Costs and Benefits of Energy Efficiency Investments in Texas Buildings and Vehicles

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AUTHORS

James Fine, Ph.D.
Environmental Defense Fund

Chris Mihm
Consultant

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Contact the author at:
James Fine, Ph.D.
Environmental Defense Fund
916.492.4698
JFine@edf.org

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Executive Summary

Available energy efficiency measures will generate economic returns while avoiding greenhouse gas emissions. These investments are justified on economic grounds, whether or not one is persuaded to act in the face of scientific consensus that climate change is a serious risk to ecosystems and economies. Investment in energy efficiency is a "no regrets" strategy to fight global warming because it pays for itself quickly and continues to provide economic returns for decades. This study quantifies the costs and benefits of energy efficiency investments in buildings and cars for the State of Texas. We find that economic benefits associated with energy bill savings are much larger than capital costs, and the investments have the potential to avoid millions of tons of greenhouse gas emissions annually.

Already the second largest population in America, Texas is among the fastest growing states and is expected to have 25 million people by 2010 and 50 million by 2040.[1] The Austin area alone is expected to balloon to five times the current population over the next 30 years. This reality presents both risks and opportunities. The next two decades of growth are pivotal for fundamental global processes governing our climate, for our communities today and the generations to come.

Texas is also the second largest economy in the United States, and 15th globally, with an annual output of over one trillion dollars.[2] Unfortunately, there remains an unnecessary direct relationship between economic production and air pollution, and Texas emits 10% of U.S. global warming pollution (typically referred to as “greenhouse gases” or GHGs). If Texas were a country, it would be the world’s seventh most emissive nation.

Despite the sheer size and diversity of Texas’ economy, we can pinpoint two major sources of emissions: electricity generation by large power plants and fuel combustion by vehicles. Electric power generation supplies industrial, commercial and residential customers, with the latter two categories comprising one third of total electricity demand. Commercial and residential electricity use is responsible for about 600 million metric tons of carbon dioxide equivalents ($MMTCO_2E$) per year from power plants.[3] By combusting fossil fuels, the transportation sector in Texas also emits about 600 $MMTCO_2E$.

[1] TXSDC, 2008. The Texas State Data Center forecasts four migration scenarios. For this figure, net migration scenario is assumed to equal levels observed from 1990 through 2000. Since 2000, however, population growth slowed, so TXSDC has developed new forecasts based on migration between 2000 and 2004 that predicts lower population levels in 2050. Nevertheless, significant growth in both population and supporting infrastructure is quite likely even if it doesn't quite double between 2010 and 2040.

[2] BEA, 2006, www.bea.gov.

[3] EIA, 2008. Texas State Energy Profile.

Is There a Global Climate Crisis?

Global warming presents acute and severe risks for Texas.[4] For example, coastal development is a key artery of the state's economic lifeline but is threatened by predicted sea level rise affecting waters and increasingly severe weather in the Gulf of Mexico. But whether you believe we ought to act now to fight global warming, energy efficiency makes economic sense for both electricity customers and electricity resource planners.

Does Texas face an electricity supply crisis?

Air pollution is not the only issue in Texas. The Electric Reliability Council of Texas (ERCOT), the agency overseeing 85% of statewide power generation, estimates that peak demand for electricity has increased at an annual rate of 2.5% from 1990 to 2006 and will experience similarly high annual growth going forward.[5] ERCOT acknowledges the potential for an electricity supply shortfall[6] and estimates that available generation capacity for electricity production will drop below the minimum level required to maintain reliability within the next few years.[7]

Texas is growing in and around its cities, creating dense and sprawling metropolitan areas with a variety of environmental problems. This study does not attempt to present a comprehensive solution to the expanding population and economy, but it uses integrated "bottom-up" econometrics models of Texas' commercial and residential buildings, passenger vehicles and power plants to estimate the potential to avoid growth in electric power demand by making energy efficiency investments. In so doing, these investments will also avoid greenhouse gas emissions and lower electricity and fuel bills.

Vehicle Fuel Use

In 2008, gasoline prices across America hit record highs. Living in an oil-rich state, Texas has historically paid below average prices for petroleum products, but an abundance of this natural resources has also meant underinvestment in alternatives. Texas has limited public transit and a vast landscape of long travel distances exacerbated by suburbanization.

For residents in sprawling cities such as Houston, long commutes and congestion are the norm, but there are few alternatives to driving private vehicles. Each year Texans drive over 200 billion miles and consume more than 10 billion gallons of fuel.

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[4] Texas' Changing Economic Climate. Environmental Defense Fund.

[5] ERCOT, 2006a.

[6] This prospect was first reviewed in the ACEEE 2007 report for Texas and is derived from the mid 2006 ERCOT. As a matter of both public policy and prudent operational policy, ERCOT requires that generation capacity in ERCOT exceed peak demand by 12.5% (the planning "reserve margin"). Reserve margins assure that there is enough generation available in real time—despite power plant, fuel availability, or transmission outages—to meet peak loads regardless of forecasting errors and a lack of demand-reducing mechanisms other than involuntary customer outages.****

[7] "Reliability" in this context means the ability to provide electricity to meet consumer needs at all periods of the year; it includes a "reserve capacity" that is 12.5% greater than anticipated peak demand. A study commissioned by the Natural Resources Defense Council posits that Texas is already in a state of crisis and does not have sufficient capacity to provide electricity to consumers. (Optimal Energy, 2007).

But with growth comes opportunity. Texas is positioned to seize the present political moment to plan for aggressive investments in energy and fuel efficiency. The environmental performance of the building stock can be dramatically improved at no net costs. This report summarizes analyses of anticipated capital costs, energy savings and GHG emissions reductions in Texas from energy efficiency policy. We focus on commercial and residential buildings, passenger vehicles and light duty trucks.

Residential and Commercial Buildings

Opting for more efficient lighting, heating and ventilation, and maintaining the systems well reduces energy use and saves consumers money on electricity bills. For example, a small investment of $1,000 to hire a professional to adjust air-cooling equipment controls saved one business over $40,000 per year.[8] Findings in this study indicate that Texas can improve building energy efficiency to save residential and commercial electricity consumers $10.9 billion and $6.7 billion, respectively, in 2030. Aggregated over the study period, building energy efficiency investments can avoid over 750 million metric tons of global warming pollution (i.e., $MMTCO_2E$). This is an average net savings to households of $760 in 2030 and over $11,000 for an average size commercial building.[9]

Table A shows modeling results, and Table B lists the measures analyzed. Table A shows the benefits from moderately aggressive policies to speed energy efficiency investments.[10] Figures 1 and 2 show how avoided electricity bills stack up against capital costs throughout the study period, 2010 thru 2030.

We find that benefits will far exceed costs, even at the low end of the range. The net present value of energy efficiency investments inspired by aggressive policy action is $3.4 billion and $5.4 billion for commercial and residential buildings, respectively.[11] These results consider both avoided energy bills and capital costs. In 2030, capital investments are estimated at $136 million and $769 million for commercial and residential buildings, respectively. The annual avoided emissions grow throughout the study period to 26.5 and 34.9 $MMTCO_2E$, respectively, from commercial and residential energy efficiency investments.

[8] See case study in commercial efficiency section for detail.

[9] The average size of a commercial building in Texas is about 60,000 square feet (ACEEE, 2007). The average Texas home size is about 1,800 square feet (Navigant, 2002).

[10] High and low values are organized according to their potential to influence net present value results. That is, “low” range results include input assumptions that are likely to decrease the economic benefits and increase costs, whereas high range values tend to increase benefits and decrease costs. This explains why capital costs are lower in the "high" range.

[11] Based on a 3% annual discount rate; results in the Tables A and B also show net present value calculated using a 7% discount rate.

TABLE A

Costs and Benefits in 2030 with Low, Middle and High Input Assumptions

Commercial	**Low**	**Mid**	**High**
Capital Investments ($2008 Millions)	$43	$136	$129
Avoided Electricity Bills ($2008 Millions)	$2,700	$6,700	$39,900
Net Present Value (3% discount rate)	$1,400	$3,400	$20,700
Net Present Value (7% discount rate)	$600	$1,500	$9,000
Avoided GHG Emissions (MMTC Eq, 2030)	16.0	26.5	88.8
Avoided GHG Emissions (MMTC Eq, 2008-2030)	52.4	80.4	225.0
Avoided GHG Emissions (MMTCO2 Eq, 2030)	58.8	97.2	325.5
Avoided GHG Emissions (MMTCO2 Eq, 2008-2030)	192.2	294.9	824.9
Residential	**Low**	**Mid**	**High**
Capital Investments ($2008 Millions)	$694	$769	$537
Avoided Electricity Bills ($2008 Millions)	$4,100	$10,900	$27,800
Net Present Value (3% discount rate)	$1,900	$5,400	$14,400
Net Present Value (7% discount rate)	$800	$2,300	$6,200
Avoided GHG Emissions (MMTC Eq, 2030)	19.7	34.9	50.3
Avoided GHG Emissions (MMTC Eq, 2008-2030)	73.3	127.3	200.5
Avoided GHG Emissions (MMTCO2 Eq, 2030)	72.4	128.0	184.4
Avoided GHG Emissions (MMTCO2 Eq, 2008-2030)	268.9	466.7	735.2

TABLE B

Commercial and Residential Energy Efficiency Measures Analyzed for this Report

Commercial	**Residential**
CFL bulbs; T8 and T5 lamps	CFLs
Occupancy Sensor	Wall Insulation
Daytime Dimming	Duct Improvements
Chillers Package	
Duct Testing and Seal	
Retro-Commissioning	
New AC unit	

Figure 1: Net Present Value of Commercial Measures
With Midrange Input Assumptions and 3% Discount Rate

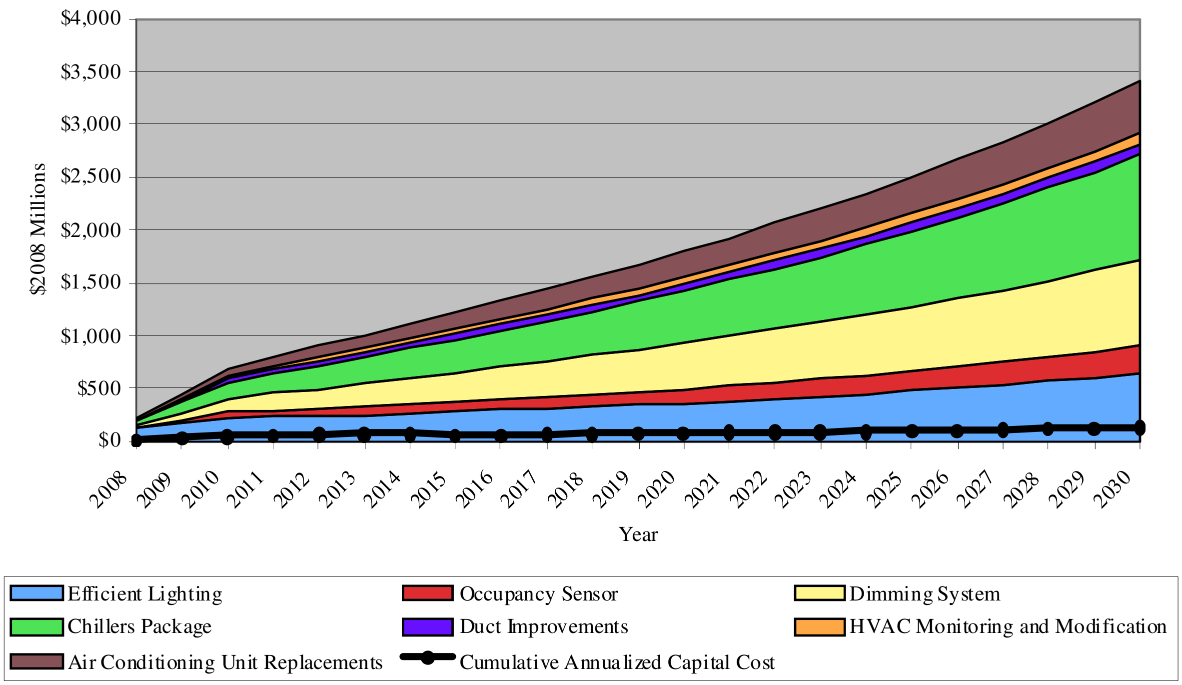
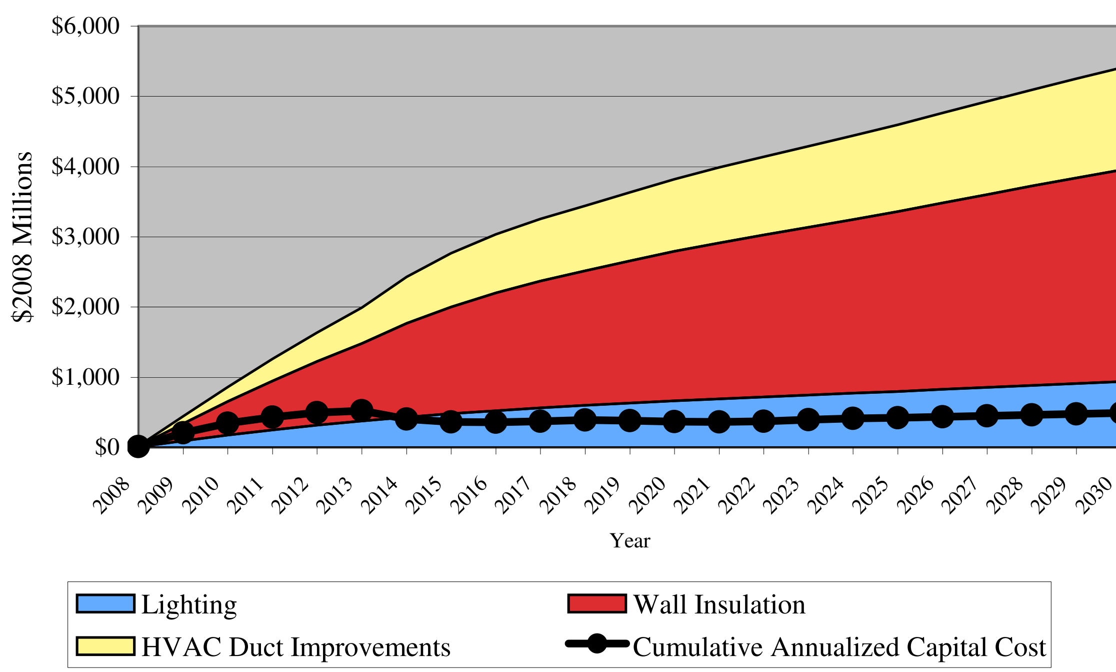


