MULTI-FAN BLOWER DOOR TESTING LESSONS LEARNED

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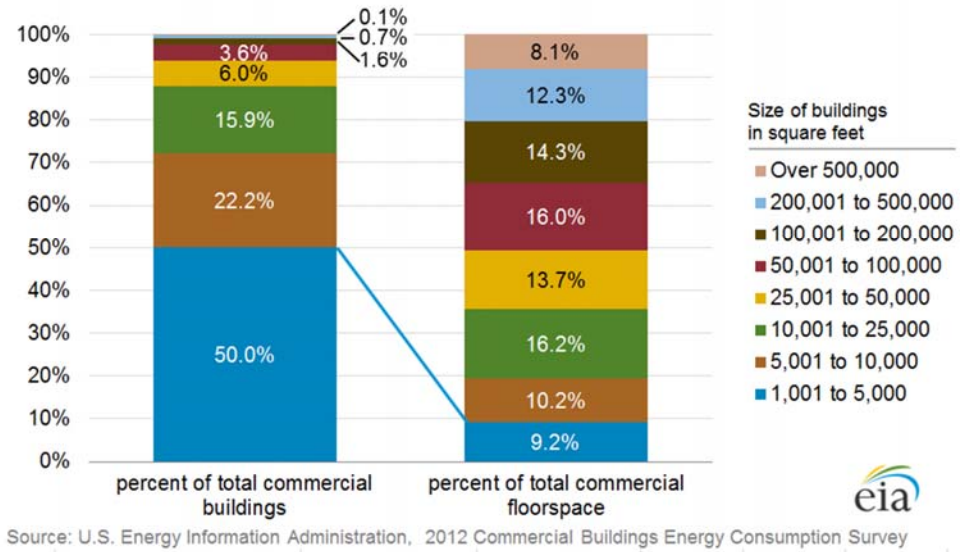
OVERVIEW OF PRESENTATION

- Why small commercial?
- ACBI Overview
- Southface's approach
- Lesson's learned
- Multi-Fan BD testing
- Cool BD videos
- New free resources
- Next steps

WHY SMALL COMMERCIAL? (≤50K SF)

Figure 2. About half of all commercial buildings make up less than 10% of total floorspace



Source: U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey

HERS RATERS & SMALL COMMERCIAL

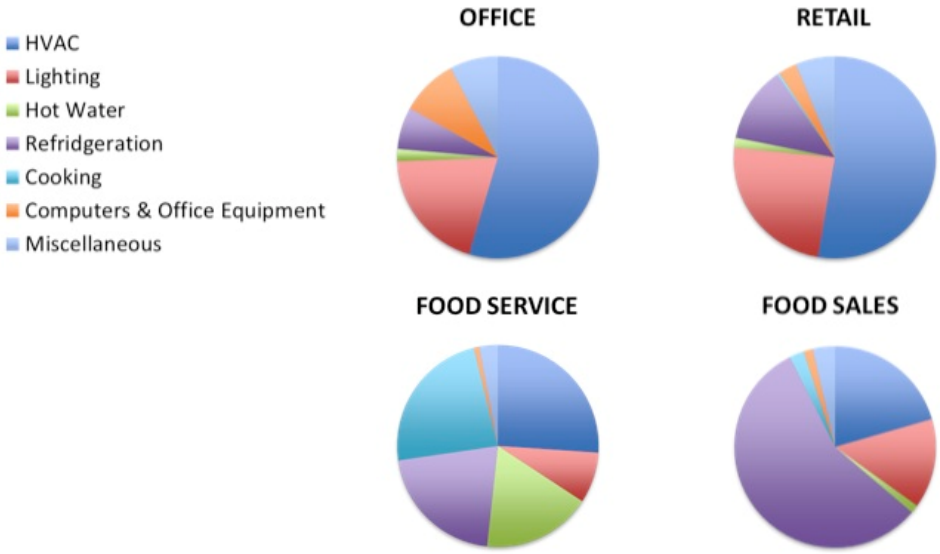
- New market
- Building characteristics
- Systems
- Processes
- Who else is serving this market?

1. Reduce Loads
2. Match Systems to Reduced Loads
3. Use High Efficiency Systems
4. Refine System Integration

Advanced Energy Design Guidelines

SMALL COMMERCIAL ENERGY CONSUMPTION

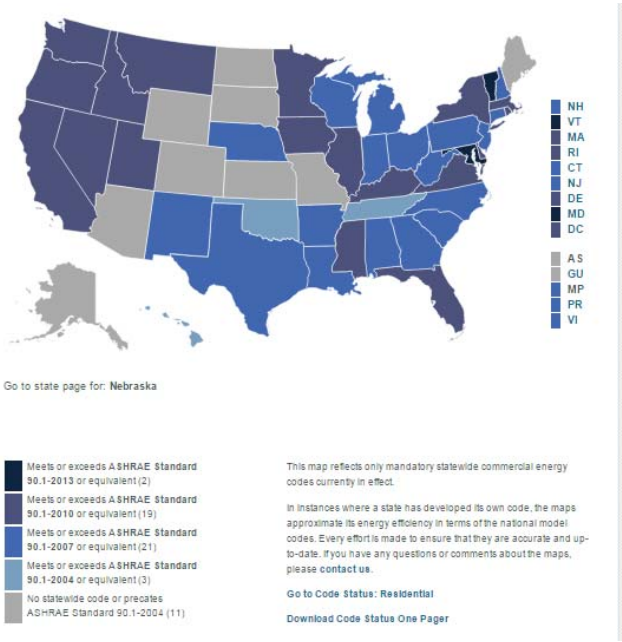
What is the biggest use of energy in small commercial buildings?



