THE NEW MOTHER LODE

The Potential for More Efficient Electricity Use in the Southwest

A report in the Hewlett Foundation Energy Series

November 2002

APPENDICES

SWEEP

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APPENDIX A—BUILDING ENERGY EFFICIENCY ANALYSIS

Residential and nonresidential building prototypes were developed using the DOE-2.2 building energy simulation computer program. The DOE-2.2 prototypes were used to evaluate energy savings estimates for a number of energy efficiency measures. Nonresidential building prototypes were developed based on previous studies and data from the Southwest Energy Efficiency Project, ACEEE, Nevada Power Co., analysis done for an energy efficiency advisory group in Utah (Nichols and von Hippel 2001), and a report done for Xcel Energy in Colorado (Nexant 2001). Residential building prototypes were developed using data from a number of sources including Southwest Energy Efficiency Project, ACEEE, Nevada Power Co., analysis done for an energy efficiency advisory group in Utah (Nichols and von Hippel 2001), and a report done for Xcel Energy in Colorado (Nexant 2001). Modifications were made to the prototypes to reflect the unique characteristics of buildings and building practices in the southwest region. Eight nonresidential and four residential building prototypes were developed.

<u>Nonresidential</u>	<u>Residential</u>
Existing Office	Existing Multifamily Apartment
New Office	New Multifamily Townhouse
Existing Retail	Existing Single Family Detached
New Retail	New Single Family Detached
Existing School	
New School	
Existing Food Service/Sales	
New Food Service/Sales	

Section A-1 provides a description of each building prototype. Section A-2 provides a description of each energy efficiency measure. This appendix includes more energy efficiency measures than were included in the analysis to indicate that more efficiency measures are available than time or budget permitted to include in this report.

A-1. BUILDING PROTOTYPES

Existing Office

The existing office building prototype is a three-story building with 60,000 square feet of conditioned floor area. The base case has no insulation in the walls and an average of R-7.1 insulation in the roof. Peak lighting power intensity is 2.0 W per square foot (sf) assuming standard T12 fluorescent lamps and electromagnetic ballasts (E source 1997a). The office equipment peak power intensity is 1.4 W/sf (RMA 2002). Windows are metal frame single-pane with a U-value of 1.11 Btu/hr-ft^2-F and a solar heat gain coefficient of 0.72. The window-to-wall area ratio is 0.30, floor to ceiling height is 10 ft, and floors are medium weight (70 lb/cf). Peak occupancy level is 275 sf/person. The HVAC system is a reheat fan system serving two zones per floor (perimeter and core) with a 70 hp fan supply fan and a 23 hp return fan. Chilled water is provided by two 75 ton hermetic reciprocating chillers (3.82 COP, 150 tons total). Heat rejection is accomplished with two induced-draft cooling towers with a total capacity of 190 tons.

Space heating is provided by two 75 percent efficient hot water boilers with a total capacity of 3,510 kBtu/hr. Occupancy, lighting, miscellaneous equipment, and service hot water schedules and minimum outdoor air ventilation requirements are taken from ASHRAE (ASHRAE 1989a, ASHRAE 1989b).

New Office

The new office building prototype is a three-story building with 60,000 square feet of conditioned floor area. The base case has metal-frame walls with nominal R-11 insulation and R-19 insulation in the ceiling. Lighting peak power intensity is 1.76 W/sf based on use of energy saving fluorescent lamps and energy-efficient magnetic ballasts. The office equipment peak power intensity is 1.4 W/sf. Windows are metal frame double-pane with a U-value of 0.65 Btu/hr-ft^2-F and a solar heat gain coefficient of 0.62. The window-to-wall area ratio is 0.30, floor to ceiling height is 10 ft, and floors are medium weight (70 lb/cf). Peak occupancy level is 275 sf/person. The HVAC system is a variable air volume (VAV) system serving two zones per floor (perimeter and core) with a 55 hp fan supply fan and a 18 hp return fan. Chilled water is provided by two 65 ton hermetic centrifugal chillers (4.23 COP, 130 tons total). Heat rejection is accomplished with two induced-draft cooling towers with a total capacity of 165 tons. Space heating is provided by two 80 percent efficient hot water boilers with a total capacity of 3,874 kBtu/hr. Occupancy, lighting, miscellaneous equipment, and service hot water schedules and minimum outdoor air ventilation requirements are taken from ASHRAE (ASHRAE 1989a, ASHRAE 1989b).

Existing Retail

The existing retail building prototype is a one story building with 10,000 square feet of conditioned floor area. The base case has no insulation in the walls and R-11 insulation in the roof. Lighting peak power intensity is 2.1 W/sf and electronic equipment peak power intensity is 0.5 W/sf. The windows are metal frame single-pane with a U-value of 1.11 Btu/hr-ft^2-F and a solar heat gain coefficient of 0.72. Window-to-wall area ratio is 0.19, floor to ceiling height is 15 ft, floor weight is medium (60 lb/cf). Peak occupancy level is 300 sf/person. The HVAC system consists of two packaged single-zone (PSZ) systems with cooling capacity of 12.5 ton and 240 kBtu/hr gas furnace. The PSZ system serving the northeast zone has a 2.6 hp fan and the PSZ system serving the southwest zone has a 3.3 hp fan. Occupancy, lighting, miscellaneous equipment, and service hot water schedules and minimum outdoor air ventilation requirements are taken from ASHRAE (ASHRAE 1989a, ASHRAE 1989b).

New Retail

The new retail building prototype is a one story building with 10,000 square feet of conditioned floor area. The base case has metal-frame walls with nominal R-11 insulation and R-19 insulation in the ceiling. Lighting peak power intensity is 1.76 W/sf and electronic equipment peak power intensity is 0.5 W/sf. The windows are metal frame double-pane with a U-value of 0.65 Btu/hr-ft^2-F and a solar heat gain coefficient of 0.62. Window-to-wall area ratio is 0.19, floor to ceiling height is 15 ft, floor weight is medium (60 lb/cf). Peak occupancy level is 300 sf/person. The HVAC system consists of two packaged single-zone (PSZ) systems with cooling capacity of 10 ton and 195 kBtu/hr gas furnace. The PSZ system serving the northeast zone has a 1.9 hp fan and the PSZ system serving the southwest zone has a 2.5 hp fan. Occupancy, lighting, miscellaneous equipment, and service hot water schedules and minimum outdoor air ventilation requirements are taken from ASHRAE (ASHRAE 1989a, ASHRAE 1989b).

Existing School

The existing school prototype is a two story building with 40,000 square feet of conditioned floor area. The base case has metal-frame walls with nominal R-11 (R-5.5) insulation in the walls and R-11 insulation in the roof. Lighting peak power intensity is 2.4 W/sf in the classrooms, library, kitchen, and dining areas, 0.65 W/sf in the gym, and 0.8 W/sf in the auditorium. Electronic equipment peak power intensity is 0.2 W/sf in the classrooms, 0.9 W/sf in the library and auditorium, 0.02 W/sf in the gym, 0.1 W/sf in the dining room and 15 W/sf in the kitchen.

Peak gas equipment intensity is 148 Btu/hr-sf in the kitchen. The windows are metal frame single-pane with a U-value of 1.11 Btu/hr-ft^2-F and a solar heat gain coefficient of 0.72. Window-to-wall area ratio is 0.30, floor to ceiling height is 10 ft in all rooms except the gym and auditorium that have 32 ft ceiling height. Floor weight is medium (60 lb/cf). Average peak occupancy level is 86.5 sf/person. The building is served by packaged single zone AC systems with the following capacity levels: all classrooms 35-tons, library-7 tons, auditorium-4 tons, gym-5 tons, kitchen-7 tons, and dining rooms-6 tons (Las Vegas prototypes have roughly 50% more installed cooling capacity). Occupancy, lighting, miscellaneous equipment, and service hot water schedules and minimum outdoor air ventilation requirements are taken from ASHRAE (ASHRAE 1989a, ASHRAE 1989b).

New School

The new school prototype is a two story building with 40,000 square feet of conditioned floor area. The base case has metal-frame walls with nominal R-11 (R-5.5) insulation and R-19 insulation in the ceiling. Lighting peak power intensity is 2.1 W/sf in the classrooms, library, kitchen, and dining areas, 0.65 W/sf in the gym, and 0.8 W/sf in the auditorium. Electronic equipment peak power intensity is 0.2 W/sf in the classrooms, 0.9 W/sf in the library and auditorium, 0.02 W/sf in the gym, 0.1 W/sf in the dining room and 15 W/sf in the kitchen. Peak gas equipment intensity is 148 Btu/hr-sf in the kitchen. The windows are metal frame double-pane with a U-value of 0.65 Btu/hr-ft^2-F and a solar heat gain coefficient of 0.62. Window-to-wall area ratio is 0.30, floor to ceiling height is 10 ft in all rooms except the gym and auditorium that have 32 ft ceiling height. Floor weight is medium (60 lb/cf). Average peak occupancy level is 86.5 sf/person. The building is served by packaged single zone AC systems with the following capacity levels: all classrooms-35 tons, library-7 tons, auditorium-4 tons, gym-5 tons, kitchen-7 tons, and dining rooms-6 tons (Las Vegas prototypes have roughly 50% more installed cooling capacity). Occupancy, lighting, miscellaneous equipment, and service hot water schedules and minimum outdoor air ventilation requirements are taken from ASHRAE (ASHRAE 1989a, ASHRAE 1989b).

Existing Food Service/Sales

The existing food service/sales prototype is a one-story building with 4,000 total square feet of conditioned floor area (2,000 kitchen/office/storage and 2,000 restaurant/food sales area). The base case has no insulation in the walls and R-11 insulation in the roof. Lighting peak power intensity is 1.88 W/sf. The peak power intensity for other electrical equipment is 1.15 W/sf in the kitchen and 0.20 W/sf in the restaurant area. The windows are metal frame single-pane with a U-value of 1.11 Btu/hr-ft^2-F and a solar heat gain coefficient of 0.72. The window-to-wall area ratio in the office is 0.39. Floor to ceiling height 15 ft and floor weight is medium (60 lb/cf). Peak occupancy is 250 sf/person in the kitchen/office/storage areas and 40 sf/person in the restaurant. The HVAC system consists of two packaged single-zone (PSZ) systems one for the kitchen/office/storage areas and one for the restaurant. The kitchen/office/storage PSZ has cooling capacity of 14 tons and heating capacity of 430 kBtu/hr. The restaurant PSZ has cooling capacity of 10 tons and heating capacity of 360 kBtu/hr. Base cooling EER is 8.1 and furnace efficiency is 75%. Custom and packaged display refrigeration systems are each modeled as 50% of the refrigeration load. Occupancy, lighting, miscellaneous equipment, and service hot water schedules and minimum outdoor air ventilation requirements are taken from ASHRAE (ASHRAE 1989a, ASHRAE 1989b).

New Food Service/Sales

The new food service/sales prototype is a one-story building with 4,000 total square feet of conditioned floor area (2,000 kitchen/office/storage and 2,000 restaurant/food sales area). The base case has metal-frame walls with nominal R-11 (R-5.5) insulation and R-11 insulation in the ceiling. Lighting peak power intensity is 1.88 W/sf.

The peak power intensity for other electrical equipment is 1.15 W/sf in the kitchen and 0.20 W/sf in the restaurant area. The windows are metal frame double-pane with a U-value of 0.65 Btu/hr-ft^2-F and a solar heat gain coefficient of 0.62. The window-to-wall area ratio is 0.39. Floor to ceiling height is 15 ft and floor weight is medium (60 lb/cf). Peak occupancy is 250 sf/person in the kitchen/office/storage areas and 40 sf/person in the restaurant. The HVAC system consists of two packaged single-zone (PSZ) systems one for the kitchen/office/storage areas and one for the restaurant. The kitchen/office/storage PSZ has cooling capacity of 2 tons and heating capacity of 100 kBtu/hr. The restaurant PSZ has cooling capacity of 5 tons and heating capacity of 280 kBtu/hr. Base cooling EER is 8.5 and furnace efficiency is 80%. Custom and packaged display refrigeration systems are each modeled as 50% of the refrigeration load. Occupancy, lighting, miscellaneous equipment, and service hot water schedules and minimum outdoor air ventilation requirements are taken from ASHRAE (ASHRAE 1989a, ASHRAE 1989b).

Existing Multifamily Apartment

The existing multifamily apartment prototype is 900 sf and is modeled with two adiabatic walls. Construction is wood frame with concrete floor. The base case has no insulation in the walls and R-19 ceiling insulation in the roof (Las Vegas prototype has R-11 walls). Lighting peak power intensity is 0.9 W/sf and the peak internal loads are 1.5 Btu/hr-ft^2. Windows are double-pane metal frame having a U-value of 0.6 Btu/hr-ft^2-F and a solar heat gain coefficient of 0.76. The window-to-floor area ratio is 0.12, floor to ceiling height is 9 ft. Peak occupancy level is 2 persons per unit. Infiltration is 0.7 air changes per hour. Base duct leakage is 30%. The heating system is a 78% efficient natural gas furnace. Each unit has a 2 ton 8 SEER/6.5 EER split system air conditioner. Occupancy, lighting, miscellaneous equipment, and domestic hot water schedules and minimum outdoor air ventilation requirements are taken from ASHRAE (ASHRAE 1989a, ASHRAE 1989b).

New Multifamily Townhouse

The new multifamily townhouse apartment prototype is 1200 sf. Construction is wood frame with a slab floor. The base case has R-13 wall insulation and R-30 ceiling insulation. Lighting peak power intensity is 0.9 W/sf and the peak internal loads are 1.5 Btu/hr-ft^2. Windows are double-pane metal frame with a U-value of 0.6 Btu/hr-ft^2-F and a solar heat gain coefficient of 0.76. The window-to-floor area ratio is 0.10, floor to ceiling height is 9 ft. Peak occupancy level is 2 persons per unit. Infiltration is 0.6 air changes per hour. Each unit has a separate central air conditioner and heating system. The heating system is a 78 percent efficient gas furnace with 60 kBtu/hr capacity. The central A/C unit is 3 tons with a 10 SEER/8.5 EER. Occupancy, lighting, miscellaneous equipment, and domestic hot water schedules and minimum outdoor air ventilation requirements are taken from ASHRAE (ASHRAE 1989a, ASHRAE 1989b).

Existing Single Family Detached

The existing single family detached prototype is a two-story building with 1,680 square feet of conditioned floor area. Construction is wood frame with a crawl space. The base case has R-11 insulation in the walls and R-19 ceiling insulation in the roof. Lighting peak power intensity is 0.9 W/sf and the peak internal loads are 1.15 Btu/hr-ft^2. Windows are double-pane metal frame with a U-value of 0.6 Btu/hr-ft^2-F and a solar heat gain coefficient of 0.76. The window-to-floor area ratio is 0.17 and floor to ceiling height is 8 ft. Peak occupancy level is 3 persons. Infiltration is 0.7 air changes per hour. Base duct leakage is 29%. The heating system is a 75 percent efficient gas furnace 150 kBtu/hr capacity, and the 8 SEER/6.8 EER central air conditioning system has a capacity of 4 tons (Las Vegas prototype was modeled with an 10 SEER/8.5 EER AC unit). Heating setback is from 10 PM to 6 AM, setpoint is 69 F and setback is 64 F. Cooling setforward is from 9 AM to 5 PM, setpoint is 76 F and setforward is 84 F.

New Single Family Detached

The new single family detached prototype is a two-story building with 2,100 square feet of conditioned floor area. Construction is wood frame with a crawl space. The base case has R-13 wall insulation and R-30 ceiling insulation. Lighting peak power intensity is 0.9 W/sf and the peak internal loads are 1.7 Btu/hr-ft^2. Windows are double-pane metal frame with a U-value of 0.6 Btu/hr-ft^2-F and a solar heat gain coefficient of 0.76. The window-to-floor area ratio is 0.23, floor to ceiling height is 9 ft. Peak occupancy level is 2 persons per unit. Infiltration is 0.6 air changes per hour. Base duct leakage is 22%. The heating system is a 78 percent efficient gas furnace 150 kBtu/hr capacity, and the 8.5 EER central air conditioning system has a capacity of 5 tons. Heating setback is from 10 PM to 6 AM, setpoint is 69 F and setback is 64 F. Cooling setforward is from 9 AM to 5 PM, setpoint is 76 F and setforward is 84 F.

A-2. MEASURE DESCRIPTION

The following list of energy efficiency measures includes all those that were included in the buildings sector energy efficiency analysis. In addition, it includes some efficiency measures that were not included in the analysis because either they are alternatives to measures that were included or they are viewed as less desirable. The existence of a wide range of efficiency measures reinforces the conclusion that substantial energy savings are possible in both new and existing buildings. Further, there is every likelihood that new, practical, cost-effective energy efficiency measures will become available over the

18 year period covered by this analysis. However, since we made no assumptions about savings resulting from these potential new measures, our analysis is conservative.

Efficient Office Equipment

Measure Description

Electronic equipment such as personal computers, monitors, printers, and copiers consumed about 9 percent of all electricity used in the commercial sector in the United States as of 2000 (Roth, Goldstein and Kleinman 2002). The energy-efficient office equipment measure consists of replacing inefficient computers, video display terminals (VDTs), and printers with efficient Energy Star products, sleep-mode enabled software (to power down monitors), and plug load sensors (to turn off task lights, monitors, and peripherals when users are away). EPA's Energy Star program in cooperation with major electronic manufacturers is hastening the evolution towards more energy-efficient electronic office equipment. Most computer and peripheral products are EPA Energy Star certified. These products include portable laptops that plug into desktop "docking" systems, and monitors, desktop computers and printers that have a low-energy "sleep" mode (when inactive for a predetermined period of time). When the market is saturated (in 4-6 years), these innovative products should reduce office equipment energy use by approximately 63% compared to average components in use today (Suozzo et al. 2000).

Base Case Equipment Power Density Levels

Baseline prototypical office equipment power density levels (1.4 W/sf) for new and existing office buildings are based on Robert Mowris and Associates measurements in offices in northern California and ESOURCE estimates (RMA 2002; E source 1997b). The tables provide base case office equipment power density levels for each building prototype and vintage.

Incremental Cost

Incremental cost for efficient office equipment is assumed negligible due to EPA's Energy Star program and the general trend towards more energy-efficient office equipment technologies (Ledbetter and Smith 1996; Suozzo et al. 2000). A cost of $30 per workstation is assumed for a plug load sensor/control.

Efficient Lighting

Measure Description

The energy efficient lighting measure consists of replacing the standard fluorescent fixtures, lamps, and ballasts with high efficiency components. The high efficiency components are typically fixtures with specular reflectors, tri-phosphor T-8 lamps (32 W), and electronic ballasts. Incandescent lighting fixtures are replaced with IR halogen lamps or compact fluorescent lamps where appropriate. Efficient lighting power density (W/sf) is based on previous studies by ACEEE, Lawrence Berkeley National Laboratory, and Robert Mowris and Associates.

Base Case Lighting Levels

Baseline prototypical lighting levels (W/sf) for new and existing buildings are based on E SOURCE estimates (E SOURCE 1997a). The tables provide base case lighting levels for each building prototype and vintage.

Incremental Cost
The average incremental cost for efficient lighting is $37 per fixture for existing construction and $29 per fixture for new construction (XENERGY 2001).

Efficient Custom Refrigeration

Measure Description
Efficient custom refrigeration measures focus on reducing refrigerated loads and improving design and performance of refrigeration equipment. Peak demand and energy savings are 30% based on implementing the following set of measures for high-, medium-, and low-temperature refrigeration display cases.

