PNNL-14073

Energy Savings and Economic Analysis of Updating New Mexico's Commercial Building Energy Code

D.W. Winiarski
D.B. Belzer
K.A. Cort
E.E. Richman

January 2003

Prepared for the Building Energy Codes Program, U.S. Department of Energy

Prepared by Pacific Northwest National Laboratory, Operated for the U.S. Department of Energy by Battelle

Executive Summary

This paper presents an assessment of the energy savings and economic impact for New Mexico to adopt the 2000 International Energy Conservation Code (2000 IECC). Currently, the state of New Mexico bases its commercial building energy code on the 1986 Model Energy Code, which in turn references American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 90a-1980 for the commercial building portion of the energy code. New Mexico also has a separate and state-developed energy standard for school construction, the 1995 Energy Efficiency Standards for Construction and Remodeling Procedure for Public School Buildings (hereafter referred to as the *NM School Standard).*

New Mexico's Energy, Minerals and Natural Resources Department requested that the U.S. Department of Energy compare the energy usage and economic cost of New Mexico's current commercial building energy code (ASHRAE 90a-1980) with the 2000 IECC for a small office and small retail building. In addition, the department requested a comparison of the energy and economic costs for a typical elementary school building constructed to meet both the NM School Standard and the 2000 IECC.

For both the office and retail buildings examined, it was clear that substantial cost-effective energy savings were available for the adoption the 2000 IECC over the current New Mexico code. An assessment of the change from adoption of the higher equipment efficiency requirements in the 2000 IECC was not made since the 2000 IECC equipment efficiency standards are already captured as minimum federal manufacturing standards, and the heating, ventilation, and air-condition (HVAC) and service water heating (SWH) equipment typical for these buildings is no longer produced at the 90a-1980 efficiency levels.

A comparison of the energy and economic impact of adopting the 2000 IECC in place of the NM School Standard was not as clear. The NM School Standard is more of a guide to construction choices than a traditional prescriptive energy code. This is particularly evident in its requirement that evaporative cooling be considered in the building design if it is "cost effective." For this reason, in the evaluation of the energy code for school buildings, two different HVAC cooling systems were examined: a building with standard, direct expansion (DX)-packaged equipment and a building with a 2-stage (i.e., indirect and direct) evaporative cooler and no DX cooling. These were compared to a similar building assuming use of DX-packaged equipment and assuming construction under the 2000 IECC requirements. In this comparison, implementation of the 2000 IECC standard resulted in a more efficient and cost-effective building than either the DX-cooled building or the building with a combined indirect/direct evaporative system constructed under the NM School Standard. In addition, simulations were conducted that looked at including only the envelope or only the lighting sections of 2000 IECC while keeping all the remaining requirements of the current New Mexico state building code. A detailed description of the building energy use and economic analysis are provided in the report.

Contents

1. INTRODUCTION **5**

1.1 Objective 5
1.2 Scope 5

2. BACKGROUND **6**

3. MODELING ASSUMPTIONS **7**

3.1 Base Buildings Simulated 7
3.2 Building Envelope 7
3.3 Building Envelope Requirements 8
3.4 Lighting Requirements 10
3.5 Equipment 12
3.6 Simulation Tool and Modeling 13

4. SIMULATION RESULTS **15**

5. ECONOMIC ANALYSIS **17**

5.1 Envelope 18
5.2 Lighting 19
5.3 Mechanical Equipment 22

6. RESULTS **24**

6.1. Office and Retail 24
6.2. Education 24

7. CONCLUSION **30**

8. REFERENCES **31**

APPENDIX -- ANALYSIS OF PROPOSED LIGHTING AMENDMENT **33**

Acronyms

AF	Area factor
ASHRAE	American Society of Heating, Refrigeration and Air-Conditioning Engineers
BLAST	Building Loads Analysis and System Thermodynamics
BLCC	Building Life-Cycle Cost Program
CBECS	Commercial Building Energy Consumption Survey
CFL	Compact fluorescent light
DOE	U.S. Department of Energy
DX	Direct expansion
ECMD	Energy Conservation and Management Division
EPACT	Energy Policy Act 1992
EPCA	Energy Policy and Conservation Act
HID	High-intensity discharge
HVAC	Heating, ventilation, and air-condition
IECC	International Energy Conservation Code
IES	Illuminating Engineering Society
LCC	Life-cycle cost
LPD	Lighting power density
MEC	Model Energy Code
NAECA	National Appliance Efficiency and Conservation Act
NMEMNRD	New Mexico Energy, Minerals and Natural Resources Department
OMB	Office of Management and Budget
RCR	Room cavity ratio
RF	Room factor
SUF	Space utilization factor
SWH	Service water heating
UPD	Unit power density
VAV	Variable air volume
WWR	Window-wall-ratio

1. Introduction

1.1 Objective

The state of New Mexico has ASHRAE Standard 90A-1980 as well the NM School Standard as the statewide building energy efficiency codes. This report was prepared in response to a request for technical assistance from the State of New Mexico's Energy, Minerals and Natural Resources Department, Energy and Economic Division. The request specified the need for an objective analysis that would assess the impacts of adopting 2000 IECC as the state commercial building energy code. The request specified that the analysis focus on three building types including a retail, office, and school building.

1.2 Scope

This report provides an analysis with the scope limited to office, retail, and schools, which represent approximately 60% of the commercial construction in New Mexico (Census 2000). Within these building types, the impacts of the building envelope and lighting requirements are assessed. Changes in mechanical equipment efficiency requirements were not addressed since the 2000 IECC equipment efficiency standards are already captured as minimum federal manufacturing standards, and the heating, ventilation, and air-condition (HVAC) and service water heating (SWH) equipment typical for these buildings is no longer produced at the 90a-1980 efficiency levels[1].

The study period is forty years. This time horizon was chosen to capture the economic impact of changes in building energy consumption from required energy-related designs and materials that occur over the life of the building. Specific simulation and Life Cycle Cost (LCC) assumptions are discussed in the respective sections of this report.

This report includes a summary of background information regarding various building code requirements, and a description of the assumptions required to complete the quantitative analysis. The report includes sections that describe the building simulation process as well as the economic model and the assumptions used to calculate LCC savings for each building type. Detailed quantitative results are included Section 6. In addition, an energy and LCC analysis of adopting 2000 IECC with a proposed amendment to allow up to 2.0 watts per square foot (W/ft^2) of lighting in any building is included in the appendix.

---

[1] In addition, a new federal manufacturing standard as referenced under the Energy Policy and Conservation Act (EPCA) will soon be adopted. Under this legislation, the energy efficiency of most of the heating cooling, air conditioning (HVAC) and service water heating (SWH) equipment regulated under IECC will be updated to levels at least as stringent as those in 2001 IECC. The potential quantitative impact of the equipment standards has been evaluated in detail in the report, *Screening Analysis for EPACT-Covered Commercial HVAC and Water heating Equipment.*

2. Background

In November 2001, the New Mexico Energy, Minerals and Natural Resources Department (NMEMNRD), Energy Conservation and Management Division (ECMD), serving as the State Energy Office, requested the U. S. Department of Energy (DOE) to provide an energy and economic analysis of the impact of adopting the 2000 version of the International Energy Conservation Code (herein referred to as the *2000 IECC*). The request specified that the commercial analysis target three building types: 1) a 10,000 sq ft retail building, 2) a 10,000 sq ft office building, and 3) a 100,000 sq ft elementary school building.[2]

The comparison would use as its basis the current commercial energy codes used by New Mexico. For privately funded construction, such as the office and retail buildings, New Mexico currently uses the 1986 Model Energy Code (MEC), which references ANSI/ASHRAE/IES 90a-1980 (herein referred to as *Standard 90a-1980* or *90a-1980*) for commercial construction. For school buildings, NMEMNRD analyzes all public school designs to see that they meet the 1995 Energy Efficiency Standards for Construction and Remodeling Procedure for Public School Buildings (hereafter referred to as the NM School Standard). This procedural guide serves as the minimum energy code for school building construction by providing guidance on design choices as well as a process for reviewing school construction.

[2] This building was later revised to a 50,000 sq ft building after discussions with the state energy office representative, Harold Trujillo.

3. Modeling Assumptions

The 2000 IECC has two distinct paths to compliance: Chapter 7, which requires the user to meet the requirements of ANSI/ASHRAE/IES 90.1-1989 for compliance, and Chapter 8, which provides an alternative and generally simplified path to compliance. Discussions with representatives from NMEMNRD indicated that NMEMNRD's primary interest for a state code was in the Chapter 8 path. For this exercise, we modeled the 2000 IECC's Chapter 8 requirements.

3.1 Base Buildings Simulated

The aspect ratio and window-wall-ratio (WWR) for the simulation were based on a review of the 1992 Commercial Building Energy Consumption Survey (CBECS) microdata (EIA 1992) and (EIA 1995). This data provides the results of detailed surveys of building characteristics for the United States. For office and retail buildings, the CBECS data was queried for buildings less than 25,000 ft^2 in floor area in the western census region to develop representative WWR and aspect ratios. For the elementary school construction, the average WWR and aspect ratio was obtained for buildings less than 50,000 ft^2 floor area. Buildings with non-square or non-rectangular shapes were not utilized in the aspect ratio calculation. These characteristics were then used for the modeled buildings. Table 1 lists the characteristics chosen for the prototype buildings. The buildings were modeled as lightweight frame wall construction.

Table 1. Characteristics for Simulated Buildings

Building Type	Floor Area (ft^2)	Number of Floors	Aspect Ratio	WWR
Office	10,000	2	2	19%
Retail	10,000	1	2.6	12%
Elementary School	50,000	1	2.6	17%

3.2 Building Envelope

Envelope characteristics were obtained from three different sources. The current New Mexico state energy code references the 1986 MEC, which in turn references ASHRAE Standard 90a-1980 for most commercial structures. The requirements found in ASHRAE Standard 90a-1980 were used to define the envelope and lighting energy requirements for office and retail buildings under the current standard. For schools, New Mexico has a separate standard for school construction, the NM School Standard, which was used to develop the baseline energy characteristics for the school building. The NM School Standard has minimum requirements for the building wall, roof, and perimeter (i.e., slab edge) insulation. It also requires double-pane windows for schools in Albuquerque. In addition, the NM School Standard has maximum limits for WWR in specific orientations. Finally, the standard requires vestibules or "non-thermostated" corridors at all public entrances. However, the standard allows any of these requirements to be omitted in construction if it can be shown that they are not able to pay for themselves in less than 10 years.

Based on discussions with NMEMNRD[3], all buildings were presumed to be built with metal frames, built-up roofs, and a slab-on-grade construction. In addition, roof plenums were assumed for the analysis.

[3] Conversation between Harold Trujillo and David Winiarski, 1/22/02.