CODES AND PROGRAM REQUIREMENTS

Air Leakage Testing

- GSA – new buildings
- Washington – >5 stories
- US Army Corps – new buildings and major renovations
- ASHRAE 189.1
- LEED BD+C
- EarthCraft Light Commercial
- IECC 2012 & beyond



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ADVANCED COMMERCIAL BUILDINGS INITIATIVE

Research

Demonstrate

Deploy

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PARTNERSHIPS

GRANTS TO GREEN™

OAK RIDGE National Laboratory

RESURGENS 1867 ATLANTA, GA. 1965

ATLANTA BETTER BUILDINGS CHALLENGE

Vermont Energy Investment Corporation

BOYS & GIRLS CLUB OF AMERICA

Georgia Tech College of Architecture

EARTH CRAFT Light Commercial ™

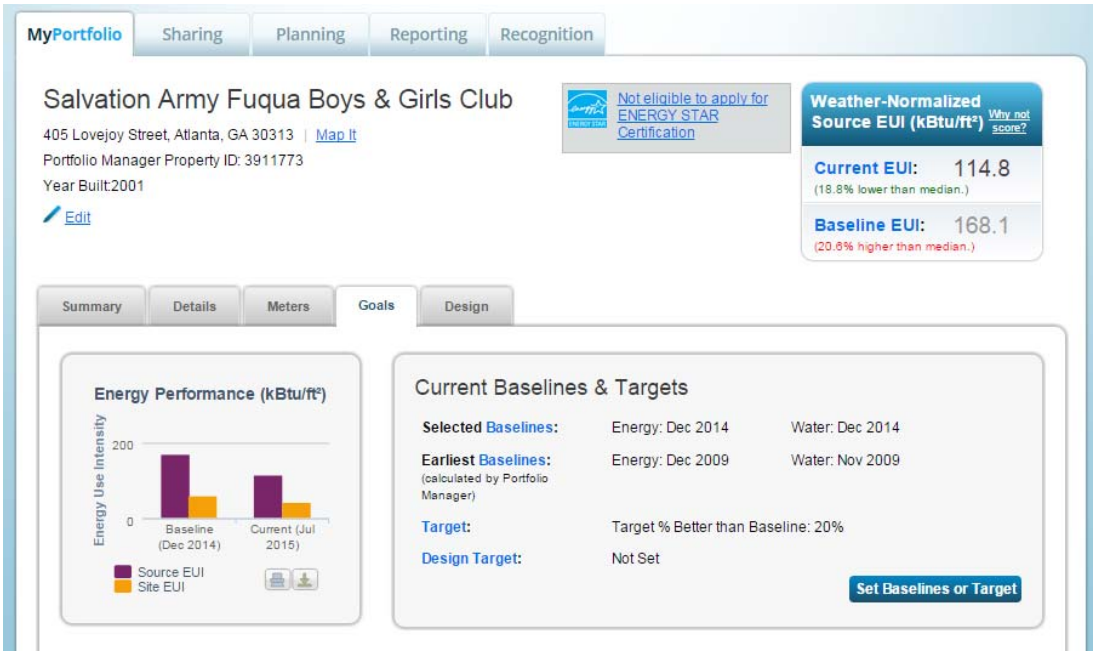
SOUTHFACE APPROACH

20% improvement over existing

1. Benchmark
2. Assessment
3. Analysis
4. Recommendations & Projected Savings
5. Bids & Implementation
6. Verify
7. Ongoing support

LC1

BENCHMARK – ENERGY STAR PORTFOLIO MANAGER (ESPM)



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Slide 11

LC1 change these to show the benchmakring bit of ESPM isntead of the goals and anlaysis bit
Laura Capps, 9/18/2015

BENCHMARK – ESPM

Metrics Comparison for Your Property & Your Target Change Time Period

Metric	Jun 2014	Current (Jul 2015)	Target*	Median Property*
ENERGY STAR score (1-100)	Not Available	Not Available	Not Available	50
Source EUI (kBtu/ft²)	205.6	114.8	136.5	141.4
Site EUI (kBtu/ft²)	74.0	40.5	48.1	49.9
Source Energy Use (kBtu)	3,565,592.8	1,991,440.5	2,366,529.3	2,452,736.3
Site Energy Use (kBtu)	1,283,525.9	702,880.8	833,278.8	865,695.5
Energy Cost ($)	41,538.34	28,032.45	29,955.46	34,525.86
Total GHG Emissions (Metric Tons CO2e)	203.8	114.0	135.5	140.4

* To compute the metrics at the target and median levels of performance, we will use the fuel mix associated with your property's current energy use.

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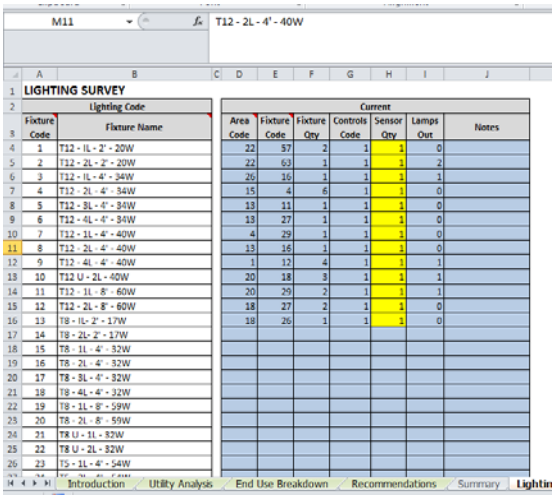
ASSESSMENT & ANALYSIS



M11 | T12 - 2L - 4' - 40W

LIGHTING SURVEY

	Lighting Code		Current						
	Fixture Code	Fixture Name	Area Code	Fixture Code	Fixture Qty	Controls Code	Sensor Qty	Lamps Out	Notes
4	1	T12 - 1L - 2' - 20W	22	57	2	1	1	0	
5	2	T12 - 2L - 2' - 20W	22	63	1	1	1	2	
6	3	T12 - 1L - 4' - 34W	26	16	1	1	1	1	
7	4	T12 - 2L - 4' - 34W	15	4	6	1	1	0	
8	5	T12 - 3L - 4' - 34W	13	11	1	1	1	0	
9	6	T12 - 4L - 4' - 34W	13	27	1	1	1	0	
10	7	T12 - 1L - 4' - 40W	4	29	1	1	1	0	
11	8	T12 - 2L - 4' - 40W	13	16	1	1	1	0	
12	9	T12 - 4L - 4' - 40W	1	12	4	1	1	1	
13	10	T12 U - 2L - 40W	20	18	3	1	1	1	
14	11	T12 - 1L - 8' - 60W	20	29	2	1	1	1	
15	12	T12 - 2L - 8' - 60W	18	27	2	1	1	0	
16	13	T8 - 1L - 2' - 17W	18	26	1	1	1	0	
17	14	T8 - 2L - 2' - 17W							
18	15	T8 - 1L - 4' - 32W							
19	16	T8 - 2L - 4' - 32W							
20	17	T8 - 3L - 4' - 32W							
21	18	T8 - 4L - 4' - 32W							
22	19	T8 - 1L - 8' - 59W							
23	20	T8 - 2L - 8' - 59W							
24	21	T8 U - 1L - 32W							
25	22	T8 U - 2L - 32W							
26	23	T5 - 1L - 4' - 54W							

