used to simulate the airtightness test



Predicting Airtightness Improvement

- General approach to predicting the post-retrofit airtightness

Calibrate Pre-Retrofit Model

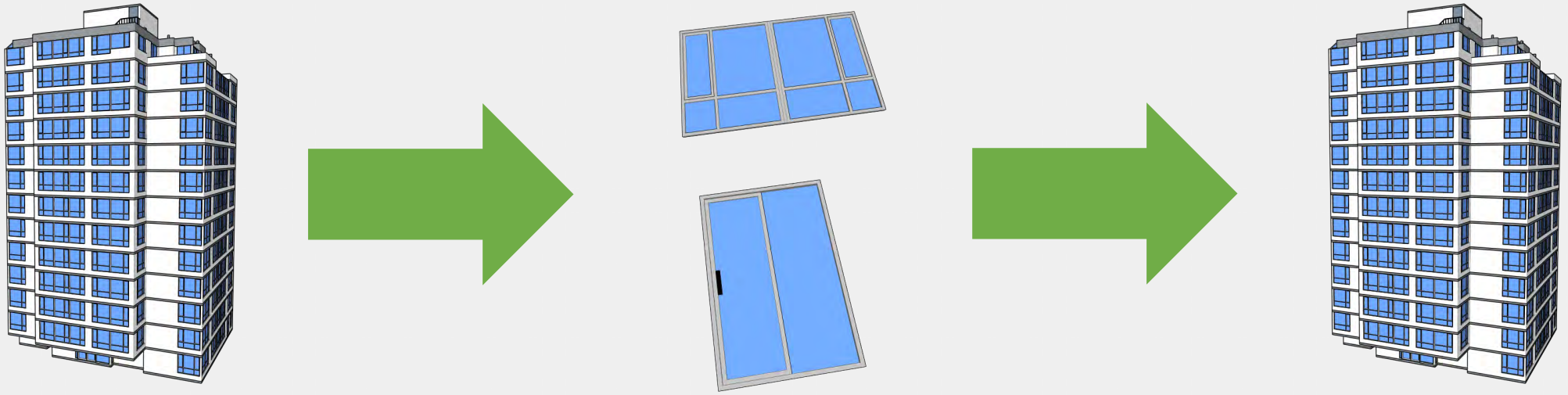
- Determine likely pre-retrofit component leakage rates

