

# ENERGY EFFICIENCY/RENEWABLE ENERGY (EE/RE) MEASURES FOR K-12 SCHOOLS IN TEXAS

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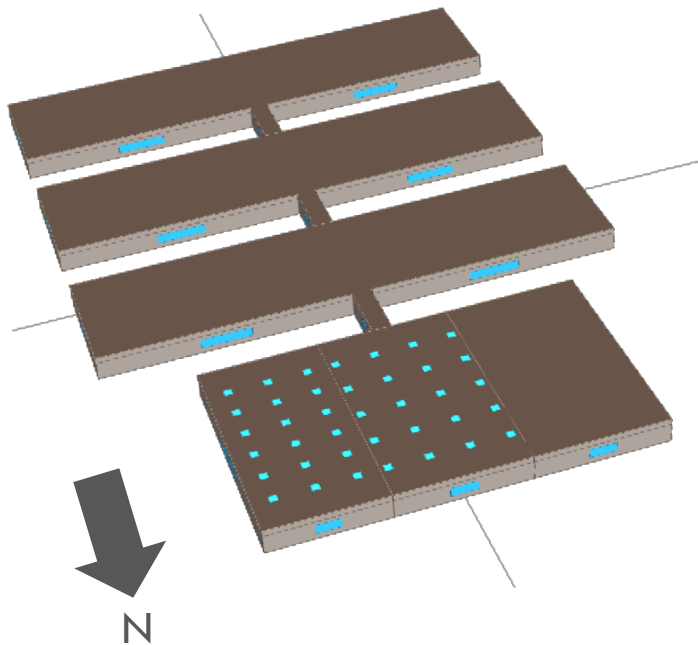
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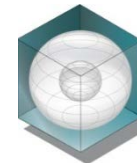
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**Introduction**

**Methodology**

**Base-Case School Model**

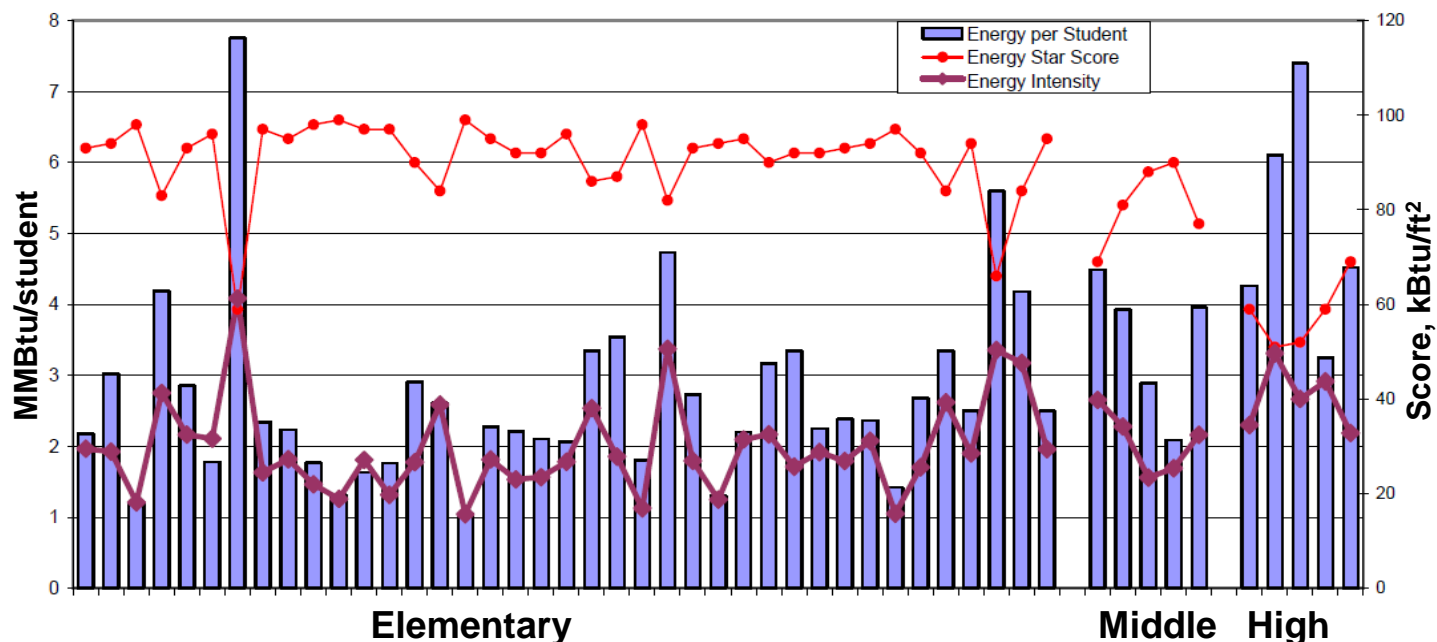
**18 EE/RE Measures**

**Results**

**Summary**

## Energy Saving Potential in High Performance Schools

- Energy use of the most efficient schools = 1/3 of the least efficient schools (EPA 2010)
- 20% to 40% energy savings in high performance schools (Im and Haberl 2006)



Source: California Energy Commission report (HPCBS # E2P2.1T3d)