Figure 2: Net Present Value of Residential Measures
Midrange Input Values with 3% Discount Rate



Vehicles

In 2002, California adopted Assembly Bill 1493 (AB1493) to reduce greenhouse gas emissions from cars. The emissions standards, also known as the "Clean Car" standards, can be met through several compliance pathways. For simplicity, we represent their benefits by comparison to Federal CAFE standards for new cars and fleet average fuel efficiency forecasts from the California Air Resources Board. In addition to fuel efficiency standards, CARB is planning to reduce the carbon content of fuel sold in California by 10 percent by 2020. If implemented in Texas, a low carbon fuel standard (LCFS) would further reduce greenhouse gas emissions.

Tables C and D summarize findings for cars and light trucks in 2020 and 2030, respectively, for the two fleet scenarios. The Clean Car and LCFS standards combined will reduce emissions significantly while saving drivers money inform avoided fuel costs. Texas drivers will save on average \$420 and \$620 per year in 2030 in avoided fuel costs. Subtracting the capital costs of improvements from the fuel cost savings provides a general estimate of net savings. The California Air Resources Board estimates that annualized costs of vehicle modifications to meet the Clean Car standards will average \$158 per car or \$43 per truck.[12] We gauge the net benefits to consumers by subtracting CARB's cost estimate from our estimate of avoided fuel costs. This calculation yields a net benefit to drivers of 2030 model cars of approximately \$262 annually and to drivers of average light duty trucks of \$597 annually.

Statewide, the fleet will avoid consumption of 3.5 billion gallons of fuel in 2030, which translates into 37 tons of avoided global warming pollution and nearly \$9 billion in avoided fuel costs. Aggregated for the 20-year study period from 2010 thru 2030, avoided greenhouse emissions exceed 440 $MMTCO_2E$.

TABLE C

Summary of Findings for 2020 from Clean Cars and LCFS Standards

	Cars	Light Trucks	Cars + Trucks
Avoided Fuel Use Bills (Millions of Gallons/Year)	937	469	1,406
Avoided Fuel Use Bills (Gallons/Day)	0	0	0
Avoided Fuel Costs (All Cars & Light Trucks, \$2005 Millions)	\$2,237	\$1,119	\$3,356
Additional VMTs (All Cars & Light Trucks, Millions)	2,382	682	3,064
Avoided Fuel Costs (\$2005 Per Vehicle)	\$280	\$400	-
Additional VMTs (Miles Per Vehicle)	177	149	-
Avoided GHG Emissions (All Cars & Light Trucks, MMTC Eq, 2020)	4.525	1.747	6.3
Avoided GHG Emissions (All Cars & Light Trucks, MMTCO2 Eq, 2020)	16.591	6.404	23.0

[12] See Tables 10.2-1 and 11.4-1 of California Environmental Protection Agency, California Air Resources Board, Addendum Presenting And Describing Revisions To: Initial Statement Of Reasons For Proposed Rulemaking, Public Hearing To Consider Adoption Of Regulations To Control Greenhouse Gas Emissions From Motor Vehicles, September 10, 2004.

TABLE D
Summary of Findings for 2030 from Clean Cars and LCFS Standards

	Cars	Light Trucks	Cars + Trucks
Avoided Fuel Use (Millions of Gallons/Year)	2,114	1,470	3,584
Avoided Fuel Use (Millions of Gallons/Day)	5.79	4.03	9.82
Avoided Fuel Costs (All Cars & Light Trucks, $2005 Millions)	$5,218	$3,628	$8,846
Additional VMTs (All Cars & Light Trucks, Millions)	5,918	1,886	7,804
Avoided Fuel Costs ($2005 Per Vehicle)	$420	$620	-
Additional VMTs (Miles Per Vehicle)	513	527	-
Avoided GHG Emissions (All Cars & Light Trucks, MMTC Eq, 2030)	7.3	2.8	10.1
Avoided GHG Emissions (All Cars & Light Trucks, MMTCO2 Eq, 2030)	26.8	10.2	37.1
Avoided GHG Emissions (All Cars & Light Trucks, MMTC Eq, 2010-2030)	87.4	33.4	120.8
Avoided GHG Emissions (All Cars & Light Trucks, MMTCO2 Eq, 2010-2030)	320.4	122.5	442.8

In terms of total energy use in Texas, the commercial and residential sector account for about one-quarter, whereas the transportation sector is another quarter. Texas has enormous potential for energy efficiency investments in these sectors. The story of Two Houston Center provides a teaser of what it possible for Texas.

Two Houston Center sits in the middle of downtown Houston where it is often hot and humid. In 2007, the building owners set "realistic but challenging" goals to reduce their energy consumption. Many of the competitors were moving toward energy efficient buildings as the real estate industry learned the value of "green" features and investments. The initial goal was to reduce energy use by 20% over the next 10 years. This was a realistic objective and kept apace with the competition. What started as a reputation builder quickly became much more. The team found that simply replacing their 30-year-old water cooling "chillers" cut energy use by 10 percent. This simple investment saves $300,000 per year in energy bills and repaid initial capital costs in less than four years. In addition to cutting operating costs, the conservation goals will avoid 4 million pounds of greenhouse gas emissions each year.

Introduction

Mounting scientific evidence leaves little doubt that climate change presents a severe risk to us all. What we do (or don't do) over the next 20 years will have a profound effect on the costs of dealing with climate change. Further, expert reports suggest that early action on climate change can significantly outweigh the costs.

In 2007, the Intergovernmental Panel on Climate Change (IPCC) reported that greenhouse gas (GHG) emissions due to human activities have grown rapidly since pre-industrial times, with 70% of the increase occurring between 1970 and 2004. Carbon dioxide (CO2) is the most pervasive greenhouse gas. According to recent measurements, atmospheric CO2 concentrations are at 380 parts per million (ppm). The IPCC has identified 450 ppm of CO2 as a critical stabilization level beyond which some of the worst effects of climate change become essentially inevitable. However, if stabilization efforts are undertaken presently to slow emissions, we can significantly reduce the likelihood of bearing the enormous ecological and economic impact of the worst effects of global warming. In sum, global warming must be addressed immediately.

Unfortunately, a growing emissions inventory is taking the U.S. in the wrong direction. Since 1990, greenhouse gas emissions in the U.S. have risen 1.2% each year and now total over 7 billion tons annually (McKinsey, 2006). In the next twenty years, millions of more homes and thousands of more businesses will need energy, and millions of new vehicles will require fuel.

One immediate means to reduce emissions is to make better use of energy through more efficient buildings and cars. Using less energy mitigates GHG emissions, but they need not compromise the needs of consumers. Simple solutions and technologies are available now that save money on monthly expenditures, and quickly pay back the initial investment.

The Texas Energy Regional Planning Council (ERCOT) identified demand side management (DSM) as one of the four major themes in the Texas Energy Plan 2005. The plan called for the governor to provide incentives to allow utilities and consumers to implement more efficiency and conservation measures. More specifically, the council called for the Texas Energy Savings Act to reduce 15% of transmission and generation growth in demand compared against business as usual, to use Systems Benefit Funds for consumer education, and to restore the Texas Emissions Reduction Plan funding for energy efficiency. Texas already has consumer incentive programs in place; there are already eleven energy efficiency programs offered by cities and utilities in Texas.[13] There is far more to be done, and the potential gains to households, business operators and our environment are substantial given more aggressive investment in energy efficiency.

Electricity generation and vehicle emissions account for most of the United States' GHG emissions. The U.S. generates 24% of total global carbon dioxide emissions, with nearly 40% coming from the electricity sector. Furthermore, nearly 83% of electricity emissions come from coal-fired power plants (EDF, 2008a). The State of Texas is responsible for 10% of total U.S. emissions.

[13] www.eetd.lbnl.gov/EnergyCrossroads/states/tx.html.

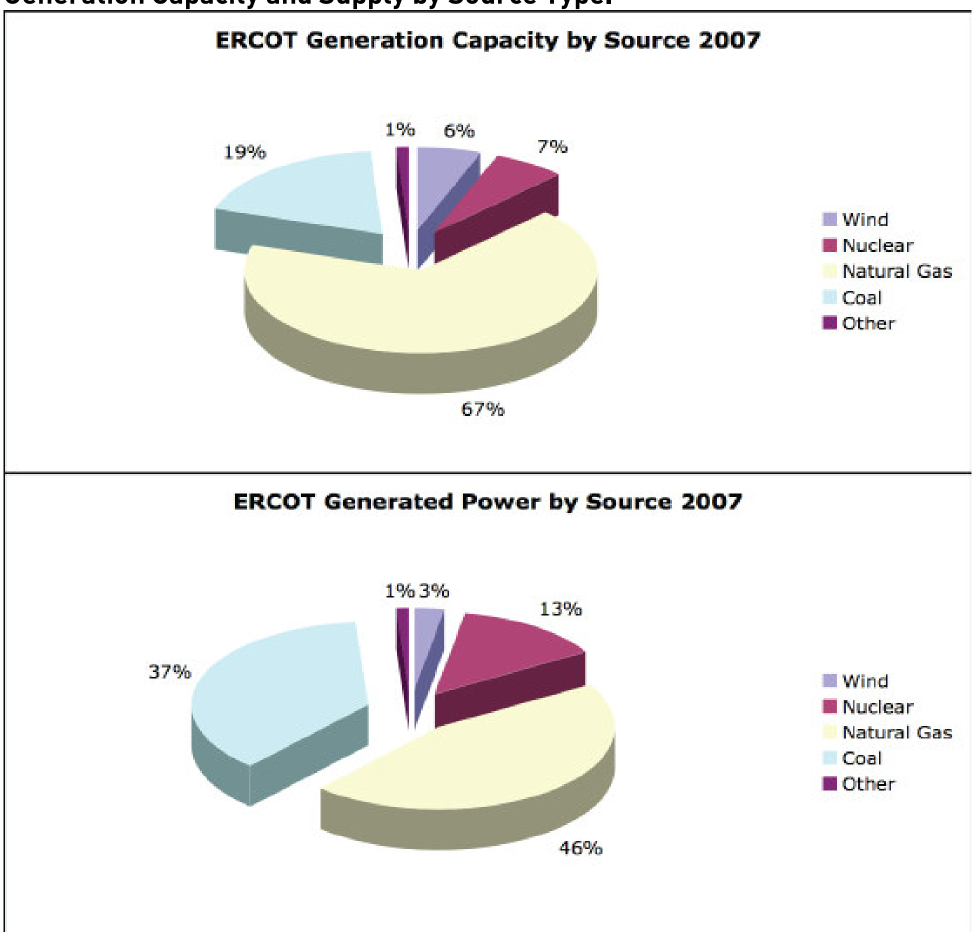
Texas Electricity Demand Trends and Forecast

Texas is already the biggest state in the U.S and it's growing steadily. Formerly small towns are now merging with the larger metropolitan areas. Demand for electricity and transportation fuel has grown apace.

