

RECOMMENDATIONS FOR 15% ABOVE-CODE ENERGY EFFICIENCY MEASURES FOR COMMERCIAL OFFICE BUILDINGS

Soolyeon Cho

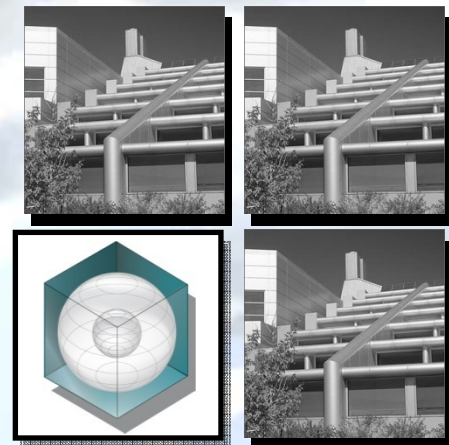
Jaya Mukhopadhyay

Charles Culp, Ph.D., P.E.

Jeff Haberl, Ph.D., P.E.

Bahman Yazdani, P.E.

**Energy Systems Laboratory
Texas Engineering Experiment Station
Texas A&M University System**



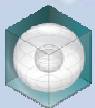
ACKNOWLEDGEMENTS

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Students: Mini Malhotra, Piljae Im, Seongchan Kim, Ben Burkert, Indira Mohandross, Matt Moss, Megan Bednarz, Grant Marvin.

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OUTLINE

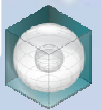
Introduction

Base-Case Building

Energy Efficiency Measures

Results

Conclusion



INTRODUCTION

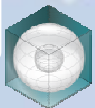
THE 79TH LEGISLATURE TO ENHANCE EFFECTIVENESS OF SENATE BILL 5

Requires the Laboratory

To develop 3 methods for achieving at least 15% potential energy savings in residential, commercial and industrial construction.

The Process

Worked on residential and commercial measures
Held stakeholders meetings
Refined measures



BASE-CASE

As per ASHRAE 90.1-1999

Two system types:

Electric cooling Natural gas heating (Electric / Gas)

Electric cooling Electric heating (All - Electric)

Building Envelope

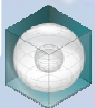
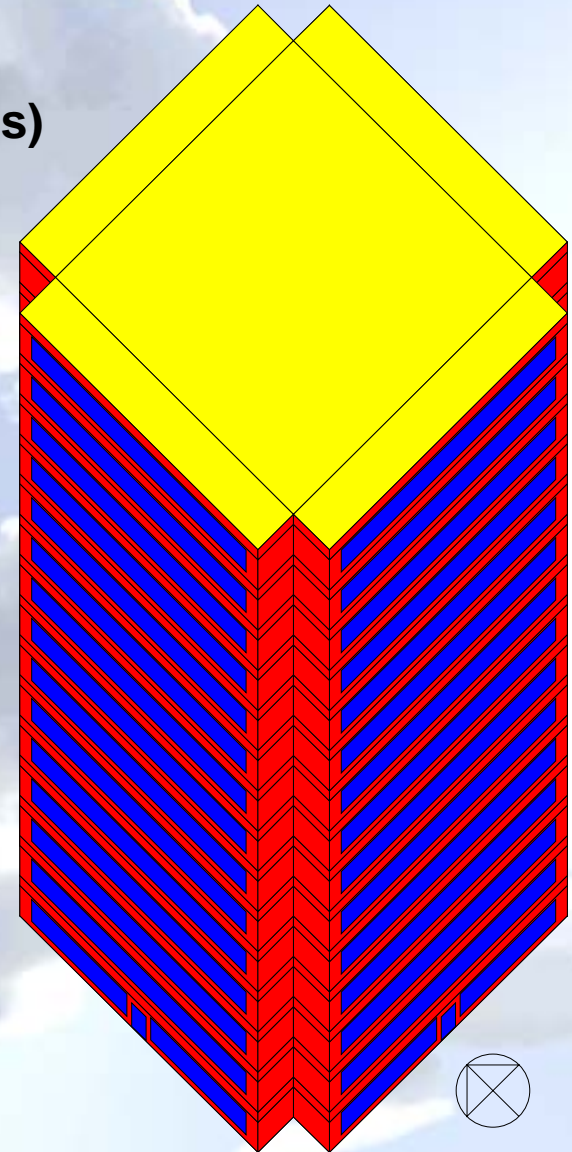
- 6-story office building (89,304 ft²) in Houston, TX
- Roof R-value: R-15
- Wall R-value: R-13