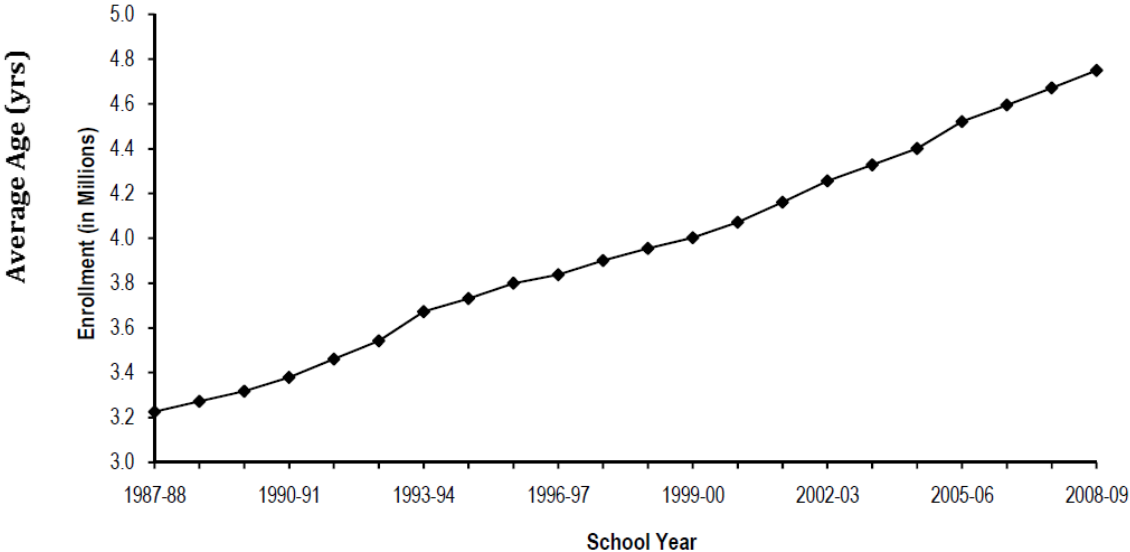
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# Introduction

## Energy Saving Potential in Texas Public Schools

- Average age of Texas public schools: 32.2 to 35.2 years old
- Average enrollment growth rate of Texas public schools: 20.1% over the past 10-year period

Statewide Enrollment, Texas Public Schools, 1987-88 Through 2008-09

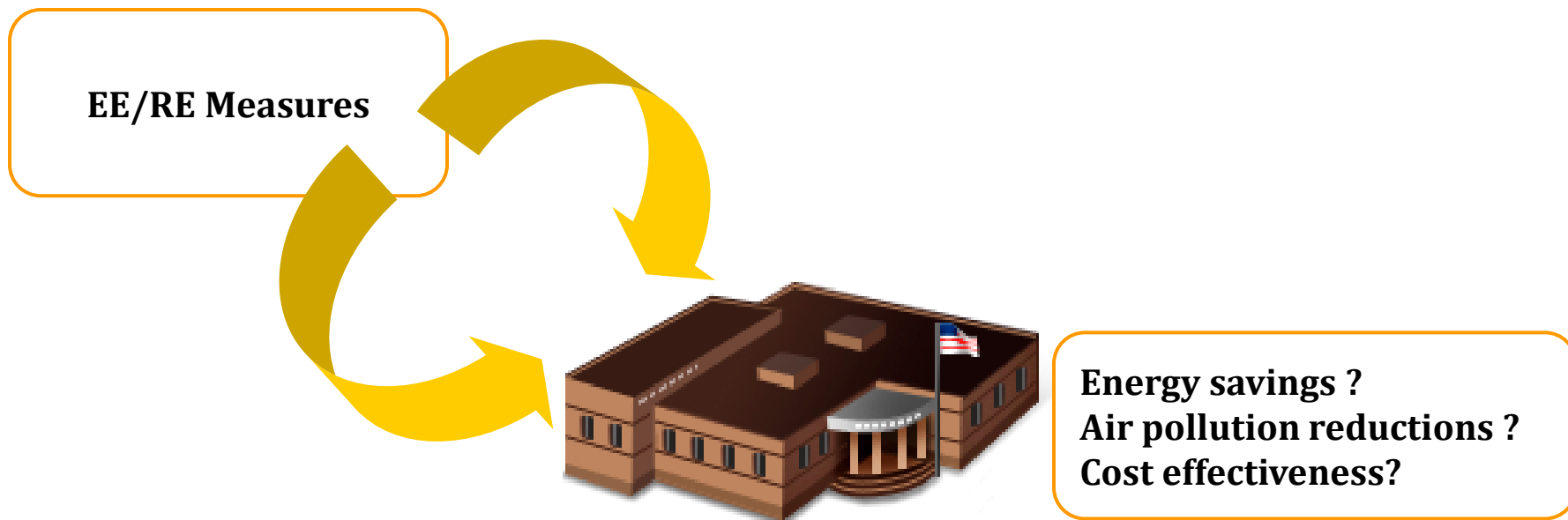


Source: ~~2006-09~~ 2009 *Report of Texas Comptroller of Public Accounts*

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## Energy Efficiency/Renewable Energy (EERE) Projects for Texas Public Schools

