3 ENERGY EFFICIENCY IN RESIDENTIAL BUILDINGS

3.1 INTRODUCTION TO RESIDENTIAL BUILDINGS IN APPALACHIA

The Appalachian residential sector consumed about 1.8 quads of energy in 2006 at a cost of about $14 billion (2006 dollars).[6] Electricity and natural gas comprised the majority of delivered energy at 49 percent and 35 percent, respectively, excluding electricity related losses; these drop to 24 percent and 17 percent, respectively, when losses are included (Figure 3.1) (EIA, 2008a). The primary end use for energy was space heating (36.8 percent), followed by water heating (13.3 percent), and miscellaneous electric load (8.2 percent) (EIA, 2008a).

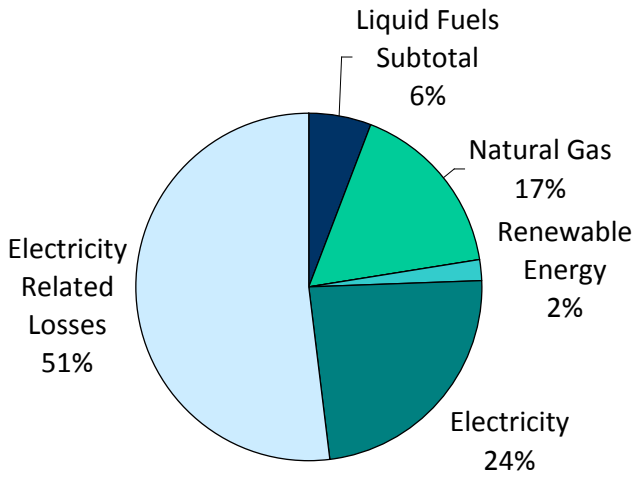

Figure 3.1 Residential Sector Energy Sources by Fuel, 2006
(EIA, 2008a)

From 2008 to 2030, residential energy consumption in the Appalachian Region is expected to increase between 30 percent and 32 percent up to between 2.47 and 2.58 quads, see Figure 3.2 (EIA, 2007a; 2008a). The lower forecasted growth in residential energy consumption is the result of the *AEO 2008* forecast, which projects higher energy prices, slower economic growth, and stronger lighting and appliance standards as a result of the Energy Independence and Security Act of 2007. Each of these factors subdues the growth in energy use, compared with the *AEO 2007* forecast.

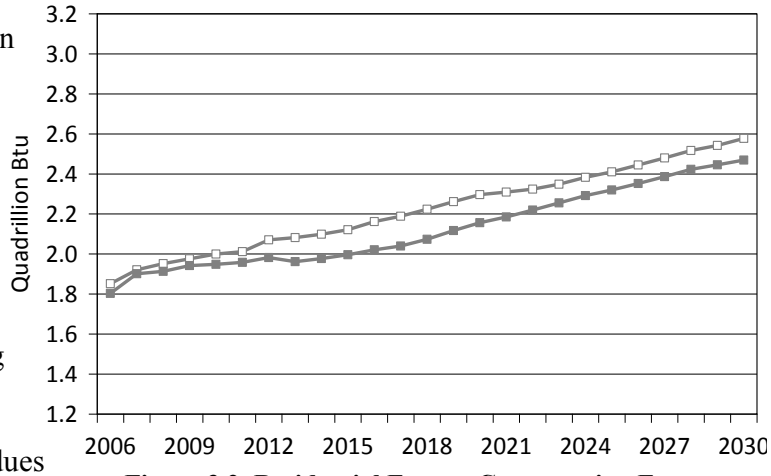

Figure 3.2 Residential Energy Consumption Forecast for the Appalachian Region (Quads)
(EIA, 2007a; 2008a)

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

On a per capita basis, Appalachia, as a whole, had residential electric energy intensity of 58 million Btu and residential fuel intensity of 20 million Btu in 2005, compared to a national average of 50 million Btu and 22 million Btu (EIA, 2008a). The higher intensity of residential electricity use in the Region is possibly a function of the Region's reliance on electricity for home heating and air conditioning and often high numbers of Heating Degree Days (HDD) and Cooling Degree Days (CDD) in the mixed climate. It may also reflect the Region's relatively inefficient building stock. The Appalachian Region does have lower residential fuel intensity than the national average, reflecting lower use of propane, natural gas, and fuel oil; likely due to relative accessibility of electricity to fuels, at least outside of the metropolitan areas.

While the Appalachian Region is largely rural, seventeen metropolitan areas are at least partially within the Region. Also in 2005, Appalachian metropolitan areas averaged per capita residential electric intensity of 63 million Btu and residential fuel intensity of 28 million Btu, compared to the top 100 metropolitan average of 41 and 21 million Btu, respectively, see Figure 3.3 (Brown, Southworth, and Sarzynski, 2008). These data, while averages, show that the largest 100 metropolitan areas are more energy efficient for residential fuels and residential electricity, per capita, than the nation as a whole, while Appalachian metropolitan areas are more energy intense than the Appalachian Region as a whole. Comparing Appalachia to the rest of the nation offers anecdotal evidence to the potential for energy efficiency.

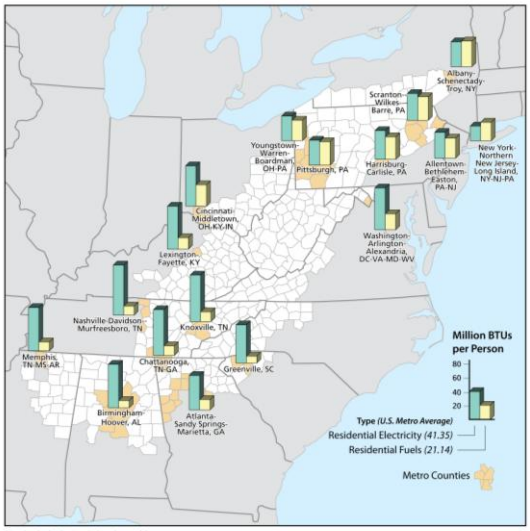

Figure 3.3 Map of Residential Footprints
(values can be found in Appendix B)

3.2 POLICY OPTIONS FOR RESIDENTIAL ENERGY EFFICIENCY

This study models four policy packages to encourage energy efficiency in residential buildings: Model Building Energy Codes, Expansion of the Weatherization Assistance Program, Existing Home Retrofits, and Super-Efficient Appliance Deployment. There are several other kinds of policies that could be used to encourage more efficient use of energy in residential buildings. Table 3.1 lists examples of policy actions, including those modeled; these policies could be used as substitutions to the modeled packages, or as complementary actions. While this study sought to model policies that have been shown to reduce energy consumption in the past by overcoming barriers to efficiency in residential buildings, policy makers in Appalachia may seek to target different barriers or segments of the residential market. For example, the policy of expanding Weatherization Assistance targets the barriers of high first costs and lack of access to capital for the low-income market segment; the other policies do not specifically target this segment of the population (Brown et al., 2008). Many current polices, see Appendix A, are focused on reaching different segments of the market (consumers of all income groups, construction contractors, manufacturers) to overcome the barrier of lack of trusted information; policy makers may choose to continue to target this barrier with their limited resources rather than attempting to target the barrier of "high costs" (Brown et al., 2008) That being said, the actual form of policies adopted within the Appalachian Region will depend on the specific goals and capacity of each policy making body.