Fenestration

- 50% window to wall area ratio
- U-value: 1.22 Btu/hr °F ft²
- SHGC: 0.44 for North, 0.17 for other orientations

Lighting Power Density

- 1.3 W/ft²



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BASE-CASE

As per ASHRAE 90.1 1999

Two system types:

Electric cooling Natural gas heating (Electric / Gas)

Electric cooling Electric heating (All - Electric)

HVAC System Characteristics

- VAV system with terminal reheat
- Supply air static pressure of 2.5
- Constant supply air temperature of 55F

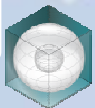
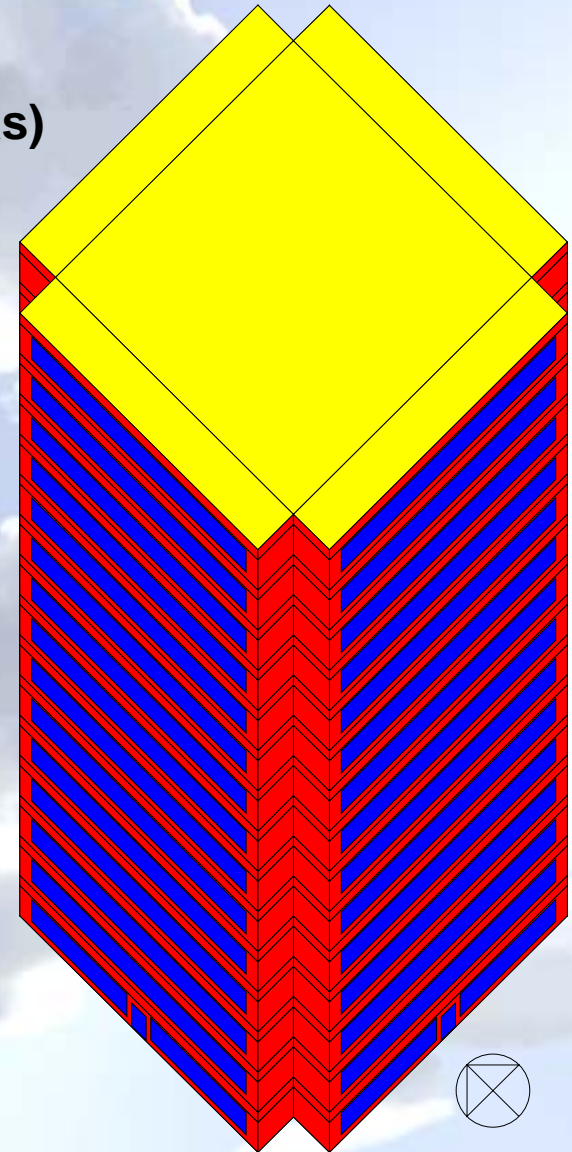
Plant Characteristics

For cooling

- 160 ton screw chiller with 4.9 COP

For heating

- Electric/gas building - conventional boiler,
2 - 731 kBtu/hr hot water gas boilers
(75% eff)
- All-electric building - electric resistance boiler
(100% eff)



ENERGY EFFICIENCY MEASURES

10 INDIVIDUAL MEASURES

Envelope, Fenestration & Space Condition Measures

1. Decreased Glazing U-value

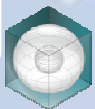
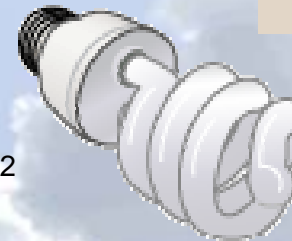
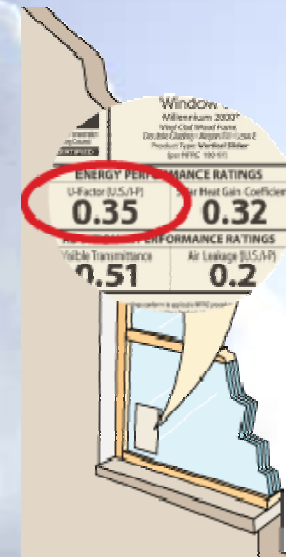
From 1.22 Btu/hr ft² 0.45 Btu/hr ft²