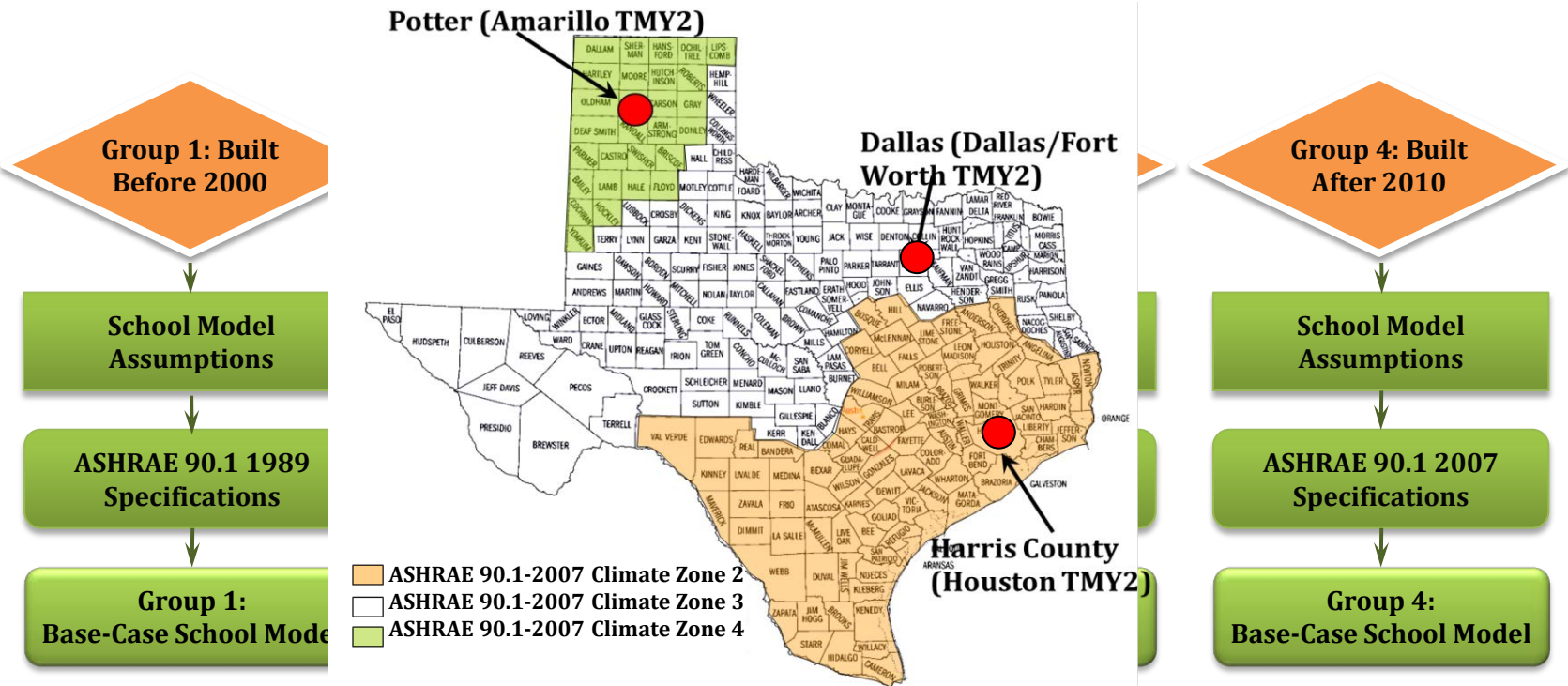
- To analyze potential energy savings and resultant air pollution reductions associated with the energy savings from the application of **cost-effective energy efficiency and renewable energy projects** applied to **new and existing** Texas Independent School Districts (ISDs)