- Floating head-pressure control
- Night covers for display cases
- Strip curtains for walk-in boxes
- Glass or acrylic doors - low temperature case
- Anti-Sweat heater control
- Case lighting electronic ballasts
- Insulate suction lines
- Cooler or freezer door gaskets
- Auto-closers for coolers or freezers
- Evaporative fan controller
- Permanent split capacitor (PSC) motor evaporator fan
- Electronically commutated motor (ECM) evaporator fan

Incremental Cost and Lifetime
Incremental cost for efficient custom refrigeration is $630 per ton (XENERGY 2001). Measure life is 15 years.

Efficient Packaged Refrigeration

Measure Description
Nationally, packaged refrigeration equipment accounts for about two-thirds of commercial-sector refrigeration energy use. About 88% of this use comes from five types of equipment: vending machines, reach-in refrigerators and freezers, walk-in refrigerators and freezers, ice-makers, and beverage merchandisers according to a 1996 study for DOE (ADL 1996). This study also examined opportunities for cost-effective energy savings for each of these products and found that energy use could be reduced by an average of about 30% with measures that provide a simple payback to the consumer of two years or less, and by an average of about 40% for measures with a simple payback of five years or less. To model this measure in our analysis, we took the average cost of saved energy ($0.011/kWh saved) and savings (32%) from a 1998 ACEEE study (Suozzo and Nadel 1998).

Recent product introductions show that these figures may be conservative (Kubo and Nadel 2002). For example, Royal Vendors has recently commercialized its "Econocool" vending machine that reduces energy use by approximately 50% relative to its previous model, and an incremental retail cost of about $75 (less than a one-year payback at $0.08/kWh). And Delfield has just commercialized its Vantage 6000 model, which reduces energy use 68% relative to Delfield's previous model, at no incremental cost. Design changes lower underlying production costs, thereby freeing funds to pay for the efficiency improvements.

Incremental Cost and Lifetime
Incremental cost for efficient custom refrigeration is $250 per ton based on information obtained by ACEEE. Measure life is 15 years.

Wall, Ceiling/Roof Insulation

Measure Description
Installing fiberglass or cellulose insulation material in floor, wall or roof cavities will reduce heat transfer across these surfaces. The type of building construction limits insulation possibilities. Choice of insulation material varies depending on the wall or roof construction type. Wall construction types include, but are not limited to, mass walls, metal frame walls, wood frame walls, curtain walls, precast concrete panels, and tilt-duct concrete panels. Nominal R-values are used as the performance factor for insulation levels. For each commercial building prototype, the assumed overall wall or ceiling R-value are given followed by the nominal R-value for cavities (given in parentheses). The overall R-values include the thermal resistances of construction layers (gypsum, air gaps, framing, sheathing, concrete, roofing, etc.).

Base Case Insulation Levels
Assumed prototypical insulation levels for existing buildings are based on survey data. The tables provide base-case insulation levels for each building prototype and vintage.

Wall Insulation in Metal Frame Walls
Insulation installed in metal frame walls will have an effective R-value that is about 50% less than the nominal R-value of the insulation (CEC 1992). This is due to the high thermal conductance of metal framing relative to wood framing. In our analysis we conservatively assumed metal frame walls exist in all new nonresidential construction.

Incremental Cost
Insulation costs are greater for retrofit installations where blown-in insulation is typically the only option. Assumed costs for insulation are shown below (XENERGY 2001).

Table A-1. *Insulation Costs.*

Type of Insulation	Retrofit Cost ($/sf)	New Cost ($/sf)
Wall Insulation		
R-8 (R-4 for metal frame)	0.91	0.23
R-11 (R-5.5 for metal frame)	1.00	0.25
R-19 (R-9.5 metal frame)	1.25	0.35
Ceiling Insulation		
R-4	0.21	0.19
R-8	0.25	0.23
R-11	0.27	0.25
R-19	0.37	0.35
R-30	0.48	0.46

Efficient Windows

Measure Description

The important energy performance parameters for windows are U-value, solar heat gain coefficient (SHGC), visible light transmission and air leakage. The window U-value varies as a function of the number of panes, gap thickness, gap fill (air or inert gas), presence of low-emissivity (low-e) coatings, and frame type. The shading coefficient and visible transmission vary as a function of glass type and spectrally-selective coatings. Air leakage depends on the frame characteristics and window design (e.g., casement vs. slider), and installation details.

Base Case Windows

For nonresidential prototypes, base case windows are assumed to be single-pane with metal frames. For residential prototypes, base case windows are assumed to be double-pane metal frame windows. U-values and shading coefficients for each prototype are given in the tables.

Double Pane, No Thermal Break (NTB)

Replacing single pane with double pane windows reduces the U-value and heat transfer by 40%. This also reduces the shading coefficient, solar heat gain and the cooling load.

Double Pane, Thermal Break (TB)

A metal window frame acts like a short circuit to heat transfer. Adding a thermal break to the metal frame will reduce the overall U-value by about 20%, depending on window size.

Double Pane Low-e, NTB and TB

Adding a low-e coating improves the U-value by about 15%. The low-e coating also provides a better shading coefficient than standard double pane glass while maintaining good visible light transmission. High performance spectrally-selective coatings cost slightly more but provide much more flexibility and savings potential. Window manufacturers have different techniques of adding the coatings. Some manufacturers use low-e coated thin film plastic suspended between the double panes, some use “soft” low-e sputter coatings added to the inside of the outside lite, some use "hard" low-e pyrolytic coatings that can be added to either the inside or outside lite.

Incremental Costs and Window Performance Characteristics
The U-values, solar heat gain coefficients and costs for all window types evaluated in the study are shown below along with assumed costs per square foot. The U-values and solar heat gain coefficients were calculated using the WINDOW 4.0 computer program produced by Lawrence Berkeley Laboratory. High performance window savings are based on DOE-2 simulations. High performance low-e squared windows (argon gas fill and vinyl frames) are modeled with 0.4 Btu/ft^2-hr-°F U-factors and 0.55 SHGC in mountain zones (i.e., Denver) and 0.4 SHGC in desert climate zones (i.e., Las Vegas). Baseline window modeling assumptions are described for each prototype in Section A-1. Incremental measure cost is \$2.50/ft^2 for existing residential buildings and \$2.00/ft^2 for new residential buildings for low-e squared windows with vinyl or metal frame with a thermal break (XENERGY 2001). The incremental cost is \$18.20/ft^2 for existing commercial buildings and \$4.39/ft^2 for new commercial buildings for low-e squared windows with metal frames (XENERGY 2001). Measure lifetime is assumed to be 25 years.

<u>Efficient HVAC Retrofit</u>

Measure Description
The efficient HVAC retrofit consists of the following three measures:

1. *Variable Frequency drive (VFD) fan control.* VFDs for fans or chilled water pumps are much more efficient at regulating speed or torque than throttling valves, inlet vanes and fan dampers. Energy required to operate a fan or pump motor can be reduced as much as 85% during reduced load conditions by installing a VFD. VFD fan control provides a method to vary the amount of constant temperature air delivered to the space. Other less efficient methods to create a variable air volume (VAV) system involve the use of fan inlet (vortex) dampers or discharge damper control. Terminal sections may be single duct variable volume units with or without reheat, controlled by space thermostats. VAV systems reduce energy use by reducing the volume of air handled by the entire system as a function of the air required to meet the needs of the warmest or coolest zone. When the space demands peak cooling the fan operates at full speed (and/or VAV dampers are fully opened). When less cooling is required the fan operates at low speed and the primary air flow to the space is reduced to the minimum flow rate to ensure adequate ventilation. When in space heating mode, the supply air flow is held at a low flow rate, reducing the heating energy use. There are many VAV system variations, such as VAV with reheat, VAV dual duct, VAV dual fan/dual duct, VAV with fan-powered boxes, etc. All of these are multiple zone systems. It is not generally practical nor desirable to use VAV for a single zone building such as a supermarket or warehouse. These types of buildings typically have constant-volume, variable-temperature packaged single zone HVAC systems.

2. High efficiency fans. Overall fan efficiency is the multiplicative product of the fan motor and fan blade efficiencies. This study assumes that overall fan efficiency can be improved from 55 percent to 70 percent.

3. High efficiency chiller. This study assumes the high efficiency centrifugal chillers for the office building prototypes are 6.3 COP (0.56 kW/ton). The ASHRAE Standard 90.1-1999 (ASHRAE 1999) requires a centrifugal chiller less than 150 tons in capacity to have an efficiency of 0.75 kW/ton or less. An efficiency of 0.56kW/ton represents very good practice for hermetic centrifugal chillers using non-ozone depleting refrigerants (Suozzo et al. 2000). Higher efficiency can be achieved by increasing condenser and evaporator area, but this can make the cooling system less practical and/or cost effective.

Base Case Air Handling System
VAV retrofit is only considered for existing large buildings having multi-zone systems. We assume that VAV systems are standard for new buildings having multiple zone systems. For this study only the existing medium-size office building and school prototypes were considered for the VAV retrofit measure.

Incremental Cost
The incremental cost for VSD fan control is $125/hp (XENERGY 2001). The technology involves adding an electronic variable-speed controller to the fan motor. The incremental cost for a high efficiency fan motor is $8/hp (XENERGY 2001). The incremental cost for a high efficiency chiller is assumed to be $53/ton based on $653/ton for a high efficiency hermetic centrifugal chiller and $600/ton for a standard chiller. Costs for existing and new construction are assumed to be the same since the existing cost is for replace-on-burnout.

HVAC Retro-commissioning

Measure Description
HVAC retro-commissioning involves the following measures:

1. Check and correct Energy Management Control (EMS) system settings to ensure efficient HVAC system operation.

2. Check and correct HVAC temperature controls for chilled water, condensing water, and supply air. Cooling tower approach temperature might be reduced to 5°F.

3. Balance airflow, check/correct fan controls and fan dampers, and check/correct or implement economizer controls for use of outdoor air for cooling.

Base Case
The base case assumes that the EMS is not operating efficiently and that HVAC temperature controls for chilled water, condensing water, and supply air are not optimized. Fan dampers might be non-functional

and economizer control might be absent or non-functional. For this study only the existing medium office prototype was considered for HVAC retro-commissioning.

Incremental Cost and Lifetime

An incremental cost of $0.19/ft^2 for HVAC retro-commissioning (low-cost recommendations only) is assumed (Nadel, Gordon, and Neme 2000). Measure life is assumed to be 10 years.

<u>High Efficiency 11.5 EER Air-Cooled Package Air Conditioner</u>

Measure Description

Over 50% of current commercial air conditioning capacity is provided by packaged units with air handler, compressor, and compressor mounted in a metal box (E SOURCE 1997b). These units are typically roof-mounted to save interior space and have capacities ranging from 1 to 100 tons (5-20 tons are typical). Packaged units are attractive to builders and developers, especially those that build on speculation, because of their low first cost (often less than $500/ton). This emphasis fosters inefficiency. For example, packaged units monitored by PG&E in San Ramon, California had an overall efficiency of 1.75 COP (6 EER). California's Title 24 standards set minimum efficiency of 8.9 EER (1.34 kW/ton). Actual operating efficiencies are often less than rated efficiencies due to improper refrigerant charge/airflow, thin uninsulated cases which can leak substantial amounts of hot rooftop air; constricted high velocity, high-pressure duct work, and undersized, low-performance heat exchangers.

Much higher efficiencies are obtainable at reasonable cost through better design, materials, and controls, but have not yet been realized due to emphasis on first cost. To address this problem, a group of utilities and other energy organizations have been working through the Consortium for Energy Efficiency (CEE) to create a market for high-efficiency 11.5 EER (1 kW/ton) packaged AC equipment (Kubo, Sachs, and Nadel 2001). A number of products with this with efficiency are commercially available (Suozzo et al. 2000).

Incremental Cost and Lifetime

The incremental cost for a high efficiency 11.5 EER air-cooled packaged air conditioner is about $100/ton more than a 8.9 EER unit (Nadel, Gordon, and Neme 2000). Lifetime is assumed to be 20 years.

<u>13 SEER Split-System Central Air Conditioner</u>

Measure Description

The 1990 national appliance efficiency standards for residential central air conditioners (CAC) require a minimum SEER of 10. High efficiency CACs with SEER of 13 or greater are available at a reasonable cost from most suppliers. Very high efficiency CACs with variable speed drive (VSD) compressors have SEERs of 16.9 to 18. The very high efficiency units have air- or water-cooled condensers. VSD CACs have better part-load performance than constant speed CACs, but their peak efficiency is not as good as high efficiency CACs. Typical CACs are split systems with an outdoor section housing the compressor and condenser and an indoor section housing the evaporator. The indoor and outdoor (split) systems are connected by a pair of refrigerant lines and control wiring. High efficiency CACs can be installed in new construction or retrofit into existing construction.

Incremental Cost and Lifetime

The cost for high efficiency SEER 13 CAC is approximately $170/ton more than a SEER 10 unit (Thorne, Kubo and Nadel 2000). Measure lifetime is 18 years.

Thermostatic Expansion Valves (TXVs)

Measure Description

TXVs optimize refrigerant flow and maintain constant superheat as the load conditions on the indoor coil vary to allow split-system central air conditioners to operate more efficiently. Most TXV units (i.e., evaporator/condenser pairs) get a 5-10% efficiency boost in their ARI rating compared to non-TXV units. TXV units are easier to charge and less likely to be improperly charged since the TXV subcooling method is easier to perform than non-TXV superheat method. TXV units maintain relatively constant efficiency even if the system is incorrectly charged (O'Neal and Farzad 1989). With non-TXV units, efficiency falls off in proportion to overcharge. TXVs also gain additional savings by reducing or eliminating efficiency degradation when a unit has improper charge and/or airflow. Typical non-TXV units operate 10-20 percent less efficiently than the ARI rating due to improper charge/airflow. For example, an EER of 7.6 is typical for SEER 10 non-TXV units (i.e., 1.58 kW/ton including fan). Installing TXV evaporator coils on SEER 10 units will increase the SEER to 11 and the EER to 8.9 (i.e., 1.35 kW/ton). This represents a potential peak load reduction of 0.23 kW/ton per TXV.

Incremental Cost and Lifetime

The incremental cost for a factory-installed TXV coil is about $15/unit at time of manufacture based on information collected by ACEEE. Measure lifetime is 18 years.

High Efficiency Fan on Air Handler Unit

Measure Description

Use of an electronically-commutated fan motor (ECM) can cut the fan electricity consumption in a residential HVAC system by 50% or more. The ECM generally is installed on the forced-air HVAC system at time of manufacturer and is not intended as a retrofit measure. This is a variable-speed fan using approximately 150 to 375 Watts/1,000 cfm compared to standard constant speed fans using 465 Watts/1,000 cfm. Savings in fan energy are approximately 10 to 70 percent with average savings of 40 percent.

Incremental Cost and Lifetime

The cost for the ECM fan on the air handler is $170 per system and includes appropriate variable speed controls (Kubo, Sachs and Nadel 2001). Measure lifetime is 23 years.

Energy Star Programmable Thermostat and Time Clocks

Measure Description
Energy Star programmable thermostats turn-off or setback HVAC equipment during periods when the building is occupied or unoccupied. Setback (or setup for cooling) thermostats are typically used for residential applications to reduce energy and peak demand during day or night periods. They are used in commercial applications for areas where it is undesirable to shut off equipment due to such concerns as freeze protection or the need to provide some conditioning for equipment.

Commercial time clocks automatically turn-off HVAC equipment during periods when the building is unoccupied. Time clocks are for areas where occupancy is either predicable or non-critical.

Residential energy savings for programmable thermostats are based on measured field studies showing 8% average cooling savings and 9% average heating savings. Savings are less than manufacturers' estimates due to the calibrated DOE-2 baseline where the occupants manually setup/setback the thermostat during the day while away at work (e.g., 8:00 AM to 6:00 PM).

Incremental Cost and Lifetime
Incremental measure cost is $162 installed (XENERGY 1996). Measure lifetime is 12 years.

Air Conditioner Diagnostic and Tune-up

Measure Description
AC diagnostic tune-up includes checking and correcting refrigerant charge and airflow on split-system central air conditioning (CAC) units and central heat pump units. Most split-system AC units have capillary tube or piston metering devices (i.e., non-TXV, thermal expansion valves) and require the correct charge to operate at rated efficiencies. Typical units are under- or over-charged by as much as 20 to 40 percent and this reduces efficiency on average by 15-30 percent. Cooling and heat pump heating energy savings estimates of 17% are based on average measured savings from seven field studies (Neme, Proctor and Nadel 1999).

Incremental Cost
Measure cost is $156 (XENERGY 2001). Measure lifetime is assumed to be 10 years.

Duct Sealing (residential and small commercial)

Measure Description
Duct leakage in forced-air distribution systems represents one of the largest energy losses in residential and small commercial buildings (Modera 1993). Duct leakage can add 20-30% to heating and cooling energy use. 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. California field studies have shown that duct leakage is even larger in small commercial buildings than

in residences - 35% versus 20-30% of fan flow. These studies have also shown that the duct leaks in small commercial buildings are outside the conditioned space more than 50% of the time, and that duct systems are frequently located outside the building insulation. The impacts of duct leakage during the cooling season increase rapidly at high outdoor temperatures (peak demand periods), which means that fixing those leaks has much higher impact on energy use during peak periods as compared to milder weather conditions. The full peak electricity demand reduction associated with duct sealing can be realized in small commercial buildings since these buildings are cooled throughout the day. Duct sealing requires the use of diagnostic equipment to detect and quantify the extent of the leaks. Leaks are sealed using hand applied or Aeroseal applied mastic or UL-rated metal or butyl tape. Savings are typically 15-20% of heating and cooling energy consumption (Neme, Proctor and Nadel 1999).

Duct testing and sealing savings are based on sealing both supply and return ducts to a maximum leakage of 15 percent of measured system flow at 25 Pascal pressure (supply and return). This is the Energy Star duct leakage performance specification. Baseline duct leakage is modeled with an assumed air loss of 29% of fan flow. Measure lifetime is 20 years.

Incremental Cost
Incremental measure cost is $75 for duct testing by itself. The incremental cost for residential duct testing and sealing is about $450 (XENERGY 2001). The incremental cost for small commercial duct testing and sealing is $160/ton (based on a pilot project implemented by Southern California Edison Company in 2001).

Duct Insulation

Measure Description
Conduction through uninsulated or poorly insulated ducts can add 10-15% to heating and cooling energy use. Houses with ducts in basements typically have losses of about 10% and houses with ducts outside the conditioned space (i.e., ducts in attics, garages, or vented crawl spaces) typically have losses of about 15%. Savings are based on measured data. Savings estimates used for duct insulation are based on insulating with R-8 insulation.

Incremental Cost and Lifetime
Incremental costs per square foot of floor area are roughly $0.15 to $0.20 per square foot of floor area. Measure lifetime is 25 years.

Evaporative Air Conditioner

Measure Description
Direct evaporative coolers contain evaporative pads (usually of aspen wood fibers). A pump lifts sump water to the distributing system and it flows down through the pads back to the sump. A fan within the cooler pulls the hot, dry outdoor air through the evaporative pad. As the air passes through the wetted pad, water evaporates, and the air becomes both cooler and more humid. Cooler and higher humidity air is then delivered to the conditioned space. As air passes through a direct evaporative cooler, its dry-bulb

temperature approaches the wet-bulb temperature. Energy is neither gained nor lost from the air, but is exchanged within the air such that the air becomes both cooler and more humid. Sensible heat in the air is converted to latent heat through evaporation, creating an energy-equivalent rise in the air's humidity as the dry-bulb temperature is lowered. This is an "adiabatic" process.