2. Energy Efficient Lighting

Lighting Power Density – From 1.3 W/ ft² to 1 W/ ft²

3. Window Shading

2.5 ft Width of Overhangs on all orientations except north



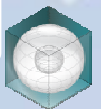
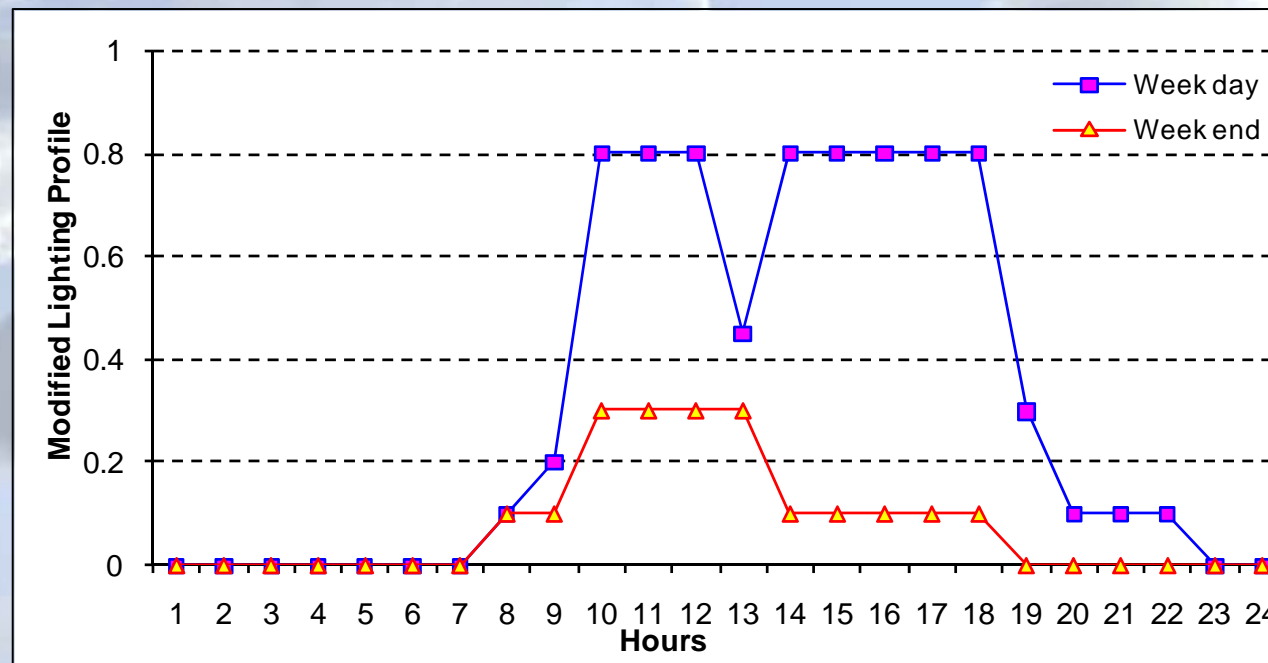
ENERGY EFFICIENCY MEASURES

10 INDIVIDUAL MEASURES

Envelope, Fenestration & Space Condition Measures

4. Installation of Occupancy Sensors for Lighting

Modifying electric lighting profiles



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Source: ASHRAE Standard 90.1-1989

