The Addition of Moisture Transport to the Air Leakage Energy Calculator

Andre Desjarlais

Som Shrestha, PhD

Oak Ridge National Laboratory

abaa EDUCATION

Air Barrier Association of America (ABAA) is a Registered Provider with The American Institute of Architects Continuing Education Systems. Credit earned on completion of this program will be reported to CES Records for AIA members. Certificates of Completion for non-AIA members are available on request.

This program is registered with the AIA/CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

air barrier
abaa
association of
america

CONTINUING EDUCATION
AIA

Presentation summary

- Why do we care air leakage?
- Web-based tool to estimate energy savings associated with air tightness
- Why do we care moisture transfer?
- Addition of moisture transport to the web-based tool
- Some examples

air barrier
abaa
association of
america

Buildings use a lot of energy

40% of all energy and 75% of all electricity used in the US

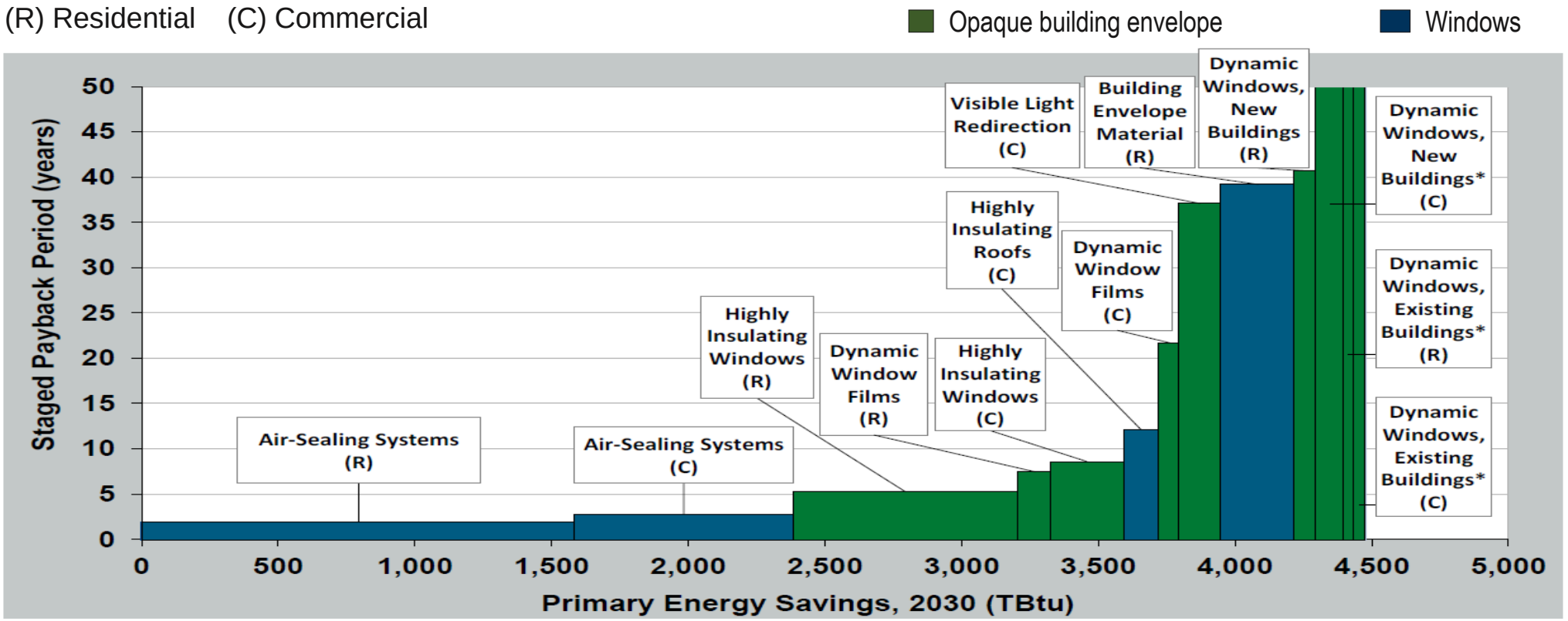
Source: US Department of Energy

air barrier
abaa
association of america

Windows and Building Envelope R&D ET roadmap

air barrier
abaa
association of america

Windows and building envelope R&D ET roadmap



air barrier
abaa
association of
america

Vancouver BC circa 1990

air barrier
abaa
association of
america

Industry's concern?

PAGE A12 The Olympian

Business

EDITOR: FRIEDA BUSH (news@theolympian.com): 754-5403 WED

MARKETS IN BRIEF

10,727.19
80.61
DOW

3956.42
-23.87
NASDAQ

1,480.88
5.26
S&P 500

BUSINESS IN BRIEF

WALL STREET

Paper, aluminum ead stocks higher

Old Economy stocks ame out on top Tuesday s two stalwarts of tradi- ional businesses — pa- er and aluminum — led he market higher, with a ittle help from an upbeat peech from Federal Re-

[redacted] makes offer in defective siding lawsuit

THE ASSOCIATED PRESS

FEDERAL WAY — The Weyerhaeuser Co. expects to pay as much as $82 million to homeowners around the country to settle claims of defective exterior hardboard siding.

The settlement proposed Monday by the forest products giant is intended to resolve a class-action lawsuit filed in 1998 in Superior Court in San Francisco and similar litigation pending in Oregon, Iowa, South Carolina and Texas. The dismissal of a similar case in Washington state is on appeal.

"Weyerhaeuser is stepping up to the plate to solve problems with one of its products," said Christopher I. Brain of Seattle, one of the principal lawyers representing homeowners.

Deterioration of the half-inch board, a tightly squeezed composite of wood chips, fiber, resin and wax, took many forms, including swelling, warping, splitting, rotting and even sprouting mushrooms, Brain said.

Weyerhaeuser is taking an $82 million charge after taxes in the second quarter to cover claims by homeowners who installed the siding between Jan. 1, 1981, and Dec. 31, 1999, said Bob Dowdy, vice president and general counsel.

Dowdy would not say Weyerhaeuser was admitting responsibility for the defective siding.

"What we're saying here is that we would rather have a fair and independent process for people who have our siding to resort to than to continue to have a prolonged and expensive piece of litigation with an uncertain outcome for everyone involved," he said.

Under a product liability settlement that was negotiated in 1996 involving Inner Seal pressed wood-flake siding, Louisiana-Pacific Corp. of Portland, Ore., had paid about $470 million to settle claims as of early this year.

Georgia-Pacific, Jefferson Smurfit and Masonite also have settled class-action suits over siding, while siding-related lawsuits are pending against Boise Cascade and Stimson Lumber.

Under the proposed Weyerhaeuser settlement, which is subject to review in the California court later this year, a court-appointed inspector would examine structures to assess claims for compensation.

Brain would not comment on the amount of the settlement or other terms but estimated the siding had been applied to hundreds of thousands of houses and other structures. He said "at least 500,000" people could receive payments over the nine-year term of the proposed settlement.

About 2 billion square feet of the siding was produced at a Weyerhaeuser plant in Klamath Falls, Ore., over 35 years before the line was discontinued in 1996 — the year after the first claims were brought.

The siding carried a 30-year warranty, and company officials said there were warranty claims in about 2 percent of total square footage that was sold.

Most sales were to builders and contractors on the West Coast, but some also was distributed to consumers through retailers such as Eagle Hardware and Garden and Home Depot, Brain said.

air barrier
abaa
association of america

Moisture and buildings

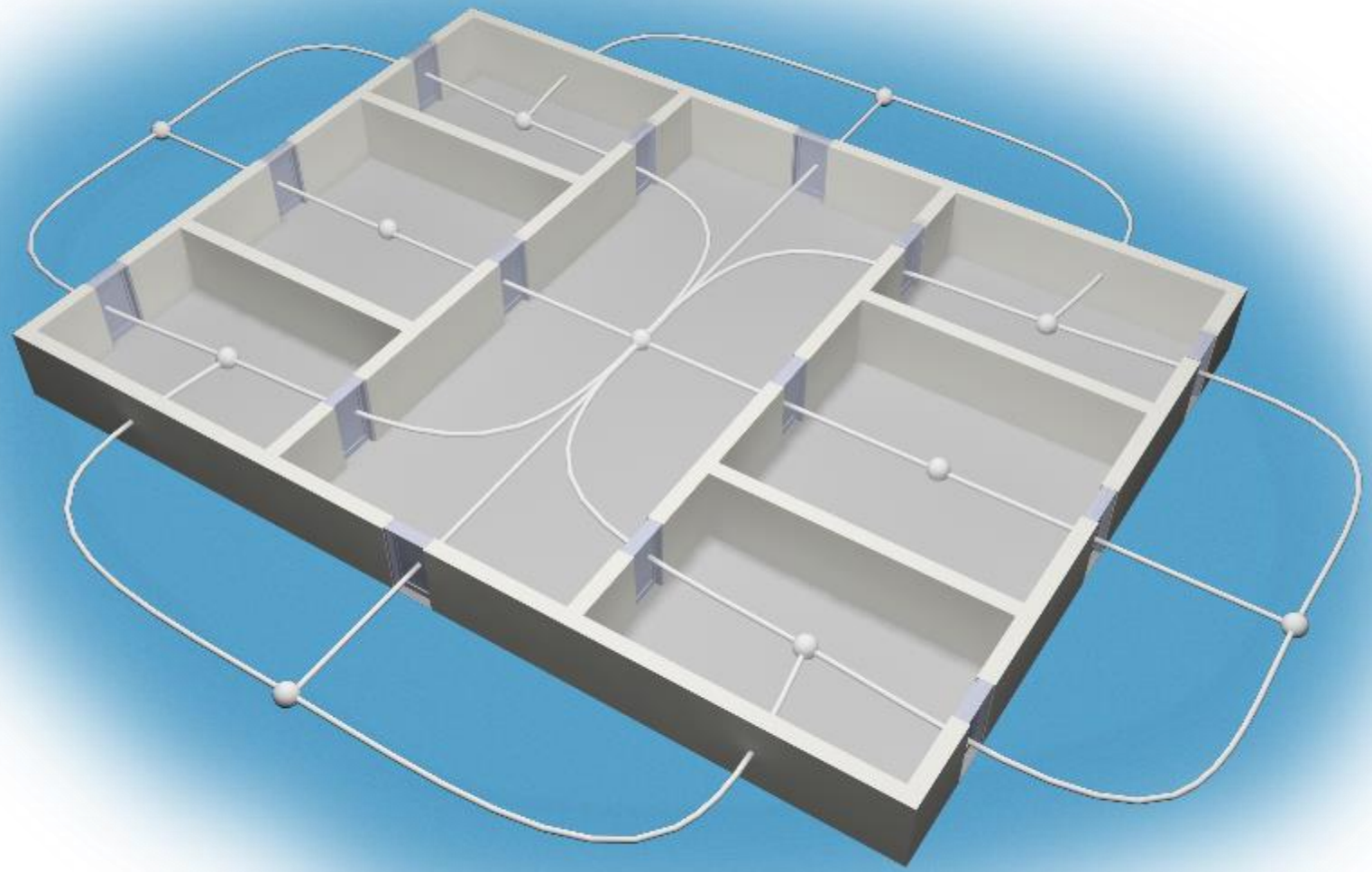
- Moisture involved in almost all building envelope performance problems
  - Energy inefficiency
  - Mold (IAQ)
  - Corrosion
  - Wood rot
  - Termites
  - Staining

