2 METHODOLOGY

A variety of sources of data and models are used in energy-engineering analyses to forecast the energy savings potential, administrative, and implementation costs of each energy-efficiency policy bundle. These methodologies are summarized in each of the sector chapters and are described in greater detail in Appendices B through E. The results of these policy analyses are then input into the DEEPER model created by ACEEE to evaluate the macro-economic impacts of proposed policies. In addition, the project team created an Advisory Group and Stakeholder group to review and guide the research.

For the purposes of this study, *energy efficiency* refers to the long-term reduction in energy consumption as a result of the increased deployment and improved performance of energy-saving equipment and practices. In the electricity sector, energy efficiency is also a low-cost contributor to system adequacy – the ability of the electric system to supply the aggregate energy demand at all times. When applied to transportation systems, energy efficiency is a major contributor to energy security. In addition, environmental benefits often come hand-in-hand with energy efficiency, along with productivity gains and job growth. At the same time, energy efficiency typically requires increased utility and government costs to transform markets. This chapter describes the methodology used to estimate how much energy-efficiency improvement could occur in Appalachia that would be cost-effective and feasible given the wide array of associated costs and benefits.

2.1 THE BASELINE FORECAST

The ―business-as-usual" baseline forecast of Appalachian energy consumption derived for this study is based on supplemental data from the National Energy Modeling System (NEMS) used to support the *Annual Energy Outlook* (EIA, 2007a; 2008a). The Appalachian Region baseline forecast is derived from population-weighted portions of the four census divisions comprising the 410-county Region. Regional populations within each census division were calculated using the Regional Economic Models, Inc. (REMI)[5] estimates of population by county for 2002, based on ARC sub-region growth rates (North 0.28 percent, Central 0.39 percent, and South 1.13 percent).

While the AEO-based method used here does not result in county-by-county populations that exactly match REMI's 2020 and 2030 forecast, they are generally within a close margin. For example, the total Appalachian Region's population is less than 0.2 percent higher in 2020 and less than two percent lower in 2030 in this study compared with the REMI forecast. Total census division populations are based on the *AEO* 2007 population forecast (EIA, 2007a). Over the study horizon, the Appalachian Region is increasingly weighted in three of the four census divisions. In contrast, the proportion of the Region's population residing in the South Atlantic census division (from Virginia through Georgia) shrinks over time; this is likely due to much higher growth rates in the non-Appalachian portions (especially coastal areas) of the South Atlantic division (Table 2.1).

[5] REMI, 2007

Table 2.1 Population Weighted Census Division Portions
(EIA, 2007a, REMI, 2007)

Year	Total ARC Population	%			
		Middle Atlantic	East North Central	South Atlantic	East South Central
2006	23,862,608	16.79	3.18	14.29	41.56
2013	25,056,158	17.11	3.18	13.56	43.27
2020	26,331,378	17.26	3.19	13.14	44.80
2030	28,307,471	17.66	3.26	12.61	47.10

Using the same estimates of county population described above, portions of each state population were also developed (Table 2.2). These state population portions are used when modeling administrative costs for several of the policy packages.

Table 2.2 Appalachian State Population Portion Estimates and Projections, 2006-2030 (WV = 100%)

YEAR	%											
	AL	GA	KY	MD	MS	NY	NC	OH	PA	SC	TN	VA
2006	25.7	29.0	16.4	32.2	50.6	5.6	66.5	12.9	24.1	15.1	41.7	22.7
2013	25.9	28.2	16.7	30.6	50.4	5.7	61.5	13.0	25.7	15.3	42.4	22.5
2020	26.1	27.8	17.2	29.3	50.6	5.8	57.0	13.2	27.5	15.7	43.3	22.5
2030	26.3	27.7	18.1	27.9	51.3	6.0	51.3	13.7	30.8	16.4	44.5	22.8

Using REMI estimates, the Gross Appalachian Regional Product (GRP) would almost double between 2006 and 2030, growing to $1,320 billion (in 1996-$). The Region‘s annual growth rate of about 2.4 percent is significantly lower than the EIA forecast of a 2.9 percent annual GDP growth nationwide. Given the inertia that characterizes most economic systems, we can imagine that the distribution of distressed and prosperous counties in the Region would not change much over our planning horizon.

This business-as-usual ―baseline” future paints the Appalachian Region over the next 25 years, much as it is today. In this scenario, the nation remains uncommitted to climate policy, coal continues to be an economically competitive energy resource, and oil persists as the dominant transportation fuel. As such, energy efficiency still is expected to carry the external benefits of reduced greenhouse gas emissions and improved energy security. Many energy-efficiency investments are more cost-effective than many supply-side options, but numerous barriers including the policy environment often hinder energy-efficiency investments (Prindle, 2007; Brown and Chandler, 2008).