Table 3.1 Policy Actions that Support Residential Energy Efficiency

Actions	Residential Building Codes	Weatherization	Retrofits	Super-Efficient Appliance Deployment
Research, Development, and Demonstration	Support for research and development in advanced building processes and materials	Development of new insulation, heating, and cooling technologies useful for the local climate	Development of new insulation, heating, and cooling technologies useful for the local climate	Support for research and development for innovation in appliance performance
Financing	Low or no-interest loans for incremental cost of improvements for new construction Support for Energy-Efficiency Mortgages (EEMs)	N/A	Low or No-Interest Loans for Incremental Cost of Improvements for Existing Buildings	Low or No-Interest Loans for ENERGY STAR® Appliances
Financial Incentives	*Incremental cost rebates to builders for homes that meet or exceed building energy code* Permit fee or Property tax reductions for efficient homes	*Grants or publicly funded provision of retrofits*	*Incremental cost rebates or grants for retrofits* Tax credits for efficient purchases	*Incremental cost rebates or grants for efficient appliances* Tax credits for efficient purchases Appliance Buyback Programs
Pricing	N/A	N/A	N/A	N/A
Voluntary Agreements	Agreement between major builders in the area to meet or exceed code	N/A	N/A	N/A
Regulations	*Model Building Energy Code legislation* *Allowing third party compliance inspection* Energy-efficiency rating and labeling	N/A	Allowing third party compliance inspection *Resale energy rating and labeling*	Broad appliance standards with tighter requirements Standby Efficiency Standards
Information Dissemination & Training	*Training architects, builders, contractors, and code enforcement officials*	Training contractors, weatherization officials, and community providers *Public Awareness campaigns to inform consumers of the benefits of conservation and efficiency measures*	Training architects and contractors *Public Awareness campaigns to inform consumers of the benefits of conservation and efficiency measures* Advanced metering (interior, real-time, with price signal)	*Public Awareness campaigns to inform consumers of the benefits of conservation and efficiency measures* Advanced metering (interior, real-time, with price signal)
Procurement	N/A	N/A	N/A	Government efficient appliance lead by example programs

Table 3.1 Policy Actions that Support Residential Energy Efficiency

Actions	Residential Building Codes	Weatherization	Retrofits	Super-Efficient Appliance Deployment
Market Reforms	N/A	N/A	*Enable On-bill Financing for Retrofits*	N/A
Planning Techniques	Evaluation and monitoring for feedback	N/A	N/A	N/A
Capacity Building	Centers for energy efficiency to train next generation of architects, builders, retrofitters	Centers for energy efficiency to train next generation of architects, builders, retrofitters	Centers for energy efficiency to train next generation of architects, builders, retrofitters	N/A

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

3.2.1 Research, Development, and Demonstration (RD&D)

Developing advanced building processes and technologies can help to improve the performance of new buildings (and some retrofit buildings). Research in this area drives the capability to meet greater efficiency levels over time. In addition, RD&D programs help to offset commercialization barriers, especially those of uncertain performance and costs, by pushing innovations out of the laboratory (Brown et al., 2008). Having a research program, especially when combined with commercialization and deployment efforts, allows a state or locality to keep talented researchers and money for new technology from leaving the area. Research and development programs can work hand in hand with capacity building and technology pull measures. Both South Carolina‘s ―SC Launch!” and Kentucky‘s ―Energy Research and Development Grants for Renewable Energy and Energy Efficiency” are examples of state efforts to encourage innovation.

3.2.2 Financing

Financing policies can help to reduce the ―first cost” burden, making efficient investments more affordable. Loans available for incremental costs to builders and homeowners allow them to invest in more efficient equipment and materials; buyers (who are passed the cost through builders) and homeowners then benefit from lower energy consumption and greater comfort levels. Many utilities offer loans for efficiency improvements; for example, Bristol Tennessee Essential Services (BTES) offers loans up to $10,000 for qualified homeowners through their ―Energy Savers Loan Program” (BTES, 2008). Because incremental costs for more efficient homes and retrofit materials are not very high, and the turnaround is fairly short, revolving loan funds can be utilized. Supporting Energy-Efficiency Mortgages, which offer lower rates for qualified efficient homes, by streamlining verification of the residence‘s performance and connecting consumers with suitable lenders, can ease the first cost to buyers of efficient new homes without significant public cost.

3.2.3 Financial Incentives

Financial incentive policies can provide carrots to builders and new home buyers, also addressing the barrier of high costs. 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 (PG&E, 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 fall short of the code-prescribed level of efficiency by six percent or more.[7]

Within the Appalachian Region, the New York State Energy Research and Development Authority (NYSERDA) offers incentives for energy-efficient multifamily buildings through their ―EnergySmart Multifamily Performance Program" and ―Green Affordable Housing Options." Using another approach, the city of Asheville, NC, offers rebates on building permit fees for certain sustainable building practices. By offering incentives to builders, such policies increase the supply of efficient buildings.

Virginia adopted legislation in 2007 allowing local governments the ability to create a new classification and incentivize tax rates for buildings that are 30 percent more efficient than the Virginia Uniform Building Code; this type of policy, when implemented by towns and cities that can afford such incentives, can increase demand for efficient homes by offering buyers lower taxes. Wisconsin offers ―cash-back" to builders or homebuyers for meeting Wisconsin's ENERGY STAR heating, cooling, and lighting performance objectives (WFOE, 2008).

3.2.4 Voluntary Agreements

Voluntary agreements have been used by the U.S. DOE to motivate private builders to construct more energy-efficient homes. DOE's Building America program is an example of voluntary innovation by many leading builders, and it offers a competitive advantage to participating builders.[8] Programs like these can reduce uncertainties and prevent any one builder from facing all the costs of innovating while knowing that imitators will also be able to reap the rewards.

3.2.5 Regulations

Regulating building practices, enabling innovative financing and verification mechanisms, and requiring the provision of information can lead to more efficient homes. Model energy codes set new minimum levels of efficiency; and by periodically reviewing and updating code requirements, current building practices can keep up with advances in construction materials and practices.

Some regulations set the foundation for other policies to work; for example, regulating contractors enables third party verification of savings and labeling while regulating lenders or utility actions enables on-bill financing or energy-efficient mortgages.[9] With a third-party contracting program,

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[7] Utility residential new construction programs offer incentives to builders to meet or exceed model energy codes.
[8] http://www.buildingamerica.gov
[9] On-bill financing refers to programs, run through utility or municipal energy retailers, that allow consumers to acquire a favorable loan for energy-efficient retrofits or upgrades that are paid back through their energy savings; this is conceptually similar to the services offered by energy services companies (ESCOs) through ―performance contracting."

builders or retrofitters would be required to contract with a state or locally certified third party to verify compliance; any expenses associated with inspection and verification would be undertaken by the builder or contractor rather than the jurisdiction. California, New York, and Washington already use this type of program for building energy codes, with high compliance rates (EPA, 2006; Smith and McCullough, 2001; Vine, 1996). However, allowing for third party contracting takes time; for example, the state of Washington spent three years (with utility funding) setting up training and certification programs to move their non-residential code to a system allowing for third party inspection (Kunkle, 1997).

3.2.6 Information Dissemination, Training, and Capacity Building

Training and information as well as capacity building programs can support the goals of improved energy performance by ensuring that a knowledgeable workforce is prepared to produce efficient homes. Information dissemination programs include TV and radio outreach, flyers, conferences, websites, school visits, and other media. Training programs include certification for particular trades, seminars to keep government officials current, and testing for professional licenses. Capacity building refers to developing schools, centers, and technology specific parks; in general, they are designed specifically to build the capacity of an area or a people to achieve a goal – in this case, energy efficiency. There are several examples of training, information, and capacity building programs already at work in the Appalachian Region (see Appendix A). To illustrate, Kentucky offers financial support to public universities and colleges participating in energy efficiency and renewable energy research. Also, West Virginia‘s Building Professional‘s Energy Training Program offers seminars on current building and code topics.

3.3 MODELED SAVINGS IN APPALACHIAN RESIDENTIAL BUILDINGS

The following sections describe each of the modeled policies in more detail and estimate their projected savings. At the end of the chapter, aggregated results for the sector are reported along with a discussion of the findings. Appendix B provides greater detail on the modeling methodology.