The "wet-bulb depression" is the incoming dry-bulb temperature minus the incoming outdoor wet-bulb temperature. The effectiveness of an evaporative cooler is defined as the dry-bulb temperature drop of the air divided by the maximum potential temperature drop expressed as a percentage. Direct evaporative cooling effectiveness depends upon the outdoor wet bulb temperatures and humidity levels. Most commercial evaporative coolers have an effectiveness of 85%, which means that the dry-bulb temperature of the incoming air is reduced by 85 percent of the difference between the dry-bulb and the wet-bulb temperature of the air.

Direct evaporative coolers are manufactured in sizes ranging from 2,000 to 20,000 cfm using current technology and available equipment. Evaporative coolers are not applicable to sites where high indoor humidity is a concern. If an evaporative cooler is used in an inappropriate climate, it may not have the ability to cool but instead raise the humidity level in the room.

Incremental Cost and Lifetime
Incremental measure cost is $130 per ton. Measure lifetime is 10 years.

Indirect Direct Evaporative Air Conditioner (IDAC)

Measure Description
Indirect direct (evaporative) air conditioner (IDAC) savings are based on DOE-2 modeling to first screen the measure for comparable level of service to see if the cooling load can be met in all climate zones. The cooling load cannot be met by this technology in all climate zones. The manufacturer recommends a 2-ton rating for the 1 kW model and 70% average cooling savings for IDAC based on 1 kW required for fans and pumps. This compares to 3.75 kW for a conventional 10 SEER central air conditioner. An average cooling savings of 70% is used for screening purposes.

Incremental Cost and Lifetime
Incremental measure cost is $1,931 for the 1,750 cfm model and $2,575 for the 2,300 cfm model (XENERGY 2001). These estimates are based on a cost of $4,200-5,200 for the IDAC minus a cost of $2,300-2,600 for a conventional central air conditioner. Measure lifetime is 18 years.

Blower Door-Guided Infiltration Reduction

Measure Description
Infiltration/exfiltration is caused by wind, mechanically-induced pressure differences from furnace blowers and other fans, and "stack effect," which is due to the buoyancy of warm air. Except in areas of particularly high winds, stack effect infiltration is the primary cause of convective losses in most buildings. Its magnitude varies with indoor-outdoor temperature difference and the height of the

structure. Negative pressures, causing infiltration, are concentrated at the bottom of the conditioned envelope and positive pressures, causing exfiltration are concentrated at the top. Accordingly, conventional infiltration stopping measures like weather stripping windows at the middle of the envelope are not very effective in dealing with stack-effect convective losses (although they are useful for combating wind and mechanically-induces pressures.) Instead, air sealing should be concentrated at sill plates in the basement, where wires and pipes penetrate basements and attics, and at the tops of interior as well as exterior walls. Blower doors both help in quantifying the extent of the leakiness in a dwelling and demonstrating the locus of many (not all) leakage points. This study assumes that infiltration can be reduced from 0.7 to 0.4 air changes per hour (ACH) in existing construction and 0.6 to 0.4 ACH for new construction.

Incremental Cost and Lifetime

The cost to reduce infiltration for existing construction is $0.46/sf and the cost for new construction is $0.24/sf (XENERGY 2001). It is easier to reduce infiltration in new construction than in existing construction and the costs reflect this fact. Measure lifetime is 10 years.

Whole House Fan

Measure Description

Whole house fan savings are based on DOE-2 modeling with the following assumptions: 1) Fan is "on" (and CAC off) if the outside air temperature is less than the indoor CAC setpoint of 78 degrees Fahrenheit; and 2) Fan is "off" if the outside air is greater than or equal to the CAC setpoint, or if the outdoor temperature is less than 65 degrees Fahrenheit. The fan consumes 0.22 kW (1/3 hp motor as per manufacturer). A post-processor spreadsheet is used to calculate the fan energy based on run time. Energy savings based on DOE-2 simulations range from 6 percent (climate zone 15) to 51 percent (climate zone 7) with an average of 19 percent. Reported annual energy savings estimates range from 15-20 percent (Curtis 1999).

Incremental Cost and Lifetime

Incremental measure cost is $560 installed based on prices from Home Depot and XENERGY 1996. Measure lifetime is 20 years.

Window Film

Measure Description

Reflective window film reduces solar energy gains, thus reducing mechanical cooling energy consumption. Addition of film is often cost effective on all clear glass except North-facing exposures. Typical film thickness is 0.001 to 0.004 inches. Films are made with a variety of adhesives and are applied on-site to the interior surface (i.e., facing the room) of single- or double-pane windows. Historical problems of fading, installation difficulties, and poor adhesive performance have been solved through advancements in film and adhesive technologies and better application processes. "Second generation" window films often have low emissivity coatings that provide good visible transmittance (VT), solar heat gain coefficients (SHGC), and shading coefficients (SC). Besides reducing cooling loads, adding reflective films improves shatter resistance and blocks up to 99% of ultraviolet radiation. Summer comfort near windows is improved as well. However, winter space heating energy use will typically increase from 10 to 25% due to the loss of winter-time solar gains.

Incremental Cost

Window film savings are based on DOE-2 modeling assuming a 30% shading coefficient. Incremental measure cost is $3.45 per square foot (XENERGY 1996). Cost effectiveness for window film is affected by higher heating energy use in winter due to reduced solar gain.

Solar Sunscreens

Measure Description

Solar sunscreens savings are based on DOE-2 modeling assuming a 32% shading coefficient during the cooling season and removal of sunscreens during winter to avoid increased heating costs.

Incremental Cost and Lifetime

Incremental measure cost is $598 installed based on $2.72 per square foot (XENERGY 1996). Measure lifetime is 20 years.

Solar Powered Attic Ventilation Fans

Measure Description

Solar powered attic ventilation fans cool attics and reduce air conditioning loads. Solar attic ventilation fans are easily installed on all new or existing attics to remove heat build-up during the day. Solar attic fans use a small photovoltaic panel to power the fan. Attic ventilation can reduce the temperature of attic spaces by 20-40F and save 10-20 percent on peak cooling demand. Typical airflow is 850 cfm.

Incremental Cost and Lifetime

Solar attic fans cost approximately $350 for equipment and $100 for installation (www.solaratticfans.com). Measure lifetime is 10 years (manufacturer warranty).

Radiant Barriers

Measure Description

Radiant barriers are factory installed on roof sheathing to reduce radiant heat gain to attic spaces. This can reduce the temperature of attic spaces by 20-40F and save 10-20 percent on peak cooling demand. Radiant barriers are a low-cost and effective measure for all new construction. Radiant barriers can be cost effectively added to existing homes when the roof is being redone and the roof sheathing needs to be replaced.

Incremental Cost

In new construction radiant barriers add approximately $0.50 per square foot to the cost of conventional roof sheathing (XENERGY 2001).

Cool Roofs

Measure Description

Light or white colored cool exterior surfaces reduce solar absorption and increase reflectance thereby reducing cooling loads. This measure is most appropriate to roof applications. In addition to reducing cooling loads, a white surface roof lasts longer than a dark roof since reducing absorbed solar radiation prolongs the integrity of the roof membrane by limiting temperature swings and deleterious radiation. The extended life of white roof surfaces is not accounted for in this study.

Incremental Cost and Lifetime

In new construction a white surface roof is primarily a design measure, and therefore, cost is negligible. For existing construction, the cost is also assumed to be negligible since the roof color can be selected at the time of replacement. If an existing roof were painted white as a retrofit measure the cost would be $0.50/sf (XENERGY 2001). The high cost of painting an existing roof surface white before it needs to be resurfaced (due to leaks and/or failure) is prohibitive. The assumed lifetime for this measure is 20 years.

Table A-1 Summary Table of DOE2.2 Analysis for the Southern States (Arizona, Nevada, New Mexico)

Existing Residential - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Cooling Savings %	Cum. Cool Savings %	Cum. Heat Savings %	Total Electric *kWh/sf*	Total Gas *kBtu/sf*	Energy Efficiency Measure Cost: *Cost Code*	*$/unit*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life	Increm. Measure Cost $/sf
Base Existing (R-19 roof, R-11 wall)	n/a	n/a	n/a	8.46	26.01	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	4%	4%	-18%	8.22	28.33	I	$0.00	0.001	roof area	0.00	0.00	20	$0.00
AC Diagnostic Tune-up (proper charge/airflow)	13%	16%	-18%	7.54	28.33	I	$75.00	0.001	unit	0.83	0.83	10	$0.01
Programmable Thermostat	10%	24%	-3%	7.06	26.36	F	$98.00	0.001	unit	0.83	0.83	15	$0.01
ECM Fan on Air Handler Unit	9%	31%	-4%	6.55	26.54	I	$170.00	0.001	unit	1.51	1.01	23	$0.01
4 Interior CFLs (13-35W), 1 Exterior CFL (13-18W)	0%	31%	2%	6.46	25.80	F	$10.00	0.003	unit	1.61	1.15	8	$0.00
Duct Testing & Sealing (29% to 15%)	17%	43%	12%	5.66	24.45	F	$0.27	1.000	floor area	2.05	1.44	25	$0.02
Energy Star Central A/C (13 SEER, TXV)	28%	59%	12%	4.75	24.45	I	$209.99	0.002	AC tons	4.12	2.19	18	$0.04
Energy Star Windows, Vinyl+Low-e2 (u=0.32, SHG	23%	69%	7%	4.20	25.19	I	$2.50	0.190	window area	5.19	2.66	30	$0.03
R-38 Roof Insulation (Upgrade from R-19)	2%	69%	7%	4.17	25.07	F	$0.37	1.000	floor area	14.98	3.18	30	$0.02
All Measures	69%	69%	7%	4.17	25.07	I/F	$1.85	1.000	average	n/a	3.18	20	$0.15

New Residential - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Cooling Savings %	Cum. Cool Savings %	Cum. Heat Savings %	Total Electric *kWh/sf*	Total Gas *kBtu/sf*	Energy Efficiency Measure Cost: *Cost Code*	*$/unit*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life	Increm. Measure Cost $/sf
Base Existing (R-30 roof, R-13 wall)	n/a	n/a	n/a	6.10	22.33	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	1%	1%	-1%	6.06	22.38	I	$0.00	1.000	roof area	0.00	0.00	20	$0.00
Duct Testing & Sealing (29% to 6%)	26%	27%	26%	5.03	20.89	I	$0.12	1.000	floor area	0.71	0.68	25	$0.01
Programmable Thermostat	10%	34%	35%	4.73	20.36	I	$58.00	0.0005	unit	0.76	0.70	15	$0.00
AC Diagnostic Tune-up (proper charge/airflow)	13%	42%	35%	4.39	20.36	I	$50.00	0.0005	unit	0.90	0.74	10	$0.00
Radiant Barrier Roof Sheathing	9%	47%	35%	4.17	20.36	I	$97.50	0.0005	roof area	1.38	0.80	30	$0.00
ECM Fan on Air Handler Unit	10%	53%	33%	3.83	20.48	I	$170.00	0.000	unit	1.80	0.94	23	$0.01
4 Interior CFLs (13-35W), 1 Exterior CFL (13-18W	0%	53%	33%	3.79	20.48	I	$10.00	0.002	unit	2.14	1.07	8	$0.00
Energy Star Windows, Vinyl+Low-e2 (u=0.32, SHG	22%	63%	46%	3.25	19.75	I	$2.00	0.190	window area	4.01	1.64	30	$0.02
Energy Star Central A/C (13 SEER, TXV)	31%	74%	46%	2.79	19.75	I	$209.00	0.002	AC tons	7.19	2.61	18	$0.04
R-38 Roof and R-19 Wall Insulation Upgrade	1%	75%	51%	2.78	19.44	I	$0.23	1.120	wall+roof are	10.29	3.04	30	$0.02
All Measures	75%	75%	51%	2.78	19.44	I	$1.46	1.000	average	n/a	3.04	21	$0.11

Table A-1 Summary Table of DOE2.2 Analysis for the Southern States (Arizona, Nevada, New Mexico), continued

Existing Multi-Family - Percentage Savings and Unit Costs By Efficiency Measure.

	Cooling Savings	Cum. Cool Savings	Cum. Heat Savings	Total Electric	Total Gas	Energy Efficiency Measure Cost				Marginal CSE	Average CSE	Estimated Measure	Increm. Measure
Description	%	%	%	*kWh/sf*	*kBtu/sf*	*Cost Code*	*$/unit*	*unit/sf-floor*	*unit*	$/MMBtu	$/MMBtu	Life	Cost $/sf
Base Existing (R-19 roof, uninsulated wall)	n/a	n/a	n/a	9.14	43.56	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	8%	8%	-7%	8.63	45.56	I	$0.00	1.000	roof area	0.00	0.00	20	$0.00
AC Diagnostic Tune-up (proper charge/airflow)	13%	20%	-7%	7.91	45.56	I	$75.00	0.001	unit	1.04	1.04	10	$0.01
Programmable Thermostat	10%	28%	6%	7.43	41.85	F	$98.00	0.001	unit	1.22	1.12	15	$0.01
Duct Testing & Sealing (29% to 15%)	16%	39%	24%	6.73	37.17	F	$0.28	1.000	floor area	1.68	1.34	25	$0.02
4 Interior CFLs (13-35W) and 1 Exterior (13-18W)	0%	39%	24%	6.33	37.17	F	$10.00	0.006	unit	2.13	1.43	8	$0.01
Energy Star Central A/C (13 SEER, TXV)	30%	58%	24%	5.22	37.17	I	$209.00	0.002	AC tons	3.53	1.94	18	$0.04
Energy Star Windows, Vinyl+Low-e2 (u=0.32, SH(	22%	67%	26%	4.65	36.66	I	$2.50	0.190	window area	4.98	2.31	30	$0.03
ECM Fan on Air Handler Unit	9%	70%	25%	4.29	36.91	I	$170.00	0.001	unit	4.05	2.41	23	$0.01
R-38 Roof Insulation (Upgrade from R-19)	2%	70%	29%	4.26	35.91	F	$0.37	1.000	roof area	7.58	2.78	30	$0.02
All Measures	70%	70%	29%	4.26	35.91	I/F	$2.02	1.000	average	n/a	2.78	20	$0.16

New Multi-Family - Percentage Savings and Unit Costs By Efficiency Measure.

	Cooling Savings	Cum. Cool Savings	Cum. Heat Savings	Total Electric	Total Gas	Energy Efficiency Measure Cost				Marginal CSE	Average CSE	Estimated Measure	Increm. Measure
Description	%	%	%	*kWh/sf*	*kBtu/sf*	*Cost Code*	*$/unit*	*unit/sf-floor*	*unit*	$/MMBtu	$/MMBtu	Life	Cost $/sf
Base Existing (R-30 roof, R-13 wall)	n/a	n/a	n/a	6.62	24.75	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	3%	3%	-3%	6.49	25.08	I	$0.00	1.000	roof area	0.00	0.00	20	$0.00
Radiant Barrier Roof Sheathing	10%	13%	-3%	6.05	25.08	I	$56.25	0.0008	roof area	0.69	0.56	30	$0.00
Programmable Thermostat	10%	21%	10%	5.66	23.62	I	$58.00	0.0008	unit	0.86	0.71	15	$0.00
Energy Star Windows, Vinyl+Low-e2 (u=0.32, SH(	29%	44%	8%	4.61	23.92	I	$2.00	0.120	window area	1.53	1.11	30	$0.02
AC Diagnostic Tune-up (proper charge/airflow)	12%	51%	8%	4.30	23.92	I	$50.00	0.0008	AC tons	1.70	1.18	10	$0.01
Duct Testing & Sealing (29% to 6%)	23%	62%	29%	3.80	21.53	I	$0.21	1.000	floor area	1.98	1.37	25	$0.01
4 Interior CFLs (13-35W), 1 Exterior CFL (13-18W	0%	62%	29%	3.51	21.53	I	$10.00	0.004	unit	2.22	1.44	8	$0.01
ECM Fan on Air Handler Unit	8%	65%	29%	3.26	21.53	I	$170.00	0.001	unit	4.15	1.63	23	$0.01
Energy Star Central A/C (13 SEER, TXV)	29%	75%	29%	2.81	21.53	I	$209.00	0.003	AC tons	7.90	2.52	18	$0.04
R-38 Roof Insulation Upgrade	0%	75%	31%	2.81	21.36	I	$0.33	0.500	roof area	8.06	2.76	30	$0.01
All Measures	75%	75%	31%	2.81	21.36	I	$1.46	1.000	average	n/a	2.76	21	$0.11

Table A-1 Summary Table of DOE2.2 Analysis for the Southern States (Arizona, Nevada, New Mexico), continued

Existing Medium Office - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Electric Savings %	Cum. Elec. Savings %	Cum. Gas Savings %	Total Electric *kWh/sf*	Total Gas *kBtu/sf*	Energy Efficiency Measure Cost: *Cost Code*	*$/unit*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life	Increm. Measure Cost $/sf
Base Existing (R-7.1 roof, R-1 wall)	n/a	n/a	n/a	27.56	25.18	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	2%	2%	0%	27.02	25.27	I	0.00	0.333 333	roof area	0.00	0.00	20	$0.00
Efficient Lighting (2 W/sf to 0.83 W/sf)	22%	24%	-14%	20.90	28.80	I	37.00	0.013 500	# fixtures	0.56	0.51	30	$0.03
Eff. Office Equip. (1.4 W/sf to 0.65 W/sf)	15%	38%	-25%	16.99	31.40	I	30.00	0.003 633	workstations	0.68	0.57	5	$0.03
Eff. HVAC (Eff. Fans, VSD, Chiller 0.56 kW/ton	18%	53%	-6%	13.00	26.81	I	142.17	0.002 500	chiller tons	0.76	0.63	15	$0.03
R-26.1 roof (add R-19)	3%	54%	10%	12.65	22.63	F	0.37	0.333 333	roof area	1.29	0.66	20	$0.01
Retrocommissioning	5%	56%	19%	12.06	20.46	F	0.19	1.000 000	floor area	1.52	0.71	30	$0.01
Window, TB-Low-e (SC=0.3, u=0.356)	6%	59%	40%	11.32	15.20	F	18.20	0.070 850	window area	6.57	1.14	30	$0.08
All Measures	59%	59%	40%	11.32	15.20	I/F	2.57	1.000 000	floor area	n/a	1.14	21	$0.20

New Medium Office - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Electric Savings %	Cum. Elec. Savings %	Cum. Gas Savings %	Total Electric *kWh/sf*	Total Gas *kBtu/sf*	Energy Efficiency Measure Cost: *Cost Code*	*$/unit*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life	Increm. Measure Cost $/sf
Base New (R-19 roof, R-5.5 wall)	n/a	n/a	n/a	21.59	9.38	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	1%	1%	-1%	21.43	9.46	I	0.00	0.333 333	roof area	0.00	0.00	20	$0.00
Eff. Office Equip. (1.4 W/sf to 0.65 W/sf)	19%	20%	-22%	17.32	11.47	I	30.00	0.003 633	workstations	0.64	0.61	5	$0.03
Efficient Lighting (1.76 W/sf to 0.7 W/sf)	26%	45%	-64%	11.89	15.42	I	29.00	0.013 514	# fixtures	0.74	0.68	15	$0.04
Eff. HVAC (Eff. Fans, Chiller 0.56 kW/ton)	8%	51%	-69%	10.64	15.89	I	84.21	0.002 167	chiller tons	1.21	0.75	20	$0.01
Window, TB-Low-e (SC=0.3, u=0.356)	4%	53%	-13%	10.10	10.59	I	4.39	0.070 850	window area	1.88	0.85	30	$0.02
R-30 roof, R-9.5 wall (R-19)	1%	54%	9%	9.98	8.49	I	0.29	0.545 317	wall+roof area	3.06	0.91	30	$0.01
All Measures	54%	54%	9%	9.98	8.49	I	1.15	1.000 000	floor area	n/a	0.91	20	$0.09