# Methodology

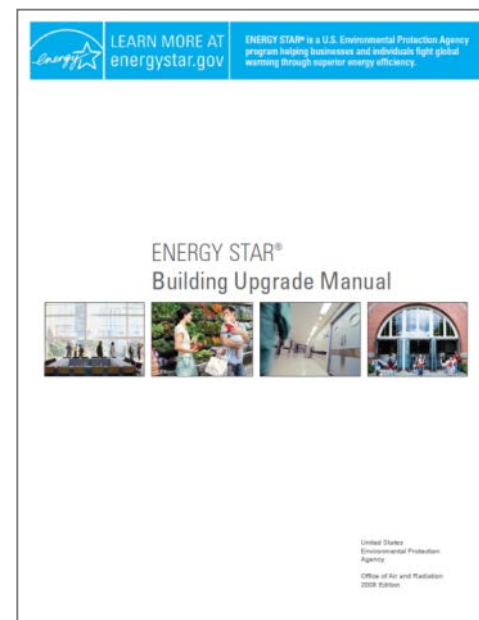
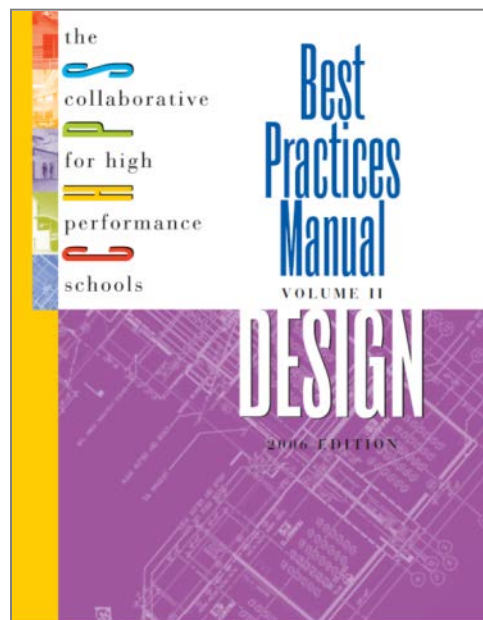
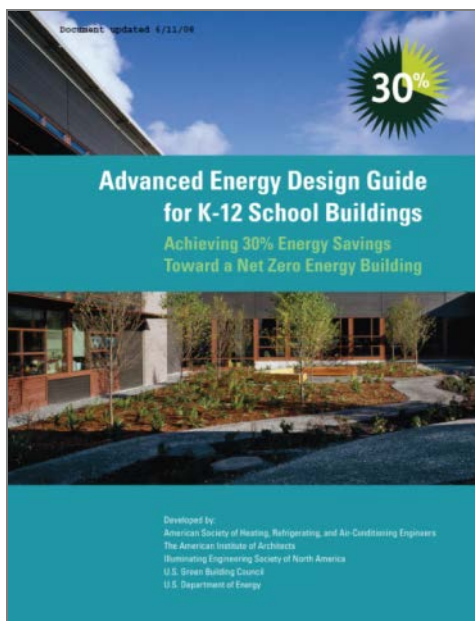
## Overall Approaches

- Define **three representative counties** for Texas Climate Zones
- Define **four groups by construction year** for each county
- Define input parameters per the corresponding **ASHRAE 90.1**
- Simulate for base cases



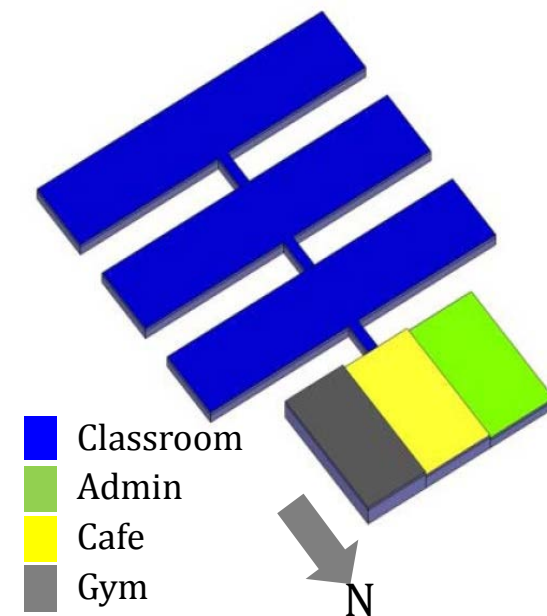
## EE/RE Measures

- Sources
  - ASHRAE's AEDG for K-12 Schools (2008)
  - Collaborative for High Performance Schools (CHPS) Best Practices Manual (2006)
  - U.S. EPA Energy Star Building Upgrade Manual (2008)
- Interview with a Maintenance Manager of College Station school district



## Base-Case School Model

- Sources
  - ASHRAE Standard 90.1-1989, 1999, 2004, and 2007
  - U.S. EPA Energy Star labeled schools in Texas (2010)
  - Texas Education Agency K-12 schools database (2010)
  - EnergyPlus Benchmark school models (2010)
  - NREL's Advanced Energy Design Guide (AEDG) for K-12 schools (2007)
- Field Survey
  - Field survey of elementary schools in Bryan/College Station school district
  - Interview with a Maintenance Manager of College Station school district





## Characteristics of Base-Case Model

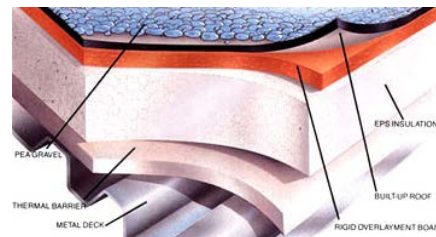
- Building Envelope
  - 1-story, 79,430 ft<sup>2</sup>
  - 10% WWR
- Space Condition
  - Heating: 70 F (60.8 F setback)
  - Cooling: 77 F (87.8 F setup)
- HVAC System Characteristics
  - 30 ton PVAVS for Classrooms
  - 10 ton PSZ for Admin/Café/Gym
  - 80% eff. gas boilers and furnaces
- SHW System Characteristics
  - Two Gas Storage Water Heaters