Nevertheless, some amount of ―naturally occurring energy-efficiency improvement" is incorporated in the baseline forecast. The magnitude of this can be highlighted by comparing the *Annual Energy Outlooks* published in 2007 and 2008 (EIA, 2007a; 2008a) (Figure 2.1). The *AEO* 2008 includes several strong efficiency policies promulgated in the Energy Independence and Security Act of 2007 (EISA, 2007), which were not reflected in the *AEO* 2007. In addition, the *AEO* 2008 uses higher energy prices and a slower GDP growth rate. Based on the *AEO* 2007, energy consumption in the Appalachian Region was forecast to grow to 11.2 quads by 2030. In contrast, the forecast based on the *AEO* 2008 is 11 percent lower, projecting 10.1 quads of energy consumed in the Appalachian Region in 2030. The biggest difference is in the transportation sector where 40 percent stricter fuel economy standards for vehicles are required in 2020.

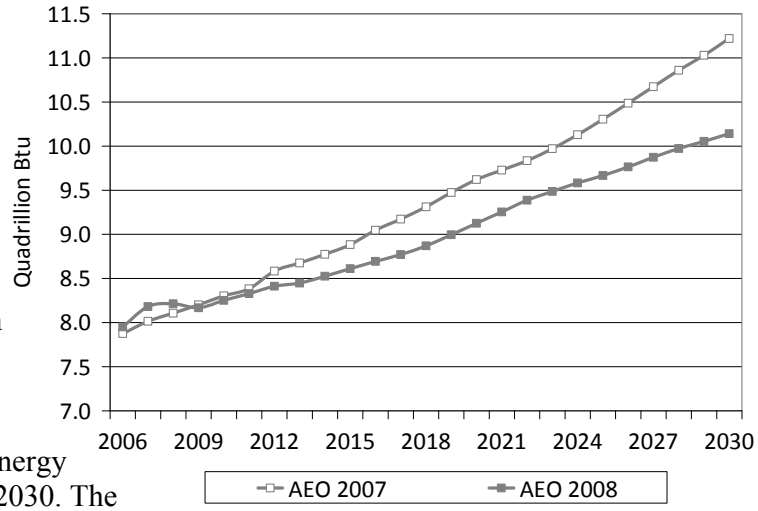


Figure 2.1 ARC Energy Consumption Forecast (Quads)
(EIA, 2007a, 2008a)

2.2 DEFINITION OF ECONOMIC ENERGY-EFFICIENCY POTENTIAL

When evaluating the potential for any energy alternative to be deployed in future years, four types of estimates are generally used (Rufo and Coito, 2002; NYSERDA, 2003; Eldridge, Elliott, Neubauer, 2008).

- *Technical potential* refers to the complete penetration of all energy-efficient applications that are technologically feasible, regardless of economic cost-effectiveness.
- *Economic potential* is defined as that portion of the technical potential that is judged cost-effective.
- *Maximum achievable potential* is defined as the amount of cost-effective (economic) potential that is achievable over time under the most aggressive program scenario possible. It takes into account administrative and program costs as well as market barriers that prevent 100 percent market penetration.
- *Program potential* is the subset of maximum achievable potential that would occur in response to specific policies such as subsidies and information dissemination aimed at promoting the deployment of cost-effective energy efficiency.

Energy Efficiency in Appalachia estimates the program potential for energy-efficiency improvements in each of the Region's four sectors. Our analysis of potential in each sector uses a common baseline forecast, identical energy price projections (Table 1.2), the same discount rates for calculating cost-effectiveness, and the same economic tests of cost-effectiveness.

2.2.1 Cost-Effectiveness Tests

Many cost-effectiveness tests have been used to estimate the economic payback to investments in energy efficiency. Four tests, in particular, are most common: the participants cost test, total resource cost test, rate impact measure, and societal test. Each of these tests answers a distinct set of questions (NAPEE, 2007a, p. 5-2).

Participants Cost Test:

Is it worth it to the customer to install energy efficiency?

Is a customer likely to want to participate in a program that promotes energy efficiency?

Total Resource Cost Test:

What is the Regional benefit of the energy-efficiency project including the net costs and benefits to the utility and its customers?

Is more or less money required by the Region to pay for energy needs?

Ratepayer Impact Measure:

What is the impact of the energy-efficiency program on the utility‘s operating margin?

Would the project require an increase in rates to reach the same operating margin?

Societal Test:

What is the overall benefit to the community of the energy-efficiency program, including indirect benefits?

Are all of the benefits (including indirect benefits) greater than all of the costs regardless of who pays the costs and who receives the benefits?

