Cost-effectiveness Analysis of Building Air Leakage Testing

DOE Proposal: C-1; ICC proposal: TBA
For 2018 IECC commercial code
Pacific Northwest National Lab
September 2015
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PURPOSE

Determine cost-effective building size for air barrier testing.

BASIS

Simulation of change in leakage from 1.0 cfm/sf to 0.4 cfm/sf for the mid-rise apartment and large office buildings.

The cost-effectiveness analysis is conducted according to the DOE cost-effectiveness methodology.[1] In the DOE method, the long term economic impacts for two cases are determined:

- Scenario 1 is for publicly-owned buildings and is based on a FEMP method.[2]
- Scenario 3 is for privately-owned buildings and is based on the 90.1-2016 scalar method.[3]

DOE prototypes[4] for large office and mid-rise apartments are simulated in EnergyPlus.

40.0 year measure life is the accepted value used by ASHRAE 90.1 committee for envelope analysis.

Scenario 1 factors

Electric UPW factor[5] with 3% discount and EIA energy escalation for present value (PV) savings: 25.70
Blended Fossil UPW factor with 3% discount and EIA energy escalation for PV savings: 30.41
For years 31-40, the equivalent year 1-30 compound rate was applied
In Scenario 1, measures are found cost-effective when the savings to investment ratio (SIR) ≥ 1.0.

Scenario 3 factors

(90.1-2016) Scalar threshold :	Electric	18.2	17.5%	**Blended**
	Fossil	21.4	82.5%	**20.8**

In Scenario 3, measures are found cost-effective when the simple payback ≤ the scalar threshold.

[1] Hart, R., and Liu, B. (2015). *Methodology for Evaluating Cost-effectiveness of Commercial Energy Code Changes.* Pacific Northwest National Laboratories for U.S. Department of Energy; Energy Efficiency & Renewable Energy. PNNL-23923 Rev1. https://www.energycodes.gov/development/commercial/methodology.
[2] Fuller, Sieglinde, and Stephen Petersen. "LIFE-CYCLE COSTING MANUAL for the Federal Energy Management Program." NIST, U.S. Deptartment of Commerce, 1995. http://fire.nist.gov/bfrlpubs/build96/PDF/b96121.pdf.
[3] Based on the approach and assumptions established by the ASHRAE Standard 90.1project committee for 90.1-2016.
[4] Details on building prototypes available at: https://www.energycodes.gov/commercial-prototype-building-models.
[5] Rushing, Amy S., Joshua D. Kneifel, and Priya Lavappa. *Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis-2014: Annual Supplement to NIST Handbook 135*, 2015. http://dx.doi.org/10.6028/NIST.IR.85-3273-29.

ENERGY PRICES

Commercial Sector			2014	Annual Average		Most recent full year			
			2015 July	EIA Short Term Energy Outlook					
Fossil Price			Conversion to therms				quads heating per BEDB		UPW
Natural Gas	8.87	$/ kCuFt	0.097124	$0.8615	$/therm	1.69		89.4%	30.29
Heating Oil	3.72	$/ gal	1.385	$2.6859	$/therm	0.20		10.6%	31.44
Blended Fossil Rate				**$1.0555**	**$/therm**	1.90			**30.41**

