4 ENERGY EFFICIENCY IN COMMERCIAL BUILDINGS

4.1 INTRODUCTION TO COMMERCIAL BUILDINGS IN APPALACHIA

The Appalachian commercial sector consumed about 1.47 quads of energy in 2006, while total expenditures were more than $10 billion (2006 dollars).[16] Electricity (55 percent) and natural gas (32 percent) were the dominant forms of delivered energy, excluding electricity related losses (EIA, 2008a). When losses are included, the contribution from electricity and natural gas drops to 25 and 15 percent, respectively.

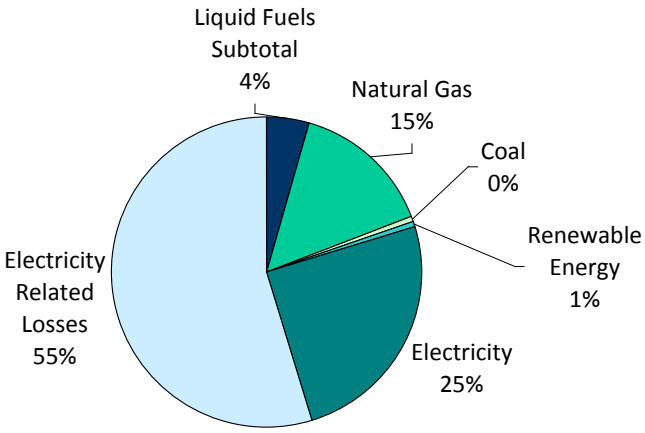

Figure 4.1 Commercial Sector Energy Sources by Fuel, 2006
(EIA, 2008a)

From 2008 to 2030, commercial energy consumption in the Appalachian Region is expected to increase between 45 percent and 63 percent up to between 2.26 and 2.55 quads, Figure 4.2 (EIA, 2007a; 2008a). According to these forecasts, energy consumption is growing more rapidly in commercial buildings than in any other sector.

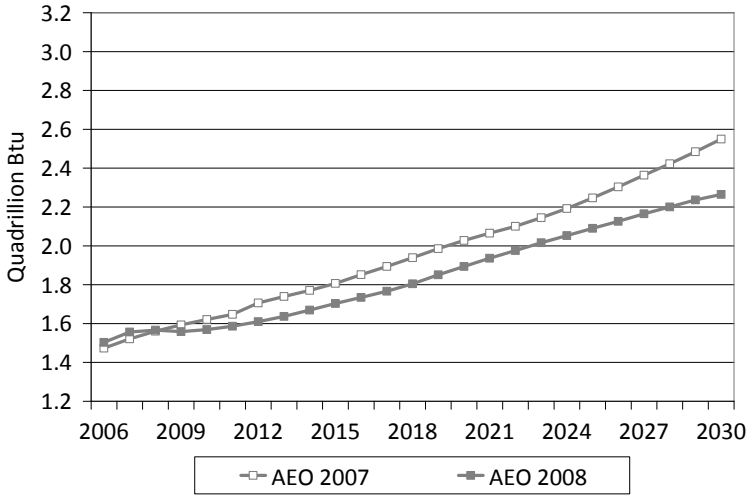

Figure 4.2 Commercial Energy Consumption Forecast for the Appalachian Region (Quads), 2006-2030
(EIA, 2007a; 2008a)

Commercial buildings offer significant energy-efficiency potential – mostly through upgrades to existing building stocks. Due to the longevity of commercial buildings and an economy that is ever more service based, new commercial buildings represent even less of the total stock of commercial buildings than new homes represent of the residential stock each year. See Table 4.1 for median commercial building lifetimes.

[16] Costs include those for distillate fuel oil, residual fuel oil, natural gas, and electricity based on population-weighted average Appalachian prices. Other fuels, such as liquid propane gas, kerosene, coal, and renewable energy were also used by Appalachian commercial buildings in 2006 but excluded from the cost given.

Table 4.1 Median Lifetimes for Selected Building Types
(EIA, 2008b, Table 12)

	Median Expected Lifetime (years)	Gamma[a]
Assembly	80	1.8
Education	80	2.6
Food Sales	65	2.5
Food Service	65	2.5
Health Care	65	2.3
Lodging	69	2
Large Office	73	2
Small Office	73	2
Mercantile/Service	65	1.8
Warehouse	80	1.6
Other	75	2.5

[a] ―Gamma‘ is the ―rate at which buildings retire near their median expected lifetime” (EIA, 2008b).

Types of commercial buildings and end uses in the Appalachian Region differ slightly from national averages. The most significant differences in floorspace are in three building types: the Region has more floorspace in ―Assembly” and less in ―Food Sales” and ―Warehouse.”[17] The Appalachian Region does not differ significantly from national averages in commercial end-uses.

4.2 POLICY OPTIONS FOR COMMERCIAL ENERGY EFFICIENCY

This study models four policies, coupled with incentives, to encourage energy efficiency in commercial buildings: Commercial Building Energy Codes with Third Party Verification, Support for Commissioning of Existing Commercial Buildings, Efficient Commercial HVAC and Lighting Retrofit Incentive, and Tightened Office Equipment Standards with Efficient Use Incentive. There are several other kinds of policies that could be used to encourage more efficient use of energy in commercial buildings. Table 4.2 lists examples of policy actions, including those modeled; listed policies could be used as substitutions or complementary actions. The actual form of policies adopted within the Appalachian Region will depend on the specific goals and capacity of each policy making body.

[17] Religious worship buildings are included in assembly.

Table 4.2 Policy Actions that Support Commercial Energy Efficiency

Actions	Commercial Building Codes	Existing Building Commissioning	HVAC and Lighting Retrofits	Office Equipment Standards
Research, Development, and Demonstration	Support for research and development in advanced building processes and materials	Development of new insulation, heating, and cooling technologies useful for the local climate	Development of new lighting, heating, cooling, and ventilation technologies useful for the local conditions	Support for research and development for innovation in appliance performance
Financing	Low or no-interest loans for incremental cost of improvements for new construction Enable performance contracting	N/A	Low or no-interest loans for incremental cost of improvements for existing buildings Enable performance contracting	Low or no-interest loans for ENERGY STAR equipment Enable performance contracting
Financial Incentives	Incentives to builders for exceeding codes Rebates or lower fees for builders for LEED or ENERGY STAR ratings	*Incentives for cost of commissioning study and necessary repairs or replacements*	*Incremental cost incentives for efficient retrofits* Tax credits for efficient purchases	*Incentives to use efficiency features and lower consumption* Tax credits for efficient purchases Equipment buyback programs
Pricing	N/A	N/A	N/A	N/A
Voluntary Agreements	Agreement between major builders in the area to meet or exceed code	N/A	N/A	N/A
Regulations	*Model Building Energy Code Legislation* *Allowing third-party compliance inspection*	N/A	Tighter lighting and HVAC equipment standards	*Tighter office equipment standards* Standby efficiency standards
Information Dissemination & Training	*Training Architects, Builders, Contractors, and Code Enforcement Officials* Public Awareness campaigns to inform consumers of the benefits of conservation and efficiency measures	Training Architects, Builders, Contractors, and Building Managers Public Awareness campaigns to inform consumers of the benefits of conservation and efficiency measures	Training Architects, Builders, Contractors, and Building Managers Awareness campaigns to inform executives of the benefits of efficiency measures Advanced metering or billing methods	Awareness campaigns to inform executives of the benefits of conservation and efficiency measures Advanced metering and billing
Procurement	Government lead by example procurement programs	Government lead by example procurement programs	Government lead by example procurement programs	Government lead by example procurement programs
Market Reforms	N/A	N/A	N/A	N/A