air barrier
abaa
association of
america

Develop an air leakage calculator

air barrier
abaa
association of
america

Air leakage calculation is not a trivial task



air barrier
abaa
association of
america

Energy and cost savings depend on

- Air leakage rates
- Weather
- Building type
- HVAC efficiency
- Energy and demand price

air barrier
abaa
association of
america

Challenges

- Air leakage rates depend on multiple variables
  - Envelope airtightness
  - HVAC system operation
  - Occupancy
  - Weather
  - Stack effect
- Typical assumptions
  - Constant leakage rate
  - Leakage rates from simplified algorithms

} **Under- or over-estimated energy use**

air barrier abaa association of america

Infiltration modeling in EnergyPlus

- ZoneInfiltration:DesignFlowRate
  - DOE commercial prototype building models
- ZoneInfiltration:EffectiveLeakageArea
  - DOE residential prototype building models
- ZoneInfiltration:FlowCoefficient
- AirflowNetwork
  - Future effort

Typically
do not take into account

- Temperature difference
- Stack effect
- Wind direction

air barrier
abaa
association of
america

ZoneInfiltration:DesignFlowRate
DOE commercial prototype buildings

$$Air\ leakage\ rate = (I_{design})(F_{schedule})[A + B|T_{zone} - T_{odb}| + C(WindSpeed) + D(WindSpeed^2)]$$

Default values

$A = 0$

$C = 0.224$

$D = 0$

$B = 0$ → Does not take into account effects of temperature difference

air barrier association of america

ZoneInfiltration:DesignFlowRate
DOE commercial prototype buildings

$$Air\ leakage\ rate =$$

$$(I_{design})(F_{schedule})[A + B|T_{zone} - T_{odb}| + C(WindSpeed) + D(WindSpeed^2)]$$

I_{design} in most DOE prototype buildings

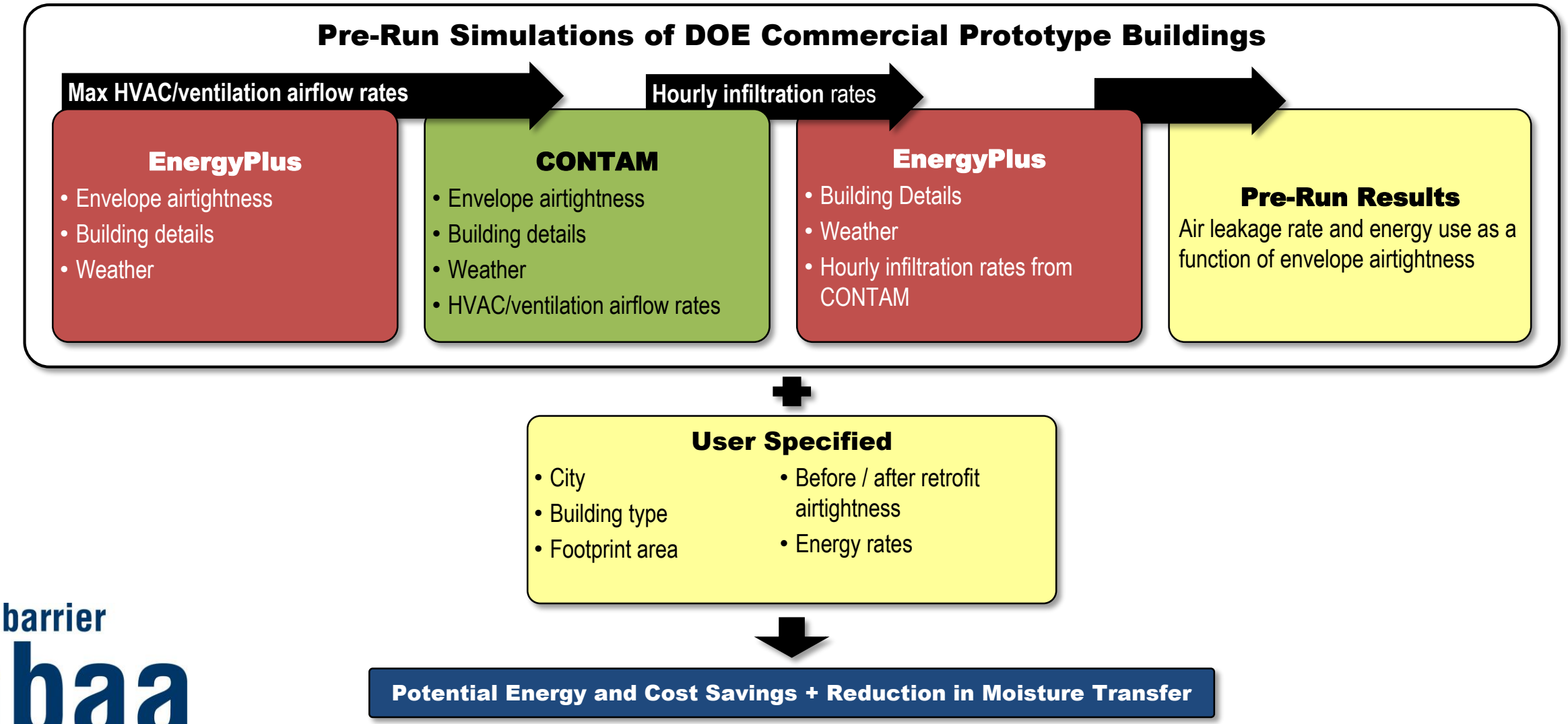
- Air leakage rate when HVAC is off = 1 L/s·m^2 at 75 Pa
- Air leakage rate when HVAC is on = 0.25 L/s·m^2 at 75 Pa (75% reduction)

air barrier abaa association of america

Objective

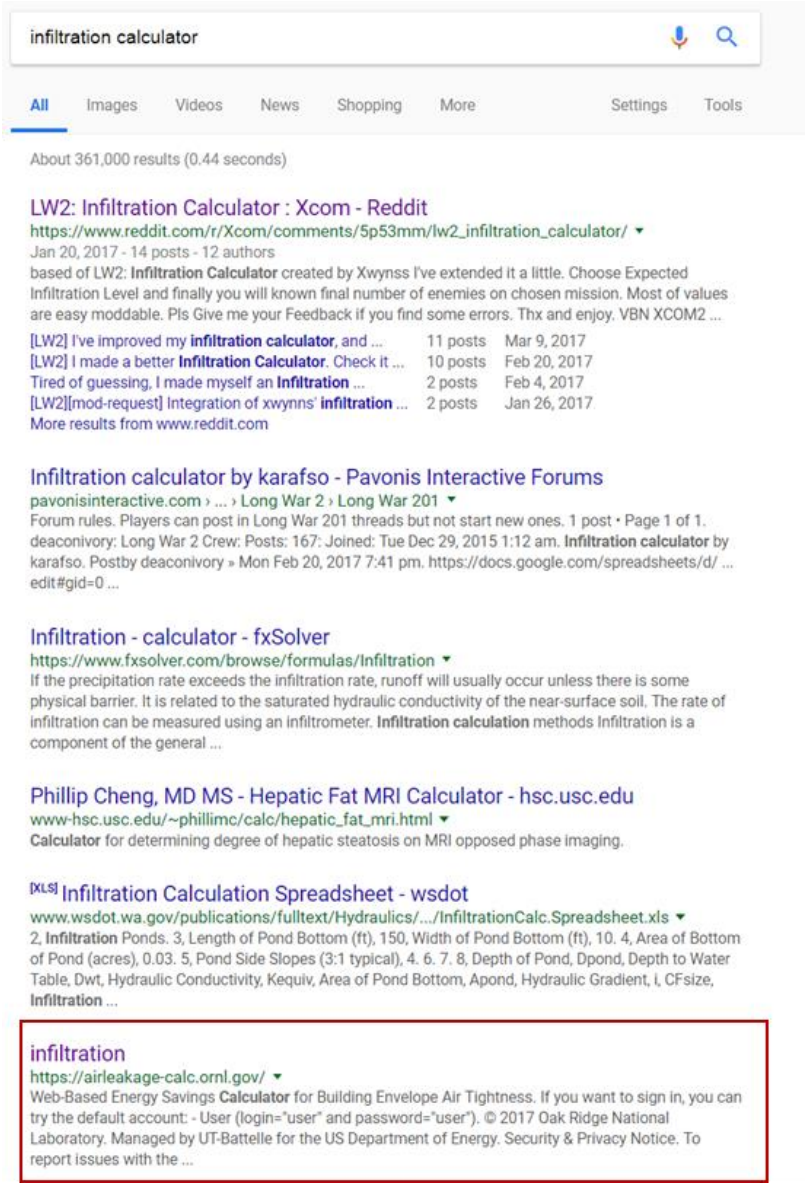
- Create an easy-to-use online tool using the simulation results of the best-in-class building energy simulation tool EnergyPlus and the whole building airflow simulation tool CONTAM.
- Online calculator estimates the potential energy and cost savings + reduction in moisture transfer from improvements from improvements in airtightness.
- Further increase market penetration of air barriers.

