Control of air flows to reduce energy use in buildings

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WHY GREEN BUILDINGS CANNOT BE BUILT WITHOUT AIR BARRIER SYSTEMS

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National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

Outline

- Background
- Airtightness of U.S. commercial buildings
- Energy impacts
- What about existing buildings?
- Conclusions

Background

- Why do we care about airtightness?
  - Estimation of infiltration rates for IAQ & energy analysis
  - Durability of envelope
  - Protection of building air from external threats
  - Leakage through walls is a bad way to ventilate!
- Size of energy liabilities of air leakage previously unknown – very little study
- Commercial and institutional buildings often assumed to be airtight, especially newer (and greener) buildings

Background

- Persily (1998) debunked myth of airtight commercial buildings
- Many energy and IAQ analyses still employ this assumption
- Lack of whole building airtightness or continuous air barrier requirements in U.S. (ASHRAE Standard 90.1, building codes, etc.) but its changing

Airtightness of U.S. commercial buildings

Latest reference: *Emmerich, S.J. and Persily, A.K., Airtightness of Commercial Buildings in the U.S. (2005) AIVC Conference, Brussels, Belgium*

Airtightness of U.S. commercial buildings

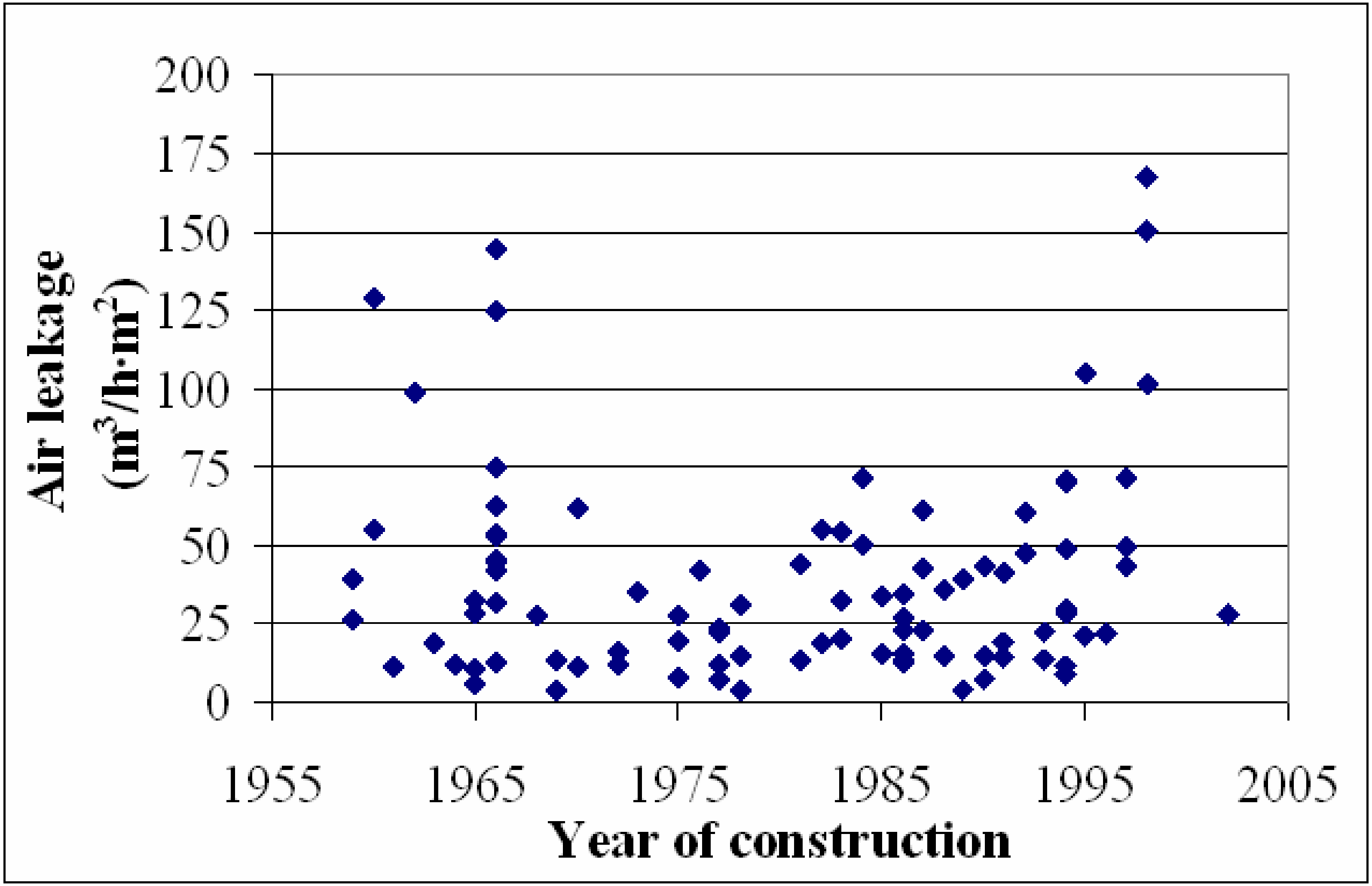
- Update 1998 analysis by Persily (re-examine trends)
- Envelope airtightness data for ~200 commercial and institutional buildings in the U.S.
- Additional published and previously unpublished data
- Data from fan pressurization testing (ASTM E779)