3.3.1 Residential Building Codes with Third Party Verification

Residential building energy codes define engineering and construction requirements to meet particular efficiency targets for new residential buildings.[10] Building energy codes impact consumption based on structural changes – as such, they primarily impact heating and cooling loads. Appendix B.1 presents the methodology for estimating savings for residential energy codes.

Ten of the 13 states in the Appalachian Region require new construction of residential buildings to meet recent building codes. Five of these 10 states enforce the most recent 2006 IECC code (Table

[10] These codes affect residential structures with fewer than three stories; residential structures with more than three stories are considered commercial buildings. Since the number of floors is not included in building data, all residential units in Appalachia are assumed to be under three stories. This could be a slight distortion if there are a great number of high rise apartment complexes in the region, but the generally rural and suburban region is not expected to have many high rise units.

3.2). However, compliance rates are unknown and efforts to improve new buildings beyond code are uneven. Nine Appalachian states have less than three percent penetration rates for ENERGY STAR Qualified New Homes, while the top performer, Nevada, had a 71 percent penetration rate (ENERGY STAR, 2008).[11] The higher penetration rates are found in states where state and local governments and homebuilders have publicly committed to ENERGY STAR goals. For example, in Nevada, 23 of 54 home builders who are ENERGY STAR partners have committed to build all their homes to ENERGY STAR specifications.[12]

Table 3.2 Status of Appalachian State Residential Building Energy Codes and Percent of ENERGY STAR Qualified New Homes

State	Residential Energy Code	Mandatory?	ENERGY STAR Qualified %
Alabama	2000 IECC	No	<3
Georgia	2006 IECC	Yes	<3
Kentucky	2006 IRC	Yes	3-11
Maryland	2006 IRC	Yes	3-11
Mississippi	PRIOR 92 MEC	No	<3
New York	2004 IECC	Yes	13
N. Carolina	2003 IECC	Yes	<3
Ohio	2006 IECC	Yes	13
Pennsylvania	2006 IECC	Yes	<3
S. Carolina	2003 IECC	Yes	<3
Tennessee	92 MEC	No	<3
Virginia	2003 IECC	Yes	<3
W. Virginia	2003 IRC	Yes	<3

Establishing mandatory residential energy codes in Alabama, Mississippi, and Tennessee, keeping all of the Appalachian states up-to-date with codes, and driving greater code compliance could have a significant impact on consumption across the Region over time. Building energy codes are most successful when suppliers and consumers of new residences are motivated to improve the energy performance of the new home, and when their compliance can be verified. Ensuring greater compliance will require third-party verification of measures; accordingly, staff engineers or inspectors would need to be hired and trained to verify installation of proper measures. Greater education of consumers could also encourage market demand for compliance from builders.

This study assumes that all Appalachian counties adopt, or are otherwise subject to, the 2006 IECC by 2009 and subsequently more efficient codes every three years thereafter; codes are assumed to become effective the year following adoption. To illustrate, the 419,000 single and multi-family homes projected to be built from 2013 to 2015 in Appalachia are assumed to be built to the 2009 IECC code and therefore use 18 percent less energy for space heating, space cooling, and water

[11] ENERGY STAR penetration rates reflect ENERGY STAR's calculation of the portion of new site built single family homes in a state that meet ENERGY STAR requirements.
[12] Nevada's ENERGY STAR factsheet describes how Nevada is achieving high penetration: http://www.naseo.org/taskforces/energystar/factsheets/Nevada07.pdf

heating than they would have if built to 2005 current practice. Homes built from 2016 to 2019 are assumed to use 30 percent less energy (Appendix B, p. 3). Third-party verification of measures is also assumed, and the administrative personnel are assumed to serve in training and liaison roles. While the actual verification of compliance is completed by a third-party hired by the builder, the codes officials train and approve these verification firms; officials also provide random verification spot checks as well as ongoing training and support to verifiers and construction firms.

These codes lead to substantial energy savings as shown in Table 3.3. By 2030, four percent of the forecast residential energy consumption in Appalachia is offset by this one policy. These savings are similar to those modeled recently by the Eldridge et al. (2008) assessment of energy-efficiency potential in Maryland. Advanced building codes generated electricity savings of two percent of Maryland's projected consumption in 2025.

Table 3.3 Energy Savings from Residential Building Codes

Year	Electricity Savings (GWh)	Natural Gas Savings (trillion Btu)	Fuel Oil Savings (trillion Btu)	Total Primary Energy Saved (trillion Btu)	% of Sector Primary Energy[a]
2010	25.23	0.15	0.03	0.54	0.03
2013	201.19	1.14	0.19	4.22	0.22
2020	1,586.97	8.01	1.21	32.42	1.50
2030	4,888.73	22.46	3.15	98.66	4.00

[a] Based on the EIA, 2008a forecast.

The costs reported in Table 3.4 include an incremental investment cost for more efficient building of $1,000 real 2006 dollars per new home constructed. The administrative costs reflect new personnel; two training staff per state (costs apportioned) and one verification liaison per 10,000 constructed homes per year who works with third-party verification firms and construction firms to ensure that compliance is achieved. The annual energy savings increase from $10 million in 2010 to $1.6 billion in 2030.

Table 3.4 Costs and Savings from Residential Building Codes			
Year	**Energy Savings**	**Admin Costs**	**Investment Costs**
	(million 2006$)	**(million 2006$)**	**(million 2006$)**
2010	10.30	10.21	102.00
2013	73.70	11.18	113.03
2020	530.71	10.42	102.21
2030	1,607.90	9.83	91.48

Figure 3.4 shows how investment and energy savings vary over the study period. Public investment is the administrative costs of the program while private investment is the incremental costs of improvement. If there were some form of public incentive for meeting or exceeding the codes, public investment would be higher while private investment would be lower.

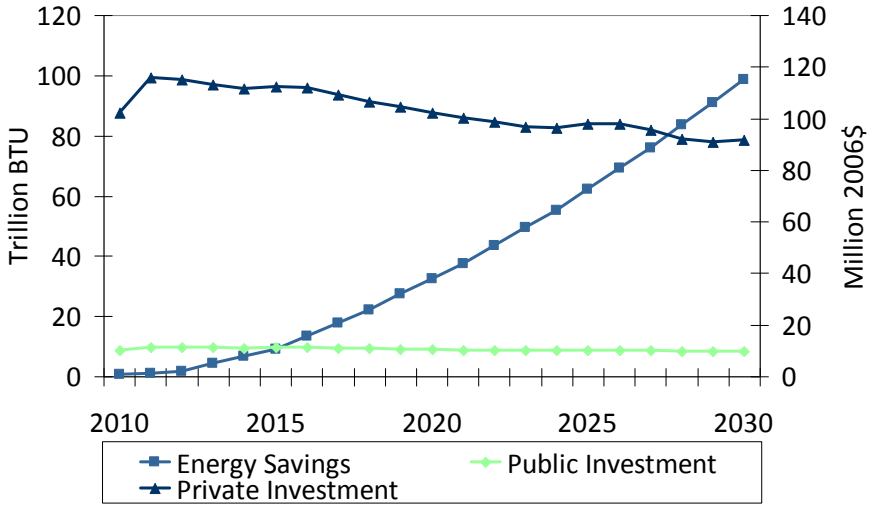

Figure 3.4 Annual Investment and Energy Savings from Residential Building Codes, 2010-2030

The Residential Building Energy Code with Third-Party Verification is cost-effective with a benefit-to-cost ratio of about 3.4 for participants and about 3.7 for total resource costs. With $220.5 million in program spending and an additional $2.2 billion in customer investments over the 2010-2030 period, the Appalachian region could see net cumulative savings of 802.5 trillion Btu, saving $13.1 billion in energy bills by 2030. This is the equivalent of about 4.0 percent of the EIA's forecast consumption of residential energy in the Appalachian Region in 2030 or 18.9 percent of forecast growth (EIA, 2008a).