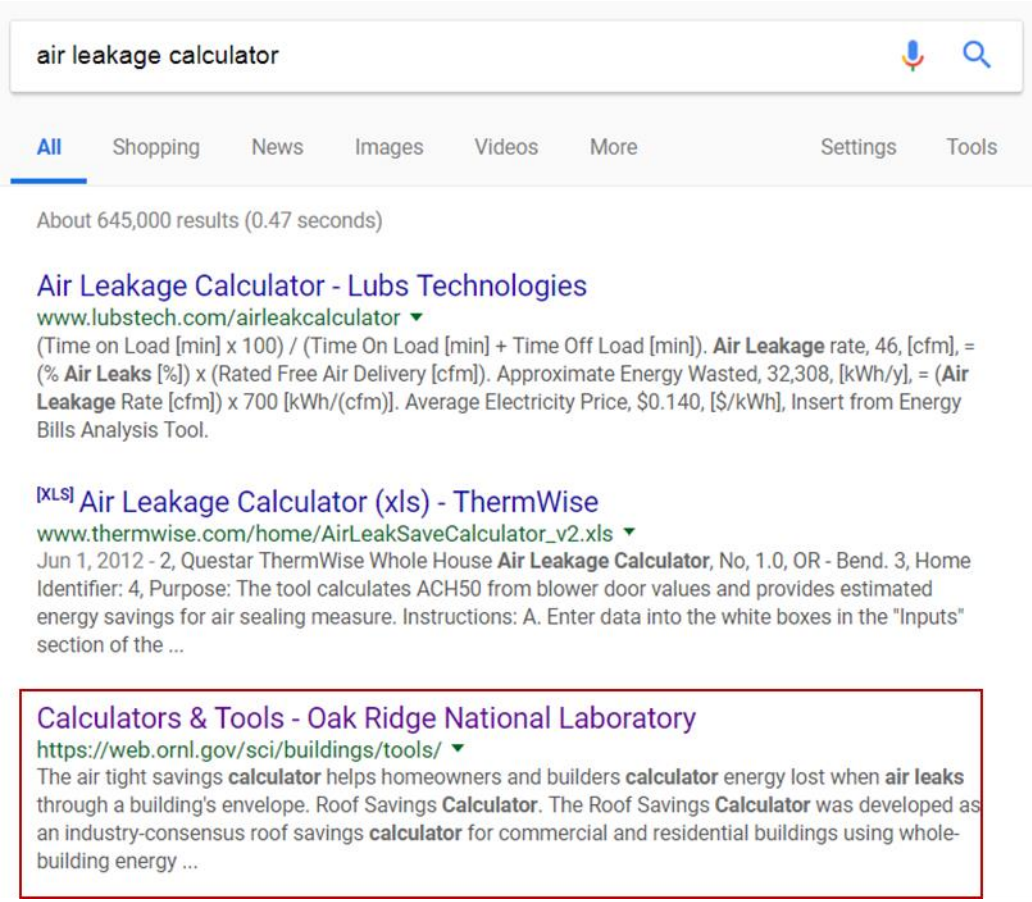
Calculations flow



air barrier association of america

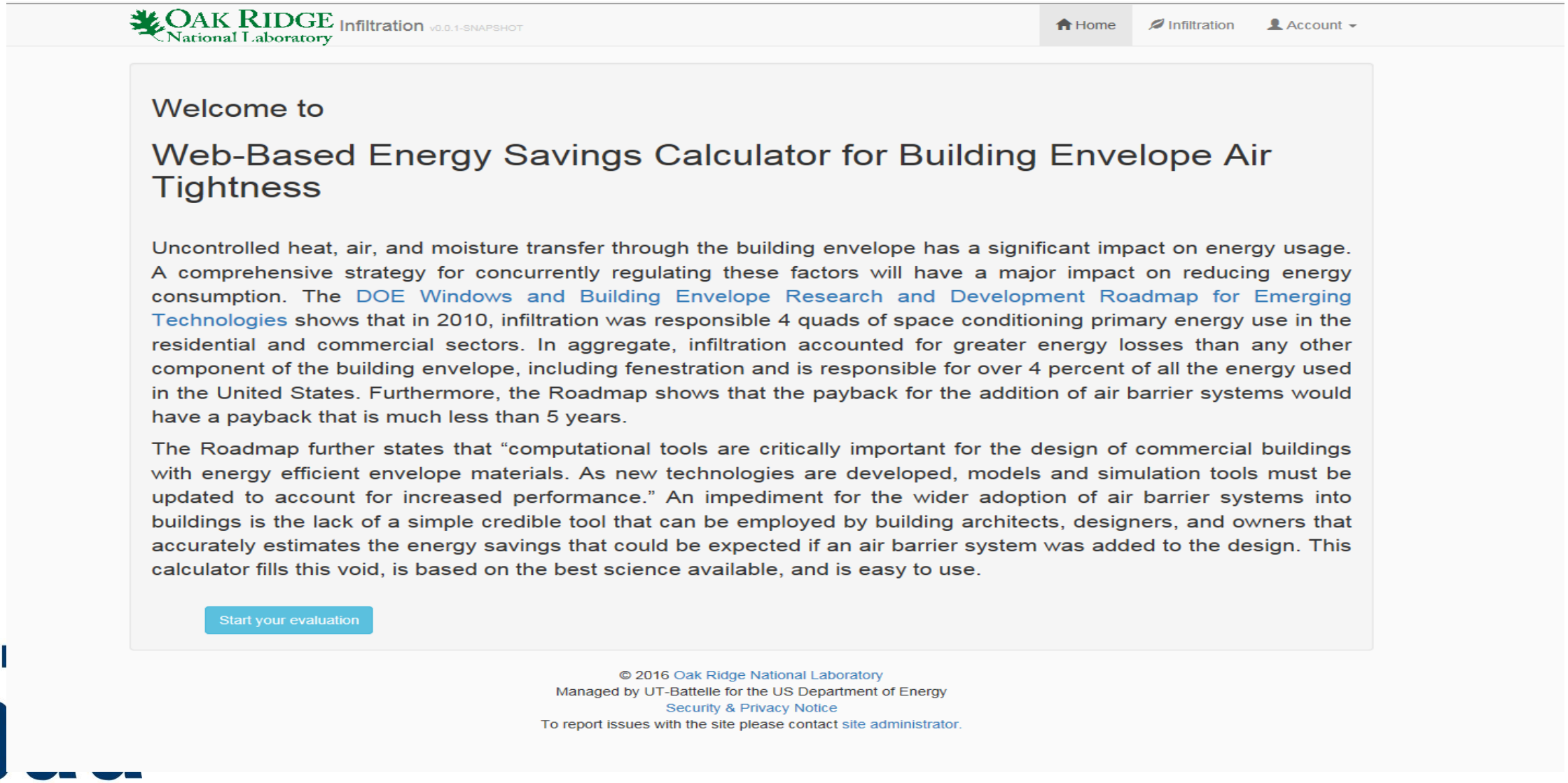
Easy to find





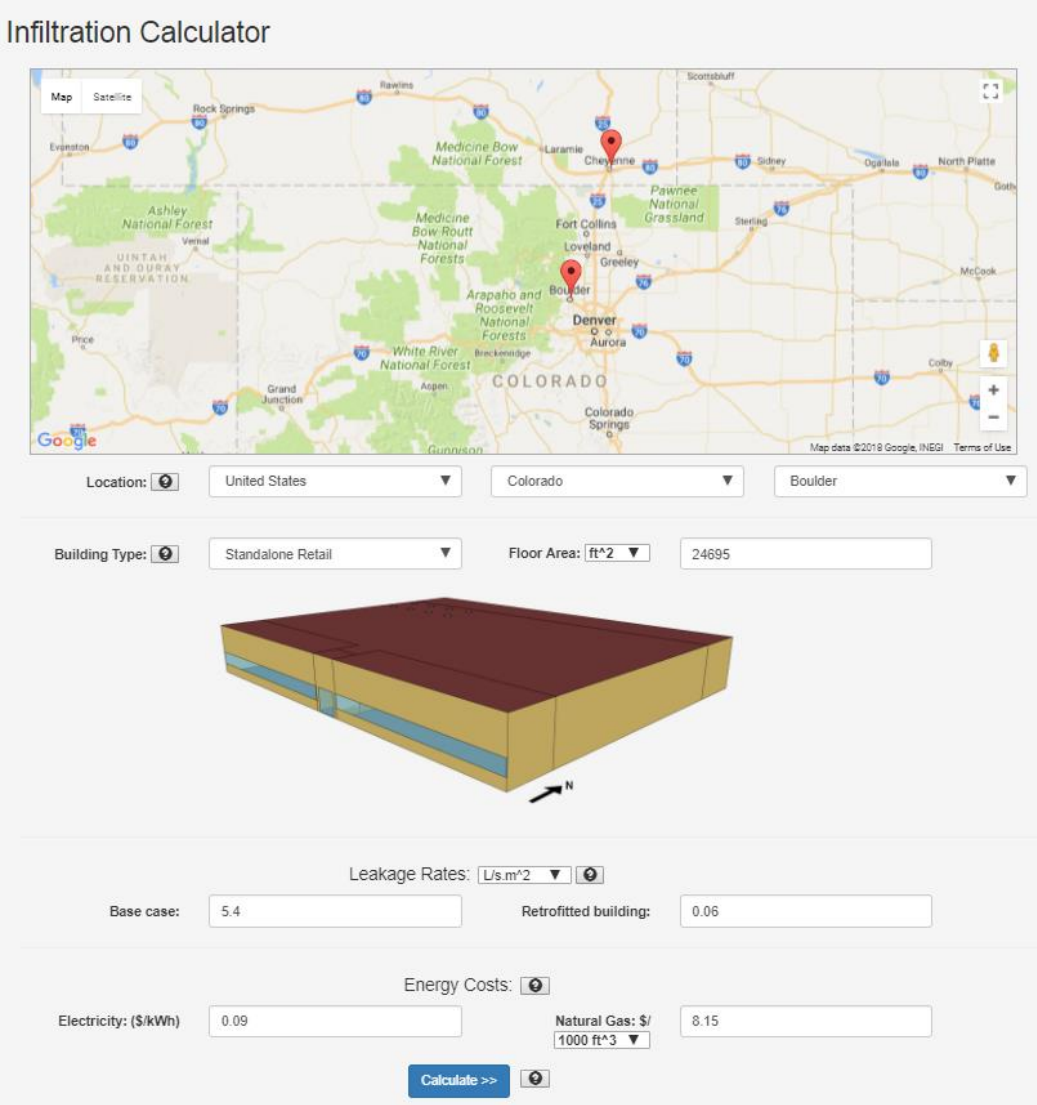
air barrier
abaa
association of
america

The tool



air barr
ab
association of
america

Easy to use



User Inputs

- Location
- Building type
- Floor area
- Envelope airtightness
- Energy rate
- Can switch between IP and SI units
- Descriptions of the input parameters are available

air barrier abaa association of america

Locations

air barrier
abaa
association of
america

Building types

- DOE commercial prototype building models
- ASHRAE 90.1-2013 compliant
- 16 building types
- 3 building types *(standalone retail, medium office, and mid-rise apartment)* in the first-phase (28.6% of commercial building footprint)
- 4 building types *(High-Rise Apartment, Hospital, Large Hotel, and Secondary School)* in the second-phase (27.8% of commercial building footprint)

air barrier
abaa
association of
america

DOE commercial prototype building models (ASHRAE 90.1-2013) used

Building	Total Floor Area, ft^2	Number of Floors	Construction Volume Weights
Standalone Retail	24,695	1	15.3%
Mid-Rise Apartment	33,700	4	7.3%
Medium Office	53,600	3	6.0%
High-Rise Apartment	84,360	10	9.0%
Hospital	241,410	5	3.4%
Large Hotel	122,132	7 (including basement)	5.0%
Small Hotel	43,200	4	1.7%
Large Office	498,600	13 (including basement)	3.3%
Small Office	5,500	1	5.6%
Outpatient Healthcare	40,950	3	4.4%
Restaurant Fast Food	2,500	1	0.6%
Restaurant Sit Down	5,502	1	0.7%
Stripmall	22,500	1	5.7%
Primary School	73,960	1	5.7%
Secondary School	210,900	2	10.4%
Warehouse	49,495	1	16.7%