Table 4.2 Policy Actions that Support Commercial Energy Efficiency

Actions	Commercial Building Codes	Existing Building Commissioning	HVAC and Lighting Retrofits	Office Equipment Standards
Planning Techniques	Low or No-Interest Loans for Incremental Cost of Improvements for New Construction	N/A	N/A	N/A
Capacity Building	Centers for energy efficiency to train next generation of architects, builders, retrofitters	Centers for energy efficiency to train next generation of architects, builders, retrofitters	Centers for energy efficiency to train next generation of architects, builders, retrofitters	N/A

This table describes policy actions available that could further the savings from the policy packages modeled in this study. The policy actions shown in *italics* are modeled in this study, while the others are not.

4.2.1 Research, Development, and Demonstration

Developing advanced building processes and technologies can help to improve the performance of commercial buildings. Building materials and construction and renovation processes are especially important in commercial buildings where ownership changes hands – leading to renovations – many times in the course of the building‘s lifetime. Supporting advanced building materials and process research can help a state or locality to keep talented researchers and money for new technology from leaving the area. Research and development programs can work hand-in-hand with capacity building measures. Demonstration projects can be integrally linked to state procurement programs to help pull new technologies out of the research pipeline. Some states and localities create lead-by-example programs specifically requiring that government buildings must meet stricter standards or achieve year over year savings; these types of procurement programs help generate a demand pull that can keep innovations coming to the marketplace.

4.2.2 Financing

Financing policies can help to reduce the ―first cost” burden, making efficient investments more affordable. Loans available for incremental costs to builders allow them to invest in more efficient equipment and materials; commercial building owners/buyers (who are passed the cost through builders) and commercial building lessees then benefit from lower energy consumption and greater comfort levels. Many commercial buildings are plagued with the economic reality of the principle (owner) not being responsive to the agent‘s (lessees) needs; if owners do not pay the energy bills, they have less of an incentive to invest in equipment with a higher cost.

Mississippi‘s Energy Investment Loan program is broad-based and geared towards helping to drive innovation and offers loans from $15,000 to $300,000 at three percent below prime for capital improvements or design and development of innovative energy conservation practices. North Carolina also has a broad-based loan program based on a service contract structure; the Energy Improvement Loan Program (EILP) provides loans, secured with a letter of credit for non-government borrowers, with interest rates of one percent or three percent, depending on the project, for renewable energy, recycled energy, or energy savings. A more targeted loan program, the New

York Energy Smart Loan Fund, provides for reduced interest rates compared to the lender‘s normal rate for certain renewable or energy efficiency improvements.[18]

State agency performance contracting is a popular financing mechanism. To illustrate, in New York, the New York Power Authority offers performance contracting for state-owned buildings and schools.[19] Some states do not allow agencies to enter into contracts that cover more than the current fiscal year, which can prevent cost effective energy-efficient improvements. While performance contracting may present fiscal complications, it can save energy and taxpayer money in the long run.

4.2.3 Financial Incentives

Tax credits, rebates, reduced fees, and grants can all be used as financial incentives to encourage efficient technologies and practices for commercial buildings. Incentives help to reduce the burden of high costs and may help drive capital towards energy-efficiency improvements. There are many examples of financial incentives already in place throughout Appalachia and the rest of the nation. For example, Maryland‘s Green Building Tax Credit program encourages more efficient new large (more than 20,000 square feet) commercial buildings in targeted areas by offering a credit up to eight percent of the cost of building construction. In New York, there is both a prequalified cost-reduction program and a tax credit available for certain retrofits and new commercial buildings.[20]

Financial incentives are also used for transfers within state government: for example, Virginia‘s Technical Assistance Grant Program offers grants for technical assistance to reduce energy consumption in support of Executive Order 48, which calls for reducing energy consumption in state government facilities. Similarly, West Virginia‘s Lighting Grants Program provides 50/50 matching grants to state and local government facilities and schools; nonprofit hospitals, and public libraries for lighting improvements having a payback less than five years based on an EPA ENERGY STAR lighting audit.

4.2.4 Voluntary Agreements

Voluntary agreements, where builders agree to work towards greater efficiency, can have significant savings. For example, the Model Conservation Code in the northwest was gradually adopted by states as codes after builders innovated through voluntary standards (EPA, 2006). The Building America and Rebuild America programs are good examples of national voluntary innovation programs, with many leading builders, states, and national laboratories partnered together to improve building materials, technologies, and process.

4.2.5 Regulations

Regulating minimum efficiency levels through promulgation of standards and codes can reduce proliferation of poorly performing equipment, buildings, and practices. Model energy codes, subject to review and update, set a new minimum level of efficiency; this ensures that the average new

[18] The interest rate reduction for New York‘s Energy Smart Loan Fund for most of the state is up to 4.0 percent (400 basis points). Con Edison customers may be eligible to receive an interest rate reduction up to 6.5 percent (650 basis points) less than a Participating Lender's or Lessor's normal market rate. See http://www.nyserda.org/loanfund.default.asp

[19] Details about New York Power Authority‘s performance contracting program can be found at: http://www.nypa.gov/services/esp.htm

[20] See http://www.nyserda.org/programs/Existing_Facilities/default html and http://www.dec ny.gov/regs/4475 html

commercial building doesn't fall too far behind the leading new commercial buildings as materials, practices, and habits change. Regulation and standards-setting can be done at all levels of government; however, local and state standards and regulations are subject to pre-emption by the federal government.

Some regulations set the foundation for other processes to work; for example, regulating contractors enables third party verification of savings and labeling while regulating lenders or utility actions enables performance contracting or other favorable financing options.[21] With a third-party verification program, builders or retrofitters would be required to contract with a state or locally certified third party to verify compliance; any expenses associated with inspection and verification would be undertaken by the builder or contractor rather than the jurisdiction. California, New York, and Washington already use this type of program for building energy codes, with high compliance rates (EPA, 2006; Smith and McCullough 2001; Vine 1996). However, allowing for third party contracting takes time; for example, from adoption to effectiveness, the state of Washington spent three years (with utility funding) setting up training and certification programs to move their non-residential code to a system allowing for third party inspection (Kunkle, 1997).

