ENERGY EFFICIENCY IN APPALACHIA

HOW MUCH MORE IS AVAILABLE, AT WHAT COST, AND BY WHEN?

Appendices

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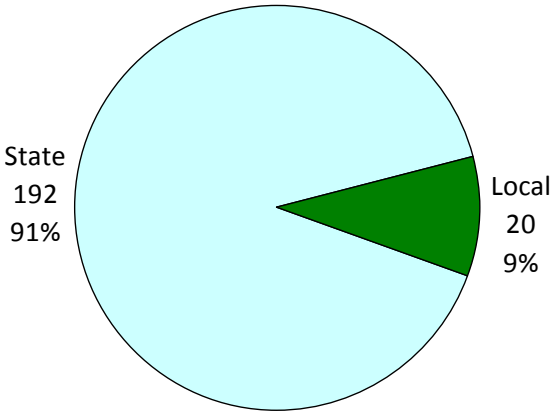
APPENDIX A: ARC ENERGY EFFICIENCY POLICY INVENTORY

A policy inventory was developed to better assess the current status and approach of the Appalachian Region to energy efficiency. The inventory was compiled by Georgia Institute of Technology researchers and sent to state energy offices for review. As of September 2008, ten states have replied with corrections and additions to the inventory (AL, GA, KY, MS, NY, OH, PA, SC, TN, VA, and WV) while two states have yet to respond (MD made aware of the purpose and intent of this in inventory for their own reference.

The Appalachian Region has over 200 policies promoting energy efficiency identified in this inventory. However, they differ in scope, inter level of support. Policies are even nested in di levels: locally, state, region, and Federal. The very few local level policies identified in Appa however, there may be policies in place that we identified. Figure A.1 shows that 91 percent of policies identified in the region are at the state Federal policies are not included in this policy inventory, and no applicable policies were iden at the Regional level.



Policies can be organized into 12 distinct categ described by Geller (2002); Figure A.2 shows l categories. A description of each policy option along with some examples from current programs in Appalachia follows.

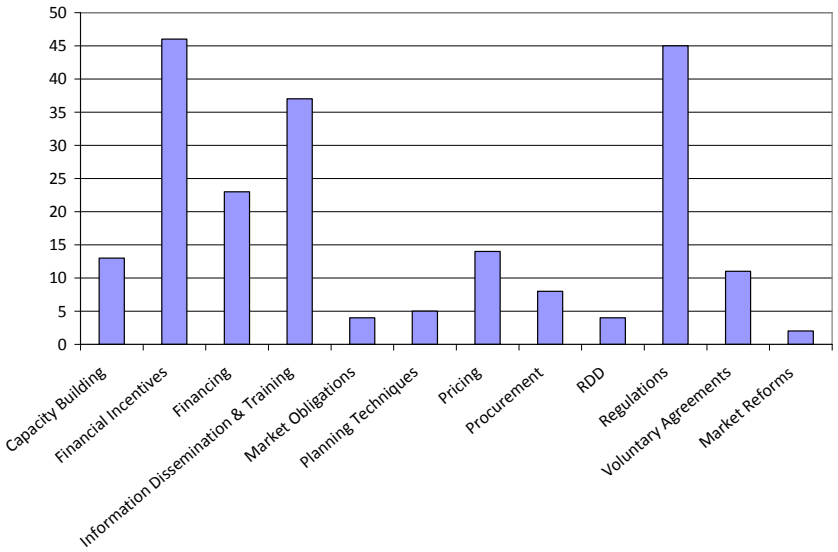


Figure A.2 Policy Options (count) in the Appalachian Region

Some policies are designed to fit into more than one of these categories, like market obligation policies that also require state lead-by-example procurement. In this case, policies are not double counted; rather they appear under just one option.

RESEARCH, DEVELOPMENT, AND DEMONSTRATION

These policies generally are used to get technologies and practices from the lab to the marketplace. Throughout the region, there are three identified policies supporting research, development, and demonstration for energy efficiency. Kentucky, South Carolina, and Virginia have targeted programs for innovation, including energy efficiency; they are all designed as competitive grant programs. New York has an office of energy research, and has been active in efficiency research and development for more than three decades.

Kentucky's Energy Research and Development Grants for Renewable Energy and Energy Efficiency, operated by the Kentucky Office of Energy Policy since 2005, awarded five research and development grants in 2007 via competitive solicitation for renewable energy and energy efficiency initiatives for a total of over $518,000.

Perhaps the most well known research effort in the Appalachian region is NYSERDA. Since 1975, NYSERDA has conducted a multifaceted energy and environmental research and development program. NYSERDA's R&D Program supports the development and commercialization of innovative energy and environmental products, technologies, and processes that improve the quality of life for New York's citizens and help New York businesses to compete and grow in the global economy. NYSERDA R&D activities are organized into seven primary program areas: Energy Resources; Transportation and Power Systems; Energy and Environmental Markets; Industry; Buildings; Transmission and Distribution; and Environmental Research.

FINANCING

Governments offer financing programs to increase adoption rates for technologies that may have longer paybacks or may not qualify for traditional financing. Financing programs include no interest loans, low interest loans, access to standard rate loans, and the ability to utilize performance contracting (for government agencies).

There are 23 financing programs to advance energy efficiency in Appalachia (Figure A.3). Seven of these allow government agencies to contract for energy services, through performance contracting or Energy Service Contracting Organizations (ESCOs), or allow special lease financing, on similar terms, from a government fund. Sixteen are loan programs: three are loans with technical assistance, two are no-interest loan programs, and eleven are low-interest loan programs.

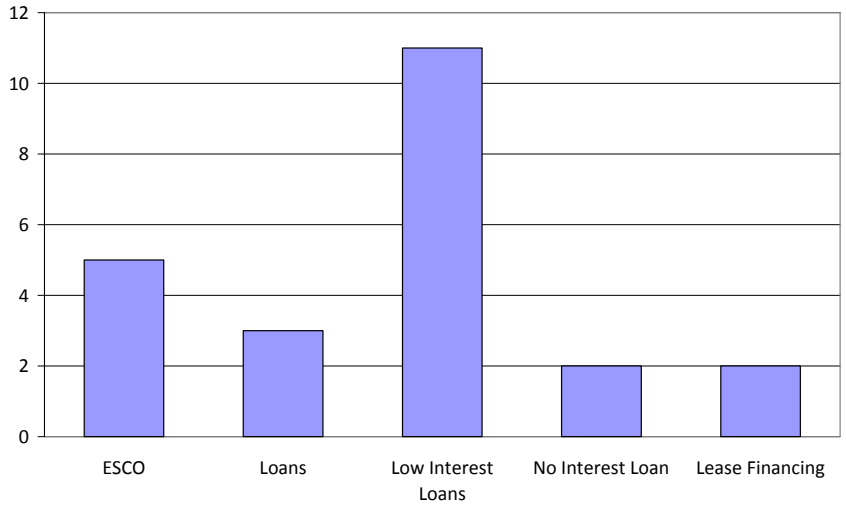


Figure A.3 Financing Mechanisms Used for Energy Efficiency in Appalachia

West Virginia, Ohio, and Georgia do not have financing programs for energy efficiency in this policy inventory. Table A.1 shows the number of financing policies by state for those that use this type of policy to promote energy efficiency.

Table A.1 Financing Policies by State

State	Number of Policies
AL	2
KY	1
MD	3
MS	4
NC	2
NY	3
PA	2
SC	2
TN	2
VA	2

Mississippi's Energy Investment Loan Program provides low interest (three percent below prime) loans "to individuals, partnerships, or corporations, for either capital improvements, or in the design and development of innovative energy conservation processes." The broad scope of this policy makes it stand out, as most financing programs target one sector or technology.

In South Carolina, the ConserFund is a low-interest revolving loan program administered by the SC Energy Office for energy-efficiency improvements in state agencies, public colleges or universities, school districts, local governments, and private nonprofit organizations.

FINANCIAL INCENTIVES

Financial incentives help to encourage early and wider adoption of efficient technologies and practices by reducing or eliminating the incremental cost of adoption of energy-efficient technologies and practices (Geller, 2002, p.55). These incentives come in the form of grants, tax credits, tax exemptions, and rebates.

Forty-six programs for energy efficiency in Appalachia come in the form of financial incentives. Twenty-three are grants, while nine are tax credits; five are tax exemptions or tax holidays. Of seven types of rebates, three programs are designed as rebates/reimbursements, two as tax rebates, and two as fee rebates. Single programs are designated as "tax" and "mix." Figure A.4 shows the frequency of these programs.

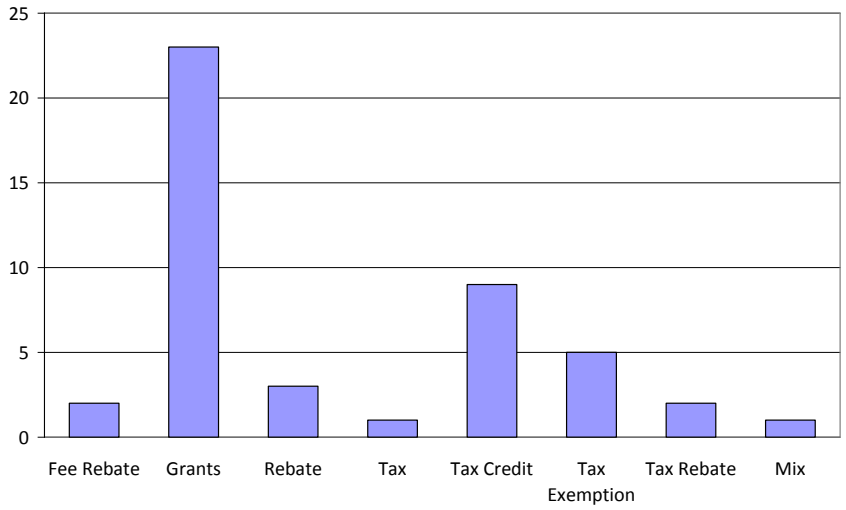


Figure A.4 Financial Incentives for Energy Efficiency Used in Appalachia

The program labeled "tax" provides an interesting example for energy-efficiency financial incentives. In 2007, the Virginia legislature passed a bill that allows local governments to create a new real estate classification for buildings that achieve efficiencies at least 30 percent greater than the Virginia Uniform Building Code; with this new classification, local governments could offer incentivized tax rates for efficient buildings. One city, Roanoke, VA, appears to have taken this option up already.

Efficiency Long Island, labeled "mix," is set to offer a combination of financial incentives; this program is intended to succeed and expand upon Long Island Power Authority's (LIPA) Clean Energy Initiative that expires at the end of 2008. Efficiency Long Island is a 10-year, $924 million energy-efficiency program that will make a wide array of incentives, rebates and initiatives available to LIPA's residential and commercial customers to assist them in reducing their energy usage and thereby lowering their bills.

The breakdown by location can be seen in Table A.2. Alabama and Tennessee have no identified financial incentive programs for energy efficiency. Within North Carolina, two financial incentives are at the local level in Asheville, NC.

Table A.2 Financial Incentives Policies by State

State	Number of Policies
GA	1
KY	2
MD	4
MS	1
NC	3
NY	19
OH	2
PA	4
SC	5
VA	4

PRICING

Pricing policies include added taxes and fees and net-metering programs that encourage energy efficiency. Besides net-metering programs, pricing policies have not been employed by governments in Appalachia. However, states do have varying levels of utility and fuel taxes. These taxes could have some implications for consumption behaviors. Previous research efforts by the ARC identified Regional price elasticities of electricity to be -0.15, -0.17, and -0.55 for residential, commercial, and industrial users, respectively (CBER, 2006). While pricing consumers out of the market for energy could be a concern with the region‘s large proportion of population in poverty, pricing mechanisms could be used with other programs to reduce peak demand. Pricing measures could also be used to discourage excessive use without impacting the average customer bill (when much higher prices are set at levels above typical consumption); a grim trigger policy like this can keep consumption from reaching the trigger point, but will not incentivize reductions below that point.

Georgia, Kentucky, Maryland, New York, North Carolina, Ohio, and Pennsylvania have state-wide net-metering programs. In addition, Tennessee‘s Tennessee Valley Authority also sponsors a net-metering type program which uses dual-metering and directly purchasing renewable generated power at 10 cents per kWh. These net-metering programs have varying rules on maximum installation, forms of generation, and payback structures.

For example, Pennsylvania’s net-metering policy requires investor-owned utilities to offer the program to residential customers with systems up to 50 kilowatts (kW) in capacity; nonresidential customers with systems up to three megawatts (MW) in capacity. In addition, customers (of any sector) with system capacities between three and five MW must be allowed to participate in net-metering if they make their systems available to the grid during emergencies, or if a microgrid system is in place in order to maintain critical infrastructure. Pennsylvania allows many sources to

be eligible for net metering: photovoltaics (PV), solar-thermal energy, wind energy, hydropower, geothermal energy, biomass energy, fuel cells, combined heat and power (CHP), municipal solid waste, waste coal, coal-mine methane, other forms of distributed generation (DG), and certain demand-side management technologies.

VOLUNTARY AGREEMENTS

Voluntary Agreements can be faster than regulations at achieving goals set by government officials. Throughout Appalachia, however, voluntary agreements are mainly found as partnerships between state and Federal government organizations.

About half (six) of Appalachian states are partners with the U.S. Environmental Protection Agency (EPA) in the Clean Energy Environment program; of these states, Georgia, New York, Ohio, and Pennsylvania were charter state partners, and North Carolina joined shortly after the publication of the Clean Energy-Environment guide to action in 2005. Virginia joined in February of 2008. Several Appalachian states are partners with the Building America and Rebuild America programs.

An illustrative voluntary agreement intrastate is Georgia's Earthcraft house partnership between Southface Energy Institute and the Greater Atlanta Home Builders Association that seeks to provide builders with greater information about comfort and energy efficiency that can be achieved through design and construction practices.

REGULATIONS

Regulations can set a minimum standard for efficiency to discourage waste. In Appalachia, most states or local governments have building codes for new residential and commercial buildings that meet or exceed the standards of the 2003 International Energy Code. However, only New York and Maryland have efficiency standards for appliances; most of these were preempted by Federal appliance standards in 2005.

INFORMATION DISSEMINATION AND TRAINING

These programs seek to distribute information, raise public knowledge, provide accessible information, or train persons for particular tasks. Many information programs are packaged with financial assistance; for example, in New York, seven programs are grants with technical assistances. Only two of these are grouped in the information section, while the other five are counted under financial incentives.

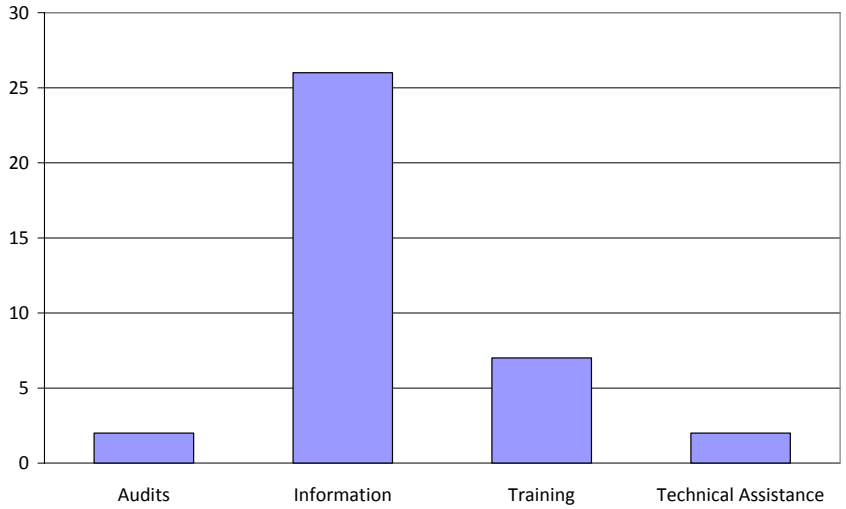


Figure A.5 Information Dissemination and Training Program Types Used in Appalachia

Most states in Appalachia use Information Dissemination and Training to promote energy efficiency. The number of programs within states can be seen in Table A.3.

Table A.3 Information Dissemination and Training Policies by State

State	Number of Policies
AL	4
GA	4
KY	6
MD	6
MS	1
NC	3
NY	4
OH	1
SC	2
TN	2
VA	2
WV	2

PROCUREMENT

Procurement programs establish demand for particular products through government acquisition. These programs can also be used to demonstrate the applicability of products or practices. Procurement programs are sometimes combined with market reform or market obligations or state agency financing mechanisms. Seven programs across Appalachia were identified as requiring government agencies to adopt or purchase certain types of equipment.

By January 1, 2008, all Tennessee state agencies, universities, and community colleges having more than 10 state-owned vehicles in their fleet are required to develop and implement plans to increase the state's use of alternative fuels and hybrid electric or other fuel-efficient or low-emission vehicles. Specifically, they must incorporate a goal to reduce or displace at least 20 percent of the fleet's consumption of petroleum by January 1, 2010. The goal is reduced to a minimum of 10 percent reduction if the fleet includes vehicles modified for educational, emergency, or public safety purposes or vehicles used for emergency or law enforcement purposes.

MARKET REFORMS

Sweeping changes to the market for energy can be considered market reforms. These could be privatization, deregulation, reregulation, or other structural changes. Not all market reforms are designed to promote efficiency; this policy inventory does not include deregulation of natural gas or electric utilities as efficiency policies. Surcharges, like public benefits funds, can also be used as market reforms. New York and Pennsylvania have implemented Public Benefits Funds as surcharges on energy bills. The collected funds are used to provide for low income energy bill relief and to incentivize greater renewable energy and energy efficiency.

Pennsylvania has its public benefits funds program created through individual settlements with the state's five major distribution utilities: Metropolitan Edison Company (Met-Ed), Pennsylvania Electric Company (Penelec), PECO Energy (PECO), PP&L (PPL), and Allegheny Power/West Penn Power Company (WPP). These utilities created individual "Sustainable Energy Funds" with the goals of promoting (1) the development and use of renewable energy and advanced clean-energy technologies, (2) energy conservation and efficiency, and (3) sustainable-energy businesses. Each utility has established an oversight board and designated a fund administrator. [Because of this set-up, financial incentives are in the utility service areas rather than state-wide or locality based policies.]

MARKET OBLIGATIONS

Obligations to have particular fuel or efficiency mixes, such as renewable or sustainable energy portfolio standards, fall under the category of market obligations. New York, North Carolina, Ohio, and Pennsylvania have portfolio standards that include energy efficiency as a qualified source. Virginia has a targeted goal for renewable energy and energy efficiency.