Box 3.1. Manufactured Housing Codes

The Appalachian Region has a growing proportion of homes that are manufactured off-site. This type of single family home has a higher stock turnover rate than stick built homes, but a lower average energy efficiency. Requirements for manufactured housing efficiency have not changed since 1994, but EISA 2007 requires DOE to establish new standards based on the 2009 IECC by 2011; see Table 3.5 for insulation requirements for the current code (EISA, 2007, Sec. 413, 24 CFR 3280).

Table 3.5 Insulation Requirements for Manufactured Homes (24 CFR 3280)

Zone #	Single-Wide			Double-Wide		
	1	2	3	1	2	3
Ceiling	R-14	R-19	R-19	R-14	R-22	R-22
Walls	R-11	R-13	R-19	R-11	R-13	R-19
Floor	R-11	R-19	R-19	R-14	R-19	R-22

ASHRAE (2005) found savings of 24-29 percent in heating and cooling energy needs for manufactured homes meeting the ENERGY STAR requirements compared to those meeting current codes; further, they found that these ENERGY STAR homes would just barely meet the requirements of 2006 IECC.

ENERGY STAR qualified manufactured homes must be designed, produced, and installed in accordance with EPA guidelines by an ENERGY STAR certified manufactured housing plant. Manufactured housing plants can be certified by a third party Quality Assurance Provider who is certified by the EPA to perform plant inspections. After meeting several requirements for design and installation, at least three homes of the same design must be proven in the field before the plant can apply for ENERGY STAR certification. Many manufactured housing plants in Appalachian states are already ENERGY STAR partners; however, only a few have produced a significant number of ENERGY STAR labeled manufactured homes (EPA, 2008). Because a large portion of national manufactured homes are produced in Appalachian states by a few companies, it may be easier to influence building practices in this area than it is with stick-built homes.

If all new mobile homes in the Appalachian region were built to ENERGY STAR requirements, saving 25 percent in heating and cooling end-uses, the region could have cumulative annual savings of 4 trillion Btu (site) by 2030 or about 6.8 percent of all mobile home consumption (site). A more aggressive mobile home standard that increases from 25 percent in 2010 to 50 percent by 2030 could save more than six trillion Btu (site) or about 10.3 percent of all mobile home energy consumption (site).

3.3.2 Expanded Low-Income Weatherization Assistance

Weatherization programs improve the efficiency of homes for low-income persons. These programs reduce energy consumption and therefore lower energy costs while improving comfort, health, and safety. Nationally, 25 percent of households are considered to be eligible for weatherization assistance under the Weatherization Assistance Program (WAP); eligibility is determined by income

at or below 150 percent of the poverty level by DOE, but states can set their own criteria.[13] Across the Appalachian Region, a greater percentage of persons live in poverty than the national average (in 2000, the national poverty rate was 12.4 percent).

Table 3.6 Poverty Rates for Appalachian States, 2005
(Census, 2008)

	Individuals	Families
United States	13.3	10.2
Alabama	17.0	13.7
Georgia	14.4	11.6
Kentucky	16.8	13.4
Maryland	8.2	6.0
Mississippi	21.3	16.8
New York	13.8	11.1
North Carolina	15.1	11.7
Ohio	13.0	9.9
Pennsylvania	11.9	8.6
South Carolina	15.6	12.5
Tennessee	15.5	12.5
Virginia	10.0	7.4
West Virginia	18.0	14.0

States can provide for additional weatherization above that provided through Department of Energy funding; sources for these funds include utilities, community organizations, and public benefits charges.

This study assumes that one percent of single family and manufactured homes are weatherized each year through this expanded program, reaching 15 percent of Appalachian homes by 2030 (beyond the homes reached by the existing Weatherization Assistance Program). Energy savings estimates for this program are shown in Table 3.7.

[13] Current year documentation can be found at http://www.waptac.org/sp.asp?id=6878

Table 3.7 Energy Savings from Expanded Weatherization					
Year	**Electricity Savings**	**Natural Gas Savings**	**Fuel Oil Savings**	**Total Primary Energy Saved**	**% of Sector Primary Energy**
	(GWh)	**(trillion Btu)**	**(trillion Btu)**	**(trillion Btu)**	
2010	113.95	0.54	0.11	2.27	0.12
2013	461.47	2.19	0.43	9.24	0.47
2020	1,299.61	6.19	1.19	26.23	1.22
2030	2,612.21	12.13	2.21	53.00	2.15

Table 3.8 investment costs are based on an investment of $2,300 per home and administrative cost are set at a level of 10 percent of the investment (the Federally defined limit for such costs). Energy savings reflect the consumer‘s bill savings based on their reduced consumption and forecast energy prices (EIA, 2008a).

Table 3.8 Costs and Savings from Expanded Weatherization			
Year	**Energy Savings**	**Admin Costs**	**Investment Costs**
	(million 2006$)	**(million 2006$)**	**(million 2006$)**
2010	20.41	17.18	171.77
2013	78.35	17.80	177.97
2020	217.81	19.22	192.22
2030	455.48	21.01	210.11

Figure 3.5 shows how investments in weatherization and energy savings change over the study period. There is no private investment assumed in this model for expanded weatherization. The public investment includes the administrative costs and the cost of improvements; if the low-income weatherization program were designed as a cost-share program; public investments would be lower while private investment would be higher.

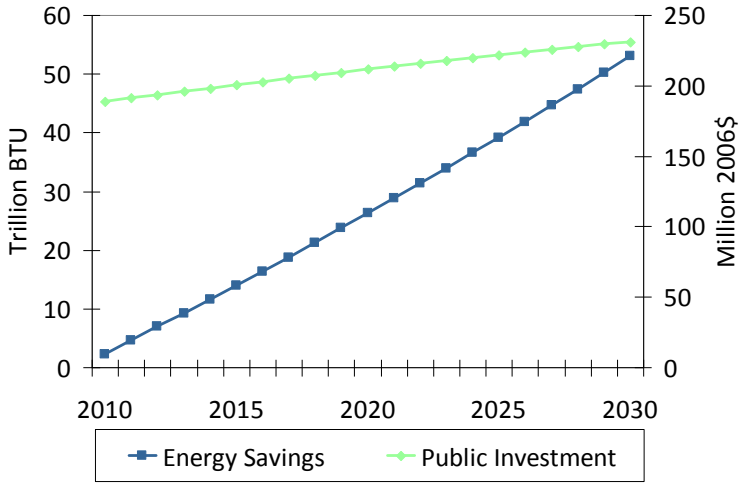

Figure 3.5 Annual Investment and Energy Savings from Expanded Weatherization, 2010-2030

Weatherization of low-income homes has been touted as an effective program for more than 20 years. As mentioned above, not only does weatherization reduce energy bills for low-income consumers, it also improves comfort, health, and safety for the families served – the existing program favors homes with children and the elderly. In addition, if energy bills are lower, consumers will be more likely to be able to pay their bills, and less likely to request heating bill assistance funds, like LIHEAP, or shirk on payment, leading to charge-offs. These non-energy benefits can be considerable; Schweitzer and Tonn (2002) determined that the non-energy benefits of weatherization were about $3,809 over the lifetime of the retrofits, and most of these benefits accrue to society as a whole.[14] More detail on benefits and costs are in the summary of this chapter.

The Expanded Low-Income Weatherization Assistance Program is cost-effective over the lifetime of the measures with a benefit-to-cost ratio of about 2.1 for participants and about 1.3 for total resource costs. With $4 billion in program spending over the 2010-2030 period, the Appalachian Region could see net cumulative savings of 1.1 quads, saving $11.4 billion in energy bills by 2050. This is the equivalent of about 2.1 percent of the EIA's forecast consumption in 2030 or 10.2 percent of forecast growth (EIA, 2008a).