Summary of Data

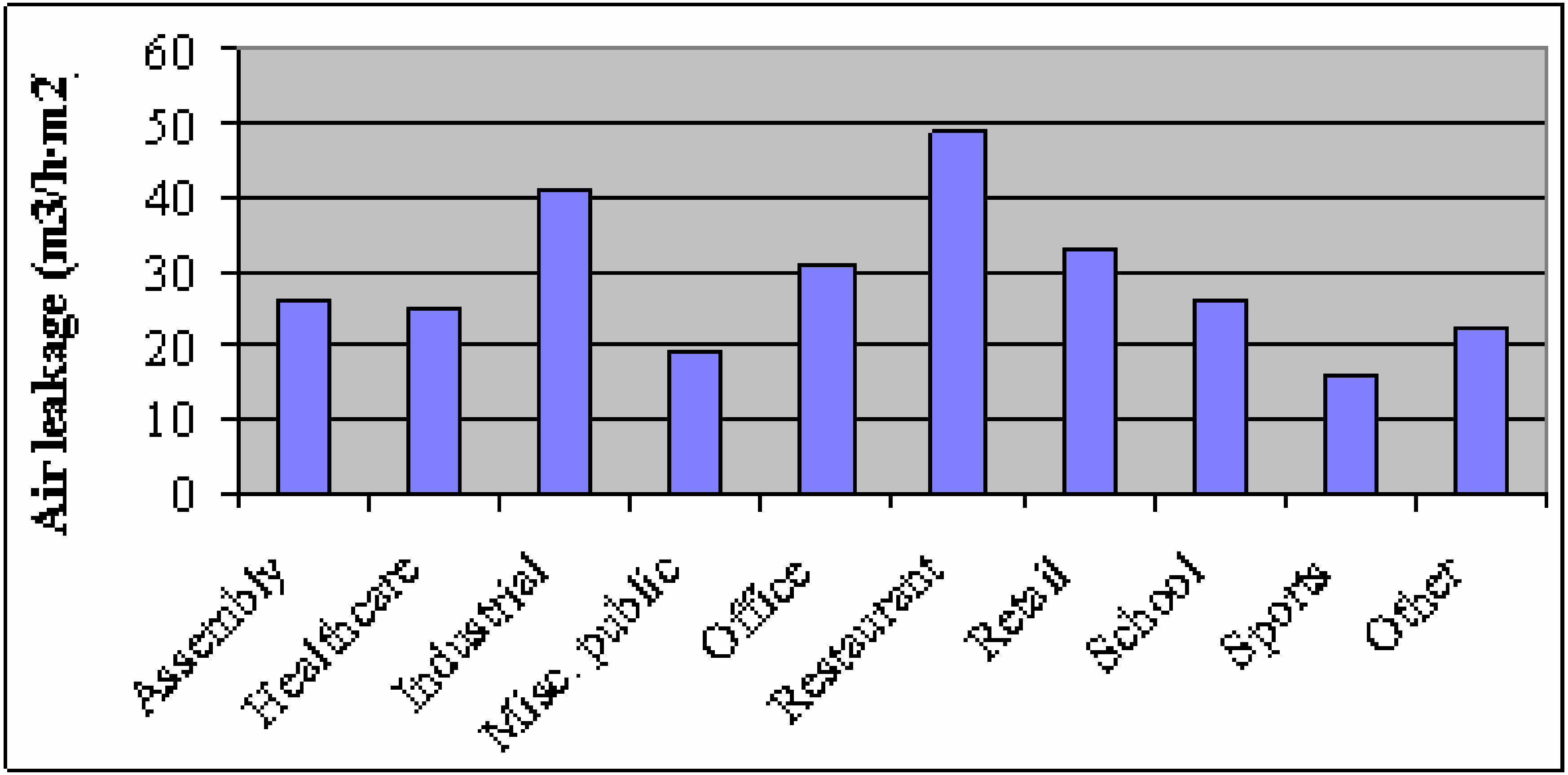
Units	Mean	Std Dev.	Min	Max
$m^3/h\text{-}m^2$ @ 75 Pa	**28.4**	**35.8**	**2.7**	**168**
cfm/ft^2 @ 0.3 in H_20	**1.56**	**1.97**	**0.15**	**9.24**