Introduction | Utility Analysis | End Use Breakdown | Recommendations | Summary | Lightin

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RECOMMENDATIONS

Energy Projects (7)

Name	Date Implemented	Estimated Savings
Domestic hot water loop timer	12/31/2014	$175
High-efficiency appliances	12/31/2014	$4,921
Install vending machine controls	12/31/2014	$161
LED lighting & lighting controls	11/20/2014	$6,875
Low-flow plumbing fixtures	9/30/2014	$344
Remove old appliance	9/1/2014	$105
Upgrade HVAC controls	10/24/2014	$4,204

Total Project Investment
$78,681.00
Total Estimated Savings
$16,785.00

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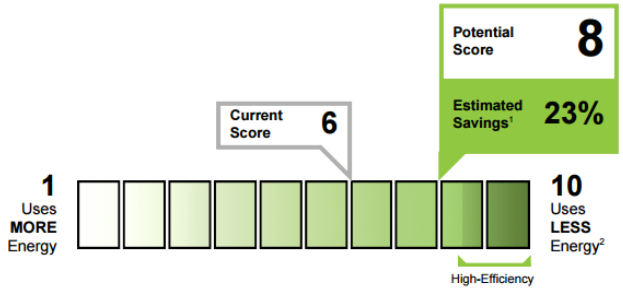
ASSESS –BUILDING ENERGY ASSET SCORE

BUILDING ENERGY 1
ASSET SCORE
OVERALL BUILDING SCORE

BUILDING INFORMATION
Fuqua Boys & Girls Clubs-Rerun
405 Lovejoy Street
Atlanta, GA 30313

Building Type: **Education**
Gross Floor Area: **17,480 ft²**
Year Built: **2001**
Score Date: **02/17/2015**
Building ID #: **1338**



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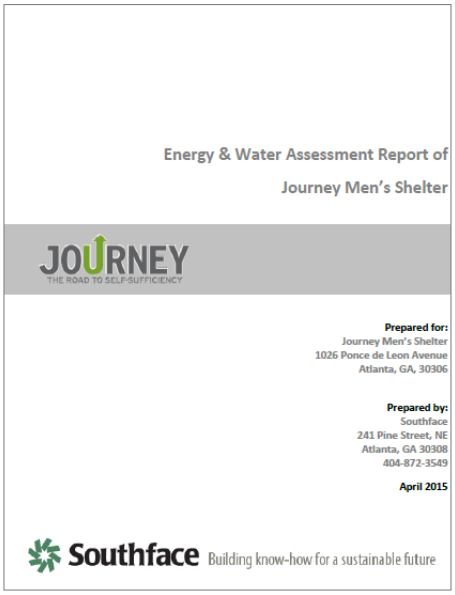
PRESENTATION & REPORT



Energy & Water Assessment Report of

Journey Men's Shelter

JOURNEY

THE ROAD TO SELF-SUFFICIENCY

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April 2015

Southface Building know-how for a sustainable future

BIDS, IMPLEMENTATION & VERIFICATION

1. **ENERGY STAR Water Heater**
   - ENERGY STAR Tankless Water Heater minimum efficiency rating at or above 93% with combustion air inlet and exhaust piping fully ducted to exterior
   - Activation flow rate at or below lowest flow water fixture (0.5 GPM)
   - Water temperature max 125°F
   - Accessible hot water lines insulated to min R-4

2. **Bathroom Efficiency**
   - Bathroom sinks and hand sink in kitchen (4 sinks total), faucets are WaterSense labeled with maximum flow rate of 0.5 GPM
   - Shower heads (2 heads total) are detention grade and WaterSense labeled with maximum flow rate of 1.5 GPM or less
   - Toilets (3 toilets total) are single flush, WaterSense labeled with maximum flush rate of 1.28 GPF
   - Urinal (1 urinal total) is WaterSense labeled with maximum flush rate of 0.125 GPF

3. **Kitchen Efficiency**
   - ENERGY STAR Commercial Refrigerator (~49 CF capacity)
   - ENERGY STAR Residential Refrigerator (~23 CF capacity)
   - ENERGY STAR Commercial Dishwasher: under-the-counter high-temperature with built-in sanitation heat-booster
   - Kitchen faucets (up to 2 faucets total) maximum flow rate of 2.2 GPM or less and preferably WaterSense labeled
   - Pre-rinse spray valves (up to 2 total) are WaterSense labeled with maximum flow rate of 1.28 GPM or less

PERFORMANCE – FOLLOW UP

Performance Comparison

		Progress		Performance Goals		
	Year Ending 12/31/2014 (Baseline)	Year Ending 7/31/2015 (Selected)	% Change	Property's Target	National Median	ENERGY STAR Score of 75
ENERGY STAR Score	N/A	N/A	N/A	N/A	50	75
Energy						
Site EUI (kBtu/ft²)	60.1	40.5	-32.5	48.1	49.9	N/A
Source EUI (kBtu/ft²)	170.6	114.8	-32.7	136.5	141.4	N/A
$	37,444.33	28,032.45	-25.14	29,955.46	34,525.86	N/A
$/ft²	2.16	1.62	-25.14	1.73	1.99	N/A
Greenhouse Gas Emissions						
Metric Tons CO2e/year	169.3	114	-32.66	135.5	140.4	N/A
kgCO2e/ ft2/year	9.8	6.6	-32.66	7.8	8.1	N/A

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LESSONS LEARNED – LIGHT COMMERCIAL

- Commercial Buildings are Systems Too!
  - Subcontractors and repair persons only know what they know
  - "Sprinkler pipes could freeze – better heat the vented attic!"
- Occupants aren't "Owner" of commercial spaces
  - Turn things off? – not my job!
  - "Maybe it's supposed to be on…"
- No feedback
  - Accountant pays utility bills but doesn't share cost implications with others
- Landlord focus is on complaints
  - Often, doesn't care about utilities
- Designers still old school –
  - Cheap first cost
  - Aesthetics

Light commercial projects typically don't have facility staff!