Adjust Component Leakage Rates

- Estimate post-retrofit component leakage rates

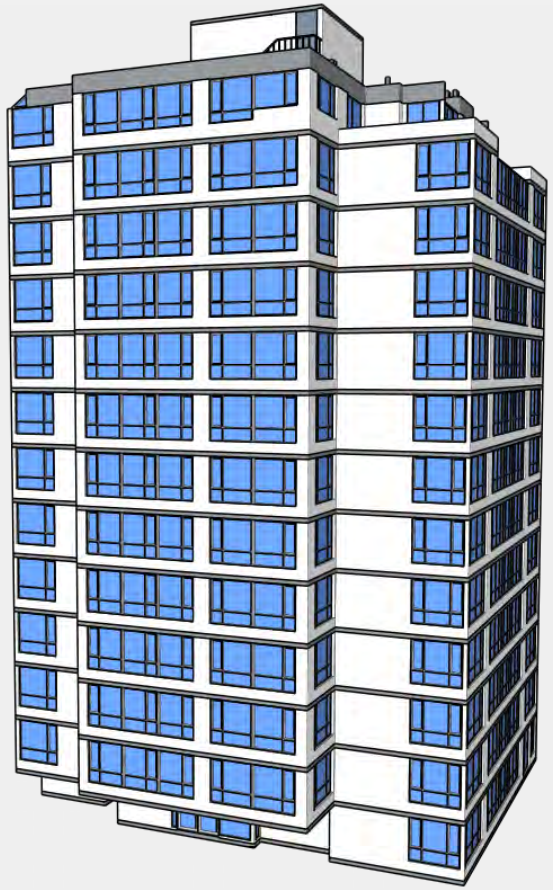
Run Post-Retrofit Model

- Run and extract airtightness predictions



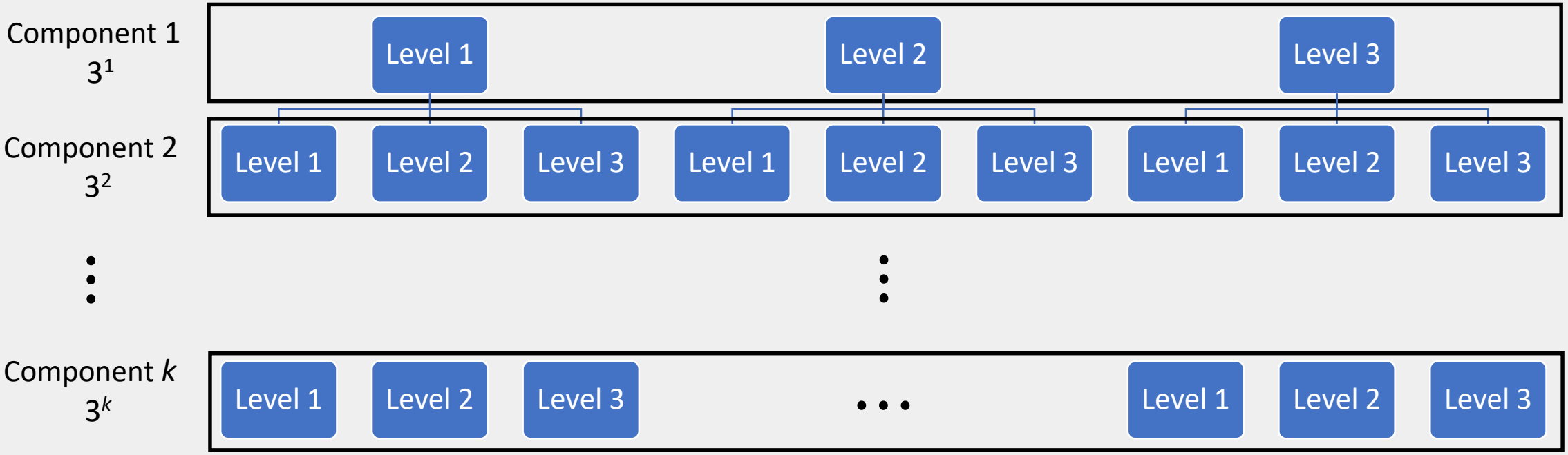
Calibrate Pre-Retrofit Model

- Use component leakage data
  - Component leakage databases:
    - AIVC database
    - ASHRAE database
  - Data is outdated—typically measured pre-2000
  - Can still be used for older buildings
- Test leakage rates using 3^k factorial analysis (or sampling)



Calibrate Pre-Retrofit Model

- 3^k factorial analysis



Calibrate Pre-Retrofit Model

- Test at Min, “Average”, and Max from the databases
- Two Models: Model 4 and Model 5
  - Model 4 uses 8 variables (over 6000 iterations)
  - Model 5 uses 10 variables (over 55,000 iterations)

Model 4	Model 5
• Does not include fixed window leakage • Coupled the concrete wall leakage rate with the concrete roof leakage rate	• Leakage rate for fixed walls taken from another study[1] • Wall and roof varied independently

[1]Weidt, J., and Weidt, J. 1980. Air Leakage of Newly Installed Residential Windows. United States Department of Energy.

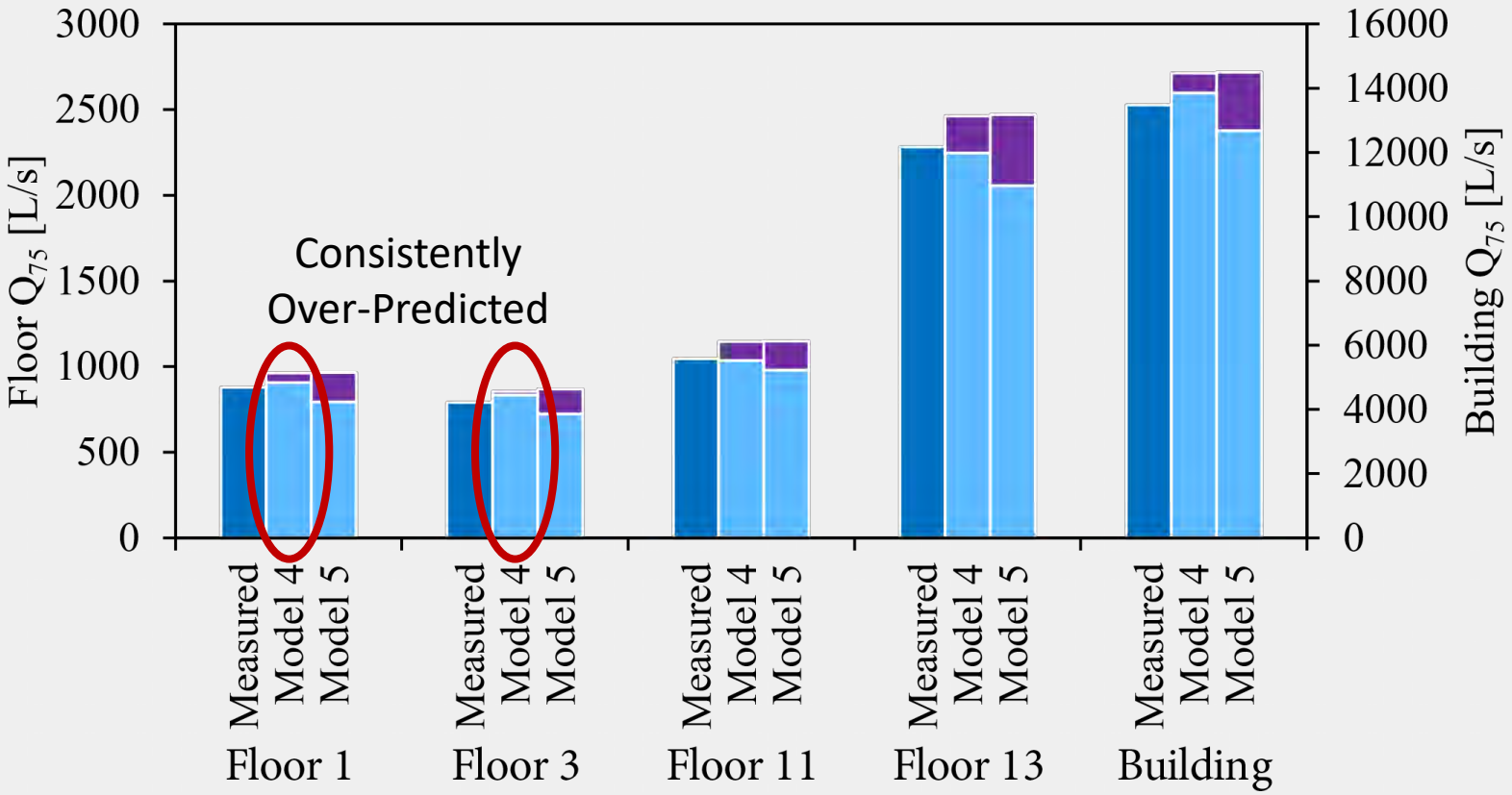
Calibrate Pre-Retrofit Model

- Criteria to be part of calibration set
  - Each floor less than 10% different from measured rate
  - Range of percentage difference across the floors has to be less than 10%

$$\text{Percentage Difference} = \frac{Q_{75(\text{modelled})} - Q_{75(\text{measured})}}{Q_{75(\text{measured})}} \times 100$$