North Carolina's Renewable Energy and Energy Efficiency Portfolio Standard requires investor-owned utilities in the state to supply 12.5 percent of 2020 retail electricity sales in the state from eligible energy resources by 2021. Up to 25 percent of the requirements can be met through energy efficiency technologies, including combined heat-and-power systems powered by non-renewable fuels. After 2018, up to 40 percent of the standard can be met through energy efficiency. The requirements are less stringent for municipal utilities and electric cooperatives, which must meet a target of 10 percent renewables by 2018 and are subject to slightly different rules.

Within Ohio's Alternative Energy Resource Standard (effective January 1, 2009), utilities are required to implement energy efficiency and peak demand reduction programs that achieve a cumulative energy savings of 22 percent by the end of 2025, and reduce peak demand by 1.0 percent in 2009 and 0.75 percent annually thereafter through 2018.

CAPACITY BUILDING

Capacity Building includes developing centers for energy efficiency that work with the private sector to carry out demonstrations, provide information and training, offer financing, and promote efficiency. Capacity building also allows for the production of local skill building; creating local capacity to carry out necessary energy related activities. Thirteen energy efficiency programs with capacity building focus have been identified in five states (Table A.4). Within Appalachia, most capacity building seems to be achieved through funding of centers at state colleges and universities.

Table A.4 Capacity Building Policies by State

State	Number of Policies
KY	3
MD	1
NC	2
NY	5
WV	2

The Southeastern Combined Cooling, Heating and Power Regional Application Center (CHPCenterSE), is directed by the Mississippi Development Authority-Energy Division, Mississippi State University's Micro-CHP Application Center and North Carolina State University's NC+CHP Application Program. The new Regional center seeks to double the installed CHP capacity in the Southeast by the year 2010. They will also coordinate and conduct education and outreach activities to stimulate market development as guided by a CHP Center Roadmap, which will be developed in the first three months of the project. While this center will be located in North Carolina, it demonstrates how effective interstate cooperation can produce meaningful savings.

New York's Saratoga Technology + Energy Park is a unique venture by the New York State Energy Research and Development Authority (NYSERDA) to provide an "integrated knowledge community." The park actively recruits innovative energy technology firms to do business within the area.

PLANNING TECHNIQUES

Integrated planning methods that take into account interactions as well as differential short and long term impacts of policies or practices are considered planning techniques. Five policies in Appalachia were identified as planning for energy efficiency, from North Carolina, New York, and Virginia.

In North Carolina, the Division of Bicycle and Pedestrian Transportation (DBPT) works with localities to create a four-year schedule of projects using the locality's priority listing of needs along with the adopted project selection criteria. All project requests are documented and distinguished as independent or incidental (part of a highway project). Independent project requests are evaluated by DBPT using project selection criteria. A prioritized list of these projects is presented to the North Carolina Bicycle Committee, which reviews the list, makes revisions and recommendations, and

adopts a four-year schedule of projects. The adopted schedule is sent to the North Carolina Board of Transportation for approval and inclusion in the state's TIP.

An example of a local planning effort that is broader in scope is PlaNYC. PlaNYC was developed for New York City as a sustainability plan for the city that identifies energy planning and energy efficiency as significant action objectives.

Beyond these policies set in place by state and local governments, there are a number of nationwide programs that are available in Appalachia. These nationwide programs are sponsored by the Federal government or non-profit organizations.

REFERENCES

Center for Business and Economic Research (CBER). 2006. *Energy Efficiency and Renewable Energy in Appalachia: Policy and Potential*. http://www.arc.gov/images/reports/2006/energy/arc_renewable_energy_full.pdf

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APPENDIX B: RESIDENTIAL POLICY AND METHODOLOGY DETAIL

RESIDENTIAL MODEL BUILDING ENERGY CODES

Introduction

Residential model building energy codes prescribe the minimum level of efficiency that must be achieved in new residential single and multi-family (less than three stories) construction. Manufactured (and mobile) homes are covered under Federal manufactured housing efficiency requirements. Residential building energy codes focus on shell efficiency and construction/design; HVAC and appliances are not specifically addressed. This study assumes that Appalachian counties all adopt the 2006 IECC by 2009 and subsequently more efficient codes every three years thereafter; codes are assumed to become effective the year following adoption. In 2015, this study assumes that the Region ―catches up" to the current code cycle; therefore, the code adopted in 2015 is assumed to be a modeled 2015 code rather than the modeled 2012 code.

The 2006 IECC simplified codes and compliance by reducing the number of climate zones and separating climate zones by geography rather than just heating degree days (HDD). Compliance may be achieved through meeting prescriptive ―R" values, whole house ―UA" values, or through building energy simulation software, not including appliances (BECP, 2006). The differences by climate zone can be seen for the four climate zones in the Appalachian Region in Table B.1, and the breakdown of climate zones by state for the Appalachian Region is in Table B.2.

Table B.1 2006 IECC Prescriptive Requirements by Climate Zone (ICC, 2006)

Climate Zone	Fenestration U-Factor	Skylight U-Factor	Glazed Fenestration SHGC	Ceiling R-Value	Wood Frame Wall R-Value	Mass Wall R-Value	Floor R-Value	Basement Wall R-Value	Slab R-Value and Depth	Crawl Space Wall R-Value
3	.65	.65	.4	30	13	5	19	0	0	5/13
4	.4	.6	N.R.	36	13	5	19	10/13	10, 2 ft	10/13
5	.35	.6	N.R.	36	19 or 13+5	13	30	10/13	10, 2 ft	10/13
6	.35	.6	N.R.	49	19 or 13+5	15	30	10/13	10, 4 ft	10/13

In the northern climate zones (5 and 6), a vapor retarder is required; in southern climates zones (3), the solar heat gain coefficient must be less than 0.40 (BECP, 2006).

Table B.2 Climate Zones for Appalachian Portions of States
(ICC, 2006)

Climate Zone	AL	GA	KY	MS	MD	NC	NY	OH	PA	SC	TN	VA	WV
3	X	X		X						X			
4		X	X		X	X		X			X	X	X
5					X	X	X	X	X				X
6							X		X				

Codes adopted in later years are expected to continue to increase efficiency through reduced heat loss, more efficient windows, duct sealing measures, and passive solar design.

Methodology

Forecasts of housing starts are available by census division as part of the EIA's *Annual Energy Outlook 2008* (EIA, 2008). These forecasts are population weighted to the Appalachian portion of each census division to construct a housing start forecast unique to the Region (REMI, 2007). The portion of new housing construction that is single or multi-family homes is set to have a reduced consumption relative to the forecast without building codes.

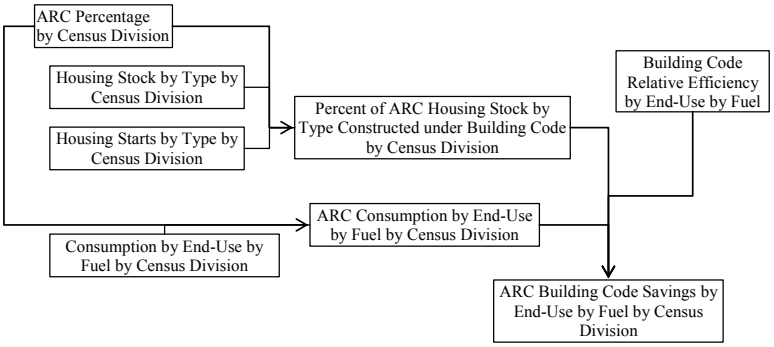


Figure B.1 Residential Model Building Energy Code Methodology

Building codes are only anticipated to reduce consumption for space heating, space cooling, and water heating loads by improving shell efficiency. The three major fuels used for these purposes (electricity, natural gas, and distillate fuel oil) are modeled for savings. Reduced consumption for other fuels (e.g., wood, kerosene, and LPG) and for other end-uses, such as lighting, may also follow building energy code changes, but they are not included in this assessment. Figure B.1 shows how energy savings from residential building codes are determined.

Energy Savings

Energy savings for building energy codes are determined by changing the anticipated efficiency of newly constructed homes. The modeled efficiencies are shown in Table B.3.

Table B.3 Achievable Efficiencies if Building Codes are Adopted and Enforced

Year Operational[a]	% Savings Relative to Baseline[b]	Potential Code	Homes Built to This Code[c]
2010	6	2006 IECC	330,105
2013	18	2009 IECC	335,092
2016	30	2015 IECC	329,656
2019	36	2018 IECC	312,876
2022	42	2021 IECC	301,258
2025	48	2024 IECC	303,090
2028	54	2027 IECC	292,890

[a] The ―Year Operational" is in three year increments because we assume a three year code adoption cycle.
[b] Relative savings are to year 2005 RECS estimates for the end-uses modeled to be impacted by building codes: Space Heating, Space Cooling, and Water heating. This is not whole house efficiency. This number should be interpreted to mean that the 418,865 single and multi-family homes built from 2013 to 2015 use 18 percent less energy for space heating, space cooling, and water heating than they would have if built with NEMS assumed efficiencies for the same years.
[c] Single Family and Multi-Family Homes are included. Mobile Homes (about 12 percent of ARC housing units) are not included. Number reflects 80 percent compliance.

The current study's estimates of savings relative to the year 2005 RECS estimates are intentionally conservative. Lucas (2006) estimated annual savings of 16-17 percent in West Virginia by adopting the 2003 IECC (unamended) in place of the 2003 IRC with amendments. The 2003 IECC and 2006 IECC are similar in efficiency requirements as the major changes are in ease of compliance and structure. Further, our assumptions are not as aggressive as the ―30 Percent Solution" that would set the 2009 IECC for residential buildings at 30 percent more efficient than current model energy code; supporters include many national, regional, utility, and trade organizations (EECC, 2008).

Because building codes accelerate the adoption of advanced building materials and technologies that would be adopted in the future anyway, savings beyond 2030 are not included in this analysis.

Policy Implementation Cost

This policy assumes a change in the way energy codes are handled; therefore, high compliance rates, modeled at 80 percent, do not require significantly higher public administration costs. Because compliance is verified with third parties paid by the construction firms, public administration of the program requires: maintaining a certification program for third-party verifiers, training of construction and verification firms, and periodic review of the competence of third-party verifiers. This study assumes that two training administrators, at $75,000 each, will be required per state (only that portion of the state that is in the ARC is counted as a cost), and one additional verification liaison will be required per every 10,000 homes built in the Appalachian Region per year at $75,000.

A business roundtable study, which included survey results from building code offices around the country concluded that it is ~~a~~lmost impossible to develop a meaningful relationship between the number of staff, professional competence, or level of service provided by a code enforcement agency and its allocated financial resources" (Business Roundtable, 1982). As such, it is unclear what level of program costs will be necessary to achieve successful code compliance in any particular jurisdiction.

Incremental investment costs vary by climate zone and current practice. Because current practice is unknown, it is assumed that current homes are built to the prescriptive envelope of each state's building energy code. A handful of estimates of compliance costs in areas with similar climate zones to the Appalachian Region are shown in Table B.4. The present study assumes that each home has an incremental cost of $1,000 which likely overestimates costs in climate zone 4 and 5, which makes up most of the Appalachian Region, but may underestimate costs in climate zone 3 and 6.

Table B.4 Incremental Cost Estimates for Building Code Compliance

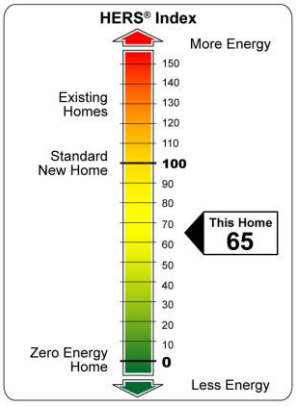
State	Code Studied	Climate Zone[a]	Cost Estimate (per home)	Reference
Illinois	none to 2006 IECC	4	573-1715	Lucas, 2007
Illinois	none to 2006 IECC	5	1173-3062	Lucas, 2007
Iowa	1992 MEC to 2003 IECC	5,6	0-500	Lucas, 2003
Kentucky	1992 MEC to 2000 IECC	4	0-300	Lucas, 2001
West Virginia	2003 IRC amended to 2003 IECC	4	639	Lucas, 2006
West Virginia	2003 IRC amended to 2003 IECC	5	659	Lucas, 2006

[a] Climate zone is the 2006 IECC climate zone. Previous code cycles had more zones.

This study does not include an incentive for meeting or exceeding the building energy code; however, there are options for incentivizing highly efficiency construction, described below.

The actual program or measure used for distributing these incentive funds may have a significant impact on compliance. Several program design options exist. An example would be requiring new residences to have a Home Energy Rating Score (HERS) score below a certain level to get a tax

credit or rebate. New Mexico passed efficiency legislation in 2007 allowing for builder tax rebates for new homes with a HERS rating of 60 or less (NM, 2007).



Another option would be to support utility residential new construction programs. For example, PG&E (California) operates a residential new construction program that provides an incentive of $400 or $500 to builders per ENERGY STAR home; it also provides incentives for outfitting compliant homes with energy efficient appliances (P&GE, 2008). Vine (1996) presented compliance levels from California, Oregon, and Washington and found that utility residential new construction programs achieved near 100 percent compliance from builders while residences built outside of the program were found to be six percent (or more) less efficient than the code prescribed.[1]

Market Penetration

The purpose of this study is to estimate cost-effective energy savings; since building energy codes are required to be cost-effective before adoption, we assume compliance at 80 percent. Total homes affected by each code are given in Table B.3 (above).

EXPANSION OF WEATHERIZATION ASSISTANCE

Introduction

The Weatherization Assistance Program (WAP) was created by the Energy Conservation and Production Act of 1976 (Title IV) to reduce heating bills for low-income families and seniors. Weatherization programs specifically target heating loads; they have a dual purpose of reducing energy consumption and corresponding bills while improving resident comfort (Schweitzer and Tonn, 2002).

This study assumes that each year an additional one percent of homes are weatherized over and above those that would have been weatherized based on current levels. About 19 percent (1,750,093) of Appalachian single family and manufactured homes (15 percent of all homes) are weatherized under this expanded program between 2010 and 2030.[2]

The present study‘s one percent additional weatherization measure represents an ambitious effort to reduce heating consumption and improve comfort within Appalachian homes. While a disproportionate number of these homes are expected to be in the 410-county Appalachian Region due to higher poverty levels, weatherization data are not available at this level for all states (see Table B.5 for an example from Ohio). Of the 40,391 homes weatherized in the 2007 Program Year in the thirteen Appalachian states, a population weighted estimate assumes 8,856 were in Appalachian Region counties (about one-tenth the annual effort required to meet one percent).

[1] Utility residential new construction programs offer incentives to builders to meet or exceed model energy codes.
[2] Weatherization assistance is also available to certain small multi-family units, but multi-family structures are not included for this study.

Table B.5 Appalachian Region Households Eligible and Served by Weatherization Assistance Program in Ohio, 2003
(OOEE, 2006)

Region	% Households Eligible for HWAP	% Eligible Households Served	% Households Served
Adams	38.10	12.50	5
Athens	40.10	6.70	3
Belmont	35.80	7.20	3
Brown	26.60	9.90	3
Carroll	29.10	3.70	1
Clermont	18.60	4.30	1
Columbiana	30.50	5.60	2
Coshocton	28.80	15.00	4
Gallia	36.80	7.30	3
Guernsey	35.40	7.50	3
Harrison	33.80	7.40	3
Highland	30.30	8.40	3
Hocking	31.00	6.70	2
Holmes	37.70	3.90	1
Jackson	35.80	9.80	4
Jefferson	33.80	5.70	2
Lawrence	38.10	8.30	3
Meigs	39.90	10.50	4
Monroe	34.60	5.70	2
Morgan	38.30	8.10	3
Muskingum	29.60	6.50	2
Noble	33.00	8.70	3
Perry	30.10	8.40	3
Pike	35.70	10.90	4
Ross	28.30	6.60	2
Scioto	38.80	6.40	2
Tuscarawas	27.60	5.00	1
Vinton	37.20	11.20	4
Washington	29.50	6.50	2

The Department of Energy provides funding to states for WAP, although states can also use a portion of LIHEAP funds for weatherization, and states also seek other sources of funding, such as utility partnerships (WAPTAC, 2008). Ohio was the first state to legislatively set aside the maximum of 15 percent of LIHEAP funding for weatherization efforts in 1981 (OOEE, 2006).

Many states also partner with gas and electric utilities to offer more weatherization services; weatherization improves the client's ability to pay for energy bills, so the utilities also benefit (McCold et al., 2008). DeRamos (2002) and OOEE (2006) found that savings and performance were better (up to an additional 30 percent) in homes that received joint utility and weatherization program service. Total funding for each of the Appalachian states and a population weighted Appalachian Region is shown in Table B.6.

Table B.6 WAP Funding from All Sources ($million), 1997-2007
(Census, 2005; WAPTAC, 2008)

State	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
AL	1.77	2.32	1.96	2.30	2.42	3.12	3.12	3.45	3.46	3.83	3.28
GA	6.82	6.79	6.42	4.79	4.98	6.75	6.85	6.41	6.42	10.33	7.43
KY	10.09	4.91	4.84	6.93	7.61	8.06	7.89	7.32	8.68	10.28	8.96
MD	3.71	1.87	3.04	3.17	3.56	4.54	2.83	4.28	5.46	6.02	5.60
MS	1.02	1.02	1.08	0.98	1.11	1.11	1.62	3.82	1.66	1.85	1.48
NY	33.75	30.16	36.68	59.44	52.39	62.43	62.16	61.22	60.65	65.31	63.60
NC	9.31	8.22	6.81	9.44	8.17	8.85	10.54	9.58	9.92	14.59	9.90
OH	24.88	26.83	31.94	33.47	35.18	32.72	50.41	48.60	49.24	56.64	52.44
PA	17.83	19.11	19.63	25.70	27.02	32.92	32.49	33.72	34.76	43.09	33.12
SC	2.97	2.74	2.39	2.82	3.39	3.62	2.98	3.63	3.63	3.98	3.64
TN	3.83	4.74	4.24	5.50	4.86	6.55	5.98	6.69	6.35	7.24	5.99
VA	4.87	7.44	7.43	9.27	9.74	10.53	9.73	10.82	11.16	15.59	9.97
WV	3.63	2.79	3.98	3.68	5.24	5.90	5.77	5.75	5.75	7.39	7.27
ARC[a]	28.20	26.61	27.93	33.27	34.44	39.21	41.57	43.01	42.98	54.18	44.50

[a] ARC Population weights for years 1997-2007 are based on the relative populations in 2005 using Census estimates of population for 2005 and REMI estimates of ARC county populations for 2005. This funding approximation does not claim that any particular WAP funding was distributed in the ARC counties.

Methodology

Housing forecasts are available by census division as part of the EIA's *Annual Energy Outlook 2008* (EIA, 2008). Weatherization savings are calculated by summing the end-use savings by fuel for one percent of single family and manufactured homes each year.