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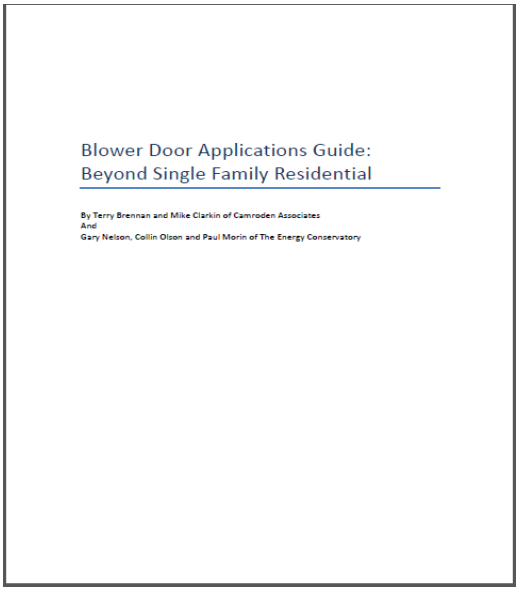
LESSONS LEARNED

- Utility rate structures matter
- Equipment off when unoccupied
- Combustion safety
- LED upgrades
  - New LED fixture
  - Keep fixture housing + LED "guts"
  - Swap LED tubes (ballasts)
- Vending machines
- Hot water
- Sprinkler piping
- Verification
- Implementation ≠ job complete
  - Top down support & Education
- Ventilation

MULTI-FAN BLOWER DOOR TESTING - AN EXCELLENT RESOURCE

http://support.energyconservatory.com/hc/en-us/articles/202478994-Beyond-Residential

- Explains both theory and application
- Great websites, videos and training information from both:
  - Retrotec
  - Energy Conservatory


Blower Door Applications Guide:
Beyond Single Family Residential

By Terry Brennan and Mike Clarkin of Camroden Associates
And
Gary Nelson, Collin Olson and Paul Morin of The Energy Conservatory

BIG PICTURE TEST PROCESS

- Follow a protocol
- Map equipment location
- Pre-test planning
  meeting of all participants – assign roles/stations
- Gather all equipment – confirm that it works
- Arrive, install equipment & prep building for testing
- Use software to perform testing
- Diagnose leaks and document results

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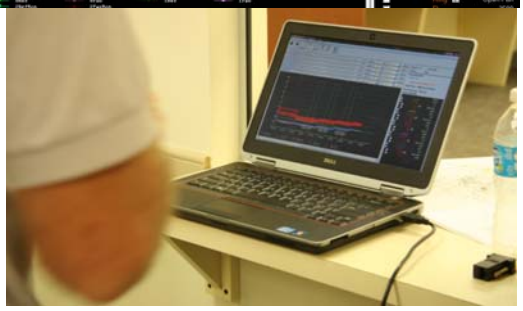
BD TESTING COMMERCIAL BUILDINGS

- Configure hardware and run software
- Prompts for baseline(s)
- Prompts for data recording periods
- Graphs results



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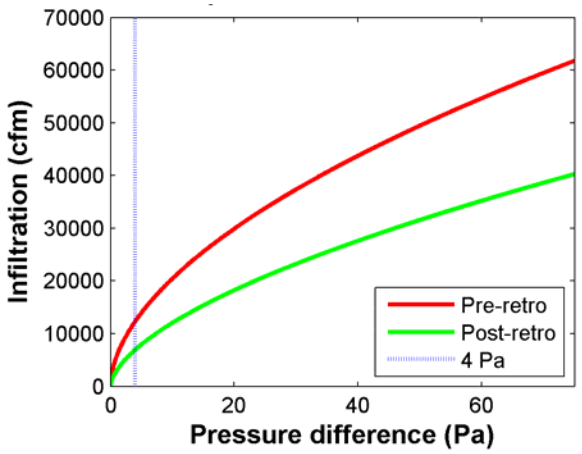
MULTI-POINT CURVE FIT – CONFUSING RESULTS

- ASTM Standard E779-03[3]: multi point test from ±20 Pa to ±75 Pa

Power Law equation: $Q = C * \Delta P^n$

- Q – infiltration rate
- C – flow coefficient
- ΔP – pressure difference across envelope
- n – flow exponent



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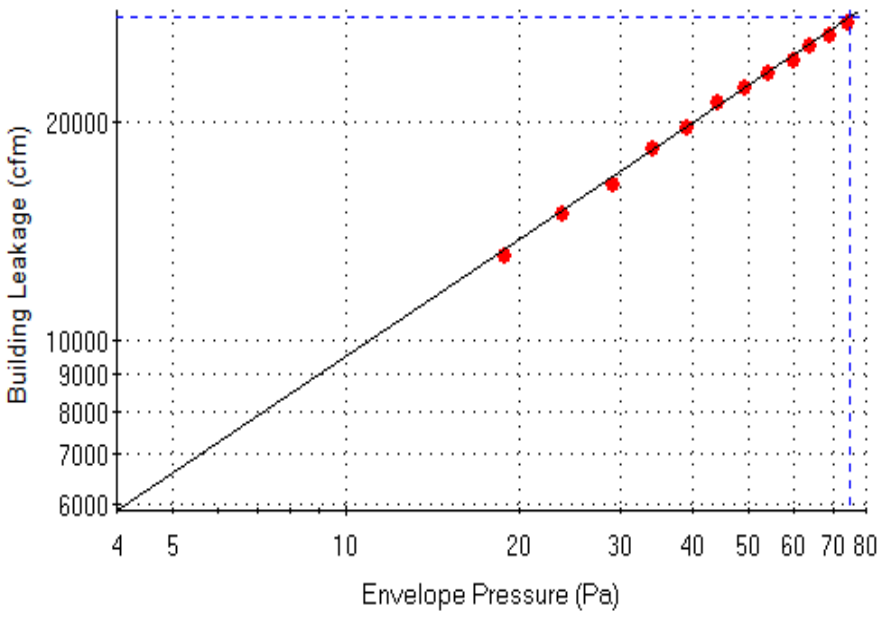
A BETTER WAY TO PLOT THE RESULTS