Characteristics	Assumptions			Information Source
	Harris County (Climate Zone 2)	Dallas county (Climate Zone 3)	Potter county (Climate Zone 4)	
<b>Building</b>				
Building Type	Primary School			
Gross Area (sq. ft.)	79,430			TEA Survey: Primary School
Number of Floors	1			EnergyPlus Benchmark
Ceiling-to-Floor Height (ft.)	10 ft (Classroom, Admin, Café, Gym)			EnergyPlus Benchmark
Orientation	South facing			
<b>Construction</b>				
Wall Construction	Steel-Framed with 4" studs spaced at 16" on center			EnergyPlus Benchmark
Roof Configuration	Flat built-up, Insulation entirely above deck			EnergyPlus Benchmark
Foundation Construction	4" Concrete slab-on-grade floor			EnergyPlus Benchmark
Wall Absorptance	0.55			DOE 2.1E BDL SUMMARY, Page 12
Wall Insulation (hr-sq.ft.-°F/Btu)	R-13			ASHRAE 90.1-1999 Appendix B
Roof Absorptance	0.7			ASHRAE 90.1-1999 11.4.2
Roof Insulation (hr-sq.ft.-°F/Btu)	R-15 ci			ASHRAE 90.1-1999 Appendix B
Slab Perimeter Insulation	None			ASHRAE 90.1-1999 Appendix B
Ground Reflectance	0.24			DOE 2.1E BDL SUMMARY, Page 20
U-Factor of Glazing (Btu/hr-sq.ft.-°F)	1.22		0.57	ASHRAE 90.1-1999 Appendix B
Solar Heat Gain Coefficient (SHGC)	0.25	0.39		ASHRAE 90.1-1999 Appendix B
Window Area	10% Window to wall ratio			Bryan/College Station School Survey
Exterior Shading	None			ASHRAE 90.1-1999 11.4.2
<b>Space Conditions</b>				
Space Heating Set point	70 F(Occupied), 60.8 F(Unoccupied)			
Space Cooling Set point	77 F(Occupied), 87.8 F(Unoccupied)			EnergyPlus Benchmark
Lighting Power Density (W/ft <sup>2</sup> )	1.5			ASHRAE 90.1-1999 Table 9.3.1.1
Equipment Power Density (W/ft <sup>2</sup> )	1.06			AEDG
<b>Mechanical Systems</b>				
HVAC System Type	PVAVS: Classroom PSZ: Admin/Café/Gym			EnergyPlus Benchmark
Air Conditioning System Efficiency	PVAVS: 9.5 EER PSZ: 10.3 EER			ASHRAE 90.1-1999 Table 6.2.1A
Heating System Efficiency (%)	80%			ASHRAE 90.1-1999 Table 6.2.1F
Cooling Capacity (Btu/hr)	Autosized			
Heating Capacity (Btu/hr)	Autosized			
Economizer	No			ASHRAE 90.1-1999 6.3.1
Ventilation	15 % of design flow			
Supply Air Flow (cfm/sq.ft)	Classroom: 1.00 cfm/sq.ft. Admin: 1.03 cfm/sq.ft. Cafe: 1.69 cfm/sq.ft. Gym: 1.72 cfm/sq.ft.			Simplified School Model (Im 2009)
Supply Fan Power (hp/1000cfm)	PVAVS: 1.7 hp/1000cfm PSZ: 1.2 hp/1000cfm			ASHRAE 90.1-1999Table 6.3.3.1
DHW System Type	Two gas storage water heaters (125 gallon, 199,000 Btu/hr)			EnergyPlus Benchmark
DHW Heater Efficiency (%)	80 % Et			ASHRAE 90.1-1999Table 7.2.2
DHW Temperature Setpoint (F)	140 F			EnergyPlus Benchmark

## Envelope and Fenestration Energy Efficiency Measures

### 1) Increased Roof Insulation

- Installs higher level of roof insulation for efficient thermal envelope

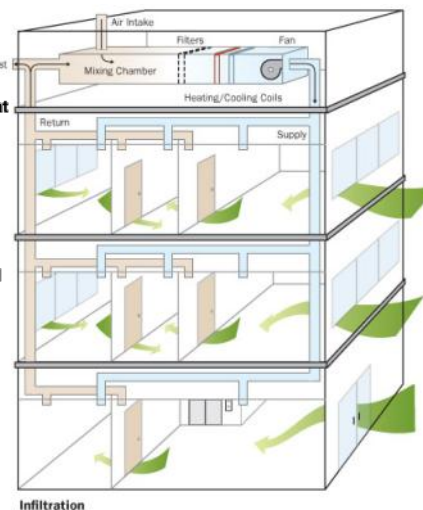
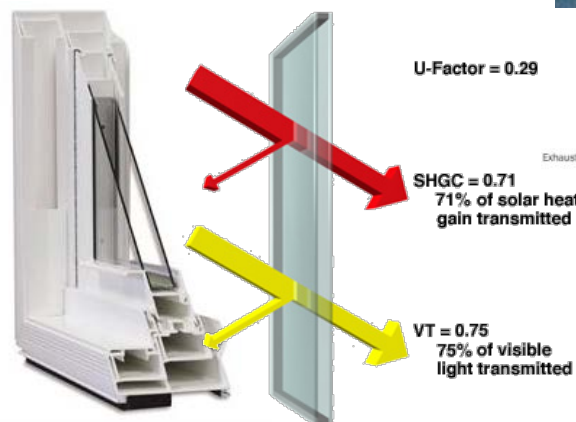


### 2) Decreased Glazing U-Value

- Selects lower U-value glazing

### 3) Decreased Infiltration

- Improves air tightness of building envelope
- Minimizes thermal bridging (e.g., continuous insulation)
- Uses air barriers