Standalone retail building specs

Characteristic	Description
Floor area (m^2)	2300 (Length 54.3 m × width 42.4m)
Number of floors	1
Floor to ceiling height (m)	6.1
Window-to-wall ratio (%) **Windows on south-facing façade**	25.4
Building Envelope	
Walls	20.3 cm concrete masonry block + insulation per ASHRAE 90.1 + 1.3 cm drywall
Roof	Roof membrane + insulation per ASHRAE 90.1 + metal decking
Window U-factor and SHGC	Per ASHRAE 90.1
Foundation	15.2 cm concrete slab-on-grade + insulation per ASHRAE 90.1
Air leakage rates for prototype buildings (not used in the present study)	HVAC off = 1 L/s·m^2 at 75 Pa HVAC on = 25% of HVAC off rate = 0.25 L/s·m^2 at 75 Pa
HVAC	
Heating type	Gas furnace inside the packaged air conditioning unit
Cooling type	Packaged air conditioning unit
Size	Autosized to design day
Efficiency	Based on climate location and design cooling/heating capacity and ASHRAE 90.1 requirements
Thermostat setpoint (°C)	23.9 cooling / 21.1 heating
Thermostat setback (°C)	29.4 cooling / 15.6 heating
Ventilation	Per ASHRAE 62.1

air barrier
abaa
association of
america

Air leakage rates: standalone retail building

Case	Air Leakage Rate at 75 Pa (L/s·m^2)	Air Leakage Rate at 75 Pa (CFM/ft^2)	Source
Baseline	5.4	1.06	Emmerich et al (2005)
1	2.0	0.4	IECC (2015)
2	1.25	0.25	USACE (2012)
3	0.25	0.05	DOE (2014)

air barrier
abaa
association of
america

Energy costs

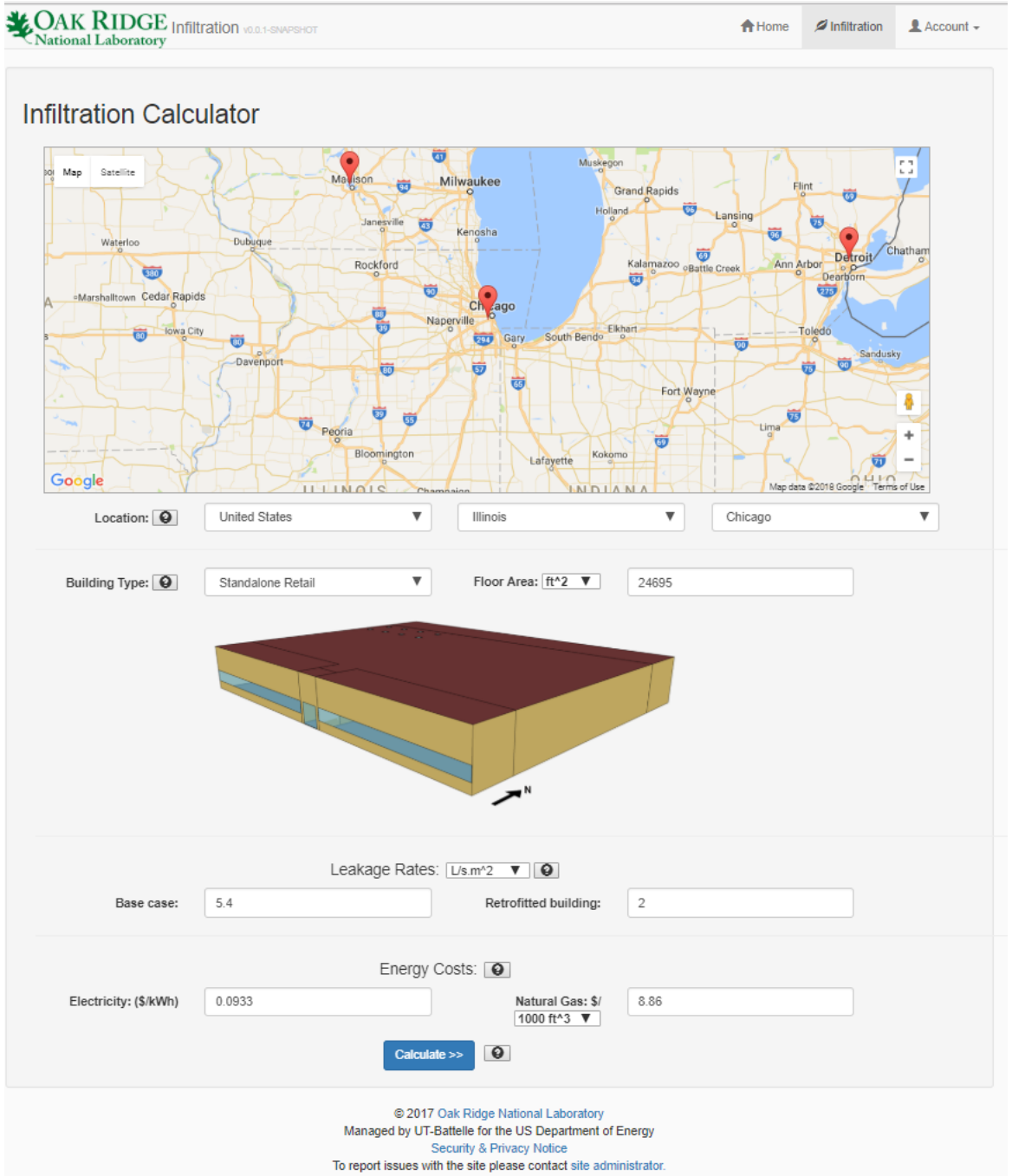
- Select the default values
  - Electricity and natural gas for US cities: U.S. EIA
  - Energy prices for Canada: rates used to develop the National Energy Code of Canada for Buildings 2011(NECB 2011)
- User-defined electricity and natural gas prices