4.2.6 Information Dissemination & Training and Capacity Building

Lack of sufficient, trusted information is almost always a barrier to energy efficiency; there is simply not enough time for people and organizations to learn about energy savings measures and figure out how to incorporate the measures in a beneficial way (Brown et al., 2008). Training and information as well as capacity building programs can support the goals of improved energy performance by ensuring that there is a knowledgeable workforce in place to produce efficient homes. Most states offer programs to provide information to consumers through websites, printed brochures or flyers, and seminars or workshops. An example of capacity building is West Virginia's Building Energy Use Centers which provide the state with educational centers and the technical expertise to support programs like *Saving Energy in West Virginia Schools*.

4.3 MODELED SAVINGS IN APPALACHIAN COMMERCIAL BUILDINGS

4.3.1 Commercial Building Energy Codes with Third Party Verification

Building codes lay out requirements for new building construction. For commercial buildings, model building energy codes, like the International Energy Conservation Code (IECC), are developed by either the ASHRAE or the International Code Council (ICC). One of the requirements for modifications to the code is that they be cost effective.

A problem that arises with modeling building energy code savings is dealing with under- or over-compliance. In some cases, the newer code recommendations are such an improvement that there is compliance with the newer code before its adoption (over-compliance); therefore, the assumption that existing buildings do not already meet the newer code (built into an efficiency model) would lead to an over-estimation of savings. In other cases, promulgated codes are not enforced, and under-compliance with the existing codes could lead to an under-estimation of savings.

[21] See section 4.2.1 for examples of financing mechanisms

As shown in Table 4.3, three of the 13 Appalachian states do not have mandatory commercial building energy codes: Alabama, Mississippi, and Tennessee. Four of the ten states with mandatory codes have dated vintages from 2003.

Table 4.3 State Commercial Building Energy Codes

State	Commercial Energy Code	Mandatory
Alabama[1]	ASHRAE/IESNA 90.1-2001	No
Georgia	ASHRAE/IESNA 90.1-2004	Yes
Kentucky	2006 IECC and 2006 IBC	Yes
Maryland	2006 IECC	Yes
Mississippi[2]	ASHRAE 90-1975	No
New York	2006 IECC	Yes
N. Carolina[3]	2003 IECC (ASHRAE 90.1-2004)	Yes
Ohio	2006 IECC (ASHRAE 90.1-2004)	Yes
Pennsylvania	2006 IECC (ASHRAE 90.1-2004)	Yes
S. Carolina	2003 IECC	Yes
Tennessee[4]	ASHRAE 90A-1980 and 90B-1975	No
Virginia	2006 IECC	Yes
W. Virginia	2003 IECC	No

[1] Alabama's code is state specific – the Alabama Building Energy Conservation Code is mandatory for state government buildings and recommended for other commercial buildings (ADECA, 2005). There are also local adoptions of 2003 and 2006 IECC.
[2] Mississippi's commercial code is mandatory for state government buildings, public buildings, and high-rises (BCAP, 2008).
[3] North Carolina's code is state specific, but it is based on the 2003 IECC with reference to the ASHRAE 90.1-2004.
[4] Tennessee is scheduled to update to the 2003 IECC on January 1, 2009 (TNleg, 2008).

The policy package modeled here assumes that all states within the Appalachian Region adopt the 2006 IECC commercial code or equivalent in 2009 with an effective date of 2010. The initial savings are assumed to come exclusively from lighting with this change, as the major difference between the 2001 and 2003 IECC (and 2004 ASHRAE 90.1) commercial code was in lighting density requirements. If the shell efficiencies are significantly different from the current practice in Mississippi and Tennessee (with codes based on ASHRAE 1975 and 1980 versions), savings for space heating and cooling in new buildings will be underestimated. Documentation of the methodology for calculating savings from improved commercial building energy codes can be found in Appendix C.1. These savings are assumed to be made through 80 percent compliance with model building code legislation enabled by third-party verification of code compliance.

Energy savings from Commercial Building Codes are expected to be about 2.3 percent of forecast commercial consumption by 2030 (Table 4.4). For comparison, this is about half the percent of energy savings estimated for residential building codes with third-party verification (see Chapter 3).

Table 4.4 Energy Savings from Commercial Building Codes

Year	Electricity Savings	Natural Gas Savings	Fuel Oil Savings	Total Primary Energy Saved	% of Sector Primary Energy
	(GWh)	(trillion Btu)	(trillion Btu)	(trillion Btu)	
2010	84	0.00	0.00	0.92	0.06
2013	391	0.05	0.01	4.34	0.27
2020	1,551	0.73	0.11	18.48	0.98
2030	3,993	3.12	0.00	51.09	2.26

Costs for administering the commercial building energy codes are less than $2 million, annually, and includes two training personnel per state (apportioned) and one verification liaison per 10 million new square feet of commercial floorspace. Investment costs reflect the incremental cost of meeting the codes and increase from around $37 million in 2010 to nearly $47 million in 2030. Energy bill savings grow from almost $8 to $388 million over the study‘s time horizon (Table 4.5).

Table 4.5 Costs and Savings from Commercial Building Codes

Year	Energy Savings	Admin Costs	Investment Costs
	(million 2006$)	(million 2006$)	(million 2006$)
2010	7.95	1.60	37.47
2013	36.03	1.63	38.80
2020	144.65	1.72	42.39
2030	387.87	1.83	46.74

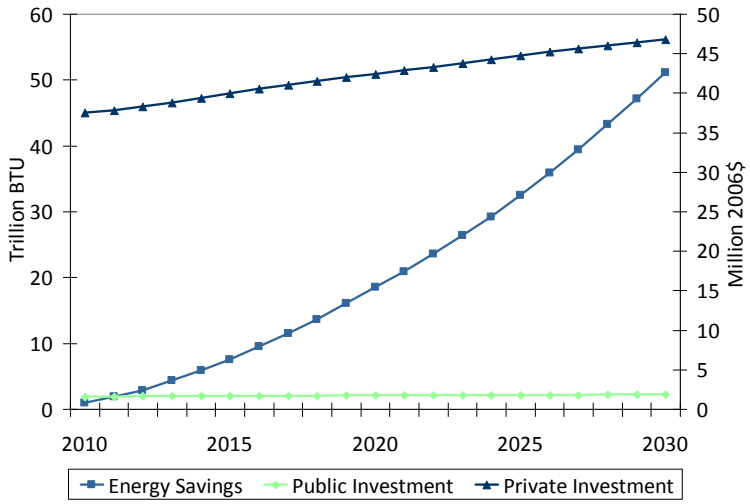

Figure 4.3 Annual Investment and Energy Savings from Commercial Building Codes, 2010-2030

Figure 4.3 illustrates the time-line of expenditures and savings for commercial building codes. Public investment (administrative costs and incentives) remains less than $2 million throughout the program while private investment increases to cover the incremental costs of more efficient commercial buildings. Annual savings grow steadily throughout the study horizon because of the long lifetime of building stock and a growing number of commercial buildings are meeting energy codes.

The Commercial Building Energy Codes with Third Party Verification is cost-effective with a benefit-to-cost ratio of about 2.5 for participants and about 2.8 for society. With $36.2 million in program spending and an additional $887.7 million in customer investments over the 2010-2030 period, the Appalachian region could see net cumulative savings of 441.5 trillion Btu, saving $3.4 billion in energy bills by 2030. This is the equivalent of about 2.3 percent of the EIA's forecast consumption or 7.3 percent of forecast growth (EIA, 2008a).