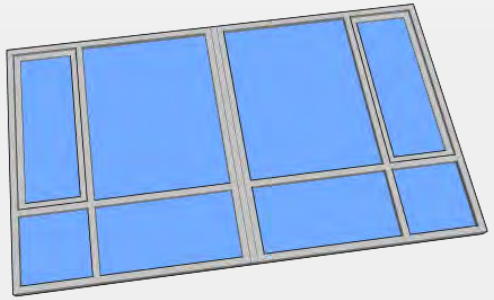
Iteration	Floor 1	Floor 3	Floor 11	Range	Calibrated?
1	5%	2%	12%	10%	No. Floor 11 Fails.
2	−9%	5%	9%	18%	No. Range Fails.
3	−2%	7%	5%	9%	Yes

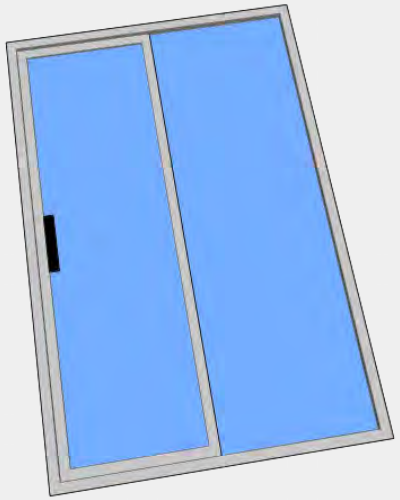
Pre-Retrofit Calibrated Air Leakage Rates



Adjust Component Leakage Rates

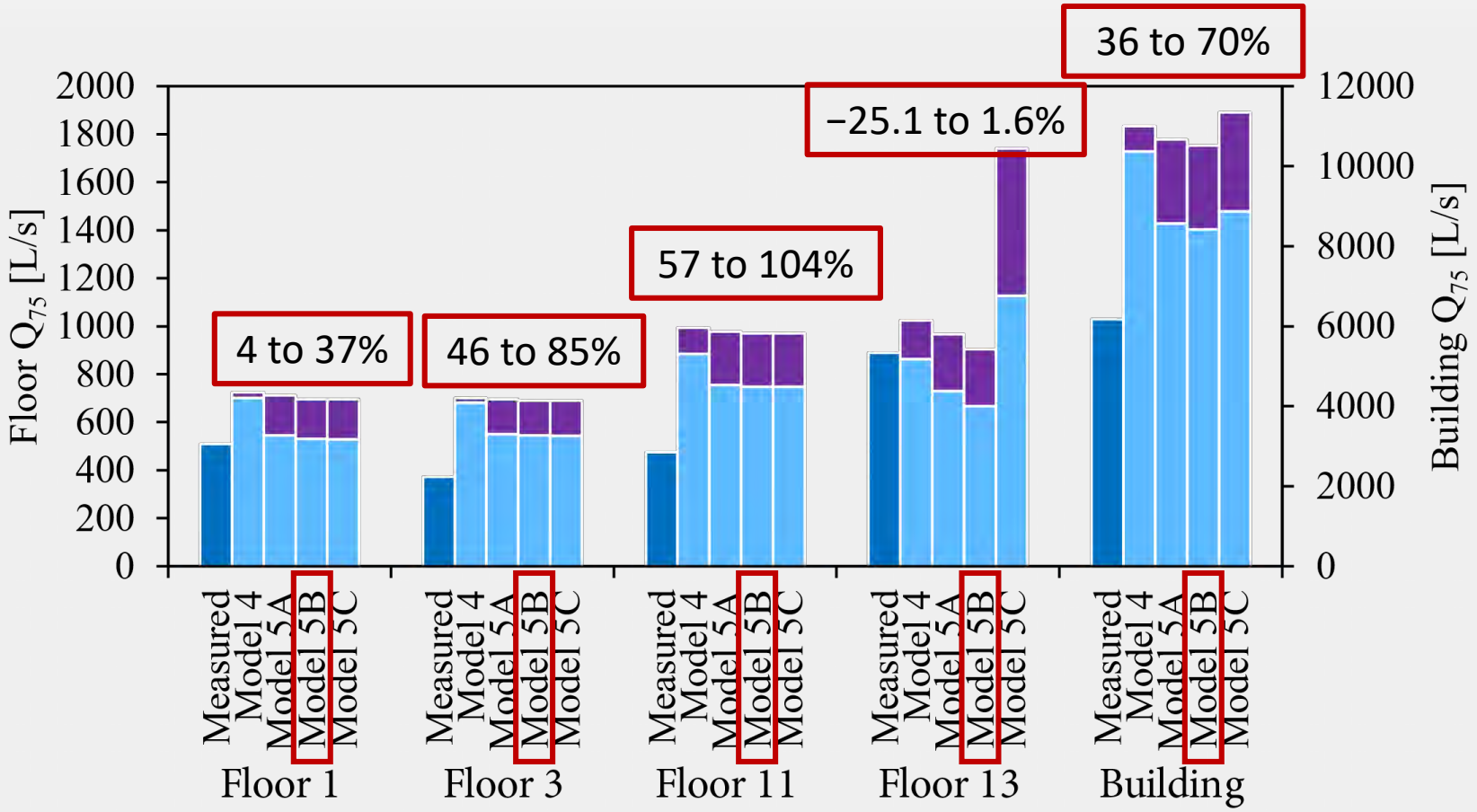
- Component Leakage Rates adjusted using literature and specifications
  - 3^k factorial analysis for components using literature
  - Single value used for specifications
- Orme et al. (1998) would not agree
  - Outdated conclusion?