air barrier
abaa
association of
america

Some examples

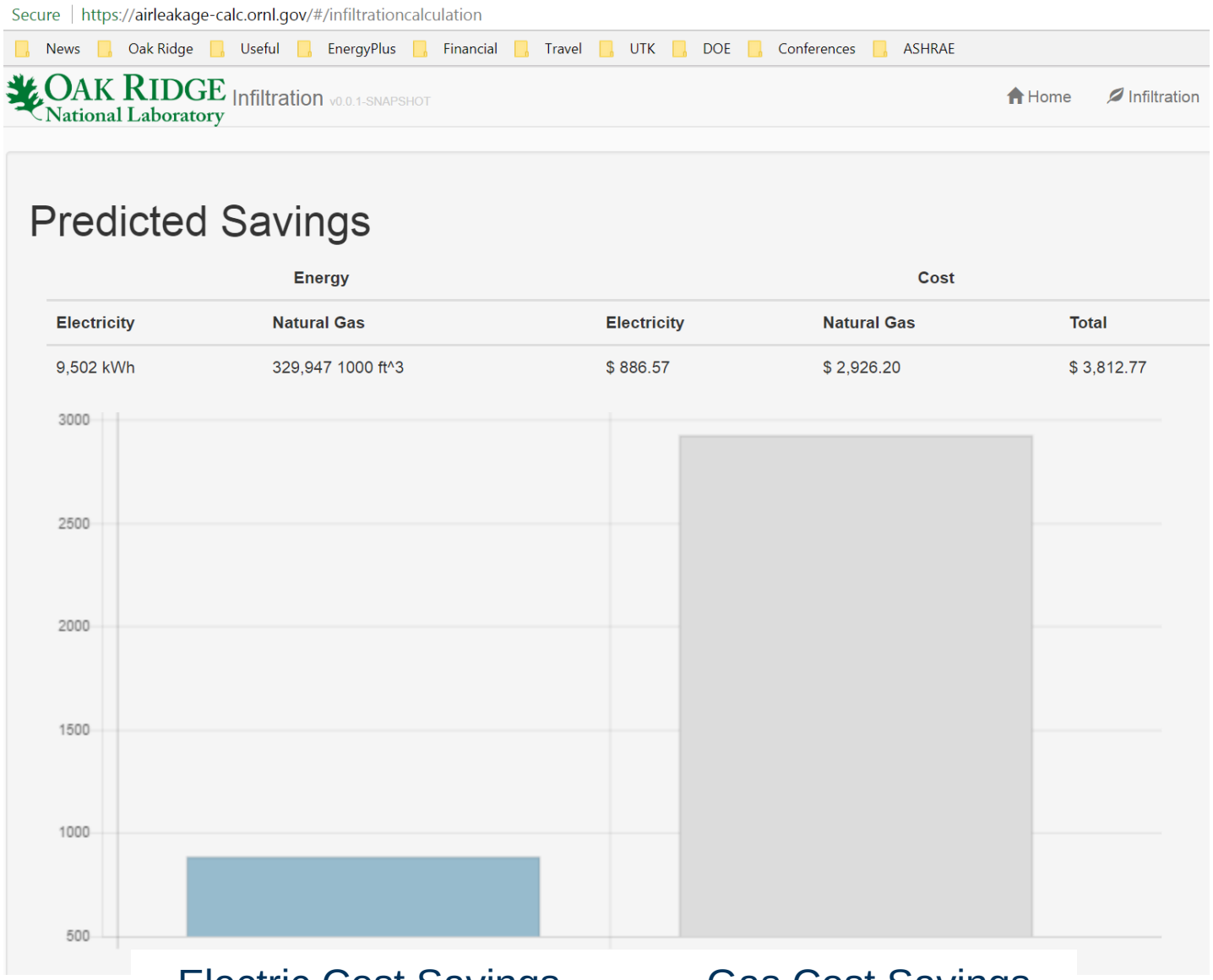
air barrier
abaa
association of
america

Calculator input



air barrier
abaa
association of
america

Calculator output



Electric Cost Savings Gas Cost Savings

air barrier abaa association of america

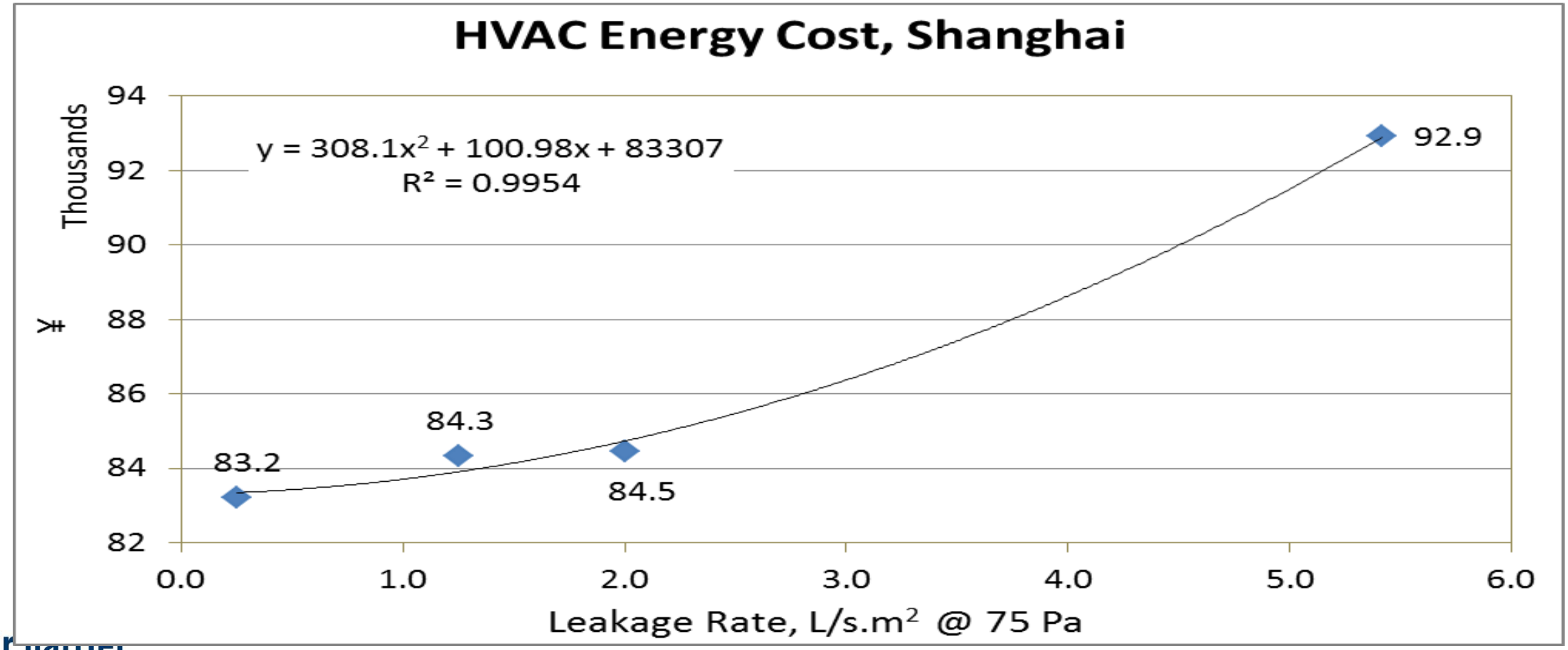
Sample cities

City	DOE Climate Zone	Prototype Building Model Used in Calculator	Electricity Price	Natural Gas Price
Shanghai, China	3A (warm, humid)	Memphis, TN	¥0.781/kWh[e] (≈$0.12/kWh)	¥3.65/m^3 [f] (≈$15.9/1000 ft^3)
Chicago, IL	5A (cold, humid)	Chicago, IL	$0.0933/kWh[a]	$8.86/1000 ft^3 [b]
Winnipeg, Canada	7 (very cold)	Duluth, MN	C$0.14/kWh[c] (≈$0.10/kWh)	C0.1605m^3$ [d] (≈$3.4/1000 ft^3)