3.3.3 Residential Retrofit Incentive with Resale Energy Labeling and On-Bill Financing

Policies to encourage existing home retrofits can reduce the financial barriers faced by homeowners in that they tend to have high discount rates and lack adequate access to capital (Brown and Chandler, 2008). In addition, retrofit of existing homes innovates within the current stock of homes rather than waiting for new, more efficient homes to be built. This innovation alleviates efficiency problems with slow housing turnover (survival rates of 98-99.7 percent). Homeowners are already turning to retrofits for comfort and safety; remodeling expenditures doubled for owner-occupied homes over the 1995-2005 decade with extra insulation as a popular project (AIA, 2006a, b). However, the interval for a major home renovation, including the envelope/shell is 30-50 years. This long interval suggests that each renovation not bringing a home to meet current standards is a lost opportunity (Jakob, 2006). Banfi et al. (2008) found that consumers (both renters and owners) report a willingness to pay for energy-efficient measures, such as windows, insulation, and ventilation technologies, that is higher than the cost of the same measure's installation; they suggest that this may represent either an overstatement of willingness to pay or an indication that the market has not fully developed.

[14] Schweitzer and Tonn (2002) report savings in 2001 dollars; to remain consistent with the currency of this report, the $3,346 in reported 2001 savings was converted to 2006 dollars.

The present analysis assumes the retrofit program runs as an incentive measure for 20 percent of investment cost, to accompany two other policies – home energy disclosure and on-bill financing. While the incentive only lasts for 10 years – to 2020 – the program continues to provide support for the disclosure and financing mechanisms as well as public awareness campaigns until 2030.

Home energy disclosure would provide information to home buyers (for new and resale residences) on the energy efficiency of the home. In Kansas, home energy disclosures have been required on new residential construction since 2001, but legislation in 2007 extended the requirement to include resale homes (Kansas, 2007a; KEC, 2008). While policy makers might expect opposition from industry, realtors, and architects, for such a requirement, recent history shows that this is not a concern. The Kansas experience shows strong support from these groups (Aron, 2007; Bell, 2007; Neu Smith, 2007). Also, resale energy labeling could encourage home buyers to recognize the energy costs of the homes they are considering and may drive greater investment in retrofits before or after homes are sold.

On-bill financing refers to programs, run through utility or municipal energy retailers that allow consumers to acquire a favorable loan for energy-efficient retrofits or upgrades that are paid back through their energy savings. This is conceptually similar to the services offered by energy services companies as ―performance contracting." On-bill financing reduces the first cost to the consumers (and allows for pass-through of costs to the next owner). This could make the costs less daunting and allow for homeowners to pass the costs on if they have to sell their home before these costs are paid for by the energy savings (Brown, Southworth, and Sarzynski, 2008). Kansas has also passed legislation to allow utilities to enter into contracts with customers, or landlords of customers, to finance energy-efficiency improvements; the amount must be approved by the Kansas Corporation Commission and would be repaid through energy savings (Kansas, 2007b). Some utilities in the Appalachian Region already offer on-bill payment of financing for energy efficiency. An example is Cherokee Electric Cooperative in Alabama which offers the Energy Conservation Home Improvement Loan Program with low-interest loans for up to 10 years and on-bill payment (Cherokee, 2008).

Regardless of the form of the program, retrofits of homes would offer greater savings per home than weatherization and are not limited to low-income homeowners. Programs of this nature could encourage investment in rental properties and larger homes. For this policy, we assume that two percent of all existing single family homes are retrofit each year from 2010 to 2030. The costs per home are more than under the weatherization program – $3,400 per home.

Resale energy labeling would require an additional field in the Multiple Listing Service for home energy consumption. It is not envisioned to require a Home Energy Rating System or audit; both of these have been shown to be costly and therefore engender opposition from real estate professionals. Instead, utilities (or other energy providers) would be required to provide the information on average consumption. This is information that the utilities (or other energy providers) would already have and does not require an audit as utilities generally have incentive to have correct consumption information for billing purposes. Administrative costs on the part of the government are expected to be minimal. Energy consumption information should be provided on an average annual or average monthly basis for the whole residence and per square foot for each fuel used in the home provided by an energy company (electricity, natural gas, fuel oil, etc).

Labeling programs provide potential buyers with information on the energy integrity of homes. They do not mandate efficiency improvements, but may encourage improvements when energy costs are

high. These can easily be compared to the provision of the U.S. Environmental Protection Agency (EPA) mileage estimates provided for new vehicle sales; consumers may choose more efficient vehicles based on this information.

The energy savings reported in Table 3.9 amounts to a 7.3 percent reduction of residential energy consumption. It translates to a simple payback of about six years, following an incremental investment of $3,400 per retrofit home. This payback period is considerably longer than some studies claim for retrofits (see Appendix B.3); however, lower energy prices in Appalachia and a greater reliance on electricity for heat can explain some of this difference.

Table 3.9 Energy Savings from Existing Home Retrofits

Year	Electricity Savings	Natural Gas Savings	Fuel Oil Savings	Total Primary Energy Saved	% of Sector Primary Energy
	(GWh)	(trillion Btu)	(trillion Btu)	(trillion Btu)	
2010	382	2.23	0.43	8.11	0.42
2013	1,535	9.04	1.72	32.76	1.67
2020	4,222	25.52	4.68	91.47	4.24
2030	8,241	49.75	8.58	180.20	7.30

The costs reported in Table 3.10 are based on the incremental cost of $3,400 for efficient retrofits, and a small administrative staff to support oversight of labeling and incentive distribution. The energy bill savings are based on forecast energy prices and modeled energy savings by census division (EIA, 2008a).

Table 3.10 Costs and Savings from Existing Home Retrofits

Year	Energy Savings	Admin Costs	Investment Costs
	(million 2006$)	(million 2006$)	(million 2006$)
2010	75	0.99	466
2013	288	0.99	483
2020	790	0.98	523
2030	1,631	0.33	572

Figure 3.6 shows how investments and energy savings change over the study horizon. The modeled program assumes that private investment continues, and picks up the difference when the incentive for efficient retrofits is removed. As such, this program is modeled as a market transformation. Over the first 10 years, when there is an incentive, consumers become familiar with the energy labeling, and on-bill financing mechanisms become commonplace. By 2020, consumers and the contractors performing retrofits are interested in ensuring greater energy efficiency with their retrofits and are willing to cover the entire incremental costs of these improvements.

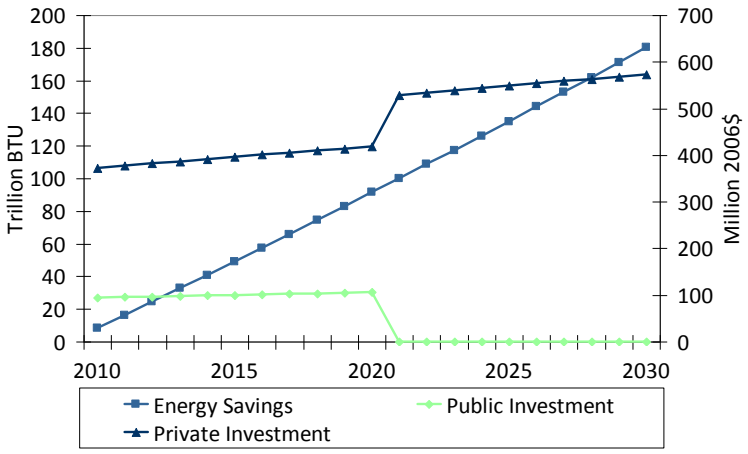

Figure 3.6 Annual Investment and Energy Savings from Existing Home Retrofits, 2010-2030

In total, the Efficient Residential Retrofit Incentive with Enabling Home Labeling and On-Bill Financing is cost-effective with a benefit-to-cost ratio of about 1.5 for participants (all retrofit home occupants) and about 1.7 for total resource costs; more detail on benefits and costs are in the summary of this chapter. With $1.1 billion in program spending and an additional $9.86 billion in private investments over the 2010-2030 period, the Appalachian Region could see net cumulative savings of 3.8 quads, saving $33.5 billion in energy bills by 2050. This is the equivalent of 7.3 percent of the EIA's forecast consumption in 2030 or 34.6 percent of forecast growth (EIA, 2008a).