4.3.2 Support for Commissioning of Existing Commercial Buildings

Building a commercial structure is a complicated process, combining architectural design and construction as well as building systems design (e.g., HVAC) and installation. Often many different designers, contractors, and subcontractors are a part of the process, and as the complexity of the project increases, so does the probability of incorrect installation. In addition to problems with construction or installation, as a building matures, equipment can become obsolete or be altered to operate off-design. Building commissioning is a multi-phase process to ensure building performance is as designed and that the building's operation meets the needs of its occupants. According to the New York State Energy Research and Development Authority (NYSERDA, 2004) the commissioning of existing buildings should include four steps: planning, investigation, implementation, and handoff. Through measurement and inspection, a building's envelope, HVAC equipment, and other systems are evaluated against initial design documentation and corrective actions are taken, often with resulting energy savings.

Commissioning existing buildings in the Appalachian Region could lead to immediate energy savings. In a meta-analysis conducted by Lawrence Berkeley National Laboratory, up to 57 percent of the total building energy was saved, though the median value for buildings that did not purchase thermal products was 10 percent (Mills et al., 2004).

One policy that currently supports commissioning of existing buildings in the Appalachian Region is the NYSERDA Existing Facilities Program (NCSC/IREC, 2008). This program provides financial incentives for energy-efficiency improvements to most non-single family structures. Actions undertaken to correct off design performance that cost more than $10,000 are eligible for energy rate

rebates as well as reduction in demand rate charges. A public benefit fund is the source of funds for this program.

Findings from the LBNL meta-analysis (Mills et al., 2004) and a study by Portland Energy Conservation and Oak Ridge National Laboratory (Haasl and Sharp, 1999) were used to estimate the energy savings potential in the ARC Region. The modeled program consists of commissioning incentives for the first ten years of the program as well as program administration to lead public-awareness campaigns, evaluate private-sector commissioning companies, study program effectiveness, and suggest program improvements as needed. Details of the modeling methodology are provided in Appendix C.2.

Energy savings from commissioning of existing buildings are shown in Table 4.6. Modeled savings from commissioning grow from about three trillion Btu in the first year of the program to 391 trillion Btu by 2030. Energy savings grow from 7.8 percent of forecast commercial energy consumption in 2020 to 17 percent in 2030.

Table 4.6 Energy Savings from Commissioning of Existing Commercial Buildings

Year	Electricity Savings	Natural Gas Savings	Fuel Oil Savings	Total Primary Energy Saved	% of Sector Primary Energy
	(GWh)	(trillion Btu)	(trillion Btu)	(trillion Btu)	
2010	213	0.69	0.38	3.25	0.21
2013	1,868	5.84	1.50	28.11	1.72
2020	9,886	30.54	5.82	148.15	7.82
2030	26,611	76.51	11.46	390.77	17.26

The costs and savings related to the commissioning of existing commercial buildings can be found in Table 4.7. Energy savings are based on savings by fuel and forecast energy prices (EIA, 2008a). Administrative costs include costs of personnel to distribute and monitor incentives as well as provide information to increase awareness of the benefits of commissioning. Investment costs reflect the full cost of commissioning, both public incentive and private expenditure.

Table 4.7 Costs and Savings from Commissioning of Existing Commercial Buildings			
Year	**Energy Savings**	**Admin Costs**	**Investment Costs**
	(million 2006$)	**(million 2006$)**	**(million 2006$)**
2010	22.67	1.33	22.68
2013	183.16	5.02	72.57
2020	971.08	8.44	129.70
2030	2,759.95	9.70	151.39

The public investment, including administrative costs and an incentive, rises and falls over the first ten years, as a reflection of the declining incentive rate. Private investment grows to a steady state while annual energy savings increase the entire study horizon (Figure 4.4).

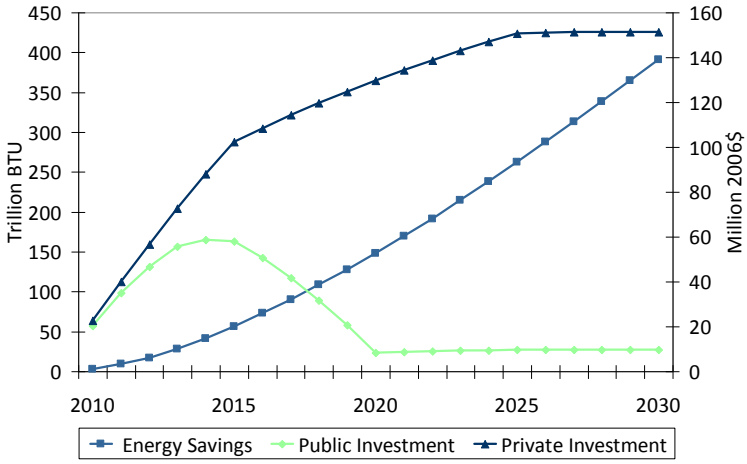

Figure 4.4 Annual Investment and Energy Savings for Commissioning, 2010-2030

Support for Commissioning of Existing Commercial Buildings is cost-effective with a benefit-to-cost ratio of about 8.1 for participants and about 9.5 for total resource costs. With $522 million in program spending and an additional $2.4 billion in customer investments over the 2010-2030 period, the Appalachian Region could see net cumulative savings of 3.5 quads, saving $23.4 billion in energy bills by 2030. This is the equivalent of about 17.3 percent of the EIA's forecast consumption or 56.1 percent of forecast growth (EIA, 2008a).

4.3.3 Efficient Commercial HVAC and Lighting Retrofit Incentive

Retrofits are designed as improvements to existing buildings. Major structural renovations to commercial buildings may occur only once or twice during its lifetime. In contrast, commercial lighting and HVAC equipment are replaced more frequently.

A commercial retrofit program would include incentives and information to accelerate adoption of more efficient products. This type of program helps to induce stock turnover – removing the least efficient equipment, while also fostering investment in newer technology. High demand for the most efficient products can drive investment in commercialization of even better equipment, which in turn pushes the market to a more efficient average and can reduce the costs of efficiency as a product attribute. The modeling methodology for commercial retrofits is detailed in Appendix C.3.

Lighting represents about 13 percent of commercial energy consumption in the Appalachian Region (EIA, 2008a). Savings in lighting have a short payback and offer great opportunities – especially for buildings designed before computers were commonplace. For example, computer workstations require less ambient lighting than paper workstations. In addition, newer lights give off greater lighting, so fewer lights are needed even in areas where non-computer work is occurring. Savings come through upgrading magnetic to basic or premium electronic ballasts, greater lumens per watt for newer lamps, and fewer lamps overall.