# 18 EE/RE Measures

## Lighting Energy Efficiency Measures

### 4) Decreased Lighting Power Density

- Uses T8 lamps instead of T12



### 5) Occupancy Sensor for Lighting Control

- Utilizes occupancy sensors for indoor lighting controls



### 6) Daylight Dimming Controls

- Adjusts lighting levels by the level of daylight detected using photo sensors



### 7) Skylights

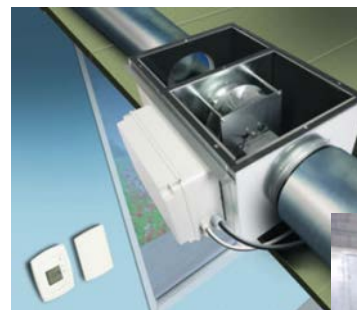
- Skylights in the cafeteria and gymnasium



## HVAC System Energy Efficiency Measures (1/2)

### 8) OA Demand Control

- Utilizes CO<sub>2</sub> sensors to ventilate the building by actual occupancy



### 9) Improved AC Efficiency (EER)

- High EER rating AC  
(e.g. 10.6 EER PVAVs & 12.2 EER PSZ systems)



### 10) Improved Heating System Efficiency

- Higher than 90% AFUE
- Condensing boilers



## HVAC System Energy Efficiency Measures (2/2)

### 11) Decreased Supply Fan Power Consumption

- Low power consumption supply fan

### 12) PVAVS with VFD for Fan Control

- Variable speed control for fans using Variable Frequency Drives (VFDs)

### 13) PVAVS with Variable Speed for HW Pump

- Variable speed control for hot water pumps using Variable Frequency Drives (VFDs)



# 18 EE/RE Measures

## SHW Energy Efficiency Measures

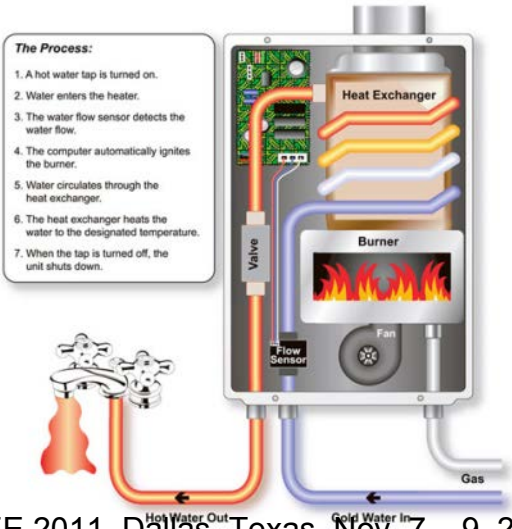
### 14) Improved SHW Heater Efficiency

- Higher than 95% thermal efficiency
- Condensing water heater



### 15) Tankless Water Heater

- Provides hot waters as needed
- Eliminates standby energy losses



## Renewable Energy Efficiency Measures

### 16) Solar PV

- Converts sunlight into electricity
- Simple sustainable energy technology



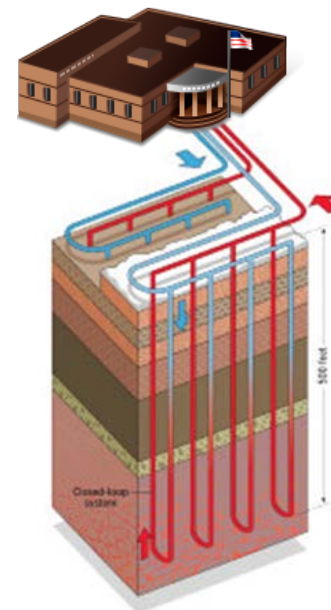
### 17) Solar SHW

- Converts sunlight into useful thermal energy for water heating systems



### 18) Ground Source Heat Pump

- Pumps heat from/to the ground
- Utilizes constant ground temperature
- Provides both heating and cooling



- 1. Base-Case Energy Use**
- 2. Energy Savings from Individual EEMs**
- 3. Incremental Cost Analysis**