3.3 Building Envelope Requirements

Section 4.0 of Standard 90a-1980 has separate overall wall performance criteria for heating and cooling. In addition, there are total thermal performance criteria for roofs (including skylights). A spreadsheet was developed for the office and retail buildings to determine specific combinations of wall, roof, and fenestration construction elements that met the wall and roof performance requirements of Standard 90a-1980 for the Albuquerque climate. Because of the need to meet both the heating and cooling performance requirements, as well as the discrete performance available in real building materials, it is not possible to exactly match the 90a-1980 performance requirements. Rather, we selected from a large set of window and wall assemblies that are typical construction choices, those that would provide minimum compliance with the Standard 90a-1980 heating and cooling envelope requirements.

The 2000 IECC offers essentially two paths to envelope compliance for commercial buildings: Chapter 7, which references ANSI/ASHRAE/IESNA 90.1-1989, and Chapter 8, which provides an alternative set of envelope criteria. The 2000 IECC's Chapter 8 relies on geographically based climate maps to determine criteria, with nine distinct climate zones for New Mexico. The Albuquerque metropolitan area, alone, is spread across three counties, each with a different climate zone. Because the bulk of the population is in the county of Bernalillo, the corresponding 2000 IECC climate zone (i.e., 9B) for this county was used for the analysis.

Tables 2 - 4 show the envelope requirements for the current New Mexico codes and for the 2000 IECC, Zone 9B, for each of the buildings examined. In addition, the tables show the corresponding requirements from Standard 90.1-1999, Table B-13, which shows the appropriate ANSI/ASHRAE/IESNA 90.1-1999 prescriptive envelope requirements for the Albuquerque climate[4].

Table 2. Envelope Requirements for Office Building, 19% WWR

Building Type	**90a-1980**	**IECC Chapter 8**	**90.1-1999**
Roof U-Value (Btu/ft^2-F)	0.085	0.051	0.063
Roof Description	R-11 Continuous	R-19 Continuous	R-15 Continuous
Opaque Wall U-Value (Btu/ft^2-F)	0.132	0.132	0.124
Opaque Wall Description	Steel frame, 16" OC, R-11	Steel frame, 16" OC, R-11	Steel frame, 16" OC, R-13
Window U-Value (Btu/ft^2-F)	0.98	0.5	0.57
Window SC	0.85	0.5	0.45
Window Description	Vinyl frame, single-pane clear glass	Not described	Aluminum frame, thermally broken, double-pane, Low E
Slab on Grade Edge Insulation	R-3.8 for 48"	N.R.	N.R.

[4] ANSI/ASHRAE/IESNA 90.1-1999, is currently referenced in Chapter 7 of the most current, 2001 version, IECC, so the information may be of interest to the state of New Mexico if they later choose to adopt the 2001 or subsequent versions of the IECC.

Table 3. Envelope Requirements for Retail Building, 12% WWR

Building Type	**90a-1980**	**IECC Chapter 8**	**90.1-1999**
Roof U-Value (Btu/ft^2-F)	0.085	0.051	0.063
Roof Description	R-11 Continuous	R-19 Continuous	R-15 Continuous
Opaque Wall U-Value (Btu/ft^2-F)	0.132	0.132	0.124
Opaque Wall Description	Steel frame, 16" OC, R-11	Steel frame, 16" OC, R-11	Steel frame, 16" OC, R-13
Window U-Value (Btu/ft^2-F)	1.22	0.5	0.57
Window SC	0.85	0.5	0.45
Window Description	Aluminum frame, single- pane clear glass	Likely an aluminum frame thermally broken, double-pane, Pyrolytic Low E	Aluminum frame, thermally broken, double-pane, Low E

Table 4. Envelope Requirements for Elementary School Building, 17% WWR

Building Type	**Current New Mexico Codes**	**IECC Chapter 8**	**90.1-1999**
Roof U-Value (Btu/ft^2-F)	0.032	0.051	0.063
Roof Description	R-30 Continuous	R-19 Continuous	R-15 Continuous
Opaque Wall U-Value (Btu/ft^2-F)	0.070	0.132	0.124
Opaque Wall Description	Steel frame, 16" OC, R-6+R-13	Steel frame, 16" OC, R-11	Steel frame, 16" OC, R-13
Window U-Value (Btu/ft^2-F)	0.79	0.5	0.57
Window SC	0.68	0.5	0.45
Window Description	Aluminum frame w/o thermal break, double-pane	Not described. Likely an aluminum frame thermally broken, double-pane, Pyrolytic Low E	Aluminum frame, thermally broken, double-pane, Low E
Slab on Grade Edge Insulation	R-5	N.R.	N.R.

In comparing the envelope requirements for the office and retail buildings, it is clear that the 2000 IECC is more stringent than 90a-1980 for the roof and windows, with similar requirements for the wall insulation level. ASHRAE 90a-1980 is more stringent for slab insulation; however, it appears that the 2000 IECC is the more stringent standard for the overall envelope. For the office and retail buildings modeled, the ASHRAE 90.1-1999 envelope requirements lie somewhere between the ASHRAE 90a-1980 and the 2000 IECC.

In comparison to the requirements for school buildings, the NM School Standard has minimum requirements for roof, walls, and slabs that are more stringent than those assumed for the 2000 IECC, but has less stringent requirements for window U-Values and solar heat gain coefficient (SHGC) than the 2000 IECC baseline building, at least for the assumed 17% WWR. However, because of the variation in the 2000 IECC envelope requirements for buildings with a different WWR, a school building with less than 10% WWR would typically have less stringent U-Value and SHGC requirements under the 2000 IECC. Because the assumed building design had 17% WWR on all orientations, the current NM School Standard's limits on glazing by orientation did not come into play for this analysis. These limits on glazing would effectively prevent construction of some potentially inefficient building designs that would otherwise be permitted under the 2000 IECC. On the other hand, the 2000 IECC envelope requirements would become significantly more stringent for high WWR buildings, which would also effectively limit energy inefficient designs with high WWR.

3.4 Lighting Requirements

Uniform Power Density Requirements
The ASHRAE 90a-1980 lighting procedure follows the full Illuminating Engineering Society (IES) Lumen method, but refers to the IES Unit Power Density procedure as the "recommended" method for application. The IES Unit Power Density procedure,[5] referred to as "LEM-1,"was used to develop 90a-1980 lighting requirements in the form of UPDs. LEM-1 includes a base Unit Power Density (UPD), an Area Factor (AF), or Room Factor (RF) adjustment and an additional Space Utilization Factor (SUF).

To ensure consistent application of the lighting design among the different standards, each space type UPD as prescribed by the 90a-1980 standard (LEM-1) was applied to the models that were used to develop current ASHRAE/IESNA lighting requirements [6] to come up with comparable whole building lighting power density (LPD) requirements for the building types addressed in this study (See Table 5). The ASHRAE/IESNA Standard 90.1 models are based on the lighting requirements and configuration of various space types (e.g., office, hallway, sales area, etc.) found within a given building type. In order to compare the two standards, the LEM-1 UPD values for each space type are matched with the space types used to develop the ASHRAE/IESNA lighting models wherever possible. Where space type matches were not possible between LEM-1 and the ASHRASE/IESNA models, lighting values from ASHRAE/IESNA 90.1-1999 were used since these represent a best guess at current "good" lighting practices.

The current ASHRAE lighting model forces the AF/RF factors for space types into three main Room Cavity Ratios (RCR). The RCR is a factor that characterizes room configuration as a ratio between the walls and ceiling and is based upon room dimension. Again, in order to compare the two standards, the Area and Room Factors from the 90a-1980 were placed into the three RCR categories prescribed by ASHRAE/IES, which is a necessary assumption to make when individual room dimensions are unknown

---

[5] Found in the IES LEM-1-19182 publication

[6] The methodology for the space type and LPD models is incorporated in a large spreadsheet that was developed by the lighting subcommittee of the SSPC 90.1 ASHRAE Standards Committee in support of the ASHRAE/IESNA 90.1-1999 energy standard. A working version of the spreadsheet tool with additional detailed descriptions of the various parts is available for review on the IESNA Web site, available URL: http://206.55.31.90/cgi-bin/lpd/lpdhome.pl. An offline version of the spreadsheet was modified in three ways: 1) Technologies for magnetic ballasts and T-12 lamps were added, 2) A series of worksheets to estimate lighting system costs was added, and 3) A revised formula (consistent with the most recent ASHRAE/IES work) was used in the calculation of LPDs.

and "typical" space assumptions have to be made.

The SUF is a reduction factor for those cases where it can be determined that the total area of visual tasks in the room is less than 50% of the total room area. A similar factor does not exist in the IECC or in the ASHRAE/IESNA lighting models. However, the 1999 lighting models do apply task and general foot-candle levels with associated areas. A review of all the space models determined that for all but a few (half dozen or so) of the cases where this 50% rule applied, there was no SUF applied by LEM-1. Because LEM-1 is SUF applied only to specific situations and given that there is no way to identify specific task data, no SUF values were incorporated into this study.

NM School Standard Lighting Requirements

The NM School Standard for school construction requires the use of LEM-2[7] for determining UPDs. Most of the differences between LEM-1 and LEM-2 are minor and do not impact the resulting allowable LPD requirements. For example, LEM-2 includes a reference to use high-intensity discharge (HID) lighting in warehouse, shops and outdoor fixtures, but this would have no impact on the allowable LPD.

The NM School Standard also includes a requirement for photocells on all outdoor lighting and user controls for all rooms and indoor areas as well as general requirement to maximize day lighting. The 2000 IECC does not regulate the effectiveness of lighting technology; however, it does require photocells on outdoor lighting and bi-level switching (a "part-level" capability) in most building areas unless there is only one luminaire for the area or if the lighting is controlled by an occupant sensor. Because of the similarity to the NM School Standard, it is believed that these bi-level switching requirements in the 2000 IECC would provide for similar levels of energy savings in daylit areas and possibly greater levels of savings through the prescriptive requirements for bi-level switching in non-daylit areas. It is not possible to evaluate the NM School Standard's clause regarding "maximum use of day lighting," as it does not provide any guidance as to how this should be accomplished.

Table 5 shows the results of the lighting analysis for the four building types in terms of whole building LPDs. The 2000 IECC has lower LPD allowances than 90a-1980. ASHRAE 90.1-1999 and the 2000 IECC are equivalent across these three building types.

Table 5. Allowed Whole Building Uniform Lighting Power Densities

Building type	**Lighting Power Density (w/ft^2)**		
	90a-1980 or Current NM Schools Standard	**90.1-1999**	**2000 IECC**
Office	1.91	1.3	1.3
Retail	3.31	1.9	1.9
School	1.95	1.5	1.5

[7] Found in the IES LEM-2-1984 publication

3.5 Equipment

Space Cooling, Heating and Service Hot Water Equipment
For small buildings in the United States, direct expansion (DX) cooling systems predominate, with either an electric furnace, heat pump, or gas furnace backup. While the majority of these systems are forced air, both water loop heat pumps and ground source/ground water heat pumps are used. For this analysis, we assume that the majority of the equipment used for these small buildings is single-zone in nature, and using an average energy efficiency ratio (EER) rating for all classes of equipment can best reflect the relative energy use between standards. For this analysis, we used shipment weighted EER estimates for all unitary and applied heat pumps and air-conditioners, as well as room air-conditioners. We specifically did not include packaged terminal air-conditioners and heat pumps since they are overwhelmingly used by a single building category (i.e., Lodging) that was not included in this analysis.