Retrofitting lighting assumes that lighting as an end-use will become 60 percent more efficient than forecast by 2030. Of this 60 percent, 14 percent is for replacement of ballasts, the other 46 percent is an assumed technology development and decrease in lamps per square foot. This model reflects adoptions of efficient technology without changing the standards for lighting; if standards are tightened, savings expected from an incentivized retrofit would need to be reduced in comparison to a new forecast stock efficiency. Reductions in lighting energy use have been shown to increase heating loads while reducing cooling loads; however, there is less of an increase in heating because this usually occurs at night (Sezgen and Koomey, 1998). The present study does not model this effect for the Appalachian Region; future research may examine this effect and adjust forecast savings.

In addition to savings discussed here via retrofit of lighting equipment, some energy used for lighting could be saved through conservation and management practices. About half of the commercial floorspace in the ARC is reported to be at least partially lit when the building is closed (Figure 4.5).

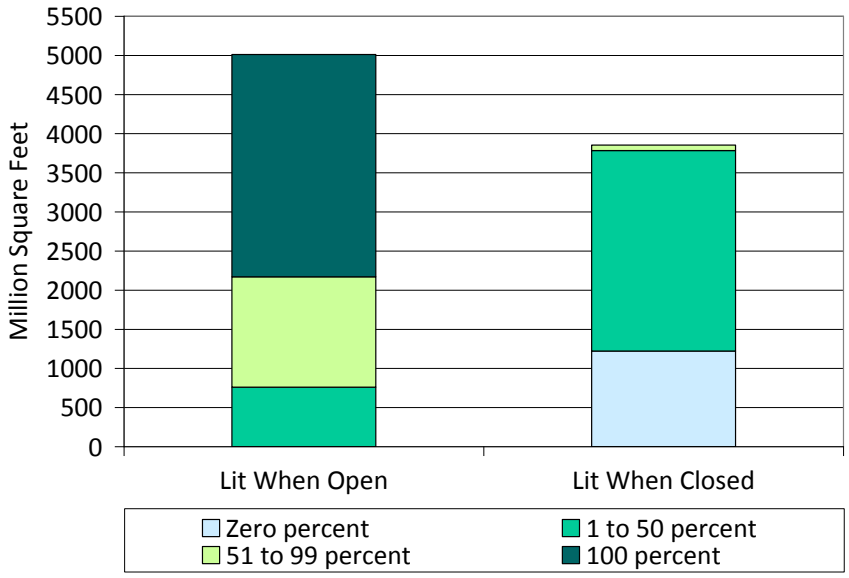

Figure 4.5 Percent of ARC Commercial Floorspace Lit When Buildings are Open and Closed, 2003 (million square feet)
(Source: EIA, 2007b)

In addition to lighting, we model savings from retrofit of heating, ventilation, and cooling (HVAC) equipment – which accounts for about 28 percent of commercial consumption in the Appalachian Region. Most of the commercial floorspace in the Region is heated or cooled (Figure 4.6). Table 4.5 shows several types of polices that could complement or substitute for the modeled program of incentivizing highly efficient replacements for lighting and HVAC retrofits.

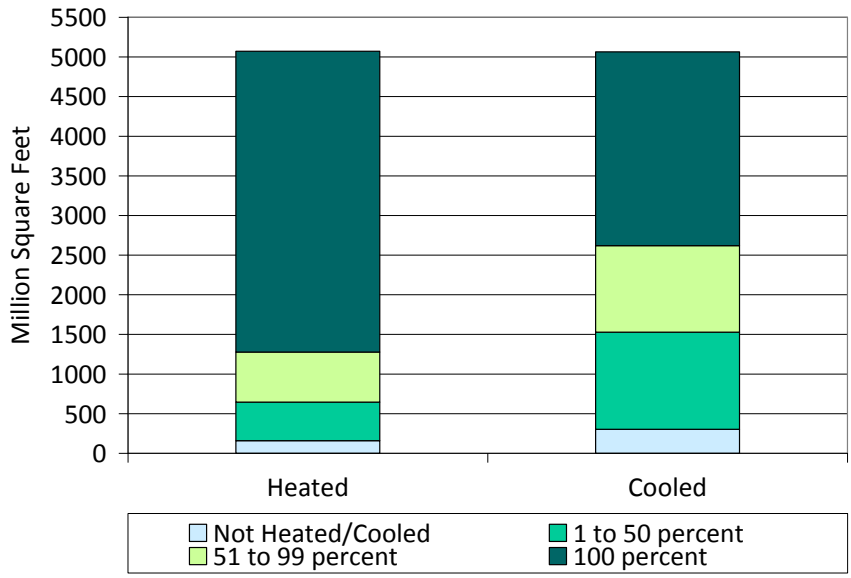

Figure 4.6 Percent of ARC Commercial Floorspace Heated and Cooled, 2003 (million square feet)
(EIA, 2007b)

Modeled energy savings from HVAC and Lighting Retrofits exceed 10 percent of forecast commercial consumption by 2020 and reach almost 20 percent by 2030 (Table 4.8).

Table 4.8 Energy Savings from HVAC and Lighting Retrofits

Year	Electricity Savings (GWh)	Natural Gas Savings (trillion Btu)	Fuel Oil Savings (trillion Btu)	Total Primary Energy Saved (trillion Btu)	% of Sector Primary Energy
2010	712	1.50	0.41	9.44	0.60
2013	3,489	7.46	1.28	46.66	2.85
2020	14,129	29.70	4.46	194.55	10.27
2030	31,661	61.40	8.33	447.08	19.74

Energy bill savings are based on savings by fuel and forecast energy prices (EIA, 2008a). The administrative costs reflect personnel to distribute incentives, monitor performance, and provide information. Investment costs represent the total incremental cost of the efficient technologies, including incentives. Table 4.9 illustrates these costs and savings for select years.

Table 4.9 Costs and Savings from HVAC and Lighting Retrofits

Year	Energy Savings (million 2006$)	Admin Costs (million 2006$)	Investment Costs (million 2006$)
2010	87.88	0.47	217.75
2013	403.56	1.93	225.31
2020	1,607.94	5.78	245.08
2030	3,688.81	11.04	79.17

Figure 4.7 shows the annual public investment, including administrative costs and incentives, rising slowly during the incentive period (2010 to 2020) and then dropping to a maintenance level that covers administrative costs for continuing education and outreach efforts. Private investment, incremental costs minus incentives until 2020, continues to grow until it plateaus and drops. The drop is caused by a decrease in the rate of retrofit – rather than five additional percent of buildings retrofit, only one percent are retrofit in the last years of the study horizon; this is due to reaching a large percentage of buildings over the aggressive first years of the program. Savings grow rapidly until 2027 when their growth is slowed by the same phenomenon.