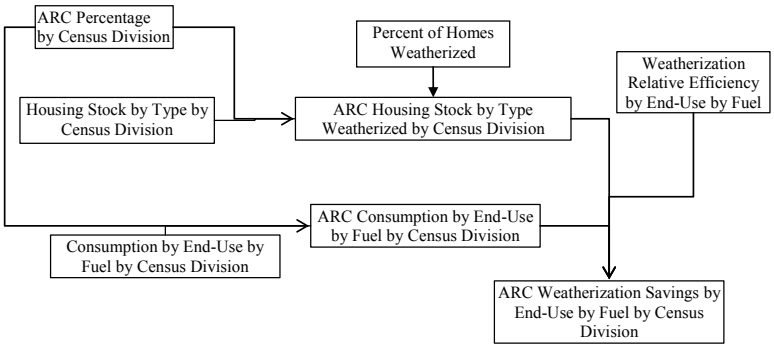


Figure B.2 Expanded Low Income Weatherization Program Methodology

Energy Savings

Energy savings for weatherization are based on Berry and Schweitzer's (2003) meta-evaluation of state weatherization studies; savings percentages are shown in Table B.7.

Table B.7 Achievable Efficiencies for Weatherization

Fuel	End-Use	Savings (Post vs. Pre) Percent
Natural Gas	Heating	30.8
Natural Gas	Whole House	21.9
Electricity	Heating	26.7
Electricity	Whole House	10.5

Berry and Schweitzer (2003) found savings for heating oil and propane to be slightly lower than natural gas; however, Shen et al. (1996) found heating oil and propane savings not significantly different from natural gas savings. In the present study, heating oil savings are set at the same levels as natural gas (30.8 percent for heating and 21.9 percent total) and propane savings are not modeled.

In hot and humid climates in the southern portion of the Appalachian Region, improvements in space cooling are also made (McCold et al., 2008). This study assumes a 10 percent savings in space cooling energy use. In many weatherization programs, it is standard practice to install a water heater blanket; at a cost of just $10 to $20, these blankets can save four percent to nine percent in water heating costs (DOE/EERE, 2008).

Energy savings are modeled to last 20 years. For examination of costs and benefits of this program, savings out to 2050 (for those homes weatherized in 2030) are included. Since the EIA forecast for energy prices ends at 2030, this study assumes that prices and avoided costs are constant at 2030 levels until 2050. This assumption likely underestimates the value of energy saved during the period from 2030 to 2050.

Policy Implementation Cost

Investment costs are assumed to be $2,300 per home (2006 dollars), as allowed by the Department of Energy program, but funds from other sources (such as utility programs) are assumed to be leveraged to provide greater service levels to clients.

An additional 10 percent is assumed to be spent on administration of the program. Weatherization is currently a program with no participant cost-share; the modeled program assumes no private investment.

Market penetration

This study assumes that about 15 percent of Appalachian homes are weatherized under this program expansion from 2010 to 2030. Since this is an extension of the existing weatherization program that we assume will continue over the study horizon, the total number of homes weatherized should be higher. Between the original and extended program, a significant number of qualified homes will be provided weatherization assistance.

RETROFIT OF EXISTING HOMES

Introduction

Retrofitting of existing homes seeks to reduce energy consumption in homes that do not qualify for the Weatherization Assistance Program. It is hoped that, in combination, these two programs could improve the energy consumption levels of most homes in the Region to at least the performance of the 2006 IECC by 2030.

Existing home retrofits already occur; however, they do not always target energy-efficient improvements. This study assumes that energy-efficiency improvements are encouraged when homeowners seek to remodel and also whenever siding, roofing, wiring, or heating and cooling equipment would need to be replaced.

The retrofit program would probably come in the form of a tax credit, grant, or rebate program. It is designed as an incentive measure to accompany two other policies – home energy disclosure and on-bill financing.

Methodology

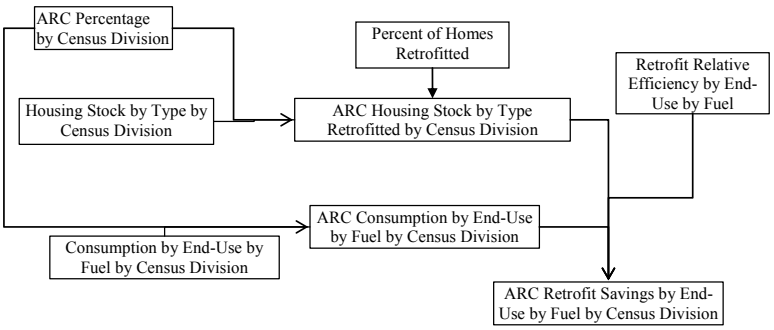


Figure B.3 Retrofit of Existing Homes Methodology

Housing forecasts are available by census division as part of the EIA's *Annual Energy Outlook 2008* (EIA, 2008). Retrofit savings are calculated by summing the end-use savings by fuel. The model assumes retrofit of two percent of single family homes each year.

Baseline Energy Savings

While it can be compared to the weatherization program, the retrofit program includes more measures, at a greater expense, and should yield higher savings. The assumed efficiency improvements are 50 percent for heating, and 40 percent for cooling, lighting, and water heating loads better than forecast.

Energy savings are modeled to last 20 years. For examination of costs and benefits of this program, savings out to 2040 (for those homes undergoing retrofit in 2020) are included. Since the EIA forecast for energy prices ends at 2030, this study assumes that prices and avoided costs are constant at 2030 levels until 2040. This assumption likely underestimates the value of energy saved during the period from 2030 to 2040.

Policy Implementation Cost

Investment costs are assumed to be $3,400 per home. Retrofits are expected to include items like those suggested by the Energy Efficient Rehab Advisor, which is an online retrofit savings estimator provided by the U.S. Department of Housing and Urban Development (Table B.8 – Table B.10).

Table B.8 Suggested Retrofits, Costs, and Savings for Homes in Central States (HUD, 2005)

Retrofits	Cost ($)	Annual Energy Savings ($)	Payback (Years)
Programmable Thermostat	115	195	0.6
Seal Air Leaks	540	401	1.3
Heating and Cooling System Tune-up	191	137	1.4
Seal Duct Leaks	432	285	1.5
Insulate Walls to R11	1015	348	2.9
Upgrade Gas Water Heater	115	21	5.4
Insulate Ceilings to R38 (R30 in warmer climates)	950	169	5.6
Total	3358	1556	2.2

Note: Costs and Savings based on a typical 2000 sq ft home in Nashville, TN, with a finished basement and natural gas heating

Table B.9 Suggested Retrofits, Costs, and Savings for Homes in Southeastern States
(HUD, 2005)

Retrofits	Cost ($)	Annual Energy Savings ($)	Payback (Years)
Programmable Thermostat	115	146	0.8
Heating and Cooling System Tune-up	191	113	1.7
Insulate Ducts	388	108	3.6
Seal Duct Leaks	443	131	3.9
High Efficiency Central Air Conditioner	486	121	4
Seal Air Leaks	554	66	8.4
Insulate Floors to R19	776	85	9.1
Total	2953	770	3.8

Note: Costs and Savings based on a typical 2000 sq ft home in Houston, TX, with a finished basement and natural gas heating

Table B.10 Suggested Retrofits, Costs, and Savings for Homes in Northeastern States
(HUD, 2005)

Retrofits	Cost ($)	Annual Energy Savings ($)	Payback (Years)
Programmable Thermostat	115	183	0.6
Heating System Tune-up	96	122	0.8
Seal Duct Leaks	443	311	1.4
Windows (U-factor 0.35) and Skylights (U-factor 0.6 or less)	744	341	2.2
Insulate Ceilings to at least R49 – install vapor retarders	643	268	2.4
Seal Air Leaks	554	66	8.4
Insulate Ducts to R6	443	183	2.4
Total	3038	1474	2.1

Note: Costs and Savings based on a typical 2000 sq ft home in Burlington, VT, with a finished basement and fuel oil heating

These investment costs are expected to be born primarily by the homeowner (participant). A public incentive of 20 percent is assumed until 2020. After 2020, the program is only providing public awareness of energy-efficiency measures, aiding the administration of the residential home energy labeling program, and supporting on-bill financing.

Administrative costs are expected to include one administrator at $150,000 and one employee at $75,000 per state, proportioned to ARC counties, for a total of $.99 million per year. After 2020, these administrative costs are reduced to $330,000 per year.

Market Penetration

This study assumes that about 38 percent of Appalachian single family homes are retrofitted between 2010 and 2030 under this program (accounts for 28 percent of all Appalachian housing units in 2030).

RESIDENTIAL EFFICIENT APPLIANCE INCENTIVE

Introduction

The present study assumes that appliances are improved over time with greater improvements after cyclical updates to the ENERGY STAR guidelines. Thus, the most efficient appliances are modeled to improve to efficiencies three percent better than forecast stock efficiency each five years. For example, modeled end-use appliances consume 97 percent energy relative to stock appliances in 2010; with improvements every five years until they consume 86 percent relative to stock in 2030. This assumption is made because ENERGY STAR guidelines are not available for the period under evaluation (2010-2030). In some cases, appliances are more disaggregate than forecast end-use data allow. For example, ―cooking" and ―microwave" as end-uses are modeled, while specific ovens and cooktops are not.

The present study does not evaluate the secondary market for appliances. When equipment is replaced, it is assumed to be replaced at the current efficiency or the high efficiency level. Reducing the availability of outdated appliances to secondary markets may be necessary to achieve the modeled savings. The best known type of policy for this purpose has been ―bounty" programs for refrigerators due to the great technical improvements in energy consumption. Refrigerator recycling programs are in place in 14 states across the nation – no statewide efforts were identified in Appalachia; such programs prevent older less-efficient refrigerators from entering the secondary market (ENERGY STAR, 2008).[3]

[3] New York Power Authority does run a refrigerator recycling program for public housing residents, see http://www.nypa.gov/services/esprograms2 htm

Methodology

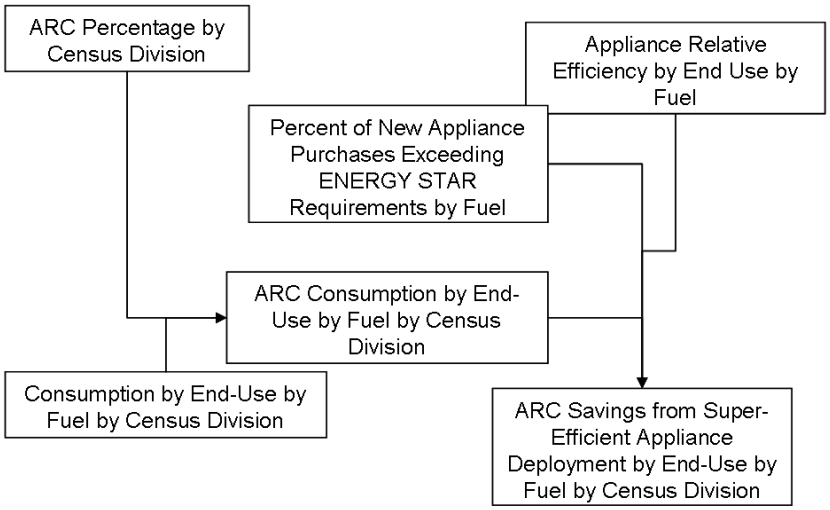


Figure B.4 Residential Super-Efficient Appliance Deployment Methodology

Energy Savings

Energy savings are represented by a percentage of end-use consumption. We multiplied the percent savings projected by year to the AEO forecast of consumption for that end-use by turnover for the end-use based on an average equipment lifetime.

Table B.11 Modeled End-Uses for Super-Efficient Appliance Deployment by Fuel

		Savings Modeled		
End-use	**Lifetime**	**Electricity**	**Natural Gas**	**Distillate**
Cooking	15	X		
Microwave	6	X		
Clothes Washer	14	X		
Dryer	14	X	X	
Freezer	19	X		
Refrigerator	19	X		
Security System	10	X		
DVD Players	8	X		
Home Audio	5	X		
PC	8	X		
TV	8	X		

Policy Implementation Cost

We assume administrative costs similar to a standards program of $0.13 per MBtu based on 1995 cost of .095/MBtu from the Clean Energy Future study and a 1.32 inflation factor (Interlaboratory Working Group, 2000 [Appendix E]; BLS, 2008).

Investment costs vary widely by appliance, brand, model, and location. In order to generalize, we assumed a cost of $30 per MBtu (delivered) saved, representing a three year payback with energy prices at $10 per MBtu. This cost overestimates the incremental cost of some end-use appliances and underestimates others.

This program is expected to be accompanied by an incentive program that will cover 40 percent of the incremental costs of adopting the higher efficiency models from 2010 to 2015 and 20 percent from 2015 to 2020. In effect, this market transformation program helps to accelerate the adoption of efficient appliances that would be adopted anyway at some later point in the future. As such, the savings beyond 2030 are not included in this analysis.

Market Penetration

This study assumes that 50 percent of new purchases or replacement products from 2010 to 2020 and 40 percent from 2020 to 2030 are more efficient than forecast stock efficiency in the *Annual Energy Outlook* which already assumes some efficiency gains (EIA, 2007; 2008).

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APPENDIX C: COMMERCIAL POLICY AND METHODOLOGY DETAIL

COMMERCIAL BUILDING MODEL BUILDING ENERGY CODES

Introduction

Commercial model building energy codes prescribe the minimum level of efficiency that must be achieved in new commercial buildings.[1] The present study assumes that all counties in the Appalachian Region adopt and enforce the 2006 IECC effective by 2010 and update to new building codes every three years. The 2006 IECC reduces the number of climate zones for different requirements; it also reduces the allowed glazing area to 40 percent (from 50 percent). See Table C.1 for details of the 2006 IECC for the climate zones in the Appalachian Region; a breakdown of climate zones by Appalachian state is given in Table C.2. Codes adopted in later years are expected to continue to increase efficiency through reduced heat loss, more efficient windows, duct sealing measures, and passive solar design.

[1] A commercial building is anything other than a low-rise (1-3 stories) house, condominium, or apartment (R-2, R-3, and R-4).

Table C.1 2006 IECC Commercial Envelope Prescriptive Requirements by Climate Zone
(ICC, 2006, Table 502.3)

Climate Zone	3	4	5	6
Vertical Fenestration (40 percent maximum of above grade wall)				
Framing materials other than metal with or without metal reinforcement or cladding				
U-factor	0.65	0.4	0.35	0.35
Metal framing with or without thermal break				
Curtain Wall/Storefront U-factor	0.6	0.5	0.45	0.45
Entrance Door U-factor	0.9	0.85	0.8	0.8
All Other U-factor[1]	0.65	0.55	0.55	0.55
Metal SHGC-All Frame Types				
SHGC: PF < 0.25	0.25	0.4	0.4	0.4
SHGC: 0.25 ≥ PF < 0.25	0.33	NA	NA	NA
SHGC: PF ≥ 0.5	0.4	NA	NA	NA
Skylights (3% maximum)				
Glass; U-factor	0.9	0.6	0.6	0.6
Glass; SHGC	0.4	0.4	0.4	0.4
Plastic; U-factor	1.3	1.3	1.3	0.9
Plastic; SHGC	0.35	0.62	0.62	0.62

[1]*All others includes operable windows, fixed windows and non-entrance doors.*
PF: Projection factor

Table C.2 Climate Zones for ARC Portions of States
(ICC, 2006)

Climate Zone	AL	GA	KY	MS	MD	NC	NY	OH	PA	SC	TN	VA	WV
3	X	X		X						X			
4		X	X		X	X		X			X	X	X
5					X	X	X	X	X				X
6							X		X				

While some Appalachian jurisdictions may not currently have the capacity to administer and enforce building codes, regional, national training, or grant programs could help; spillover effects between residential and commercial energy code activities are expected. On July 9, 2008, H.R. 4461 –Community Building Code Administration Grant Act (CBCAG)" passed the house. If passed by the senate (S 2458), enacted, and funded, CBCAG Act would authorize a grant program through the U.S. Department of Housing and Urban Development (HUD) to provide competitive matching funds grants to local jurisdictions to build-up their local building code administration and enforcement capabilities.

Methodology

New commercial floorspace forecasts are available by building type, by census division as part of the EIA's *Annual Energy Outlook* 2008 (EIA, 2008). We used population weights to the Appalachian portion of each census division to construct a new commercial construction floorspace by building type forecast unique to the Region (REMI, 2007).

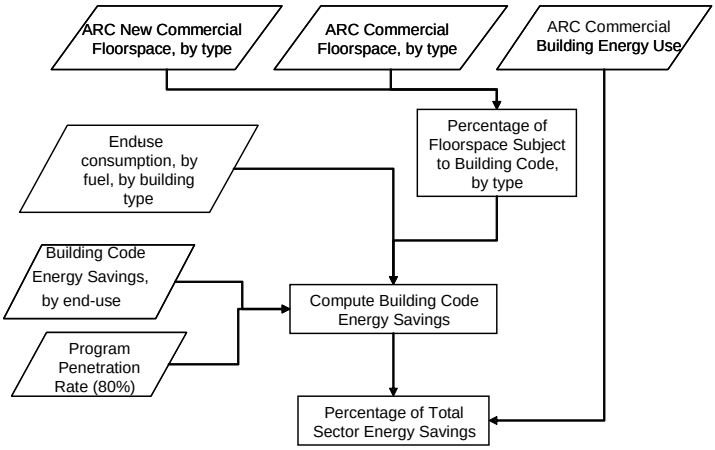

Figure C.1 Commercial Model Building Energy Codes Methodology

Building codes are only anticipated to reduce consumption for space heating, space cooling, and lighting loads by improving shell efficiency and reducing/modifying lighting fixtures. The three major fuels used for these purposes, electricity, natural gas, and distillate fuel oil, are modeled for savings. Reduced consumption for other fuels (e.g. wood, kerosene, and LPG) and for other end-uses may also follow building energy code changes, but they are not included in this assessment.

Energy Savings

Energy savings for building energy codes are determined by changing the anticipated efficiency of newly constructed floorspace. The modeled efficiencies are shown in Table C.3.

Table C.3 Achievable Efficiencies if Building Codes are Adopted and Enforced

Year Operational[1]	Lighting Savings Relative to Baseline[2] %	Space Heating/ Cooling Savings Relative to Baseline[2] %	Potential Code	Floorspace built to this code[3] (million sq ft)
2010	20	0	2006 IECC	303
2013	30	3	2009 IECC	315
2016	33	6	2012 IECC	328
2019	36	9	2015 IECC	340
2022	39	12	2018 IECC	350
2025	42	15	2021 IECC	361
2028	45	18	2024 IECC	371

[1] The ―Year Operational" is in three year increments because we assume a three year code adoption cycle.
[2] Relative savings are to *AEO 2008* forecast of consumption estimates for the end-uses modeled to be impacted by building codes: Space Heating, Space Cooling, and Lighting.
[3] All 11 types of commercial buildings are included. Square footage listed is 80 percent of the forecast constructed floorspace during the time the code would be in force; this relates to our assumed compliance rate of 80 percent.