Existing Retail - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Electric Savings %	Cum. Elec. Savings %	Cum. Gas Savings %	Total Electric *kWh/sf*	Total Gas *kBtu/sf*	Energy Efficiency Measure Cost: *Cost Code*	*$/unit*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life	Increm. Measure Cost $/sf
Base Existing (R-11 roof, R-1 wall)	n/a	n/a	n/a	19.01	8.48	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	4%	4%	-13%	18.30	9.61	I	$0.00	1.000	roof area	0.00	0.00	20	$0.00
Efficient Lighting (2.1 to 0.93 W/sf)	37%	40%	-72%	11.48	14.62	I	$37.00	0.013	fixtures	0.70	0.64	15	$0.04
Eff. Pkg. HVAC (11.5 EER)	16%	51%	-72%	9.29	14.62	I	$100.00	0.003	A/C tons	0.90	0.70	20	$0.02
Commercial Duct Testing and Sealing	15%	58%	-33%	7.92	11.24	F	$150.00	0.003	AC tons	1.75	0.87	20	$0.03
R-30 roof (add R-19)	3%	52%	-51%	9.04	12.78	F	$0.35	1.000	roof area	5.28	0.91	30	$0.02
Eff. Window, TB-Low-e (SC=0.3, u=0.356)	10%	57%	-40%	8.18	11.87	F	$18.20	0.155	window area	19.10	2.55	30	$0.18
All Measures	57%	57%	-40%	8.18	11.87	I/F	$4.25	1.000	floor area	n/a	2.55	22.5	$0.32

New Retail - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Electric Savings %	Cum. Elec. Savings %	Cum. Gas Savings %	Total Electric *kWh/sf*	Total Gas *kBtu/sf*	Energy Efficiency Measure Cost: *Cost Code*	*$/unit*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life	Increm. Measure Cost $/sf
Base New (R-19 roof, R-5.5 wall)	n/a	n/a	n/a	15.25	5.20	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	3%	3%	-9%	14.86	5.66	I	$0.00	1.000	roof area	0.00	0.00	20	$0.00
Efficient Lighting (1.76 to 0.93 W/sf)	34%	36%	-50%	9.75	7.81	I	$29.00	0.013	fixtures	0.71	0.66	15	$0.03
Eff. Pkg. HVAC (11.5 EER)	11%	44%	-50%	8.49	7.81	I	$100.00	0.003	A/C tons	1.28	0.78	30	$0.02
R-30 roof upgrade, R-9.5 walls (upgrade to R-19	2.0%	45%	-33%	8.31	6.90	I	$0.11	1.445	wall+roof area	4.76	0.94	20	$0.01
Commercial Duct testing and sealing	13%	52%	-6%	7.25	5.53	I	$125.00	0.003	AC tons	5.93	1.69	5	$0.07
Eff. Window, TB-Low-e (SC=0.3, u=0.356)	7%	55%	-6%	6.87	5.51	I	$4.39	0.155	window area	11.70	2.14	30	$0.04
All Measures	55%	55%	-6%	6.87	5.51	I	$1.76	1.000	floor area	n/a	2.14	20	$0.14

Table A-1 Summary Table of DOE2.2 Analysis for the Southern States (Arizona, Nevada, New Mexico), continued

Existing School - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Electric Savings %	Cum. Elec Savings %	Cum. Gas Savings %	Total Electric *kWh/sf*	Total Gas *kBtu/sf*	Energy Efficiency Measure Cost: *Cost Code*	*$/unit*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life	Increm. Measure Cost $/sf
Base Existing (R-11 roof, R-5.5 wall)	n/a	n/a	n/a	15.77	16.48	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	5%	5%	-6%	14.98	17.41	I	$0.00	1.000	roof area	0.00	0.00	20	$0.00
Eff. Office Equip. (classes 0.9 W/sf to 0.5 W/sf)	11%	15%	-6%	13.47	17.41	I	$30.00	0.001 250	workstations	0.57	0.39	5	$0.01
Eff. Pkg. HVAC (11.5 EER)	9%	22%	-7%	12.23	17.56	I	$100.00	0.001 600	Pkg. AC tons	1.04	0.62	20	$0.01
Efficient Lighting (2.4 W/sf to 1.03 W/sf)	27%	46%	-21%	8.45	20.02	I	$37.00	0.018 875	# fixtures	1.88	1.26	15	$0.07
Commercial Duct Testing and Sealing	9%	50%	3%	7.83	16.01	F	$150.00	0.001 750	Pkg. AC tons	2.06	1.36	20	$0.02
R-30 roof (add R-19)	5%	53%	11%	7.46	14.61	F	$0.35	1.000 000	roof area	4.44	1.55	30	$0.02
Eff. Window, TB-Low-e (SC=0.3, u=0.356)	12%	58%	17%	6.58	13.72	F	$18.20	0.106 850	window area	12.93	2.71	30	$0.13
All Measures	58%	58%	17%	6.58	13.72	I/F	$3.45	1.000 000	floor area	n/a	2.71	20	$0.28

New School - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Electric Savings %	Cum. Elec Savings %	Cum. Gas Savings %	Total Electric *kWh/sf*	Total Electric *kBtu/sf*	Energy Efficiency Measure Cost: *Cost Code*	*$/unit*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life	Increm. Measure Cost $/sf
Base New (R-19 roof, R-5.5 wall)	n/a	n/a	n/a	12.99	14.94	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	3%	3%	-4%	12.54	15.52	I	$0.00	1.000	roof area	0.00	0.00	20	$0.00
Commercial Duct Testing and Sealing	15%	17%	15%	10.72	12.68	I	$150.00	0.001 450	Pkg. AC tons	0.82	0.69	20	$0.02
Eff. Pkg. HVAC (11.5 EER)	12%	25%	15%	9.69	12.68	I	$100.00	0.001 450	Pkg. AC tons	1.12	0.82	20	$0.01
Efficient Lighting (2.11 W/sf to 1.03 W/sf)	24%	47%	6%	6.95	14.04	I	$29.00	0.018 875	# fixtures	2.00	1.32	15	$0.05
Eff. Office Equip. (classes 0.9 W/sf to 0.5 W/sf)	3%	49%	5%	6.59	14.15	I	$30.00	0.001 250	workstations	2.49	1.38	5	$0.01
R-30 roof upgrade, R-9.5 walls (upgrade to R-19	2%	50%	11%	6.46	13.28	I	$0.11	1.612 075	wall+roof area	5.21	1.51	30	$0.01
Eff. Window, TB-Low-e (SC=0.3, u=0.356)	4%	52%	12%	6.24	13.21	I	$4.39	0.106 850	window area	13.76	1.90	30	$0.03
All Measures	52%	52%	12%	6.24	13.21	I	$1.59	1.000 000	floor area	n/a	1.90	20	$0.13

Existing Food Service/Sales - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Electric Savings %	Cum. Elec Savings %	Cum. Gas Savings %	Total Electric *kWh/sf*	Total Gas *kBtu/sf*	Energy Efficiency Measure Cost: *Cost Code*	*$/unit*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life	Increm. Measure Cost $/sf
Base Existing (R-11 roof, R-1 wall)	n/a	n/a	n/a	50.69	113.85	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	2%	2%	-1%	49.82	115.20	I	$0.00	1.000	roof area	0.00	0.00	20	$0.00
Efficient Lighting (1.88 to 1.27 W/sf)	9%	11%	-5%	45.19	119.23	I	$37.00	0.007	fixtures	0.54	0.46	15	$0.02
Commercial Duct Testing and Sealing	14%	24%	8%	38.62	105.08	F	$150.00	0.0073	AC tons	1.08	0.85	20	$0.09
Eff. Pkg. HVAC (11.5 EER)	14%	32%	8%	34.33	105.08	I	$100.00	0.007	A/C tons	1.34	0.97	20	$0.06
Eff. Package Refrig. (30% improvement)	3%	35%	8%	32.88	105.08	I	$250.00	0.00090	Refrig. Tons	1.48	1.01	15	$0.02
R-30 roof (add R-19)	2%	36%	9%	32.40	103.69	I	$0.35	1.000	roof area	3.68	1.09	30	$0.02
Eff. Custom Refrig. (30% improvement)	3%	39%	9%	31.11	103.69	I	$630.00	0.00090	Refrig. Tons	4.17	1.29	15	$0.05
Eff. Window, TB-Low-e (SC=0.3, u=0.356)	2%	40%	10%	30.66	102.34	F	$18.20	0.403	window area	80.92	3.48	30	$0.48
All Measures	40%	40%	10%	30.66	102.34	I/F	$10.52	1.000	floor area	n/a	3.48	20.625	$0.83

New Food Servce/Sales - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Electric Savings %	Cum. Elec Savings %	Cum. Gas Savings %	Total Electric *kWh/sf*	Total Gas *kBtu/sf*	Energy Efficiency Measure Cost: *Cost Code*	*$/unit*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life	Increm. Measure Cost $/sf
Base New (R-19 roof, R-5.5 wall)	n/a	n/a	n/a	40.40	112.15	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	1%	1%	-1%	39.94	113.35	I	$0.00	1.000	roof area	0.00	0.00	20	$0.00
R-30 roof upgrade, R-9.5 walls (upgrade to R-19	1%	2%	1%	39.42	111.40	I	$0.11	0.403	wall+roof area	0.40	0.27	30	$0.00
Commercial Duct Testing and Sealing	13%	14%	11%	34.57	99.30	I	$125.00	0.0025	AC tons	0.41	0.39	20	$0.03
Efficient Lighting (1.64 to 1.27 W/sf)	7%	21%	10%	32.04	101.48	I	$29.00	0.007	fixtures	0.77	0.48	15	$0.02
Eff. HVAC (11.5 EER)	10%	27%	10%	29.55	101.48	I	$100.00	0.003	A/C tons	0.80	0.55	20	$0.02
Eff. Custom Refrig. (30% improvement)	2%	30%	6%	28.43	105.01	I	$300.00	0.00090	Refrig. Tons	3.35	0.72	15	$0.03
Eff. Package Refrig. (30% improvement)	2%	32%	3%	27.47	108.87	I	$235.00	0.00090	Refrig. Tons	3.45	0.84	15	$0.02
Eff. Window, TB-Low-e (SC=0.3, u=0.356)	12%	38%	-3%	25.05	114.96	I	$4.39	0.403	window area	4.76	1.50	30	$0.11
All Measures	38%	38%	-3%	25.05	114.96	I	$3.04	1.000	floor area	n/a	1.50	20	$0.24

Table A-2 Summary Table of DOE2.2 Analysis for the Northern States (Colorado, Utah, Wyoming)

Existing Residential - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Cooling Savings %	Cum. Cool Savings %	Cum. Heat Savings %	Total Electric *kWh/sf*	Total Gas *kBtu/sf*	Energy Efficiency Measure Cost: *Cost Code*	*$/unit*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life	Increm. Measure Cost $/sf
Base Existing (R-19 roof, R-11 wall)	n/a	n/a	n/a	5.20	69.82	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	12%	12%	2%	4.99	68.93	I	$0.00	0.001	roof area	0.00	0.00	20	$0.00
Programmable Thermostat	9%	20%	15%	4.85	61.90	F	$98.00	0.001	unit	0.67	0.49	15	$0.01
Duct Testing & Sealing (29% to 15%)	15%	32%	37%	4.63	49.59	F	$0.27	1.000	floor area	1.33	0.96	25	$0.02
4 Interior CFLs (13-35W), 1 Exterior CFL (13-18W	1%	32%	41%	4.41	47.68	F	$10.00	0.003	unit	1.13	0.98	8	$0.00
AC Diagnostic Tune-up (proper charge/airflow)	13%	41%	44%	4.25	45.88	I	$75.00	0.001	unit	1.67	1.05	10	$0.01
ECM Fan on Air Handler Unit	2%	43%	46%	4.04	44.48	I	$170.00	0.001	unit	2.16	1.16	23	$0.01
Energy Star Central A/C (12 SEER, TXV)	38%	64%	49%	3.66	42.85	I	$108.00	0.002	AC tons	3.05	1.52	18	$0.02
Energy Star Windows, Vinyl+Low-e2 (u=0.32, SHC	36%	77%	53%	3.43	40.66	I	$2.50	0.190	window area	6.83	2.04	30	$0.03
R-38 Roof Insulation (Upgrade from R-19)	5%	78%	59%	3.43	37.75	F	$0.37	1.000	floor area	7.76	2.40	30	$0.02
All Measures	78%	78%	59%	3.43	37.75	I/F	$1.61	1.000	average	n/a	2.40	20	$0.13

New Residential - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Cooling Savings %	Cum. Cool Savings %	Cum. Heat Savings %	Total Electric *kWh/sf*	Total Gas *kBtu/sf*	Energy Efficiency Measure Cost: *Cost Code*	*$/unit*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life	Increm. Measure Cost $/sf
Base Existing (R-30 roof, R-13 wall)	n/a	n/a	n/a	3.87	39.10	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	3%	3%	-1%	3.84	39.33	I	$0.00	1.000	roof area	0.00	0.00	20	$0.00
Duct Testing & Sealing (29% to 6%)	18%	21%	25%	3.65	32.42	I	$0.12	1.000	floor area	0.95	0.94	25	$0.01
Programmable Thermostat	10%	28%	31%	3.56	30.81	I	$58.00	0.0005	unit	1.08	0.97	15	$0.00
4 Interior CFLs (13-35W), 1 Exterior CFL (13-18W	1%	29%	31%	3.39	30.81	I	$10.00	0.002	unit	2.12	1.12	8	$0.00
AC Diagnostic Tune-up (proper charge/airflow)	14%	38%	31%	3.28	30.81	I	$50.00	0.0005	unit	2.85	1.25	10	$0.00
ECM Fan on Air Handler Unit	2%	40%	30%	3.10	31.04	I	$170.00	0.000	unit	3.85	1.51	23	$0.01
Energy Star Windows, Vinyl+Low-e2 (u=0.32, SH(	31%	58%	40%	2.91	28.34	I	$2.00	0.190	window area	5.17	2.37	30	$0.02
Radiant Barrier Roof Sheathing	10%	63%	40%	2.86	28.34	I	$97.50	0.0005	roof area	6.42	2.46	30	$0.00
R-38 Roof and R-19 Wall Insulation Upgrade	3%	64%	44%	2.86	27.37	I	$0.23	1.120	wall+roof area	15.25	3.11	30	$0.02
Energy Star Central A/C (12 SEER, TXV)	24%	72%	45%	2.76	27.10	I	$108.00	0.002	AC tons	17.72	3.89	18	$0.02
All Measures	72%	72%	45%	2.76	27.10	I	$1.22	1.000	average	n/a	3.89	21	$0.09

Table A-2 Summary Table of DOE2.2 Analysis for the Northern States (Colorado, Utah, Wyoming), continued

Existing Multi-Family - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Cooling Savings %	Cum. Cool Savings %	Cum. Heat Savings %	Total Electric *kWh/sf*	Total Gas *kBtu/sf*	Energy Efficiency Measure Cost: *Cost Code*	*$/unit*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life	Increm. Measure Cost $/sf
Base Existing (R-19 roof, uninsulated wall)	n/a	n/a	n/a	5.71	97.11	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	13%	13%	-5%	5.55	100.89	I	$0.00	1.000	roof area	0.00	0.00	20	$0.00
Duct Testing & Sealing (29% to 15%)	15%	26%	16%	5.38	84.12	F	$0.28	1.000	floor area	1.07	1.21	25	$0.02
Programmable Thermostat	9%	32%	23%	5.30	78.83	F	$98.00	0.001	unit	1.72	1.35	15	$0.01
AC Diagnostic Tune-up (proper charge/airflow)	13%	42%	23%	5.19	78.83	I	$75.00	0.001	unit	1.49	1.75	10	$0.01
4 Interior CFLs (13-35W) and 1 Exterior (13-18W)	1%	42%	23%	4.79	78.83	F	$10.00	0.006	unit	2.13	1.80	8	$0.01
Energy Star Windows, Vinyl+Low-e2 (u=0.32, SHG	33%	61%	30%	4.18	73.80	I	$2.50	0.190	window area	4.16	2.08	30	$0.03
ECM Fan on Air Handler Unit	2%	62%	29%	4.17	74.42	I	$170.00	0.001	unit	4.24	2.47	23	$0.01
Energy Star Central A/C (12 SEER, TXV)	38%	77%	29%	3.99	74.42	I	$108.00	0.002	AC tons	11.43	2.87	18	$0.02
R-38 Roof Insulation (Upgrade from R-19)	8%	78%	30%	3.97	73.24	F	$0.37	1.000	roof area	17.04	3.36	30	$0.02
All Measures	78%	78%	30%	3.97	73.24	I/F	$1.80	1.000	average	n/a	3.36	20	$0.14

New Multi-Family - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Cooling Savings %	Cum. Cool Savings %	Cum. Heat Savings %	Total Electric *kWh/sf*	Total Gas *kBtu/sf*	Energy Efficiency Measure Cost: *Cost Code*	*$/unit*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life	Increm. Measure Cost $/sf
Base Existing (R-30 roof, R-13 wall)	n/a	n/a	n/a	3.98	57.25	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	12%	12%	-5%	3.90	59.50	I	$0.00	1.000	roof area	0.00	0.00	20	$0.00
Duct Testing & Sealing (29% to 6%)	18%	27%	22%	3.80	47.84	I	$0.21	1.000	floor area	1.17	1.32	25	$0.01
Programmable Thermostat	9%	34%	28%	3.76	45.10	I	$58.00	0.0008	unit	1.47	1.35	15	$0.00
4 Interior CFLs (13-35W), 1 Exterior CFL (13-18W	2%	35%	28%	3.46	45.10	I	$10.00	0.004	unit	2.12	1.49	8	$0.01
Energy Star Windows, Vinyl+Low-e2 (u=0.32, SHG	30%	55%	30%	3.11	44.02	I	$2.00	0.120	window area	2.89	1.88	30	$0.02
ECM Fan on Air Handler Unit	2%	55%	29%	3.10	44.54	I	$170.00	0.001	unit	5.77	2.41	23	$0.01
AC Diagnostic Tune-up (proper charge/airflow)	14%	62%	29%	3.06	44.54	I	$50.00	0.0008	AC tons	13.07	2.61	10	$0.01
Radiant Barrier Roof Sheathing	8%	65%	29%	3.04	44.54	I	$56.25	0.0008	roof area	15.76	2.72	30	$0.00
R-38 Roof Insulation Upgrade	1%	65%	30%	3.04	44.25	I	$0.33	0.500	roof area	33.67	3.16	30	$0.01
Energy Star Central A/C (12 SEER, TXV)	24%	73%	30%	2.98	44.25	I	$108.00	0.003	AC tons	41.70	4.09	18	$0.02
All Measures	73%	73%	30%	2.98	44.25	I	$1.20	1.000	average	n/a	4.09	21	$0.09