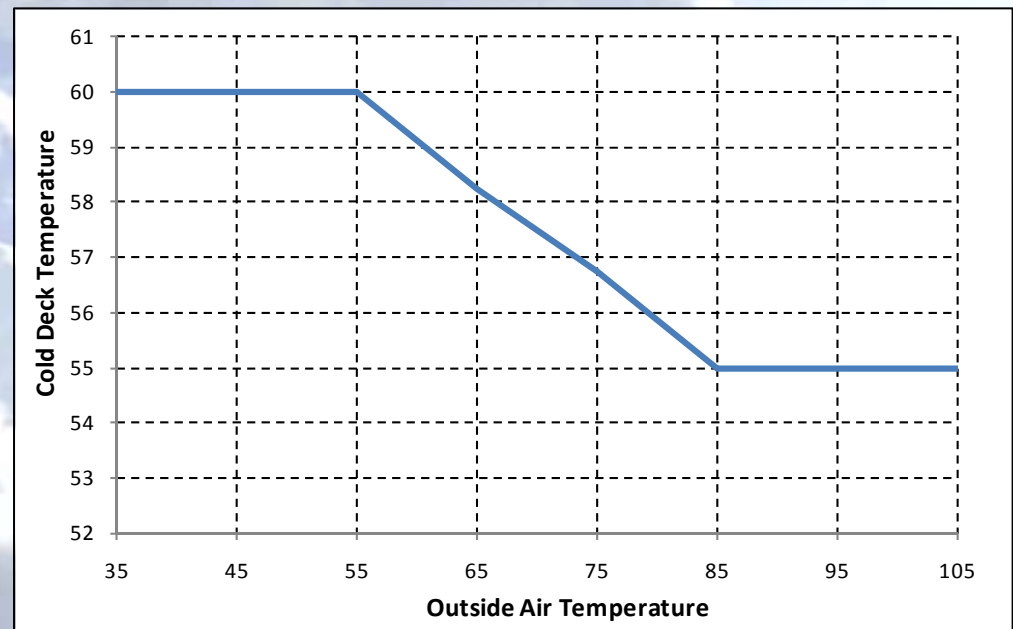
ENERGY EFFICIENCY MEASURES

10 INDIVIDUAL MEASURES

HVAC System Measures

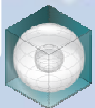
5. Cold Deck Reset

Cold deck temperature decreases linearly as outdoor temperature increases



6. Supply Fan Total Pressure

From 2.5 in.W.G. to 1.5 in.W.G.



ENERGY EFFICIENCY MEASURES

10 INDIVIDUAL MEASURES

Plant Equipment Measures

7. Chiller COP

From 4.9 COP to 6.1 COP

8. Boiler Efficiency (For Gas Building Only)

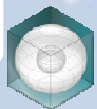
From 75% to 95% (condensing boiler)

9. VSD on Chilled Water Pumps

From constant speed to variable speed drives

10. VSD on Hot Water Pumps

From constant speed to variable speed drives



ENERGY EFFICIENCY MEASURES

COMBINED SET OF MEASURES

Combination 1

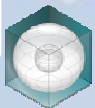
- Decreased Glazing U-factor
- Decreasing Lighting Power Density

Combination 2

- Occupancy Sensor Installation
- Cold Deck Reset

Combination 3

- Decreased Glazing U-factor
- Raising chiller COP
- VSD on Chilled Water Pump
- VSD on Hot Water Pump



RESULTS

PROCESS ADOPTED FOR ANALYSIS

CALCULATING ENERGY SAVED

- Annual energy use & demand use for individual and combined measures

CALCULATING COSTS

- Energy Cost
- First Costs

PAYBACK
Number of Years

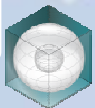
INTRODUCTION

BASECASE

EEM'S

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RESULTS

Envelope and Fenestration Measures for Electric / Gas Building

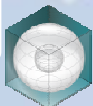
EEM	ENERGY USE (MBtu/yr)					ENERGY SAVINGS			FIRST COST (\$)	PAY BACK (yrs)
	COOLING	HEATING	DHW	OTHER	TOTAL	MBtu/yr	%	\$/yr		
BASECASE	1126	590	43	3899	5658					
GLAZING U-FACTOR	1125	68	43	3815	5051	606	10.7	7,631	95,130 174,150	12-23
LIGHTING LOAD	1064	702	43	3460	5258	389	6.9	18,277	0	Inst.
OCCUPANCY	976	879	43	3024	4922	736	13.0	33,032	26,500 28,000	0.8
SHADING	1058	590	43	3859	5549	108	1.9	4,223	67,900 110,000	12-26

Energy Savings

- Glazing: 10.7%
- Lighting Loads: 6.9%
- Occupancy Sensors: 13%

Payback Period

- Lighting Loads: Instant
- Occupancy sensors: 0.8 years



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RESULTS

HVAC System Measures for Electric / Gas Building

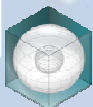
EEM	ENERGY USE (MBtu/yr)					ENERGY SAVINGS			FIRST COST (\$)	PAY BACK (yrs)
	COOLING	HEATIN	DHW	OTHER	TOTA	MBtu/yr	%	\$/yr		
BASECASE	1126	590	43	3899	5658					
COLD-DECK RESET	1053	384	43	3905	5385	273	4.8	3,887	0 800	0-0.2
SUPPLY FAN TOTAL PRESSURE	1109	591	43	3841	5583	75	1.3	2,958	0 200	0-0.1

Energy Savings

- Cold Deck Reset : 4.8%
- Supply Fan Total Pressure : 1.3%

Pay Back Period

- Cold Deck Reset : Instant to 0.2 years
- Supply Fan Total Pressure: Instant to 0.1 years