The current study's estimates of savings relative to the *AEO* 2008 (EIA, 2008) estimates are intentionally conservative. Generally untouched by building codes is ―wasted energy" from unused energy services in transitional spaces – such as lobbies and hallways. Pitts and Bin Saleh (2007) show that transitional spaces make up 10-40 percent of commercial buildings; further, they model several building designs and conclude that space conditioning savings would be about 13 percent if buildings were designed with a non-cooled, but ventilated, transitional buffer surrounding the main building space.

Policy Implementation Cost

Administrative costs are assumed to include two training administrators per state, proportioned, at $75,000 each and one additional verification liaison at $75,000 for each 10 million square feet of new floorspace per year.

Investment costs are assumed to be $0.30 per square foot of new floorspace. There is no incentive for compliance included; however, enabling and then requiring third-party verification of code compliance can increase compliance. Trainers/verifiers working with code officials can spot-check third-party verification reports and offer guidance to construction and verification firms.

Market Penetration

The purpose of this study is to estimate cost-effective energy savings; since building energy codes are required to be cost-effective before adoption, we assume compliance at 80 percent. This compliance rate reflects less than total participation because some shirking is expected despite having

a third-party verification procedure. Total commercial floorspace affected by each code are given, above, in Table C.3.

COMMISSIONING OF EXISTING BUILDINGS

Introduction

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.

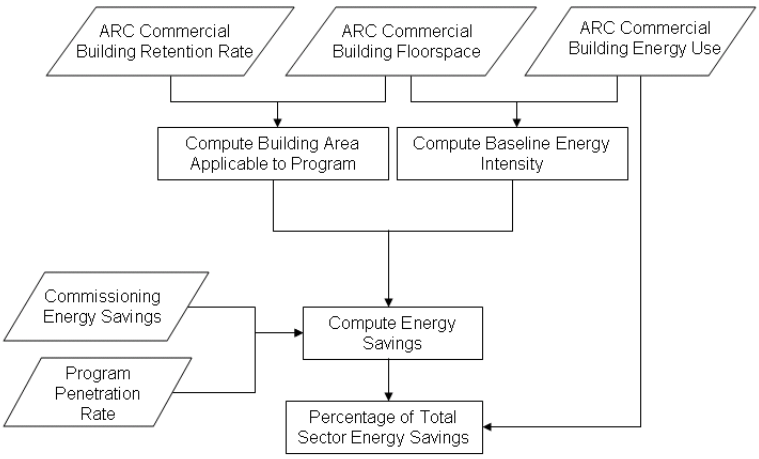

Figure C.2 Commissioning of Existing Buildings Energy Savings Methodology

As with the residential buildings stock, the retention rate for commercial structures in the ARC Region was assumed to be 98 percent. This assumed, coupled with values for the commercial building floorspace and energy consumption in the ARC yielded both the total building area that would be subject to the commissioning program as well as a baseline commercial building energy intensity value. The energy intensity is then multiplied by the program square footage to yield the baseline energy consumption for existing buildings.

Energy Savings

Data related to commissioning of existing commercial buildings are generally limited to individual case studies or broad averages made from many different building types. Since data specifically related to the ARC Region were not available, the latter approach was used. In a meta-analysis performed by Evan Mills of Lawrence Berkeley National Laboratory (Mills et al., 2004), the median energy savings yielded after commissioning was 10 percent of site energy for buildings that did not purchase thermal products from outside sources. This value was applied to the applicable building housing stock, and a near linear increase in the total commissioned square footage was assumed. By 2030, all of the floorspace under this program is assumed to be commissioned. All buildings constructed after 2010 were excluded as they are subject to other policies in this assessment. These newer buildings, which may have been commissioned upon construction, could be re-commissioned at a later date; however, building re-commissioning is not addressed under this program.

To estimate the total program energy savings, the site energy savings of 10 percent was applied to the square footage to be commissioned during each year. These numbers were then compared with the

total sector energy consumption. To make this comparison, it was assumed that energy savings were proportional to the baseline energy consumption by energy/fuel source. Estimates of these values were supplied by the U.S. Energy Information Administration (2007). The site electricity was converted to primary energy, which includes generation, transmission, and distribution losses, and the total energy saved by the program was compared with the sector energy consumption.

Policy Implementation Costs

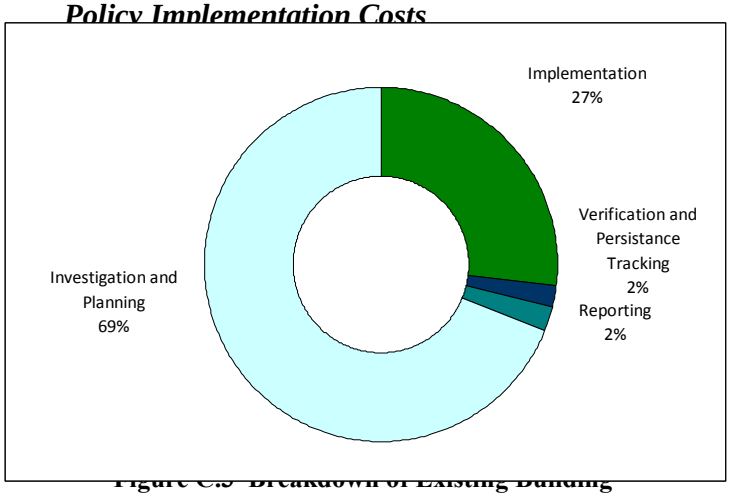

Figure C.3 Breakdown of Existing Building Commissioning Investment Costs
(Mills et al., 2004)

Investment costs for the commissioning of existing buildings were derived from Mills et al. (2004). In their meta-analysis, it was found that the median, inflation-adjusted commissioning costs were $0.30 per square foot (Mills et al., 2004). Figure C.3[2] illustrates the components of commissioning investment costs and their relative importance. For the 55 buildings that reported commissioning costs breakdowns, the majority of costs were used to investigate and plan commissioning.

In the same study, incentives from utilities played a large role in overall project funding. Of 48 projects reporting utility incentives, the median level of support was 82 percent of the total project cost and was covered by the utility in order to decrease energy demand. This value was used as a program starting point, steadily decreasing to no support by year 2020.

Much of the personnel costs related to this program are covered in the investment cost required of the building owner, which may or may not be subsidized by an outside entity such as a utility. It was assumed that the program would require a director for each state in the Appalachian Region at $150,000 per year, population-weighted to only include costs associated with the Region, with supporting staff members added at $90,000 per year for every 10,000,000 square feet commissioned per year.

COMMERCIAL RETROFITS IN LIGHTING AND HVAC

Introduction

Commercial retrofits offer an opportunity to improve end-use consumption to the best available technology. A program for commercial retrofits is expected to encourage investment by offering a matching incentive in the form of a tax credit, grant, or rebate. Amman and Mendelsohn (2005) reviewed commercial retrofit programs and suggested that an integrated ―whole building" approach would likely achieve even greater savings especially in areas where systems overlap.

Due to the variant nature of buildings and their circumstances, we have chosen to model only targeted retrofits of lighting and HVAC to best available technology – although a policy or measure developed for commercial retrofits could also use a systems approach. The modeled efficiencies are

[2] Adapted from Figure 13 ―Commissioning Cost Allocation" (Mills et al., 2004, p. 35)

about what would be required, independent of savings in other end-uses, to meet the Building Owners and Manager's Association's (BOMA) challenge to reduce commercial building consumption by 30 percent by 2012 (BOMA, 2007).

Figure C.4 Example of Improved Lighting Appearance with Energy Saving Lighting Retrofits
(Efficient Lighting, 2008)

Methodology

The present study uses a consumption reduction figure for the four end-uses affected (heating, cooling, ventilation, and lighting). There may be some overlap between savings characterized in the Commissioning of Existing Buildings program and this retrofit program because both target existing building stock. DeCanio and Watkins (1998) found that characteristics of firms are important in their adoption of these cost-effective retrofits. However, data on firm characteristics are not available for the Region, so the present study assumes constant adoption over all types.

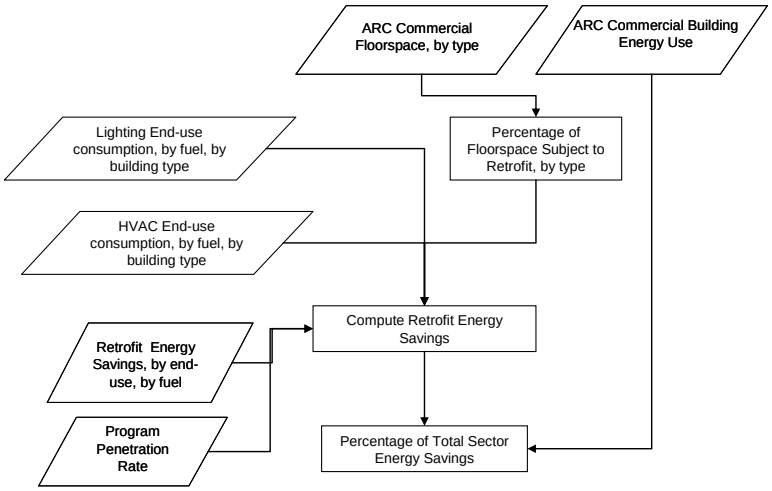

Figure C.5 Commercial Retrofit of HVAC and Lighting Methodology

Energy Savings

Energy savings for commercial building retrofits of HVAC and lighting equipment are determined by changing the anticipated efficiency of heating, cooling, ventilation, and lighting end-uses. The modeled efficiencies compared to the stock equipment efficiencies from the *AEO* 2008 are shown in Table C.4 (EIA, 2008).

Savings for duct-sealing alone have been shown to be around 15 percent with a payback of 1.1 years (Jump, Walker, and Modera, 1996; Franconi, Delp, and Modera, 1998). Similarly, Woods (2006)

describes several cases of air sealing (rooftops, doors, windows) where savings were between 19 and 35 percent with paybacks from less than half a year to around five years.

Table C.4 Modeled End-Use Efficiencies for Retrofit Equipment Compared to *AEO 2008* Stock Equipment
(EIA, 2008)[a]

	Electricity								Natural Gas				Distillate	
	Lighting (lumens per watt)		Space Heating		Space Cooling		Ventilation (cubic feet per minute per		Space Heating		Space Cooling		Space Heating	
	AEO 2008	Present	AEO 2008	Present	AEO 2008	Present	AEO 2008	Present	AEO 2008	Present	AEO 2008	Present	AEO 2008	Present
2010	42.90	61.29	1.18	1.68	2.96	4.23	0.25	0.35	0.77	1.10	0.92	1.32	0.78	1.11
2011	43.34	63.73	1.19	1.75	3.01	4.43	0.25	0.37	0.77	1.14	0.94	1.38	0.78	1.15
2012	43.70	66.21	1.20	1.81	3.06	4.64	0.25	0.38	0.77	1.17	0.96	1.45	0.78	1.18
2013	44.00	68.76	1.20	1.88	3.10	4.85	0.25	0.39	0.78	1.21	0.97	1.52	0.78	1.22
2014	44.27	71.41	1.21	1.95	3.14	5.07	0.25	0.41	0.78	1.26	0.99	1.59	0.78	1.26
2015	44.52	74.19	1.22	2.03	3.18	5.30	0.26	0.43	0.78	1.30	1.00	1.67	0.78	1.31
2016	44.74	77.14	1.22	2.11	3.22	5.55	0.26	0.44	0.78	1.35	1.01	1.74	0.78	1.35
2017	44.96	80.29	1.23	2.19	3.25	5.81	0.26	0.46	0.78	1.40	1.02	1.83	0.78	1.40
2018	45.16	83.62	1.23	2.28	3.29	6.09	0.26	0.48	0.78	1.45	1.04	1.92	0.79	1.45
2019	45.33	87.18	1.24	2.38	3.32	6.38	0.26	0.50	0.79	1.51	1.05	2.01	0.79	1.51
2020	45.49	90.99	1.25	2.49	3.35	6.70	0.26	0.53	0.79	1.57	1.06	2.11	0.79	1.57
2021	45.64	93.14	1.25	2.56	3.38	6.90	0.27	0.54	0.79	1.61	1.07	2.17	0.79	1.61
2022	45.77	95.35	1.26	2.62	3.41	7.10	0.27	0.56	0.79	1.64	1.07	2.24	0.79	1.64
2023	45.91	97.68	1.27	2.69	3.44	7.31	0.27	0.57	0.79	1.68	1.08	2.30	0.79	1.68
2024	46.04	100.09	1.27	2.76	3.46	7.53	0.27	0.59	0.79	1.72	1.09	2.37	0.79	1.72
2025	46.15	102.56	1.28	2.84	3.49	7.75	0.27	0.60	0.79	1.76	1.10	2.44	0.79	1.76
2026	46.26	105.13	1.28	2.92	3.51	7.98	0.27	0.62	0.79	1.80	1.10	2.51	0.79	1.80
2027	46.35	107.79	1.29	3.00	3.53	8.22	0.27	0.64	0.79	1.85	1.11	2.58	0.79	1.84
2028	46.43	110.54	1.29	3.08	3.56	8.47	0.27	0.65	0.80	1.90	1.11	2.65	0.79	1.89
2029	46.52	113.45	1.30	3.17	3.58	8.72	0.28	0.67	0.80	1.94	1.12	2.73	0.79	1.93
2030	46.59	116.49	1.31	3.26	3.59	8.98	0.28	0.69	0.80	1.99	1.12	2.81	0.79	1.98

[a] The present study also considers savings for Ventilation provided by natural gas and distillate fuel oil. These are small portions of the equipment stock, and the *AEO 2008* did not include stock efficiency data for these fuels in their forecast (EIA, 2008).

Policy Implementation Cost

Administration of a retrofit incentive program (such as allowing for a tax credit or grant) is not expected to be burdensome. One administrator at $75,000 per 500 million square feet of retrofit space per year is assumed.

Investment costs are set at $1.00 per retrofit square foot. This assumption is general because data were not available on equipment capacity and age at the level of detail required for modeling by equipment costs. If data are collected at this level in a future analysis, the costs could better approximate the true investment necessary to achieve these savings. We assume these costs are reasonable. For example, a 5,000 square foot building would have an incremental cost of $5,000. This assumes that the building was already undergoing replacement of equipment; the incremental costs represent the difference in cost for purchasing higher efficiency equipment.

The present study includes an assumption of a significant 30 percent incentive to undergo commercial retrofits; the incentive is in place from 2010 to 2020. While this makes adoption more likely, it increases the public cost of the program. An incentive program at a lower level could be

designed to achieve a significant portion of the modeled savings. Amman and Mendelsohn (2005) reviewed several commercial retrofit programs and found varying incentive structures from fixed amounts to 100 percent of cost, depending on the provider and the program goals.

Market Penetration

We assume to reach nearly all lighting and HVAC equipment within the Appalachian commercial floorspace with efficient retrofits. With heating and cooling equipment having lifetimes less than 20 years and lighting having lifetimes less than 10 years, it is not unreasonable that all equipment could be replaced over the program lifetime.

COMMERCIAL INCENTIVES FOR EFFICIENT OFFICE EQUIPMENT AND USE

Introduction

Equipment standards set minimum efficiency levels for products to enter the market in a given state or nationwide. For those appliances not covered by Federal standards, states can set efficiency standards; however, Federal law preempts state action if the appliance is covered by Federal standards (EPA, 2006). This study considers improved equipment standards for office equipment, including computers. Greater savings could be achieved if cooking and miscellaneous plug-loads were addressed as well.

The present study does not evaluate the secondary market for commercial equipment. Reducing the availability of outdated appliances to secondary markets may be necessary to achieve the modeled savings. The best known type of policy for this purpose has been for refrigerators due to the great technical improvements in energy consumption behavior. Refrigerator recycling programs are in place in 14 states; such programs prevent older less-efficient refrigerators from entering the secondary market (ENERGY STAR, 2008).

Methodology

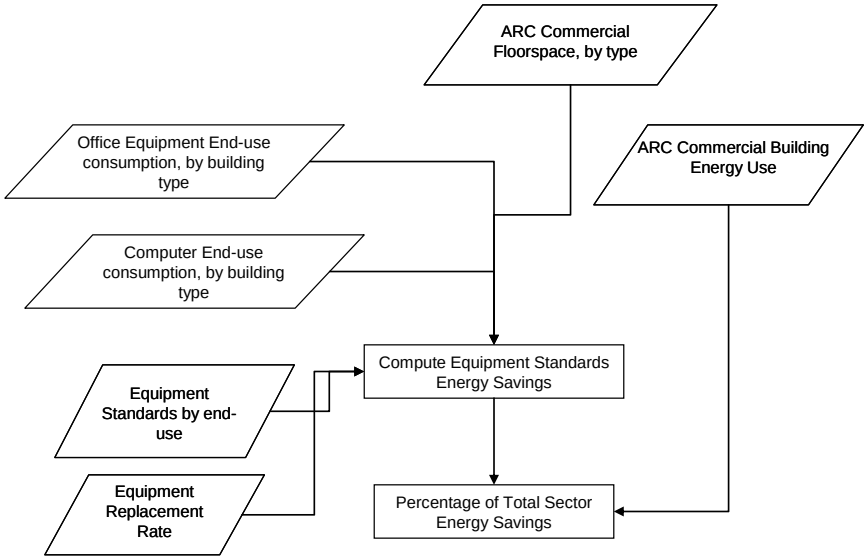

Figure C.6 Office Equipment Incentives Methodology

Energy Savings

The present study assumes that Office Equipment (PC and other), as an end-use becomes 40 percent more efficient from 2010 to 2030. This is driven by the assumption that standards set the minimum efficiency at 20 percent better than the stock efficiency in 2010 and these standards increase every five years such that the standards average 40 percent better than stock efficiency in 2030. Adoption is set to five percent per year, based on office equipment lifetimes. Due to short lifetimes, 100 percent of the equipment is assumed to be replaced over the study time horizon. The market already adopts ENERGY STAR labeled equipment with substantial savings potential, as shown in Table C.5.