- Data becomes easier to read when plotted on logarithmic scale
- Curve allows leakage estimation at any pressure (e.g. 4 Pa)



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ELR75 – A BETTER METRIC

- Leakage occurs through skin of building (not through volume)
- Normalizing leakage at 75Pa (0.3 in w.c.) based on shell area is most common for commercial buildings

Example Calculation

A 1,280 square foot building has an SFBE of 3,224 square feet and a measured fan flow of 1,483 at CFM_{75}. Determine the Envelope Leakage Ratio at 75 Pa by dividing the cubic feet per minute of air volume moved through the fan by the total square footage of the building thermal envelope.

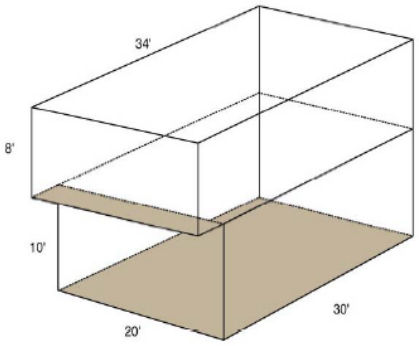
Top Flat Ceiling Area
$20'x\ 34' = \mathbf{680ft^2}$

Building Envelope Floor Area (includes shaded area)
$20'x\ 30' + 20'\ x\ 4' = \mathbf{680ft^2}$

Gross Exterior Insulated Wall Area $= \mathbf{1,864ft^2}$
1st Floor: $(20' + 30' + 20' + 30) \times 10' = 1{,}000ft^2$
2nd Floor: $(20' + 34' + 20' + 34') \times 8' = 864ft^2$

$\boldsymbol{SFBE} = 680ft^2 + 680ft^2 + 1864ft^2 = \mathbf{3,224ft^2}$

$\boldsymbol{Fan\ Flow\ Measurement} = \mathbf{1,483\ CFM_{75}}$



$$\boldsymbol{ELR_{75}} = \frac{\boldsymbol{CFM_{75}}}{\boldsymbol{SFBE}}$$

$$\boldsymbol{ELR_{75}} = \frac{1{,}483\ CFM_{75}}{3{,}224\ sf}$$

$\boldsymbol{ELR_{75}} = \mathbf{0.46}$ *Envelope Passes*

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- Utility Chases
- Metal Roof Decking
- Gabled Roof Junctions
- Mechanical RTU Penetrations
- Roof Membrane Connections

BD REVEALS COMMON LEAKAGE PATHWAYS

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UTILITY CHASE

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METAL BUILDING ROOF

Roof above shims

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GABLED ROOF

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RTU LEAKAGE

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FLAT ROOFED STRIP MALL

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PARAPET LEAK

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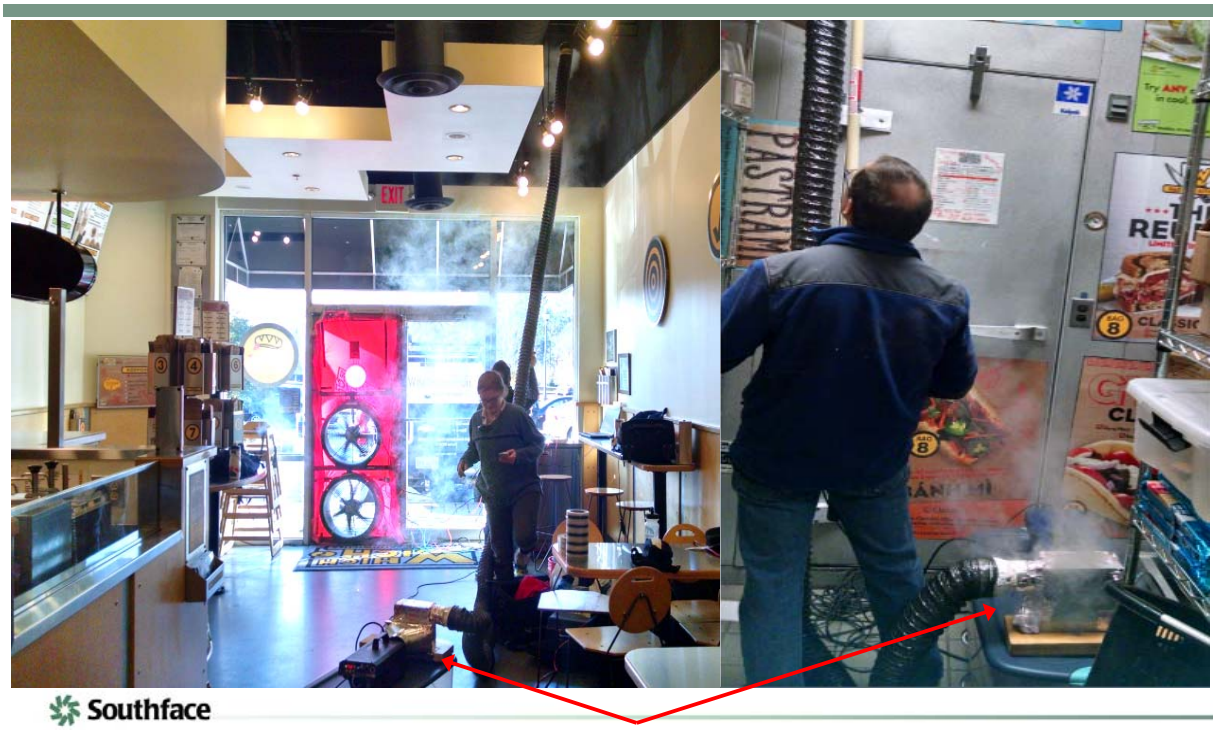
HOW TO GET FOG IN THE RIGHT PLACE