Though the Lone Star State has enjoyed a natural endowment of petroleum reserves, when it comes to electricity supply, Texas has a diverse resource mix that includes natural gas, coal, hydroelectric, nuclear, and wind. Despite the dominance of natural gas generating capacity, Texas uses more coal than any other state.[14] As shown in Figure 3, 2007 generation capacity was 65% natural gas, 20% coal, about 6% wind and nuclear, and less than 1% hydro, but in 2006 the actual supply was 45% natural gas, 37% coal, 13% nuclear, and a paltry 4% renewable wind and solar.[15]

FIGURE 3

Generation Capacity and Supply by Source Type.[16]



The figures above represent the contrast between energy source capacity and the actual amount of that source used to generate electricity. In 2007, 45% of the energy generated was from natural gas, and 38% was from coal. Despite the disproportionately large amount of natural gas generation capacity, coal was still used to produce almost half the generated power in 2007.

[14] EIA State Energy Profile, 2007b.

[15] Jones, 2006 and Jones, 2007.

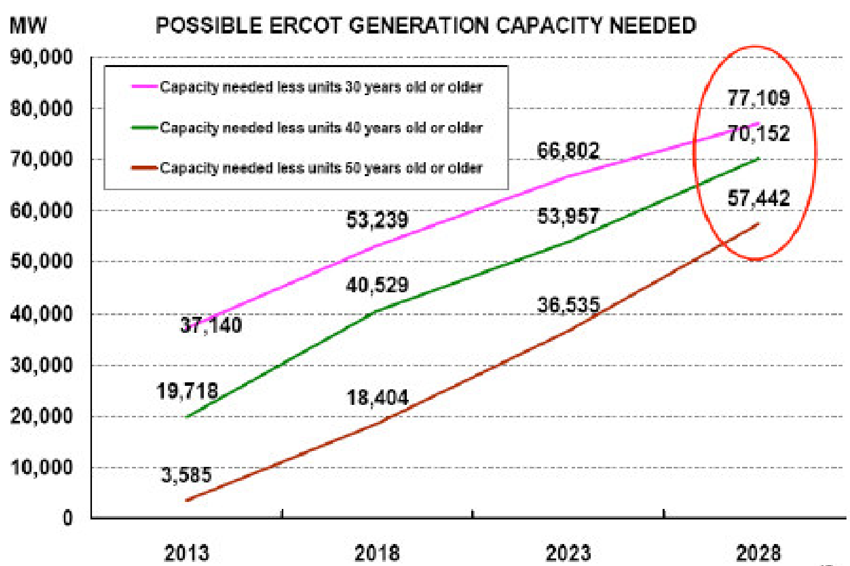
[16] ERCOT, 2007; PUCT, 2008.

Expectations of population and economy-wide growth suggest the need for up to 80,000 MW of new generation capacity by 2030. The current electricity supply portfolio emits an enormous amount of greenhouse gas pollution. The immediate question is how to meet growing demand while reducing emissions. The cleanest and cheapest method is to minimize growth in the need for electricity. Investments in energy efficiency pay back quickly, avoid emissions, and save consumers money for decades to come.

Texas experienced above average growth in energy demand over the last ten years. In 2007, ERCOT experienced the highest summer peak demand in history. Over the past ten years, electricity demand in the ERCOT region has grown nearly 23% while peak demand has grown 24% (ERCOT, 2007). In addition to weather factors and changing demographics, economics plays an integral role in driving energy demand. Texas is expected to outperform the U.S. as a whole in the regional economic outlook.[17] The parts of Texas expecting significant growth are already the economic powerhouses of Texas and the nation. Houston, Dallas, and San Antonio are already among the top 10 metropolitan areas in the country when ranked by population, and they all expect considerable growth (US Census, 2007). As shown in Figure 4, ERCOT forecasts that Texas will need between 60,000 and 80,000 MW of new electricity generation capacity by 2030.[18]

FIGURE 4

ERCOT Required Capacity based on Retirement Age of Power Plant[19]



[17] ERCOT, 2007, Planning Long-Term Hourly Peak Demand Forecasts.

[18] The range depends on demand growth and retirement rate of existing generation resources. If power plants are required to retire earlier (e.g., after 30 years of operation rather than 50 years) there will be more need for new capacity. PUCT, 2008.

[19] ERCOT, 2007.

Renewable Energy

Texas' oil heritage may soon be recast by its renewable energy resources. Already the largest wind producer in the U.S., the state's renewable portfolio standard (RPS) requires 5,880 MW by 2015 and 10,000 MW from renewable sources by 2025. However, Texas just finalized a plan for a 17,000-MW increase in wind capacity that will meet the RPS ahead of schedule.[20] Nevertheless, emissions from electricity production continue to dominate the state's energy supply portfolio.

Emissions

Electricity generation in Texas—mostly the ERCOT region—is cleaner than most states because capacity is dominated by natural gas power plants that are less polluting than coal-based generation common to the Eastern and Midwestern states. However, coal capacity is used preferentially, so it comprises a larger proportion of electricity generation than the supply portfolio would imply.

As shown in Figure 3, coal-fired power plants supplied one-third of all power in 2007. Coal-power was also responsible for 1.7 times more GHG emissions than the natural gas plants in Texas, even though the gas plants supplied almost half of the electricity.

There are numerous costs associated with air pollutant emissions, notably the localized health effects caused by high levels of ozone and particulate matter. Looming on the horizon are the enormous costs of failing to act decisively to stem global warming pollution. There is another potential cost to Texas – or to any regime that follows rather than leads in the fight against global warming. That economic risk is the cost of greenhouse gas emissions allowances within a state, regional, national or international cap-and-trade program aimed at reducing emissions. It appears likely that a federal program will be forthcoming, but Texas may act now to join an existing regional emissions trading system such as the Western Climate Initiative or the Regional Greenhouse Gas Initiative. In either event, Texas businesses would be required to reduce emissions or purchase emission allowances.

[20] This statement is based on an article from MSNBC written in 2007. Further information can be found in the ERCOT report "Energy Demand Reveres Capacity, summer and Winter Fuel types" and TREIA PROGRAM ON TEXAS RENEWABLES").

Methods

We analyze the economic costs and benefits of achieving improved energy efficiency in Texas commercial buildings and homes, vehicles and power plants. Scenarios are developed to explore the baseline expectations for business as usual efficiency improvements and to estimate the consequences of investing in more efficiency sooner. We focus on commercial and residential buildings and passenger vehicles because there are many "no regrets" technologies available now that reduce emissions and save money. Our assumptions are conservative estimates that draw on previous studies that expect much faster rates of adoption. We also limit our inquiry to only a few technologies and no substantive behavior change on the part of the user. Our conclusions are based on three models:

1. Texas Building Energy Efficiency Model (TEEM) – an econometric model of the commercial and residential energy efficiency investments from 2008 through 2030 developed by Environmental Defense Fund.

2. VISION AEO 2008 – a comprehensive transportation model that calculates vehicle miles traveled, fuel use, and emissions based on vehicle fleet characteristics and fuel costs developed by Argonne National Laboratory.

3. Texas Electricity Model - a proprietary model of the Texas electricity grid developed by Erin O'Neil to analyze load growth characteristics, fuel sources, fuel prices, capacity additions, carbon policy, and emissions based on various decisions regarding the utility sector.

Together, these three modeling tools provide a bottom-up platform that builds upon data about the population of commercial and residential buildings, vehicles and power plants in Texas and about the economic and physical characteristics of current and future lighting, weatherization and HVAC technologies and their integration into existing and new buildings.

Building Sector: Texas Energy Efficiency Model (TEEM)

The Texas Energy Efficiency Model is a spreadsheet model that calculates the economic and emissions consequences of energy efficiency investments in commercial and residential buildings from 2008 through 2030. Measures analyzed are listed in Table E, with more details available in the Appendices.

TABLE E
Measures Modeled in TEEM

Commercial	Residential
CFL bulbs; T8 and T5 lamps	CFLs
Occupancy Sensor	Wall Insulation
Daytime Dimming	Duct Improvements
Chillers Package	
Duct Testing and Seal	
Retro-Commissioning	
New AC unit	

Developing the TEEM model and calculating costs and benefits involved several steps:

1) Forecast the market growth. Calculate the number of residential buildings based on data from the Texas State Data Center.
2) Forecast the market growth of commercial floor space in Texas, calibrated from the EIA data for the West South Central Census division.
3) Identify specific existing technologies to analyze.
4) Determine the power savings of each measure per home for the residential model and per square foot in the commercial model.
5) Determine the costs of implementing each technology and calculate the amortized payment for each technology.
6) Determine the efficiency growth (i.e., rate of improvement of existing technology, as well as updating two generations of lighting), price curve, and market penetration for each technology.
7) Calculate the cumulative kWh saved by technology.
8) Calculate total savings per technology for rate-paying customers.
9) Calculate net present value for 3% and 7% discount rates.
10) Develop a set of emissions factors and calculate total emissions avoided by energy efficiency investments.
11) Calculate aggregate savings.
12) Develop two scenarios – a Reference Case and Investment Case to quantify the benefits of pushing to integrate efficient technologies into existing and new buildings.
13) Represent uncertainty by creating low, middle and high input values for the reference and investment cases, and for the attributes of each technology type.
14) Solicit external peer review.
15) Modify model based on peer review comments and recommended literature.
16) Conduct scenario and uncertainty analyses.
17) Summarize and report results.

Important assumptions are shown in Table F. Considerably more detail about TEEM is provided in Appendices A and B.

TABLE F

TEEM Financial and Market Transformation Assumptions

Input Parameter	Low	Mid	High
Amortization Rate for Capital Loans (%/year)	12.0%	10.0%	8.0%
Length of Loan for Capital Investments (Years)	3	5	7
Electricity Rates ($/kWh) – Commercial	$0.087	$0.109	$0.131
Electricity Rate Growth (%/year) - Commercial	1.0%	2.0%	4.0%
Electricity Rates ($/kWh) – Residential	$0.107	$0.134	$0.161
Electricity Rate Growth (%/year) - Residential	1.0%	2.0%	4.0%
Commercial Market Share Growth Rate for New Buildings (%/year)	4.0%	8.0%	16.1%
Commercial Market Share Growth Rate for Existing Buildings (%/year)	3.5%	6.9%	13.9%
Residential Market Share Growth Rate for New Houses (%/year)	4.5%	9.0%	18.0%
Residential Market Share Growth Rate for Existing Houses (%/year)	2.5%	5.0%	10.0%
Capital Costs and Energy Savings from Pre-existing EE Investments	95.0%	95.0%	95.0%
Emissions Factor (CO2 pounds per kWh)	1.42	1.47	1.52

Transportation Sector: VISION Model

We utilized the *VISION AEO 2008 Expanded Model* to quantify the emissions and economic dimensions of adopting a low-carbon fuel standard and greenhouse gas emissions standards for the Texas vehicle fleet. VISION is built with default national data that we adapted by inserting the Texas vehicle fleet data provided by the Texas Department of Transportation. We also adjusted parameters to represent Texas, such as current fleet fuel efficiency and the percentage of forecasted light-duty truck (LDT) sales compared to passenger cars. We adjusted fuel efficiency forecast parameters to represent the 2008 CAFE standards in the Reference Case and the combined effects of emissions standards and fuel carbon content standards in the Investment Case.

Adapting VISION to Texas

To calibrate the VISION AEO 2008 model for the State of Texas, we obtained a snapshot of registered vehicles in Texas by age and vehicle type. The Texas Commission for Environmental Quality (TCEQ) provided data from July 2008. The VISION model forecasts to 2100 using trends observed since 1970. However, we report results only thru 2020. The data provided by the TCEQ aggregates vehicles older than 1980, so we distributed those vehicles evenly into older age groups represented in VISION.

In addition to inputting the Texas vehicle fleet, we adjusted market share forecasts for light trucks and passenger cars. We set the Texas market share of light duty trucks at 40% from 2000 to 2030 based on the existing fleet composition. This is important because the Reference and Investment case fuel economy standards are different for passenger cars and light duty trucks. We used default values for the market penetration of new technologies like electric vehicles and plug in electric vehicles.