[a] http://www.eia.gov/electricity/sales_revenue_price/
[b] http://www.eia.gov/dnav/ng/ng_sum_lsum_a_EPG0_PCS_DMcf_a.htm
[c] https://www.ovoenergy.com/guides/energy-guides/average-electricity-prices-kwh.html
[d] http://www.economicdevelopmentwinnipeg.com/uploads/document_file/natural_gas_rates.pdf?t=1433529826
[e] http://news.asean168.com/a/20150413/5318.html
[f] http://gas.gold600.com/

air barrier abaa association of america

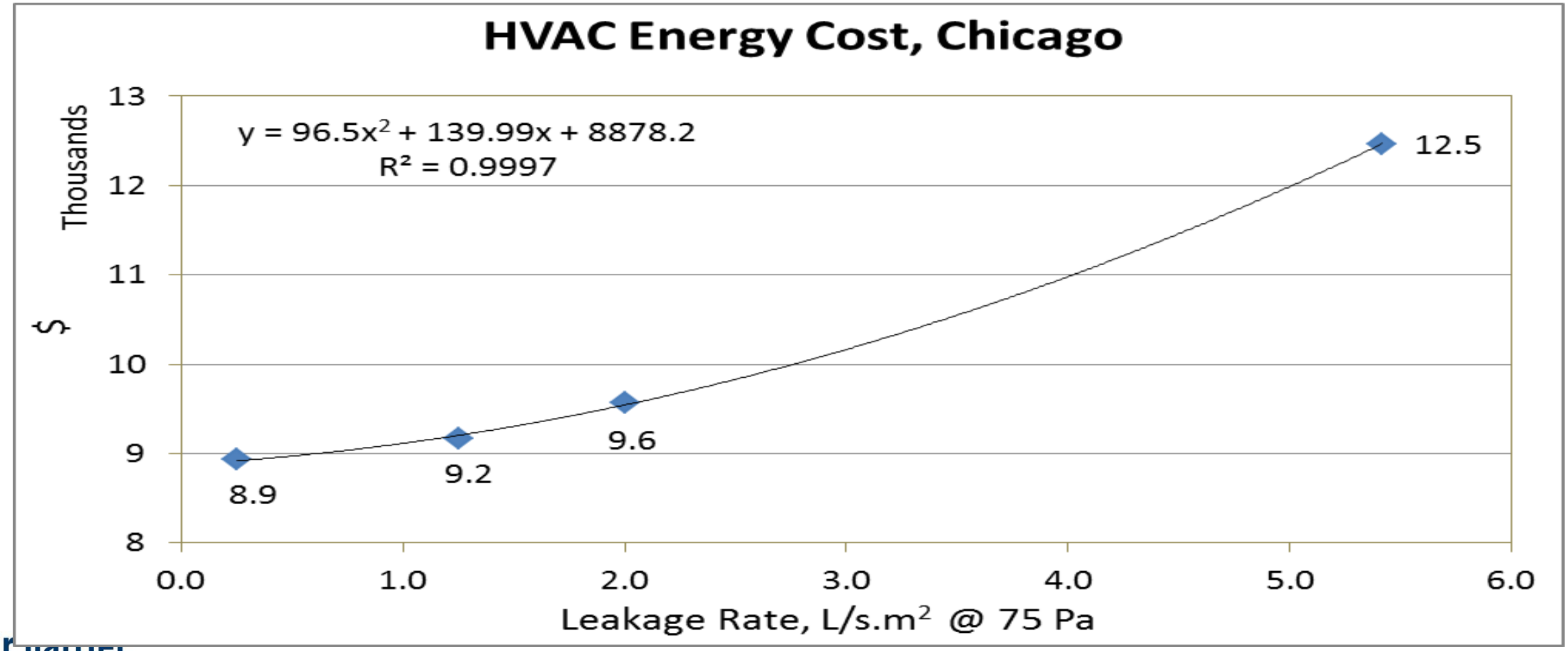
Energy savings - Shanghai



HVAC energy cost for a prototype standalone retail building in Shanghai

air barrier
abaa