- Persily 1998 reported average of 28.7
- Normalized by **above-grade** envelope surface area
- Around 15 h^{-1} at 50 Pa for a typical house

Airtightness vs Construction Year

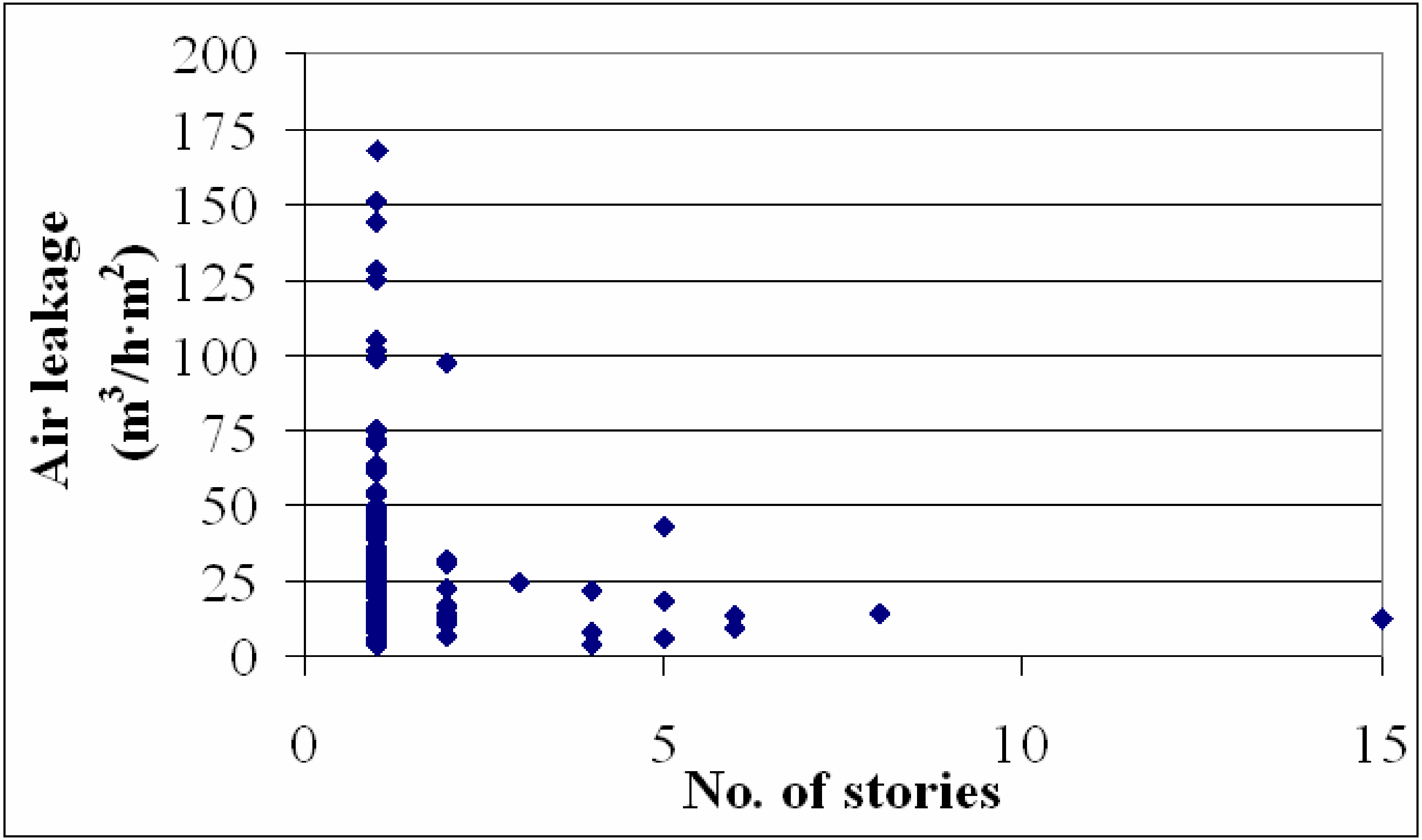


Airtightness vs. Building Type

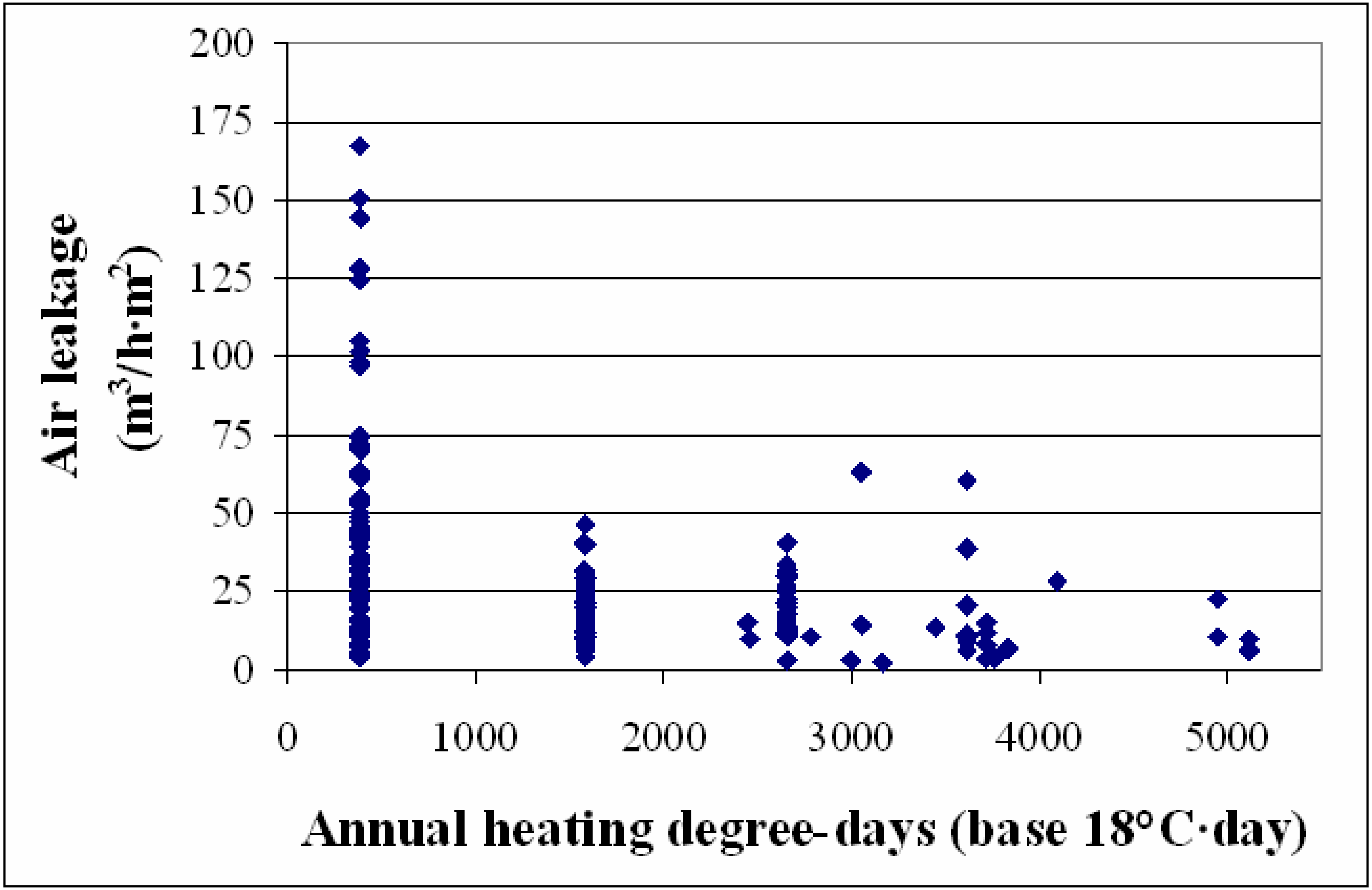


Offices 34; Schools 70; Sports 16; Restaurant 15; Other 66

Airtightness vs. Number of Stories



Airtightness vs. Climate



Summary & Discussion

- Airtightness of 201 U.S. commercial and institutional buildings – similar average as 1998 Persily analysis
- Airtightness levels comparable with US homes
- Modest number of buildings & a nonrandom sample
- Still no correlation with year of construction
- Trends suggest that tall buildings are tighter and buildings in hot climate are leakier
- **More data needed** in North, West and for **green** buildings

Energy impacts of air leakage

Reference: *Emmerich, S.J., Anis, W., McDowell, T.P. 2007. Simulation of the Impact of Commercial Building Envelope Airtightness on Building Energy Utilization. ASHRAE Transactions, Vol. 118 (2).*

U.S. air barrier study

- With input from 90.1 Envelope task group, NIST conducted simulation study of potential energy savings due to requirement for continuous air barriers in typical U.S. commercial buildings
- Used CONTAM/TRNSYS coupled multizone airflow & building energy analysis tool
- 3 buildings modeled: 2 story office, 1 story retail and 5 story residential
- CBECS data shows 2 story office building under twenty five thousand sq. ft. most common commercial building.