Table A-2 Summary Table of DOE2.2 Analysis for the Northern States (Colorado, Utah, Wyoming), continued

Existing Medium Office - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Electric Savings %	Cum. Elec. Savings %	Cum. Gas Savings %	Total Electric *kWh/sf*	Total Gas *kBtu/sf*	*Cost Code*	Energy Efficiency Measure Cost *$/unit*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life	Increm. Measure Cost $/sf
Base Existing (R-7.1 roof, R-1 wall)	n/a	n/a	n/a	23.42	43.46	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	2%	2%	0%	22.99	43.24	I	0.00	0.333 333	roof area	0.00	0.00	20	$0.00
Efficient Lighting (2 W/sf to 0.83 W/sf)	25%	27%	-12%	17.08	48.65	I	37.00	0.013 500	# fixtures	0.60	0.55	30	$0.03
Eff. Office Equip. (1.4 W/sf to 0.65 W/sf)	17%	43%	-21%	13.31	52.52	I	30.00	0.003 633	workstations	0.74	0.62	5	$0.03
Eff. HVAC (Eff. Fans, VSD, Chiller 0.56 kW/ton	14%	54%	-4%	10.81	45.01	I	142.17	0.002 500	chiller tons	1.05	0.73	15	$0.03
R-26.1 roof (add R-19)	2%	55%	12%	10.61	38.22	F	0.37	0.333 333	roof area	1.11	0.76	20	$0.01
Retrocommissioning	4%	56%	21%	10.22	34.52	F	0.19	1.000 000	floor area	1.63	0.80	30	$0.01
Window, TB-Low-e (SC=0.3, u=0.356)	6%	59%	38%	9.66	26.74	F	18.20	0.070 850	window area	6.23	1.27	30	$0.08
All Measures	59%	59%	38%	9.66	26.74	I/F	2.57	1.000 000	floor area	n/a	1.27	22	$0.19

New Medium Office - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Electric Savings %	Cum. Elec. Savings %	Cum. Gas Savings %	Total Electric *kWh/sf*	Total Gas *kBtu/sf*	*Cost Code*	Energy Efficiency Measure Cost *$/unit*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life	Increm. Measure Cost $/sf
Base New (R-19 roof, R-5.5 wall)	n/a	n/a	n/a	19.19	18.80	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	1%	1%	-1%	19.09	18.91	I	0.00	0.333 333	roof area	0.00	0.00	20	$0.00
Efficient Lighting (1.76 W/sf to 0.7 W/sf)	27%	28%	-33%	13.83	24.95	I	29.00	0.013 514	# fixtures	0.80	0.79	15	$0.04
Eff. Office Equip. (1.4 W/sf to 0.65 W/sf)	20%	47%	-61%	10.12	30.25	I	30.00	0.003 633	workstations	0.78	0.79	5	$0.03
R-30 roof, R-9.5 wall (R-19)	1%	48%	-33%	10.02	24.98	I	0.29	0.545 317	wall+roof area	1.63	0.85	30	$0.01
Window, TB-Low-e (SC=0.3, u=0.356)	3%	50%	3%	9.54	18.20	I	4.39	0.070 850	window area	1.75	0.95	30	$0.02
Eff. HVAC (Eff. Fans, Chiller 0.56 kW/ton)	6%	54%	3%	8.88	18.30	I	84.21	0.002 167	chiller tons	2.21	1.03	20	$0.01
All Measures	54%	54%	3%	8.88	18.30	I	1.15	1.000 000	floor area	n/a	1.03	20	$0.09

Existing Retail - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Electric Savings %	Cum. Elec. Savings %	Cum. Gas Savings %	Total Electric *kWh/sf*	Total Gas *kBtu/sf*	*Cost Code*	Energy Efficiency Measure Cost *$/unit*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life	Increm. Measure Cost $/sf
Base Existing (R-11 roof, R-1 wall)	n/a	n/a	n/a	14.25	34.10	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	3%	3%	-8%	13.79	36.95	I	$0.00	1.000	roof area	0.00	0.00	20	$0.00
Efficient Lighting (2.1 to 0.93 W/sf)	44%	46%	-46%	7.64	49.93	I	$37.00	0.013	fixtures	0.91	0.87	15	$0.04
Commercial Duct Testing and Sealing	9%	52%	-10%	6.80	37.47	F	$150.00	0.003	AC tons	1.44	1.04	20	$0.03
Eff. Pkg. HVAC (11.5 EER)	9%	56%	-10%	6.25	37.47	I	$100.00	0.003	A/C tons	3.61	1.22	20	$0.02
R-30 roof (add R-19)	1%	57%	4%	6.19	32.83	F	$0.35	1.000	roof area	4.33	1.42	30	$0.02
Eff. Window, TB-Low-e (SC=0.3, u=0.356)	7%	59%	10%	5.89	30.59	F	$18.20	0.155	window area	34.56	3.42	30	$0.18
All Measures	59%	59%	10%	5.89	30.59	I/F	$4.25	1.000	floor area	n/a	3.42	23	$0.32

New Retail - Percentage Savings and Unit Costs By Efficiency Measure.

Description	Electric Savings %	Cum. Elec. Savings %	Cum. Gas Savings %	Total Electric *kWh/sf*	Total Gas *kBtu/sf*	*Cost Code*	Energy Efficiency Measure Cost *$/unit*	*unit/sf-floor*	*unit*	Marginal CSE $/MMBtu	Average CSE $/MMBtu	Estimated Measure Life	Increm. Measure Cost $/sf
Base New (R-19 roof, R-5.5 wall)	n/a	n/a	n/a	12.32	16.16	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	2%	2%	-8%	12.07	17.48	I	$0.00	1.000	roof area	0.00	0.00	20	$0.00
Efficient Lighting (1.76 to 0.93 W/sf)	38%	40%	-54%	7.43	24.85	I	$29.00	0.013	fixtures	0.88	0.86	15	$0.03
R-30 roof upgrade, R-9.5 walls (upgrade to R-19	0.6%	40%	-26%	7.37	20.36	I	$0.11	1.445	wall+roof area	2.50	1.04	20	$0.01
Eff. Pkg. HVAC (11.5 EER)	7%	45%	-26%	6.75	20.36	I	$100.00	0.003	A/C tons	2.62	1.23	30	$0.02
Commercial Duct testing and sealing	9%	50%	3%	6.19	15.59	I	$125.00	0.003	AC tons	6.88	2.18	5	$0.07
Eff. Window, TB-Low-e (SC=0.3, u=0.356)	5%	52%	4%	5.96	15.47	I	$4.39	0.155	window area	18.48	2.78	30	$0.04
All Measures	52%	52%	4%	5.96	15.47	I	$1.76	1.000	floor area	n/a	2.78	20	$0.14

Table A-2 Summary Table of DOE2.2 Analysis for the Northern States (Colorado, Utah, Wyoming), continued

Existing School - Percentage Savings and Unit Costs By Efficiency Measure.

	Electric Savings	Cum. Elec. Savings	Cum. Gas Savings	Total Electric	Total Gas	Energy Efficiency Measure Cost				Marginal CSE	Average CSE	Estimated Measure Life	Increm. Measure Cost $/sf
Description	%	%	%	*kWh/sf*	*kBtu/sf*	*Cost Code*	*$/unit*	*unit/sf-floor*	*unit*	$/MMBtu	$/MMBtu	Life	Cost $/sf
Base Existing (R-11 roof, R-5.5 wall)	n/a	n/a	n/a	12.00	47.86	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	4%	4%	-5%	11.46	50.13	I	$0.00	1.000	roof area	0.00	0.00	20	$0.00
Commercial Duct Testing and Sealing	12%	15%	19%	10.20	38.59	F	$150.00	0.001 750	Pkg. AC tons	0.87	0.77	20	$0.02
Eff. Pkg. HVAC (11.5 EER)	10%	22%	18%	9.33	39.05	I	$100.00	0.001 600	Pkg. AC tons	1.53	0.95	20	$0.01
Efficient Lighting (2.4 W/sf to 1.03 W/sf)	32%	51%	7%	5.86	44.44	I	$37.00	0.018 875	# fixtures	2.27	1.55	15	$0.07
R-30 roof (add R-19)	4%	53%	15%	5.67	40.64	F	$0.35	1.000 000	roof area	4.02	1.74	30	$0.02
Eff. Office Equip. (classes 0.9 W/sf to 0.5 W/sf)	3%	54%	15%	5.52	40.64	I	$30.00	0.001 250	workstations	5.78	1.83	5	$0.01
Eff. Window, TB-Low-e (SC=0.3, u=0.356)	4%	55%	24%	5.38	36.28	F	$18.20	0.106 850	window area	21.66	3.30	30	$0.13
All Measures	55%	55%	24%	5.38	36.28	I/F	$3.45	1.000 000	floor area	n/a	3.30	20	$0.28

New School - Percentage Savings and Unit Costs By Efficiency Measure.

	Electric Savings	Cum. Elec. Savings	Cum. Gas Savings	Total Electric	Total Electric	Energy Efficiency Measure Cost				Marginal CSE	Average CSE	Estimated Measure Life	Increm. Measure Cost $/sf
Description	%	%	%	*kWh/sf*	*kBtu/sf*	*Cost Code*	*$/unit*	*unit/sf-floor*	*unit*	$/MMBtu	$/MMBtu	Life	Cost $/sf
Base New (R-19 roof, R-5.5 wall)	n/a	n/a	n/a	10.40	42.45	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	2%	2%	-4%	10.18	44.00	I	$0.00	1.000	roof area	0.00	0.00	20	$0.00
Commercial Duct Testing and Sealing	11%	12%	20%	9.12	34.05	I	$150.00	0.001 450	Pkg. AC tons	0.85	0.82	20	$0.02
Eff. Pkg. HVAC (11.5 EER)	9%	18%	20%	8.53	34.05	I	$100.00	0.001 450	Pkg. AC tons	1.95	1.07	20	$0.01
Efficient Lighting (2.11 W/sf to 1.03 W/sf)	27%	43%	10%	5.95	38.36	I	$29.00	0.018 875	# fixtures	2.42	1.67	15	$0.05
Eff. Office Equip. (classes 0.9 W/sf to 0.5 W/sf)	4%	46%	8%	5.61	38.85	I	$30.00	0.001 250	workstations	2.96	1.74	5	$0.01
R-30 roof upgrade, R-9.5 walls (upgrade to R-19	1%	47%	15%	5.55	36.03	I	$0.11	1.612 075	wall+roof area	3.36	1.84	30	$0.01
Eff. Window, TB-Low-e (SC=0.3, u=0.356)	2%	48%	17%	5.45	35.12	I	$4.39	0.106 850	window area	15.99	2.31	30	$0.03
All Measures	48%	48%	17%	5.45	35.12	I	$1.59	1.000 000	floor area	n/a	2.31	20	$0.13

Existing Food Service/Sales - Percentage Savings and Unit Costs By Efficiency Measure.

	Electric Savings	Cum. Elec. Savings	Cum. Gas Savings	Total Electric	Total Gas	Energy Efficiency Measure Cost				Marginal CSE	Average CSE	Estimated Measure Life	Increm. Measure Cost $/sf
Description	%	%	%	*kWh/sf*	*kBtu/sf*	*Cost Code*	*$/unit*	*unit/sf-floor*	*unit*	$/MMBtu	$/MMBtu	Life	Cost $/sf
Base Existing (R-11 roof, R-1 wall)	n/a	n/a	n/a	39.50	240.78	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	2%	2%	-2%	38.79	245.55	I	$0.00	1.000	roof area	0.00	0.00	20	$0.00
Efficient Lighting (1.88 to 1.27 W/sf)	11%	13%	-7%	34.48	257.76	I	$37.00	0.007	fixtures	0.74	0.69	15	$0.02
Commercial Duct Testing and Sealing	9%	21%	12%	31.30	212.09	F	$150.00	0.0073	AC tons	1.12	0.99	20	$0.09
Eff. Package Refrig. (30% improvement)	4%	24%	12%	29.91	212.09	I	$250.00	0.00090	Refrig. Tons	1.54	1.05	15	$0.02
R-30 roof (add R-19)	2%	25%	14%	29.49	206.50	I	$0.35	1.000	roof area	2.33	1.14	30	$0.02
Eff. Pkg. HVAC (11.5 EER)	8%	30%	14%	27.65	206.50	I	$100.00	0.007	A/C tons	3.13	1.38	20	$0.06
Eff. Custom Refrig. (30% improvement)	4%	33%	14%	26.41	206.50	I	$630.00	0.00090	Refrig. Tons	4.36	1.61	15	$0.05
Eff. Window, TB-Low-e (SC=0.3, u=0.356)	2%	34%	16%	26.12	201.15	F	$18.20	0.403	window area	57.64	4.26	30	$0.48
All Measures	34%	34%	16%	26.12	201.15	I/F	$10.52	1.000	floor area	n/a	4.26	21	$0.82

New Food Servce/Sales - Percentage Savings and Unit Costs By Efficiency Measure.

	Electric Savings	Cum. Elec. Savings	Cum. Gas Savings	Total Electric	Total Gas	Energy Efficiency Measure Cost				Marginal CSE	Average CSE	Estimated Measure Life	Increm. Measure Cost $/sf
Description	%	%	%	*kWh/sf*	*kBtu/sf*	*Cost Code*	*$/unit*	*unit/sf-floor*	*unit*	$/MMBtu	$/MMBtu	Life	Cost $/sf
Base New (R-19 roof, R-5.5 wall)	n/a	n/a	n/a	31.89	256.78	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cool Roof (ABS = 0.7 to 0.3)	1%	1%	-1%	31.64	259.33	I	$0.00	1.000	roof area	0.00	0.00	20	$0.00
R-30 roof upgrade, R-9.5 walls (upgrade to R-19	1%	2%	2%	31.34	252.40	I	$0.11	0.403	wall+roof area	0.29	0.29	30	$0.00
Commercial Duct Testing and Sealing	7%	9%	19%	29.13	208.14	I	$125.00	0.0025	AC tons	0.38	0.37	20	$0.03
Efficient Lighting (1.64 to 1.27 W/sf)	8%	16%	17%	26.81	212.92	I	$29.00	0.007	fixtures	0.98	0.48	15	$0.02
Eff. HVAC (11.5 EER)	6%	20%	17%	25.64	212.92	I	$100.00	0.003	A/C tons	1.70	0.62	20	$0.02
Eff. Package Refrig. (30% improvement)	3%	23%	15%	24.46	218.70	I	$235.00	0.00090	Refrig. Tons	3.32	0.77	15	$0.02
Eff. Custom Refrig. (30% improvement)	3%	27%	12%	23.43	224.75	I	$300.00	0.00090	Refrig. Tons	6.00	0.96	15	$0.03
Eff. Window, TB-Low-e (SC=0.3, u=0.356)	10%	31%	10%	21.86	230.30	I	$4.39	0.403	window area	7.88	1.78	30	$0.11
All Measures	31%	31%	10%	21.86	230.30	I	$3.04	1.000	floor area	n/a	1.78	21	$0.24

APPENDIX B—RESIDENTIAL APPLIANCES AND EQUIPMENT ANALYSIS

The residential building prototypes developed by Robert Mowris and Associates using the DOE2.2 computer program were augmented by considering potential energy efficiency measures for water heating, refrigeration, lighting, and other end-uses as described below. Table B.1 provides baseline energy use, energy savings, and costs for these additional energy efficiency measures.

Water Heating

Base Case Energy Consumption

The assumed baseline electricity consumption is derived from the 1997 Residential Energy Consumption Survey (RECS) (EIA 1999). The survey estimated that water heating consumed 2,552 kWh per year in households that contain an electric water heater in the Rocky Mountain region in 1997. In addition, we reduced this value by about 5 percent to account for the improvement in the average efficiency of new electric water heaters since 1997.

Measure Description, Performance and Incremental Cost

Hot water consumption can be reduced by installing high-efficiency clothes washers, dishwashers, and low-cost measures such as low-flow showerheads and faucet aerators. Electricity consumption for heating water can be reduced by installing high-efficiency electric water heaters, heat pump water heaters, or solar water heaters. After all lower-cost measures are installed, heat pump water heaters and solar water heaters are cost effective only for large families with relatively high hot water consumption.

2007 Standard clothes washer

Upgrade from 0.82 MEF (baseline) to 2007 DOE standard of 1.26 MEF. The energy savings estimate is derived from a DOE study (DOE 2000). Incremental cost is an ACEEE estimate (Suozzo and Nadel 1998). Average cost of saved energy is negative due to consumer bill savings from reduction in water consumption (a negative cost of saved energy indicates that the measure is cost-effective even when energy savings are ignored).

High-efficiency clothes washer

Upgrade from 1.26 MEF (2007 DOE standard) to 1.63 MEF (CEE Tier 3). Incremental cost is an ACEEE estimate (Suozzo and Nadel 1998) based on a DOE-sponsored analysis (DOE 2000).

High-efficiency dishwasher

Upgrade to ENERGY STAR dishwasher. Energy savings and measure costs are derived from an ACEEE analysis (Kubo, Sachs and Nadel 2001).

Low-cost package

Install low-flow showerheads, aerators, and pipe insulation to reduce energy consumption for water heating about 280 kWh per year. Energy savings and incremental cost values are from an ACEEE study (Suozzo and Nadel 1998).

High efficiency electric water heater
Upgrade to a water heater with 0.93 energy factor (EF). Incremental cost is ACEEE estimate based on market data and Goldberg et al. 1998.

Heat pump water heater
Upgrade from 0.93 EF to 2.47 EF (ECR 2001). Applied to only large households of 5 or more persons. We assume that 40% of families have 5 or more persons per household (ACEEE estimate based on Bureau of Census data) and that 30% will achieve cost-effective savings from installing heat pump water heaters and 10% from solar water heaters. The incremental cost of $550 is from a study sponsored by U.S. DOE (ECR 2001).

Solar water heater
The solar water heater is sized to meet 90% of the water heating load. Again the solar water heater is only considered as an option for larger households. Performance and cost are taken from a study conducted for southern California (Muller and Sachs 1993).

Refrigeration

Base Case Energy Consumption
The average electricity consumption for refrigeration in the Rocky Mountain region in 1997 was 1,213 kWh per household (EIA 1999). Looking past 2002, we reduced this by one-third to account for the effects of the 2001 refrigerator and freezer standards. There were approximately 1.2 refrigerators per household in 1997.

Measure Description, Performance, and Incremental Cost
Electricity use for refrigeration is reduced by installing Energy Star refrigerators (15% improvement over 2001 standard). Energy Star models consume 15% less electricity than models just meeting the 2001 standard. The incremental cost is estimated to be $37, although past experience has shown that manufacturers often find ways of producing more efficient refrigerators for very little or no incremental cost.

Lighting

Base Case Energy Consumption
The 1997 RECS indicates that an average household in the Rocky Mountain region uses 940 kWh per year on lighting (EIA 1999). We assume that 90% of lamps are incandescent, and that there is one torchiere-style lamp per household (Kubo, Sachs and Nadel 2001).

Measure Description, Performance, and Incremental Costs
Electricity use for lighting can be reduced by replacing standard incandescent lamps with energy-saver incandescent lamps and compact fluorescent lamps (CFLs). Additional savings can be achieved by replacing popular halogen torchiere lamps with CFL-based torchiere lamps.

Energy-saver lamps
Energy-saving incandescent lamps reduce electricity consumption by 10%. The incremental cost is only $0.10 per lamp (Nadel et al. 1997).