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INFLATED TPO MEMBRANE

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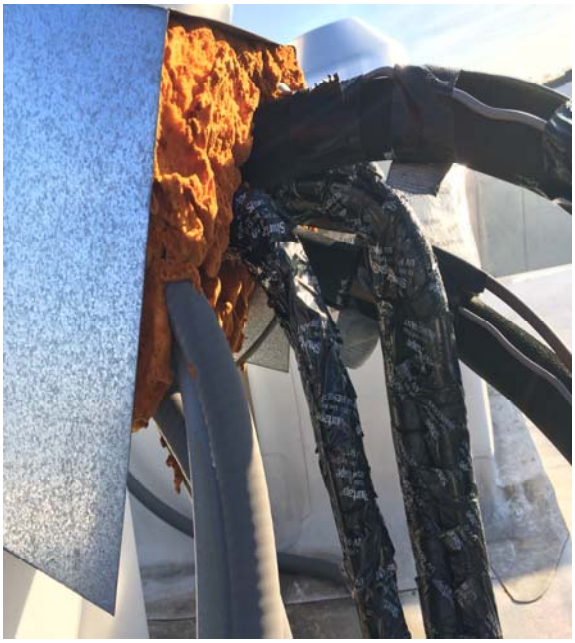
DETAILS



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WHAT'S WRONG?

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COMBUSTION SAFETY

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ORIGINAL 12 BUILDINGS

Test Buildings	Date of Test	Cond. Floor Area (s.f.)	SFBE	# of Stories	ELR75	Depressurization @-75Pa (masked)	Pressurization @+75Pa (masked)
	7/17/2014	17,283	48,330	1	**0.240**	11,602	12,355
	7/30/2014	2,318	9,775	1	**0.141**	1,378	1,366
	6/19/2014	3,533	12,437	2	**0.189**	2,353	2,674
	8/6/2014	5,946	11,637	3	**0.167**	1,938	2,331
	9/16/2014	12,864	36,845	1	**0.456**	16,794	20,319
	5/20/2014	11,117	29,008	3	**0.461**	13,365	14,234
	5/15/2014	17,176	41,635	1	**0.560**	23,322	23,539
	4/10/2014	5,910	15,422	1	**0.702**	10,823	9392**
	6/10/2014	34,200	69,600	2	**0.887**	61,751	74,721
	10/10/2014	34,200	69,600	2	**0.578**	40,212	44,683
	5/28/2014	3,035	8,804	1	**1.277**	11,245	12,154
	11/22/2014	3,035	8,804	1	**1.412**	12,428	12,422
	6/19/2014	7,912	20,956	1	**0.423**	8,854	9,234
	7/15/2014	5,020	15,402	2	**1.438**	22,151	22,308

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ANALYZING TESTING RESULTS

- **All buildings are created unequal** – no apparent correlation between age, type of construction, location, etc.
- **Air Sealing** – starts at design
- **Existing buildings** – can be retro sealed
- **Designed air barrier** – 0.25 ELR_{75}; (average existing 0.76 – over 3 times leakier!)
- **Modeling tools** vary significantly in predicted savings from air sealing – approximately~10%

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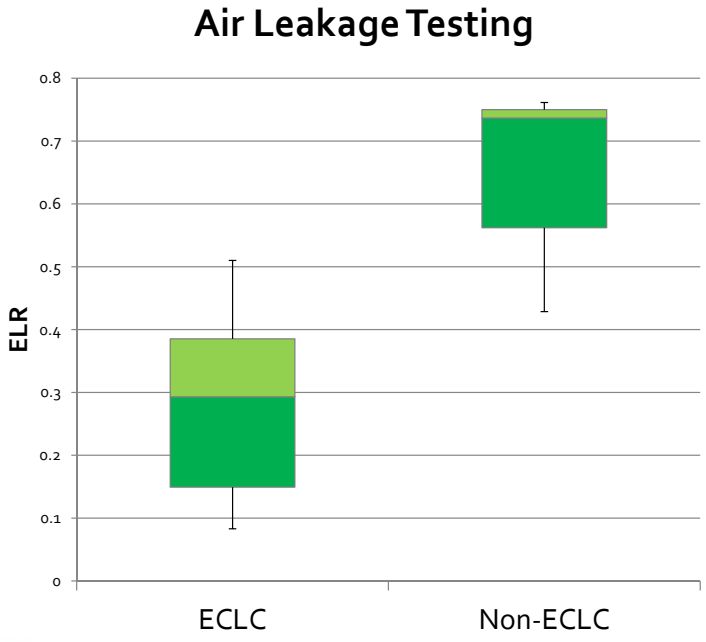
BUILDING ENVELOPE



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ADDITIONAL BUILDINGS – SIMILAR RESULTS

Test Buildings	Date of Test	Cond. Floor Area (s.f.)	SFBE	# of Stories	ELR75	Depressurization @-75Pa (masked)	Pressurization @+75Pa (masked)
	11/11/2014	4,261	13,219	1	0.429	5,666	5,518
	11/17/2014	6,692	16,829	2	1.201	20,214	19,589
	12/4/2014	2,128	5,760	1	0.623	3,587	3,628
	12/10/2014	1,081	3,562	1	0.626	2,230	2,269
	12/15/2014	1,480	5,480	1	0.562	3,081	3,501
	12/16/2014	2,207	8,878	1	0.750	6,662	6,745
	12/17/2014	1,586	6,743	1	0.761	5,134	5,134
	12/18/2014	1,895	7,907	1	0.737	5,825	5,662
	12/19/2014	1,561	6,674	1	0.330	2,200	2,181
	1/14/2015	12,142	32,873	1	0.639	21,020	22,286
	2/4/2015	3,416	9,336	1	0.493	4,601	4,672
	2/9/2015	4,236	10,390	1	0.500	5,195	5,194
	11/12/2015	11,417	20,297	3	0.184	3,740	4,738
	1/11/2016	3,020	8,123	1	0.517	4,200	4,553
	1/12/2016	4,315	14,359	1	1.028	14,758	16,428
	1/13/2016	3,900	12,000	1	1.244	14,933	15,513
	8/22/2012	21,628	44,259	2	0.339	15,019	n/a
	5/22/2014	11,202	37,370	1	0.188	7,030	n/a
	6/11/2014	1,634	4,847	2	0.394	1,910	2,352
	6/11/2014	500	2,545	1	0.251	638	791
	7/10/2014	6,082	13,937	1	1.021	14,224	
	7/29/2014	4,615	11,165	1	1.296	14,467	15,824
	8/4/2014	4,615	14,668	1	0.581	8,515	
	8/18/2014	4,615	14,668	1	0.422	6,192	6,402
	8/26/2014	1,135	3,949	1	0.313	1,238	
	8/26/2014	1,680	6,409	1	0.360	2,310	
	10/2/2014	1,135	3,949	1	0.13	514	
	10/2/2014	1,680	6,409	1	0.12	798	