We use the participants test and the total resource cost test to evaluate the cost-effectiveness of each of the modeled energy policies and each sector‘s bundle of policies.

The participants test compares the costs and benefits experienced by participants in the energy policy or program. If the net present value of their benefits is greater than the net present value of their costs, then the benefit/cost ratio is greater than 1.0 and the policy is cost-effective. Typically these net present value calculations use a discount value of 10 percent to reflect the private-sector nature of the investments made.

The total resource cost (TRC) test was developed originally to evaluate demand-side management (DSM) programs operated by utilities (OTA, 1993). It is a measure of the total net benefits of a program from the point of view of the utility and its ratepayers as a whole. A policy or program is cost-effective if it does not increase the total costs of meeting the customers‘ service needs. We use a seven percent discount rate to calculate these net present values, which is the rate recommended by the Office of Management and Budget‘s Circular No. A-94 (p. 8).

The benefits and costs included in these two economic tests, along with their discount rates, are summarized in Table 2.3.

Table 2.3 Benefits and Costs Included in the Economic Tests		
	Energy-Efficiency Benefits	**Energy-Efficiency Costs**
Participants Cost Test	Reduction in energy bill, plus incentives from utility and government programs (10 percent discount rate)	Participants‘ direct investment, plus incentives from utility and government programs (10 percent discount rate)
Total Resource Cost Test	Avoided supply costs (based on retail energy prices) (seven percent discount rate)	Utility and government program costs (including administrative costs and incentives to participants) plus participants‘ direct investment (seven percent discount rate)

We are not able to use the ratepayer impact measure (RIM) test because we are unable to estimate the utility‘s change in revenues or costs as the result of the policies modeled here. We are also not able to use the societal test because of the wide range of co-benefits and costs produced by energy-efficiency policies. For example, no consensus exists today to place a value on avoiding the emission of a ton of carbon dioxide (Tol, 2005). Similarly, it is difficult to put a value on the time lost and activities foregone by drivers and passengers as a result of speed limit enforcement, or the lives saved. Typically, the RIM test is the most difficult to pass, while the societal and participants tests are the easiest.

2.2.2 Life-Cycle of Energy Savings

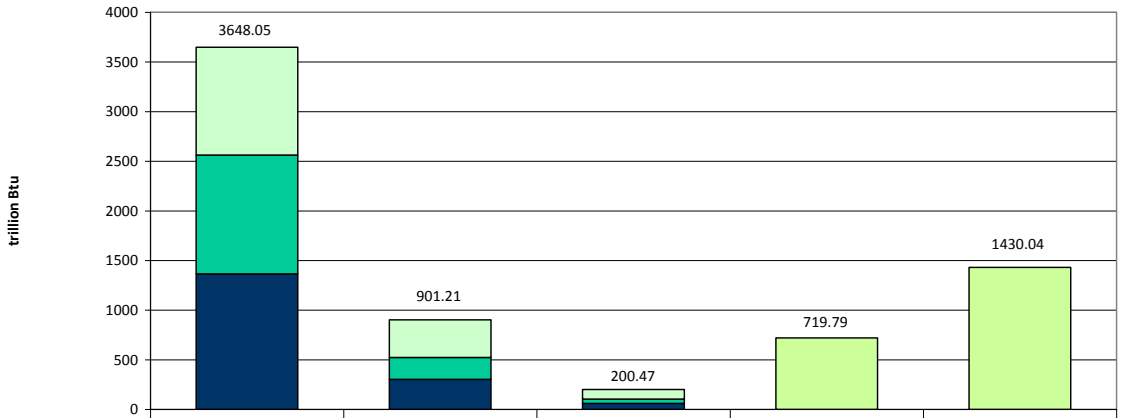
The energy required to produce a unit of fuel or electricity for consumption by an ―end-user” can be large relative to the energy contained in the ―delivered” unit of fuel or electricity. Energy is required to mine coal and drill for petroleum; energy is used to create the compressed air that drives natural gas pipelines; fuels are used to propel the trains and barges that ship coal; and energy is lost in the transmission of electricity from the power plant to the consumer. Energy is also embodied in the power plants, trucks, trains, and other equipment that comprises the energy production and delivery supply chain. As a result, various ―adders” have been created to augment the energy contained in the delivered fuel or electricity to account for the full life cycle of energy consumed. As explained below, we use the electricity adder in this study, but we do not use adders for other fuels.

In the case of electricity, 2.2 million Btu are lost in the electric generation, transmission and distribution steps that deliver 1 million Btu to the consumer in the form of delivered energy. That is, 68.5 percent of the energy embodied in the fuel used to generate electricity in the United States in 2006 is lost principally in the form of waste heat (EIA, 2008a, Table A2). These electricity-related losses do not include the energy required to mine the coal or the energy embodied in the various supply chain equipment. However, this adder of 2.2 is a typical factor used to more completely account for the energy saved when less energy is used by the consumer, and we use it in *Energy*

Efficiency in Appalachia. This adder is justifiable because most electricity-related losses occur in the Appalachian Region.