Compact fluorescent lamps
We assume that the six most heavily used 67W lamps (energy-saver lamps that replaces a standard 75W incandescent lamps) are replaced with CFLs. Energy consumption per lamp is reduced by 70%. The assumed cost of $12 per CFL is conservative since high quality CFLs are now widely available at substantially lower first costs, and costs are rapidly declining (Calwell et al. 2002).

CFL Torchiere lamp
We assume that 227 W torchiere lamps (weighted average of halogen- and incandescent- models) are replaced with 75 W CFL torchiere lamps. Average usage is assumed to be 4 hours per day, 350 days per year. The incremental cost of $40 is based on an ACEEE study (Kubo, Sachs and Nadel 2001).

Heating, Ventilation, and Air-Conditioning (HVAC)

Base Case Energy Consumption

Central air conditioning
The 1997 RECS survey indicates that the average cooling energy use for households with central air conditioning in the Rocky Mountain region was 2,292 kWh per year (EIA 1999).

Room air conditioning
The 1997 RECS survey indicates that the average energy consumption for homes using room air conditioning in the Rocky Mountain region was 769 kWh per year (EIA 1999). In addition, we adjusted this value to account for the improvement in room AC efficiency as a result of new national efficiency standards.

Central heating
The 1997 RECS survey indicates that homes in the Rocky Mountain region with electricity as their main heating fuel consumed 3,044 kWh per year for space heating (EIA 1999). For homes with gas forced-air heating, electricity consumption by furnace fans used in the heating system is typically about 900 kWh per year (Kubo, Sachs and Nadel 2001).

Ceiling fans
We estimate that ceiling fans typically consume 300 kWh per year (Kubo, Sachs and Nadel 2001). The 1997 RECS indicates that on average, there were approximately 1.3 ceiling fans per household in the Rocky Mountain region. This leads to the base case consumption level for ceiling fans of 390 kWh per year per household.

Measure Description, Performance, and Incremental Cost

Appendix A provides estimates of the savings potential from high efficiency central air conditioning systems, based on building simulation analysis using the DOE2.2 model. We also assume that improvements in heat pumps, windows, walls, ducts, and thermostats as evaluated with the DOE2.2 model save heating electricity use by heat pumps and electric resistance heating systems. Electricity consumption for HVAC can be further reduced by replacing room air conditioners (ACs) with Energy Star models and by installing more efficient ceiling fans. With respect to heating, high efficiency furnace fans can also reduce electricity use, although most of the saved electricity will be replaced by additional gas or oil consumption (i.e., the "waste heat" from an inefficient furnace fan contributes to space heating).

Central air-conditioning and space heating
The DOE2.2 analysis indicates that cooling electricity use can be reduced by approximately 70% on average in the southwest region (savings potential varies between 55 and 78%, depending on climate and housing type) through a combination of efficiency measures. By examining results of the DOE2.2 analysis, we estimate that these measures also will cut electricity consumption for central space heating (in those homes with electric space heating) by about 35%. Detailed savings descriptions and incremental cost values are presented in Appendix A.

Room air conditioning
Energy Star room ACs can reduce electricity use by approximately 9% due to EER increasing from 9.7 to 10.7 on average. The incremental cost of $66 for an Energy Star room AC unit is based on a study sponsored by the California Energy Commission (XENERGY 2001).

Furnace fans
It is possible to reduce the electricity consumption of furnace fans during the heating season by about 72% through the use of variable speed (ECM type) fans (Kubo, Sachs and Nadel 2001). We apply this savings percentage to furnace fan electricity use as estimated by the DOE 2.2 model in the base case. The incremental cost of $170 for a variable speed furnace fan is based on an ACEEE study (Kubo, Sachs and Nadel 2001).

Ceiling fans
Energy Star ceiling fans are now available. These fans have more efficient fan motors and CFLs if the ceiling fan includes lights. One study estimates that the use of both more efficient fan motors and CFLs can cut the electricity use of a typical ceiling fan by about 180 kWh (60%). Current models on the market that incorporate both these design improvements have an incremental cost of about $40.

Consumer Electronics (standby power consumption)

Base Case Energy Consumption
Various residential electronic products (TVs, VCRs, audio systems, microwave ovens, phones, battery chargers, etc.) consume electricity when they are not in use. This phenomenon is known as standby power consumption. Studies in the mid- to late-1990s found that households consume about 50W of standby power on average, which amounts to 438 kWh per year (Thorne and Suozzo 1998). Limited data collected more recently suggests that this value could be even higher, but these studies do not involve measurements in a random sampling of households. To be conservative, we assume base standby power consumption of 438 kWh per year.

Measure Description, Performance, and Incremental Cost
Standby power can be reduced significantly through better product design and use of better components. The U.S. EPA has started an Energy Star program which limits the standby power consumption for qualifying electronic products. The Energy Star program's Tier 2 levels require most products to consume less than 1 watt during standby or "off" periods in order to qualify. In

addition, the Bush Administration has issued an Executive Order that directs Federal agencies to purchase electronic products with no more than 1 watt standby power consumption wherever available and cost-effective on a lifecycle cost basis (White House 2001). Many products are now available that meet the Energy Star and Federal Executive Order thresholds. We assume that purchase of qualifying products can reduce standby power consumption by 75% on average, meaning a reduction from 438 kWh/yr to 109 kWh/yr once all of the electronic products in a household are replaced. Furthermore, we assume the incremental cost for this level of efficiency improvement is $24 and that electronic products have a seven year lifetime on average. These values were derived from an analysis conducted by ACEEE (Kubo, Sachs and Nadel 2001).

Table B-1. *Residential appliances and equipment analysis (state-by-state saturation and usage adjustments are not shown here)*

		Without saturation adjustment of electric vs gas								***With saturation adjustment***			
End Use	Measure	Base Use (kWh)	Svg Potential (kWh)	Incre. Cost ($)	Avg Life (yrs)	Avg CSE ($/kWh)	Imple. by 2020 (%)	Svg in 2020 (kWh)	Svg in 2020 (%)	Sat. rate of Equip. (%)	Avg HH baseline (kWh)	Avg HH svg in 2020 (kWh)	Avg HH svg in 2020 (%)
Water heating	2007 standard clothes washer	2,436	512	75	14	($0.03)	100%	512	21%	35%	840	135	16%
Water heating	High efficiency clothes washer	1,924	431	100	14	($0.02)	100%	431	22%	35%	664	114	17%
Water heating	Low water use dishwasher	1,493	103	20	13	$0.02	100%	103	7%	35%	515	20	4%
Water heating	Low-cost package	1,390	278	46	10	$0.02	50%	139	10%	35%	480	48	10%
Water heating	EF .93 tank	1,112	60	17	12	$0.03	100%	60	5%	35%	384	21	5%
Water heating	Heat pump water heater	2,024	1,262	550	15	$0.04	30%	379	19%	35%	698	131	19%
Water heating	Solar water heater	2,024	1,822	1,800	20	$0.08	10%	182	9%	35%	698	63	9%
Water heating	All Water Heating	2,436				$0.04		1,805	74%		840	531	63%
Refrigeration	High efficiency refrigerator	809	121	37	19	$0.02	100%	121	15%	100%	809	121	15%
Lighting	Energy-saver lamps	940	85	3	2	$0.02	100%	85	9%	100%	940	85	9%
Lighting	Compact fluorescent lamps	855	332	72	8	$0.03	100%	332	39%	100%	855	332	39%
Lighting	CFL Torchieres	524	214	40	10	$0.02	100%	214	41%	100%	524	214	41%
Lighting	All Lighting	940				$0.03		630	67%		940	630	67%
Ventilation	Ceiling Fans	386	231	40	10	$0.02	100%	231	60%	100%	386	231	60%
Electronics	Standby Power	438	329	24	7	$0.01	100%	329	75%	100%	438	329	75%
Central Heating	ECM Furnace Fan	900	650	170	20	$0.02	100%	650	72%	51%	461	333	72%
Central Heating	Reduced Resistance Heating	3,044	1,065		20	$0.02	100%	1,065	35%	27%	816	286	35%
Room A/C	Energy Star room A/C	690	64	66	12.5	$0.11	100%	64	9%	14%	94	9	9%
Central A/C	From DOE-2.2 analysis	2,292	1,604		20	$0.03	100%	1,604	70%	34%	779	545	70%

Notes: 1) See text for sources
2) Abbreviations: Svg = savings; CSE = cost of saved energy; Imple. = Implementation rate; Sat. = saturation; Equip. = appliances/equipment; HH = households
3) Base Use numbers published in RECS 1997 are for households with the specified appliance/equipment and not weighted avg numbers for all households.
4) Negative CSEs indicate that these measures are cost-effective even without energy savings (efficient clothes washers and dish washers reduce water costs).
5) Heat pump water heaters and solar water heaters are only cost-effective for large households (with 5 persons or more) when all other measures are installed.
6) Clothes washer (CW) and dishwasher (DW) savings are further adjusted by appliance saturation rates (77% for CW and 57% for DW)

APPENDIX C—INDUSTRIAL ENERGY EFFICIENCY ANALYSIS

We used the Long Term Industrial Energy Forecasting (LIEF) model, developed at Argonne National Laboratory in 1993, to develop the industrial sector electricity use projections in both the Base and High Efficiency Scenarios. LIEF is designed to study industrial energy consumption and energy savings potential (Ross et al. 1993). The LIEF model was updated and revised in 2001 to reflect data from the 1990s, establishing 1998 as the new base year (Boyd 2002). This study uses the updated version of the LIEF Model.

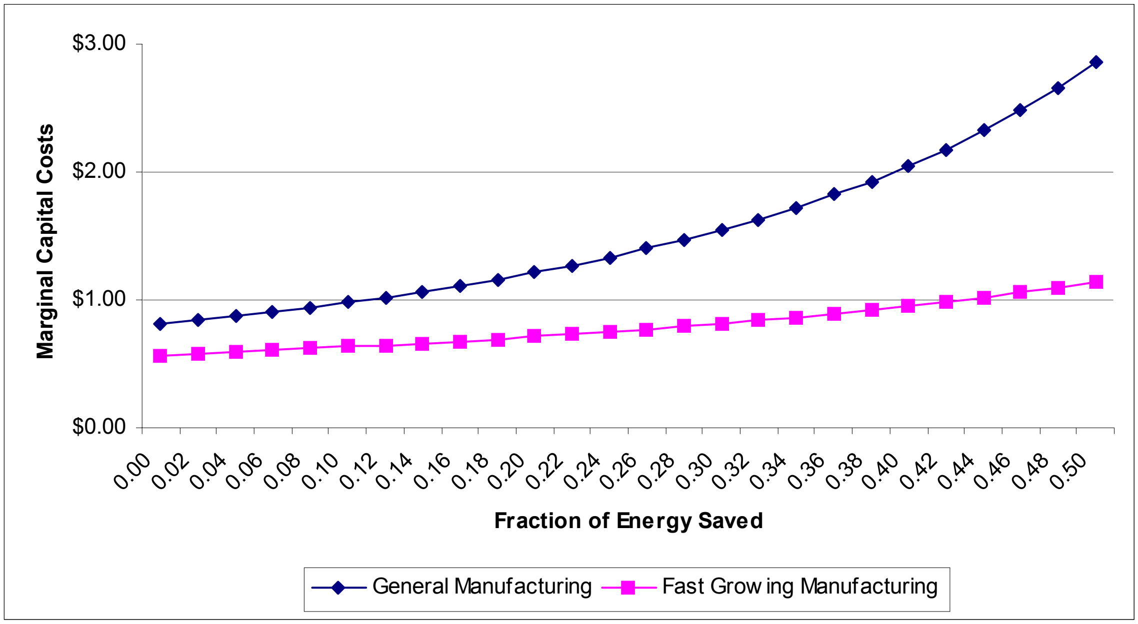
The LIEF model has been used in many other studies of industrial energy conservation potential including major assessments of potential U.S. carbon dioxide emissions reductions produced by five national laboratories (Interlaboratory Working Group 1997; Interlaboratory Working Group 2000). It was also used by a group of private sector analysts for a similar study (Alliance to Save Energy et al. 1997). In addition, it has been used in other studies of regional energy efficiency potential (Laitner et al. 1995; Nadel et al. 1997; and Goldberg et al. 1998).

The model is based upon conservation supply curves (CSCs) constructed from industrial data from 1958-85. The CSC is an analytical tool that captures both the engineering and the economic perspectives on energy conservation. The curves show the energy savings potential as a function of marginal capital cost, where the marginal capital cost can be thought of as the incremental cost required to save an additional unit of energy. The curve is upward sloping because increasing energy efficiency comes at a higher marginal cost.

An example of CSCs for the Fast-Growing and General Manufacturing Sectors in Arizona are shown in Figure C-1. The steeper curve for the General Manufacturing sector shows that greater capital outlays are required to achieve equivalent energy savings in this sub-sector as compared to Fast-Growing Manufacturing.

While this approach is less detailed than the bottom-up approached used in the analysis of energy savings potential in the buildings sectors, it provides convenient and reasonably accurate estimates of industrial energy savings potential on an aggregate basis.

__Figure C-1.__ CSC Curves for the Fast-Growing and General Manufacturing Sectors



The input variables needed to run the LIEF model include the base year electricity use by industrial sub-sector, growth in output over time by sub-sector, energy prices, capital recovery factors, and penetration rates for cost-effective energy efficiency measures. The model estimates how electricity intensity changes over time in each sub-sector based on the CSC and these various parameters.

The model breaks the industrial sector down into 17 sub-sectors: General manufacturing, Fast-growing manufacturing, Pulp and Paper, Organic and Inorganic Chemicals, Petroleum Refining, Glass, Cement, Stone and Clay, Iron and Steel, Primary Aluminum, Nonferrous Metals, Agriculture, Mining, Oil and Gas, Construction, Feedstocks and Uranium. The Feedstocks and Uranium sub-sectors are not included in our analysis because these sub-sectors were either not present in the states studied, or data were not available for them. Thus results are presented for 15 sub-sectors in LIEF.
Various estimates of industrial energy savings potential can be developed based upon altering three key input parameters in the LIEF model: the capital recovery factor (CRF), energy prices, and the penetration rate for cost-effective efficiency measures. The CRF affects industries' decisions about which efficiency measures are "cost effective" and thus merit pursuing. It is based on an implicit discount rate and an assumed average lifetime for determining the cost effectiveness of efficiency measures. Both the discount rate and the penetration rate for cost-effective efficiency measures can be influenced by policies and programs such as education and training efforts, financing, financial incentives, or voluntary commitment programs.

In the Base Scenario, a CRF of 33 percent is used. This value corresponds to a discount rate of 32 percent and 15-year lifetime. Also, it is assumed that 3.27 percent of the identified cost-effective energy savings potential are implemented annually. The cost effectiveness threshold and level of adoption are typical of decision making in industries today where a host of barriers lead to high "hurdle rates" that inhibit pursuit of energy efficiency measures with more than a 2 or 3 year payback based on energy savings alone.

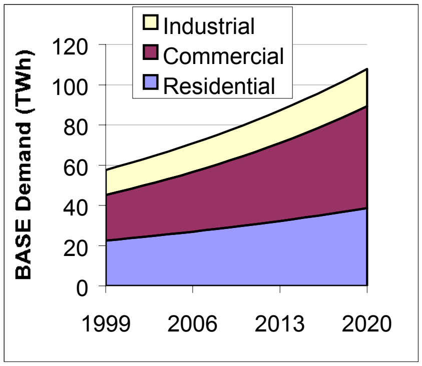
For the High Efficiency Scenario, the CRF was reduced from 33 percent to 9.6 percent and the annual penetration rate for cost-effective energy efficiency measures was increased from 3.27 percent to 6.5 percent. These values assume that industries are willing to accept lower rates of return (i.e., longer payback periods based on energy savings alone) on energy efficiency measures and are willing to implement a larger portion of available cost-effective measures each year, considering that there would be efforts to: a) educate and train industries regarding energy efficiency opportunities and their benefits, b) lower the transaction cost for obtaining energy efficiency measures, c) provide financial incentives to stimulate accelerated adoption, and d) encourage corporate commitments to reduce energy and/or carbon dioxide emissions intensity.

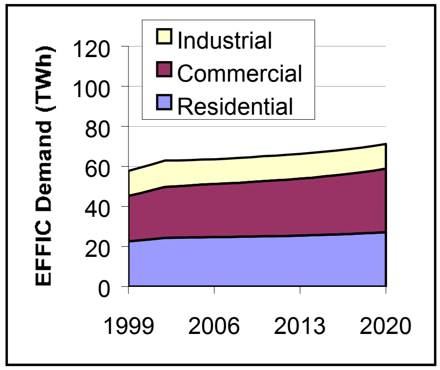
Other key assumptions in the LIEF analysis include: 1) electricity prices are kept constant over time in both Scenarios, based on 1999 average industrial electricity prices in each state; 2) implementation of efficiency measures begins in 2003 in the High Efficiency Scenario; and 3) the estimated installed cost for energy efficiency measures is increased by 10 percent to reflect the cost for policy and program implementation.

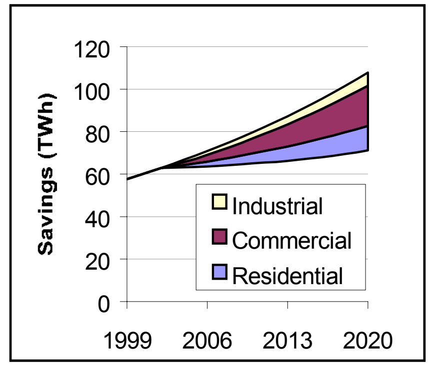
In addition, the electricity use estimates produced by the LIEF model in 2000 were calibrated to actual industrial electricity use in each state as of 2000. These calibration factors were then applied to electricity use projections during 2001-2020 in the Base Scenario.