Know-how exists to build commercial buildings much tighter.

- Use Continuous Air Barrier system
- Many published examples of very tight buildings in Canada and Europe
- Published retrofit studies have shown significant improvement in airtightness of existing buildings
- BSRIA reports that tested buildings have bettered new U.K. standard by 40 % (hundreds of buildings tested)

Model Description

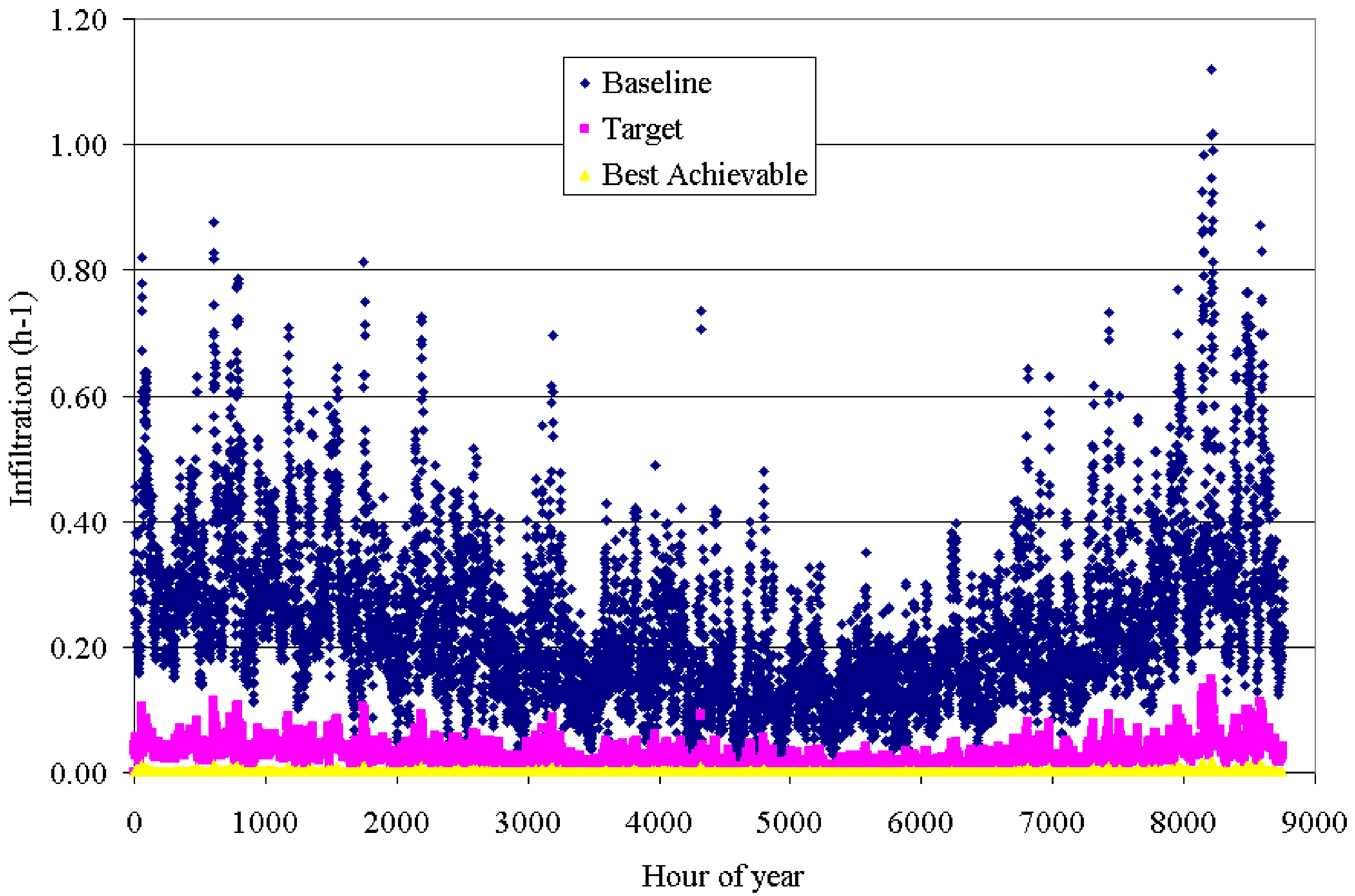
- 2-story office,1-story retail & 5-story apartment
- 5 cities: Bismarck, Minneapolis, St. Louis, Phoenix and Miami
- Building envelopes and HVAC systems defined to meet Standard 90.1
- Economizers in St Louis, Bismarck, Phoenix
- **Ventilation to meet Standard 62.1**