Table C.5 ENERGY STAR Market Share, Savings, and Lifetimes
(Sanchez et al., 2007; Koomey et al., 1995)

Equipment	2006 ENERGY STAR Market Share %	2008 ENERGY STAR Device Savings %	Equipment Lifetime (years)
Copiers	90	20	6
Fax	99	39	4
Printers	99	13	5
Scanners	85	10	4
MFD[a]	98	22	6
CRT[b]	0	47	4
LCD[c]	37	44	4
Computers	98	20	4

a: MFD – Multi-Function Device
b: CRT – Cathode Ray Tube
c: LCD – Liquid Crystal Display

While this study models an improvement in efficiency standards to best available technology, it implies that efficiency features are used. Roberson et al. (2004) found a significant percentage of office equipment in commercial buildings not taking advantage of power saving features, which generally qualify this equipment for ENERGY STAR (Table C.6). Using the power saving features of equipment already purchased has an investment cost of zero, and a corresponding immediate payback.

Table C.6 Turn Off and Power Management Status of After-Hours Office Equipment, 2000 and 2003
(Roberson et al., 2004, Table 7 p. 16)

Category	Type	# in 2003	Turn-off Rate %		Power Management Rate %	
			2000	2003	2000	2003
Computers	desktop + ICS[a]	1,498	44	37	5	7
	desktop	1,453		36		6
	ICS[a]	45		60		61
Monitors	all	1,598	32	29	56	72
	CRT[b]	1,329		32		71
	LCD[c]	269		18		75
Printers	all	353	25	23	44	31
	monochrome laser		24		53	
	high-end color		15		61	
	laser	158		15		60
	inkjet	123	31	30	3	0
	impact	22	31	27	0	0
	thermal	38		18		0
	wide format	8	57	75	32	0
	solid ink	4		0		75
MFDs[d]	all	79	18	20	56	29
	inkjet	16		19		31
	laser	63		21		28
Copiers	all	33	18	49	32	28
Fax	machines	47		2	0	6
Scanners	all	34	29	41		60

[a] ICS- Integrated Computer Systems
[b] CRT – Cathode Ray Tube
[c] LCD – Liquid Crystal Display
[d] MFD – Multi-Function Device

Policy Implementation Cost

Administrative costs are relatively low for appliance and equipment standards. In general, standards do not have a consistent expense – administrative costs would be highest in the years of adoption and lowest between adoption cycles. We assume administrative costs of $75,000 per year per 500 million square feet of floorspace. It is assumed that these administrators would be charged with promoting use of energy saving features on office equipment purchased with the program.

Investment costs vary widely by equipment type, brand, model, and location. In order to generalize, we assumed a cost of $0.10 per square foot of floorspace in buildings adopting new equipment (based on an average of nine pieces of office equipment per 1000 gross square foot of building space (Roberson et al., 2004). The density of office equipment will lead to significant variations in costs and savings across building types and specific buildings. This cost overestimates the incremental cost of types of office equipment and underestimates others.

This program is expected to be accompanied by an incentive program that will cover 20 percent of the incremental costs of adopting the higher efficiency models until 2020.

Market Penetration

This study assumes that all office equipment will be replaced with high efficiency equipment (meeting an assumed ENERGY STAR standard) at the end of its lifetime. Savings are compared to the *Annual Energy Outlook* which already assumes some efficiency gains (EIA, 2007; 2008).

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APPENDIX D: INDUSTRIAL SITES

D.1 INDUSTRIAL ASSESSMENT CENTERS

Introduction

Industrial Assessment Centers (IACs) evaluate small- to medium-sized industrial sites (less than $2.5 million in energy consumption per year) and identify savings opportunities in the form of energy efficiency, waste minimization, pollution prevention, and productivity improvement (DOE/EERE, 2008). Expansion of these centers in the Appalachian Region could yield large improvements in energy efficiency at industrial facilities.

Examples of industrial assessment findings are shown in Table D.1. Each industrial assessment yields a list of recommendations, which includes a statement of the type of recommended improvement, its cost to implement, the potential energy savings, and a quantification of how much money would be saved per year if each recommendation were implemented.

Table D.1 Examples of Recommended Improvements in Energy Consumption
(DOE/EERE, 2008)

State	Year	Principal Product	Baseline Year Energy Cost $	Potential Electricity Saved %	Potential Natural Gas Saved %
PA	2008	Chain Assemblies	602,793	26	50
WV	2008	Fiberglass Media	1,140,227	10	10
NC	2008	Cutting Tools	584,396	4	0
MS	2008	Wiring Harness Components	218,074	9	0

METHODOLOGY

Energy Savings

Figure D.1 highlights the process implemented to determine the potential energy savings that could be realized if IACs were expanded in Appalachia. First, findings yielded from industrial assessment in the states that comprise the Appalachian Region were compiled. Information related to productivity improvement and waste minimization was excluded unless there was a stated energy savings associated with these actions. These data include such information as the North American Industry Classification System (NAICS) code, baseline energy usage, recommended changes, potential energy savings, and cost of recommended changes. After these data were compiled, they were averaged by ARC subregion (North, Central, and South) while maintaining the information by separate industrial NAICS codes.

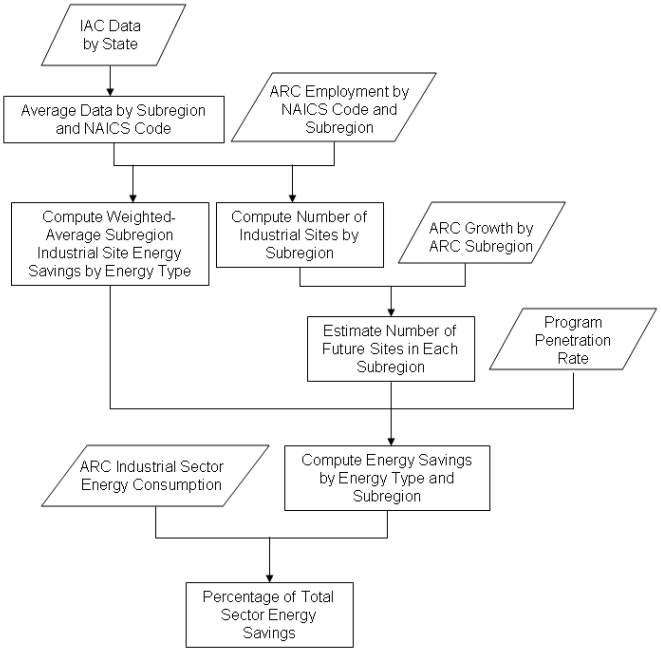

Figure D.1 IAC Energy Savings Methodology

Employment figures for the ARC (IMPLAN, 2006) were provided and used along with information provided by the industrial assessments to estimate the number of industrial sites in the ARC Region. In addition, the employment figures and IAC data were used to compute a weighted-average energy savings number by energy type for each site. These averages take into account the weighting of each industry in the subregion. The average values used for analysis are found in Table D.2. Current implementation rates can be on the order of 50 percent. In order to quantify the full potential of this policy bundle, it was assumed that all of the recommended changes are implemented. This may be possible by addressing barriers to implementation through increased education and outreach, assistance with outage planning, and low-interest loans, as mentioned in Table 5.2.

Table D.2 Average Site Energy Savings and Investment Costs for IAC Program
(Author‘s calculations; DOE/EERE, 2008)

ARC Subregion	Electricity Savings %	Natural Gas Savings %	Implementation Cost $
North	13.6	15.0	245,612
Central	4.9	13.2	121,461
South	11.7	13.4	195,643

Savings in the North subregion were found to be greatest, and the costs required to implement the changes were also the greatest. The Central subregion had much lower savings values related to electricity; however, the costs for changes were also much lower. The differences between the subregions may be due to climate and weighting of various industries in each subregion as well as a limited sample size in the Central region. The Central region is the smallest ARC subregion by area.

After estimating the number of sites in the Appalachian Region, the number of sites eligible for IAC assistance was determined. On average, approximately 90 percent of industrial sites are in the small- to medium-size range, and, therefore, eligible for industrial assessment (Soderlund, 2008). These sites represent approximately half of the total energy use in industry. The remaining 10 percent of sites would be eligible for other programs such as Energy Savings Assessments (ESAs) and/or combined heat and power systems.

The extensive market penetration of industrial assessments was estimated based upon the success of the current IAC program. Currently, approximately 40 assessments are performed in the Region per year. With a large push, a goal of 100 percent assessment by 2030 in Appalachia was assumed, which would require an eight-fold increase in the current number of assessments per year. With the number of eligible sites determined and a program penetration assumed, the program energy savings by each energy type were determined.

Policy Implementation Cost

As seen in Table D.2, the investment costs were determined from previous industrial assessment data. Since the IAC program is already in existence, administration costs were assumed to be similar to those already incurred. Each assessment requires approximately $9,000 in funds (Soderlund, 2008). Additionally, in support of the program, each state was assumed to have an administrator in charge of promoting the program. Each program champion was budgeted at $150,000 and that total was then proportioned to the Appalachian Region based on population.

D.2 ENERGY SAVINGS ASSESSMENTS

Introduction

Energy Savings Assessments (ESAs) are evaluations of major energy systems at large industrial sites (greater than $2.5 million in annual energy expenditures). Each assessment only targets one system. The U.S. Department of Energy‘s Save Energy Now program was developed to use ESAs to aid in the reduction of natural gas consumption post hurricane Katrina (Wright et al., 2007).

The results summarized by Wright et al. (2007) are for assessments that focused on steam and process heating; however, the program also trains on-site personnel to be able to conduct future ESAs at their location and provides them with tools, such as software, to aid in ESA completion. In addition, while one of the major focuses of the Save Energy Now program is reduction of natural gas usage, ESAs can also be applied to other energy-intensive processes at an industrial site.

Methodology

Energy Savings

The methodology used to determine ESA program energy savings is shown in Figure D.2. Due to confidentially issues, data, such as those available for industrial assessments, were not available. Data shared by Wright et al. (2007) were listed separately by two categories: NAICS code and state. These sets of data were combined with Appalachian Region employment information and IAC data for specific system savings to estimate weighted-average energy savings values by energy type (Table D.3).

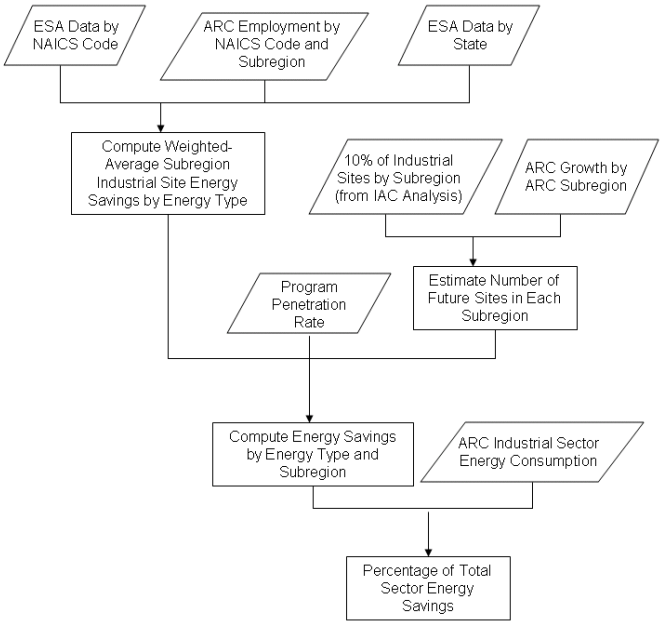

Figure D.2 ESA Energy Savings Calculation Methodology

The number of industrial sites for which the ESA program would be applicable was determined through the IAC analysis and combined with subregion growth estimates to determine the number of sites available for future assessment. In addition, it was assumed that up to four high-impact assessments could take place at each physical site location. All of these ―virtual sites" would be able to be assessed, each increasing the sector energy savings.

Table D.3 Average Site Energy Savings for ESA Program
(Author's calculations; Wright et al., 2007)

ARC Subregion	Electricity Savings %	Natural Gas Savings %
North	11.5	17.5
Central	8.4	12.8
South	7.3	11.1

Once the number of ―virtual sites" (or potential assessments) and site energy savings were determined, a penetration rate of 100 percent was assumed for each first assessment. In 2006, it is estimated that only 16 ESAs were performed in Appalachia, based on population-weighting. This was, in part, due to the limited scope of the Save Energy Now program. By 2030, it is estimated that approximately 170 assessments would be completed each year throughout the Region, with almost all being performed by on-site personnel. It was assumed that subsequent assessments would lag the first assessment due to effort required to implement first assessment recommendations. Overall, over

60 percent of available assessments were completed by 2030. All recommendations have four-year or shorter payback period, and it is assumed that all recommendations were executed.

Policy Implementation Costs

While the costs of assessing one system in a large-scale industrial plant is similar to the cost of a full industrial assessment for a small- to medium-sized facility, current program infrastructure is much smaller and would require the addition of more administrators. It was assumed that each state would have a program champion, funded at $150,000 per year and proportioned to the Appalachian Region based on population ratios in each state, with support personnel at $90,000 per year, one for every 10 new sites assessed per year in order to continue outreach and education while also monitoring the progress of every site assessed. These personnel would be tasked with tracking the results of initial assessments and for encouraging future assessments at these locations as well as assisting with such tasks as site software updates.

Based on the data available from the Save Energy Now program and scaling industrial assessment results yielded the average investment cost values shown in Table D.4.

Table D.4 Average Investment Costs for ESA Program
(Author‘s calculations; Wright et al., 2007)

ARC Subregion	Investment Cost (million 2006$)
North	1.5
Central	2.1
South	2.3

D.3 INDUSTRIAL COMBINED HEAT AND POWER

Introduction

The use of industrial combined heat and power (CHP) systems could have a large impact on industry‘s future consumption of primary energy. Many CHP systems consist of a prime mover, which produces electricity. The prime mover is coupled with one or more thermally-activated technologies, and these thermal systems use the prime mover‘s hot exhaust as an energy input to create a useful product such as steam or hot water that would otherwise be generated by using other high-value energy sources such as electricity or natural gas. The systems considered in the current study are of this type. Other types of systems could make use of fluids compressed to aid in transport (e.g., district steam used for space heating) that, instead of being throttled down to a site‘s required system pressure, is coupled with a turbine, which generates power while also reducing pressure. These types of systems are not modeled in this analysis; however, they do have the potential to yield additional energy savings for the Appalachian Region. When cost-effective for a particular site, so-called recycled energy systems, where heat is recovered from a process stream and reused to drive another, lower temperature process, are included in industrial and energy savings assessments;

therefore, they were not included in the CHP portion of the study. Through the use of this otherwise wasted energy, CHP systems can yield total system thermal efficiencies of up to 80 percent (EPA, 2008).

Methodology

Energy Savings

The methodology used to calculate the energy savings that could result from a CHP program in the Appalachian Region is detailed in Figure D.3. In order to assess the impact of expanding industrial CHP, it was necessary to determine the current level of installed CHP generation capacity in the Region. Information on current CHP installations is maintained in a database funded by the U.S. Department of Energy and administered by Energy and Environment Analysis, Inc. (EEA, 2007). Based upon the installed capacity in each ARC state, a capacity value was determined for the Region. According to this estimate, approximately four percent of the installed capacity in the ARC Region is part of a CHP system.

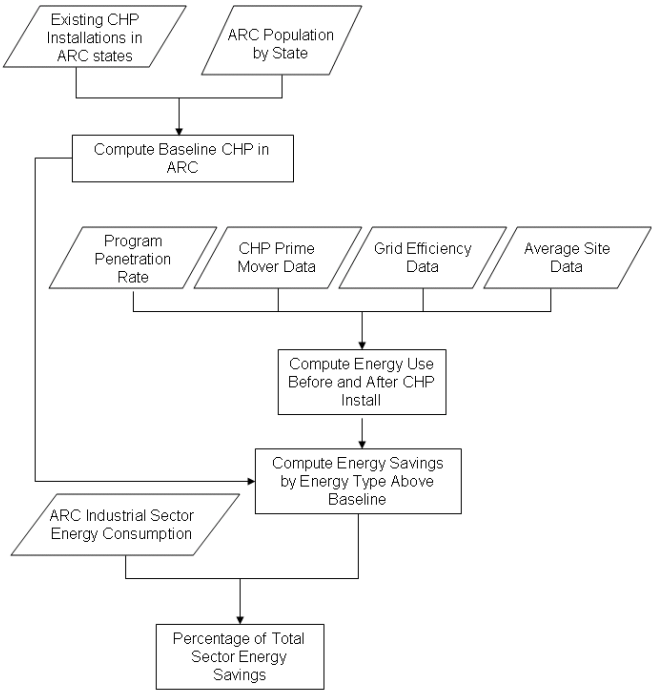

Figure D.3 Industrial CHP Energy Savings Methodology

In a study conducted by ACEEE, under an accelerated CHP scenario,[1] it is estimated that the share of installed capacity that is also part of a CHP system could reach 19 percent by 2030 (Laitner, 2008). Lemar (2001) estimated that under a ―moderate scenario" for CHP expansion and a 20-year time period, 15.7 percent of industrial electricity needs could be met by CHP. Under a much more aggressive scenario, 34.7 percent of industrial electricity could be generated by CHP systems. For the current study, it is assumed that by 2030, CHP's share of the Region's electricity generation capacity will reach 20 percent.

In addition to market penetration, characteristics of grid electricity, CHP prime mover, and site energy needs must be defined. Electricity generated in centralized power plants is subject to direct generation inefficiencies as well as energy losses due to transmission and generation. The electric efficiency related to grid-supplied electricity was calculated from EIA energy data (EIA, 2007). Including losses from generation, transmission, and distribution, the energy efficiency of grid-supplied electricity in the Appalachian Region decreases from 30.3 percent in 2010 to 25.1 percent in 2030. During the same time frame, the national average delivered electric efficiency increases from 31.7 percent in 2010 to 33.4 percent in 2030.

[1] An accelerated CHP scenario is one in which the rate of development of CHP in a Region approaches the rates seen in such countries as Finland and the Netherlands over the past 30 years.

CHP characteristics are highly dependent on the choice of prime mover. The prime mover characteristics used in this study are listed in Table D.5.

Table D.5 Example CHP Prime Mover Characteristics
(Elliot, 2008)

Type	Size (kW)	Electric Efficiency (%)	Thermal Output (Btu/ Wh)	Installed Cost ($/kW)	O&M Costs ($/k Wh)	After-treatment Cost ($/kW)
MT	60	24.6	6308	2,739	0.022	500
RE	100	28.4	6100	2,210	0.022	--
MT	250	26.0	4800	2,684	0.013	500
RE	800	35.0	2313	1,640	0.013	300
GT	3,000	26.0	5018	1,690	0.006	210
RE	3,000	35.9	3510	1,130	0.011	200
RE	5,000	39.0	3046	1,130	0.009	150
GT	10,000	29.0	4674	1,298	0.006	140
GT	40,000	37.0	2189	972	0.004	90

MT = Microturbine; RE = Reciprocating Engine; GT = Gas Turbine

In 2000, ONSITE SYCOM Energy Corporation (OSEC) published a study on the market and technical potential of industrial CHP (OSEC, 2000). A result of its analysis was a quantification of the CHP potential by SIC code,[2] which also listed such information as size of prime mover as well a ratio of site power and steam requirements. By weighting information on site energy use compiled by OSEC by Appalachian Region industrial site information derived from IAC information, an overall average power to steam ratio for the Region was determined to be 0.87. Average CHP prime mover characteristics for the Region were also determined and are shown in Table D.6.