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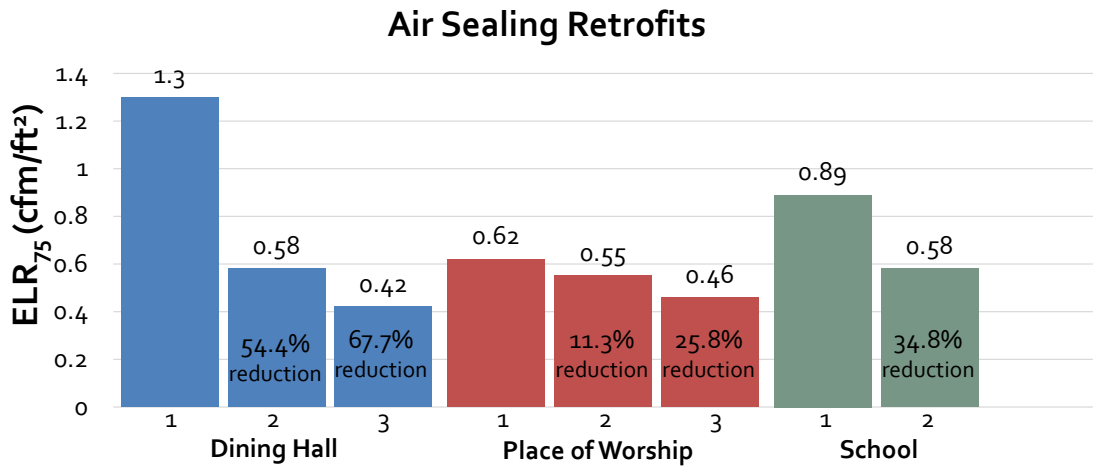
AIR SEALING RETROFITS



Air leakage of existing buildings can be substantially reduced with spray foam

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ENERGY MODELING CHALLENGES

- Commercial building air leakage testing is in its infancy (<400 buildings in largest known database); modeling default values are unsubstantiated
- Input for modeling software varies: ACH_{nat}, ACH_{50}, cfm/ft² of floor area, cfm_4/ft^2 of envelope area @ 4 Pa (ELR_4)
- Testing is conducted at accelerated pressures to minimize other driving forces – must extrapolate from multipoint regression analysis

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TESTING PROCEDURE LESSONS LEARNED

- Reinforce masking
- Duplicate fans
- Foam insulation tubes
- Theatrical fog machine, flex duct and a really long pole
- Site communication

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OTHER RESEARCH

- Atlanta Better Buildings Challenge
  - Small commercial on campus
- Third-party impact
- PPESCO
- EarthCraft Light Commercial Deep Energy

SOUTHFACE RESOURCES

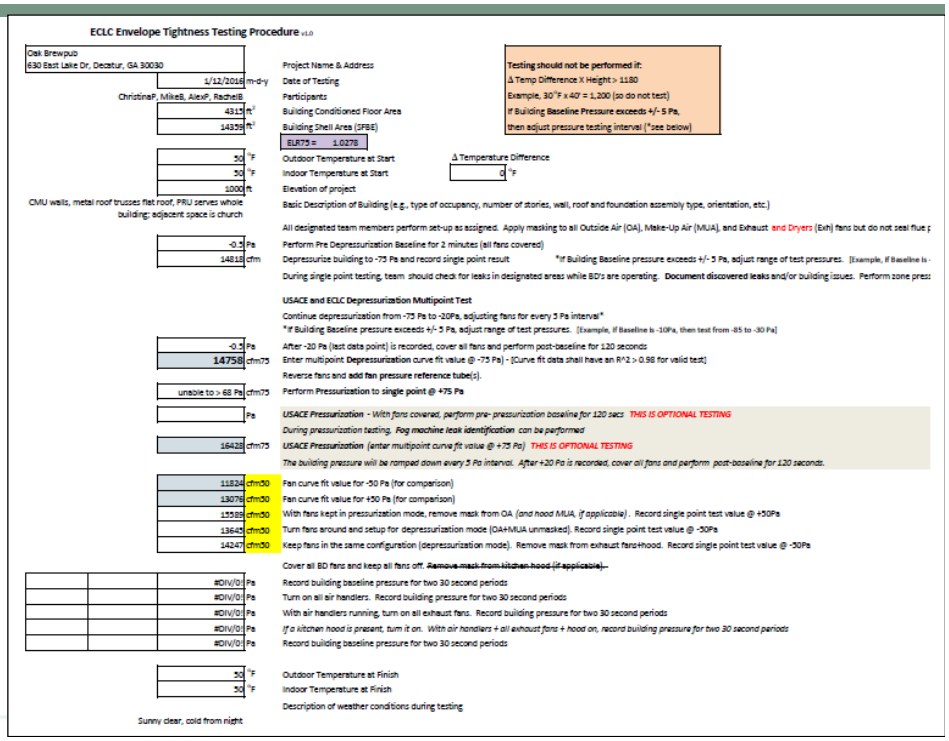
- Assessment toolkit
  - Process
  - Data collection
  - Analysis
  - Report template
  - Implementation checklist
- Quick guides
  - Fire stations
  - Rec centers
  - Small commercial on campus
- Multi-fan multi-point testing
  - Test protocol
  - Report template

Please see sign up sheet – add your name and email and we'll send you a link to these resources

SOUTHFACE RESOURCES – ONE PAGE TEST SHEET

Multi-fan multi-point testing

- Test protocol
- Paper copy is great for results tracking while performing testing
- Spreadsheet version can perform calculations