Airtightness values

		L/s.m^2 @ 75 Pa
Baseline	Bismarck	6.6
	Minneapolis	7.2
	St. Louis	9.1
	Phoenix	11.1
	Miami	11.8
Target	All	1.2
Best Achievable	All	0.2

Airtightness values based on data and judgment

Results - Infiltration in St. Louis



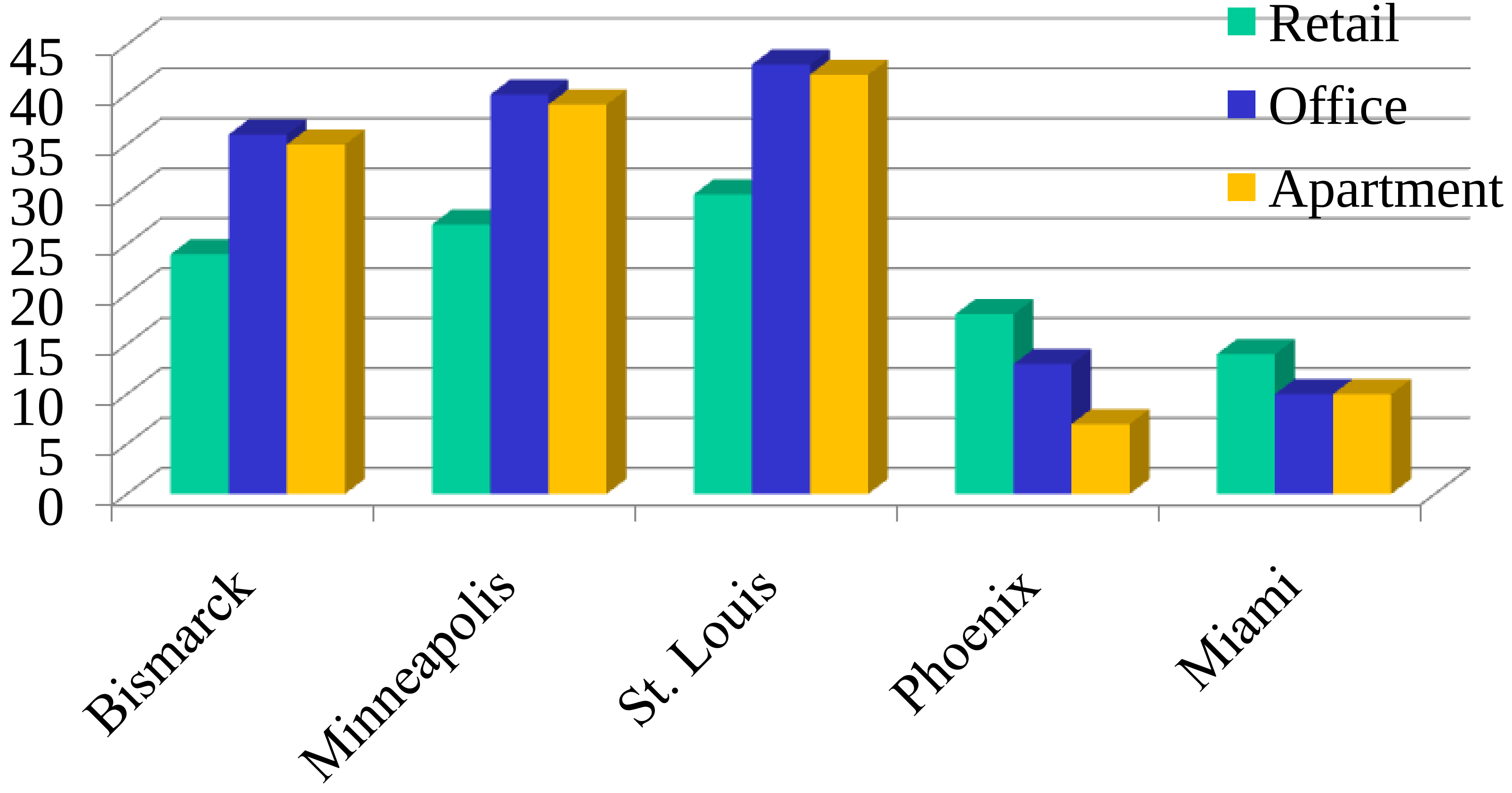
Infiltration summary

City //	Office Baseline (ach)	Reduction (%)
Bismarck	0.22	77
Minneapolis	0.23	79
St. Louis	0.26	84
Phoenix	0.17	86
Miami	0.26	89