Table D.6 Average CHP Prime Mover Characteristics for ARC Region
(Author‘s calculations)

Electric Efficiency	32.0%
Thermal Output	2,948 Btu/kWh
Installed Cost	$1,227/kW
O&M Costs	$0.0061/kWh
After-treatment Cost	$150/kW

[2] SIC codes where converted to approximate NAICS codes in order to determine Region characteristics.

While technological advances could improve prime mover performance, no such changes were assumed over the study time horizon. Additionally, raw material and manufacturing were assumed to be constant.

Policy Implementation Costs

Investment costs are a combination of installed, after-treatment, and Operations and Maintenance (O&M) costs. Over the study period, this policy scenario results in the installation of an additional 2.8 GW of CHP electric power generation capacity in the 2010-2030 period. At the average assumed price of $1,227 per kilowatt, over $2 billion dollars will be invested in equipment purchase and installation alone with an additional $580 million dollars in O&M spent.

While industrial CHP systems save energy overall when grid generation, transmission, and distribution losses are taken into account, the prices an industrial site in the Appalachian Region will pay for natural gas versus electricity in the base case do not make CHP systems a highly-attractive choice on a cost basis alone. To aid in promoting CHP in the Region, preliminary estimates suggested incentives on the order of 60 percent of the total investment cost will likely be required to encourage adoption. This high incentive rate is due to the baseline energy prices assumed for the Region, which are based on EIA's *Annual Energy Outlook 2008* values. These price values were population-weighted based upon the Appalachian portion of each census division (EIA, 2008). Discounted natural gas rates and premium pricing for electricity exported to the grid are two incentive mechanisms that could support CHP installation in the Region. As shown in Table 5.6, programs currently exist that assist CHP system owners with the high up-front costs of purchasing and installing these systems as well as guaranteeing discounted energy rates. California has a grant program which pays $600-$800/kW for the first 1,000 kilowatts of distributed generation capacity (Energetics, 2006).

A program to promote CHP in the Appalachian Region will require both education and publicity, due to economic hurdles. Administration costs are assumed to include a program directorship for each Appalachian state at $150,000 per year, proportioned to the Region based on population ratios, and one supporting staff member added for every 100 MW of additional capacity at a rate of $90,000 per year to provide public education and outreach, assistance to sites and projects, and oversight in the use of public funds for financing CHP systems.

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APPENDIX E: TRANSPORTATION

REFERENCE CASE ENERGY EFFICIENCY IN *AEO 2008* (EIA, 2008)

The *2008 Annual Energy Outlook* (*AEO*) projects energy consumption and prices based on energy-efficiency legislation enacted in the 2007 Energy Independence and Security Act (EISA, 2007). EISA established a Corporate Average Fuel Economy (CAFE) standard of at least 35 miles per gallon for cars and light trucks by 2020, a 40 percent improvement over today's fuel economy standard. Based on national fleet turnover data, we estimate that the new CAFE standard will reduce national light-duty vehicle fuel consumption by 22 percent by 2030. A host of additional policies are necessary to achieve an even more significant decrease in fuel consumption nationally and in the Appalachian Region. All policy-specific fuel savings documented in this analysis are additional to Reference Case fuel savings from the updated CAFE standard relative to a scenario with no change to fuel economy standards (Table E.1). All *AEO* projections cited here are national projections and have been scaled down by population proportion for the Appalachian Region. Please note that our estimate that gasoline savings will amount to 0.52 quads by 2030 differs slightly from *AEO 2008* estimate that the new CAFE regulations will save 0.48 quads a year by 2030.

Table E.1 2008 EISA CAFE Fuel Savings

Year	Gasoline Savings %	Gasoline Savings (million gallons)	Gasoline Savings (quads)
2010	0.2	22	0.00
2011	1	81	0.01
2012	1	186	0.02
2013	3	337	0.04
2014	4	507	0.06
2015	5	661	0.08
2016	6	844	0.10
2017	7	1,056	0.13
2018	9	1,293	0.16
2019	10	1,556	0.19
2020	12	1,843	0.23
2021	14	2,125	0.26
2022	15	2,400	0.30
2023	16	2,665	0.33
2024	17	2,920	0.36

Table E.1 2008 EISA CAFE Fuel Savings			
Year	**Gasoline Savings %**	**Gasoline Savings (million gallons)**	**Gasoline Savings (quads)**
2025	19	3,164	0.39
2026	19	3,397	0.42
2027	20	3,620	0.45
2028	21	3,831	0.48
2029	22	4,032	0.50
2030	22	4,222	0.52

CURRENT TRANSPORTATION ENERGY CONSUMPTION IN THE APPALACHIAN REGION

Gasoline consumption in the ARC Region in 2008 is estimated at 12.1 billion gallons. Gasoline use is expected to grow along with population and total vehicle miles travelled to reach 14.9 billion gallons by 2030. Similarly, consumption of diesel fuel will rise from 2.9 billion gallons in 2008 to 3.5 billion gallons by 2030. This study considers energy consumption of highway modes only.

PAY-AS-YOU-DRIVE INSURANCE

Introduction

Pay-as-you-drive insurance programs convert some of the fixed costs associated with driving into variable costs dependent on the total distance driven by a vehicle over a given year. Drivers would pay a portion of their premiums up front, and the remainder would be charged in proportion to mileage, as determined by periodic odometer readings or a mileage tracking device.

Methodology

Energy Savings

To determine the reduction in total VMT driven in Appalachia that will result from a pay-as-you-drive insurance scheme, we followed the above methodology. Estimates of the reduction in vehicle-miles traveled (VMT), and therefore energy use, resulting from a PAYD policy depend upon the price elasticity of travel demand, i.e., the percent change in travel resulting from each percent increase in the cost of travel. Estimates of elasticity vary considerably among those who

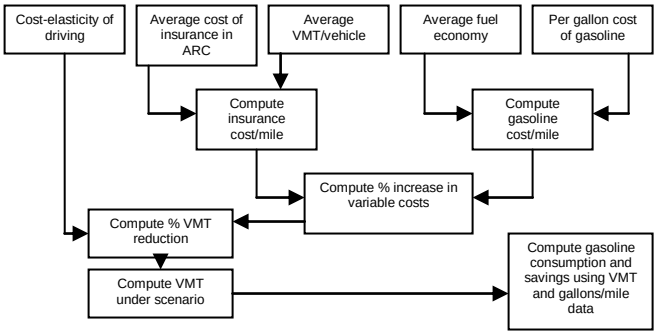

Figure E.1 Pay-As-You-Drive Insurance Energy Savings Methodology

study them, and differ also according to the time elapsed between the change in price and the response to it. We use here a value of -0.1 for the long-term elasticity of driving with respect to gasoline price; that is, over 10-15 years, we assume there is a one percent reduction in driving for a 10 percent increase in gasoline price.[1] At $3.04 per gallon, gasoline for an automobile or light truck having the average on-road fuel economy of 20.2 miles per gallon costs 14 cents per mile.[2] The average cost of an insurance policy in the Appalachian Region in 2005 was $785, and we assume that vehicles in Appalachia are driven 12,000 miles per year, roughly the national average.[3] This means an average insurance cost of 6.5 cents per mile.

If 80 percent of the cost of the insurance premium was charged on a per-mile basis, the average cost per mile would then be $0.052 per mile, about 37 percent of the per-mile cost of fuel.[4] Variable driving costs would increase by 37 percent as a result. An elasticity of -0.1 implies a corresponding reduction in driving of about four percent. Thus 100 percent adoption of PAYD insurance would be expected to reduce car and light truck energy use in Appalachia by about four percent over 10-15 years.

Policy Implementation Costs

During the pilot stage of the pay-as-you-drive insurance option, the ARC will grant $200 to insurance agencies for each one-year policy that is mileage based. We assume that 2,000 such policies will be sold in 2009, 10,000 in 2010 and 20,000 in 2011. Therefore, ARC can expect to pay incentives of $400,000 in 2009, $1.7 million in 2010 and $3.3 million in 2020 (2006 dollars).

Administrative costs were estimated based on the assumption that each Appalachian state will employ one administrator for the program at a cost of $150,000 and two program staff at the cost of $90,000. These costs were scaled by the Appalachian population in each state to estimate ARC-specific administrative costs. Also included in administrative costs is the cost of implementation incurred by insurance companies. Insurance companies could incur substantial per-vehicle monitoring costs during the pilot phase of the proposed program for distribution of mileage tracking devices and data collection expenses. However, once the program becomes mandatory, per-vehicle costs would decline as tracking device costs decline and data collection and analysis is spread over a large number of vehicles. We assume a per-vehicle cost of $40 per vehicle per year in the pilot phase and $10 per vehicle thereafter. [5]

[1] Greene and Leiby, 2006; Litman, 2008
[2] EIA, 2006
[3] Insurance rates from Bureau of Labor Statistics http://data.bls.gov; miles per year calculated from 2005 vehicle registration
[4] Bordoff and Noel (2008) assume that 84 percent of the insurance premium is charged on a per-mile basis.
[5] Bordoff and Noel, 2008

Table E.2 Summary of Energy Savings Financial Costs For Pay-As-You-Drive Insurance

Year	Reduction in VMT %	Sector Primary Energy Savings %	Investment Costs (2006$)	Admn Costs (2006$)
2009	0.00	0.0007		4,370,000
2010	0.01	0.0035		4,690,000
2011	0.01	0.0071		5,090,000
2012	0.60	0.4161		34,526,596
2013	1.00	0.6931		55,037,088
2014	1.40	0.9725		75,833,244
2015	1.80	1.2526		96,918,060
2016	2.20	1.5317		118,294,558
2017	2.60	1.8077		139,965,788
2018	3.00	2.0862		161,934,830
2019	3.40	2.3638		184,204,789
2020	4.00	2.7799		217,436,109
2021	4.00	2.7837		218,928,132
2022	4.00	2.7849		220,430,599
2023	4.00	2.7959		221,943,583
2024	4.00	2.8096		223,467,158
2025	4.00	2.8280		225,001,398
2026	4.00	2.8535		226,546,378
2027	4.00	2.8771		228,102,172
2028	4.00	2.9039		229,668,858
2029	4.00	2.9345		231,246,510
2030	4.00	2.9692		232,835,205

CLEAN CAR STANDARD

Introduction

Appalachia‘s adoption of the Clean Car Standard means that new vehicles sold in the Region by each manufacturer would need to meet the requirements shown in Table E.3 for GHG emissions, on average. Our analysis of the energy savings that result from such a policy assumes that ARC will aim to achieve the long-term standards outlined below, standards that correspond to an average fleet fuel efficiency goal of 50 miles-per-gallon by 2030.

Table E.3 Proposed Clean Car Program Greenhouse Gas Tailpipe Standards, 2009-2020
(California Air Resources Board[a])

	Year	CO^2-equivalent emissions standard (g/mi) Combined (Passenger cars and small trucks/ SUVs and large trucks/SUVs)
Near-term	2009	375.2
	2010	359.5
	2011	322.4
Mid-term	2012	290.6
	2013	284.6
	2014	279.6
	2015	270.6
	2016	262.2
Long-term	2017	246.8
	2018	230.0
	2019	220.5
	2020	215.5

[a] Comparison of Greenhouse Gas Reductions under CAFE Standards and ARB Regulations Adopted Pursuant to AB1493, CARB, 2008

Methodology

Energy Savings

Figure E.2 highlights the methodology used to determine energy savings resulting from implementation of the Clean Car Standard. Annual average fuel economy figures under the policy scenario case were obtained by assuming that the proposed greenhouse gas standards are met entirely through an increase in new vehicle fuel economy, then running a stock model run to determine fuel consumption for the entire vehicle stock. National light-duty vehicle miles traveled were scaled by ARC population to approximate ARC-specific data. Results showed that implementation of the Clean Car Standard will save the Appalachian Region more than 18 percent in energy consumption by 2030.

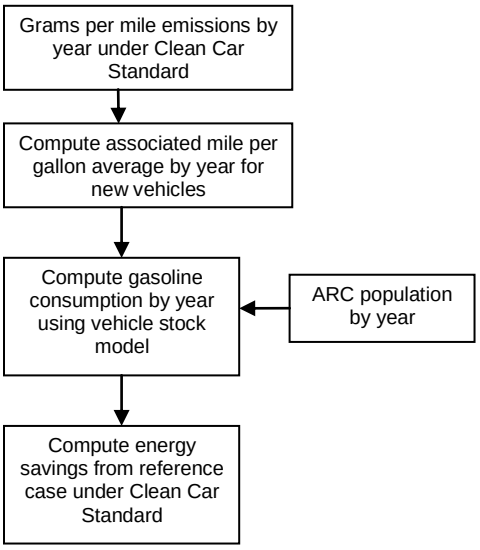

Figure E.2 Clear Car Standard Energy Savings Methodology

Policy Implementation Cost

The California Air Resources Board (CARB) estimated the increase in the purchase cost of vehicles as the new standards are phased in over the period 2009-2016. The extra first cost is less than $100 in the early years (2009-2010), but then rises to about $277-367 by 2012 and about $1,000 by 2016. We then projected costs between 2016 and 2030 based on the assumption that the increase in purchase cost of vehicles would reach $1,500 by 2020 and $3,000 by 2030. Using these cost estimates, and assuming that vehicle sales per capita in the Appalachian Region remain constant through 2030, we estimate that the Clean Car Standard leads to an investment in vehicle efficiency totaling $11.83 billion in the period 2009-2030, on a 2006 value basis.

The resulting savings in fuel costs over the lifetime of these vehicles (on average 15 years) would equal about $19.8 billion (present value), assuming gasoline prices remain at their 2007 levels. This gives a net economic benefit of $7.9 billion (2006 dollars) over the life of the vehicles purchased in 2009-2030. Here, fuel savings exclude the average gasoline tax amount for Appalachia (22.0 cents per gallon). Hence the net economic benefits reflect the loss to the Region in fuel tax revenues but not the wealth transfer from the state to consumers.[6]

Administrative costs were estimated based on the assumption that each Appalachian state will employ one administrator for the program at a cost of $150,000 and two program staff at the cost of $90,000. These costs were scaled by the Appalachian population in each state to estimate ARC-specific administrative costs.

[6] It should also be noted that the loss in the state‘s gasoline tax receipts is in the context of growing gasoline consumption; adoption of the Clean Car Standard would slow the growth in gasoline use, and therefore gasoline tax receipts, but they would not actually decline.

Table E.4 Summary of Energy Savings and Financial Costs for Clean Car Standard

Year	Gasoline Savings %	Sector Primary Energy Savings %	Investment Costs (2006$)	Admn Costs (2006$)
2011	0.2	0.14	163,701,381	4,290,000
2012	0.5	0.37	262,023,382	4,290,000
2013	0.7	0.46	376,648,018	4,290,000
2014	0.8	0.56	473,497,511	4,290,000
2015	1.0	0.72	656,280,630	4,290,000
2016	1.3	0.88	842,672,776	4,290,000
2017	1.7	1.17	938,888,979	4,290,000
2018	2.3	1.57	1,036,410,917	4,290,000
2019	3.0	2.07	1,135,252,158	4,290,000
2020	3.8	2.65	1,235,409,919	4,290,000
2021	4.8	3.34	1,326,994,975	4,290,000
2022	5.9	4.13	1,419,801,686	4,290,000
2023	7.2	5.03	1,513,842,668	4,290,000
2024	8.6	6.02	1,609,130,654	4,290,000
2025	10.1	7.10	1,705,678,493	4,290,000
2026	11.6	8.26	1,803,499,154	4,290,000
2027	13.2	9.48	1,902,605,727	4,290,000
2028	14.9	10.77	2,003,011,420	4,290,000
2029	16.6	12.11	2,104,729,565	4,290,000
2030	18.3	13.49	2,207,773,617	4,290,000

SMARTWAY HEAVY-DUTY EFFICIENCY LOANS

Introduction

Despite the availability of numerous programs and technologies to increase the efficiency of heavy trucks, trucking companies do not consistently take advantage of such options to reduce their overall diesel consumption. Barriers to adoption include high first costs, the rapid turnover of commercial trucks, limited manufacturer technology development investment and lack of a standard fuel economy test for trucks. Nevertheless, average fuel economy for new tractor-trailers could be raised by over 50 percent through a variety of cost-effective existing and emerging technologies. The program we propose is to provide low-interest loans for the purchase of a specific package of equipment to improve the efficiency of new or existing trucks. This is EPA's SmartWay package,

which consists of efficient tires, auxiliary power units, and aerodynamic devices. EPA estimates that the SmartWay package will typically improve tractor-trailer fuel economy by 12-15 percent.

Methodology

Energy Savings

About 2.1 billion miles are driven annually by long-distance trucks,[7] i.e., those having a primary range of operation over 500 miles, of Class 7 and 8 (i.e., those having gross vehicle weight rating of 26,000 lbs. or more) that are registered in the Appalachian states. These are the trucks that would use auxiliary power units, since they would frequently be away from their home bases at night. To determine the number of long distance trucks that would use auxiliary power units, we scaled national data from the 2002 Vehicle Inventory and Use Survey (VIUS) by a population ratio and thus estimated that the Appalachian Region has approximately 19,997 long-distance trucks. Of these we estimate that 20 percent already have anti-idling technology, leaving 15,998 trucks eligible to acquire auxiliary power units. Fuel consumption at idle is roughly one gallon per hour, and typical annual hours of idling is 1,830 per year. A diesel-fueled APU uses on the order of 0.18 gallons per hour, resulting in net savings for these trucks of 1,500 gallons per year.[8]

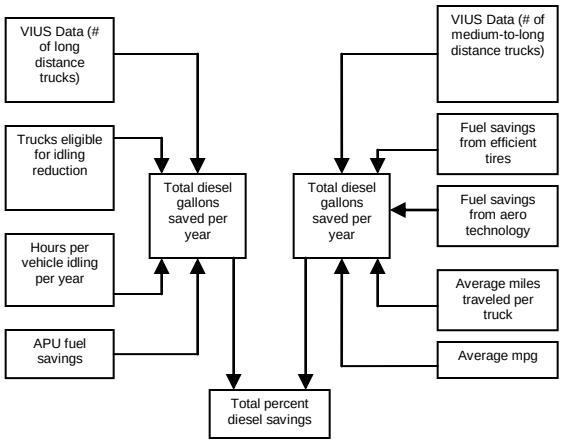

Figure E.3 SmartWay Heavy Duty Efficiency Loan Program Energy Savings Methodology[a]

[a] All national VIUS data was scaled to the Appalachian Region using Appalachia population estimates.