There are several compliance pathways for both the Clean Cars standards and the LCFS.[21] For simplicity, transparency and a coarse estimate of benefits, adjusting fuel efficiency and fuel carbon content serves as an adequate analog in the modeling construct. In the Reference Case, we adjusted the passenger car and light truck fuel efficiencies to represent the current Corporate Average Fuel Economy (CAFE) standards. In the Investment Case, we enhanced the fuel economy for passenger car and light-duty trucks to represent the emissions standards like those being promulgated by California and more than a dozen other states. In addition, we reduced the model parameters for carbon content by 10% based on the adoption of a low carbon fuel standard with goals similar to California's of reducing carbon content by 10% by 2020.

We use estimates developed by the California Air Resources Board, shown in Figure 4, for vehicle fuel efficiencies engendered by CAFE and Clean Car standards. The business as usual case has fuel efficiency equal to Federal CAFE standards and an opportunistic case has higher fuel efficiency as needed to meet greenhouse gas emissions standards.

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[21] There are several ways to forecast strategies used to comply with the Clean Car standards:

- Vehicle fuel efficiency
- Fuel switching
- Vehicle switching
- Vehicle technologies that improve air conditioning efficiencies, reduce leakage, and reduce emissions of non-CO2 greenhouse gases (notably nitrous oxide and methane)
- Combinations of the above

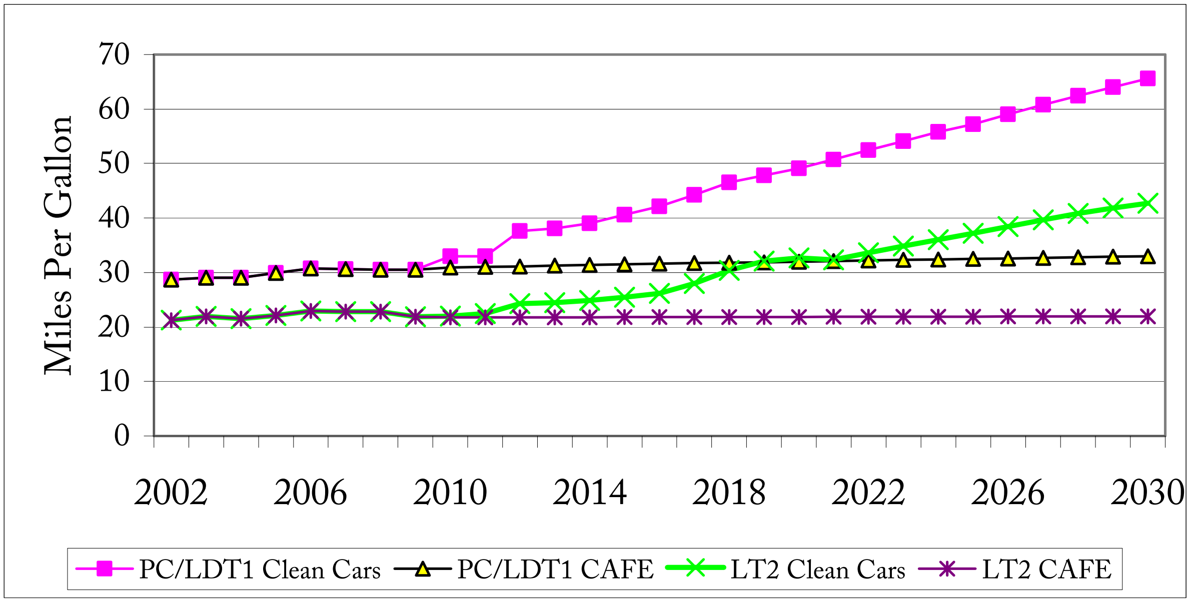
Like the Clean Car standards, there are several compliance pathways for the LCFS:

- Providing only fuels that meet the standard
- Providing a mix of higher and lower carbon fuels that on average meet the standard
- Using previously banked credits in an amount that equals the credit deficit
- Acquiring credits from other parties who earned credits by exceeding the standard
- Combinations of the above

For example, a producer may choose to meet the LCFS by a combination of selling low carbon fuels (e.g. ethanol derived from waste resources) and by buying credits from other regulated parties. The LCFS should spark research in alternatives to petroleum-based fuels, leading to GHG emission reductions over the long term.

FIGURE 4

Federal CAFE and Clean Car Standards for Cars, SUVs and Light Trucks



Fuel price assumptions in 2020 and 2030 are $2.38 and $2.47 per gallon, respectively, based on forecasts by the Federal Energy Information Administration. We consider these to be very conservative. Fuel efficiencies for the full Texas fleet and individual new cars and trucks differ as shown in Table G. We input new car fuel efficiency assumptions, whereas the model calculated fleet average fuel efficiency weighted by VMTs.

TABLE G

New Car and Fleet Average Fuel Efficiency

Year	New Car – Federal CAFE	New Car – Clean Car Standards	VMT-weighted Texas Car Fleet – Federal CAFE	VMT-weighted Texas Car Fleet – Clean Car Standards
2020	32.0	49.1	24.4	28.6
2030	33.0	65.6	25.7	40.0
	New Light Truck – Federal CAFE	**New Light Truck - Clean Car Standards**	**VMT-weighted Texas Light Truck Fleet - Federal CAFE**	**VMT-weighted Texas Light Truck Fleet - Clean Car Standards**
2020	21.9	32.7	17.3	19.4
2030	22.0	42.7	17.5	26.0

Findings

Efficiency investments in buildings and vehicles combined can avoid well over 50 millions metric tons of greenhouse gas emissions *annually* by 2030. The economic opportunities are equally impressive. Figures 1 and 2 (in the Executive Summary) show that energy bill savings in commercial and residential buildings are much greater than capital costs. As shown in Table H, the net present value of avoided electricity bills can be $3.4 billion in the commercial sector and $5.4 billion in residences by 2030.[22] Vehicle efficiency improvements by 2030 can save drivers $5.5 billion per year at the pumps while avoiding the use of about 2.5 billion gallons of fuel.

Commercial, residential and transportation sectors use half of all energy demand in Texas. Our commercial sector model indicates that EE measures can avoid 20 million tons of greenhouse gas emissions per year by 2030 with business-as-usual rates of implementation, and moderately higher rates of implementation can avoid a whopping 30 million tons of emissions.[23] Similarly, the residential sector can avoid 12 million tons of emissions from EE measures with moderately aggressive investment.

TABLE H

Costs & Benefits of Aggressive Policy in 2030 with Midrange Assumptions

	Commercial Buildings	Residential Buildings
Capital Investments ($2008 Millions)	$136	$769
Avoided Electricity Bills ($2008 Millions)	$6,700	$10,900
Net Present Value (3% discount rate, $2008 Millions)	$3,400	$5,400
Net Present Value (7% discount rate, $2008 Millions)	$1,500	$2,300
Avoided GHG Emissions (MMTCE, 2030)	7.2	9.5
Cumulative Avoided GHG Emissions (MMTCE, 2008-2030)	80.4	127.3

We must invest money in the near term to save money in the long term. We use conservative financial assumptions, including annualized capital payments on all new capital assets at an interest rate of 10% and loan repayment within five years. Lower interest loans and longer repayment schedules will sweeten the picture. Even at private lending rates, efficiency measures pay back quickly, and depreciate slowly, delivering savings for decades. We calculate capital costs and electricity savings and then discount the financial flows to arrive at a net present value estimate. The annual net present value of 2030 benefits for the commercial and residential buildings is $13 billion and $25 billion, respectively, with moderately aggressive investment.[24]

[22] Values are in 2008 dollars. Net present value calculation based on a 3% discount rate.

[23] The estimate of 30 million metric tons of avoided power plant emissions is based on the aggressive policy assumptions with high range input assumptions and current year emissions factors for the Texas electricity grid of 1.52 lbs. CO_2 per kWh. While the grid-averaged emissions rate may be lower in 2030, current emissions rates based on actual supply are most defensible for use in analyses.

[24] The numbers here are based on a 3% rate of discount. We also calculated net present value using a 7% discount rate in TEEM. This model is generating future net positive economic benefits, so higher rate of discount lower the net present value.

Residential Buildings

Texas household energy consumption makes up 10% of the total residential energy end-use in the U.S. To put this into perspective, the Texas residential sector alone consumes the same amount of energy as the typical state uses to power its entire commercial, residential, and industrial sectors (EDF calc, EIA Energy Profile, 2008b). Electric heating, soaring summer temperatures, and population size are the primary forces driving residential energy consumption in Texas. Almost all household heaters in Texas use electricity, and more than 86% of Texans have air conditioning units[25] that drive peak demand during the summer (EIA, 1997). Texas also has the second largest population in the country, and the number of households will nearly double by 2030.[26] Considering its future energy requirements, Texas should be poised to target increased energy efficiency in the residential sector to mitigate additional generating capacity needs. This study focuses on a few specific measures listed in Table E.

Our results concur with several other studies[27] and empirical evidence[28] that suggest energy efficiency measures can successfully lower energy bills, lower demand for electricity, and reduce emissions. Figure 5 shows the net present value of residential building measures.

In homes, wall insulation is an affordable investment that repays capital costs quickly. As shown in Figure 6, improving efficiency of HVAC ducts by sealing leaks and reducing internal air outflow also contributes significant energy savings. Replacing incandescent bulbs with compact fluorescent bulbs is a small portion of the total potential savings that nevertheless pays off the capital investment rapidly.

Electricity savings thru 2030 could approach 100,000 GWh in the residential building sector from just the three measures analyzed. As shown in Figure 7, avoided electricity use translates into avoided power plant emissions of 35 million metric tons of global warming pollution, with the majority of that savings from wall insulation.

Statewide, aggressive integration of energy efficiency measures from 2009 through 2030 will require a capital investment of $3.5 billion but will return savings in the form of avoided electricity bills totaling over $40 billion—a return of more than $10 for each dollar invested.[29] Doing so will also avoid 127 million metric tons of global warming pollution.

[25] The EIA 1997 housing characteristics, table HC4-7a provides household air conditioning (AC) data for the 4 most populated states in the U.S. In 1997 in Texas, 6.3 million households had AC. According to the Texas State Data Center, the 2000 population was 7.3 million.

[26] According to the Texas State Data Center and EDF calculations for intermittent years there are 8.5 million households in 2008. This number is forecasted to grow to over 13 million, a 45% total growth under the 3rd highest migration scenario (this is the TXSDC scenario assumption utilized in our economic modeling).

[27] For examples, see Itron, 2008, and ACEEE, 2007.

[28] For example, see the California Energy Commission Database for Energy Efficient Resources at www.energy.ca.gov/deer/ and at www.deeresources.com.

[29] The dollar values referred to in this sentence are not discounted.

FIGURE 5

Net Present Value in 2030 of Residential Building Efficiency (3% Discount Rate)

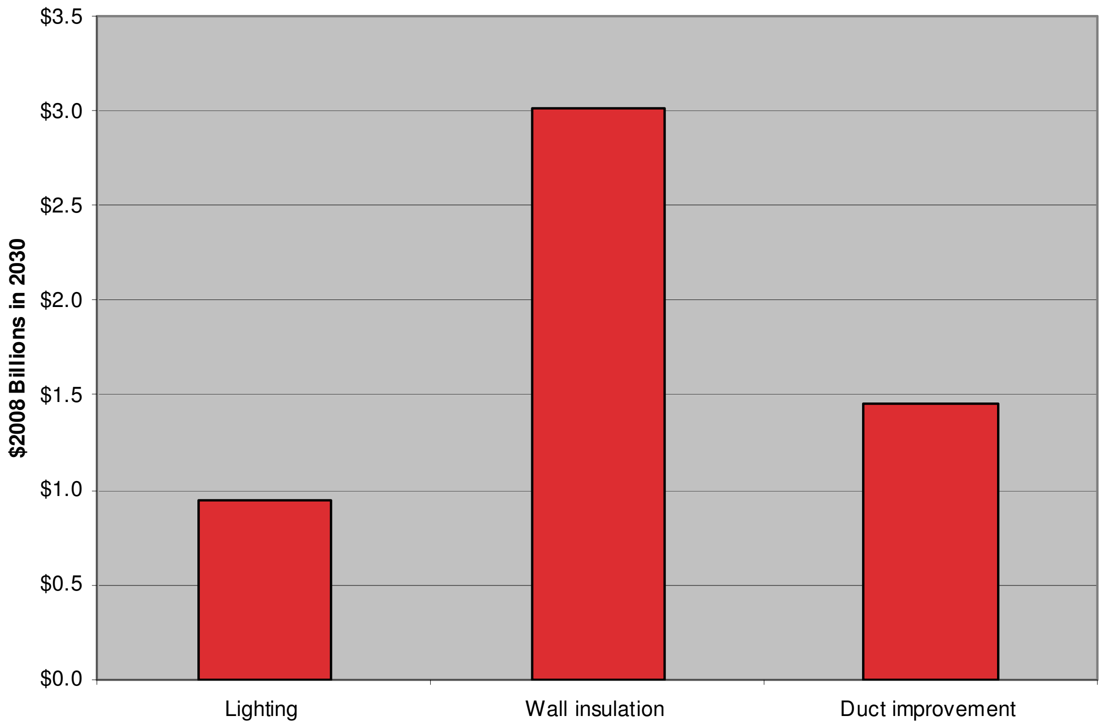
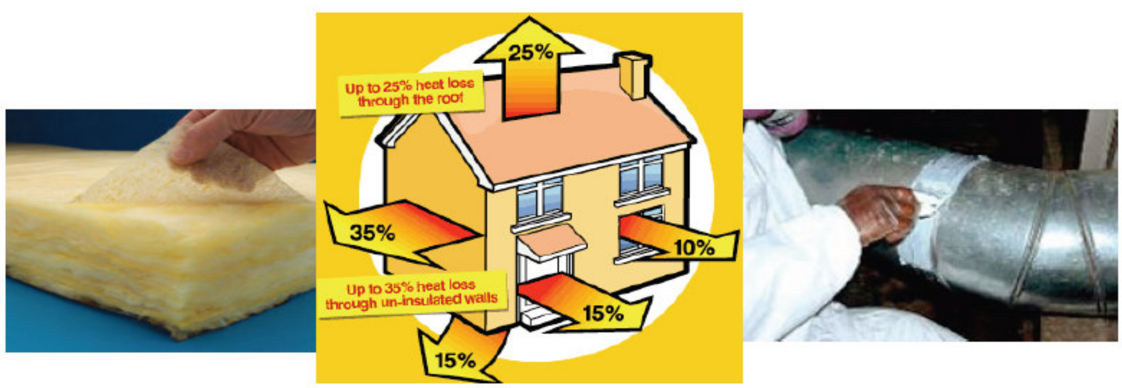