Virtually all of the shipped capacity for this equipment is covered by federal minimum manufacturing standards, as referenced in the Energy Policy and Conservation Act (EPCA), as amended, either by equipment covered under the National Appliance Efficiency and Conservation Act (NAECA) (NAECA 1987) or, for commercial equipment, the Energy Policy Act 1992 (EPACT) (EPACT 1992). This means that for states citing ASHRAE 90a-1980 building standards, the equipment efficiencies shown in ASHRAE 90a-1980 can no longer legally be purchased or sold in the United States. The EPACT, whose source was essentially ASHRAE 90.1-1989 and whose requirements were incorporated into the 2000 IECC, defines the current manufacturing standards for most commercial air-conditioning equipment. Thus, there is no real difference between what is required by the 2000 IECC, and what the minimum is that can actually be purchased in the United States today. The principle, single-zone HVAC products not currently covered under manufacturing standards are ground source heat pumps, which were not referenced at all in ASHRAE 90a-1980 and are still relatively uncommon in commercial buildings in the United States. Unit heaters as well as water chillers (which are generally too large to be used in the buildings being examined) are not commonly found in the building types being analyzed. Since the applicability of these products to this analysis is small, they have been ignored, and no effective change in equipment efficiency is assumed between the two code levels.

School buildings under New Mexico's NM School Standard are required to:

1. Use gas-fired heating equipment with a minimum efficiency of 80% (assumed combustion)
2. Use refrigerant cooling only when one-, two-, or three-stage evaporative cooling does not have a simple payback of less than 10 years
3. Use economizers
4. Use variable air volume designs with variable speed drives used to control air volume on fans and blowers with motors greater than 5 hp
5. Use air-to-air heat recovery or heat pipe heat exchangers for buildings simultaneously heated and cooled
6. Have night setback capability and time clock controls for HVAC systems
7. Load shedding capability for high-demand applications
8. Ensure specific equipment load calculations with a maximum 10% over sizing for safety factor.

Requirements similar to several of the above exist in the 2000 IECC. The 2000 IECC has requirements for night setback and time clock control and equipment sizing. It also requires economizers for the Albuquerque climate; however, the requirements only apply to systems over 7.5 tons cooling capacity.

Thus, economizers would typically be required when package systems serve multiple classrooms, but would not be required when individual cooling equipment is used for each classroom. The 2000 IECC does not regulate fuel source for heating, but when gas equipment is used, the 80% combustion efficiency would be typical of current products under federal law.

The 2000 IECC does not have any requirements similar to New Mexico's current limitation on refrigerant cooling or for variable air volume system designs with variable speed drives on systems with fans motors greater than 5 hp. The load shedding capability in the current New Mexico code does not appear to be an energy savings issue, but rather a demand limiting requirement.

To simulate the NM School Standard's limitations on refrigerant cooling, simulations were performed using an indirect evaporative cooler model. Although Appendix A of the NM School Standard suggests that single-stage evaporative cooling is appropriate for Albuquerque's climate, a 2-stage evaporative cooling model was determined to be the most typical design to make use of evaporative cooling while still maintaining comfort conditions roughly equivalent to a refrigerated cooling system.

The requirement for variable air volume was not directly modeled, since VAV was only required on fan systems with fan motors greater than 5 hp and only when it is shown to have a 10-year payback or less. It is not clear on what type of systems this requirement would apply. VAV systems are not commonly available on standard rooftop equipment under 20 tons; only schools that use large, central HVAC system designs typically use VAV equipment.

Service hot water requirements for school buildings are similar in both the New Mexico efficiency standard and the 2000 IECC. No detailed modeling of SWH loads or efficiency was attempted in this analysis.

3.6 Simulation Tool and Modeling

Building simulations were completed using the Building Loads Analysis and System Thermodynamics (BLAST) software tool (BLAST 1991) Version 3. To simplify modeling of the impacts of the lighting and envelope options, a four-zone building model was used to assess the impact of the lighting and envelope changes under the standard for all buildings. For the two-story office building, each of the four zones covers both a portion of the lower and upper floors of the building. In all cases, the long axis of the buildings examined was oriented north to south. It is noted that this orientation enhances the impact of solar loads from the large east-facing and west-facing sides of the building.

Each of the buildings was assumed to be both heated and cooled for the analysis, with a cooling setpoint of 75° F and a heating set point of 70° F. Setback controls are not required under ASHRAE 90a-1980 but are required under ASHRAE 90.1-1999 and the IECC. Although these controls are not required in 90a-1980, most cooling control systems currently on the market and used for this type of HVAC system have the capability for setback control. Since the capability for control likely exists under both standard scenarios, we have treated both scenarios equivalently, with a heating setback to 55° F and a cooling setpoint to 85° F.

For simulation of the school facility built to the current New Mexico Standard, two different systems were analyzed. The first system assumed standard DX equipment, each serving one of the four different zones for the building. These systems assumed a constant volume system with overall efficiencies typical of DX equipment under the current EPCA requirements. A 9.27 EER was assumed for BLAST's constant-volume, packaged DX system model. The second design replaced the DX cooling equipment with a two-stage indirect/direct evaporative cooler. Specifications for the indirect/direct evaporative cooler were based on discussions with Spec-Air.[8] These systems were modeled as constant-volume systems using BLAST's Evaporative Cooler Model[9].

Building schedules and peak building loads used in the analysis have been developed at the Pacific Northwest National Laboratory (PNNL) for other building simulation work and are referenced in Barwig, 1996. All systems simulated assumed natural gas was used for both space and water heat for the buildings. Table 6 shows a list of the simulation runs attempted with a brief description of the building code assumptions used for each run.

Table 6. Building Code Simulation Performed

Simulation	Building Type	Building Code Description	Cooling System	Heating System
OFF-1	Office	90a-1980	Rooftop packaged	Gas furnace
OFF-2	Office	2000 IECC	Rooftop packaged	Gas furnace
OFF-3	Office	90a-1980 with 2000 IECC Envelope Req.	Rooftop packaged	Gas furnace
OFF-4	Office	90a-1980 with 2000 IECC Lighting Req.	Rooftop packaged	Gas furnace
RET-1	Retail	90a-1980	Rooftop packaged	Gas furnace
RET-2	Retail	2000 IECC	Rooftop packaged	Gas furnace
RET-3	Retail	90a-1980 with 2000 IECC Envelope Req.	Rooftop packaged	Gas furnace
RET-4	Retail	90a-1980 with 2000 IECC Lighting Req.	Rooftop packaged	Gas furnace
EDU-DX-1	Education	1995 N.M. School Std	Rooftop packaged	Gas furnace
EDU-DX-2	Education	2000 IECC	Rooftop packaged	Gas furnace
EDU-DX-3	Education	1995 N.M. School Std with 2000 IECC Envelope Req.	Rooftop packaged	Gas furnace
EDU-DX-4	Education	1995 N.M. School Std with 2000 IECC Lighting Req.	Rooftop packaged	Gas furnace
EDU-EV-1	Education	1995 N.M. School Std	2-stage evaporative cooler	Gas furnace
EDU-EV-2	Education	2000 IECC	Rooftop packaged	Gas furnace
EDU-EV-3	Education	1995 N.M. School Std with 2000 IECC Envelope Req.	2-stage evaporative cooler	Gas furnace
EDU-EV-4	Education	1995 N.M. School Std with 2000 IECC Lighting Req.	2-stage evaporative cooler	Gas furnace

[8] Spec-Air provides commercial evaporative coolers either for stand-alone operation or use in conjunction with other HVAC equipment. Specifications are based on personal discussions with Mike Worth, vice president of Spec-Air.
[9] As a test, an additional simulation consisting of an indirect evaporative cooler used to pre-cool air for the DX system was examined. However, the additional pressure drop added to this system was such that it did not appear to save energy over the baseline DX system. As such, this design would not be required under New Mexico's NM School Standard. This illustrates a difficulty with the requirements of the current New Mexico Standard. While there is a requirement for evaporative cooling, it effectively has to be shown to meet 10-year payback criteria. Because of the different variations in evaporative cooling design, it seems difficult to enforce without detailed review of all plan drawings.

4. Simulation Results

Table 7 shows the simulated energy use for each of the different simulation runs in terms of annual fuel use, annual site energy use, and estimated annual energy cost based on the energy costs discussed in Section 3.2. To determine annual energy cost, electricity costs of $0.0720/kWh were used based on average New Mexico commercial electricity costs for 2001 and natural gas costs of $4.90/MCF were used based on average New Mexico gas costs for 2000 as reported by the Energy Information Administration (EIA) [10].

Table 7. Building Energy Simulation Results

Simulation	Lights and Plugs	HVAC	Space Heat and SWH	Total Site Energy	Energy Cost	% Energy Cost Savings
	kWh/yr	kWh/yr	Therms/yr	Mbtu/yr	($/building/yr)	
OFF-1	103967	48775	581	579	11278	
OFF-2	82356	36370	598	465	8836	21.7%
OFF-3	103967	41629	489	546	10720	5.0%
OFF-4	82356	44357	703	503	9461	16.1%
RET-1	146499	52863	229	703	14468	
RET-2	92036	32751	312	457	9136	36.9%
RET-3	146499	47190	222	683	14055	2.8%
RET-4	92036	39130	345	482	9611	33.6%
EDU-DX-1	332259	142778	6296	2251	37216	
EDU-DX-2	268151	126487	7734	2120	32112	13.7%
EDU-DX-3	332259	139965	6949	2307	37326	-0.3%
EDU-DX-4	268151	129007	7049	2060	31967	14.1%
EDU-EV-1	332259	77765	6296	2029	32534	
EDU-EV-2	268151	126487	7734	2120	32112	1.3%
EDU-EV-3	332259	76600	6949	2090	32762	-0.7%
EDU-EV-4	268151	69555	7049	1857	27685	14.9%

Annual energy cost savings above the appropriate current New Mexico baseline (e.g., OFF-1, RET-1, EDU-DX-1, or EDU-EV-1) are shown as a percentage of reduction in the annual energy cost. In the case of the education building, it is relevant to examine the energy savings and cost reduction assuming either evaporative or DX cooling.

[10] *Electric Power Monthly*. May 2002. "EIA 2001 Fuel Prices: Table 55 - Estimated U.S. Electric Utility Average Revenue per Kilowatt hour to Ultimate Consumers by Sector, Census Division, and State, Year-to-Date (February) 2002 and 2001 (Cents), Natural Gas Monthly, June 2001," Table 22 - Average Price of Natural Gas Sold to Commercial Consumers, by State, 2000-2002 (Dollars per Thousand Cubic Feet). Assumed 1028 MMBtu/MCF conversion factor." Gas costs for 2000 were used to eliminate a gas price bubble that occurred in 2001 that is not adjusted for in EIA's fuel escalation rates.