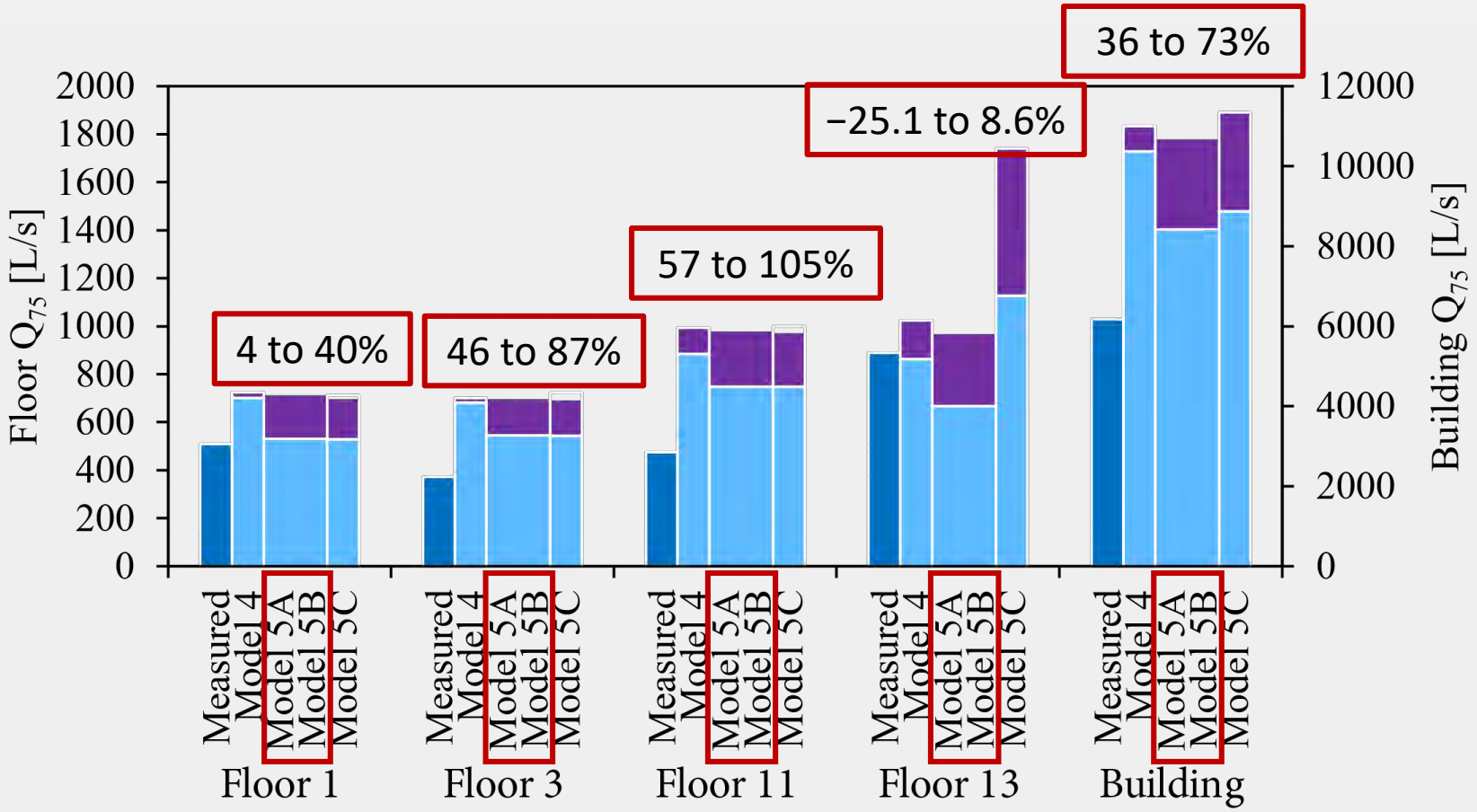


Orme, M., Liddament, M.W., and Wilson, A. 1998. Numerical data for air infiltration and natural ventilation calculations. Air Infiltration and Ventilation Centre.