FIGURE 6

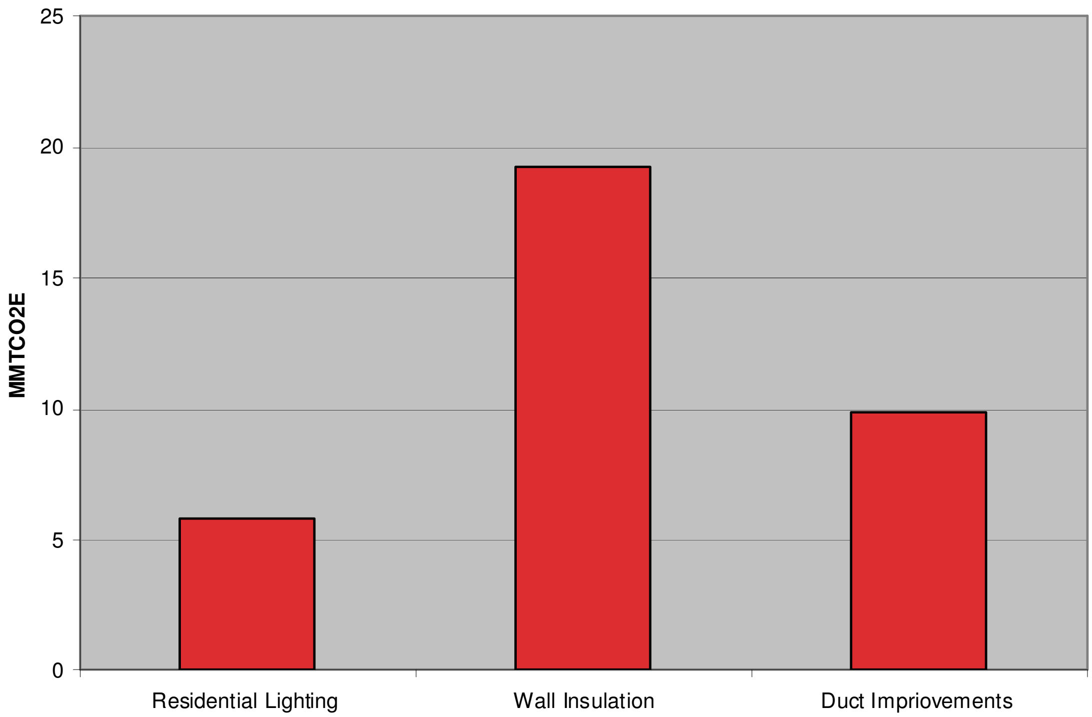
Sources of Leakage in the Building Shell, Insulation and Duct Sealing[30]



[30] Smarterhomes.org

FIGURE 7

Avoided Global Warming Pollution from Residential Building Efficiency Measures in 2030



Although there are many ways to save energy in the home, we focused on the energy efficiency measures identified in other studies and through real experience as offering great potential in the southern states.[31] Changing incandescent light bulbs, installing insulation, and enhancing the duct system in the home have been shown to represent the bulk of very cost effective measures for homes. However, TEEM peer reviewers estimated that only about one-quarter of the potential savings from energy efficiency investments are captured. We therefore consider our findings to be very conservative.

Changing a light bulb is easy. But what about changing the type of light bulb you use? Well that can be easy too, especially when it saves money. In Texas, oil is cheap and electricity is relatively expensive. Texans pay higher electricity rates than most Americans and are charged the second highest price west of the Mississippi.[32] Lighting improvements help cut back the consumption of energy in the home and save consumers money. Nationwide, lighting comprises 20% of a home's electricity use, and only about 2% of residential light bulbs in Texas are efficient CFLs (ACEEE, 2007).[33] Potential

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[31] SWEEP 2002 is a study of the southwest states and ACEEE 2007 is a Texas specific study. In each study, lighting improvements, wall insulation, and duct efficiency improvements account for the most savings.

[32] The consumer residential rate in 2007 was 12.96 cents per kWh on average according to the EIA Texas State Energy Profile. California pays almost 1 cent more on average than Texas.

[33] The EPA assumes 900 kwh per month when calculating emission per household. The average home uses 1950 kWh per year for lighting (Navigant, 2002). More information can be found at www.epa.gov/climatechange/emissions/ind_assumptions.html.

emission savings from switching to CFLs add up quickly, reaching more than 20 tons over the study period that extends to 2030.

Like other energy efficiency measures, replacing incandescent bulbs with CFLs not only yield consumer bill savings but also reduce peak demand. CFLs use about 75% less energy than conventional bulbs and can help trim peak demand while saving approximately 100 kWh per lamp.[34] In our results, aggressive investment in CFLs can avoid about 5.8 MMTCO2E and save a statewide total of $190 million in energy bills by 2030.

WEATHERIZATION: PREPARING YOUR HOME TO SAVE ENERGY

Weatherization reduces the energy consumption of a home by creating a tighter building envelope that minimizes leakage of heating and cooling into and out of conditioned spaces and protects against outside elements. Weatherization tactics include insulating walls, ceilings, floors, water heaters, air ducts, as well as door and window seals. Such improvements translate into real economic benefits for the average house. One study estimated energy savings of about $4,000 per home over the 20-year lifetime of the improvements.[35]

Benefits of the National Weatherization Assistance Program

- Reduce heating bills 32%
- Reduce overall bills by $350
- Average household savings of $4,000
- 30 million BTU saved in the U.S.
- Decreases energy use in the U.S. the equivalent to 17.9 million barrels of oil each year, enough oil to fuel over half a million people driving for an entire year[36].

Proper insulation conserves energy by preventing heating and cooling losses. However, many homes are not well insulated. Determining the amount of insulation inside the walls and ceiling is challenging, and installing insulation can be capital intensive.[37] Our modeling indicates that residential wall insulation can account for statewide electricity bill savings of $1.9 billion in 2030. It can also achieve 29,000 GWh of avoided electricity by 2030 and thus reduce global warming pollution by 19 MMTCO$_2$E in 2030 or a whopping 250 MMTCO$_2$E cumulatively from 2009 through 2030.

FIGURE 8

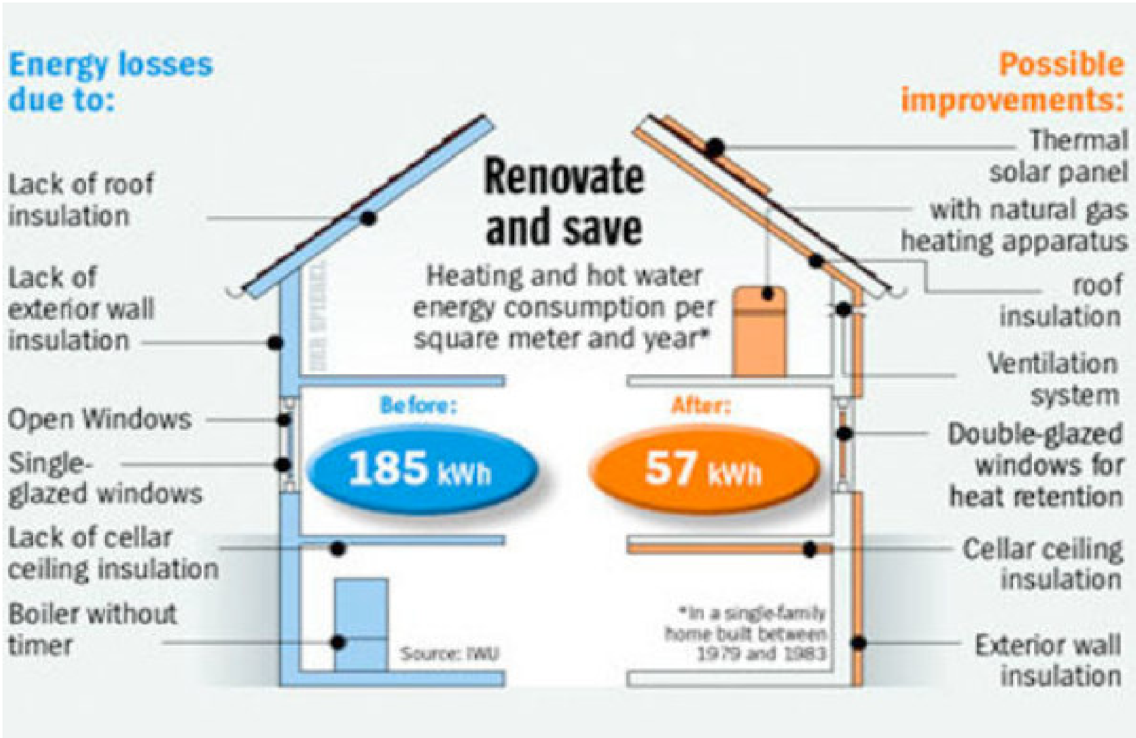
[34] PUCT, 2006. The 75% saving figure is drawn from the average lumens per watt of a CFL compared to an average lumens per watt of an incandescent bulb (Navigant, 2002). The savings per bulb ranges from 36-106 kWh per year dependant on the watt rating of the CFL. 106.5 kWh is based on the savings for a 27 watt rated CFL.

[35] ORNL, 2008. In 2003 dollars. Over the 20-year lifetime of the measures, average one-time costs were $3,000. Costs were incurred by the Weatherization Assistance Program and the participatory utility.

[36] Assumes 19.4 gallons per barrel according to the American Petroleum Institute, 32 miles per day according to EIA 12,000 miles per year, assumes 24.5 miles per gallon, over 200 million trips per year.

[37] Yet, in Texas, incentives do exist for homes with no insulation. Entergy facilitates a program in which a home with electric AC and no wall insulation (R-0) can install wall insulation (R-13) to redeem savings[37] (Entergy, 2005).

Weatherized House vs. Non Weatherized House[38]



Duct leakage in ventilation systems represents one of the largest energy losses in residential and commercial buildings, required up to 30% more heating and cooling to compensate.[39] In our study, we estimate duct improvements can return $3 billion in avoided electricity bills by 2030. Pushing hard on policies to inspire duct improvements will not only put money in the pockets of homeowners, but will also avoid demand for 15,000 GWh of electricity statewide and reduce emissions by 10 $MMTCO_2E$ in 2030.

Although we focus on a few of the most effective energy efficiency measures, there are additional ways to save energy in the home that we have not included. In this respect, our findings are conservative. Insulating pipes, installing water heater jackets or using solar water heaters are all ways to reduce energy needed to heat water. Efficient electric water heaters and water heater pumps reduce electricity and natural gas combustion for water heating (ACEEE, 2007). New or renovated homes can benefit from passive solar planning and proper insulation during the construction process.