Based on these simulation results, it is clear that, for the office and retail buildings, significant energy cost savings are obtained from the use of the 2000 IECC requirements in place of the requirements specified by ASHRAE 90a-1980. Examining the OFF-3 (90a-1980 lighting, but using the 2000 IECC envelope requirements) and OFF-4 (90a-1980 envelope, but using the 2000 IECC lighting requirements) simulations, it is clear that the majority of energy cost savings comes from the reduction in allowed lighting power. Similarly, a majority of the energy cost savings for the retail buildings comes from the lighting requirements. In both cases, however, it is clear there are savings to be achieved simply from the improved envelope requirements in the 2000 IECC.

Review of the education building case with direct expansion cooling equipment assumed (baseline EDU-DX-1) clearly indicates that there is substantial energy cost savings to be gained in using the 2000 IECC envelope and lighting requirements instead of the envelope and lighting requirements modeled for the NM School Standard. However, these savings come purely from the lower lighting LPDs mandated by the 2000 IECC. When only the envelope requirements of the 2000 IECC are applied, energy costs increase relative to the energy costs resulting from the NM School Standard for the specified building.

The energy usage of the education building constructed to the NM School Standard, substituting 2000 IECC envelope requirements, has an annual energy cost slightly higher (i.e., $<1\%$) than that of the education building constructed solely to the NM School Standard. Slight reductions in installed lighting power below that specified by the NM School Standard would result in less energy usage in education buildings.

5. Economic Analysis

The economic benefit and costs of adopting an energy code over the current baselines are assessed by evaluating the anticipated energy cost savings over a specified time horizon and then comparing these to the associated capital costs of complying with the code. This analysis for New Mexico uses the life-cycle cost (LCC) method for this comparison, which weighs the values of costs and benefits over time using the time value of money (expressed using an assumed discount rate). For this study, the LCC is a general measure of the cost of operating a building over its lifetime, including the initial incremental construction cost, replacement of key components, and annual energy expenditures.

The primary costs associated with code adoption are incremental costs of required materials and installation that result in different (and hopefully reduced) annual energy consumption (e.g., higher levels of insulation, more efficient light fixtures) relative to the cost of building materials that would satisfy the current baseline requirements. These costs are often referred to as *first costs*, as they are incurred when the building is first built. The collection and treatment of first costs for lighting and building envelope materials is discussed in the following sections. In addition, the analysis tracks replacement costs for components that will need to be replaced during the study period (assumed to be 40 years). The sum of the first cost and the replacement cost will be referred to as the *total investment cost*. Ongoing maintenance costs (excluding replacement costs) have not been examined in this analysis (i.e., it can be interpreted that maintenance costs are assumed to be the same under various requirements).

In addition to first costs, the ongoing incremental costs and benefits of adopting all or a portion of the 90.1-1999 standard are compared to that of an assumed baseline. The primary, ongoing impact of a building energy code is the energy cost reduction over the life of a building. These savings are valued using the New Mexico state average commercial gas and electricity rates over a specified time horizon (EIA 2001a). The average fuel rates are escalated throughout the first 20 years of the study period based on the Annual Energy Outlook 2002 forecasts (EIA 2001b) and are assumed to stay flat the remaining years of the study period. These values are then discounted appropriately to a present value. This study uses a constant 7% (real) discount rate. This value has been used in prior U.S. Department of Energy (DOE) analyses of residential and commercial equipment efficiency standards[11].

The economic impacts are calculated using a spreadsheet-based LCC model that can perform LCC comparisons of alternative sets of building technologies corresponding to different building standards. The model borrows elements of the Building Life-Cycle Cost Program (BLCC), which is a product from the National Institute of Standards and Technology and the DOE Federal Energy Management Program[12].

---

[11] This particular value is motivated by the recommendation of the Office of Management and Budget (OMB) in Circular A-94, (OMB1992). Circular A-94 indicates that this value corresponds to the approximate marginal pretax rate of return on the average investment in the private sector in recent years. All rates are reported as “real” rates, which refers to the discount rate above any nominal inflation rate.

[12] Portions of a spreadsheet version of the BLCC, developed by M.S. Addison and Associates (Tempe, AZ) were adapted for use in the more extensive LCC model used for this study.

5.1 Envelope

Construction costs reflect the volume of material and/or equipment purchased, as well as the actual components used. The volume of material reflects the size of the building. The component performance is described and the component costs are based on costs normalized to a per-unit basis (e.g., per square foot).

The costs for various building envelope materials are derived on a per-unit basis. Costs for walls, roofs, and floors are dependent on the type of construction (e.g., masonry wall versus frame or flat built-up roof versus pitched roof with attic) and vary with thermal performance. The component costs used for this work reflect marginal construction costs over fixed baselines and not the entire construction cost for a component. For example, window costs shown reflect the marginal construction costs for purchase and installation of a specific window type over purchase and installation of single-pane glazing. Likewise, costs shown for opaque walls represent the marginal cost for a fully framed and insulated wall with the specified insulation level above that of a metal framed wall constructed without insulation. Thus the cost differential between components built to different codes is more relevant to the reader than the magnitude of the component costs shown.

Discrete costs for various assembly types are based on cost estimates gathered during the development of the 90.1-1999 standard by the ASHRAE envelope subcommittee. These costs for windows and glazing materials were gathered and compiled by Charles Eley Associates. Although costs were collected from 1994 to1997, all costs are appropriately inflated to 2001 by using price indexes from the Producer Price Index for specific building materials[13].

The building envelope costs are measured and reported as incremental costs to achieve a certain level of thermal integrity (e.g., U-factor for walls, roofs, and windows; R-values for slab insulation). For the roof and opaque walls, the costs are estimated relative to a base wall and roof assembly containing no insulation. The window costs measure the incremental costs of glazing that has a specific U-factor and shading coefficient, as compared to a window with a single pane of clear glass.

For all envelope components, the spreadsheet model estimates the incremental costs per square foot for alternative levels of standards. The incremental costs per square foot are multiplied by the appropriate component areas in the building (e.g., roof, walls, windows) to generate a total incremental building envelope cost.

---

[13] US Bureau of Labor Statistics. 2002. *Producer Price Index Industry Series.* Public Use Data available on BLS Web site, available URL: http://data.bls.gov/labjava/outside/jsp?survey=pc

5.2 Lighting

The lighting requirements in all codes examined are essentially expressed as a limitation on installed connected lighting power per square foot of building area. The inherent flexibility in meeting these type of requirements makes evaluating the first cost of changes to the lighting requirements challenging as there are alternative ways to comply with the standard. Although a variety of alternatives may result in similar energy use outcomes, each alternative has its own distinct cost implication.

In order to assess the economic impacts of lighting code changes, the factors impacting lighting design choices must be considered. Primary lighting design choices affecting the lighting technology and the total connected power installed in a space are:

- Luminance level - this varies based on the needs of the space, including task requirements, occupants, and overall desired atmosphere of the environment, and is generally driven by the recommendation made by the Illuminating Engineering Society
- Lighting technology type - e.g., incandescent, fluorescent, HID, etc. and ballast choices)
- Light distribution technology type - e.g., lenses, louvers, reflective luminaries, reflective materials)
- Maximum allowed connected power by code.

It is anticipated that a lighting design change based on a stricter energy code involves primarily technology changes only. Other potential methods of complying with a new code include a simple lighting level reduction and/or total redesign of the space using advanced lighting techniques. Total redesign of the space, however, is considered to be uncommon in practice and will not be considered in this analysis.

An assessment of typical lighting technologies for a range of buildings is found in the ASHRAE/IESNA Lighting Design Models, as discussed in Section 3.4 of this document, in establishing the light levels building code simulations. Each space (e.g., office, hallway, sales area) within each building type in the ASHRAE 90.-1999 Whole Building Space Data Allocations is associated with up to three different lighting types with each type representing a different lighting technology and associated fixture[14]. The amount of light specified for each space (determined by IES recommendations and the ASHRAE subcommittee input) is further allocated to each of these lighting types (up to three). Each of these types is also further defined by an efficacy of the technology (e.g., lumens per watt) and standard adjustment factors (e.g., lumen depreciation, room surface).

The set of space type allocations listed in the ASHRAE 90.1-1999 Space Type Models provides one method for meeting the lighting power limit requirements of 90.1-1999/IECC 2000. These models, based on actual designer and experience input, are considered the most accurate and detailed of their kind available for providing efficient and effective lighting. The models also serve as the basis for comparison with other standards or current practice scenarios.

---

[14] For example, the three lighting types for an office conference room include linear fluorescent, wall wash fluorescent, and halogen down lights.

The approach used to evaluate lighting benefits utilizes lighting costs for systems of lighting, which include the lamp, fixture, and ballast combination. First, the ASHRAE Space Type Models are applied to the spaces in each building type to determine the lighting system that meets the standard at the lowest cost. The power densities and costs are then developed for each space and lighting system, and aggregated to the whole building level for the analysis

The assignment of differences in power densities between the 1999 standard and the 1989 standard can be evaluated as either differences in light level or the efficacy of lighting technologies—or both. Some assumptions are made to permit a reasonable assessment of the actual difference in design in order to meet the two standards and allow a comparison of energy consumption and costs. Because of the vast difference in lighting design, it is impractical to assign too much detail to a scenario; however, many common space types within buildings exhibit some common lighting design attributes. Examples of this are listed in Table 8.

Table 8. Comparison of Common Space Types to Attributes

Common Space Type	Common Lighting Design Attributes
Typical open office areas	fluorescent troffers, even spacing, little decoration
Typical enclosed offices	fluorescent troffers
Hallways/lobbies	fluorescent troffers, incandescent downlights
Large Retail spaces	Overhead fluorescent troffers, incandescent displaylights

The 2000 IECC requirements are essentially identical to the Standard 90.1-1999 requirements for the buildings examined in this study and are expected to have the same lighting technologies, lighting types, and fixture counts. Since the lighting requirements for Standard 90.1-1999 are well defined through the use of the Space Type Models, they were used as a baseline for determining capital costs for lighting under other codes.

To assess the first cost to meet the less-stringent Standard 90a-1980 for the office and retail buildings, the first step assumed a technology substitution involving two types of lighting systems:

1. Magnetic ballast-T12 lamps for electronic ballast-T8 lamps
2. Incandescent lamps for compact fluorescent lamps in downlight applications.

These substitutions were made for all the space types used in the ASHRAE methodology underlying the development of the 1999 lighting standard.[15] The 90.1-1999 whole-building LPD will increase by different percentage amounts over 90.1-1989, depending upon the assumed fractions of floor space to be served by the technologies in each of the building types.

[15] The methodology for the space type and LPD models is incorporated into a large spreadsheet that was developed by the lighting subcommittee of the SSPC 90.1 ASHRAE standards committee in support of the ASHRAE/IESNA 90.1-1999 energy standard. A working version of the spreadsheet tool with additional detailed descriptions of the various parts is available for review on the IESNA Web site, available URL: http://206.55.31.90/cgi-bin/lpd/lpdhome.pl. An offline version of the spreadsheet was modified in three ways: 1) technologies for magnetic ballasts and T-12 lamps were added, 2) a series of worksheets to estimate lighting system costs was added, and 3) a revised formula (consistent with the most recent ASHRAE/IES work) was used in the calculation of LPDs.