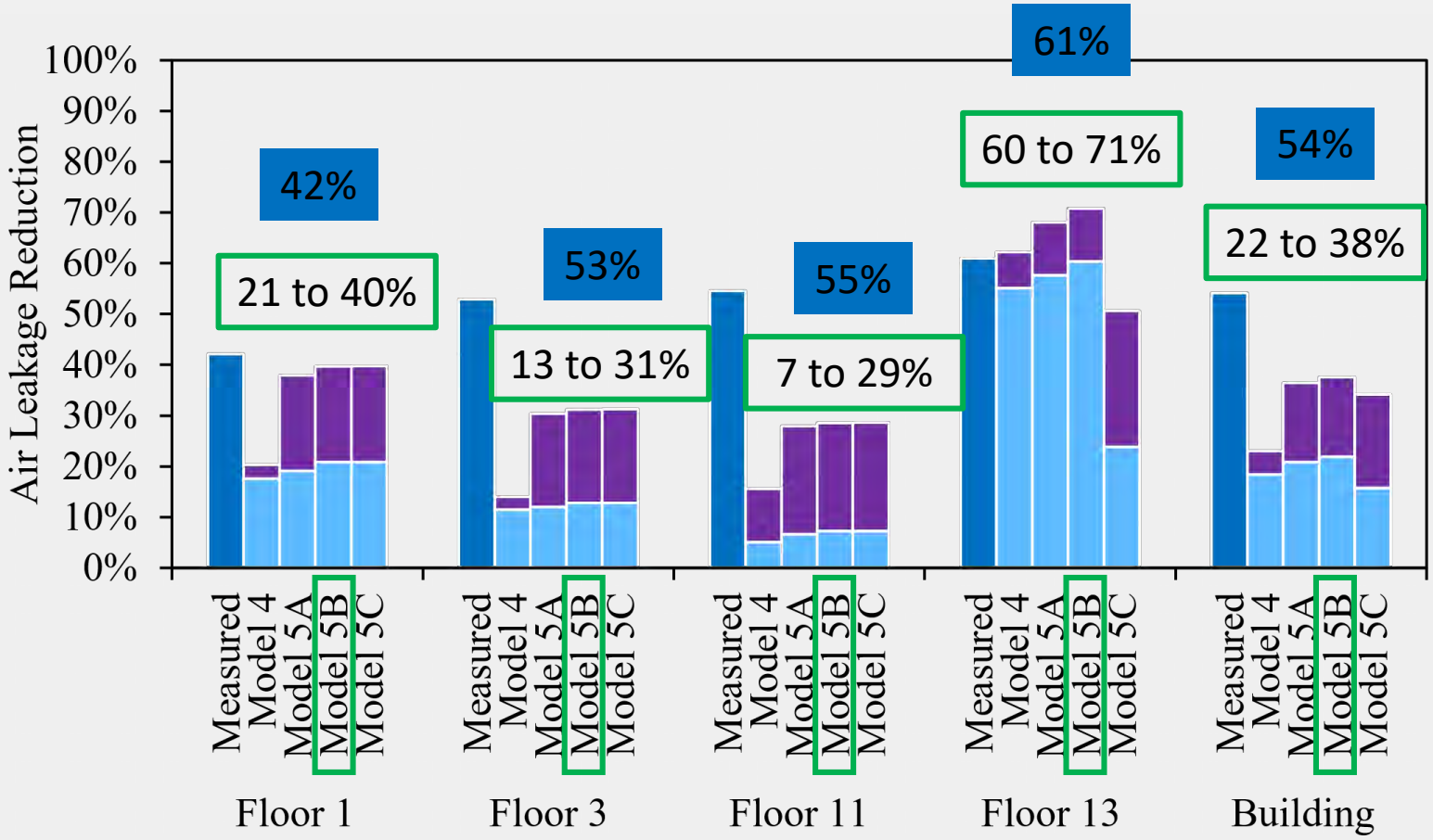
Post-Retrofit Air Leakage Rates



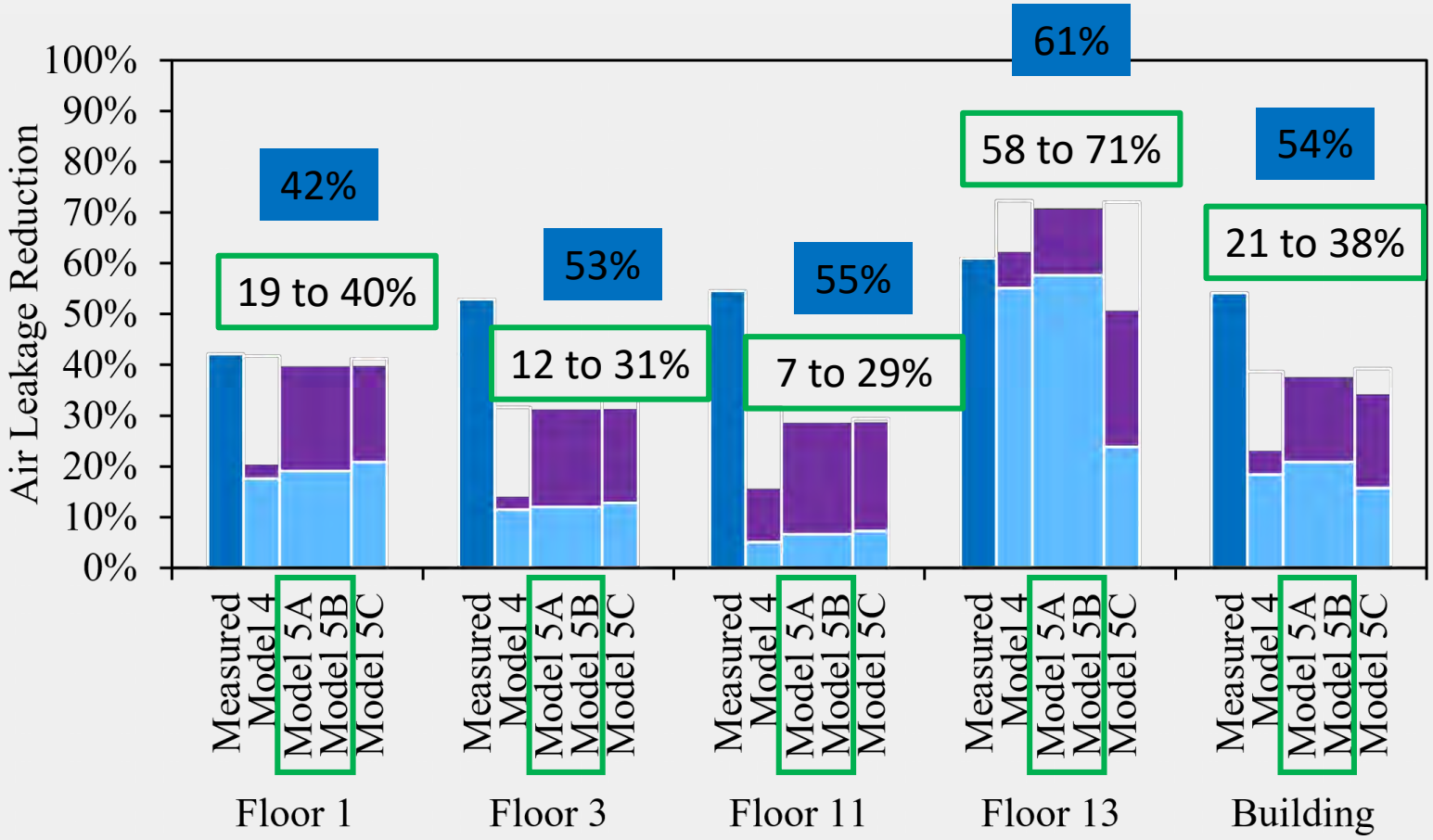
Post-Retrofit Air Leakage Rates



Post-Retrofit Airtightness Improvement