The other efficiency equipment in the SmartWay upgrade kit, namely energy-efficient tires and trailer side skirts, is beneficial to the somewhat larger set of heavy-heavy trucks that travel largely at highway speeds. We assume that trucks typically driving 200 or more miles per day fall into this category; there are 34,731 such trucks registered in the Appalachian Region. We estimate, based on EPA's documentation, that the SmartWay package saves about 12-15 percent in fuel consumption, that the fuel savings from this equipment alone totals eight percent.

The EPA has demonstrated that a low-interest loan program would allow truckers purchasing equipment in the SmartWay package to realize fuel cost savings that would exceed their monthly loan payments. We assume that usage of the loan program ramps up over five years, reaching 75 percent of trucks eligible for the various types of equipment by 2012. This results in a four percent reduction in fuel consumption over the entire truck stock by 2030.

Policy Implementation Costs

Administrative cost values are based on the assumption that each ARC state requires one administrator costing the state $150,000 and two additional staff costing $90,000 each. These costs are then apportioned by the percentage of total state population that resides within the ARC Region.

[7] Scaled from national data obtained from VIUS
[8] Stodolsky, Gaines, and Vyas, 2000

Regarding investment costs, the typical SmartWay upgrade kit costs $16,500.[9] Based on the fuel savings associated with that package and decline in truck miles per year over time, we estimate that the benefit/cost ratio for the package will be about two-to-one over the life of the truck. Private investment is expected to be higher at the beginning of the program effort, so the benefit/cost ratio varies year to year. For truck loans granted through 2020, fuel cost savings out to 2030 total $2.6 billion (2006 dollars). If we assume the benefit/cost ratio for the SmartWay upgrades is two-to-one, then cost of the program through 2020 would be about $1.3 billion, giving a net savings of $1.3 billion during 2009-2030.

Results

Table E.5 Summary of Energy Savings and Financial Costs for SmartWay Heavy Duty Efficiency Loans

Year	Diesel Savings %	Sector Primary Energy Savings %	Investment Costs (2006$)	Admn Costs (2006$)
2010	0.98	0.18	337,898,964	4,290,000
2011	1.47	0.27	355,138,295	4,290,000
2012	1.96	0.36	358,899,782	4,290,000
2013	2.36	0.43	287,852,837	4,290,000
2014	2.75	0.50	288,418,413	4,290,000
2015	3.14	0.58	297,185,679	4,290,000
2016	3.53	0.65	301,991,611	4,290,000
2017	3.93	0.73	295,200,513	4,290,000
2018	3.93	0.73	17,079,986	4,290,000
2019	3.93	0.73	17,997,312	4,290,000
2020	3.93	0.74	21,353,420	4,290,000
2021	3.93	0.74	22,010,579	4,290,000
2022	3.93	0.74	19,771,778	4,290,000
2023	3.93	0.75	21,844,172	4,290,000
2024	3.93	0.75	21,747,168	4,290,000
2025	3.93	0.75	22,722,709	4,290,000
2026	3.93	0.76	24,284,094	4,290,000
2027	3.93	0.76	25,236,861	4,290,000
2028	3.93	0.76	22,972,164	4,290,000
2029	3.93	0.76	21,304,921	4,290,000
2030	3.93	0.77	25,012,852	4,290,000

[9] U.S. EPA ―Innovative Financing – Frequently Asked Questions," http://epa.gov/smartway/documents/420f07027.htm

SPEED LIMIT ENFORCEMENT

Introduction

At high speeds, vehicle efficiency falls off rapidly with further increases in speed, as aerodynamic drag begins to dominate vehicle energy requirements. The speed at which fuel economy is highest varies from vehicle to vehicle, but is typically below 60 miles per hour (mph) for a light-duty vehicle.[10] Federal Highway Administration tests of nine light-duty vehicles in 1997 found that fuel economy declined on average by 3.1 percent when speed increased from 55 mph to 60 mph and by 8.2 percent increasing from 65 to 70 mph.[11] For a heavy truck such as a tractor trailer, fuel economy declines by about two percent per mph at highway speeds.[12] Thus, slowing high-speed driving would be one means of improving the real-world efficiencies of cars and trucks. This could be accomplished either by reducing the maximum speed limit or by more stringently enforcing the existing speed limits.

Methodology

Energy Savings

To estimate energy savings from additional enforcement, we assume that:

1. 50 percent of vehicles on highways in the Appalachian Region are exceeding speed limits;
2. they are exceeding the limit by five miles per hour on average; and
3. their fuel economy is consequently eight percent lower than it would be traveling at the speed limit.

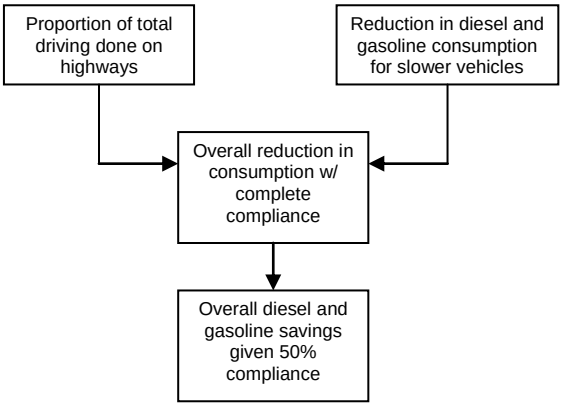

Figure E.4 Speed Limit Enforcement Energy Savings Methodology

In Appalachia, we assume that 60 percent of all travel is conducted on highways (based on the national average[13]). This leads to an estimate of energy savings of up to 2.2 percent from improved enforcement of speed limits for all vehicles. If we assume the enforcement program leads to a 50 percent reduction in speeding, estimated energy savings for both heavy and light-duty vehicles would be as shown in Tables E.6 and E.7.

Policy Implementation Costs

The cost to the Region for this effort could be paid for in full or in part from additional revenue from speeding fines collected in each state. Administrative costs associated with this policy option are

[10] "Drive more efficiently," U.S.DOE and U.S. EPA, http://www.fueleconomy.gov/feg/driveHabits.shtml
[11] Davis and Diegel, 2006
[12] "Factors Affecting Truck Fuel Economy," Goodyear Tire, http://www.goodyear.com/truck/pdf/radialretserv/Retread_S9_V.pdf
[13] Federal Highway Administration, Highway Statistics, 2006, http://www.fhwa.dot.gov/policy/ohim/hs06/index.htm

based on the assumption that the additional costs of enforcement will be recouped through increased fine revenue.

Results

Table E.6 Summary of Energy Savings and Financial Costs for Enforcement of Speed Limits (Heavy-Duty)

Year	Diesel Savings %	Sector Primary Energy Savings %	Investment Costs (2006$)	Admn Costs (2006$)
2010	1.1	0.19		4,290,000
2011	1.1	0.19		4,290,000
2012	1.1	0.19		4,290,000
2013	1.1	0.19		4,290,000
2014	1.1	0.19		4,290,000
2015	1.1	0.19		4,290,000
2016	1.1	0.19		4,290,000
2017	1.1	0.19		4,290,000
2018	1.1	0.19		4,290,000
2019	1.1	0.19		4,290,000
2020	1.1	0.19		4,290,000
2021	1.1	0.19		4,290,000
2022	1.1	0.19		4,290,000
2023	1.1	0.19		4,290,000
2024	1.1	0.19		4,290,000
2025	1.1	0.19		4,290,000
2026	1.1	0.19		4,290,000
2027	1.1	0.19		4,290,000
2028	1.1	0.19		4,290,000
2029	1.1	0.19		4,290,000
2030	1.1	0.19		4,290,000

Table E.7 Summary of Energy Savings and Financial Costs for Enforcement of Speed Limits (Light-Duty)

Year	Gasoline Savings %	Sector Primary Energy Savings %	Investment Costs (2006$)	Admn Costs (2006$)
2010	1.1	0.76		4,290,000
2011	1.1	0.76		4,290,000
2012	1.1	0.76		4,290,000
2013	1.1	0.77		4,290,000
2014	1.1	0.77		4,290,000
2015	1.1	0.77		4,290,000
2016	1.1	0.77		4,290,000
2017	1.1	0.77		4,290,000
2018	1.1	0.77		4,290,000
2019	1.1	0.77		4,290,000
2020	1.1	0.77		4,290,000
2021	1.1	0.77		4,290,000
2022	1.1	0.77		4,290,000
2023	1.1	0.77		4,290,000
2024	1.1	0.78		4,290,000
2025	1.1	0.78		4,290,000
2026	1.1	0.79		4,290,000
2027	1.1	0.80		4,290,000
2028	1.1	0.80		4,290,000
2029	1.1	0.81		4,290,000
2030	1.1	0.82		4,290,000

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APPENDIX F: THE DEEPER MODEL

The Dynamic Energy Efficiency Policy Evaluation Routine – or the DEEPER Model – is a 15-sector quasi-dynamic input-output impact model of the U.S. economy.[1] Despite its more conventional input-output framework, it is in the tradition of so-called general equilibrium models following the logic of Hanson and Laitner (forthcoming) and Laitner and Hanson (2006). Although an updated model with a new name, the model actually has a 16-year history of use and development. See, for example, Geller, DeCicco, and Laitner (1992), Laitner, Bernow, and DeCicco (1998), and Laitner and McKinney (2008) for a review of past modeling efforts in this tradition.

The DEEPER model is generally used to evaluate the macroeconomic impacts of a variety of energy-efficiency and climate policies at both the state and national level. The national model now evaluates policies for the period 2008 through 2050. For the Appalachia specific analysis, however, the DEEPER Model covers the period between 2008 through 2030. As it is now designed, the model accepts policy inputs in the form of investments and expenditures as described throughout the report. It then evaluates the changed pattern of expenditures for the net direct and indirect impacts on the different sectors of the Regional economy. DEEPER is an Excel-based analytical tool that consists generally of six sets of key modules or groups of worksheets. These six sets of modules now include:

Global data: The information in this module consists of the economic time series data and key model coefficients and parameters necessary to generate the final model results. The time series data includes the projected reference case energy quantities such as trillion Btus and kilowatt-hours, as well as the key energy prices associated with their use. It also includes the projected gross domestic product, wages and salary earnings, and levels of employment as well as information on key technology cost and performance characteristics. The sources of economic information include data from the Energy Information Administration, the Bureau of Economic Analysis, the Bureau of Labor Statistics, and Economy.com. The cost and performance characterization of key technologies is derived from available studies completed by ACEEE and others, as well as data from the Energy Information Administration‘s (EIA) National Energy Modeling System (NEMS). One of the more critical assumptions in this study is that alternative patterns of electricity consumption will change and/or defer the mix of investments in conventional power plants. Although we can independently generate these impacts within DEEPER, we can also substitute assumptions from the ICF Integrated Planning Model (IPM) and similar models as they may have different characterizations of avoided costs or alternative patterns of power plant investment and spending.

Macroeconomic model: This set of modules contains the ―production recipe” for the Region‘s economy for a given ―base year” – in this case, 2006, which is the latest year for which a complete set of economic accounts are available for the Regional economy. The I-O data, currently purchased from the Minnesota IMPLAN Group (IMPLAN, 2008), is essentially a set of input-output accounts that specify how different sectors of the economy buy (purchase inputs) from and sell (deliver

[1] There is nothing particularly special about this number of sectors. The goal is to provide sufficient detail to show key negative and positive impacts while maintaining a manageable sized model. If we choose to reflect a different mix of sectors and stay within the 15 x 15 matrix, that can be done easily. If we wish to expand the number of sectors, that would take some minor programming changes or adjustments to reflect the larger matrix.

outputs) to each other. In this case, the model is now designed to evaluate impacts for 15 different sectors, including: Agriculture, Oil and Gas Extraction, Coal Mining, Other Mining, Construction, Manufacturing, Electric Utilities, Natural Gas Distribution, Transportation, and Other Public Utilities (including water and sewage), Wholesale & Retail Trade, Services, Finance, Government, and Households.

Given the I-O assumptions mapped out for the Appalachian Region, the table that follows highlights the Type I Multipliers for each of the major sector activities within DEEPER. These multipliers refer to the direct and indirect job impacts per million dollars of revenue received by a particular sector, and the direct and indirect income and contributions to value-added (or Gross Regional Product) created by the expenditure of one dollar within each sector.

Almost the first thing that jumps out from Table F.1 is the relative low values shown for energy-related sectors compared to almost all other sectors of the economy. For example, electric utilities provide a total of 5.3 direct and indirect jobs per million dollars of revenue that they receive. All other sectors show a significantly higher impact in this regard. It is these differences that are underscored in the heuristic analysis shown in Table 7.1 in the main report. Although not quite as pronounced there is a similar pattern for both wages and salaries and contributions to the GRP. Hence, any cost-effective adjustment to the energy production patterns of the Appalachian Regional economy should leave to a small but net positive impact on the economy.

Table F.1 Appalachia Economic Multipliers for Key Sectors

SECTOR	Type I Multiplier Jobs (per million $ of final demand)	Type I Multiplier Compensation (per dollar of final demand)	Type I Multiplier Value-Added (per dollar of final demand)
Agriculture	21.5	0.224	0.646
Oil and Gas Extraction	5.1	0.167	0.742
Coal Mining	6.0	0.335	0.712
Other Mining	7.6	0.365	0.740
Construction	13.3	0.429	0.720
Manufacturing	8.3	0.338	0.630
Petroleum Refining	2.6	0.095	0.311
Electric Utility Services	5.3	0.285	0.818
Natural Gas Utility Services	3.7	0.204	0.552
Transportation Other Public Utilities	11.0	0.418	0.747
Wholesale Trade	15.3	0.461	0.863
Services	14.1	0.415	0.834
Financial Services	8.6	0.385	0.828
Governmental Services	19.7	0.885	0.974

Investment, expenditures and energy savings: Based on the scenarios mapped into the model, this worksheet translates the energy policies into a dynamic array of physical energy impacts, investment flows, and energy expenditures over the desired period of analysis. It estimates the needed investment path for an alternative mix of energy efficiency and other technologies (including efficiency gains on both the end-use and the supply side). It also provides an estimate of the avoided investments needed by the electric generation sector. These quantities and expenditures feed directly into the final demand module of the model which then provides the accounting that is needed to generate the set of annual changes in final demand (see the related module description below).

Price dynamics: There are two critical drivers that impact energy prices within DEEPER. The first is a set of carbon charges that are added to retail prices of energy depending on the level of desired level of emission reductions and also depending on the available set of alternatives to achieve those reductions. The second is the price of energy as it might be affected by changed consumption patterns. In this case, DEEPER employs an independent algorithm to generate energy price impacts as they reflect changed demand. Hence, the reduced demand for natural gas in the end-use sectors, for example, might offset increased demand by utility generators. If the net change is a decrease in total natural gas consumption, the wellhead prices might be lowered. Depending on the magnitude of the carbon charge, the change in retail prices might either be higher or lower than the set of reference case prices. This, in turn, will impact the demand for energy as it is reflected in the appropriate modules. In effect, then, DEEPER scenarios rely on both a change in prices and quantities to reflect changes in overall investments and expenditures. For this analysis, however, we have used the conservative assumption that price dynamics remain unchanged.

Final demand: Once the changes in spending and investments have been established and adjusted to reflect changes in prices within the other modules of DEEPER, the net spending changes in each year of the model are converted into sector-specific changes in final demand. This, in turn, drives the input-output model according to the following predictive model:

$$X = (I-A)-1 * Y$$

where:

X = total industry output by sector

I = an identity matrix consisting of a series of 0‘s and 1‘s in a row and column format for each sector (with the 1‘s organized along the diagonal of the matrix)

A = the production or accounting matrix also consisting of a set of production coefficients for each row and column within the matrix

Y = final demand, which is a column of net changes in final demand by sector
This set of relationships can also be interpreted as

$$\Delta X = (I-A)-1 * \Delta Y$$

which reads, a change in total sector output equals the inverted (I-A) matrix times a change in the final spending demand for each sector. Employment quantities are adjusted annually according to exogenous assumptions about labor productivity in each of the sectors (based on Bureau of Labor Statistics forecasts). Table 7.1 in the main report illustrates the approach suggested by this perspective.

Results: For each year of the analytical time horizon (again out to 2030 for the Appalachia specific analysis), the model copies each set of results into this module in a way that can also be exported to a separate report.

There are other support spreadsheets as well as routines in visual basic programming that support the automated generation of model results and reporting. For more detail on the model assumptions and economic relationships, again please refer to the forthcoming model documentation (Laitner and McKinney, forthcoming). And as alluded in the beginning of this appendix, for a review of how an I-O framework might be integrated into other kinds of modeling activities, see Hanson and Laitner (forthcoming). While not an equilibrium model we borrow from some key concepts of mapping technology representation into DEEPER using the general scheme outlined in Laitner and Hanson (2006).