The first two columns of Table 9 show the building-level LPDs that were used in the economic analysis. Column 3 displays the efficiency improvement in the LPD between the 1999 and 1989 standard. Column 4 shows the increase from the 1999 standard brought about solely by the technology substitution discussed above. For office and education buildings, the technology substitution (as described in numbers (1) and (2) above) results in an increase in the LPD that is very close to the requirements of the 1989 standard.

Table 9. Change in Lighting Power Densities from Technology Substitution

	1999 LPD[(a)]	**1989 LPD[(a)]**	**Percent Change**	**Technology Substitution (Percent Change)**
Office	1.30 w/ft^2	1.63 w/ft^2	25.4%	24.0%
Retail	1.9 w/ft^2	2.36 w/ft^2	24.2%	16.0%
Education	1.5 w/ft^2	1.79 w/ft^2	19.3 %	20.8%
(a) As used in the building energy simulations.				

As a first step, cost estimates were developed for the linear fluorescent and incandescent/compact fluorescent light (CFL) applications to the 90.1-1999 standard based upon the ASHRAE models. The less-efficient technologies (e.g. incandescent lights) were then applied to the same models (i.e., assuming the same illumination levels). A ratio was computed between the reduction in cost and the increase in the predicted LPD, going from the more-efficient to the less-efficient lighting technologies (the change in predicted LPD is equal to the percentage change in Column 4 in Table 9, multiplied by the 1999 LPD in Column 1). This ratio was then applied to the actual difference in the LPD between the two standards to make an estimate in the change in cost.

For office and education buildings, this procedure yields essentially the same cost difference as that generated by the technology substitution without any adjustment. Since the predicted change in the LPD for retail buildings was lower than the actual difference (16% vs. 24% in Table 9), this procedure provides an upper bound to the cost difference (and, concomitantly, a conservative estimate of the LCC reduction) between the two standards for this building type. A further calibration was performed to account for a revision in the way in which the LPDs were calculated in the ASHRAE models for this study, as compared to how these models were employed when developing the published standard.[16]

The investment associated with higher lighting levels found in Standard 90a-1980 and the *NM School Standard* could not be explained by a further technology substitution from the 90.1-1989 lighting power densities, particularly since efficiencies for most common fluorescent lighting ballasts are now regulated under EPACT and lower efficiency fluorescent ballasts are unavailable. Rather, costs for the Standard 90a-1980 office and retail buildings lighting power densities were modeled as scaling linearly with the costs for the lighting power densities in Standard 90.1-1989. This represents essentially an increase in the

[16] The use of the revised formula in the LPD spreadsheet (see previous footnote) causes the calculated 90.1-1999 LPDs to be higher than those published for the 1999 standard. The calculated LPDs were: 1) office, 1.40 watts/ft^2, 2) retail, 2.14 watts/ft^2, and 3) education 1.54 watts/ft^2. The revised formula ensures that the economic benefits from a technology substitution are consistent across building types. Unfortunately, it requires that the cost calibration must be performed on the basis of percentage changes rather than the absolute levels of the LPDs.

number of fixtures and lamps allowed compared with Standard 90.1-1989 as well as an increase in illumination level.

For the Education buildings, where high-efficiency lights and ballasts are already required in the NM School Standard, the lighting costs are based on scaling the 90.1-1999 lighting cost estimates with the ratio of this current New Mexico standard and the lighting power allowed in 90.1-1999. No technology substitutions were assumed. Note that this is essentially an increase in the number of fixtures and lamps allowed compared with Standard 90.1-1999. It is believed that this makes a more credible scenario than the assumption of significantly greater use of incandescent lighting in the current ASHRAE models.

Lighting costs are measured in terms of *total lighting cost in dollars per square foot for linear fluorescent and incandescent/CFL systems*. These costs include the cost of a fixture, ballast, and lamp plus the labor to install the assembly. The linear fluorescent lighting cost estimates are based on data from the Technical Support Document for the DOE's rulemaking related to fluorescent lamp ballasts (DOE 1999). For compact fluorescent and incandescent systems, data were developed from the input data used in the commercial module of the National Energy Modeling System (NEMS) and from a PNNL analysis of contractor prices from Grainger Industrial Supply. Although the lighting cost may vary for any particular building due to the type of lighting technology used, the above derivations are representative of the cost differentials.

5.3 Mechanical Equipment

As discussed in Section 3.6, mechanical equipment efficiencies were not changed between the minimum purchased under federal law and what is required under the 2000 IECC. However, to model the impact of the evaporative cooling technology in the NM School Standard, it was necessary to price and size both the costs for the packaged DX equipment and the evaporative cooling equipment that would be used in the education building under the different building codes. The first cost analysis for the cooling equipment was carried out for the other retail and office buildings, although with these buildings it is only the impact of changes in required cooling equipment capacity that impact the economics.

To account for this change in capacity, the total tonnage of required cooling capacity was extracted from the simulation results and costed on a $/ton basis. The required cooling capacity was based on the peak cooling design day loads sizing from BLAST. BLAST's design day calculations were based on ASHRAE's 1% design day mean coincident wet bulb conditions (ASHRAE 2001)[17]. No oversizing beyond these peak design day loads was included in these equipment costs. Any oversizing of cooling equipment to account for pickup loads or the discrete size availability of packaged equipment would serve to increase the total differential first cost for the building's cooling equipment under different codes.

Differential first costs for heating equipment of different sizes were not examined in this study[18]. For the evaporative cooling systems analyzed in the education building, a simplifying assumption was made that

---

[17] ASHRAE 2001 Handbook of Fundamentals (ASHRAE 2001).

[18] The capacity and cost for gas furnace heating systems in rooftop cooling equipment is closely tied to the cooling capacity of the equipment in available products, and relatively small variations in required heating capacity do not practically result in different first costs for packaged equipment.

the heating requirements would be met by duct furnaces that cost no more than the furnace in the original package product[19].

Differential first costs for cooling equipment were examined in this study. Costs for the packaged DX equipment analyzed were based on estimated first costs developed by the ASHRAE 90.1-1999 mechanical subcommittee for 7.5 ton packaged cooling equipment with an efficiency level of 9.27 EER. To this was added a 25% contractor markup for the final installed cost of $565/ton.

Costs for the two-stage evaporative cooling system were based on a cost differential of $760/ton that was reported in the NM School Standard. A 25% markup was assumed to be applied to this. This cost compares well with estimated costs from manufacturers; consultation with Spec-Air representatives[20] confirmed similar costs. Spec-Air provided estimated costs for stand-alone, two-stage evaporative coolers of approximately $1,400/ton for 5 ton products and $650/ton for 20 ton, two-stage evaporative cooling systems. It is noted that for small (i.e., 3-5 ton) packaged DX cooling systems, less expensive, pre-engineered two-stage evaporative cooling modules that attach to the rooftop DX system are available at about 50% of the costs shown here for the standalone 5-ton system. Given the range of possible designs, it was felt that the costs used in the NM School Standard were very reasonable for this study.

It is also noted here that for the engineering analysis, it was assumed that outside air was used as the "wet side" of the evaporative cooling units. A more efficient option when stringent outside air requirements exist is to use building exhaust air as the air supply to the wet side of the evaporative cooler. This was not something that could be modeled in BLAST, however, this solution has twofold benefits. First, because the building supply air starts out as cooler than the outside air, the two-stage evaporative cooler, using exhaust air, can provide cooler supply air to the building using the same unit. The second benefit is more significant. Because the exhaust air is being routed through an exhaust air/outdoor air heat exchanger, exhaust air heat recovery can be achieved during the heating season by simply turning off the water supply to the heat exchanger. According to Spec-Air, nearly 50% of the systems they sell for school applications are configured in this manner.

[19] This may under-represent the cost of the heating equipment used in the evaporatively cooled building studied.

[20] Personal conversation with Todd Freund of Spec-Air on 8/29/2002.

6. Results

Tables 10, 11, 12 and 13 show the results of the LCC analysis completed for each simulation. These tables show the relative cost assumptions for each component in the building examined, the energy savings as calculated from the simulation, the energy cost savings, and three methods of economic valuation: 1) the building LCC savings, 2) the savings-to-investment ratio, and 3) the adjusted internal rate of return on the capital cost investments. Each of these economic criteria is calculated for the simulations differently than the baseline assumptions (using 90a-1980 for office or retail buildings and the NM School Standard for school buildings with and without evaporative cooling assumptions).

It is particularly important to look at the LCC savings for the 2000 IECC, but also for the baseline building with 2000 IECC lighting levels. Progress in cost-effective, high-efficiency lighting technology has advanced much faster than cost-effective, efficiency improvements in the building envelope. For that reason, much of the current building construction in New Mexico likely has connected lighting power levels already significantly lower than the levels prescribed by the baseline codes. Hence, the reported first cost and energy usage for lighting at the current code levels may not represent a realistic baseline for assessing the actual energy savings New Mexico would gain in going to the 2000 IECC.

6.1. Office and Retail

Table 10 shows the results of the LCC analysis for a small office, while Table 11 represents the LCC analysis results for a retail building. The results of this study clearly indicate that there are significant LCC savings to be gained through adoption of the 2000 IECC over 90a-1980 for office and retail buildings, although the lighting energy savings drives these LCC savings almost completely. The energy savings from adoption of the 2000 IECC envelope is largely offset by the first cost of transitioning to the 2000 IECC envelope. Although the office building results imply a modest LCC cost savings of $678 with adoption of the IECC envelope requirements, the LCC increases by $2407 (negative LCC savings are distinguished with brackets) with the adoption of the IECC envelope requirements for the retail building. Slight changes in fuel cost or first cost assumptions could swing these numbers into negative or positive realms, and it is, therefore, difficult to judge these as significant LCC impacts for the building envelope change. However, it is clear that adopting the 2000 IECC for these buildings would remove the potential for excessive lighting energy use that currently exists in the 90a-1980 baselines.

6.2. Education

In examining the school building with DX cooling, it is clear that the 2000 IECC offers significant LCC savings over the current NM School Standard, nearly $150,000 savings in LCC and over $5100 in estimated annual energy costs savings. This LCC savings is due to both the lighting power reduction discussed previously, as well as lower costs for construction of the 2000 IECC building envelope. Even assuming the current standard with the 2000 IECC lighting levels as the baseline, the LCC savings would be approximately $37,000 with the 2000 IECC ($149,923 minus $112,833), the difference in LCC between these two scenarios shown in Table 12. This scenario, however, would have a slight increase ($145/yr) in energy costs with the 2000 IECC over this second baseline ($32,112 minus $31,967).

In examining the school building with the two-stage evaporative cooling (Table 13), the 2000 IECC still shows significant LCC savings over the current standard ($91,920). However the highest LCC savings is produced when combining the current New School Mexico Standard with the 2000 IECC lighting requirements. This appears to be due to the cost effectiveness of the evaporative cooling system. The NM School Standard baseline, in this second example, would experience a savings of approximately $5000/yr compared to the NM School Standard with DX cooling.