[38] Treehugger.com

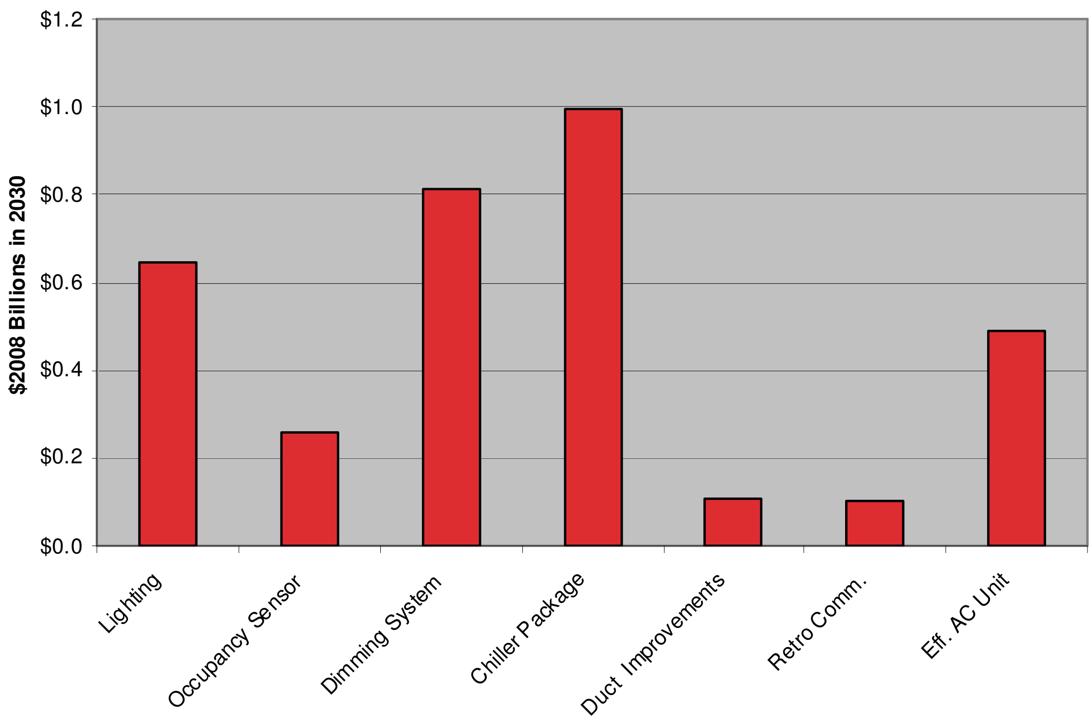
[39] Houses with basements typically have losses of about 20%, and houses with vented crawl spaces or other areas where ducts are outside the conditioned space have losses of about 30% or more (SWEEP, 2002).

Commercial Buildings

Energy efficiency in commercial buildings enhances the economic performance of tenant businesses, and reduces large quantities of GHG emissions. Commercial floor space in Texas is forecasted to grow at a rate of over 2.5 percent annually. New nonresidential construction in Texas is projected to increase by 50% in the next twenty years.[40] Energy efficiency measures can deliver substantial benefits economically and environmentally, as shown in Figures 9 and 10.

FIGURE 9

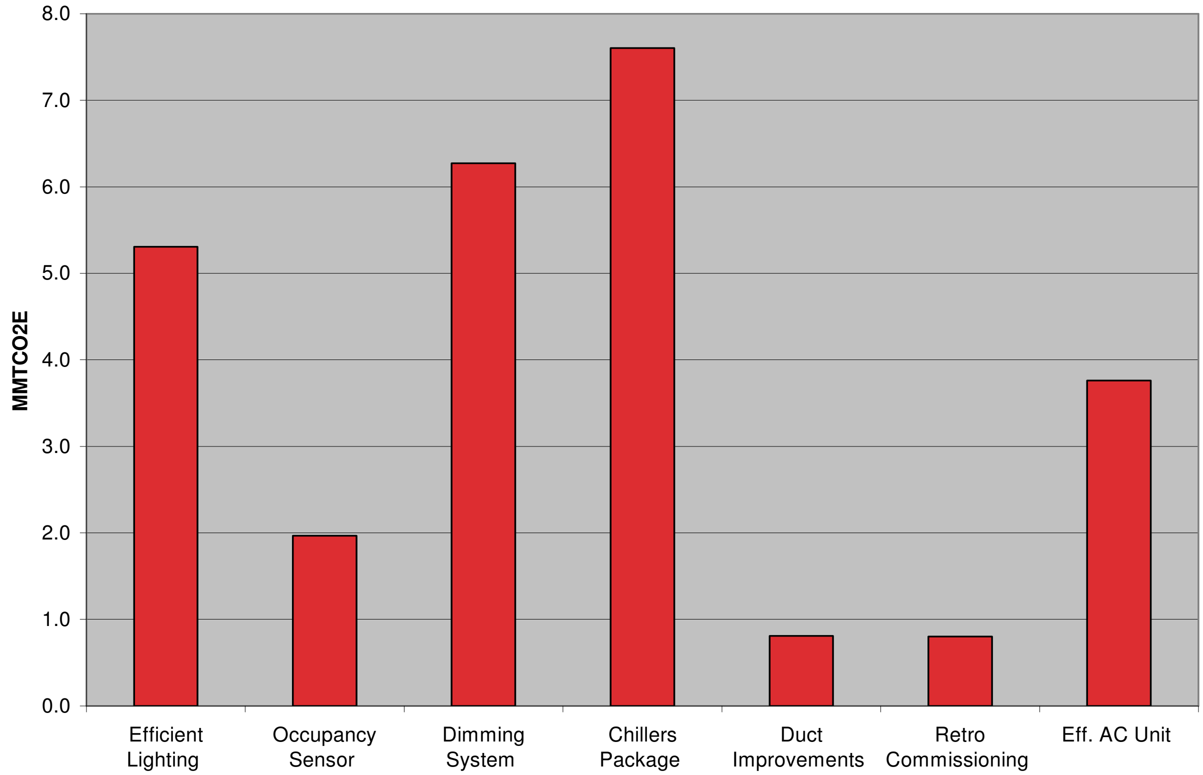
Net Present Value of Commercial Building Efficiency (3% Discount Rate)



[40] DOE, 2005.

FIGURE 10

Avoided Emissions in 2030 from Commercial Building Efficiency Measures



The commercial sector is responsible for massive energy use nationwide. McKinsey and Company estimated that the U.S. commercial sector accounts for 13% of annual greenhouse gas pollution emitted in the U.S. With business as usual energy efficiency investments, the commercial sector will cause 600 megatons of greenhouse gas emissions by 2030, more than any other sector in the U.S. inventory.[41] The same study estimated that by 2030, commercial buildings can reduce electricity consumption and avoid the equivalent of 10% of national emissions or 1.2 gigatons.[42]

Our study indicates that policies to increase energy efficiency in Texas commercial buildings will pay off handsomely. Over the next 20 years, Texas utilities will have to accommodate the energy needs of about five billion square feet of new commercial space, roughly equal to the area of 11,000 Texas Stadiums.[43] Energy efficiency can reduce a significant portion of anticipated power demand.

We study several efficiency measures proven to be significant and cost-effective for commercial buildings, including lighting improvements, occupancy sensors, daytime dimming systems, upgrading to more efficient chillers, enhancing duct performance, retro-commissioning HVAC units, and installing efficient HVAC systems. Many more measures are available but were not included in this analysis, suggesting that our findings

[41] McKinsey , 2007.

[42] McKinsey, 2007.

[43] The footprint of the Dallas Cowboy's Texas Stadium is approximately 10 acres, or 435,600 square feet.

reflect conservative estimates.

We estimate total statewide savings from commercial energy efficiency are worth $6.7 billion in avoided electricity bills in 2030. Avoiding energy use will save 24,000 GWh in 2030 and reduce greenhouse gas emissions by 26 million tons.

The cumulative avoided emissions reduced from 2009 through 2030 in commercial energy efficiency can exceed 300 $MMTCO_2E$. The net economic benefit to the state for this 21-year period, with midrange input assumptions and discounting future values at a rate of 3%, totals more than $3.4 billion for commercial building energy efficiency investments.

LIGHTING IMPROVEMENTS

Lighting accounts for 43% of end-use electricity consumption, more than any other end-use source (ACEEE, 2007a). More efficient lighting and lighting controls often require initial capital investments that are more costly than less efficient alternatives. However, these additional capital costs are quickly recouped through electricity bill savings. The U.S. Lighting Market Characterization Report delineates four main lighting technologies used in the commercial sector: T12, T8, T5, and incandescent-type bulbs. Less efficient T12 lights are used in over half of existing floor space even though four-foot T8 lamps are 30% more efficient than T12s (Navigant, 2002). T5s are among the most efficient fluorescent lighting technologies for commercial buildings, with higher efficacy than T8s. Yet, T5s are generally only installed in new or renovated building space when it is necessary to replace the entire lighting system (EDF, 2008b).[44] Further, although much of the lighting in a commercial building is provided by four-foot long fluorescent tubes, 17% is provided by incandescent bulbs (Navigant, 2002).

We calculate the costs and benefits of replacing T12s with T8s, installing T5s in new or renovated buildings, and replacing incandescent bulbs with CFLs. We do not attempt to represent the potential "game-changing" benefits of light emitting diode (LED) technology because it has only recently become viable for commercial lighting purposes. The exclusion of LED from our analysis is a primary reason to conclude that our findings about the potential savings from lighting improvements are very conservative. Our findings indicate that commercial lighting efficiency improvements can yield savings of $20 million by 2010 and ten times that—$200 million—by 2030 in avoided electricity bills.

[44] One peer reviewer of TEEM noted that this assumption is "not entirely accurate," instead suggesting that current generation T8's (with high efficiency electronic ballasts) offer efficacies equal or higher than those of many T5 systems. For modeling simplicity and clarity, we've modeled slow integration of T5 lighting in new buildings, with T8 lighting as the backstop technology for new buildings. For existing buildings, we allow T8 lighting to displace T12 lights as energy efficient measures. A second simplifying assumption that leads to conservative result is that we have not modeled LED lighting at all even though this technology has the proven potential to be twice as efficient as fluorescent lights and is commercially available.

LIGHTING CONTROLS

Occupancy sensors and daytime dimming systems reduce unnecessary use of electric lighting. Texas and California have a similar amount of commercial floor space, and the California Energy Commission (CEC) has already identified 4.6 billion square feet of commercial floor space as a target market for lighting control of fluorescent lamps that consume 21.2 billion kWh and costs nearly $2 billion per year (PIER, 2003). Occupancy sensors alone can reduce lighting electricity use almost 20% (ACEEE, 2007).

In our study, dimming systems and occupancy sensors augment the benefits of lighting fixture upgrades, and when integrated can save Texans $175 million in 2010 or $1.4 billion over twenty years in avoided electricity bills.

HVAC

Electricity for heating, cooling and ventilation (HVAC) accounts for 28% of end-use energy use in Texas, second only to lighting.[45] A combination of replacing HVAC equipment (such as chillers, fans, and packaged air-conditioning units) with more efficient units, testing and sealing air distribution ducts, and reducing HVAC loads with more efficient windows, roof insulation, and cool roofs can lower HVAC electricity consumption by almost 40%.[46] Our economic analysis considers four measures to improve the efficiency of HVAC systems:

1) Upgrading chillers
2) Duct Improvements
3) HVAC Retro-Commissioning
4) Replacing old AC units

CHILLER UPGRADES

Chillers, which cool water used to cool air in air conditioning systems, are the principal power consumer in buildings that require cooling, making them good candidates for efficiency investments. A new chiller can be twice as efficient as the original and last up to 20 years after a payback period of less than two years.[47] In Texas, about 40% of commercial floor space can benefit from installing new chillers.[48] This is a large untapped economic opportunity for commercial tenants that will also benefit the environment by reducing GHGs through avoided energy usage.

We estimate that chiller replacements could deliver $150 million in net present value with aggressive policy by 2010. Fast, aggressive action could mean cumulative avoided electricity bills of $2 billion through 2030. These same efforts to update chillers will avoid 68 $MMTCO_2E$ of global warming pollution. Chiller efficiency improvements contribute an estimated 7.6 $MMTCO_2E$ in avoided emissions in 2030, and thus comprise the largest emissions reducer—and electricity bill savings—of all the measures we examined.

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[45] EIA 1995 regional CBECS data for West South Central Region.
[46] This figure is derived from Nadel 2003** is noted as 39% in the text.
[47] SWEEPS, 2002, the payback period is 1.3 to 2 years to pay off the incremental cost, or the difference between purchasing a new chiller compared to an efficient chiller.
[48] ACEEE, 2007.