Infiltration reductions similar for retail building;
Smaller for apartment

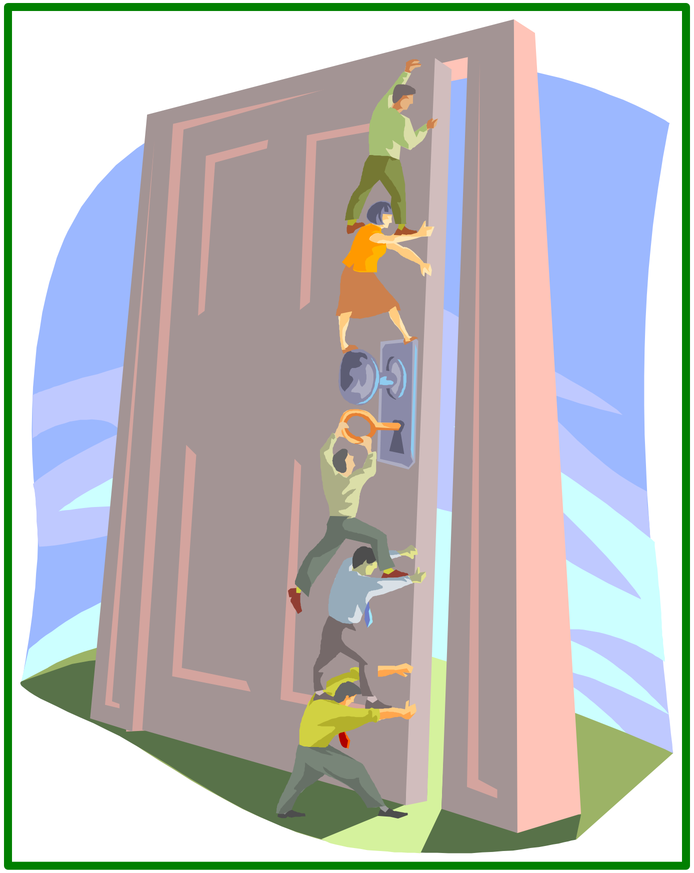
Energy Savings

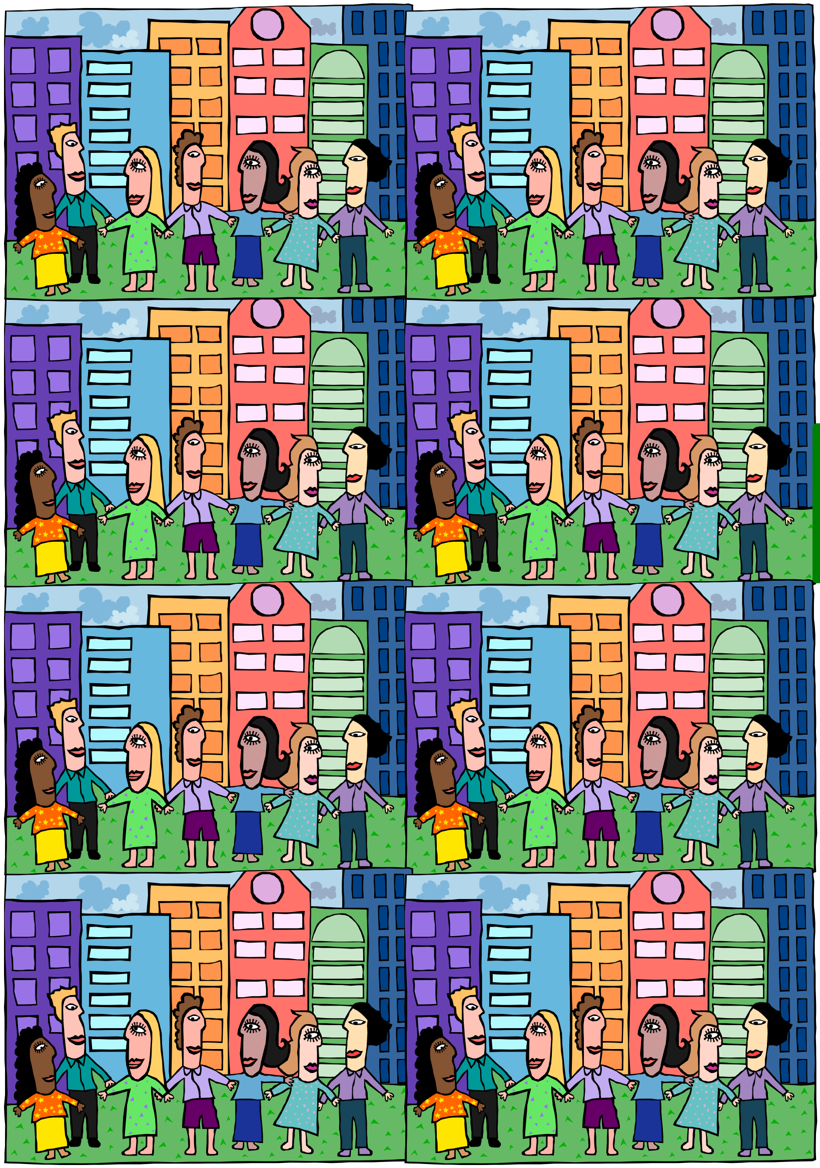
% REDUCTION in ANNUAL ENERGY USE for TARGET vs. BASELINE AIRTIGHTNESS