Table 10. Engineering and Cost Summary for Small Office Building

Small Office (WWR=0.19)

Bldg. Size	10,000 sq. ft.		Standard Level			
			90A-1980 Base	IECC2000	90A-1980 w/2000 Env.	90A-1980 w/2000 Light
Envelope	**Area (sq. ft.)**					
Windows	1,482	u-value(std)	0.980	0.500	0.500	0.980
		sh. coef.(std)	0.850	0.500	0.500	0.850
(Window-Wall Ratio = 0.19)		u-value(cost)	0.730	0.497	0.497	0.730
		sh. coef.(cost)	0.840	0.506	0.506	0.840
		cost ($/sqft)	$4.55	$8.70	$8.70	$4.55
Opaque Walls	6,318	u-value	0.132	0.132	0.132	0.132
		cost ($/sqft)	$0.33	$0.33	$0.33	$0.33
Roof	5,000	u-value	0.085	0.051	0.051	0.085
		cost ($/sqft)	$0.91	$1.36	$1.36	$0.91
	(feet)					
Slab perimeter	300	u-value	0.125	not req'd	0.125	not req'd
		cost ($/ft)*	$4.12	$0.00	$0.00	$4.12
		*24-inch depth				
Envelope Cost (incremental)			$14,615	$21,774	$21,774	$14,615
Lighting						
Lighting Power Density		watts/sqft	1.91	1.30	1.91	1.30
Lighting Cost per Sq. Foot		$/sqft	$1.84	$1.75	$1.84	$1.75
Total Lighting Cost			$18,361	$17,504	$18,361	$17,504
HVAC Equipment1	Capacity (kBtu/h)		Central, Air-Source AC >65 and < 135 kBtu/h			
		EER	9.27	9.27	9.27	9.27
		Unit Cost/ton	$565	$565	$565	$565
	Number of Units (Tons)		15.57	11.37	13.06	14.13
	Total Equipment Cost		$8,795	$6,422	$7,379	$7,983
Construction Cost			$41,772	$45,700	$47,515	$40,102
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	355	281	355	281
Electricity, HVAC		MMBtu	166	124	142	151
Natural Gas		MMBtu	58	60	49	70
Total Annual Energy Cost2			$11,278	$8,836	$10,720	$9,461
Economic Measures						
Life-Cycle Cost Savings				**$26,898**	**$678**	**$25,169**
Savings-to-Investment Ratio (SIR)				9.0	1.1	Invest. < 0
Adjusted IRR				13.1%	7.3%	Invest. < 0

Notes:

1 **Economizer used**

2 **2001 electricity price = 7.2 cents/kWh** **2001 gas price = $4.77 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Table 11. Engineering and Cost Summary for Small Retail Building

Small Retail (WWR=0.12)

Bldg. Size	**10,000 sq. ft.**		Standard Level			
			90A-1980 Base	*IECC2000*	*90A-1980 w/2000 Env.*	*90A-1980 w/2000 Light*
Envelope	**Area (sq. ft.)**					
Windows	697	u-value(std)	1.220	0.500	0.500	1.220
		sh. coef.(std)	0.850	0.500	0.500	0.850
(Window-Wall Ratio = 0.12)		u-value(cost)	1.213	0.497	0.497	1.213
		sh. coef.(cost)	0.693	0.506	0.506	0.693
		cost ($/sqft)	$1.56	$8.70	$8.70	$1.56
Opaque Walls	5,108	u-value	0.132	0.132	0.132	0.132
		cost ($/sqft)	$0.33	$0.33	$0.33	$0.33
Roof	10,000	u-value	0.085	0.051	0.051	0.085
		cost ($/sqft)	$0.91	$1.36	$1.36	$0.91
	(feet)					
Slab perimeter	447	u-value	0.125	not req'd	0.125	not req'd
		cost ($/ft)*	$4.12	$0.00	$0.00	$4.12
		*24-inch depth				
Envelope Cost (incremental)			$13,709	$21,334	$21,334	$13,709
Lighting						
Lighting Power Density		watts/sqft	3.31	1.90	3.31	1.90
Lighting Cost per Sq. Foot		$/sqft	$2.20	$1.80	$2.20	$1.80
Total Lighting Cost			$22,044	$17,983	$22,044	$17,983
HVAC Equipment1	Capacity (kBtu/h)		Central, Air-Source AC >65 and < 135 kBtu/h			
		EER	9.27	9.27	9.27	9.27
		Unit Cost/ton	$565	$565	$565	$565
	Number of Units (Tons)		14.31	9.20	12.68	11.04
	Total Equipment Cost		$8,088	$5,198	$7,167	$6,236
Construction Cost			$43,841	$44,515	$50,545	$37,928
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	500	314	500	314
Electricity, HVAC		MMBtu	180	112	161	134
Natural Gas		MMBtu	23	31	22	34
Total Annual Energy Cost2			$14,468	$9,136	$14,055	$9,611
Economic Measures						
Life-Cycle Cost Savings				**$66,404**	**($2,407)**	**$67,843**
Savings-to-Investment Ratio (SIR)				Invest. < 0	0.7	Invest. < 0
Adjusted IRR				Invest. < 0	6.0%	Invest. < 0

Notes:
1 **Economizer used**
2 **2001 electricity price = 7.2 cents/kWh** **2001 gas price = $4.77 /MMBtu**
3 **Years for Analysis = 40** **Discount Rate = 7.0%**
Life-cycle cost savings includes replacement costs and residual values

Table 12. Engineering and Cost Summary for Elementary School with DX Cooling

Elementary School (WWR=0.17)

Bldg. Size	**50,000 sq. ft.**		Standard Level			
			NM School Standard	*IECC2000*	*NM School Standard w/IECC2000 Env.*	*NM School Standard w/IECC2000 Light*
Envelope	**Area (sq. ft.)**					
Windows	2,207	u-value(std)	0.790	0.500	0.500	0.790
		sh. coef.(std)	0.680	0.500	0.500	0.680
(Window-Wall Ratio = 0.17)		u-value(cost)	0.730	0.497	0.497	0.730
		sh. coef.(cost)	0.590	0.506	0.506	0.590
		cost ($/sqft)	$5.13	$8.70	$8.70	$5.13
Opaque Walls	10,773	u-value	0.07	0.132	0.132	0.07
		cost ($/sqft)	$0.86	$0.33	$0.33	$0.86
Roof	50,000	u-value	0.032	0.051	0.051	0.032
		cost ($/sqft)	$2.04	$1.36	$1.36	$2.04
	(feet)					
Slab perimeter	998	u-value	0.125	not req'd	0.125	not req'd
		cost ($/ft)*	$4.31	$0.00	$0.00	$4.31
		*24-inch depth				
Envelope Cost (incremental)			$126,966	$90,678	$90,678	$126,966
Lighting						
Lighting Power Density		watts/sqft	1.95	1.50	1.95	1.50
Lighting Cost per Sq. Foot		$/sqft	$2.54	$1.95	$2.54	$1.95
Total Lighting Cost			$126,918	$97,629	$126,918	$97,629
HVAC Equipment1	Capacity (kBtu/h)		Central, Air-Source AC >65 and < 135 kBtu/h			
		EER	9.27	9.27	9.27	9.27
		Unit Cost/ton	$565	$565	$565	$565
	Number of Units (Tons)		56.50	51.01	57.53	52.93
	Total Equipment Cost		$31,923	$28,819	$32,506	$29,905
Construction Cost			$285,808	$217,126	$250,102	$254,500
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	1,134	915	1,134	915
Electricity, HVAC		MMBtu	487	432	478	440
Natural Gas		MMBtu	630	773	695	705
Total Annual Energy Cost2			$37,216	$32,112	$37,326	$31,967
Economic Measures						
Life-Cycle Cost Savings				**$149,923**	**$35,053**	**$112,883**
Savings-to-Investment Ratio (SIR)				Invest. < 0	Invest. < 0	Invest. < 0
Adjusted IRR				Invest. < 0	Invest. < 0	Invest. < 0

Notes:
1 **Economizer used**
2 **2001 electricity price = 7.2 cents/kWh** **2001 gas price = $4.77 /MMBtu**
3 **Years for Analysis = 40** **Discount Rate = 7.0%**
Life-cycle cost savings includes replacement costs and residual values

Table 13. Engineering and Cost Summary for Elementary School with Evaporative Cooling

Elementary School (WWR=0.17)

Bldg. Size	**50,000 sq. ft.**		Standard Level			
			NM School Standard	*IECC2000*	*NM School Standard w/IECC2000 Env.*	*NM School Standard w/IECC2000 Light*
Envelope	**Area (sq. ft.)**					
Windows	2,207	u-value(std)	0.790	0.500	0.500	0.790
		sh. coef.(std)	0.680	0.500	0.500	0.680
(Window-Wall Ratio = 0.17)		u-value(cost)	0.730	0.497	0.497	0.730
		sh. coef.(cost)	0.590	0.506	0.506	0.590
		cost ($/sqft)	$5.13	$8.70	$8.70	$5.13
Opaque Walls	10,773	u-value	0.07	0.132	0.132	0.07
		cost ($/sqft)	$0.86	$0.33	$0.33	$0.86
Roof	50,000	u-value	0.032	0.051	0.051	0.032
		cost ($/sqft)	$2.04	$1.36	$1.36	$2.04
	(feet)					
Slab perimeter	998	u-value	0.125	not req'd	0.125	not req'd
		cost ($/ft)*	$4.31	$0.00	$0.00	$4.31
		*24-inch depth				
Envelope Cost (incremental)			$126,966	$90,678	$90,678	$126,966
Lighting						
Lighting Power Density		watts/sqft	1.95	1.50	1.95	1.50
Lighting Cost per Sq. Foot		$/sqft	$2.54	$1.95	$2.54	$1.95
Total Lighting Cost			$126,918	$97,629	$126,918	$97,629
HVAC Equipment1	Capacity (kBtu/h)		Central, Air-Source AC >65 and < 135 kBtu/h			
		EER	9.27	9.27	9.27	9.27
		Unit Cost/ton	$1,325	$565	$1,325	$1,325
	Number of Units (Tons)		56.50	51.01	57.53	52.93
	Total Equipment Cost		$74,864	$28,819	$76,230	$70,129
Construction Cost			$328,749	$217,126	$293,826	$294,725
Annual Energy Consumption						
Electricity, lights and plugs		MMBtu	1,134	915	1,134	915
Electricity, HVAC		MMBtu	265	432	261	237
Natural Gas		MMBtu	630	773	695	705
Total Annual Energy Cost2			$32,534	$32,112	$32,762	$27,685
Economic Measures						
Life-Cycle Cost Savings				**$91,920**	**$33,582**	**$107,921**
Savings-to-Investment Ratio (SIR)				Invest. < 0	Invest. < 0	Invest. < 0
Adjusted IRR				Invest. < 0	Invest. < 0	Invest. < 0

Notes:

1 **No economizer used**

2 **2001 electricity price = 7.2 cents/kWh** **2001 gas price = $4.77 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

7. Conclusion

Figure 1 provides a comparison of the LCC savings per square foot by building type for adoption of the 2000 IECC envelope and lighting requirements, each individually and together.