Post-Retrofit Airtightness Improvement



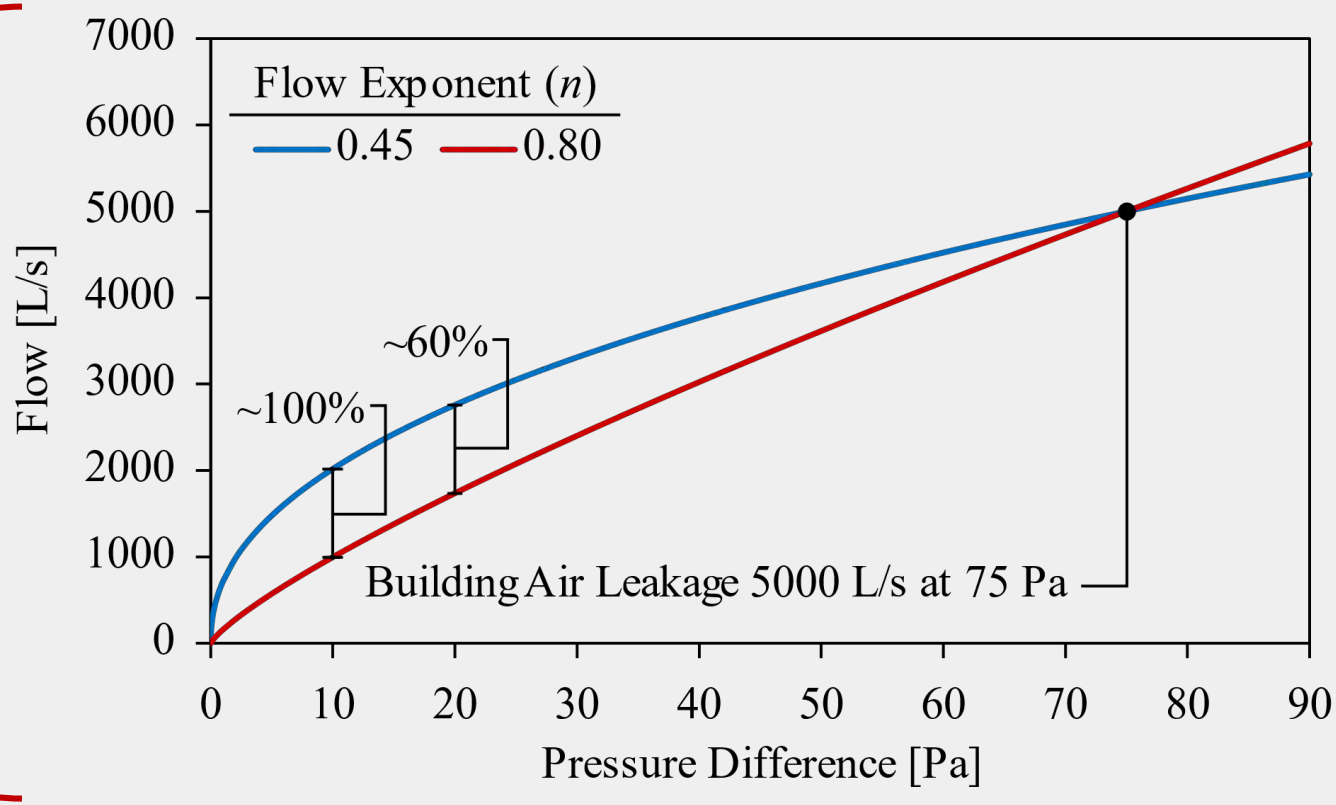
What About Infiltration?

- Need to extrapolate flows
- Typically use power law equation:

Flow Coefficient Flow Exponent

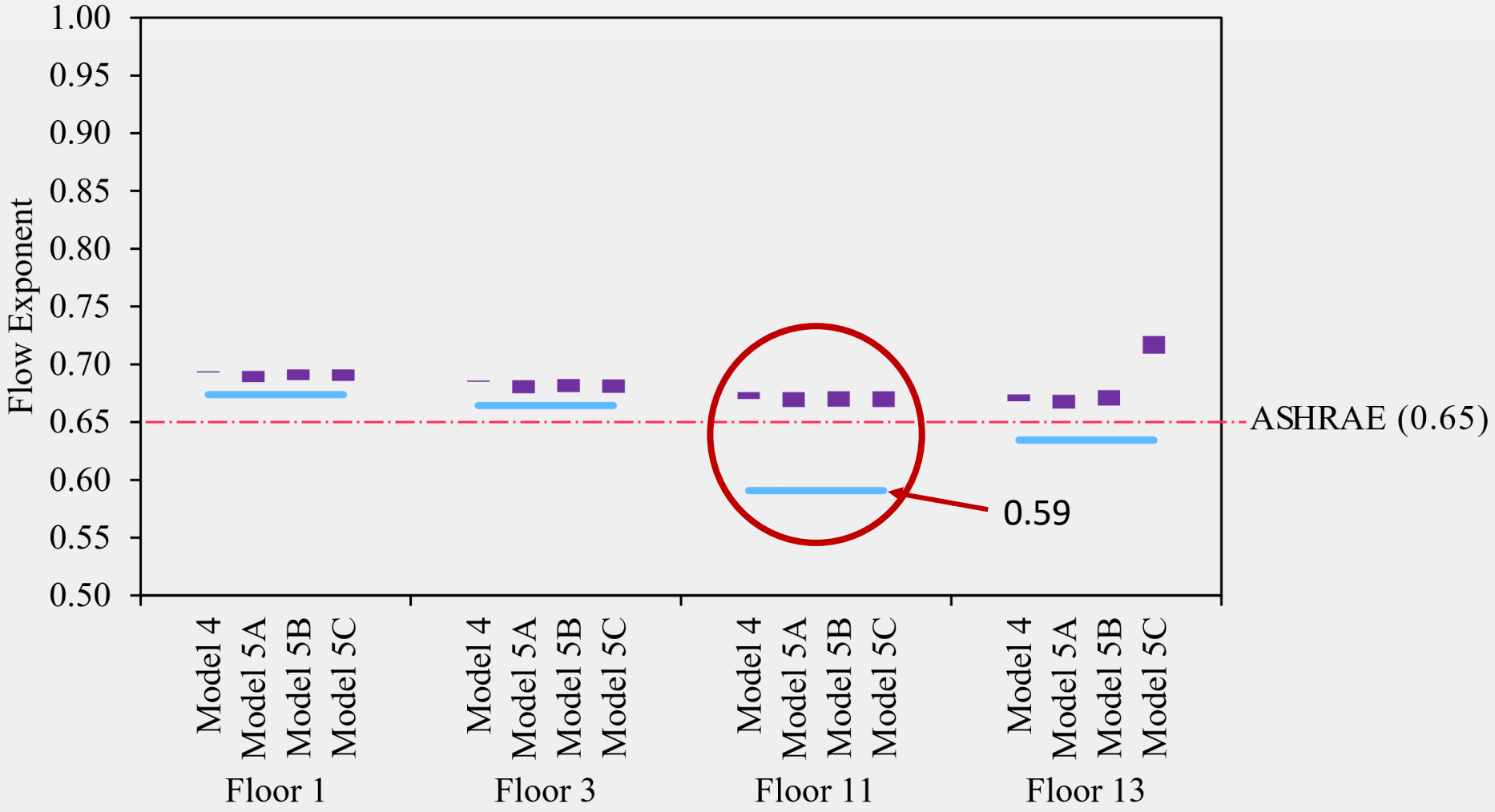
$$Q = C(\Delta P)^{n}$$

Flow Pressure Difference



Graph from: Stanton, D. 2018. Using Component Air Leakage Models to Predict the Post-Retrofit Airtightness of a High Rise Building: A Case Study. Masters, Civil Engineering, University of Toronto, Toronto, ON.