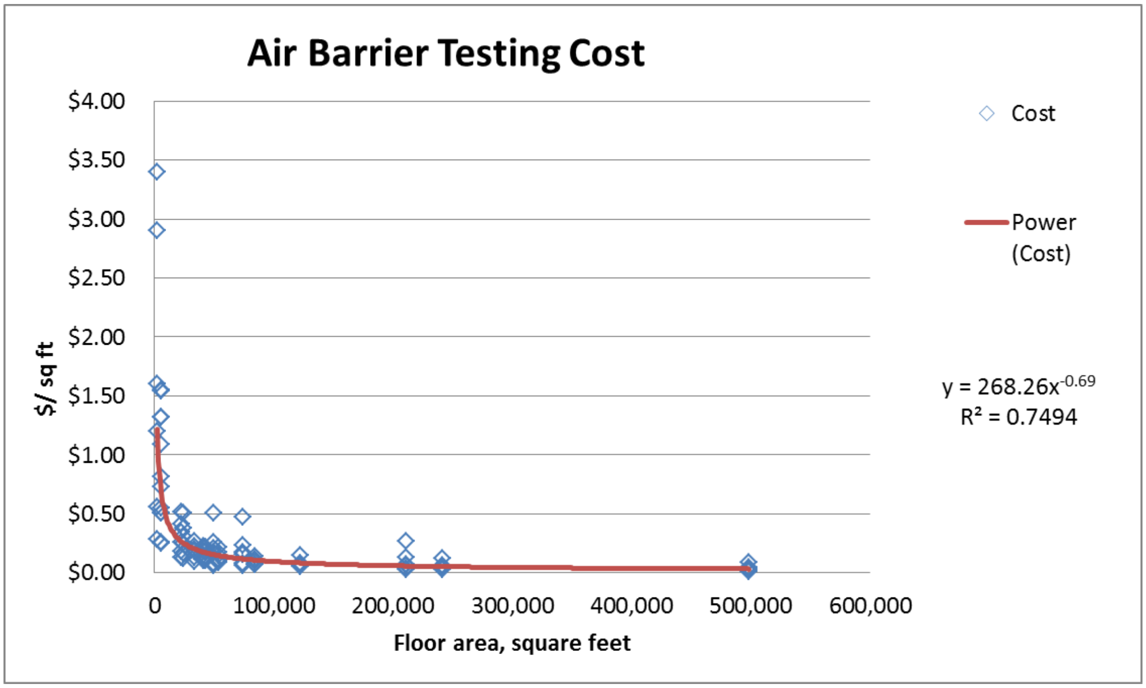
Prices	$0.1075	$/kWh	$1.0555	$/therm	(2014 EIA average)	for Scenario 1 analysis
	$0.1013	$/kWh	$1.0000	$/therm	SSPC 90.1 for 2016	for Scenario 3 analysis

Annual Energy Savings, $ per 1000 square foot of floor area (scenario 1)

Climate Zone	kWh/ 1000 sf/year		thm/1000 sf/year		Elec $/ 1000 sf/year		Gas $/1000 sf/year		Total $/ 1000sf/year	
	Lg Ofc	Mid Apt	Lg Ofc	Mid Apt	Lg Ofc	Mid Apt	Lg Ofc	Mid Apt	Lg Ofc	Mid Apt
1A	54.5	150.4	0.0	0.0	$5.85	$16.17	$0.00	$0.00	$5.85	$16.17
1B	16.6	122.3	0.0	0.0	$1.79	$13.15	$0.01	$0.00	$1.79	$13.15
2A	13.4	67.4	0.3	0.9	$1.45	$7.25	$0.35	$0.96	$1.80	$8.21
2B	1.6	268.5	0.6	1.1	$0.17	$28.87	$0.67	$1.17	$0.84	$30.04
3A	-9.7	41.7	3.0	9.3	-$1.04	$4.49	$3.14	$9.78	$2.10	$14.27
3B	-8.6	54.2	0.6	2.4	-$0.93	$5.82	$0.61	$2.52	-$0.32	$8.34
3C	-13.7	-7.2	0.1	0.8	-$1.48	-$0.77	$0.09	$0.81	-$1.39	$0.04
4A	-11.9	32.5	7.6	21.9	-$1.28	$3.50	$8.07	$23.11	$6.79	$26.61
4B	-20.4	11.9	2.3	5.5	-$2.20	$1.28	$2.46	$5.78	$0.26	$7.07
4C	-20.8	-33.3	3.3	10.9	-$2.24	-$3.58	$3.48	$11.45	$1.24	$7.88
5A	-14.8	2.6	10.5	32.4	-$1.60	$0.28	$11.04	$34.16	$9.44	$34.44
5B	-26.6	-4.0	5.6	12.7	-$2.86	-$0.43	$5.87	$13.45	$3.01	$13.01
5C	-16.7	-41.1	1.7	6.3	-$1.79	-$4.42	$1.79	$6.60	$0.00	$2.19
6A	-20.6	14.2	14.7	43.4	-$2.22	$1.53	$15.50	$45.78	$13.28	$47.32
6B	-36.1	-7.2	9.2	26.1	-$3.88	-$0.78	$9.76	$27.59	$5.88	$26.81
7	-19.8	-10.3	10.9	33.1	-$2.13	-$1.11	$11.50	$34.91	$9.36	$33.80
8	-19.5	-35.4	6.5	20.0	-$2.09	-$3.81	$6.90	$21.08	$4.81	$17.28
								Average	$3.81	$18.04