ARIZONA

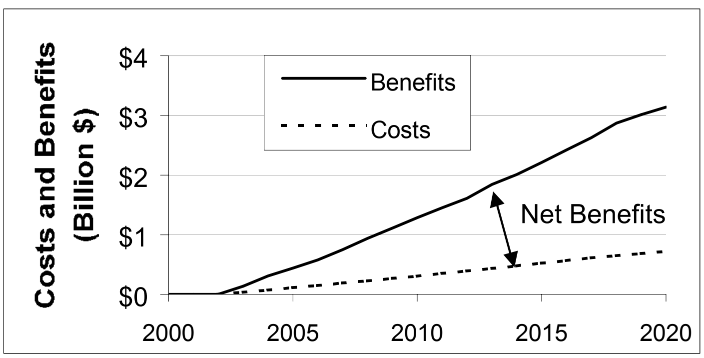
Electricity Demand by Sector



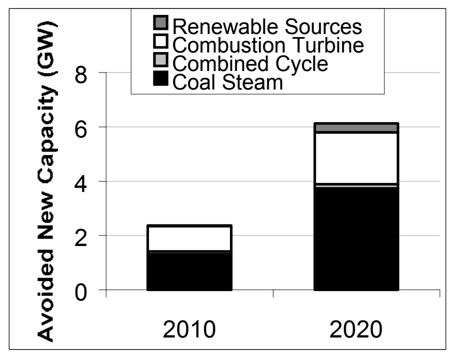




Electricity Supply Results
Annual Costs and Benefits



Avoided New Capacity



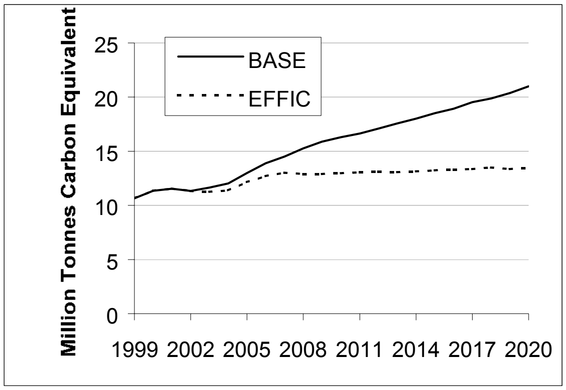
Economic Results

		2010	2020	Net Change in CPV during 2000-2020
Incremental Energy Efficiency Investments (billion 2000$)				
Commercial		0.09	0.26	1.04
Residential		0.14	0.35	1.53
Industrial		0.07	0.12	0.69
	Total:	0.30	0.72	3.26
Benefits (billion 2000$)				
Avoided Electric Supply Costs		1.22	2.98	12.90
Natural Gas Price Effects		0.06	0.16	0.85
	Total:	1.28	3.14	13.76
Net Benefits (billion 2000$)		**0.98**	**2.42**	**10.50**
Net Benefit per Household (2000$)		**531**	**1,312**	**5,690**
Benefit-Cost Ratio		**4.21**	**4.37**	**4.22**

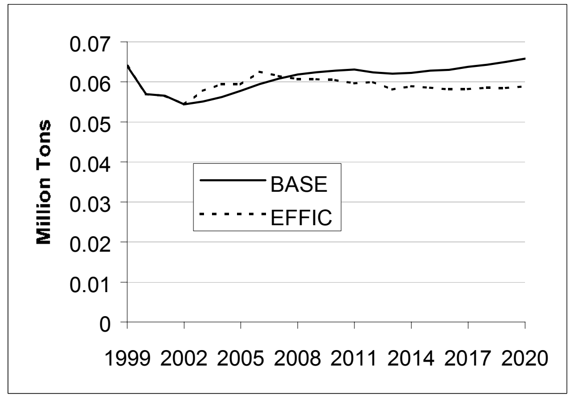
(Arizona, cont.)

Environmental Results

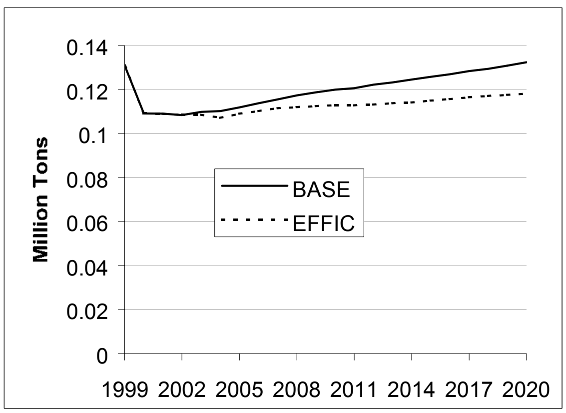
Carbon Emissions



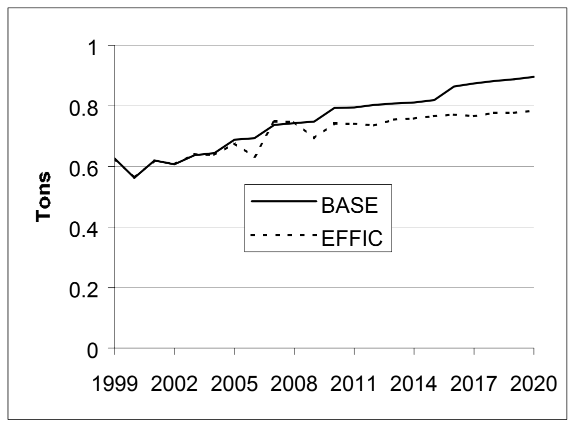
Sulfur Dioxide Emissions



Nitrogen Oxides Emissions

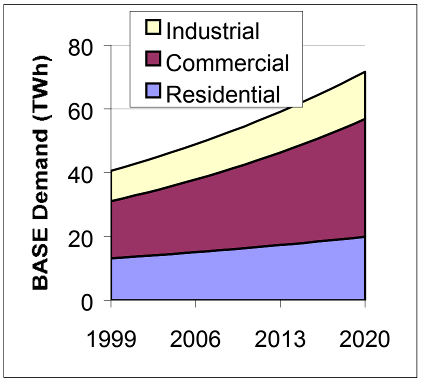


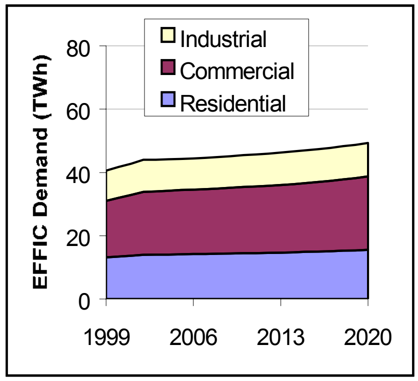
Mercury Emissions

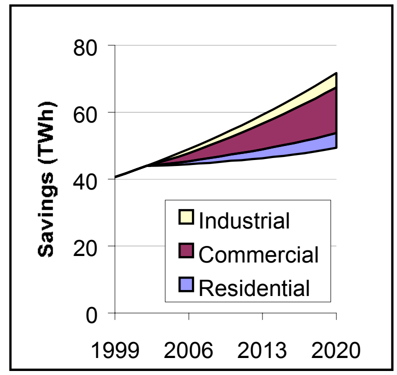


COLORADO

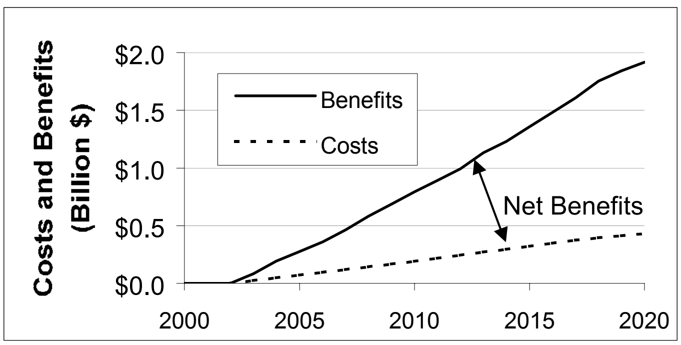
Electricity Demand by Sector



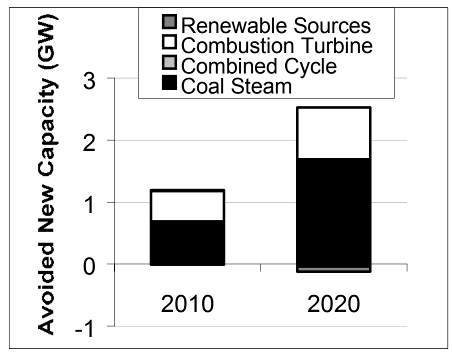




Electricity Supply Results
Annual Costs and Benefits



Avoided New Capacity



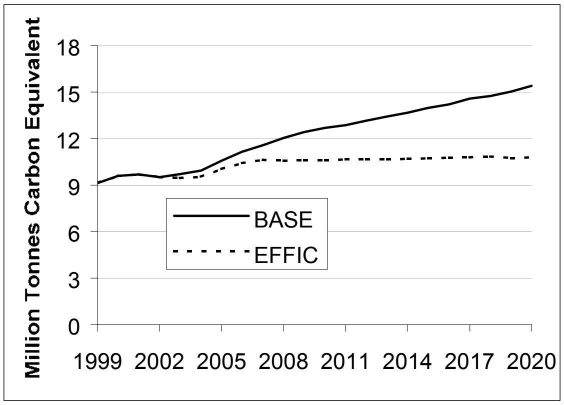
Economic Results

		2010	2020	Net Change in CPV during 2000-2020
Incremental Energy Efficiency Investments (billion 2000$)				
Commercial		0.08	0.22	0.92
Residential		0.05	0.12	0.56
Industrial		0.05	0.09	0.54
	Total:	0.19	0.43	2.01
Benefits (billion 2000$)				
Avoided Electric Supply Costs		0.75	1.82	7.93
Natural Gas Price Effects		0.04	0.09	0.53
	Total:	0.79	1.92	8.46
Net Benefits (billion 2000$)		**0.60**	**1.49**	**6.44**
Net Benefit per Household (2000$)		**380**	**937**	**4,066**
Benefit-Cost Ratio		**4.16**	**4.44**	**4.20**

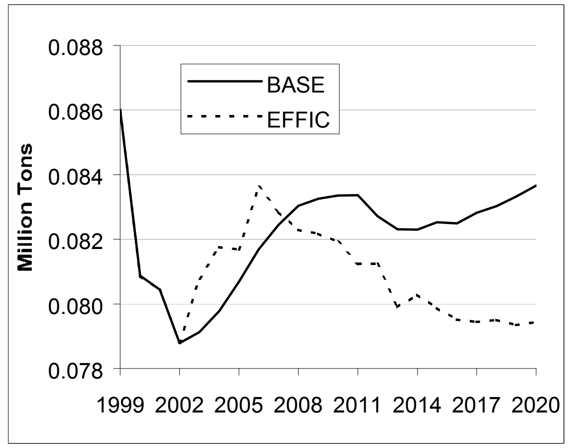
(Colorado, cont.)

Environmental Results

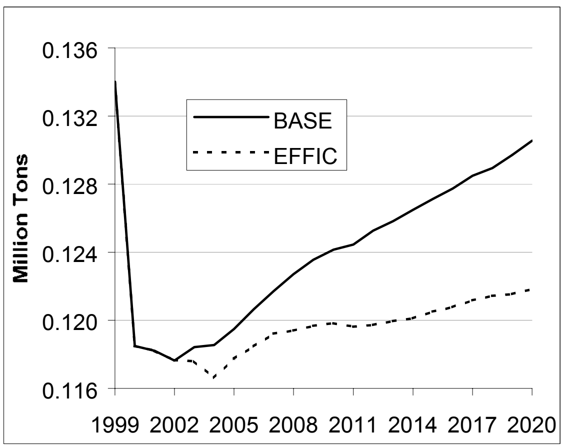
Carbon Emissions



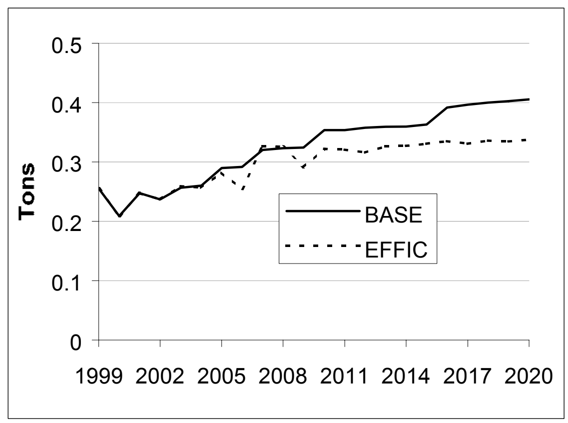
Sulfur Dioxide Emissions



Nitrogen Oxides Emissions

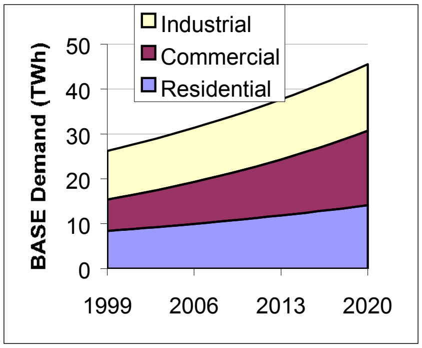


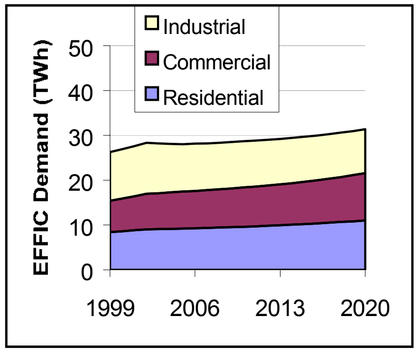
Mercury Emissions

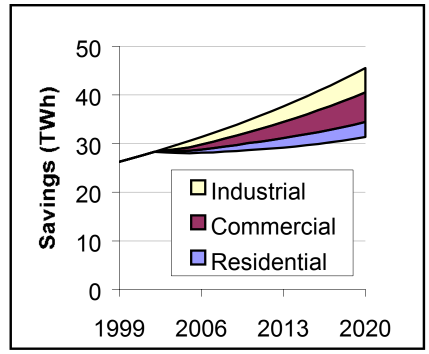


NEVADA

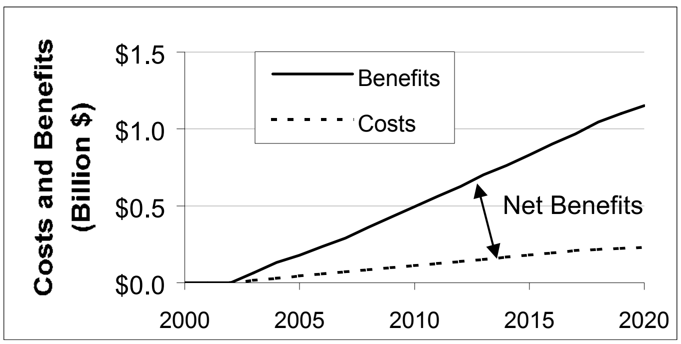
Electricity Demand by Sector



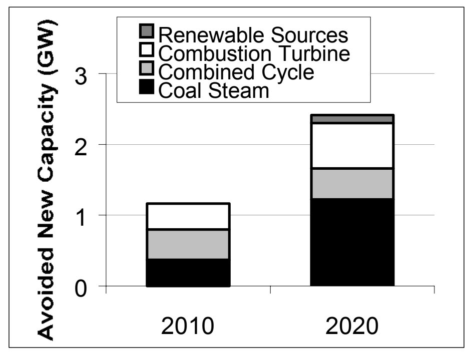




Electricity Supply Results
Annual Costs and Benefits



Avoided New Capacity



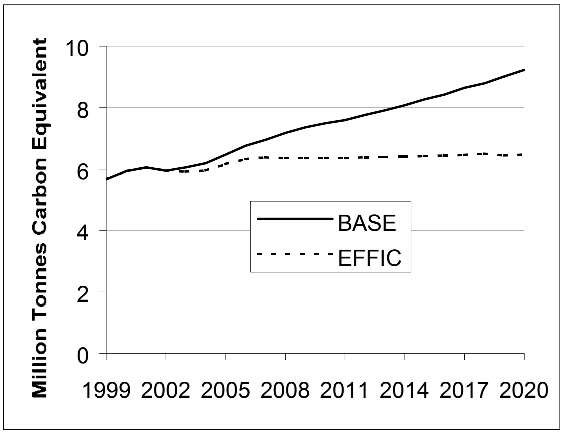
Economic Results

		2010	2020	Net Change in CPV during 2000-2020
Incremental Energy Efficiency Investments (billion 2000$)				
Commercial		0.03	0.08	0.33
Residential		0.04	0.09	0.40
Industrial		0.04	0.06	0.41
	Total:	0.11	0.23	1.14
Benefits (billion 2000$)				
Avoided Electric Supply Costs		0.47	1.09	4.87
Natural Gas Price Effects		0.03	0.06	0.35
	Total:	0.50	1.15	5.22
Net Benefits (billion 2000$)		**0.38**	**0.92**	**4.08**
Net Benefit per Household (2000$)		**542**	**1,296**	**5,746**
Benefit-Cost Ratio		**4.48**	**5.00**	**4.58**

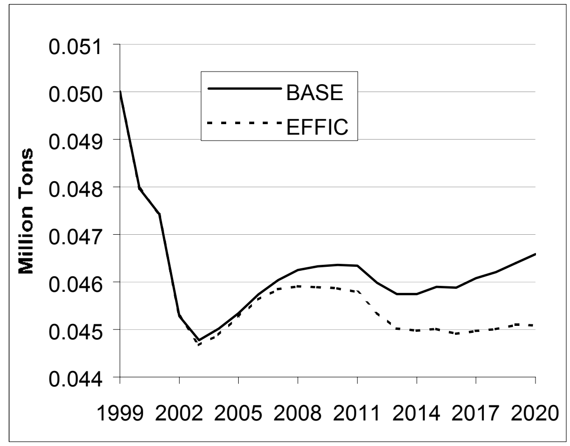
(Nevada, cont.)

Environmental Results

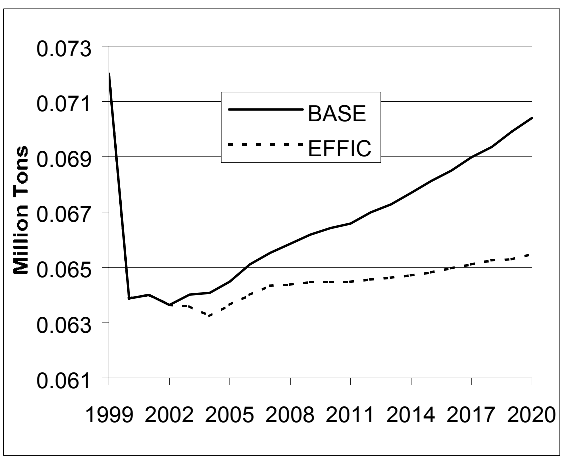
Carbon Emissions



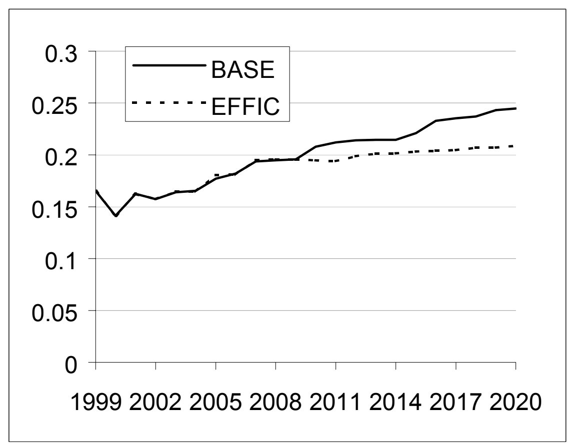
Sulfur Dioxide Emissions



Nitrogen Oxides Emissions

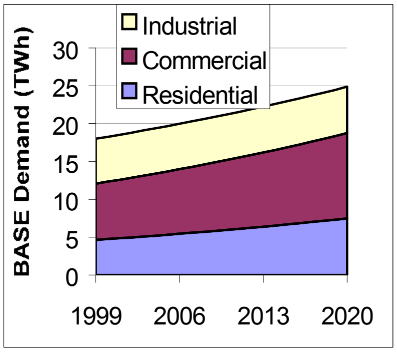


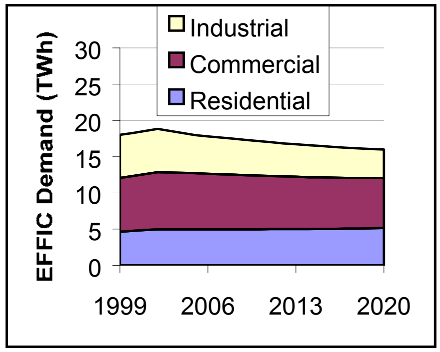
Mercury Emissions (Tons)