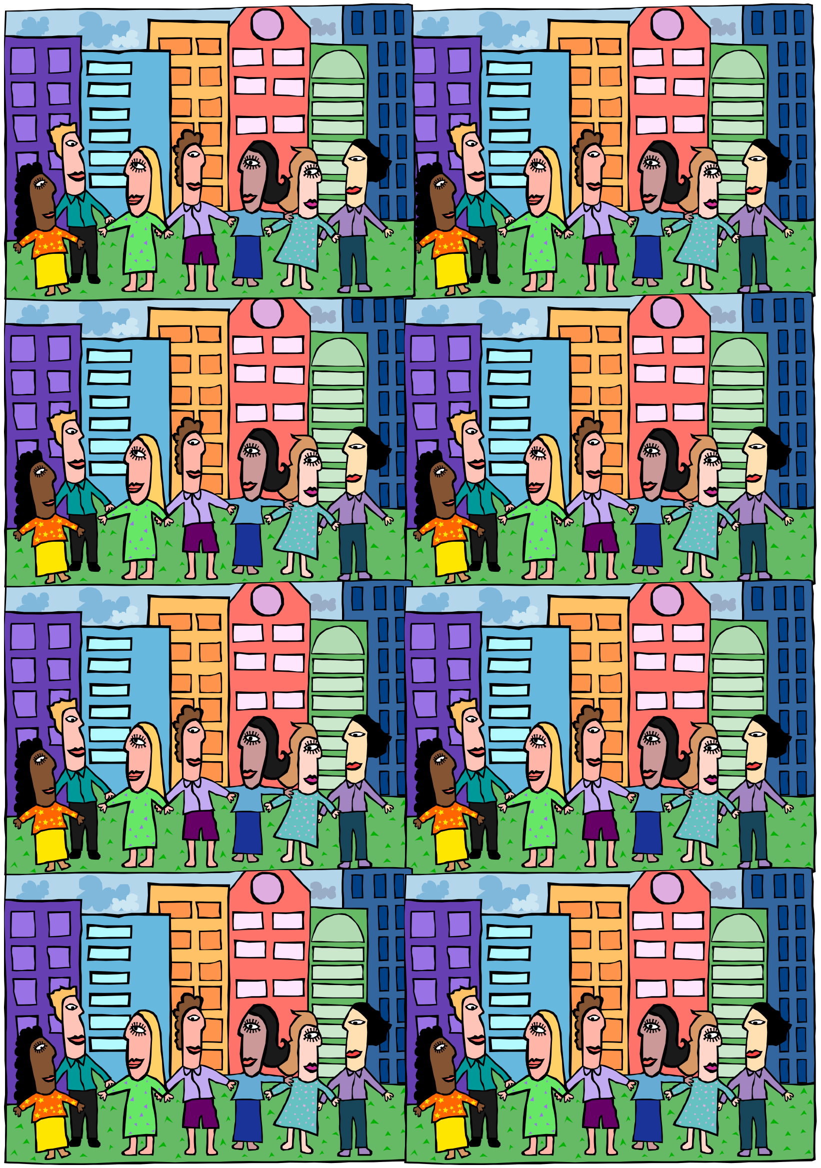


Savings similar for masonry building;

What about existing buildings?







Airtightness retrofit

- Previous NIST study estimated that infiltration is responsible for ~33 % of heating load in US office building stock
- U.S. Army Corps of Engineers performed measurements before and after sealing for 35 civilian buildings
  - Average reduction in air leakage was 47 %
- USACE/NREL simulation study estimated potential energy savings of 5 % to 40 % for army barracks if tightened

Conclusions

- U.S. commercial buildings are STILL not airtight
  - No correlation with year of construction
- Significant energy savings are possible
  - Up to ~40 % of heating and cooling energy in new buildings
- Huge potential savings in retrofit market
  - Significant efforts in residential but commercial?

Recommendations

- Extend study to other building categories
- Examine the potential interaction between airtightness and other building parameters
- Collect airtightness data for green U.S. buildings
- Analyze the costs and potential energy savings from tightening of existing buildings and develop recommendations for the existing building stock
- Develop diagnostic protocols and tools for failures of building envelopes that deteriorate IAQ and energy efficiency