3.3.4 Super-Efficient Appliance Deployment

About one-quarter of residential energy consumption goes to support lighting and appliances. While new incandescent bulb efficiency requirements within EISA 2007 are expected to reduce the lighting load, significant reductions in other appliances and electronics are not currently forecast. While energy-efficient dishwashers have nearly achieved sales saturation, less than one-third of clothes washers and refrigerators sold in 2006 met ENERGY STAR requirements (ENERGY STAR, 2007).

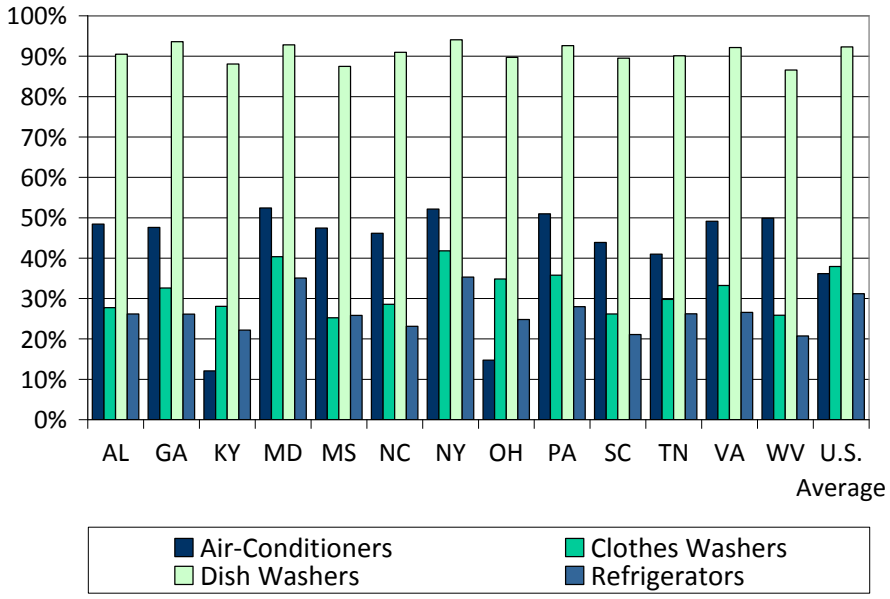

Figure 3.7 Percent ENERGY STAR Sales by Appliance by State, 2006
(ENERGY STAR, 2007)

Policies to encourage greater adoption of energy-efficient appliances and electronics come in many forms. States offer sales tax holidays, tax credits, and rebates for energy-efficient appliances. Georgia started an ENERGY STAR sales tax holiday in 2005, with other states, like North Carolina, Virginia, and West Virginia following; in the same spirit, New York is considering eliminating sales tax on ENERGY STAR labeled appliances and light bulbs (Hayes, 2008). In Japan, the most efficient equipment and appliances set the new target consumption rates (as opposed to a minimum standard set before development like our ENERGY STAR program); this ―Top Runner" program has exceeded the savings expectations of the Energy Conservation Center, Japan (ECCJ, 2008). Regional support to remove poor performing appliances from the market could significantly reduce energy consumption in newly purchased products while a companion replacement effort could accelerate stock turnover for outdated appliances and equipment. For example, New York Power Authority has a refrigerator replacement program in place for public housing residents.[15]

This study assumes that super-efficient appliances are available at technology development rates of three percent more efficient than forecast every five years, so the most efficient appliances in 2025 are nine percent more efficient than stock efficiency in the *Annual Energy Outlook 200*8 baseline forecast (EIA, 2008a). The model considers eleven residential end-uses (see Appendix B.4).

An incentive of 40 percent of the incremental cost is offered for adoption of these appliances from 2010 to 2015; from 2015 to 2020, the incentive is 20 percent of the incremental cost. These incentives are expected to drive 50 percent of appliance replacements and new purchases to super-efficient appliances available for that end-use from 2010 to 2020; after 2020, only 40 percent of new purchases are of super-efficient appliances. While this policy represents an aggressive demand pull mechanism, higher demand could drive the technology improvements faster and lead to lower incremental costs in the long run. It is envisioned that the incentive would target manufacturers,

[15] For information about New York Power Authority's refrigerator program see http://www.nypa.gov/services/esprograms2.htm

distributers, and contractors; and that it would be coupled with public information campaigns for consumers. By 2020, 0.7 percent of the residential sector's energy demand would be saved as a result of this policy, increasing to 1.7 percent in 2030.

The energy savings expected from this program are shown in Table 3.11.

Table 3.11 Energy Savings from Super-Efficient Appliance Deployment

Year	Electricity Savings	Natural Gas Savings	Fuel Oil Savings	Total Primary Energy Saved	% of Sector Primary Energy
	(GWh)	(trillion Btu)	(trillion Btu)	(trillion Btu)	
2010	51	0.02	0.00	0.75	0.04
2013	207	0.06	0.00	3.03	0.15
2020	957	0.30	0.00	14.25	0.66
2030	2,736	0.82	0.00	41.65	1.69

Table 3.12 shows the costs and energy bill savings from the Super-Efficient Appliance Deployment. The energy bill savings are based on modeled energy savings and forecast energy prices by fuel and census division (EIA, 2008a). Administrative costs include only the program staff costs while investment costs include the whole incremental cost of more energy-efficiency appliances.

Table 3.12 Costs and Savings from Super-Efficient Appliance Deployment

Year	Energy Savings	Admin Costs	Investment Costs
	(million 2006$)	(million 2006$)	(million 2006$)
2010	5.68	0.02	5.57
2013	22.12	0.02	5.67
2020	101.62	0.08	17.97
2030	294.31	0.11	26.31

Figure 3.8 shows how investments and energy savings change over time. It is clear that the five year cycle represents a significant cost increase as the incremental cost of the super-efficient appliances are assumed to rise with greater efficiency required. Public investment remains quite low, although it does reflect an incentive of 40 percent of the incremental cost until 2015 and 20 percent until 2020 on top of the administrative costs. Private investment is lower until 2020 due to the incentive. Because the policy is a designed to pull demand towards efficient products, the policy transforms the market to a more efficient equilibrium.

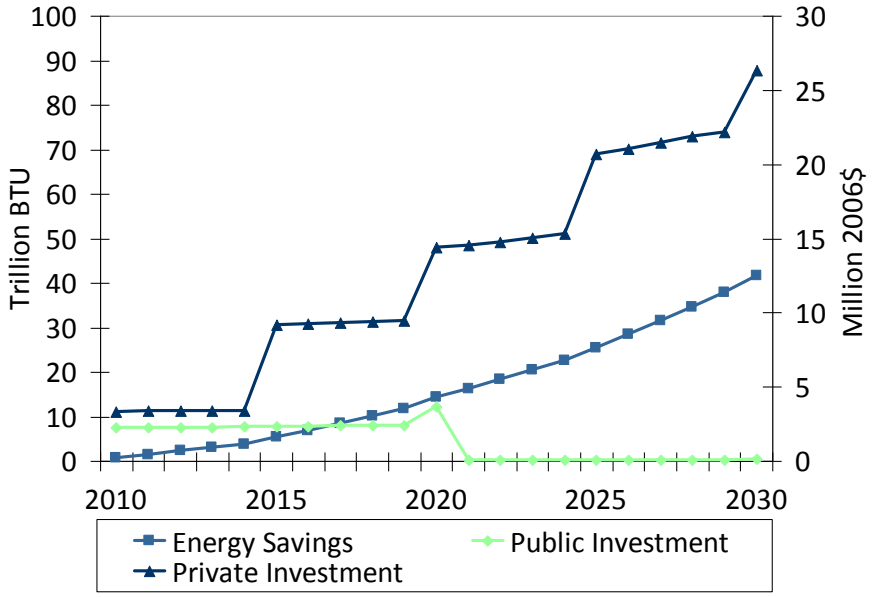

Figure 3.8 Annual Investment and Energy Savings from Super-Efficient Appliance Deployment, 2010-2030

The Super-Efficient Appliance Deployment Program is cost-effective with a benefit-to-cost ratio of about 6.7 for participants (everyone who uses appliances replaces something during this period because all modeled appliances have lifetimes of less than 20 years) and about 7.0 for total resource costs. With $27.8 million in program spending and an additional $271 million in customer investments over the 2010-2030 period, the Appalachian region could see net cumulative savings of 345 trillion Btu, saving $2.4 billion in energy bills by 2030. This is the equivalent of about 1.7 percent of the EIA's forecast consumption in 2030 or 8.0 percent of forecast growth (EIA, 2008a).