DUCT IMPROVEMENTS

Testing and sealing air distribution ducts can save on the order of 10% of total electricity consumption and yield an average payback period of three years. Duct improvements can also cut natural gas consumption by 25%, but those emissions and economic benefits are not included in our results (SWEEP, 2002).[49]

In our study, duct improvements have a 2030 net present value over $100 million, while contributing $30 million in electricity bill savings in 2010.

RETRO-COMMISSIONING

Retro-commissioning (RC) is a systematic process for optimizing building performance through HVAC system monitoring and modification. RC can improve efficiency 5% to 20% with a payback period less than two years.[50] Many buildings are in need of major HVAC improvements. For example, in a study of 60 buildings by Lawrence Berkeley National Labs (LBNL), about 90% had HVAC problems that could be rectified by RC.[51]

We estimate that RC can avoid over 1,200 GWh of electricity demand and 0.8 $MMTCO_2E$ in 2030. These numbers are smaller than estimates for the other measures but nontrivial. Over the course of the study period, aggressive policy for more RC will return $25 million in net present value as soon as 2010 and grow to $100 million by 2030.

AIR CONDITIONING (AC) UNIT REPLACEMENTS

Worn out AC units sit on top of buildings, usually out of sight, and are often neglected or forgotten. But this equipment can cost building owners a lot of money in unneeded energy use. These units might be seen atop a strip mall or behind a variety store. A 2002 study found that over 50% of commercial air-conditioning in the Southwest relies on "boxed" units—those seen atop strip malls or behind convenience stores—and that many are in need of maintenance or replacement (SWEEP, 2002). The typical payback period for replacing an AC unit with an efficient unit is four years.[52]

We find this measure to be among the most promising, with avoided electricity bills exceeding capital costs by $70 million in 2010. During the study period, AC monitoring and maintenance can save nearly $1 billion in electricity bills and 10 million tons of global warming pollution by 2030.

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[49] 25% savings assumes the building is heated with natural gas. These results are based on SWEEP 2002 study and assume a retail location in Denver or Las Vegas.

[50] Nadel et al. 2003, SWEEP, 2002.

[51] Nadel, 2002.

[52] EDF, 2008b. EER stands for "energy efficiency ratio". The highest EER is 13. An efficiency upgrade involves replacing a unit rated EER 8 or lower to at least an EER 11.5.

Vehicles

According to Texas Department of Transportation (TXDOT), the State of Texas has a little over 17 million motor vehicles[53] and consumed about 9.2 billion gallons of fuel, or 8.5% of the total U.S fuel consumption in 2007.[54] The vast distances between cities lead Texans to drive over 100 million miles each day. We analyzed the costs and benefits of instituting greenhouse gas emissions performance standards ("Clean Car" standards) and reducing the carbon content of motor fuels. The emissions standard can be met several ways: fuel switching, diversifying vehicle power systems, or using lower carbon fuels. We model the Clean Cars standards as increasing fuel efficiency of passenger vehicles and light duty trucks, as shown in Figure 4 in the Methods section.

The greenhouse gas emissions standards modeled in this study are inspired by the rule being developed in California (and adopted already by over a dozen other states). The California Air Resources Board (CARB) estimates that complying with the standard translates into lower vehicle operating costs and significantly reduced GHG emissions.

CARB estimates that annualized costs of vehicle modifications to meet the Clean Car standards will average $158 per car or $43 per truck.[55] We can gauge the net benefits to consumers by subtracting the CARB's cost estimate from our estimate of avoided fuel costs, which we find to be $420 and $640 for drivers of model 2030 cars and trucks, respectively. This calculation yields a net benefit to drivers of 2030 model cars of approximately $262 annually and to drivers of average light duty trucks of $597 annually.

Our findings concur with CARB analyses that forecasts that the average driver will save $30 per month in fuel costs as a result of the rule.[56] In California, the Clean Car standards are being counted on to deliver over 30 $MMTCO_2E$ of avoided emissions, about 50% more than the reductions anticipated from Federal CAFE standards alone (CARB, 2007). The economics of the Clean Car improvements are quite favorable because the capital costs of efficiency improvements are recouped by avoided fuel costs. CARB estimates that households will save 100 gallons per year.

The Low Carbon Fuel Standard (LCFS) is a complementary part of California's

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[53] This figure is based on the July 2008 data form TCEQ and the VISION 2008 results for Texas. See appendices for more detail.

[54] This figure includes Puerto Rico. Data comes from highway fuel use by state table, non-highway use is marginal compared to highway and is about 333 million.

[55] The scope of our analysis did not include developing our own assessment of the cost of vehicle modifications necessary to meet the Clean Car standards. The California Air Resources Board has developed estimates. See Tables 10.2-1 and 11.4-1 of California Environmental Protection Agency, California Air Resources Board, Addendum Presenting And Describing Revisions To: Initial Statement Of Reasons For Proposed Rulemaking, Public Hearing To Consider Adoption Of Regulations To Control Greenhouse Gas Emissions From Motor Vehicles, September 10, 2004. Table 10.2-1 presents annualized costs by vehicle type for 2009 through 2030, whereas Table 11.4-1 presents the annualized used vehicle estimate of $46 for cars and $51 for trucks. These point estimates do not take into account the range of costs that different types of vehicles may encounter but does give a picture of the estimated average cost per vehicle.

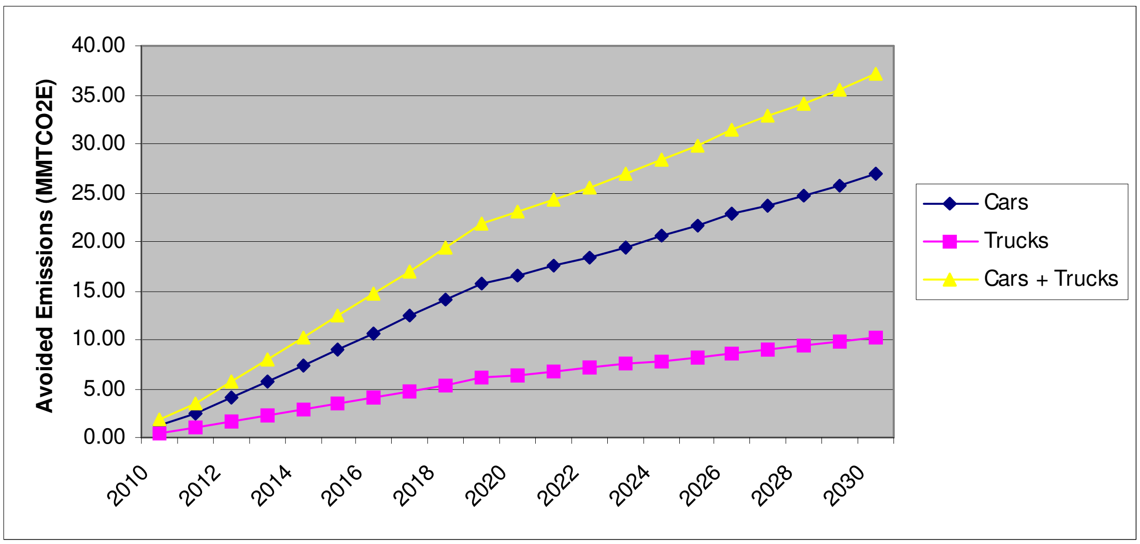
[56] CARB's analysis is based on a cost per gallon of fuel of $3.67 in 2020 (2007$), so the fuel savings associated with 100 gallons of avoided gasoline are $367. For higher incomes households that tend to drive more, the savings will exceed $400 per year.

strategy to reduce GHG emissions from mobile sources. In California, the standard is being developed to reduce the carbon intensity of gasoline and diesel transportation fuels by 10% by 2020, which is anticipated to reduce emissions from the California vehicle fleet by more than 16 $MMTCO_2E$.[57]

We find that by implementing both the Clean Car and LCFS standards, Texas can reduce vehicle-related emissions by over 10%. This means avoided emissions of almost 100 $MMTCO_2E$ from 2010 through 2030. This finding is shown in Figure 11 and is represented by the area under the curve for cars and trucks combined.

FIGURE 11

Federal CAFE and Clean Car Standards for Cars, SUVs and Light Trucks



Another important finding pertains to vehicle miles traveled (VMT). The VISION model simulates the elasticity of travel demand (i.e., changes in VMT due to changes in the marginal cost of travel). In short, drivers will travel more when the cost per mile is lower. Travel will be relatively more expensive when vehicles have lower fuel efficiency, so drivers will tend to use their vehicle less. As a result, drivers are expected to travel about 10 billion more miles with Clean Car and LCFS standards in place than without them because the better fuel efficiencies will lower the marginal cost of driving.

In Texas, the business-as-usual forecast for average car travel in 2030 is 11,844 miles per year, whereas the average truck covers 12,011 miles.[58] But our modeling indicates that these will increase to 12,357 and 12,538, respectively, with implementation of the Clean Car and LCFS standards. This indicates an underlying benefit that complements emissions reductions and consumer savings - the ability of drivers to feel more freedom and to have the opportunity to be more productive.

[57] The LCFS would apply to all transportation fuel providers, including: refiners, blenders, producers or importers of transportation fuels in California and applies to providers of gasoline, diesel, natural gas, LPG (propane), electricity, hydrogen, ethanol, bio-diesel and other mixed blends (CARB, 2008).

[58] Finding from VISION AEO Base Case.

Whereas CARB has predicted that the LCFS will not translate into higher costs for drivers, to be conservative we assume that fuel prices will increase slightly as a result of the policy.[59] For example, in 2030, the reference case fuel price for gasoline is $2.47. We assume the LCFS will increase the price to $2.60 per gallon.[60]

Despite higher VMT and higher fuel prices with the low-carbon fuel and Clean Car standards, improved fuel efficiency will save new car drivers an average of 170 gallons of gas annually, which equals $420 in avoided fuel costs (at $2.47 per gallon). Similarly, the average light truck driver avoids the need for 252 gallons of gas and saves over $620 annually. Statewide, the adoption of the Clean Car and LCFS standards for cars and trucks will mean avoiding the use of about 3.8 million and 9.8 million gallons of gas *per day* in 2020 and 2030, respectively, thereby saving over $9 million and $24 million daily in transportation fuel costs.[61]

Conclusion

Cars, trucks and buildings use the vast majority of energy in the American economy. In Texas, there is enormous potential to save in power costs and reduce emissions through energy efficiency investments. We've studied only a portion of the potential, and still our findings are staggering. In sum, Texans can dramatically improve their household economics, and commercial operations, such as small businesses, can help their bottom line immediately with investments that pay off quickly and avoid greenhouse gas emissions.

Opportunities for "win-win" energy efficiency investments in Texas are vast. True, "no-regrets" policy should take aggressive action to inspire more energy efficiency investments.

Some policies appear to be headed in the right direction. In June 2004, the Houston City Council passed a resolution requiring newly constructed or renovated municipal buildings with more than 10,000 square feet of occupied space to follow green building guidelines. While the law sets no definitive certification requirement, it does require capital improvement projects to follow LEED principles "to the greatest extent practical and reasonable."[62]

Houston's policy has yet to be implemented, but it indicates increasing awareness and commitment to deliver real economic and environmental benefits. Further efforts to improve energy efficiency in buildings and vehicles will save Texans money and reduce pollution that contributes to global warming.

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[59] See CARB, 2009, Proposed Regulation to Implement the Low Carbon Fuel Standard Volume I. Staff Report: Initial Statement of Reasons. Chapter VIII: Economic Impacts. March 5.

[60] For consistency with internal modeling assumptions, we use the default value of $2.47 to calculate personal and fleet-wide avoided fuel costs. Using the higher price per gallon will only increase the estimated benefits of the Clean Car and LCFS standards.

[61] This result is based on forecasted fuel prices of $2.47/gallon in 2030.

[62] This statement is derived from a correspondence with EDF staff and energy efficiency experts and is based on the most updated statewide codes in Texas.