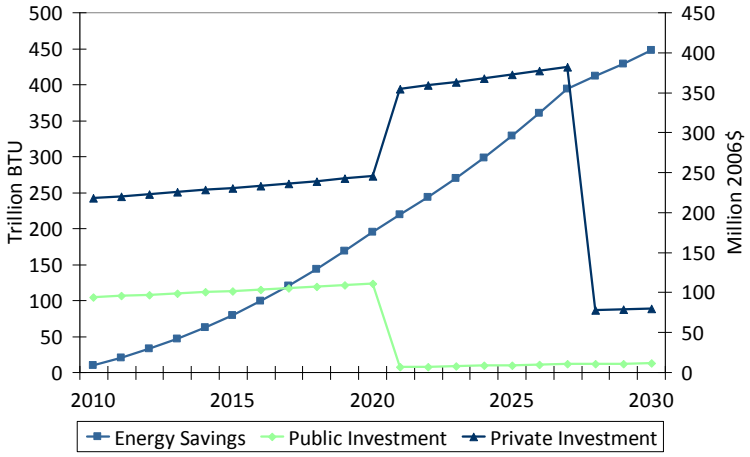

Figure 4.7 Annual Investments and Energy Savings from HVAC and Lighting Retrofits, 2010-2030

The Efficient Commercial HVAC and Lighting Retrofit Incentive is cost-effective with a benefit-to-cost ratio of about 4.8 for participants and about 5.9 for total resource costs. With $1.2 billion in program spending and an additional $5.4 billion in customer investments over the 2010-2030 period, the Appalachian Region could see net cumulative savings of 9.4 quads, saving $83.8 billion in energy bills by 2050. This is the equivalent of about 19.7 percent of the EIA's forecast consumption or 64.2 percent of forecast growth (EIA, 2008a).

Box 4.1 Research and Development Example: Solid State Lighting (SSL)

Solid-state lighting (SSL) is a form of lighting technology that is dramatically more efficient than conventional lighting technologies, such as incandescent and fluorescent bulbs. Light emitting diodes (LEDs) are the form of SSL that hold the most market potential. Colored light LEDs have been on the market for several years – they are often used in traffic lights, exit signs, and other lights that remain on almost constantly. As research has progressed, costs have gone down steadily. However, the development of white light LEDs is a recent technological breakthrough.

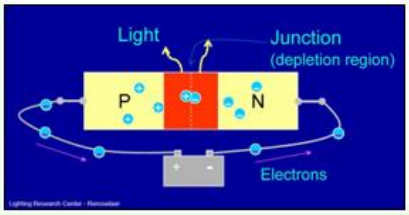

Figure 4.8 Diagram of an LED

Unlike other lighting technologies, LEDs use electric current passed through semiconductors to produce light. Different colors of light are created by using different materials in the diode. Technology improvements are expected to bring brighter white light LEDs that provide light as good as or better than existing fluorescent fixtures with 25 to 45 percent less electricity usage. With successful R&D in these products, energy savings nationwide over all sectors could be as high as three to four quads (Navigant, 2006). As SSL technology advances, it is likely to become better suited to a broader array of applications. Future R&D goals include improving the light quality, increasing efficiency, and reducing prices. The potential energy savings will depend on how quickly and to what extent these developments occur. SSL was originally chosen to represent the technology‘s potential for the commercial sector, and although it will have the greatest impact there, SSL is also expected to transform residential and industrial lighting demand. Therefore, our analysis of LEDs potential includes all three sectors.

Under the aggressive research and development agenda being pursued by the U.S. Department of Energy, these substantial energy savings are very possible. A recent study on the market potential of SSL technology by Navigant (2006) determined that by 2027, LEDs could completely replace incandescent lighting and substantially replace most other forms of lighting in all sectors – residential, commercial, and industrial. Because incandescent bulbs are the least efficient form of lighting currently on the market, replacement of these bulbs with LEDs translates into tremendous savings of electricity. Table 4.10 illustrates the savings that could be achieved from LEDs in comparison to lighting retrofits. Total market penetration potential by 2027 is estimated at 89 percent to 95 percent, depending on the sector (Navigant, 2006). With this level of the market switching to LEDs, other forms of lighting would be rendered almost obsolete.

Table 4.10 Projected Lumens per Watt

	2007	2012	2017	2022	2027
LED	53.1	111	155.3	175	183.1
Lighting Retrofits[a]	40.9	66.2	80.3	95.4	107.8
***AEO 2008* (EIA, 2008a)**	40.9	43.7	45.0	45.8	46.4

[a] Lighting retrofit efficiency only applicable to commercial sector; *AEO 2008* forecast for commercial sector lighting efficiency is included for comparison

Overall, the Navigant (2006) study estimates that LEDs could lead to 30 percent or more electricity saved annually. Following *AEO* 2008 estimates, in 2006 lighting accounted for approximately 26 percent of electricity usage in the Appalachian Region. By 2030 its share is expected to drop to 19 percent, in part due to recent Congressional action on lighting standards. Applying these percentages to our projections of electricity use in Appalachia, we estimate the amount of electricity consumed for lighting purposes was estimated, and the results are presented in Table 4.11.

Table 4.11 Electricity and Lighting Demand in the Appalachian Region

	2006	2013	2020	2030
Electricity Demand (Quads)	1.14	1.25	1.37	1.56
Percent Electricity Used in Lighting	25.8	21.2	21.2	19.0
Electricity Used in Lighting (Quads)	0.29	0.27	0.29	0.30

Figure 4.9 shows the estimated savings of primary energy for national energy consumption. The reference case in this analysis does not account for the changes in lighting standards beginning in 2008, so the energy savings attributable to LEDs estimated by Navigant are larger than possible with the updated base case scenario.

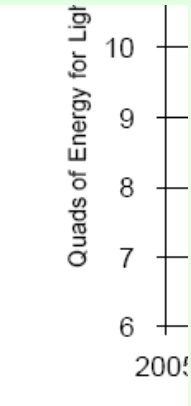

Figure 4.9 U.S. Energy Consumption for Lighting Through 2007 (Quads)

Lighting demand for the Appalachian Region is expected to increase by little more than 10 percent between 2006 and 2030 (EIA, 2008a). However, under the LED scenario lighting demand would be expected to decrease by more than 20 percent. If in 2030 the Region used 20 percent less energy for lighting than projected, a savings of 0.06 quads, or 3.8 percent of the projected BAU electricity consumption, would be expected for that year alone. Although the significant savings will not begin before 2015, the long term effects of LEDs on the electricity consumption in the Appalachian Region are substantial for all sectors.

4.3.4 Tightened Office Equipment Standards with Efficient Use Incentive

Appliance and equipment standards have been successfully applied since 1977 in the United States to set minimum efficiency levels for new appliances and equipment. However, standards have been developed more for residential appliances than commercial equipment. Rosenquist et al. (2006) use a national model of energy savings through appliance and equipment standards and find that the commercial sector standards have greater net present value than standards in the residential sector, in general. Standard-setting for office equipment – especially standby power rates – could provide savings in this sector with lower public costs than an incentive. Currently, end-uses like cooking and office equipment are not covered by Federal standards for commercial and industrial equipment; however, the EPA has developed ENERGY STAR guidelines for many of these products.[22]

Our current model focuses only on office equipment, including: computers, copiers, printers, monitors, multi-function devices, fax machines, and scanners. Savings are based on the forecast for "office equipment" as an end-use and not on proposed savings by technology, like copiers, because the EIA forecast, on which this model is based, does not provide more technology specific data. Methodology for estimating savings from commercial equipment standards can be found in Appendix C.4.