association of
america

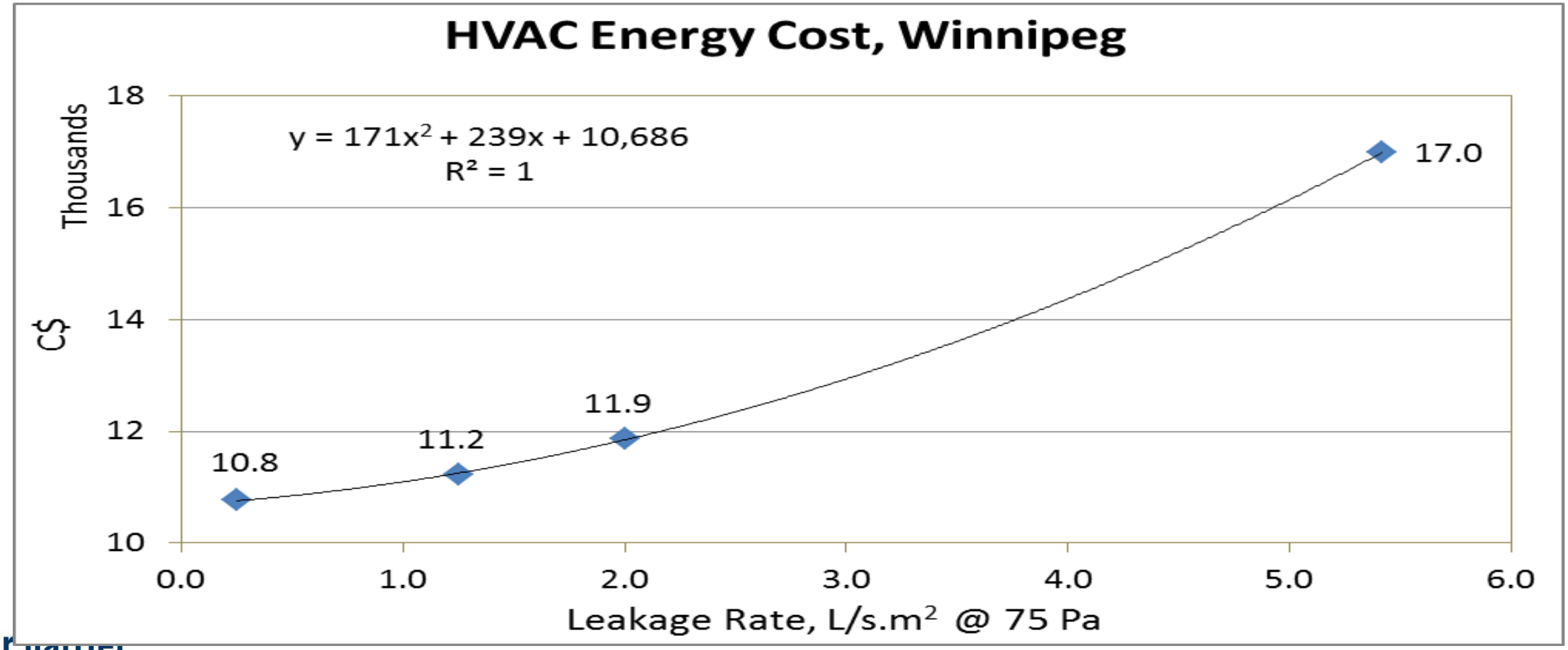
Energy savings - Chicago



HVAC energy cost for a prototype standalone retail building in Chicago

air barrier
abaa
association of
america

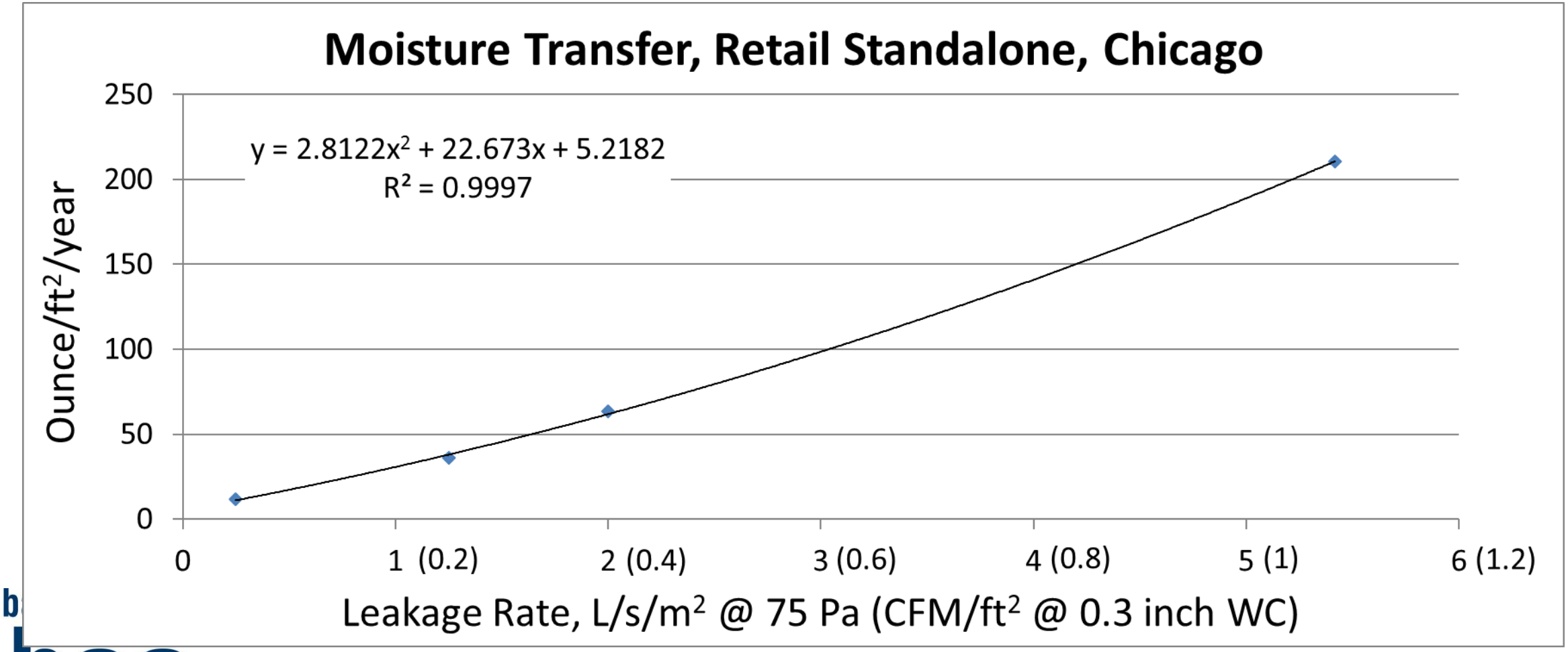
Energy savings - Winnipeg



HVAC energy cost for a prototype standalone retail building in Winnipeg

air barrier
abaa
association of
america

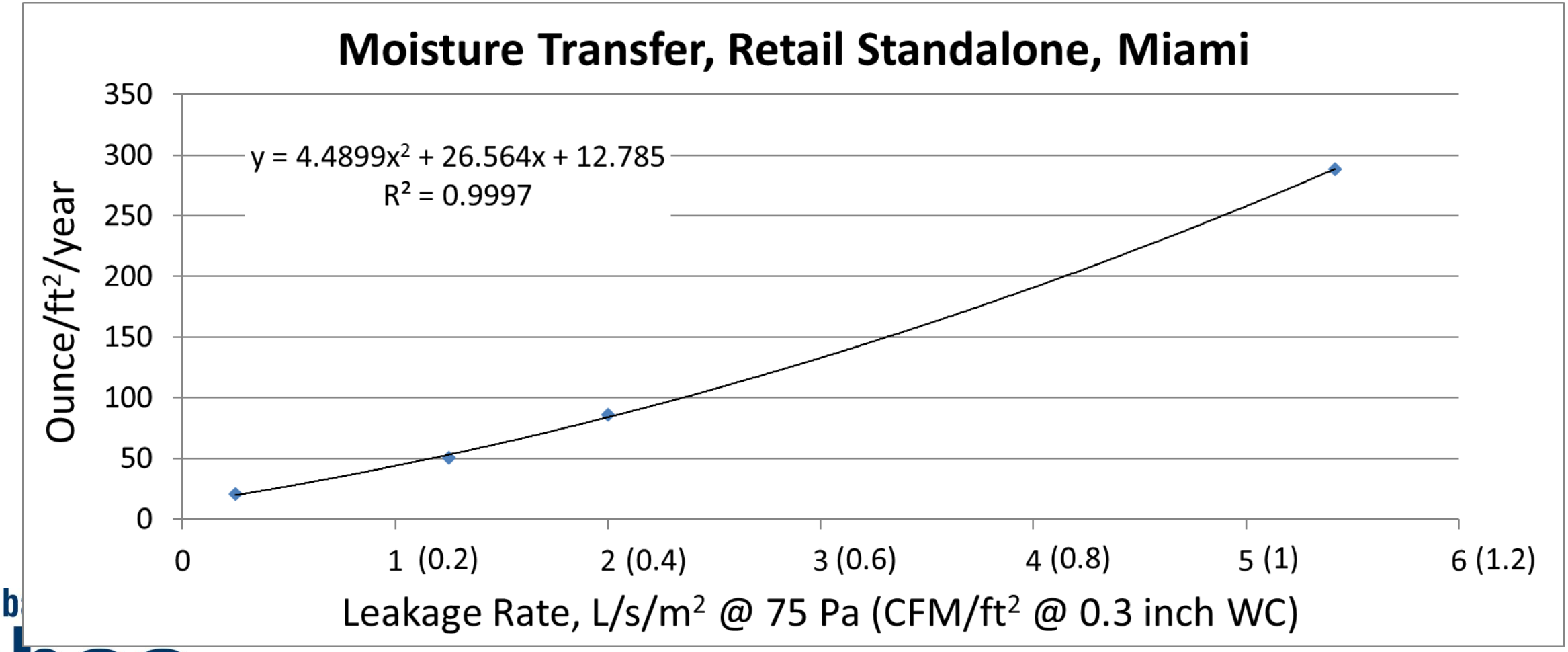
Moisture transfer – standalone retail, Chicago



air b

abaa
association of
america

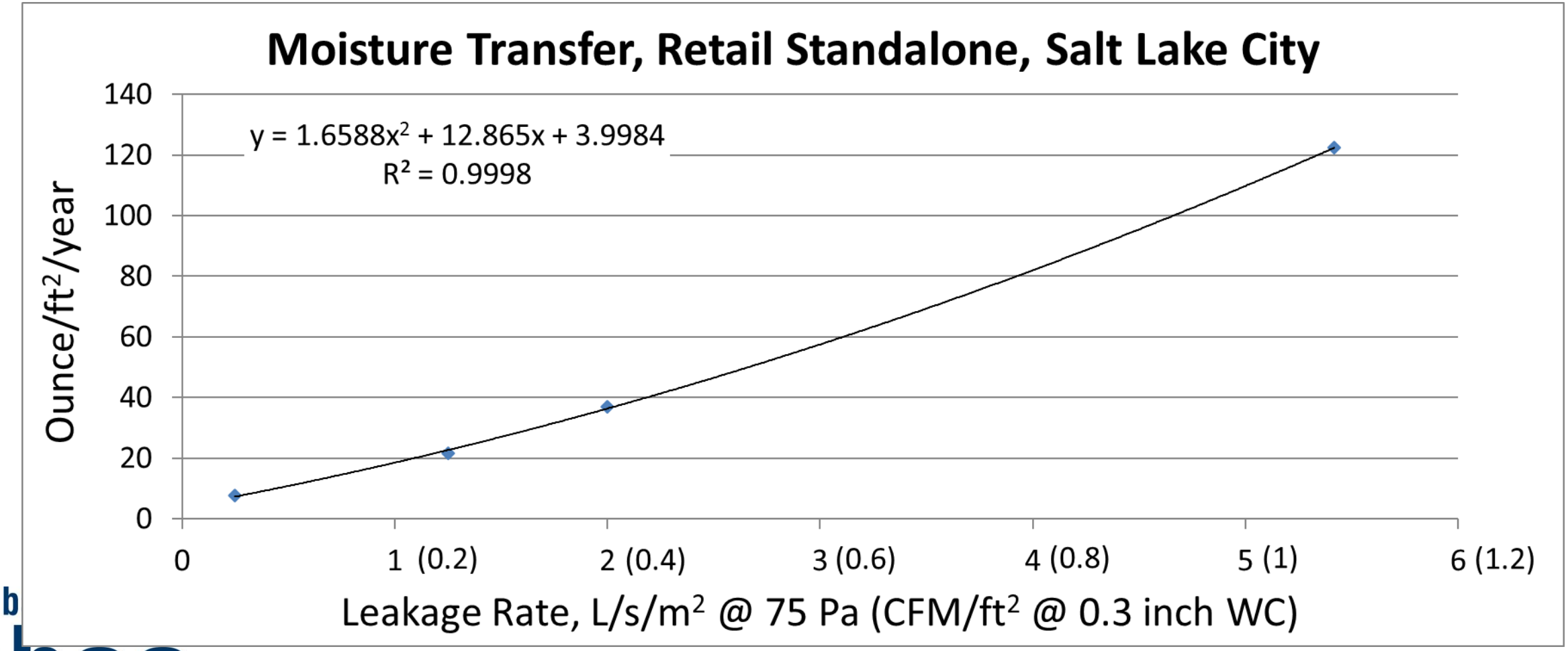
Moisture transfer – standalone retail, Miami