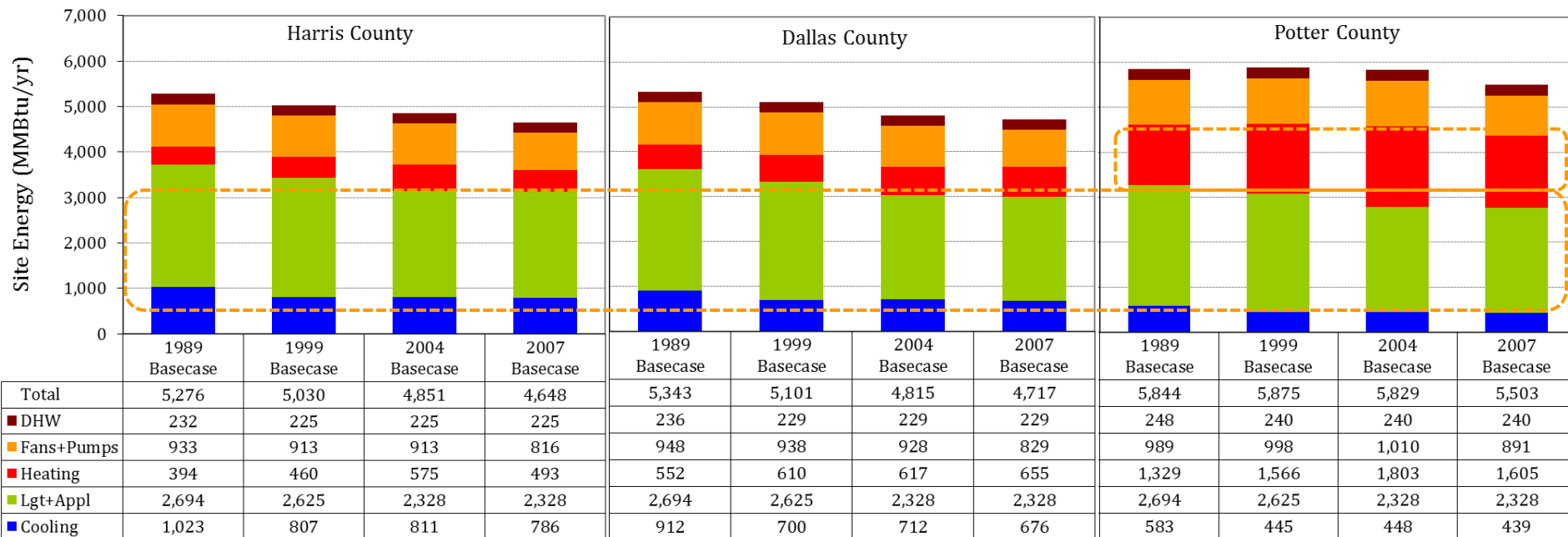
## 1. Base-Case Energy Use

## 2. Energy Savings from Individual EEMs

## 3. Incremental Cost Analysis

## Base-Case Energy Use for Different School Groups in Each Climate Zone

- High lighting & equipment energy consumption for all counties
- High heating consumption for Potter County



1. Base-Case Energy Use

**2. Energy Savings from Individual EEMs**

3. Incremental Cost Analysis

## Energy Savings from Individual EEMs

EEM #	Individual EEM	Annual Total Savings Above Base Case (%)											
		Harris County (Climate Zone 2)				Dallas County (Climate Zone 3)				Potter County (Climate Zone 4)			
		1989	1999	2004	2007	1989	1999	2004	2007	1989	1999	2004	2007
<b>Envelope Measures</b>													
1	Increased Roof Insulation	0.5%	0.9%	1.0%	0.4%	1.0%	1.2%	1.4%	0.6%	2.4%	2.8%	2.8%	1.2%
2	Decreased Glazing U-Value	1.4%	2.4%	2.9%	0.9%	2.2%	2.5%	0.5%	1.0%	3.3%	1.2%	1.2%	-
3	Decreased Infiltration	1.6%	1.8%	2.1%	2.0%	2.3%	2.4%	2.7%	2.8%	5.6%	5.8%	6.1%	6.4%
<b>Lighting Measures</b>										<b>Higher savings for Potter County</b>			
4	Decreased LPD	7.1%	5.4%	1.3%	1.3%	6.1%	5.0%	1.3%	1.2%				
5	Occupancy Sensor for Lighting Control	1.7%	1.5%	1.1%	1.1%	1.4%	1.3%	1.1%	1.0%	0.6%	0.4%	0.2%	0.2%
6	Daylight Dimming Controls	9.6%	6.6%	4.9%	5.0%	11.2%	6.0%	3.9%	3.5%	3.5%	2.5%	1.4%	1.6%
7	Skylights	1.9%	1.9%	1.4%	1.6%	1.6%	1.1%	0.8%	0.9%	-0.8%	-0.9%	-1.3%	-1.2%
										<b>Higher saving potential for older school groups</b>			
										<b>Heating penalty for Potter County</b>			

# Results

## Energy Savings from Individual EEMs

EEM #	Individual EEM	Annual Total Savings Above Base Case (%)											
		Harris County (Climate Zone 2)				Dallas County (Climate Zone 3)				Potter County (Climate Zone 4)			
		1989	1999	2004	2007	1989	1999	2004	2007	1989	1999	2004	2007
<b>HVAC System Measures</b>													
8	OA Demand Control	4.5%	4.6%	5.1%	4.8%	4.7%	4.4%	4.7%	4.7%	8.5%	9.2%	9.9%	9.6%
9	Improved AC Efficiency	6.8%	3.0%	3.6%	3.2%	6.0%	2.6%	3.2%	2.7%	<b>Higher savings for Potter County</b>			
10	Improved Heating System Efficiency	0.8%	1.0%	1.3%	1.1%	1.1%	1.3%	1.4%	1.5%				
11	Decreased Fan Power Consumption	3.5%	3.6%	3.7%	1.9%	3.5%	3.6%	3.8%	1.9%	3.3%	3.3%	3.4%	1.8%
12	PVAVS with VFD for Fan Control	<b>Higher saving potential for older school groups</b>						5.8%	5.2%	4.5%	4.3%	4.3%	3.9%
13	PVAVS with Variable Speed HW Pump							2.3%	2.3%	<b>Good Saving Potential</b>			
<b>SHW Measures</b>													
14	Improved SHW Heater Efficiency	0.7%	0.6%	0.6%	0.6%	0.7%	0.6%	0.6%	0.6%	0.7%	0.5%	0.5%	0.6%
15	Tankless Water Heater	1.1%	1.1%	1.1%	1.2%	1.1%	1.1%	1.2%	1.2%	1.0%	1.0%	1.0%	1.0%