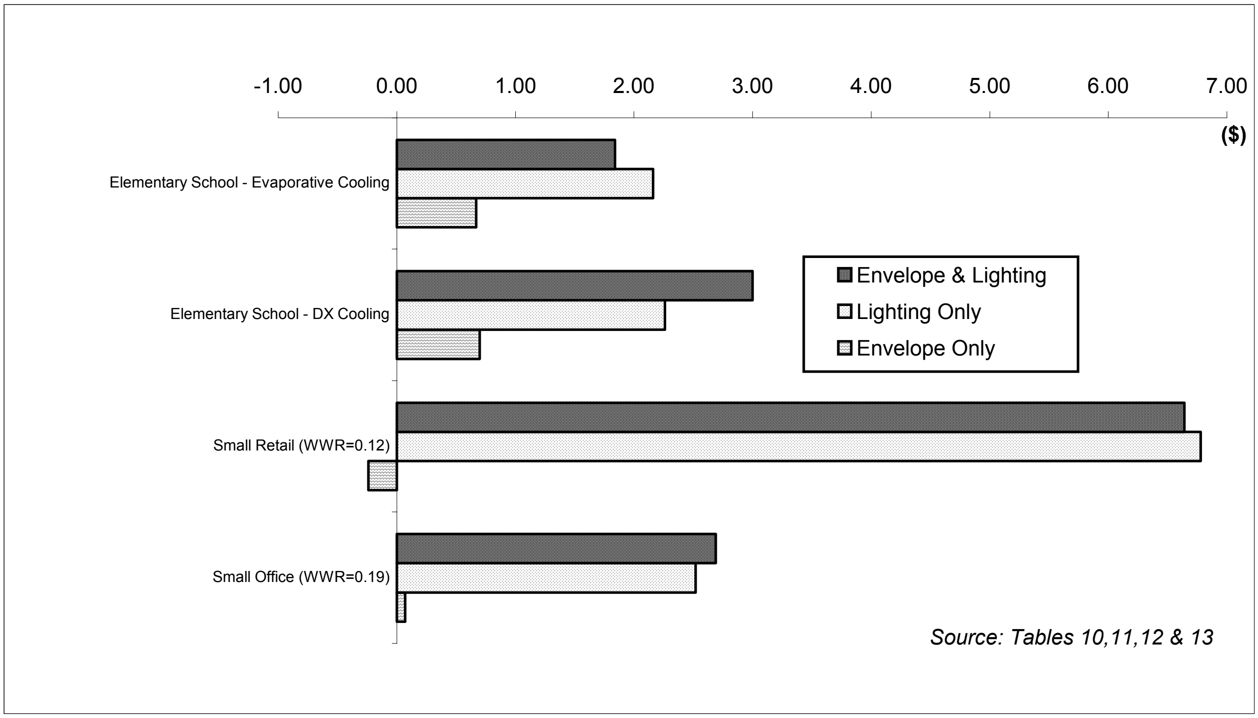

Figure 1. *A Comparison of Life Cycle Cost Saving Per Square Foot Between Different Types of Buildings*

The 2000 IECC lighting requirements appear to be highly cost-effective for these building types in terms of LCC savings relative to the 90a-1980 baseline. The LCC savings from the adoption of 2000 IECC envelope requirements are less substantial than those generated from the lighting requirements and are negative for small retail buildings with relatively low window-to-wall ratios. When lighting and envelope requirements are combined, all of the simulated buildings display savings in energy use, annual fuel cost, and life-cycle costs. Based on these limited quantitative results, it appears that adopting the 2000 IECC standard in New Mexico would provide positive net economic benefits to the state relative to the building and design requirements prescribed in ASHRAE 90a-1980 and to the New Mexico School Standard.

8. References

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). 2001. *2001 ASHRAE Fundamentals Handbook.* Atlanta, Georgia.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and Illuminating Engineering Society of North America (IESNA). 1980. *Energy Conservation in New Building Design.*

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and Illuminating Engineering Society of North America (IESNA). 1989. *Energy Standard for Buildings Except Low-Rise Residential Buildings.*

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and Illuminating Engineering Society of North America (IESNA). 1999. *ASHRAE Standard Energy Standard for Buildings Except Low-Rise Residential Buildings.*

Barwig FE, et al. 1996. *Preliminary Findings; Analysis of Commercial Space-Conditioning and Storage Water-Heating Equipment Efficiencies*. PNNL-11191, Pacific Northwest National Laboratory, Richland, Washington.

BLAST Support Office (BLAST). 1991. *Volume 1: BLAST User Manual.* University of Illinois at Urbana-Champaign, Illinois.

Energy Information Administration (EIA). 2001a. "Annual Electric Utility Report," and EIA-826, "Monthly Electric Utility Sales and Revenue Report with State Distributions." EIA-861, U.S. Department of Energy. Summer, 2001. Washington D.C.

Energy Information Administration (EIA). 2001b. *Annual Energy Outlook 2002 with Projections to 2020.* U.S. Department of Energy. December 2001. Washington D.C.

Energy Information Administration (EIA). 1992. *Commercial Building Energy Consumption and Expenditures Survey 1992* (CBECS 92), Public Use Data, Micro-data files on EIA website. [Online]. Available: ftp://ftp.eia.doe.gov/pub/consumption/commercial/micro.data/ U.S. Department of Energy. Washington D.C.

Energy Information Administration (EIA). 1995. *Commercial Building Energy Consumption and Expenditures Survey 1995* (CBECS 95), Public Use Data, Micro-data files on EIA website. [Online]. Available: ftp://ftp.eia.doe.gov/pub/consumption/commercial/micro.data/ U.S. Department of Energy. Washington D.C.

Energy Information Administration (EIA). 2000. *National Energy Modeling System (NEMS)* U.S. Department of Energy. 2000. Washington D.C.

Energy Policy Act of 1992 (EPACT). Public Law 102-486, 1096 Stat 2776.

Energy Policy and Conservation Act (EPCA). 42 USC 62901, et seq.

Illumination Engineering Society. 1982. *LEM-1-1982.*

International Code Council. 2000. *International Energy Conservation Code*, Falls Church, VA.

National Appliance Energy Conservation Act (NAECA) of 1987. Public Law 100-12.

New Mexico Energy Minerals and Natural Resources Department. 1995. *Energy Efficiency Standards Construction and Remodeling Procedure for Public School Buildings*, Sante Fe, New Mexico.

Office of Management and Budget (OMB). 1992. *Guidelines and Discount Rates for Benefit-Cost Analyses of Federal Programs.* OMB Circular A-94, available URL: http://www.whitehouse.gov/OMB/circulars/a094/a094.html

Somasundaram, S. et. al. 2000. *Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment.* Pacific Northwest National Laboratory, PNNL-13232. April 2000.

U.S. Census Bureau (Census). 2000. "1997 Economic Census Construction Geographic Area Series." U.S. Department of Commerce, March 2000. Washington D.C.Energy

U.S. Department of Energy (DOE) 2000. January 2000. "Fluorescent Lamp Ballast Technical Support Document." Available online DOE website: [Online].
Available: http://www.eren.doe.gov/buildings/codes_standards/reports/ballasts/index.htm

W. W. Grainger Industrial Supply - Lighting Catalog 2000-01. 2000. W. W. Grainger, Incorporated. Lake Forest, IL.

APPENDIX -- Analysis of Proposed Lighting Amendment

A request was made by the state of New Mexico to provide an analysis of the energy and life-cycle cost impact of adoption of the 2000 IECC with an amendment to allow for up to 2.0 watts per square foot (w/ft^2) of lighting in any building type. The energy analysis was carried out by modifying the 2000 IECC simulations to use 2 0 w/ft^2 for all buildings. Lighting component costs were also adjusted by scaling the cost estimates for the 90.1-1989 standard (see the discussion in Section 8) by the ratio of LPD between that standard and 2.0 w/ft^2.

Tables A.1-A.4 show the energy and life-cycle cost impacts of building to the IECC with the 2.0 w/ft^2 allowance for the four building configurations simulated in this document. In addition, the tables show the energy and life-cycle cost impacts of the standards shown in Tables 12-15, the current New Mexico code baselines and the 2000 IECC with no modification. Since much of the energy savings in the IECC is from the lighting changes, the 2.0 w/ft^2-allowance dramatically reduces the energy savings for this "amended" 2000 IECC version when compared to the 2000 IECC for the office and education buildings studied. For the retail building, the 2000 IECC gives an allowance of up to 1.9 w/ft^2, so the 2.0 w/ft^2 allowance for the retail building results in a relatively smaller increase in building energy use.

It is noted that the 2.0 w/ft^2 value is actually more than the current New Mexico code (ASHRAE 90a-1980) allows in the case of the office building and, for that building type, appears to be a step backwards in terms of building code efficiency, increasing building energy use for lighting as well as increasing the first cost of building construction. Using the amended IECC resulted in a minor reduction in annual energy cost of $282/year ($11,278 minus $10,996) for the office building simulated, but resulted in a negative overall LCC. 2.0 w/ft^2 is a reduction in the currently allowed LPD for the retail and education buildings, but the "amended" 2000 IECC still appears to reduce building life-cycle costs when compared to the current New Mexico codes for these buildings. The "amended" 2000 IECC, however, reduces energy use in only the retail building when compared to the current baseline. The "amended" 2000 IECC increases energy use for both the education buildings simulated when compared to the existing New Mexico School Standard.