ECLC Envelope Tightness Testing Procedure v1.0

Oak Brewpub 630 East Lake Dr, Decatur, GA 30030		Project Name & Address
1/12/2016	m-d-y	Date of Testing
ChristinaP, MikeB, AlexP, RachelB		Participants
4315	ft²	Building Conditioned Floor Area
14359	ft²	Building Shell Area (SFBE)
ELR75 = 1.0278		
50	°F	Outdoor Temperature at Start
50	°F	Indoor Temperature at Start
1000	ft	Elevation of project
CMU walls, metal roof trusses flat roof, PRU serves whole building; adjacent space is church		Basic Description of Building (e.g., type of occupancy, number of stories, wall, roof and foundation assembly type, orientation, etc.)
-0.5	Pa	Perform Pre Depressurization Baseline for 2 minutes (all fans covered)
14818	cfm	Depressurize building to -75 Pa and record single point result
-0.5	Pa	
14758	cfm75	Enter multipoint Depressurization curve fit value @ -75 Pa) - [Curve fit data shall have an R^2 > 0.98 for valid test]
unable to > 68 Pa	cfm75	Reverse fans and add fan pressure reference tube(s).
	Pa	Perform Pressurization to single point @ +75 Pa
16428	cfm75	
11824	cfm50	Fan curve fit value for -50 Pa (for comparison)
13076	cfm50	Fan curve fit value for +50 Pa (for comparison)
15589	cfm50	With fans kept in pressurization mode, remove mask from OA *(and hood MUA, if applicable)* . Record single point test value @ +50Pa
13645	cfm50	Turn fans around and setup for depressurization mode (OA+MUA unmasked). Record single point test value @ -50Pa
14247	cfm50	Keep fans in the same configuration (depressurization mode). Remove mask from exhaust fans+hood. Record single point test value @ -50Pa
		Cover all BD fans and keep all fans off. ~~Remove mask from kitchen hood (if applicable).~~
	#DIV/0!	Pa Record building baseline pressure for two 30 second periods
	#DIV/0!	Pa Turn on all air handlers. Record building pressure for two 30 second periods
	#DIV/0!	Pa With air handlers running, turn on all exhaust fans. Record building pressure for two 30 second periods
	#DIV/0!	Pa *If a kitchen hood is present, turn it on. With air handlers + all exhaust fans + hood on, record building pressure for two 30 second periods*
	#DIV/0!	Pa Record building baseline pressure for two 30 second periods
50	°F	Outdoor Temperature at Finish
50	°F	Indoor Temperature at Finish
Sunny clear, cold from night		Description of weather conditions during testing

Testing should not be performed if:
Δ Temp Difference X Height > 1180
Example, 30°F x 40' = 1,200 (so do not test)
If Building Baseline Pressure exceeds +/- 5 Pa, then adjust pressure testing interval (*see below)

Δ Temperature Difference: 0 °F

*If Building Baseline pressure exceeds +/- 5 Pa, adjust range of test pressures. [Example, if Baseline is -

During single point testing, team should check for leaks in designated areas while BD's are operating. **Document discovered leaks** and/or building issues. Perform zone press

USACE and ECLC Depressurization Multipoint Test
Continue depressurization from -75 Pa to -20Pa, adjusting fans for every 5 Pa interval*
*If Building Baseline pressure exceeds +/- 5 Pa, adjust range of test pressures. [Example, if Baseline is -10Pa, then test from -85 to -30 Pa]
After -20 Pa (last data point) is recorded, cover all fans and perform post-baseline for 120 seconds

USACE Pressurization - With fans covered, perform pre- pressurization baseline for 120 secs THIS IS OPTIONAL TESTING
During pressurization testing, Fog machine leak identification can be performed
USACE Pressurization (enter multipoint curve fit value @ +75 Pa) THIS IS OPTIONAL TESTING
The building pressure will be ramped down every 5 Pa interval. After +20 Pa is recorded, cover all fans and perform post-baseline for 120 seconds.

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ADDITIONAL RESOURCES

EarthCraft Light Commercial Guidelines

ASHRAE Advanced Energy Design Guides

ASHRAE Advanced Energy Retrofit Guides

ASHRAE 189.1 – Green Building Standard

ASHRAE Indoor Air Quality Guide

ASHRAE Audit Guide

Core Performance Standard

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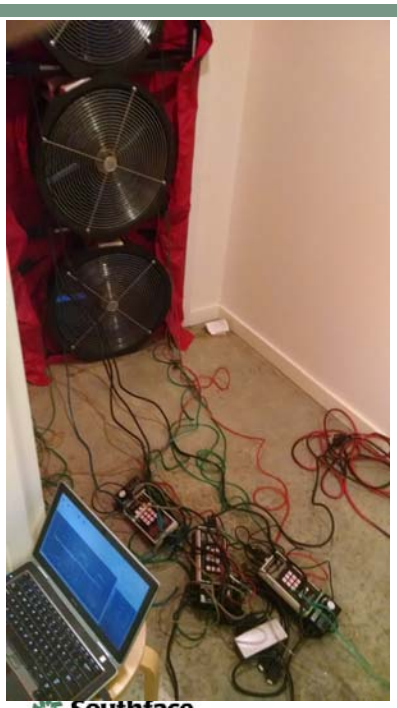
ACBI RESEARCH PLAN



Benchmark
- Multi-point Blower Door Test
- Measure building pressure under normal operation
- Pressure test for presence/function of dampers
- Measure Intentional Ventilation Rates

Interactions
- Circuit level monitoring
- Outdoor and indoor zonal temperature and Humidity monitoring

Impact
- Calibrate detailed models
- Assess infiltration impact on energy consumption

WHAT'S NEXT?

- Spray foam & moisture accumulation
- IAQ & ventilation
- CAZ guidelines
- Packaging of tools & resources
- Deployment
- Refinement

ACKNOWLEDGEMENTS/CREDITS

- US Department of Energy
- Southface team
- ~50 buildings we have been able to test (and still counting)

RESEARCH HAS NO SHORT CUTS

Questions & Answers

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- SF HERS Training
- HERS Core Apr 18-23
- HERS CAZ May 23-24

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