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RESULTS

Plant Equipment Measures for Electric / Gas Building

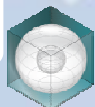
EEM	ENERGY USE (MBtu/yr)					ENERGY SAVINGS			FIRST COST (\$)	PAY BACK (yrs)
	COOLING	HEATIN	DHW	OTHER	TOTA	MBtu/yr	%	\$/yr		
BASECASE	1126	590	43	3899	5658					
CHILLER COP	905	590	43	3899	5436	221	3.9	8,718	16,000 18,000	1.8-2.1
BOILER EFFICIENCY	1126	466	43	3899	5533	124	2.2	993	25,000 35,000	25.2- 35.3
VSD ON CHILLED WATER PUMP	1061	590	43	3828	5521	137	2.4	4,885	3,700 4,700	0.8-1.0
VSD ON HOT WATER PUMP	1126	444	43	3868	5481	176	3.1	2,306	4000 5000	1.7-2.2

Energy Savings

- Chiller COP: 3.9%
- VSD on Hot Water Pump: 3.1%

Pay Back Period

- Chiller COP: 1.8 to 2.1 years
- VSD on Hot Water Pump: 1.7 to 2.7 years



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INTRODUCTION

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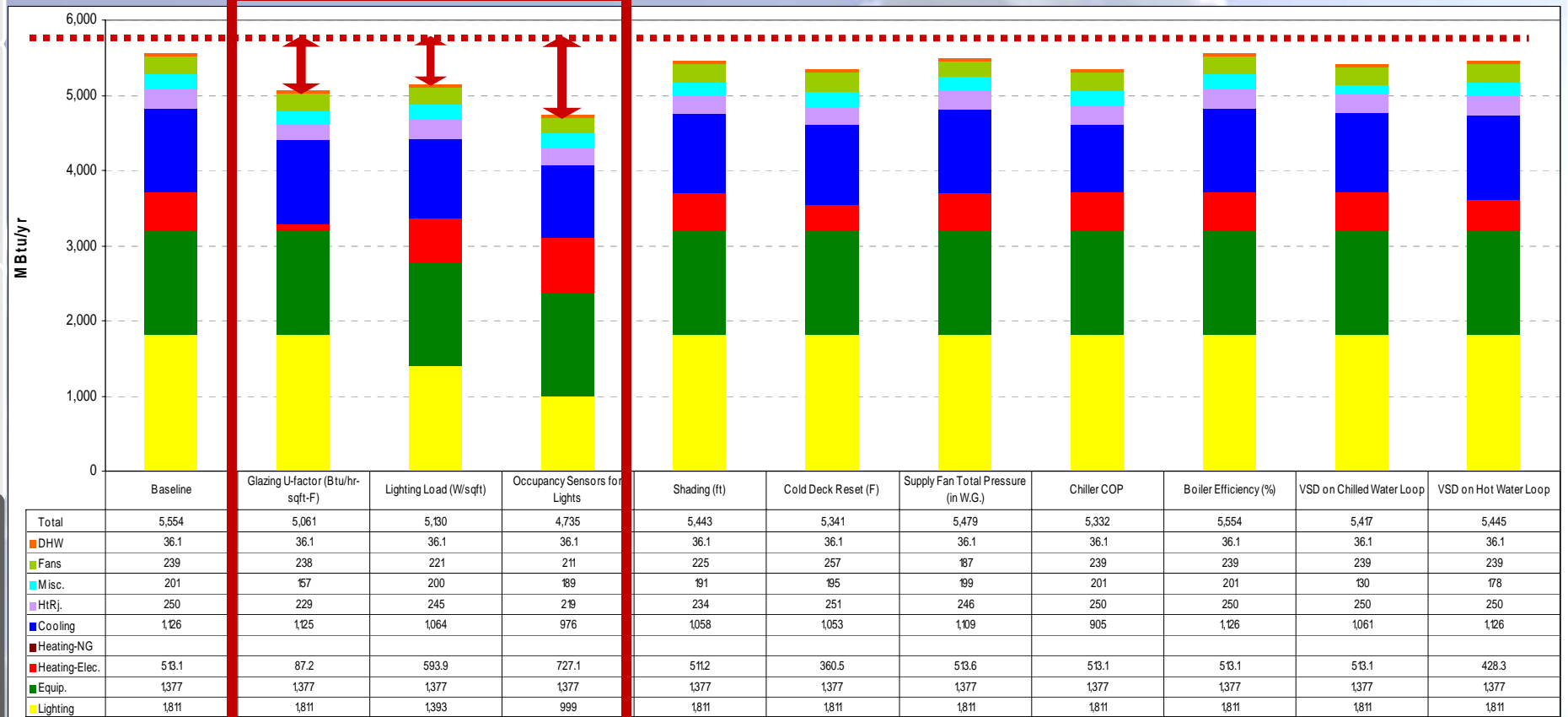
RESULTS