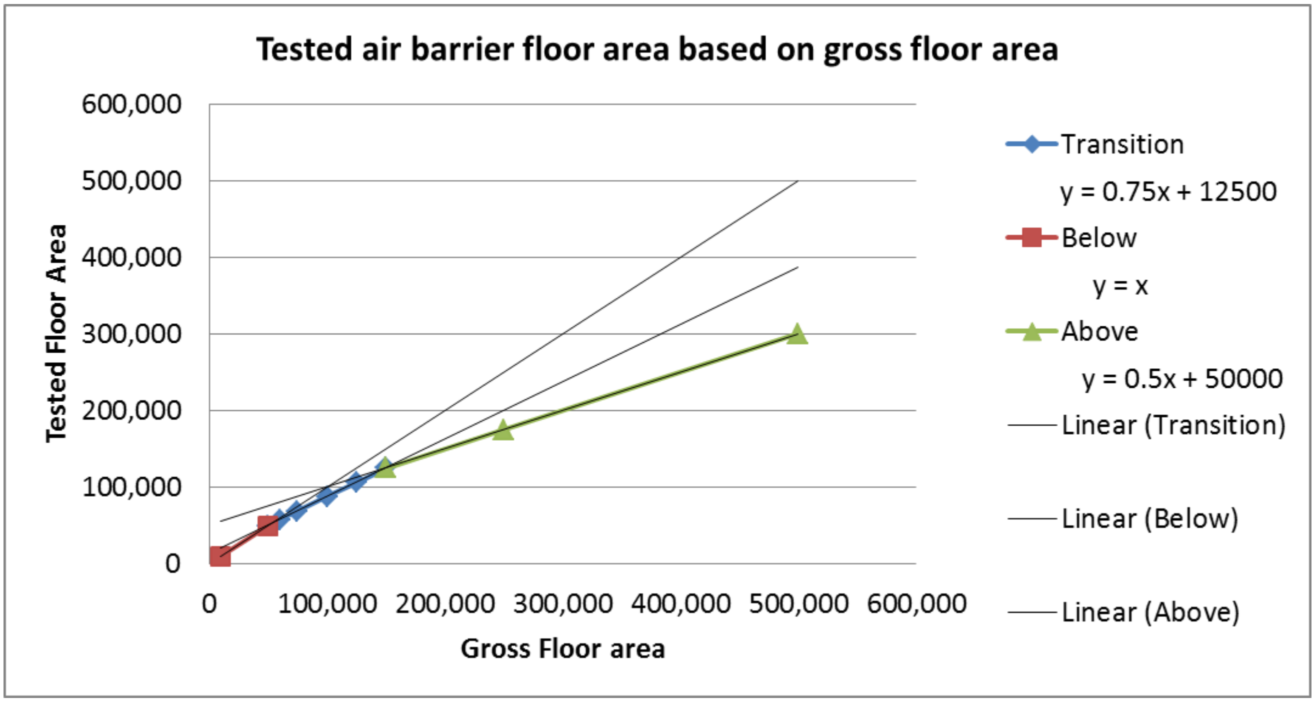
Measure Cost

Based on interviews with three providers, costs for a range of PNNL prototypes was determined:



A curve fit from the interview costs was used to develop a formula for cost per tested area of buildings. A provision in the proposal allows for only 25% of areas to be tested on mid floors in buildings over 50,000 square feet, so formulas for "tested area" relative to "total floor area" were developed:

- Below 50,000 square feet the full area is tested.
- From 50,000 to 150,000 square feet only 75% of the area above 50,000 square feet is tested.
- Above 150,000 square feet only 50% of the additional area is tested.