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Appendix A: TEEM Building Measure Assumptions

Commercial and Residential Buildings Financial, Policy, and Emission Assumptions

Variable	Value	Reference	Units
Amortization Period	5	SWEEP et al. (2002) assume 40% of capital costs are loans. We assume all of the capital investments are debts repaid over 5 years and an interest rate of 10%.	Years
Amortization Rate	10%	We assume all of the capital investment is loans. The period is 5 years at a rate of 10%.	Percent/Year
Discount Rate – Low	3%	ACEEE, 2007 uses a discount rate of 4.5%	Percent/Year
Discount Rate – High	7%	ACEEE, 2007 uses a discount rate of 4.5%	Percent/Year
Commercial Electricity Rates	$0.11	EIA Texas Energy Profile, period is Sept-08.	$/kWh
Residential Electricity Rate	$0.13	EIA Texas Energy Profile, period is Sept-08.	$/kWh
Annual Electricity Growth Rate	2%/year	EDF calculation based on EIA base case forecast for US of no increase in inflation-adjusted prices. .	Percent/Year
CO2 Emissions Factor	1.47	eGRID2006 Version 2.1, April 2007, from EDF (Ramon Alvarez) (kg per kWh conversion).	Lbs/kWh
Added percentage of New SF/Homes due to Aggressive Policy	6.40%	Investment Case Growth rates based on the SWEEP 2002 High Efficiency Scenario. The High efficiency scenario in SWEEP 2002 assumes 100% of new commercial floor space is fit with efficiency measures by 2010. Our assumptions imply 100% by 2030. SWEEP 2002 assumes 80% of existing floor space is retrofit with efficiency measures by 200. We assume 100% by 2030 is feasible in the Investment Case. We use our assumptions forecasts to develop annual growth rates. The low and high bound growth rates are half and double the midrange growth rates.	Percent/Year
Added Annual Percentage of Existing Buildings due to Aggressive Policy	3.20%	Investment Case Growth rates based on the SWEEP 2002 High Efficiency Scenario. The High efficiency scenario in SWEEP 2002 assumes 100% of new commercial floor space is fit with efficiency measures by 2010. Our assumptions imply 100% by 2030. SWEEP 2002 assumes 80% of existing floor space is retrofit with efficiency measures by 2020. We assume 100% by 2030 is feasible in the Investment Case. We use our assumptions forecasts to develop annual growth rates. The low and high bound growth rates are half and double the midrange growth rates.	Percent/Year

Residential Building Efficiency Measure Savings, Costs and Market Rates

Technology	Capital Depreciation Rate	Incremental Cost ($/home)	Cost Decrease Factor	Savings* (kWh/home/yr)	Efficacy Growth Factor	Target Market*
RESIDENTIAL						
CFL*	90%	$0.06	99.7%	76%	0.3%	1.5%
Duct Testing and Seal	95%	$252	99%	2325	100%	25%
Wall Insulation	99.7%	$569	99%	4577	0%	15%

*CFL lighting has a total potential market share of 1.5% (ACEEE, 2007). Lighting intensity 1946 kWh/home/yr. The saving factor is 76%, or 25% less energy used with a CFL based on lumens per watt (Navigant, 2002).

References for Texas Energy Efficiency Measures for Residential Buildings

Technology	Capital Depreciation Rate	Incremental Cost ($/home)	Cost Decrease Factor	Savings* (kWh/home/yr)	Efficacy Growth Factor	Target Market*
RESIDENTIAL						
CFL	Factor is 97.5%, derived from the average depreciation rate of T8 and CFL. Based on $37 per fixture, $0 salvage value, and 13 year life (SWEEP, 2002; ACEEE 2007)	Assumes 6 bulbs per house, $3.53 per bulb (Navigant 2006).	The following future improvements were assumed to occur over a 20-year period: Efficacy +5%, Life +10%, and Price -5% (Navigant, 2006).	Navigant 2002	The following future improvements were assumed to occur over a 20-year period: Efficacy +5%, Life +10%, and Price -5% (Navigant, 2006).	1.5% based on ACEEE 2007 report for Texas.
Duct Testing and Seal	Duct testing and sealing have a rate of depreciation of 8.5%. Cost is derived from $0.07/sq ft new retail, and $0.04/ sq ft. existing retail. The incremental cost for small commercial duct testing and sealing is $160/ton. Lifetime is 20 years (SWEEP, 2002).	Average of all measure costs for duct test and seal in residential table (ACEEE 2007).	Efficiency and cost decrease factors are not applied since it is not a technology device.	Average of all measure savings for duct test and seal in residential table (ACEEE 2007).	Efficiency and cost decrease factors are not applied since it is not a technology device	Sum of % applicable electric heat and heat pump in Texas homes. (ACEEE, 2007).
Wall Insulation	Duct improvements and wall insulation both have life of 20 years. Wall Insulation is based on duct depreciation factor. (ACEEE, 2007).	Average of all measure costs in residential table for wall insulation (ACEEE 2007).	EDF Calc.	Average of all measure savings for wall insulation in residential table (ACEEE 2007).	EDF Calc.	Sum of % applicable electric heat and heat pump in Texas homes. (ACEEE, 2007).

Appendix B: TEEM Building Measure Descriptions

Summary of Building Efficiency Measures

Building Measure	**Energy Intensity/Savings**	**Analytics**
COMMERCIAL BUILDING MEASURES		
Energy intensity of commercial lighting	0.58 kWh per sq meter	Energy for lighting in average commercial building is 6.23 kWh/sq. ft.
Efficient Lighting	Calculated as a function of available lumens per unit of area.	Economics of replacing T12s with T8s and T5s. T12s are 80% of existing floor space. CFLs are 75% more efficient and last 10 times longer than incandescent bulbs.
Occupancy Sensor	Saves 0.106 kWh per sq. meter	Economics of mounting occupancy sensors that save 1.18 kWh/sq ft, and cost $60 - $150 to install.
Dimming System	Saves 0.27 kWh per sq meter	Economics of dimming systems that save 3.0 kWh/sq ft.
Chillers Package	Saves 14-18% of total energy use.	Economics of more efficient fans, chillers and packaged air conditioner units that save 14 - 18 percent for 20 years, and have a 2-year payback period.
Duct Improvements	Saves 9 - 15% of total energy use.	Economics of testing and sealing air distribution ducts.
Retro Commissioning	Saves 5 - 20% of total energy use.	Economics of retro-commissioning HVAC equipment.
Efficient AC Unit	Saves 14% of energy use per sq meter	Economics of replacing air conditioning units.
RESIDENTIAL BUILDING MEASURES		
CFL	Saves 75% of lighting energy use.	Economics of replacing incandescent bulbs with CFLs.
Wall Insulation		
Duct Insulation	Saves 20-30% of heating and cooling energy use.	Economics of testing and sealing air distribution ducts.

Residential Building Descriptions

EXISTING HOME

Many reports disaggregate households into various classifications such as multi-family, or single resident apartments. We draw specifically from the Texas State Data Center data on existing households, which does not classify individual home types. However, this report does distinguish existing homes from retrofitted and new homes. We assume new and existing homes will replace six incandescent bulbs with CFL bulbs. The existing homes have no wall insulation and can benefit from duct improvements (see individual measure below for exact detail).

NEW HOME

New homes have been distinguished in the TEEM due to the assumption that new homes are more likely to install efficiency measures (SWEEP, 2002). We assume that new homes will install six CFL bulbs, full R-13 wall insulation, and make appropriate duct efficiency improvements.

RETROFITTED HOME

The TEEM also categorizes retrofitted homes. Those new or existing homes that undertook efficiency measures in the previous year fall into the category of being retrofitted. These homes are taken from the pool of available homes that can install efficiency measures in the current year and are also depreciated each year. For instance, retrofitted homes are depreciated by a factor dependant on the lifetime of the efficiency measure (see specific measure below for detail).

Commercial Building Descriptions

EXISTING SQUARE FEET

The TEEM is constructed with the assumption that in the reference case a portion of the existing floor space already has a portion of energy efficiency measures in place (see Reference Case scenario in the following section). All existing floor space has the potential to implement each efficiency measure analyzed in this report with the exception of efficient AC units. Replacing old AC units in new and existing floor space is applied to retail floor space only and is therefore restricted by the amount of retail square footage that is in Texas. The following categories and the EIA pivot tables enabled us to make a distinction as to the amount of square feet used for each measure.

NEW SQUARE FEET

New floor space has been distinguished in the TEEM due to the assumption that new buildings are more likely to install efficiency measures (SWEEP, 2002). In addition, only new buildings install T5 lamps due to the characteristics of installation (see measure below for detail). All other measures have the same assumptions, except the amount they actually install or undertake in each scenario. In other words, the Reference Case differs from the Investment Cases. The same assumptions for efficient AC units apply for new floor space as well as existing floor space.

RETROFITTED SQUARE FEET

The TEEM categorizes retrofitted floor space as new or existing floor space that undertook efficiency measures in the previous years. Retrofitted floor space is cumulative. This variable enables the TEEM to identify the cumulative savings from making an efficiency improvement in a previous year. The floor space that is retrofitted is also depreciated by a factor dependent on the lifetime of the efficiency measure (see measure description below for specific detail).

TEEM Variables

COMMERCIAL FLOOR SPACE AND RESIDENTIAL BUILDINGS

Commercial floor space is derived from the EIA West South Central Region Data and ACEEE (2007) and is calibrated for Texas then forecasted through 2030. The total floor space is divided into existing and new floor space. The market trends and forecasts for heating, ventilation, and cooling were made available from the EIA for the West South Central Census Region. These specific pivot tables developed by EIA experts detailed the fuel types, fuel costs, and expected electricity allocation for specific end uses. These were very helpful in calculating square footage in Texas and determining the variables used for each efficiency measure in our model. Residential building data was made available by the Texas State Data Center through 2040, interpolated for intermittent years, and separated into new and existing by year.

ELECTRICITY RATE

Commercial electricity rates are lower than residential rates. The electricity rate is derived from the Texas Electricity Generation model we utilize to calculate the benefits for conversion efficiency. The rate produced by this model calculates the given rate in Texas based on a change in load growth due to our assumptions of growth in energy efficiency, renewable energy and carbon price (no price in the Reference Case). Annual load growth between 1.5% and 0.9% has little to no impact on the rate the consumer pays. In other words, decreasing demand will not impact the price the consumer pays. We assume the rate grows at 2% per year.

MARKET PENETRATION (DIFFUSION) RATE

Each measure has a market share in each year in the Reference Case and the Investment Case since we assume some efficiency will occur under business as usual. The rate of market penetration distinguishes the Reference Case from the Investment Case, since it is a higher rate. The market penetration rate for new and existing commercial floor space is derived from various sources as noted in the Reference Case and Investment Case scenarios in these appendices. We assume that efficiency measures will be implemented to a greater extent each year, increasing market penetration rates each year. This rate of penetration is grown annually from 2008 to 2030 to reach the maximum penetration level for new and existing floor space in 2030. This maximum market penetration level varies for each efficiency measure and can also be defined as the percent of floor space in 2030 that will implement a certain measure (either new or existing).

REFERENCE CASE PENETRATION RATE

The Reference Case adoption rate is the annual rate the technology is adopted in commercial buildings in a business as usual scenario.

INVESTMENT CASE PENETRATION RATE

The annual rate of adoption for individual technology in policy scenarios.

EFFICACY GROWTH

Efficacy Growth is a factor applied to the savings per unit (either homes or kWh per square foot). This factor is integrated into the TEEM in order to express that technologies will become more efficient over the period of the study (see specific measure for more detail).

MEASURE COST

The measure cost is the capital cost of an energy efficiency measure. It does not include administration costs.

INCREMENTAL COST

Incremental costs include the cost per unit over the lifetime less the cost of a less efficient technology. For example, if a CFL is $10 and an incandescent bulb is $4, then the incremental cost is $6. We then calculate the cost per square foot or per house. The incremental costs were calculated individually for each measure.

COST DECREASE FACTOR

TEEM applies a factor that lowers the cost per unit per year (excluding AC units which get more expensive over time in $[2006]).

MARKET SHARE

Market share refers to the amount of units (homes or floor space) that has implemented a measure. For example, 20% of the floor space used T8s in 2001.

DEPRECIATION RATE

The depreciation rate is calculated from average measure costs and lifetime applied to the retrofitted units (homes or floor space). (See measure for detail).

LIGHTING INTENSITY FACTOR

Base use for all lighting consumption in commercial buildings is 6.23 kWh per square foot per year derived from the average of 20 building lighting intensities (Navigant, 2002). Retail and health care are the two industries ranked highest in total floor space in the U.S. and have lighting intensities of 9.5 kWh per square foot per year, 13.7 hours per day (retail) and 8.0 kWh per square foot per year, operating 16 hours per day (health care).

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New York, NY 10010
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2334 North Broadway
Boulder, CO 80304
303-440-4901

3250 Wilshire Boulevard
Los Angeles, CA 90010
213-386-5501

4000 Westchase Boulevard
Suite 510
Raleigh, NC 27607
919-881-2601

1107 9th St., Suite 510
Sacramento, CA 95814
916-492-7078

123 Mission Street
San Francisco, CA 94105
415-293-6050

1875 Connecticut Avenue, NW
Washington, DC 20009
202-387-3500

Project offices
East 3-501
No. 28 East Andingmen Street
Beijing 100007 China
+86 10 6409 7088

1116 South Walton Blvd.
Bentonville, AR 72717
479-845-8316