Energy Use Savings from Individual Measures for Electric / Gas Building



RESULTS

Energy Use Savings from Individual Measures for All-Electric Building



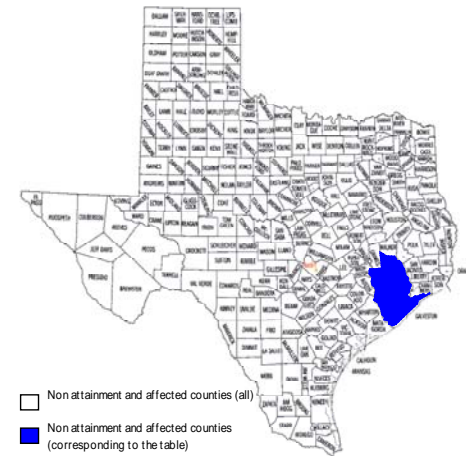
	Base Case	Glazing U factor	Lighting Loads	Occ Sensors	Shading	Cold Deck T	Supply Fan Pressure	Chiller COP	Boiler Eff	VSD Chilled Water Loop	VSD Hot Water Loop
Total	5,554	5,061	5,130	4,735	5,443	5,341	5,479	5,332	5,533	5,417	5,445
%Savings		8.9	7.6	14.7	2.0	3.8	1.4	4.0	0	2.5	2.0

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Natural Gas Heating (Brazoria, Fort Bend, Galveston, Harris, Montgomery and Waller Counties)

Description of Individual Measures

Individual Measures	Annual Energy Savings (%)	Annual Energy Savings (\$/year)	Annual Demand Savings (%)	Annual Demand Savings (\$/year)	Combined Savings (Energy+Demand) (\$/year)	Estimated Cost (\$)	
						Marginal Cost ¹	New System Cost ²
A Envelope and Fenestration Measures							
1 Glazing U Factor (1.22 to 0.45 Btu/hr-sf-F)	10.7%	\$7,114	3.2%	\$517	\$7,631	\$95,130 - \$174,150	
2 Lighting Load (1.3 to 1.0 w/sq-ft)	6.9%	\$16,582	10.4%	\$1,695	\$18,277	\$0 - \$0	
3 Occupancy Sensors Installation	13.0%	\$33,409	-2.3%	-\$377	\$33,032		\$26,500 - \$28,000
4 Shading (none to 2.5 ft overhangs)	1.9%	\$3,785	2.7%	\$438	\$4,223		\$67,900 - \$110,000
B HVAC System Measures							
5 Cold Deck Reset	4.8%	\$3,978	-0.6%	-\$91	\$3,887	\$0 - \$800	
6 Supply Fan Total Pressure (2.5 to 1.5 in-H2O)	1.3%	\$2,629	2.0%	\$329	\$2,958	\$0 - \$200	
C Plant Equipment Measures							
7 Chiller COP (4.9 to 6.1)	3.9%	\$7,717	6.1%	\$1,000	\$8,718	\$16,000 - \$18,000	
8 Boiler Efficiency (75% to 95%)	2.2%	\$993	0.0%	\$0	\$993	\$25,000 - \$35,000	
9 VSD on Chilled Water Pump (from Constant to VSD)	2.4%	\$4,764	0.7%	\$121	\$4,885	\$3,700 - \$4,700	
10 VSD on Hot Water Pump (from Constant to VSD)	3.1%	\$2,243	0.4%	\$63	\$2,306	\$4,000 - \$5,000	