**Less than 2% savings due to small SHW end-use consumption, but higher savings are expected for the K-5 to K-12 Schools.**

## Energy Savings from Individual EEMs

EEM #	Individual EEM	Annual Total Savings Above Base Case (%)											
		Harris County (Climate Zone 2)				Dallas County (Climate Zone 3)				Potter County (Climate Zone 4)			
		1989	1999	2004	2007	1989	1999	2004	2007	1989	1999	2004	2007
<b>Renewable Measures</b>													
16	Solar PV	17.9%	18.8%	19.5%	20.4%	20.1%	21.0%	22.3%	22.8%	20.1%	20.0%	20.1%	21.3%
17	Solar DHW	2.4%	2.4%	2.5%	2.6%	2.7%	2.7%	2.8%	2.9%	2.7%	2.6%	2.6%	2.7%
18	Ground Source Heat Pump	6.4%	7.6%	11.2%	10.0%	10.5%	11.2%	12.6%	14.2%	21.0%	24.2%	28.3%	26.9%
<b>Combinations</b>										<b>Higher savings for Potter County</b>			
1	AEDG	23.8%	20.2%	17.4%	13.7%	25.0%	21.5%	16.7%	14.9%				
2	ASHRAE 90.1 2007	<b>Good Saving Combinations</b>				11.7%	7.5%	2.0%	-	5.8%	6.3%	5.6%	-

1. Base-Case Energy Use
2. Energy Savings from Individual EEMs
- 3. Incremental Cost Analysis**

No.	Individual EEM	Cost/sqft	Cost Range	Payback (year) Over ASHRAE 1999		
		Average	Average	Harris	Dallas	Potter
<b>Envelope Measures</b>						
1	Increased Roof Insulation	\$0.83	\$66,192	79	69	29
2	Decreased Glazing U-Value	\$0.43	\$34,143	16	30	39
3	Decreased Infiltration	\$0.20	\$16,250	14	13	3.6
<b>Lighting Measures</b>						
4	Decreased LPD	\$1.00	\$79,430	4.6	4.7	5.6
5	Occupancy Sensor for Lighting Control	\$0.38	\$23,280	4.9	5.0	5.8
6	Daylight Dimming Controls	\$1.07	\$85,085	4.2	4.4	5.1
7	Skylights	\$2.39	\$43,736	8.6	9.8	14
<b>HVAC System Measures</b>						
8	OA Demand Control	\$0.61	\$37,360	5.0	6.3	6.7
9	Improved AC Efficiency	\$1.67	\$132,701	20	23	37
10	Improved Heating System Efficiency	\$0.38	\$30,000	63	48	18
11	Decreased Supply Fan Power Consumption	\$0.22	\$17,500	2.2	2.2	2.0
12	PVAVS with VFD for Fan Control	\$0.50	\$39,780	3.1	3.0	2.9
13	PVAVS with Variable Speed for HW Pump	\$0.06	\$5,150	3.0	3.2	2.2
<b>DHW Measures</b>						
14	Improved DHW Heater Efficiency	\$0.15	\$11,690	42	41	39
15	Tankless Water Heater	\$0.08	\$6,000	2.9	2.9	2.8
<b>Renewable Measures</b>						
16	Solar PV	\$21.14	\$1,679,333	40	36	33
17	Solar DHW	\$0.14	\$11,507	11	9.1	8.2
18	Ground Source Heat Pump	\$1.51	\$120,000	80	25	12

CATEE 2011, Dallas, Texas, Nov. 7 – 9, 2011



## Energy Efficiency/Renewable Energy (EERE) Projects in Texas Public Schools

- Analysis of the energy saving potential in new and existing Texas ISDs
- K-12 simulation model based on the DOE-2.1e program that uses ASHRAE Standard 90.1 code-compliant, 79,430 sq.ft., school buildings for three climate zones in Texas
- Four base cases (ASHRAE Standard 90.1-1989, 1999, 2004, and 2007) for each climate zone
- Eighteen energy efficient measures

## Best Individual EEMs

- Largest savings from renewable options (Solar PV and GSHP)
- High savings from lighting measures (daylight dimming controls and decreased LPD) and OA demand control and PVAVS with VFD
- Shortest payback periods (2.0 to 3.2 years for existing and 0 to 4.5 years for new schools) from decreased supply fan power, tankless water heater, and VFD for fan, and VFD for hot water pumping
- Second shortest payback periods (4.2 to 5.8 years for existing and 3.1 to 7.5 years for new schools) from lighting measures (daylight dimming controls, decreased LPD, and occupancy sensor for light control)

## ASHRAE AEDG

- 20.2% to 24.6% of a combined savings above 1999 base case (schools that built between 2000 and 2007)
- AEDG could be improved with renewable energy options

# Acknowledgement

## Acknowledgement

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**Thank You!**