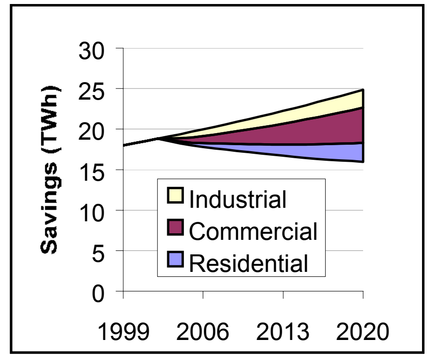


NEW MEXICO

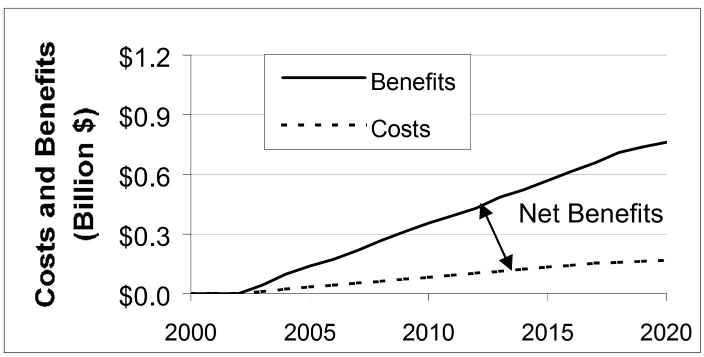
Electricity Demand by Sector



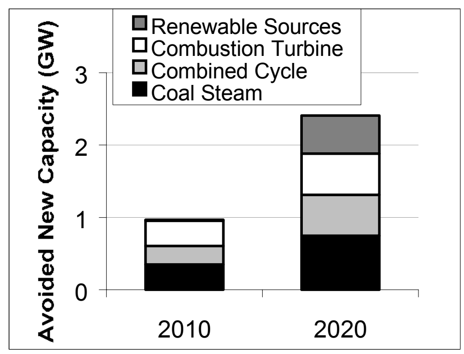




Electricity Supply Results
Annual Costs and Benefits



Avoided New Capacity



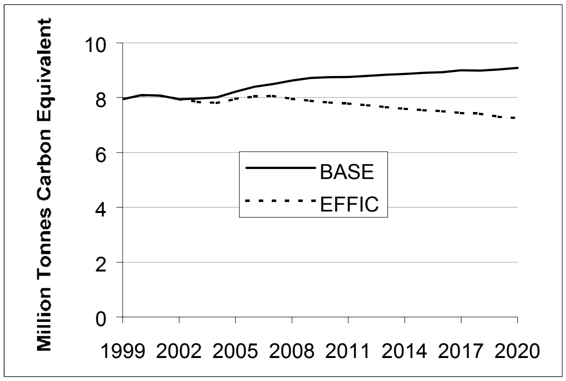
Economic Results

		2010	2020	Net Change in CPV during 2000-2020
Incremental Energy Efficiency Investments (billion 2000$)				
Commercial		0.02	0.06	0.25
Residential		0.03	0.07	0.30
Industrial		0.03	0.04	0.29
	Total:	0.08	0.17	0.85
Benefits (billion 2000$)				
Avoided Electric Supply Costs		0.34	0.72	3.40
Natural Gas Price Effects		0.02	0.04	0.23
	Total:	0.35	0.76	3.63
Net Benefits (billion 2000$)		**0.27**	**0.59**	**2.79**
Net Benefit per Household (2000$)		**384**	**839**	**3,932**
Benefit-Cost Ratio		**4.28**	**4.56**	**4.29**

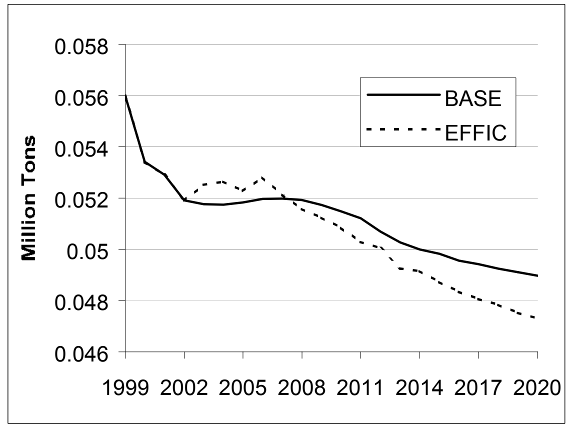
(New Mexico, cont.)

Environmental Results

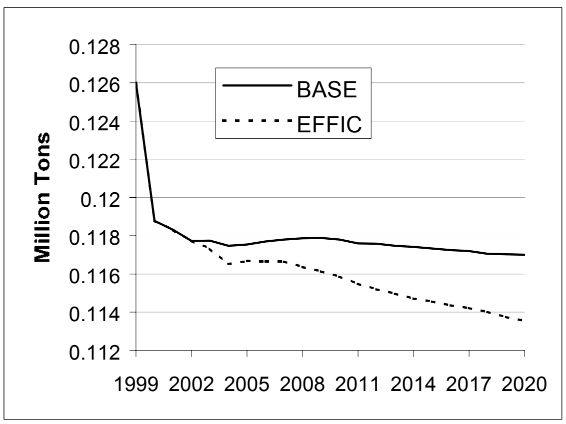
Carbon Emissions



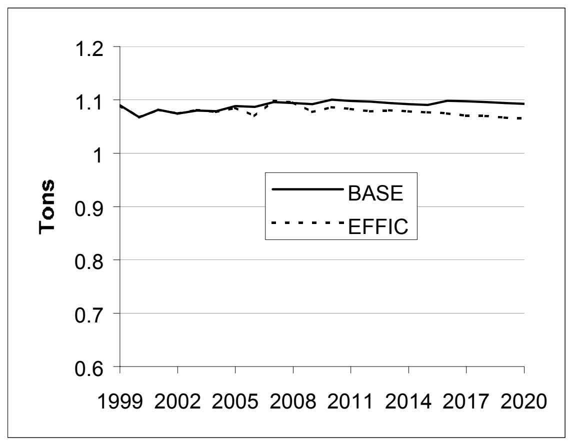
Sulfur Dioxide Emissions



Nitrogen Oxides Emissions

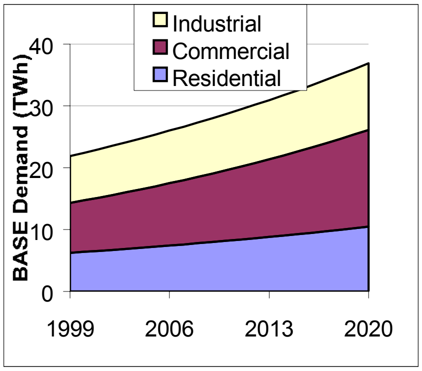


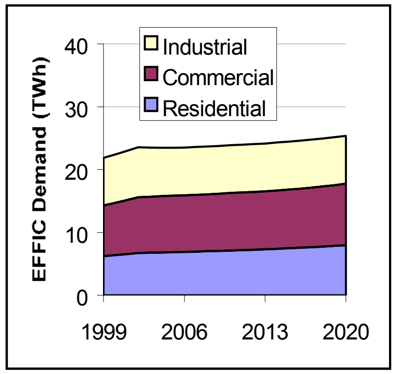
Mercury Emissions

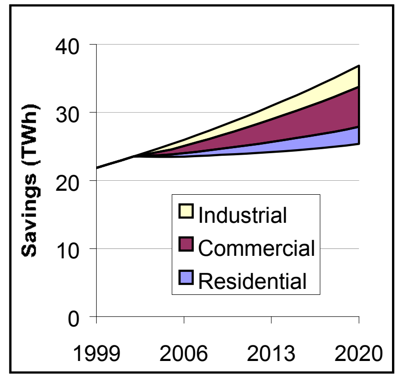


UTAH

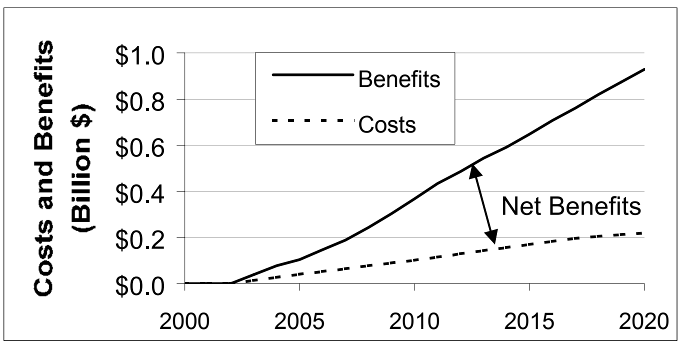
Electricity Demand by Sector



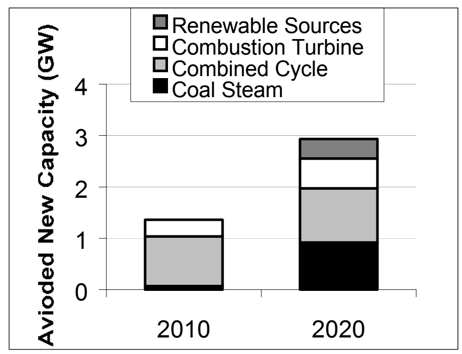




Electricity Supply Results
Annual Costs and Benefits



Avoided New Capacity



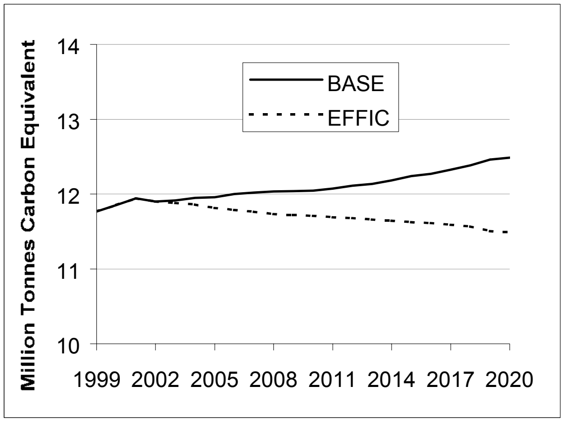
Economic Results

		2010	2020	Net Change in CPV during 2000-2020
Incremental Energy Efficiency Investments (billion 2000$)				
Commercial		0.04	0.09	0.40
Residential		0.03	0.07	0.31
Industrial		0.04	0.06	0.35
	Total:	0.10	0.22	1.06
Benefits (billion 2000$)				
Avoided Electric Supply Costs		0.35	0.88	3.65
Natural Gas Price Effects		0.02	0.05	0.28
	Total:	0.37	0.93	3.93
Net Benefits (billion 2000$)		**0.27**	**0.71**	**2.86**
Net Benefit per Household (2000$)		**316**	**837**	**3,388**
Benefit-Cost Ratio		**3.62**	**4.21**	**3.69**

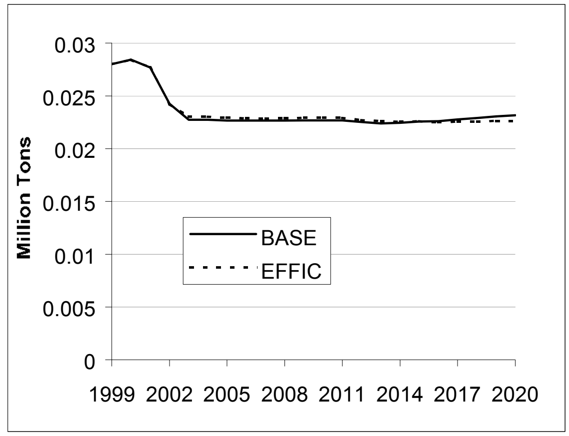
(Utah, cont.)

Environmental Results

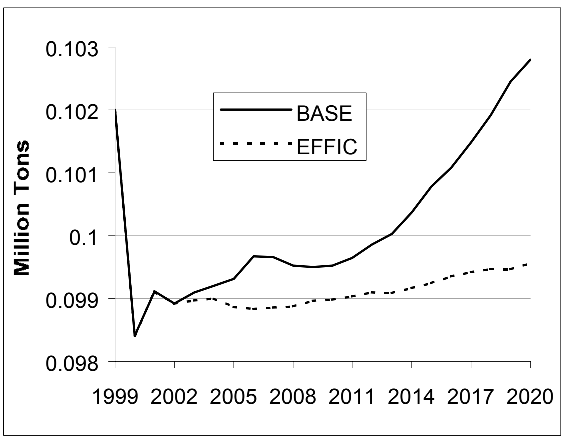
Carbon Emissions



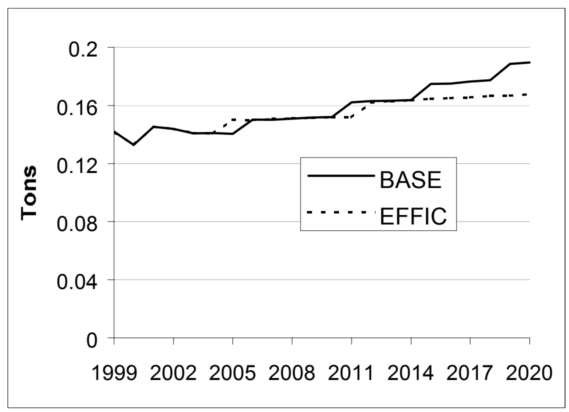
Sulfur Dioxide Emissions



Nitrogen Oxides Emissions

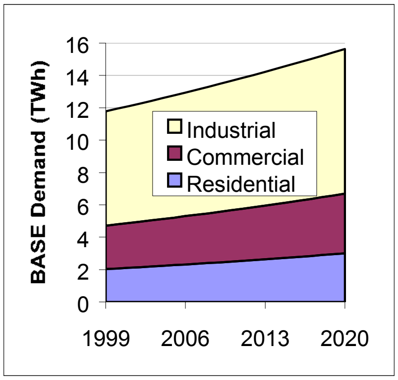


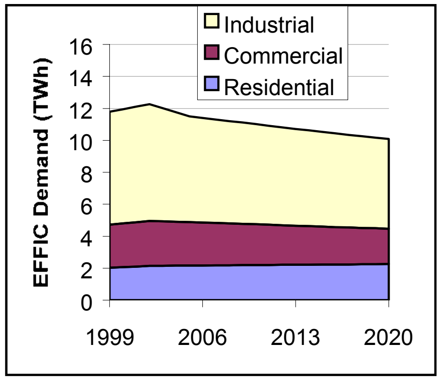
Mercury Emissions

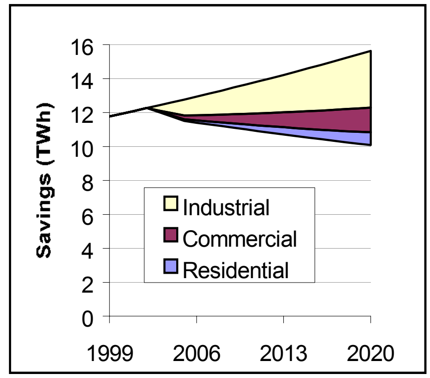


WYOMING

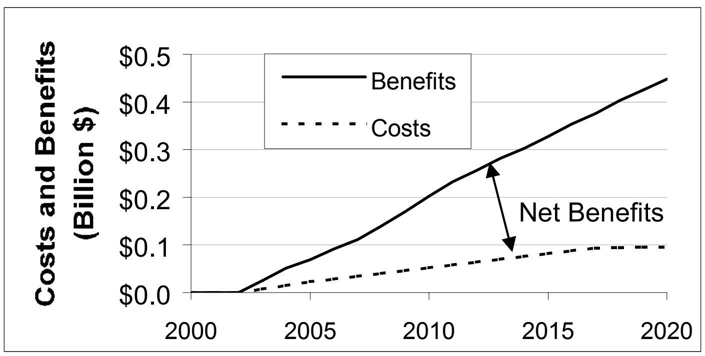
Electricity Demand by Sector



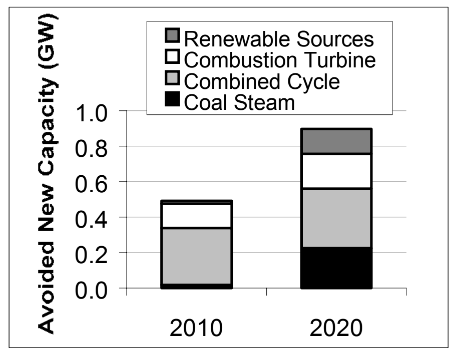




Electricity Supply Results
Annual Costs and Benefits



Avoided New Capacity



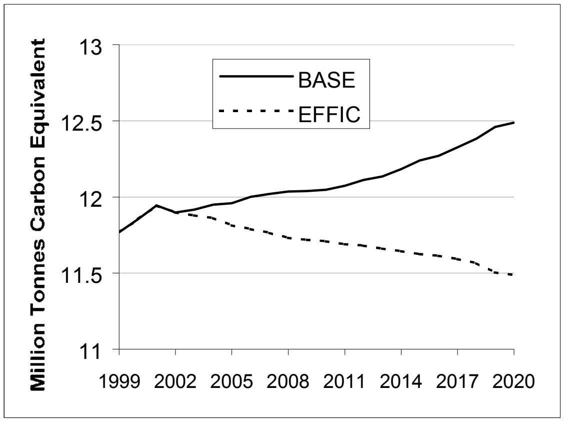
Economic Results

	2010	2020	Net Change in CPV during 2000-2020
Incremental Energy Efficiency Investments (billion 2000$)			
Commercial	0.01	0.02	0.10
Residential	0.01	0.02	0.09
Industrial	0.03	0.05	0.33
Total:	0.05	0.10	0.52
Benefits (billion 2000$)			
Avoided Electric Supply Costs	0.19	0.42	1.91
Natural Gas Price Effects	0.01	0.02	0.15
Total:	0.20	0.45	2.06
Net Benefits (billion 2000$)	**0.15**	**0.35**	**1.54**
Net Benefit per Household (2000$)	**760**	**1,781**	**7,762**
Benefit-Cost Ratio	**3.90**	**4.69**	**3.93**

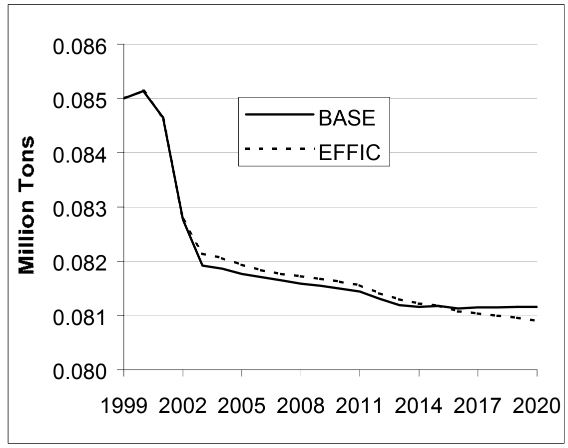
(Wyoming, cont.)

Environmental Results

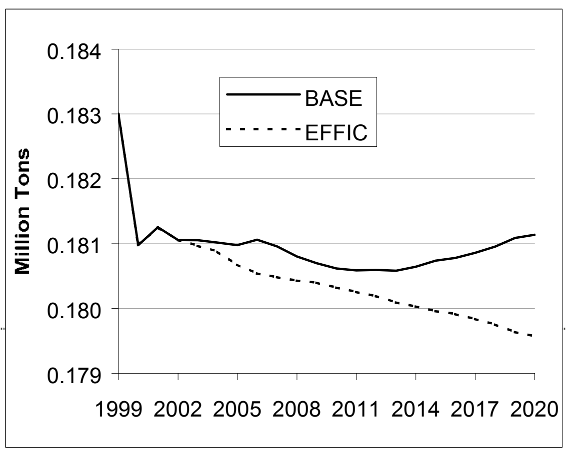
Carbon Emissions



Sulfur Dioxide Emissions



Nitrogen Oxides Emissions



Mercury Emissions