Description of Combined Measures to Achieve 15% Above Code Savings

Combination of Measures ³	Combined Energy Savings (%)	Combined Energy Savings (\$/year)	Combined Demand Savings (%)	Combined Demand Savings (\$/year)	Combined Savings (Energy+Demand) (\$/year)	Combined Estimated Cost (\$)		Combined Annual NOx Emissions Savings (lbs/year)	Combined Ozone Season Period NOx Emissions Savings (lbs/day)	Simple Estimated Payback (yrs)
						Marginal Cost ¹	New System Cost ²			
Combination 1										
1 Glazing U Factor (1.22 to 0.45 Btu/hr-sf-F)	20.1%	\$26,160	13.6%	\$2,214	\$28,374	\$95,130 - \$174,150		258	0.95	3.6 - 6.7
2 Lighting Load (1.3 to 1.0 w/sq-ft)						\$0 - \$0				
Combination 2										
3 Occupancy Sensors Installation	19.6%	\$38,856	-3.4%	-\$558	\$38,299		\$26,500 - \$28,000	371	1.37	0.7 - 0.7
5 Cold Deck Reset						\$0 - \$800				
Combination 3										
1 Glazing U Factor (1.22 to 0.45 Btu/hr-sf-F)	16.8%	\$18,719	9.5%	\$1,554	\$20,273	\$95,130 - \$174,150		187	0.71	7.5 - 12.4
7 Chiller COP (4.9 to 6.1)						\$16,000 - \$18,000				
8 Boiler Efficiency (75% to 95%)						\$25,000 - \$35,000				

Note:

- Marginal cost = new system cost - original system cost
- New system cost = new system cost only
- See individual measures above for specific savings
 - * Energy Cost: Electricity cost = \$0.119/kWh
 - Demand cost = \$5.00/kW
 - (Yearly demand cost = Sum of monthly demand cost for 12 months
 - Natural gas cost = \$0.80/therm

(Building Description)
 Building type: Office
 Gross area: 89,340 sq ft
 Building dimension: 100 ft x 100 ft
 Number of floors: 3
 Floor-to-floor height: 12 ft
 Window-to-wall ratio: 0.25

Table 5a: 15% Above Code Savings (Commercial Heating) for Brazoria, Fort Bend, Galveston, Harris, Montgomery and Waller Counties



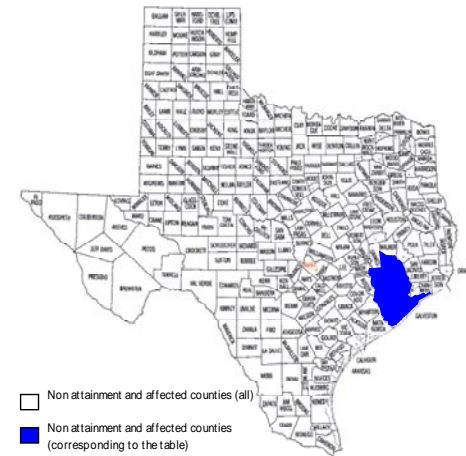
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COMBINATION	COMBINED ENERGY SAVINGS	PAYBACK YEARS
COMBINATION 1	20.1%	3.6 – 6.7
COMBINATION 2	19.6%	0.7
COMBINATION 3	16.8%	7.5 – 12.4

Electric Heating (Brazoria, Fort Bend, Galveston, Harris, Montgomery and Waller Counties)

Description of Individual Measures

Individual Measures	Annual Energy Savings (%)	Annual Energy Savings (\$/year)	Annual Demand Savings (%)	Annual Demand Savings (\$/year)	Combined Savings (Energy+Demand) (\$/year)	Estimated Cost (\$)	
						Marginal Cost ¹	New System Cost ²
A Envelope and Fenestration Measures							
1 Glazing U Factor (1.22 to 0.45 Btu/hr-sf-F)	8.9%	\$17,184	22.6%	\$4,726	\$21,910	\$95,130 - \$174,150	
2 Lighting Load (1.3 to 1.0 w/sq-ft)	7.6%	\$14,774	2.6%	\$543	\$15,317	\$0 - \$0	
3 Occupancy Sensors Installation	14.7%	\$28,545	-7.0%	-\$1,468	\$27,078		\$26,500 - \$28,000
4 Shading (none to 2.5 ft overhangs)	2.0%	\$3,849	2.3%	\$471	\$4,321		\$67,900 - \$110,000
B HVAC System Measures							
5 Cold Deck Reset	3.8%	\$7,412	5.9%	\$1,244	\$8,656	\$0 - \$800	
6 Supply Fan Total Pressure (2.5 to 1.5 in-H2O)	1.4%	\$2,616	1.4%	\$299	\$2,916	\$0 - \$200	
C Plant Equipment Measures							
7 Chiller COP (4.9 to 6.1)	4.0%	\$7,717	3.7%	\$765	\$8,482	\$16,000 - \$18,000	
8 Boiler Efficiency (Not Applicable)	n/a	n/a	n/a	n/a	n/a	n/a - n/a	
9 VSD on Chilled Water Pump (from Constant to VSD)	2.5%	\$4,764	1.0%	\$208	\$4,972	\$3,700 - \$4,700	
10 VSD on Hot Water Pump (from Constant to VSD)	2.0%	\$3,787	0.8%	\$172	\$3,960	\$4,000 - \$5,000	