air b

abaa
association of
america

Moisture transfer – standalone retail, Salt Lake City

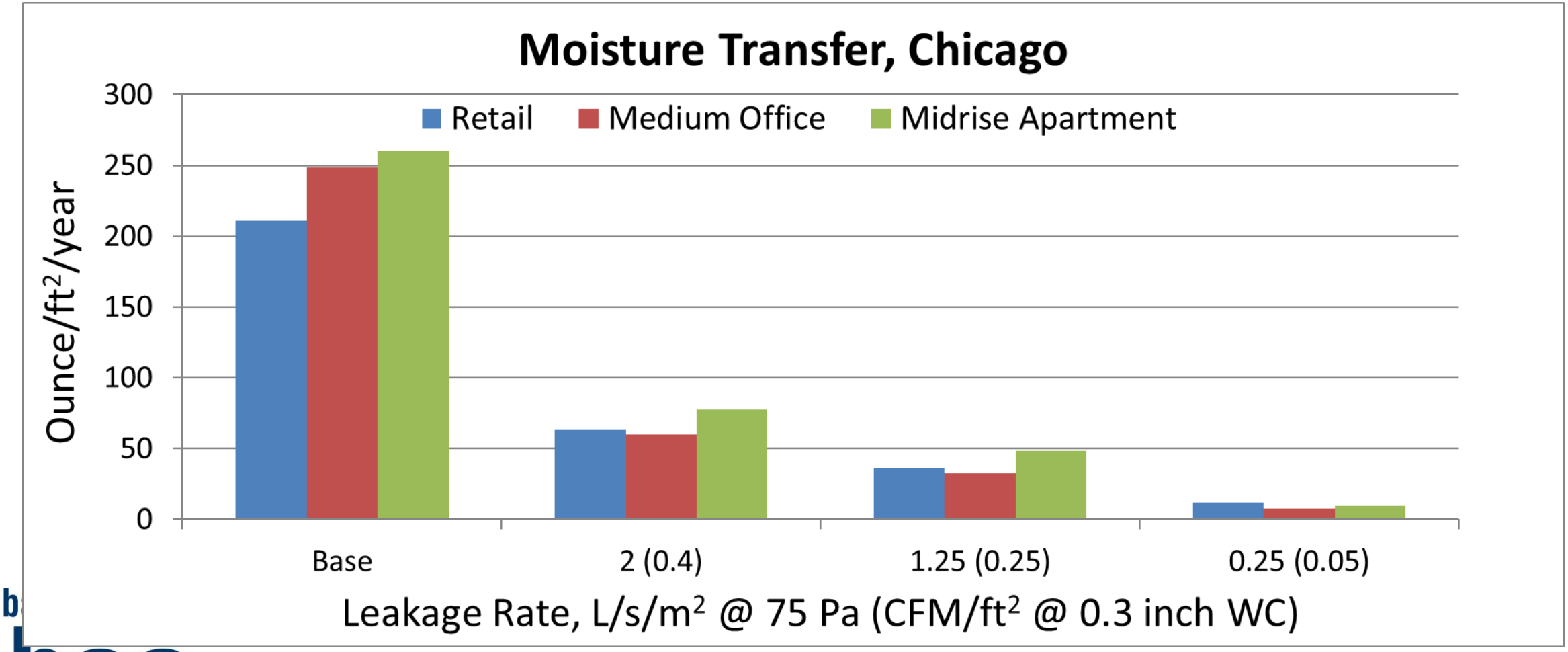


air b

abaa

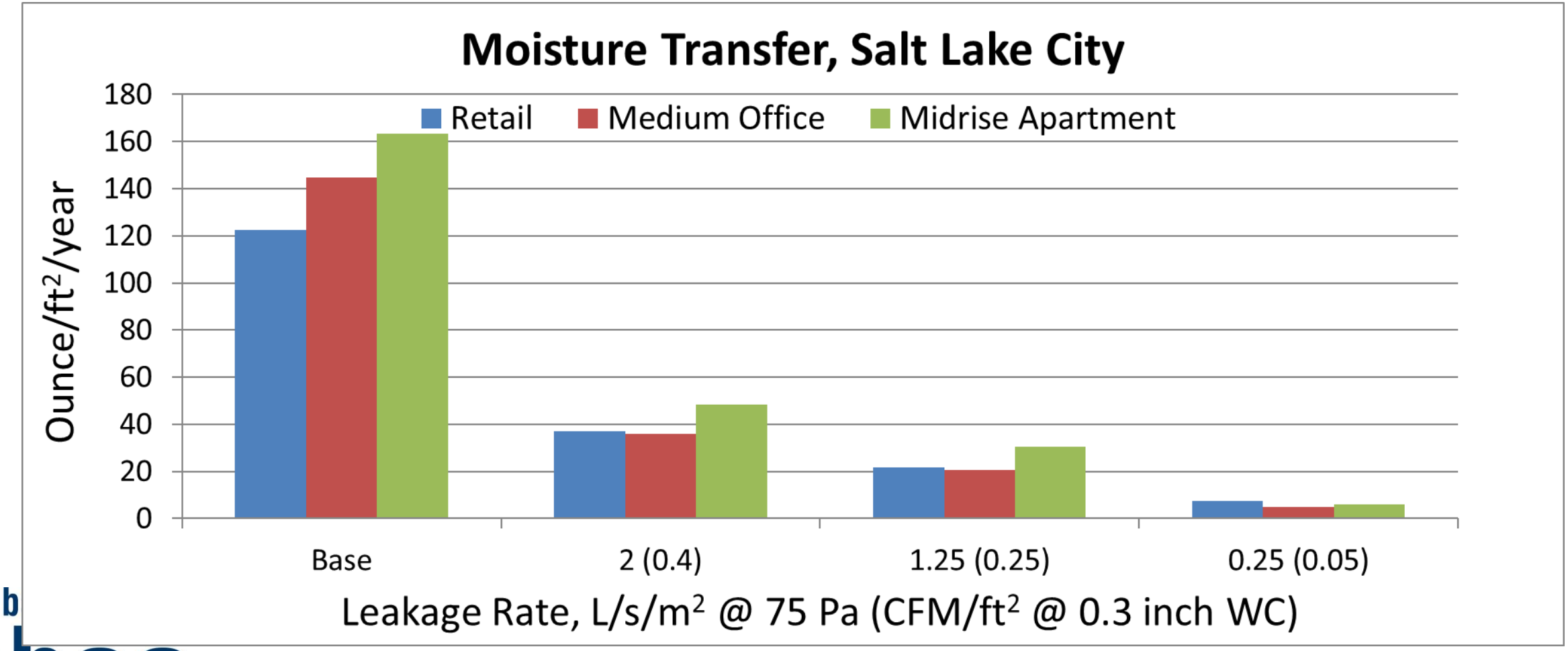
association of america

Moisture transfer by building type – Chicago



air b
abaa
association of
america

Moisture transfer by building type – Salt Lake City



air b

abaa
association of
america

Acknowledgments

- Laverne Dalgleish, ABAA
- Steven Emmerich, NIST
- Lisa Ng, PhD, NIST
- Diana Hun, PhD, ORNL
- Gina Accawi, ORNL

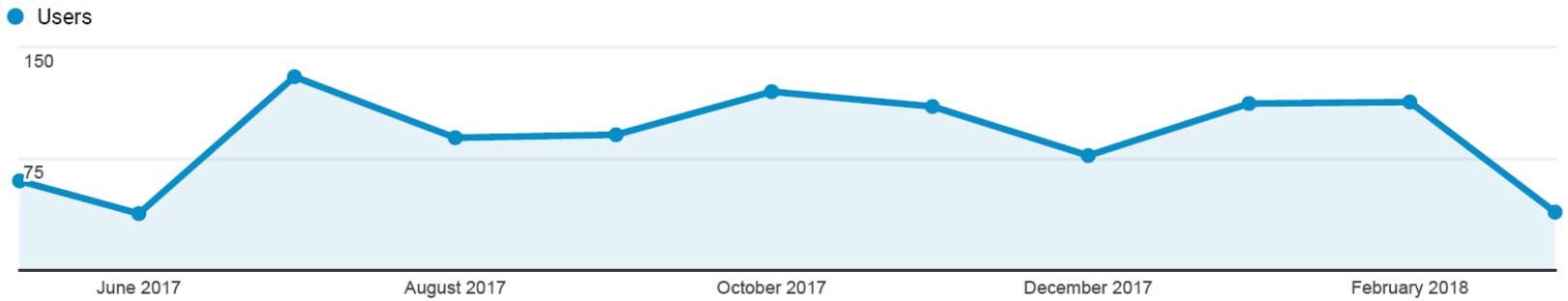
air barrier
abaa
association of
america

References

- DOE Commercial Prototype Building Models https://www.energycodes.gov/commercial-prototype-building-models
- Dols, W.S. and Polidoro, B. 2015. CONTAM User Guide and Program Documentation. Gaithersburg, MD: National Institute of Standards and Technology. Technical Note 1887.
- Emmerich, S.J., McDowell, T.P., and W. Anis. 2005. Investigation of the Impact of Commercial Building Envelope Airtightness on HVAC Energy Use. Gaithersburg, MD: National Institute of Standards and Technology. NISTIR 7238.
- IECC. 2015. International Energy Conservation Code.
- Ng, L.C., Musser A., Emmerich S.J., and A.K. Persily. 2012. Airflow and Indoor Air Quality Models of DOE Reference Commercial Buildings. Gaithersburg, MD: National Institute of Standards and Technology. Technical Note 1734.
- Polidoro, B., L. C. Ng and W. S. Dols (2016). "CONTAM Results Export Tool." NIST Technical Note 1912.
- Shrestha, S., D. Hun, L. Ng, A. Desjarlais, S. Emmerich, and L. Dalgleish. 2016. Online Airtightness Calculator for the US, Canada and China. Submitted to Thermal Performance of the Exterior Envelopes of Whole Buildings XIII International Conference.

air barrier
abaa
association of
america

User statistics



Users	Sessions	Avg. Session Duration
895	1,232	00:02:22

air barrier
abaa
association of
america

DOE commercial prototype building models (ASHRAE 90.1-2013) used

Building	Total Floor Area, ft^2	Number of Floors	Construction Volume Weights
Standalone Retail	24,695	1	15.3%
Mid-Rise Apartment	33,700	4	7.3%
Medium Office	53,600	3	6.0%
High-Rise Apartment	84,360	10	9.0%
Hospital	241,410	5	3.4%
Large Hotel	122,132	7 (including basement)	5.0%
Small Hotel	43,200	4	1.7%
Large Office	498,600	13 (including basement)	3.3%
Small Office	5,500	1	5.6%
Outpatient Healthcare	40,950	3	4.4%
Restaurant Fast Food	2,500	1	0.6%
Restaurant Sit Down	5,502	1	0.7%
Stripmall	22,500	1	5.7%
Primary School	73,960	1	5.7%
Secondary School	210,900	2	10.4%
Warehouse	49,495	1	16.7%

air barrier abaa association of america

Andre Desjarlais

desjarlaisa@ornl.gov

Dr. Som Shrestha

shresthass@ornl.gov

Visit our website: www.ornl.gov/buildings

Follow us on Twitter: @ORNLbuildings

Link to the calculator

https://airleakage-calc.ornl.gov

Discussion


OAK RIDGE
National Laboratory
BUILDING TECHNOLOGIES
RESEARCH AND
INTEGRATION CENTER