Table A-1a. Engineering and Cost Summary

Small Office (WWR=0.19)

Bldg. Size 10,000 sq. ft.			Standard Level				
			90A-1980 Base	*IECC2000*	*IECC2000_2 wsf*	*90A-1980 w/2000 Env.*	*90A-1980 w/2000 Light*
Envelope	**Area (sq. ft.)**						
Windows	1,482	u-value(std)	0.980	0.500	0.500	0.500	0.980
		sh. coef.(std)	0.850	0.500	0.500	0.500	0.850
(Window-Wall Ratio = 0.19)		u-value(cost)	0.730	0.497	0.497	0.497	0.730
		sh. coef.(cost)	0.840	0.506	0.506	0.506	0.840
		cost ($/sqft)	$4.55	$8.70	$8.70	$8.70	$4.55
Opaque Walls	6,318	u-value	0.132	0.132	0.132	0.132	0.132
		cost ($/sqft)	$0.33	$0.33	$0.33	$0.33	$0.33
Roof	5,000	u-value	0.085	0.051	0.051	0.051	0.085
		cost ($/sqft)	$0.91	$1.36	$1.36	$1.36	$0.91
	(feet)						
Slab perimeter	300	u-value	0.125	not req'd	not req'd	0.125	not req'd
		cost ($/ft)*	$4.12	$0.00	$0.00	$0.00	$4.12
		*24-inch depth					
Envelope Cost (incremental)			$14,615	$21,774	$21,774	$21,774	$14,615
Lighting							
Lighting Power Density		watts/sqft	1.91	1.30	2.00	1.91	1.30
Lighting Cost per Sq. Foot		$/sqft	$1.84	$1.75	$1.92	$1.84	$1.75
Total Lighting Cost			$18,361	$17,504	$19,227	$18,361	$17,504
HVAC Equipment1	Capacity (kBtu/h)		Central, Air-Source AC >65 and < 135 kBtu/h				
		EER	9.27	9.27	9.27	9.27	9.27
		Unit Cost/ton	$565	$565	$565	$565	$565
	Number of Units (Tons)		15.57	11.37	11.37	13.06	14.13
	Total Equipment Cost		$8,795	$6,422	$6,422	$7,379	$7,983
Construction Cost			$41,772	$45,700	$47,423	$47,515	$40,102
Annual Energy Consumption							
Electricity, lights and plugs		MMBtu	355	281	366	355	281
Electricity, HVAC		MMBtu	166	124	145	142	151
Natural Gas		MMBtu	58	60	48	49	70
Total Annual Energy Cost2			$11,278	$8,836	$10,996	$10,720	$9,461
Economic Measures							
Life-Cycle Cost Savings				**$26,898**	**($2,677)**	**$678**	**$25,169**
Savings-to-Investment Ratio (SIR)				9.0	0.6	1.1	Invest. < 0
Adjusted IRR				13.1%	5.5%	7.3%	Invest. < 0

Notes:

1 **Economizer used**

2 **2001 electricity price = 7.2 cents/kWh** **2001 gas price = $4.77 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Table A-1b. Engineering and Cost Summary

Small Retail (WWR=0.12)

Bldg. Size **10,000 sq. ft.**

			Standard Level				
			90A-1980 Base	*IECC2000*	*IECC2000_2 wsf*	*90A-1980 w/2000 Env.*	*90A-1980 w/2000 Light*
Envelope	**Area (sq. ft.)**						
Windows	697	u-value(std)	1.220	0.500	0.500	0.500	1.220
		sh. coef.(std)	0.850	0.500	0.500	0.500	0.850
(Window-Wall Ratio = 0.12)		u-value(cost)	1.213	0.497	0.497	0.497	1.213
		sh. coef.(cost)	0.693	0.506	0.506	0.506	0.693
		cost ($/sqft)	$1.56	$8.70	$8.70	$8.70	$1.56
Opaque Walls	5,108	u-value	0.132	0.132	0.132	0.132	0.132
		cost ($/sqft)	$0.33	$0.33	$0.33	$0.33	$0.33
Roof	10,000	u-value	0.085	0.051	0.051	0.051	0.085
		cost ($/sqft)	$0.91	$1.36	$1.36	$1.36	$0.91
	(feet)						
Slab perimeter	447	u-value	0.125	not req'd	not req'd	0.125	not req'd
		cost ($/ft)*	$4.12	$0.00	$0.00	$0.00	$4.12
		*24-inch depth					
Envelope Cost (incremental)			$13,709	$21,334	$21,334	$21,334	$13,709
Lighting							
Lighting Power Density		watts/sqft	3.31	1.90	2.00	3.31	1.90
Lighting Cost per Sq. Foot		$/sqft	$2.20	$1.80	$1.75	$2.20	$1.80
Total Lighting Cost			$22,044	$17,983	$17,490	$22,044	$17,983
HVAC Equipment1	Capacity (kBtu/h)		Central, Air-Source AC >65 and < 135 kBtu/h				
		EER	9.27	9.27	9.27	9.27	9.27
		Unit Cost/ton	$565	$565	$565	$565	$565
	Number of Units (Tons)		14.31	9.20	9.20	12.68	11.04
	Total Equipment Cost		$8,088	$5,198	$5,198	$7,167	$6,236
Construction Cost			$43,841	$44,515	$44,022	$50,545	$37,928
Annual Energy Consumption							
Electricity, lights and plugs		MMBtu	500	314	327	500	314
Electricity, HVAC		MMBtu	180	112	115	161	134
Natural Gas		MMBtu	23	31	30	22	34
Total Annual Energy Cost2			$14,468	$9,136	$9,482	$14,055	$9,611
Economic Measures							
Life-Cycle Cost Savings				**$66,404**	**$63,055**	**($2,407)**	**$67,843**
Savings-to-Investment Ratio (SIR)				Invest. < 0	Invest. < 0	0.7	Invest. < 0
Adjusted IRR				Invest. < 0	Invest. < 0	6.0%	Invest. < 0

Notes:

1 **Economizer used**

2 **2001 electricity price = 7.2 cents/kWh** **2001 gas price = $4.77 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Table A-1c. Engineering and Cost Summary

Elementary School (WWR=0.17)

Bldg. Size **50,000 sq. ft.**

			Standard Level				
			90A-1980 Base	*IECC2000*	*IECC2000_2 wsf*	*90A-1980 w/2000 Env.*	*90A-1980 w/2000 Light*
Envelope	**Area (sq. ft.)**						
Windows	2,207	u-value(std)	0.790	0.500	0.500	0.500	0.790
		sh. coef.(std)	0.680	0.500	0.500	0.500	0.680
(Window-Wall Ratio = 0.17)		u-value(cost)	0.730	0.497	0.497	0.497	0.730
		sh. coef.(cost)	0.590	0.506	0.506	0.506	0.590
		cost ($/sqft)	$5.13	$8.70	$8.70	$8.70	$5.13
Opaque Walls	10,773	u-value	0.07	0.132	0.132	0.132	0.07
		cost ($/sqft)	$0.86	$0.33	$0.33	$0.33	$0.86
Roof	50,000	u-value	0.032	0.051	0.051	0.051	0.032
		cost ($/sqft)	$2.04	$1.36	$1.36	$1.36	$2.04
	(feet)						
Slab perimeter	998	u-value	0.125	not req'd	not req'd	0.125	not req'd
		cost ($/ft)*	$4.31	$0.00	$0.00	$0.00	$4.31
		*24-inch depth					
Envelope Cost (incremental)			$126,966	$90,678	$90,678	$90,678	$126,966
Lighting							
Lighting Power Density		watts/sqft	1.95	1.50	2.00	1.95	1.50
Lighting Cost per Sq. Foot		$/sqft	$2.54	$1.95	$2.00	$2.54	$1.95
Total Lighting Cost			$126,918	$97,629	$100,110	$126,918	$97,629
HVAC Equipment1	Capacity (kBtu/h)		Central, Air-Source AC >65 and < 135 kBtu/h				
		EER	9.27	9.27	9.27	9.27	9.27
		Unit Cost/ton	$565	$565	$565	$565	$565
	Number of Units (Tons)		56.50	51.01	51.01	57.53	52.93
	Total Equipment Cost		$31,923	$28,819	$28,819	$32,506	$29,905
Construction Cost			$285,808	$217,126	$219,607	$250,102	$254,500
Annual Energy Consumption							
Electricity, lights and plugs		MMBtu	1,134	915	1,158	1,134	915
Electricity, HVAC		MMBtu	487	432	483	478	440
Natural Gas		MMBtu	630	773	686	695	705
Total Annual Energy Cost2			$37,216	$32,112	$37,910	$37,326	$31,967
Economic Measures							
Life-Cycle Cost Savings				**$149,923**	**$74,192**	**$35,053**	**$112,883**
Savings-to-Investment Ratio (SIR)				Invest. < 0	Invest. < 0	Invest. < 0	Invest. < 0
Adjusted IRR				Invest. < 0	Invest. < 0	Invest. < 0	Invest. < 0

Notes:

1 **Economizer used**

2 **2001 electricity price = 7.2 cents/kWh** **2001 gas price = $4.77 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values

Table A-1d. Engineering and Cost Summary

Elementary School (WWR=0.17)

Bldg. Size **50,000 sq. ft.**			Standard Level				
			90A-1980 Base	*IECC2000*	*IECC2000_2 wsf*	*90A-1980 w/2000 Env.*	*90A-1980 w/2000 Light*
Envelope	**Area (sq. ft.)**						
Windows	2,207	u-value(std)	0.790	0.500	0.500	0.500	0.790
		sh. coef.(std)	0.680	0.500	0.500	0.500	0.680
(Window-Wall Ratio = 0.17)		u-value(cost)	0.730	0.497	0.497	0.497	0.730
		sh. coef.(cost)	0.590	0.506	0.506	0.506	0.590
		cost ($/sqft)	$5.13	$8.70	$8.70	$8.70	$5.13
Opaque Walls	10,773	u-value	0.07	0.132	0.132	0.132	0.07
		cost ($/sqft)	$0.86	$0.33	$0.33	$0.33	$0.86
Roof	50,000	u-value	0.032	0.051	0.051	0.051	0.032
		cost ($/sqft)	$2.04	$1.36	$1.36	$1.36	$2.04
	(feet)						
Slab perimeter	998	u-value	0.125	not req'd	not req'd	0.125	not req'd
		cost ($/ft)*	$4.31	$0.00	$0.00	$0.00	$4.31
		*24-inch depth					
Envelope Cost (incremental)			$126,966	$90,678	$90,678	$90,678	$126,966
Lighting							
Lighting Power Density		watts/sqft	1.95	1.50	2.00	1.95	1.50
Lighting Cost per Sq. Foot		$/sqft	$2.54	$1.95	$2.00	$2.54	$1.95
Total Lighting Cost			$126,918	$97,629	$100,110	$126,918	$97,629
HVAC Equipment1	Capacity (kBtu/h)		Central, Air-Source AC >65 and < 135 kBtu/h				
		EER	9.27	9.27	9.27	9.27	9.27
		Unit Cost/ton	$1,325	$565	$565	$1,325	$1,325
	Number of Units (Tons)		56.50	51.01	51.01	57.53	52.93
	Total Equipment Cost		$74,864	$28,819	$28,819	$76,230	$70,129
Construction Cost			$328,749	$217,126	$219,607	$293,826	$294,725
Annual Energy Consumption							
Electricity, lights and plugs		MMBtu	1,134	915	1,158	1,134	915
Electricity, HVAC		MMBtu	265	432	483	261	237
Natural Gas		MMBtu	630	773	686	695	705
Total Annual Energy Cost2			$32,534	$32,112	$37,910	$32,762	$27,685
Economic Measures							
Life-Cycle Cost Savings				**$91,920**	**$16,189**	**$33,582**	**$107,921**
Savings-to-Investment Ratio (SIR)				Invest. < 0	Invest. < 0	Invest. < 0	Invest. < 0
Adjusted IRR				Invest. < 0	Invest. < 0	Invest. < 0	Invest. < 0

Notes:

1 **No economizer used**

2 **2001 electricity price = 7.2 cents/kWh** **2001 gas price = $4.77 /MMBtu**

3 **Years for Analysis = 40** **Discount Rate = 7.0%**

Life-cycle cost savings includes replacement costs and residual values