Box 3.2 Research and Development Example:
Air-Source Integrated Heat Pumps

A major manufacturer has partnered with Oak Ridge National Laboratory (ORNL) on the development of air-source integrated heat pumps (AS-IHP). Integrated heat pumps provide space heating and cooling, water heating, ventilation, and dehumidification into a single system. Efficiencies are gained over traditional HVAC systems by making use of otherwise wasted energy (e.g., heat rejected by the space cooling operation can be used for water heating). Heat pumps are a central part of the DOE's efforts to develop net-zero energy housing, or homes that produce as much energy as they consume. This technology could provide nearly 60 percent savings in both cold and mixed humid climates (even greater in hot or temperate climates), relative to a baseline system. Incremental capital costs for this advanced HVAC system are not expected to be prohibitive, ranging from $2,500 to $3,200 (2006 dollars) greater than a baseline system, with payback times averaging around eight years in cold and mixed climates (Baxter, 2006). The incremental costs are kept low because of shared components of the HVAC system and the ability to use otherwise wasted energy.

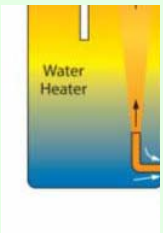

Figure 3.9 Schematic of an Air-Source Integrated Heat Pump
(Baxter, 2006)

The residential sector is responsible for approximately one third of all energy consumed in the U.S., and this holds true for the Appalachian Region as well. A new HVAC technology such as the AS-IHP that is 60 percent more efficient than traditional technologies could dramatically reduce residential energy demand (Baxter, 2006). Space heating and cooling, and water heating combined account for about 70 percent of all residential energy consumption.

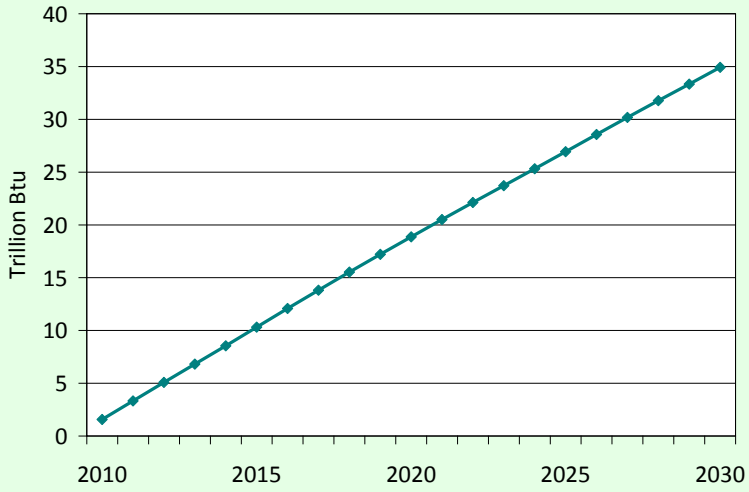

Figure 3.10 Cumulative Energy Savings from Integrated Heat Pump in Appalachian Region (Trillion Btu)

The AS-IHP is still in the development stages and is not yet commercially available. Within an average Appalachian home, installation of the AS-IHP would save approximately 37 million Btu per year. This estimate is based on the energy use of the AS-IHP in Appalachian climates as compared to the average amount of energy used in an Appalachian home on space heating and cooling, and water heating. As with any new technology it is difficult to estimate what the market potential will be, but a study from the IEA Heat Pump Programme (2006) suggests that heat pumps could reach 30 percent of the market. Figure 3.10 shows the estimated the amount of energy that could be saved from installing the AS-IHP in 30 percent of all new homes built between 2010 and 2030, assuming household energy consumption remains consistent. Roughly 1.6 trillion Btu would be saved annually under this scenario. Because the integrated heat pump is not easily adaptable to retrofits, they were not included in these estimates.

The air source integrated heat pump could provide substantial energy savings to households in the Appalachian Region. However, high upfront costs may stall its adoption by the market. Policies that support or require installment of energy-efficient technologies in all new housing, as well as incentivize retrofitting energy-efficient technologies in existing houses, would help push integrated heat pumps into the market more quickly.

3.4 SUMMARY OF RESULTS

The residential sector can quickly deliver cost-effective energy savings to consumers (Brown, et al., 2001; McKinsey, 2007). This chapter provides further evidence suggesting that Appalachian Region investments in residential programs can generate benefits to the Appalachian Region‘s residents that more than exceed their public and private investment costs. Based on the residential program and policy bundles described in this chapter, building energy codes and efficient retrofits have the largest potential for energy savings (Figure 3.11). Together they account for approximately three-fourths of the 374 trillion Btu of residential savings that are projected to occur in the year 2030.

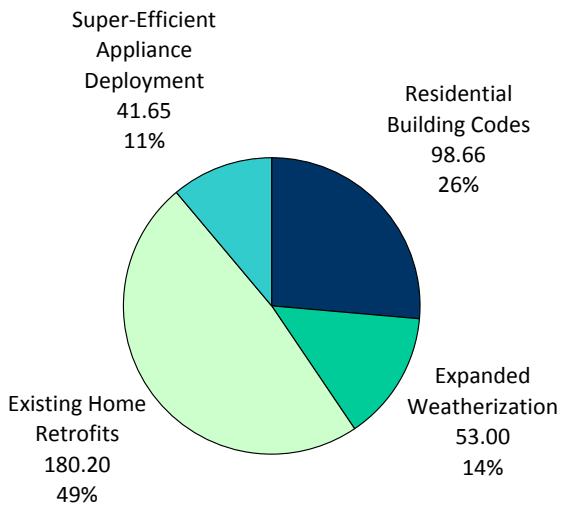

Figure 3.11 Residential Energy Savings by Policy Bundle, 2030 (trillion Btu)

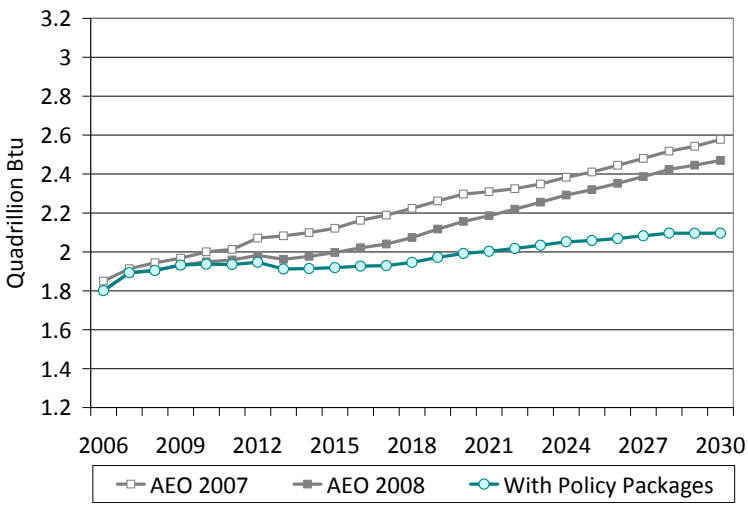

Figure 3.12 Residential Primary Energy Consumption With and Without Policy Packages (Quads), 2006-2030

Figure 3.12 shows that implementation of these policy bundles could significantly curb the growth in residential energy consumption forecast for the Appalachian Region to 2030, with nearly flat consumption from 2028 to 2030. These four policies generate savings of 15.1 percent of *AEO* 2008 forecast consumption in 2030 (EIA, 2008a).