Energy savings from Office Equipment Standards are expected to be almost three percent of forecast commercial consumption by 2020 and more than six percent in 2030 (Table 4.12).

Table 4.12 Energy Savings from Office Equipment Standards

Year	Electricity Savings (GWh)	Natural Gas Savings (trillion Btu)	Fuel Oil Savings (trillion Btu)	Total Primary Energy Saved (trillion Btu)	% of Sector Primary Energy
2010	387	0.00	0.00	4.21	0.27
2013	1,060	0.00	0.00	11.62	0.71
2020	4,673	0.00	0.00	53.20	2.81
2030	12,017	0.00	0.00	143.16	6.32

The administrative and investment costs and energy bill savings related to office equipment standards and incentives can be found in Table 4.13. Energy bill savings are based on modeled savings and forecast electricity prices (EIA, 2008a). Administrative costs reflect personnel to promulgate standards, distribute incentives, and provide public information. Investment costs are the total incremental cost of more efficient equipment compared to stock efficiency, including incentives.

[22] Chapter 7 of the Buildings Energy Data Book provides details on Federal standards: http://buildingsdatabook.eren.doe.gov/ChapterView.aspx?chap=7#2). ENERGY STAR guidelines for office equipment can be found at: http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductCategory&pcw_code=OEF

Table 4.13 Costs and Savings from Office Equipment Standards			
Year	**Energy Savings**	**Admin Costs**	**Investment Costs**
	(million 2006$)	**(million 2006$)**	**(million 2006$)**
2010	37.83	0.53	49.77
2013	96.71	0.33	25.75
2020	420.04	1.71	28.01
2030	1,098.05	3.11	31.67

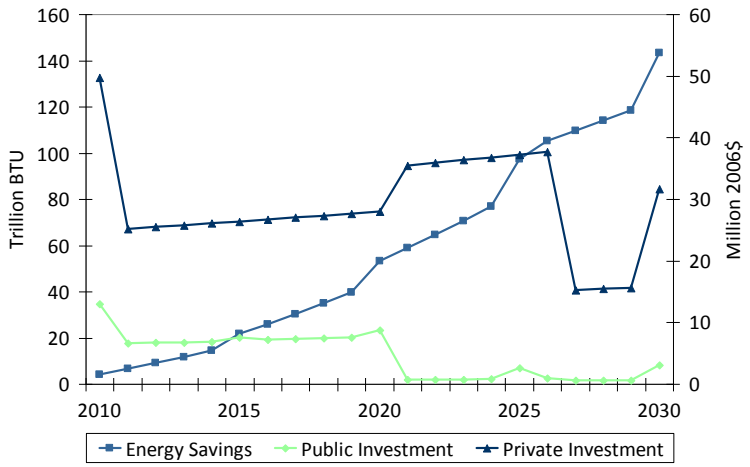

Figure 4.10 Annual Investment and Energy Savings from Office Equipment Standards, 2010-2030

The code adoption cycle is evident in the changing annual costs over the program horizon (Figure 4.10). In 2010, the costs are high as standards become effective and the newer equipment is still expensive to adopt. However, the cost ―bumps" are smaller for subsequent standards changes; this is expected because the standard has a ―built-in" increase that can be anticipated and met at lower cost than the first standard. Energy savings (all electric) rise over the study horizon with larger jumps associated with each new standard.

These results suggest that tightening standards on other equipment – especially cooking equipment which is a large end-use – could also significantly reduce commercial energy consumption. The Tightened Office Equipment Standards with Efficient Use Incentive is cost-effective with a benefit-to-cost ratio of about 8.6 for participants and about 9.9 for total resource costs. With $96.8 million in program spending and an additional $612.6 million in customer investments over the 2010-2030 period, the Appalachian Region could see net cumulative savings of 1.3 quads, saving $10.7 billion in energy bills by 2035. This is the equivalent of 6.3 percent of the EIA's forecast consumption or 20.6 percent of forecast growth (EIA, 2008a).

4.4 SUMMARY OF EFFICIENCY POTENTIAL FOR COMMERCIAL BUILDINGS

Our analysis of commercial building policies suggests that moving existing buildings and equipment to the best practice produces much greater energy savings in the Appalachian Region than improving new buildings (Figure 4.11).

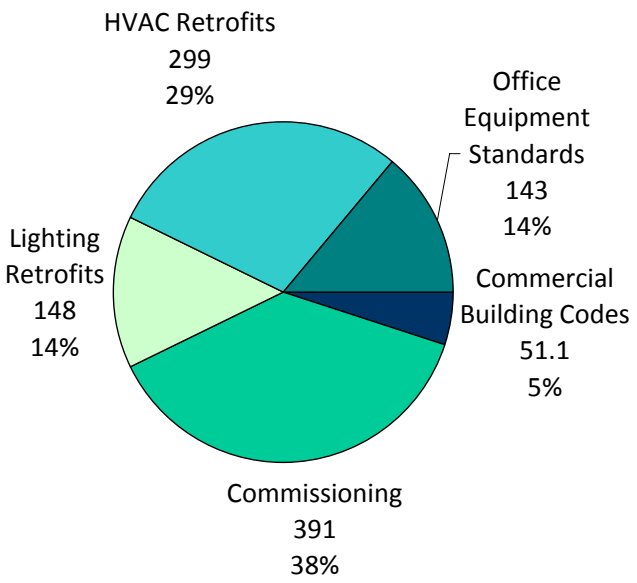

Figure 4.11 Commercial Primary Energy Savings by Policy Package (trillion Btu), 2030

However, a policy that promotes accelerated turnover of HVAC and lighting equipment would likely be used by those buildings under commissioning. Therefore, we do not expect savings from commissioning and retrofits to be completely additive. Figure 4.12 shows the relative efficiency contribution with commissioning considered as wholly included in retrofits of lighting and HVAC.

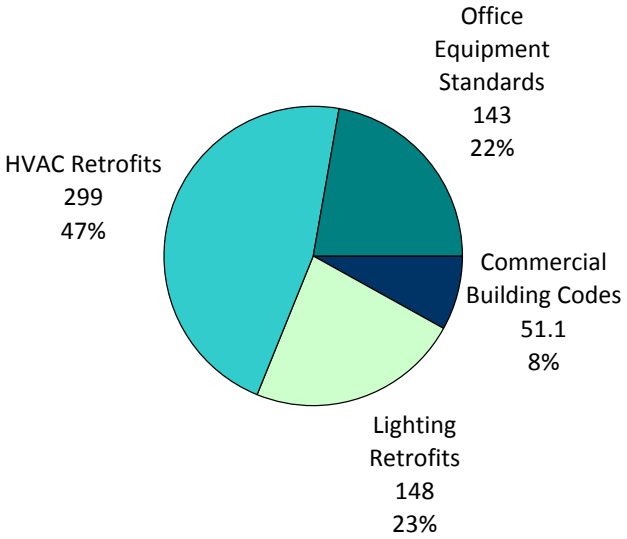

Figure 4.12 Cumulative Savings by Policy Package with Commissioning Included in Retrofits (trillion Btu), 2030

If the four policy packages presented here provide additive results, the forecast growth would be more than completely offset by efficiency, over 200 trillion Btu less than 2006 consumption (Figure 4.13).[23] Even with commissioning considered a subset of retrofits, there are significant savings (28 percent of forecast commercial consumption in 2030) – with efficiency offsetting about 92 percent of forecast growth in commercial sector consumption. Since the *AEO* 2008 forecast already includes new efficiency requirements from EISA 2007, it is clear that these policies provide even greater savings.