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APPENDIX G: SENSITIVITIES AT SECTOR LEVEL

SUPPLEMENTAL TABLES

Table G.1 Carbon Footprint and Consumption Data for 17 Appalachian Metropolitan Areas
(Brown and Logan, 2008)

			Annual metric tons of carbon emitted per person				Annual Mbtu consumed per capita			
	% in ARC	Subregion	Residential Electricity	Residential Fuel	Light Duty Vehicle	Freight Trucks	Residential Electricity	Residential Fuel	Light Duty Vehicle	Freight Trucks
Albany-Schenectady-Troy, NY	20%	Northern	0.38	0.58	1.23	0.33	36.88	38.06	63.64	16.45
Allentown-Bethlehem-Easton, PA-NJ	25%	Northern	0.56	0.47	0.96	0.37	38.19	29.69	49.84	18.70
Cincinnati-Middletown, OH-KY-IN	13%	Northern	1.25	0.45	1.14	0.44	59.46	31.50	58.91	21.86
Harrisburg-Carlisle, PA	33%	Northern	0.62	0.53	1.32	0.72	42.54	33.38	68.24	36.17
New York-Northern New Jersey-Long Island, NY-NJ-PA	4%	Northern	0.23	0.44	0.66	0.16	21.78	27.43	34.33	8.07
Pittsburgh, PA	100%	Northern	0.54	0.55	0.91	0.27	36.93	34.91	47.18	13.66
Scranton--Wilkes-Barre, PA	100%	Northern	0.58	0.55	1.01	0.51	39.79	34.99	52.27	25.79
Washington-Arlington-Alexandria, DC-VA-MD-WV	5%	Northern	1.61	0.35	0.98	0.17	62.02	23.76	50.86	8.72
Youngstown-Warren-Boardman, OH-PA	33%	Northern	0.77	0.43	1.01	0.54	36.33	30.21	52.46	27.32
Lexington-Fayette, KY	17%	Central	1.48	0.24	1.10	0.64	63.60	16.92	56.94	32.07
Nashville-Davidson--Murfreesboro, TN	23%	Central	1.15	0.19	1.32	0.57	74.21	13.53	68.19	28.48
Atlanta-Sandy Springs-Marietta, GA	43%	Southern	0.84	0.21	1.22	0.41	51.01	15.28	63.26	20.61
Birmingham-Hoover, AL	100%	Southern	0.99	0.16	1.34	0.42	64.55	10.83	69.03	21.17
Chattanooga, TN-GA	100%	Southern	1.05	0.20	1.27	0.59	68.00	14.43	65.77	29.42
Greenville, SC	67%	Southern	0.57	0.14	0.87	0.28	56.56	10.30	45.16	13.92
Knoxville, TN	100%	Southern	1.07	0.20	1.40	0.46	68.91	14.50	72.50	23.35
Memphis, TN-MS-AR	13%	Southern	0.99	0.18	1.16	0.53	64.20	13.31	60.07	26.65
Total Top 100 Metros			0.61	0.31	1.00	0.31	41.35	21.14	51.93	15.32
Appalachian Metro Average			1.05	0.42	1.35	0.53	63.21	28.07	69.90	26.60

DISCOUNT RATE SENSITIVITIES

The discount rates used in analysis can have a significant impact on the results of cost effectiveness tests. Since this study seeks to identify policies that are cost-effective, the choice of discount rate has been conservatively selected for the base analysis at seven percent for the total resource cost test and 10 percent for participants. Discount rates are generally accepted to be higher for private investment than public programs due to the greater societal concern for the future. This sensitivity analysis reports the benefit-to-cost ratio at discount rates of four, seven, and ten percent for both participants and the total resource costs.

Figures G. 1 – G. 4 show the discount rate sensitivity for each of the policies within the four modeled sectors.

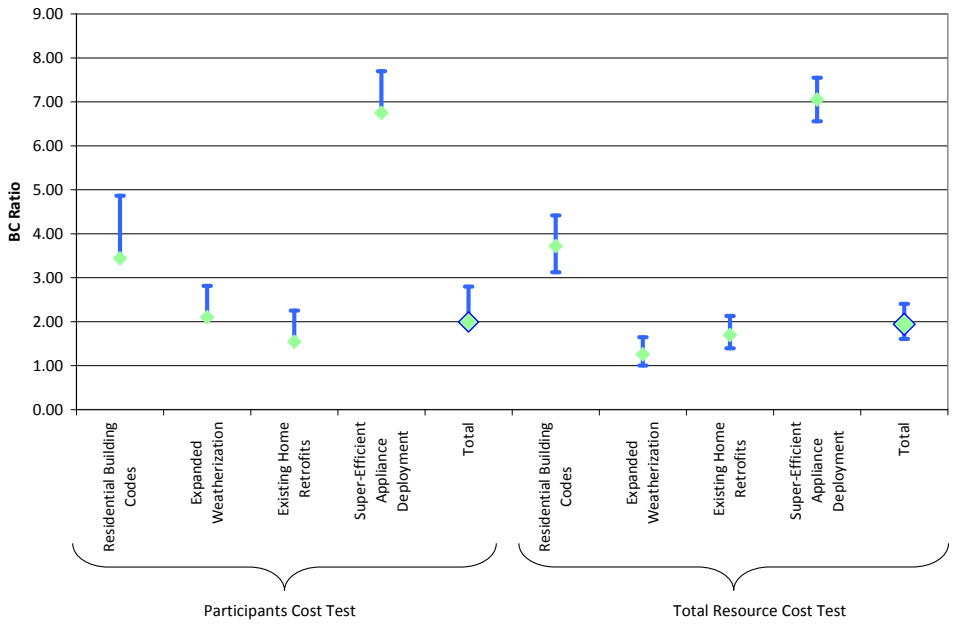


Figure G.1 Discount Rate Sensitivities for Residential Sector Policies

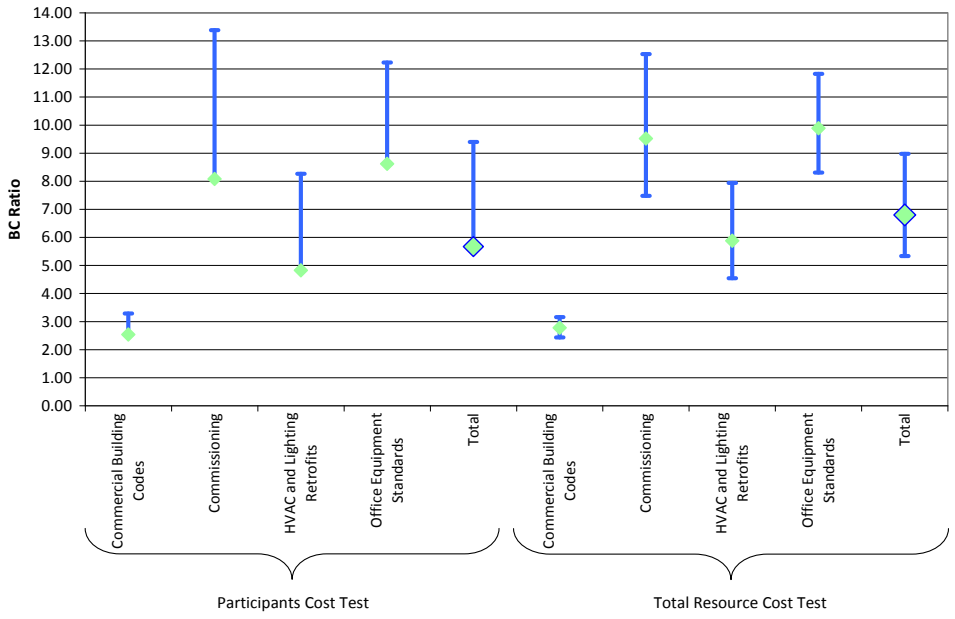


Figure G.2 Discount Rate Sensitivity for Commercial Sector Policies

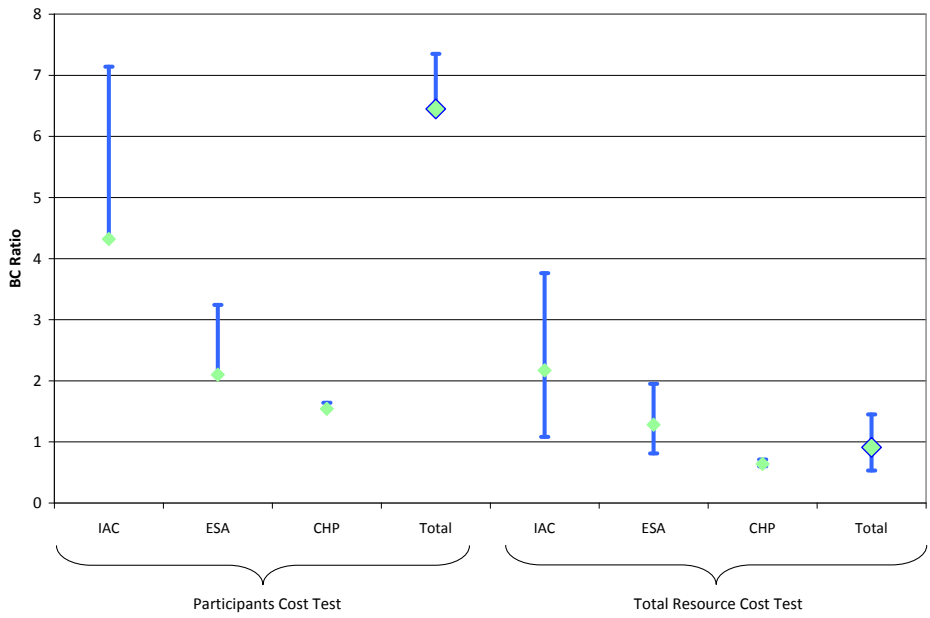


Figure G.3 Discount Rate Sensitivities for the Industrial Sector Policies

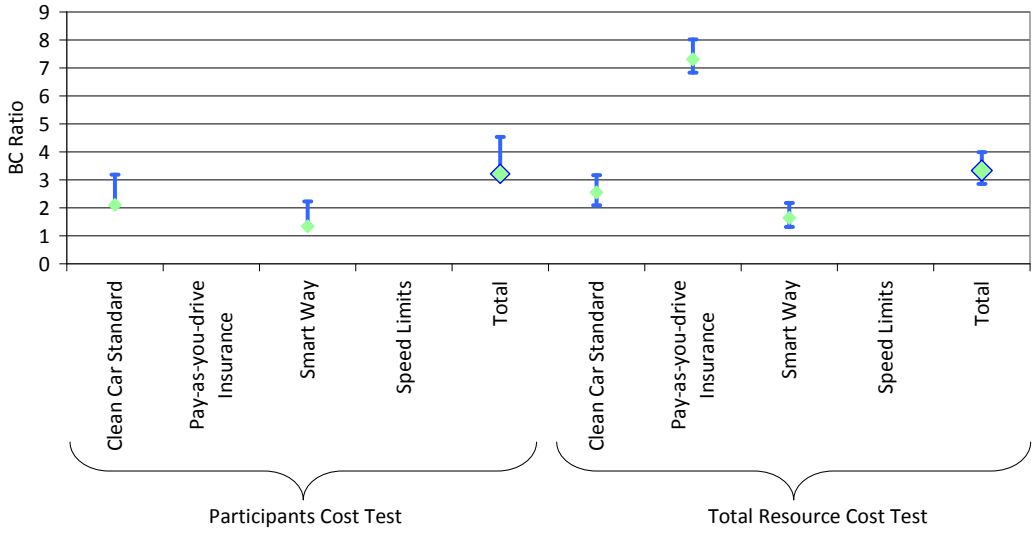


Figure G.4 Discount Rate Sensitivities for the Transportation Sector Policies

At this scale, the benefit-to-cost ratios cannot be seen for the policies of Supporting Pay as you Drive Insurance or Enforcing Speed Limits because they are too high to show on the same scale.

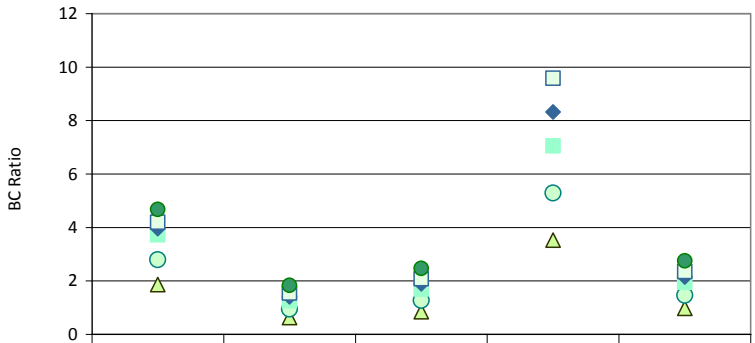
AVOIDED COST SENSITIVITIES

The avoided costs of producing the energy that will be saved by a particular policy or measure, or package of policies or measures, can have an enormous impact on the benefit-to-cost ratio on a total resource basis. In our base analysis, we assume that the avoided costs are equal to the energy price forecast; this assumption was driven by low forecast energy prices and general belief that these as

well as forecast avoided costs are understated. However, there is much uncertainty about future avoided costs, as it will be dependent upon many factors. We have considered lower and higher costs for sensitivity analysis in this study.

To model the cost effectiveness of lower avoided costs, we have used rates at 50 percent and 75 percent of forecast retail energy prices. To model the cost effectiveness of higher avoided costs, we have considered the impact of carbon taxes of $25, $50, and $100 per metric ton of carbon (MtC) (Brown & Atamturk, 2008).

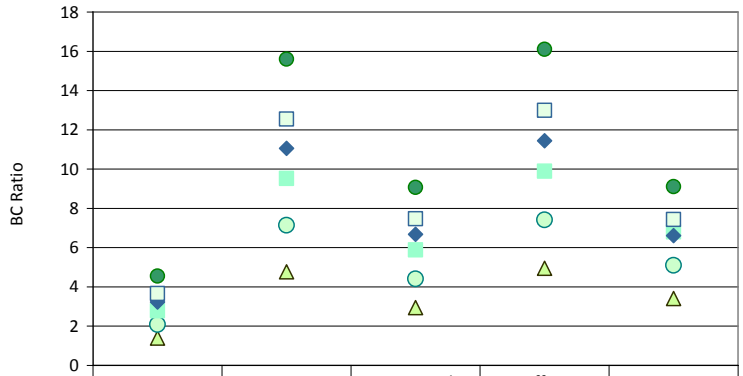
Figures G.5 – G.8 show how sensitive the cost-effectiveness of the modeled policies are to avoided costs.



	Residential Building Codes	Expanded Weatherization	Existing Home Retrofits	Super-Efficient Appliance Deployment	Total
△ 50% Lower than Energy Prices	1.86	0.63	0.85	3.52	0 97
○ 25% Lower than Energy Prices	2.79	0.94	1.27	5.29	1.46
■ Retail Energy Prices	3.72	1.26	1.70	7.05	1 94
◆ Energy Prices with $25/MtC Tax	3.96	1.40	1.89	8.32	2.15
□ Energy Prices with $50/MtC Tax	4.19	1.54	2.08	9.58	2 35
● Energy Prices with $100/MtC Tax	4.67	1.84	2.47	12.12	2.75

Figure G.5 Avoided Cost Sensitivities for the Residential Sector

Overall, the residential policy package is cost-effective for a variety of avoided cost scenarios. If future avoided costs are lower than forecast energy prices, the two residential retrofit programs may not be cost-effective.

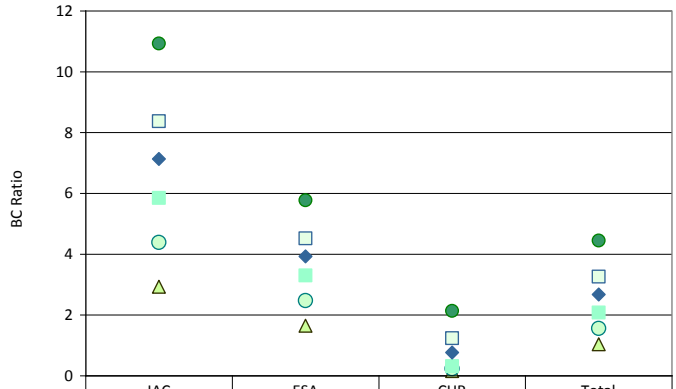


	Commercial Building Codes	Commissioning	HVAC and Lighting Retrofits	Office Equipment Standards	Total
△ 50% Lower than Energy Prices	1.39	4.76	2 94	4.94	3.40
○ 25% Lower than Energy Prices	2.08	7.14	4.41	7.41	5.10
■ Retail Energy Prices	2.78	9.52	5 88	9.89	6.80
◆ Energy Prices with $25/MtC Tax	3.22	11.05	6.68	11.44	6.61
□ Energy Prices with $50/MtC Tax	3.66	12.55	7.47	12.99	7.43
● Energy Prices with $100/MtC Tax	4.55	15.60	9 06	16.10	9.11

Commercial Policy Package

Figure G.6 Avoided Cost Sensitivities for the Commercial Sector

For all modeled avoided costs, the commercial sector policies we have considered will be cost effective over their lifetime.

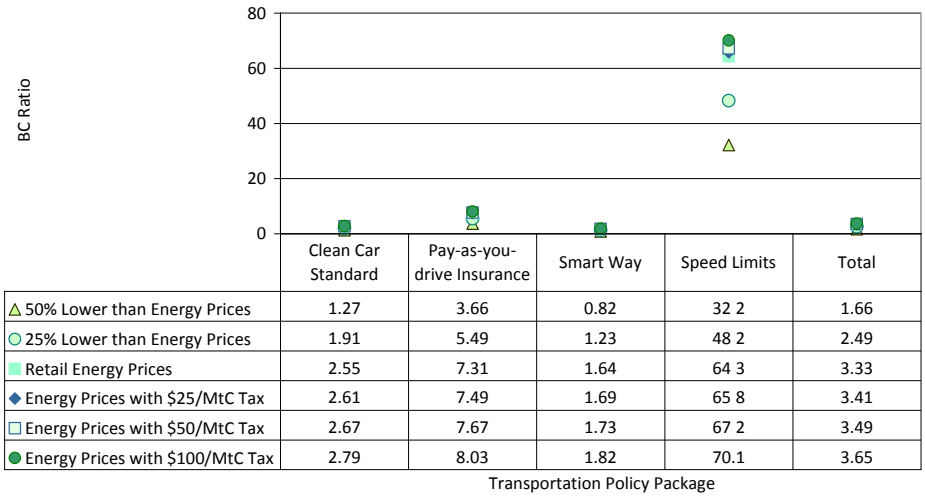


	IAC	ESA	CHP	Total
△ 50% Lower than Energy Prices	2.93	1.65	0.16	1.04
○ 25% Lower than Energy Prices	4.39	2.47	0.24	1.56
■ Retail Energy Prices	5.85	3.30	0.31	2.08
◆ Energy Prices with $25/MtC Tax	7.13	3.92	0.76	2.67
□ Energy Prices with $50/MtC Tax	8.37	4.52	1.24	3.26
● Energy Prices with $100/MtC Tax	10.93	5.77	2.13	4.45

Industrial Policy Package

Figure G.7 Avoided Cost Sensitivities for the Industrial Sector

While most of the policies modeled are cost-effective at most avoided costs, the policy to support combined heat and power modifications for industrial facilities is only cost effective when a carbon tax, or other cause for higher energy prices, is considered.



	Clean Car Standard	Pay-as-you-drive Insurance	Smart Way	Speed Limits	Total
△ 50% Lower than Energy Prices	1.27	3.66	0.82	32 2	1.66
○ 25% Lower than Energy Prices	1.91	5.49	1.23	48 2	2.49
■ Retail Energy Prices	2.55	7.31	1.64	64 3	3.33
◆ Energy Prices with $25/MtC Tax	2.61	7.49	1.69	65 8	3.41
□ Energy Prices with $50/MtC Tax	2.67	7.67	1.73	67 2	3.49
● Energy Prices with $100/MtC Tax	2.79	8.03	1.82	70.1	3.65

Figure G.8 Avoided Cost Sensitivities for the Transportation Sector

The benefit-to-cost ratios are extraordinarily high for some of our modeled transportation policies because the policies have low program costs. However, their cost effectiveness is still impacted by avoided costs. The SmartWay loan program, as modeled, would not be cost-effective from a total resource cost perspective if energy prices are much lower than forecast.

References

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