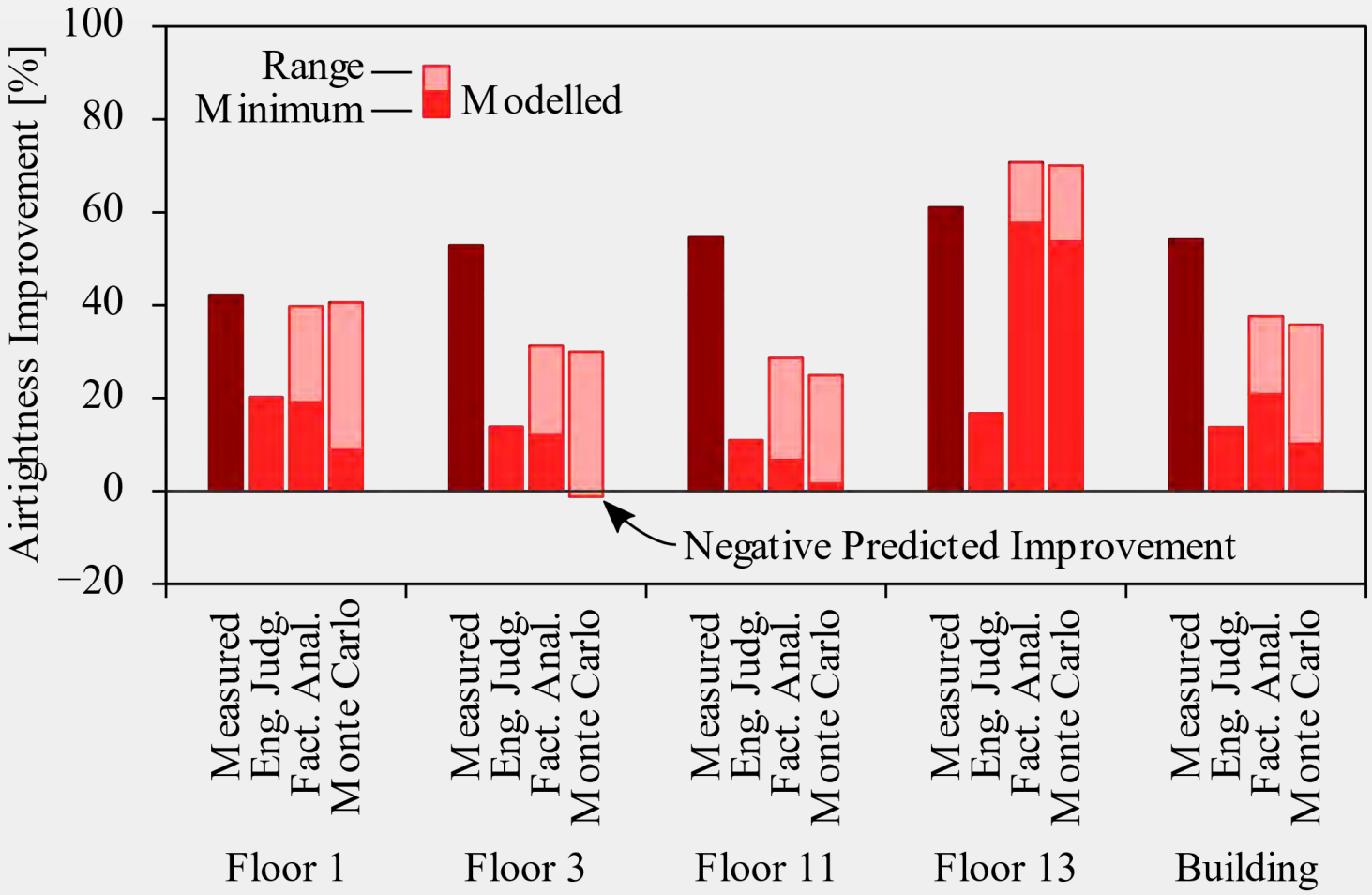
Flow Exponents



Conclusions

- Reasonable airtightness predictions can be made
- The more variables, the better…for predictions…
- Should use the full range for workmanship components
- Extension to infiltration is possible—with care
- Needs to be tested with more buildings
- Need to test with buildings that were tested with purpose provided openings sealed
- Test with buildings that have component leakage measured

Other Techniques



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Questions?

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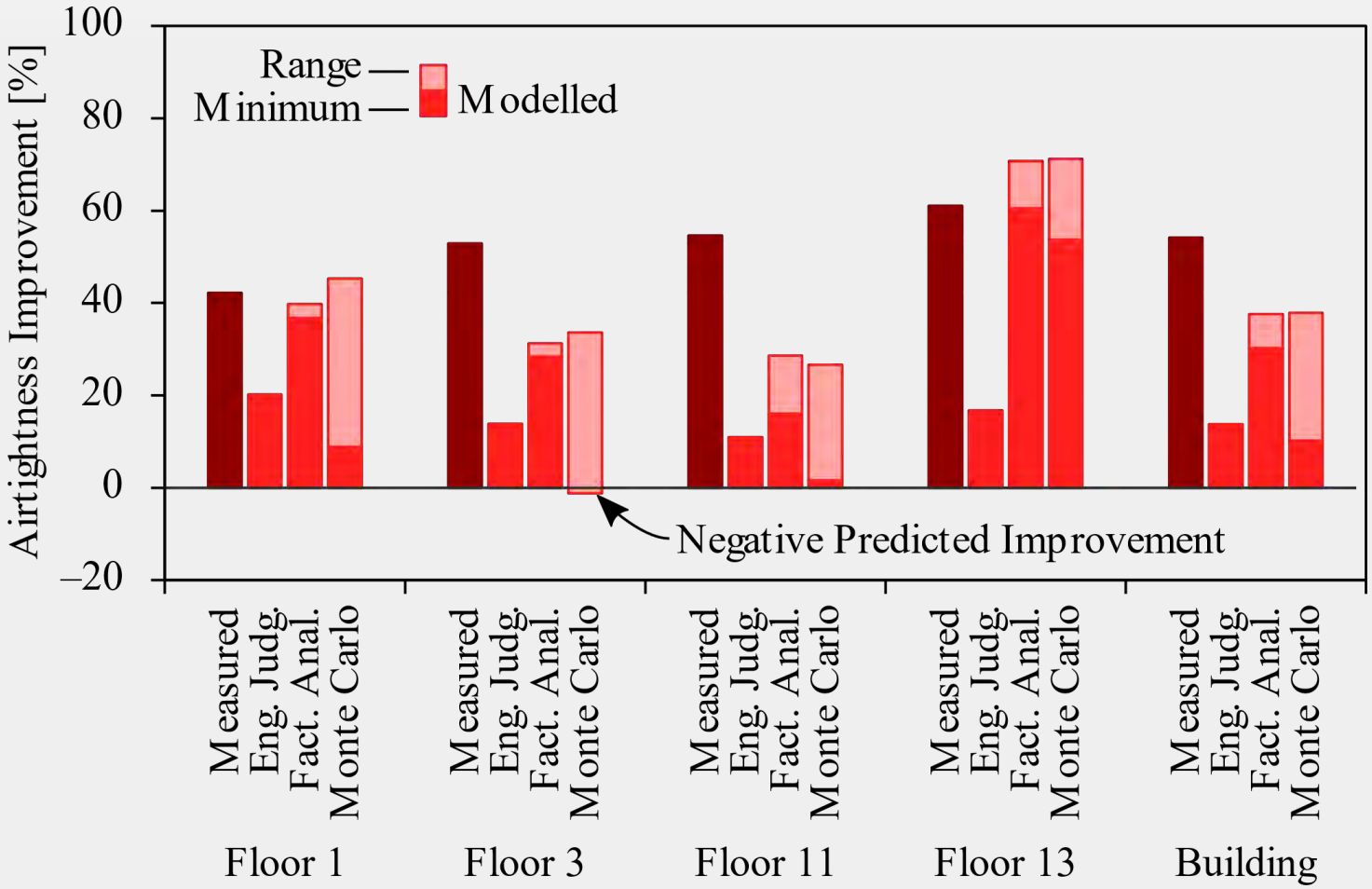
Other Techniques—Update



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