Description of Combined Measures to Achieve 15% Above Code Savings

Combination of Measures ³	Combined Energy Savings (%)	Combined Energy Savings (\$/year)	Combined Demand Savings (%)	Combined Demand Savings (\$/year)	Combined Savings (Energy+Demand) (\$/year)	Combined Estimated Cost (\$)		Combined Annual NOx Emissions Savings (lbs/year)	Combined Ozone Season Period NOx Emissions Savings (lbs/day)	Simple Estimated Payback (yrs)
						Marginal Cost ¹	New System Cost ²			
Combination 1										
1 Glazing U Factor (1.22 to 0.45 Btu/hr-sf-F)	18.5%	\$35,763	29.8%	\$6,237	\$42,000	\$95,130 - \$174,150		341	1.08	2.7 - 4.9
2 Lighting Load (1.3 to 1.0 w/sq-ft)						\$0 - \$0				
Combination 2										
3 Occupancy Sensors Installation	19.8%	\$38,343	0.0%	\$5	\$38,348	\$26,500 - \$28,000		366	1.36	0.7 - 0.8
5 Cold Deck Reset						\$0 - \$800				
Combination 3										
1 Glazing U Factor (1.22 to 0.45 Btu/hr-sf-F)	15.5%	\$30,066	27.7%	\$5,793	\$35,859	\$95,130 - \$174,150		287	0.90	4.0 - 6.7
7 Chiller COP (4.9 to 6.1)						\$16,000 - \$18,000				
9 VSD on Chilled Water Pump (from Constant to VSD)						\$3,700 - \$4,700				
10 VSD on Hot Water Pump (from Constant to VSD)						\$4,000 - \$5,000				

Note:

- Marginal cost = new system cost - original system cost
- New system cost = new system cost only
- See individual measures above for specific savings
 - * Energy Cost: Electricity cost = \$0.119/kWh
 - Demand cost = \$5.00/kW
 - (Yearly demand cost = Sum of monthly demand cost for 12 months
 - Natural gas cost = \$0.80/therm

(Building Description)

- Building type
- Gross area:
- Building dime
- Number of flo
- Floor-to-floor
- Window-to-w

Table 5b: 15% Above Code Savings (Commercial Heating) for Brazoria, Fort Bend, Galveston, Harris, Montgomery and Waller Counties

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COMBINATION	COMBINED ENERGY SAVINGS	PAYBACK YEARS
COMBINATION 1	18.5%	2.7 – 4.9
COMBINATION 2	19.8%	0.7
COMBINATION 3	15.5%	4.0 – 6.7



CONCLUSIONS

FOR ELECTRIC / GAS BUILDING IN HOUSTON:

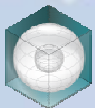
Most Effective Individual Measures

	ANNUAL ENERGY SAVINGS	PAYBACK
▪ Glazing U-value	10.7%	18
▪ Lighting Loads	6.9%	Instant
▪ Occupancy Sensors	1.9%	1

Most Effective Combination of Measures

Combination 2

	ANNUAL ENERGY SAVINGS	PAYBACK
▪ Occupancy Sensor Installation	19.6%	0.7
▪ Cold Deck Reset		



CONCLUSIONS

FOR ALL - ELECTRIC BUILDING IN HOUSTON:

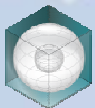
Most Effective Individual Measures

	ANNUAL ENERGY SAVINGS	PAYBACK
▪ Glazing U-value	8.9%	6
▪ Lighting Loads	7.6%	Instant
▪ Occupancy Sensors	14.7%	1

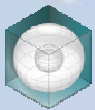
Most Effective Combination of Measures

Combination 2

	ANNUAL ENERGY SAVINGS	PAYBACK
▪ Occupancy Sensor Installation	19.8%	0.7 – 0.8
▪ Cold Deck Reset		



QUESTIONS?



ESL CONTACT INFORMATION

Soolyeon Cho: soolyeoncho@tees.tamus.edu

Jaya Mukhopadhyay: jayamukhopadhyay@tees.tamus.edu

Jeff Haberl: jhaberl@esl.tamu.edu

<http://eslsb5.tamu.edu>