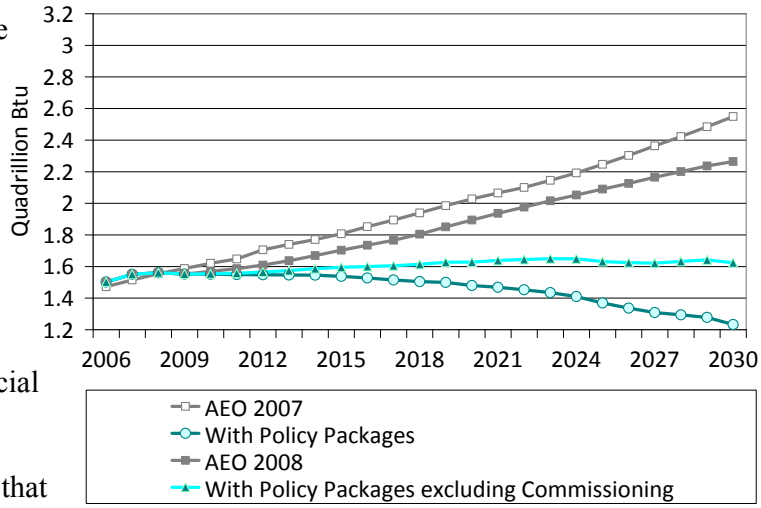

Figure 4.13 Commercial Consumption With and Without Policy Packages (trillion Btu, Primary), 2006-2030

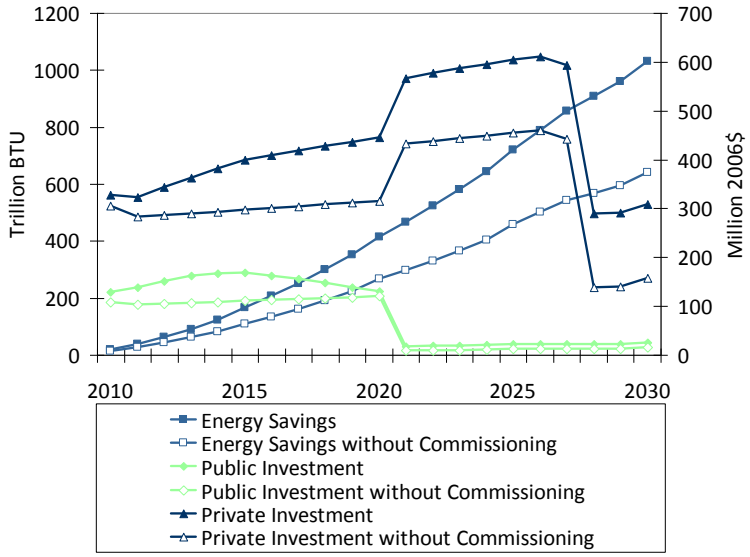

Figure 4.14 Annual Investments and Energy Savings for the Commercial Policy Package, 2010-2030

Figure 4.14 shows how investments and energy savings change over time. Public investment (administrative costs and incentives) peaks around 2015, declines as incentive percentages decrease to commissioning programs, and drops off to a maintenance level to support education and outreach after 2020; when commissioning is included in retrofits, the peak disappears. Private investment continues to grow and peaks in 2026. The drop in private investment does not reflect an end to the market transformation effect of these programs; rather, it demonstrates the saturation of commercial buildings with retrofit or new buildings and continues at a much slower pace to continuously update this vintage of buildings to better performance.

Table 4.14 shows the net present value through the participants and total resource cost tests. These reported figures are aggregate, individual costs and benefits will vary greatly – especially at the participant level where complexities of commercial buildings will favor some structures and uses much more than others. These estimated savings are in line with contemporary electricity efficiency studies for states in the Region. Efficiency potential studies completed for Georgia Power and the Georgia Environmental Facilities Authority found maximum achievable electric efficiencies of 11 percent over 10 years and 9.6 percent over five years, respectively (ICF, 2005; Nexant, 2007). A

[23] While the *AEO 2007* (EIA, 2007a) and *AEO* 2008 (EIA, 2008a) forecasts are shown, the savings are based on and subtracted from the *AEO 2008*.

study for North Carolina found a maximum achievable potential for commercial electric efficiency of 12 percent over a 10 year horizon (GDS Associates, 2006). An efficiency potential study for Kentucky modeled minimally and moderately aggressive scenarios with commercial savings of 1.5 percent and 6.8 percent, respectively, over 10 years (KPPC, 2007). More recently, a report by ACEEE et al. (2008) presented commercial savings for Virginia at 28 percent of their forecast electricity consumption in 2025.

Table 4.14 Results of Economic Tests for Commercial Policies

	Building Codes	Commissioning	Retrofit	Equipment Standards	Total
Participants Test					
NPV Benefits (billion 2006$)	0.89	8.48	13.41	2.65	25.44
NPV Costs (billion 2006$)	0.35	1.05	2.78	0.31	4.49
Net Benefits-Costs (billion 2006$)	0.54	7.43	10.63	2.34	20.95
B/C Ratio	2.54	8.08	4.83	8.62	5.67
Total Resource Cost Test					
NPV Benefits (billion 2006$)	1.29	13.61	20.60	3.81	39.31
NPV Costs (billion 2006$)	0.46	1.43	3.50	0.39	5.78
Net Benefits-Costs (billion 2006$)	0.82	12.18	17.09	3.42	33.52
B/C Ratio	2.78	9.52	5.88	9.89	6.80

The commercial policy package modeled in this study is cost-effective with a benefit-to-cost ratio of about 5.7 for participants and about 6.8 for total resource costs. With $1.9 billion in program spending and an additional $9.3 billion in customer investments over the 2010-2030 period, the Appalachian region could see net cumulative savings of 19.3 quads, saving $156.9 billion in energy bills by 2050. This is the equivalent of about 46 percent of the EIA's forecast consumption in 2030 or 148 percent of forecast growth from 2010-2030 (EIA, 2008a).

The above discussion includes all four policies as additive. As discussed previously, commissioning and retrofit of HVAC and lighting may not be additive. If commissioning results are not considered, the policy package is still cost-effective with a benefit-to-cost ratio of about 4.9 for participants and about 5.9 for total resource costs. With $1.3 billion in program spending and an additional $6.9 billion in customer investments over the 2010-2030 period, the Appalachian Region could see net cumulative savings of 11.1 quads, saving $100.1 billion in energy bills by 2050. This is the equivalent of about 28.3 percent of the EIA's forecast consumption in 2030 or 92.1 percent of forecast growth from 2010-2030 (EIA 2008a).