These estimated savings are generally lower, but not dramatically different, than other studies for states in the Region. Efficiency potential studies completed for Georgia Power and the Georgia Environmental Facilities Authority found maximum achievable electric efficiencies of nine percent over 10 years and 9.4 percent over five years, respectively (ICF, 2005; Nexant, 2007). A study for North Carolina found a maximum achievable potential for residential electric efficiency of 16.9 percent over a 10 year horizon (GDS Associates, 2006). An efficiency potential study for Kentucky modeled minimally and moderately aggressive scenarios with residential savings of 2.7 percent and 8.2 percent, respectively, over 10 years (KPPC, 2007). More recently, a report by ACEEE et al. (2008) modeled residential savings for Virginia at 26 percent of their forecast electricity consumption in 2025.

In addition to comparing our modeled savings case with the *AEO 2008*'s Reference case, we can also compare the savings forecast with two of the *AEO* 2008 alternative cases: one representing the ―Frozen Building Technology" option and another reflecting the ―High Technology" alternative (Figure 3.13). It is clear from this figure that our estimated savings from the reference case are much greater when compared to the ―Frozen Building Technology" case and still noticeably more energy-efficient than the ―High Technology" case.

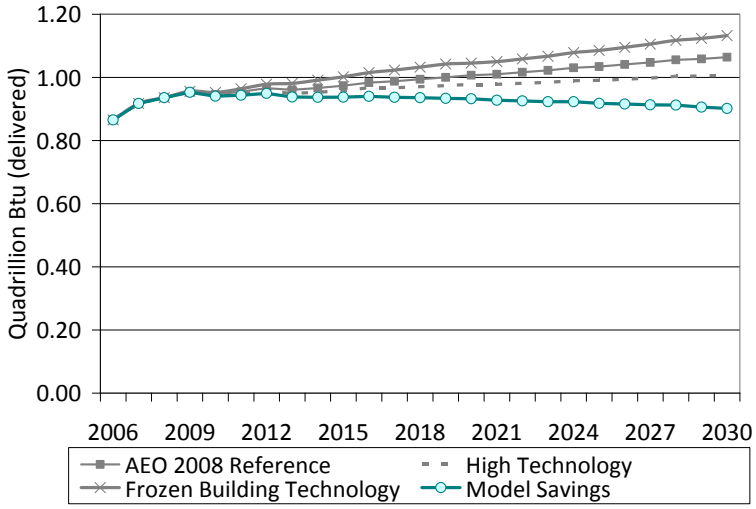

Figure 3.13 Comparison of Appalachian Residential Delivered Energy Consumption Forecast Under Four Cases (Quads), 2006-2030
(EIA, 2008a)

When considering this package of residential policies from the participants' perspective, the simple payback declines from about 4.2 years to about two years over the study horizon. The shortened payback period is largely driven by the gains in new residential building efficiency without a corresponding increase in incremental costs; it also follows an increasing cost of energy (a Btu saved in 20 years is worth more than a Btu saved today). It is assumed that materials, technology, and practice will improve over time to reduce the incremental cost of efficient buildings. The Existing Home Retrofit Program and Super-Efficient Appliance Deployment Program maintain paybacks of around six years and one year, respectively, throughout the study period. Participants do not make an investment in the expanded weatherization program as modeled, so the payback period is not considered.

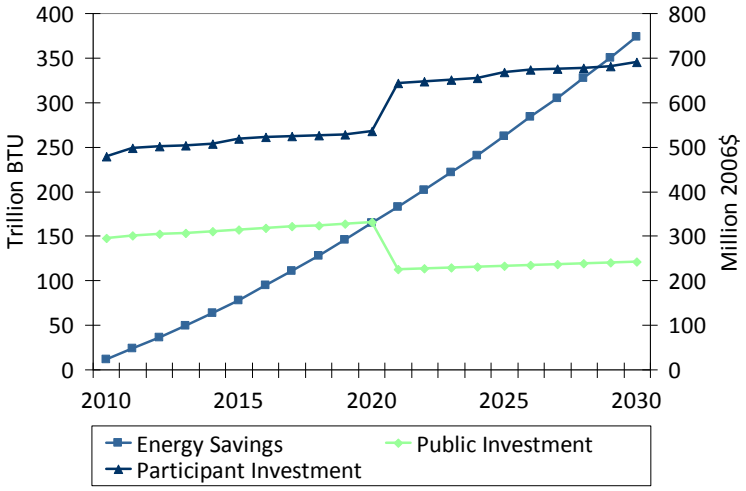

Figure 3.14 Annual Investment and Energy Savings from Combined Residential Policy Packages, 2010-2030

Figure 3.14 shows how public and private investments and energy savings change over the study horizon. The energy savings continue to accumulate at a persistent pace across the 20-year planning horizon. In contrast, the public investment drops in 2020 when the subsidies for retrofitting existing housing stock and incentives for super-efficient appliances are sunset, while the participants costs increase in a compensatory manner.

The economic feasibility of policy packages is a function of how the policy costs and benefits are distributed over time and across customer classes and residential subgroups. For the residential energy-efficiency policies modeled, the super-efficient appliance deployment, and building codes are the most cost-effective see Table 3.13. However, consideration of non-energy benefits often drive adoption of policies such as

expanded weatherization, which has the lowest total resource cost test across the four policies, but offers substantial health, comfort, and safety benefits to low-income households. Similarly, consumers often adopt more efficient retrofit measures to remove drafts or reduce noise in addition their energy benefits. Measures are only counted for benefits over their useful lives; in this analysis, we have considered retrofit and weatherization savings to accrue for 20 years. For building codes and efficient appliances, we make the conservative assumption that the market would have caught up to our program by 2030, so we do not consider benefits after this time.

Table 3.13 Results of Economic Tests for Residential Policies

	Residential Building Codes	Expanded Weatherization	Existing Home Retrofits	Super-Efficient Appliance Deployment	Total
Participants Test					
NPV Benefits (billion 2006$)	3.17	3.37	6.72	0.64	13.90
NPV Costs (billion 2006$)	0.92	1.60	4.36	0.09	6.98
Net Benefits-Costs (billion 2006$)	2.25	1.77	2.36	0.54	6.92
B/C Ratio	3.44	2.10	1.54	6.75	1.99
Total Resource Cost Test					
NPV Benefits (billion 2006$)	4.69	2.80	9.36	0.90	17.75
NPV Costs (billion 2006$)	1.26	2.23	5.52	0.13	9.14
Net Benefits-Costs (billion 2006$)	3.43	0.57	3.84	0.78	8.61
B/C Ratio	3.72	1.26	1.70	7.05	1.94

The combined residential policy package is cost-effective with a benefit-to-cost ratio of about 2.0 for participants and about 1.9 for total resource costs. With $5.1 billion in program spending and an additional $12.3 billion in customer investments over the 2010-2030 period, the Appalachian Region could cost-effectively reduce its energy consumption by 6.0 quads, saving $60.4 billion in energy bills. The savings in 2030 represent the equivalent of 18.7 percent of the EIA's forecast consumption or 71.7 percent of forecast growth (EIA, 2008a).