Cost-effectiveness

The cost-effectiveness is evaluated using Scenario 1 for the public sector and Scenario 3 for the private sector.[6] For Scenario 1, the savings to investment ratio (SIR) indicates a measure is cost-effective when greater than 1.0. In Scenario 3, the simple payback (Cost/annual savings) is compared to a scalar threshold that includes commercial discount rates and loan costs. When the payback is less than the threshold, a measure is considered cost-effective. The scalar threshold for blended savings over a 40 year measure life is 20.8 years. Results are shown only when testing is required in the proposal.

Cost-effectiveness Analysis:					DOE Commercial Methodology				Scenario 1		Scenario 3 (90.1-2016)	
Climate Zone	Testing Limit, 000 square feet		Added First cost for testing, $000		PV Savings, $000		Net PV Savings, $000		Savings to Investment Ratio		Simple Payback (20.8 threshold)	
	Lg Ofc	MidApt	Lg Ofc	MidApt	Lg Ofc	MidApt	Lg Ofc	MidApt	Lg Ofc	MidApt	Lg Ofc	MidApt
1A	75	17.5	$8.5	$5.5	$11.3	$7.3	$2.8	$1.8	1.3	1.3	20.5	20.6
1B	350	25	$12.2	$6.2	$16.2	$8.4	$4.0	$2.2	1.3	1.4	20.6	20.0
2A	350	50	$12.2	$7.7	$16.7	$10.8	$4.5	$3.1	1.4	1.4	20.6	19.9
2B	NR	9		$4.5		$7.0		$2.5		1.6		17.7
3A	350	25	$12.2	$6.2	$24.1	$10.3	$11.9	$4.1	2.0	1.7	17.5	18.4
3B	NR	50		$7.7		$11.3		$3.6		1.5		19.6
3C	NR	NR										
4A	75	9	$8.5	$4.5	$15.9	$7.1	$7.4	$2.6	1.9	1.6	17.6	19.9
4B	NR	60		$8.0		$12.5		$4.5		1.6		19.9
4C	NR	50		$7.7		$12.8		$5.1		1.7		20.6
5A	40	6	$7.2	$4.0	$11.8	$6.3	$4.6	$2.3	1.6	1.6	20.1	20.4
5B	200	25	$10.8	$6.2	$21.0	$9.9	$10.2	$3.7	1.9	1.6	18.8	20.1
5C	NR	NR										
6A	40	6	$7.2	$4.0	$16.6	$8.6	$9.4	$4.6	2.3	2.1	14.3	14.9
6B	75	9	$8.5	$4.5	$14.8	$7.4	$6.3	$2.9	1.7	1.6	20.3	19.7
7	40	6	$7.2	$4.0	$11.8	$6.2	$4.6	$2.2	1.6	1.5	20.3	20.8
8	200	17.5	$10.8	$5.5	$31.2	$9.5	$20.4	$4.0	2.9	1.7	11.8	19.2
Average:			**$9.57**	**$5.75**	**$17.4**	**$9.0**	**$7.8**	**$3.3**	**1.8**	**1.6**	**18.4**	**19.4**

NR = Testing Not Required

Conclusion

Air barrier testing is cost-effective in multiple climates; although for smaller buildings it is more likely to be cost-effective for residential buildings than for non-residential commercial buildings, as they typically have less pressurization. Larger buildings have a lower testing cost relative to savings. In some climates, air barrier testing may not be cost-effective for smaller building sizes, so a size limit was established for each climate zone.

Air barrier testing is recommended for building type and size in climates where it is found to be cost-effective.

[6] Hart, Reid, and Bing Liu. "Methodology for Evaluating Cost-Effectiveness of Commercial Energy Code Changes." Pacific Northwest National Laboratories for U.S. Department of Energy; Energy Efficiency & Renewable Energy., August 2015. https://www.energycodes.gov/development/commercial/methodology.