The same is not true of the energy-related losses associated with the delivery of other fuels to consumers in Appalachia. EPA (2006, Table 14, p. 55) suggests a range of ~~"a~~dders" that convert the greenhouse gas content of fuels into life-cycle measures, based on the energy used to refine and transport fuels. For passenger cars, the fuel cycle add-on for gasoline ranges from 0.24 to 0.31, which means that saving a million Btu of energy by consuming less gasoline in fuel-efficient cars, actually saves 1.24 to 1.31 million Btu when the energy lost in refining and transportation is included. The adder for truck diesel is slightly lower, ranging from 0.15 to 0.25. However, most of these life cycle energy losses occur outside of the Appalachian Region, since little petroleum refining occurs within the Region. As a result, we do not plus up the energy content of delivered petroleum fuels.

Figure 2.2 estimates how much of each modeled fuel was consumed in each of the four sectors in 2006 in Appalachia. Thus, it ignores the consumption of fuels by sectors that we do not address explicitly by our policy bundles, such as natural gas and electricity in transportation and coal and petrochemical feedstocks and coal used by industry. Altogether, we model 6.9 quads of the 7.9 quads that comprised the Appalachian energy budget in 2006. Slightly more than half (3.6 quads) of the modeled energy is electricity (delivered + electric-related losses).



	Electricity	Natural Gas	Fuel Oil	Diesel	Motor Gasoline
Transportation				719.79	1430.04
Industrial	1084.98	378.82	96.48		
Commercial	1198.85	220.10	43.31		
Residential	1364.22	302.29	60.69		

Figure 2.2 ARC 2006 Energy Consumption of Fuels Modeled in this Study

2.3 ENERGY-EFFICIENCY POLICY BUNDLES

To assess the magnitude of cost-effective and achievable energy-efficiency improvements in Appalachia, we assume that a set of transformative energy policies are adopted in the Region beginning in the year 2010. The policy bundles include a combination of vigorous deployment policies that increase the achievable potential for energy efficiency, and expanded RD&D funding that accelerates the advancement of energy-efficient technologies. These policy bundles were defined and then modified iteratively as the result of discussions with the project's Advisory Committee.

To aid in the definition of these bundles of policies, a policy inventory was created for each state, detailing active and imminent (promulgated but not in effect) policies. These inventories were reviewed by state energy offices in the Region and revised accordingly to reflect the latest policy actions. The inventory of state policies is described further in Appendix A.

Forecasting the economic payback to energy R&D has traditionally been challenging. As a result, we chose an illustrative case study approach. The potential impact of three specific R&D projects is illustrated in independent assessments to highlight the potential benefits of transformational technologies. Specifically, we examine the:

- Air-source integrated heat pump
- Solid state lighting
- Industrial super boiler

Table 2.4 summarizes the package of fifteen policies that are assumed to be implemented in each sector. In many cases, policies could be feasibly adopted and implemented at any level of government in this Region (national, regional, state, or local). The Energy-Efficiency Resource Assessments developed for each sector (Chapters 3-6) describe these policies in fuller details; however, they do not proscribe the governmental agencies that should administer them.

Table 2.4 Energy-Efficiency Policy Portfolio			
Residential Buildings	**Commercial Buildings**	**Industry**	**Transportation**
Improved Building Energy Code with Third Party Verification and Compliance Incentive	*Commercial Building Energy Codes with Third Party Verification and Compliance Incentives*	*Expanded Industrial Assessment Centers*	*Pay-as-You-Drive Insurance*
Expanded Weatherization Assistance Programs	*Support for Commissioning of Existing Commercial Buildings*	*Increasing Energy Savings Assessments*	*Clean Car Standards*
Residential Retrofit Incentive with Resale Energy Labeling and Incremental Cost Incentives	*Efficient Commercial HVAC and Lighting Retrofit Incentive*	*Supporting Combined Heat and Power (CHP) with Incentive*	*SmartWay Heavy Truck Efficiency Loan Program*
Super-Efficient Appliance Deployment	*Tightened Office Equipment Standards with Efficient Use Incentives*		*Speed Limit Enforcement*
Illustrative RD&D Initiative			
Air-Source Integrated Heat Pump (IHP). Accelerated RD&D is assumed to result in the commercialization of a single system based on heat pumping technology that provides space heating and cooling, water heating, ventilation and dehumidification and humidification.	*Solid State Lighting.* Accelerated RD&D is expected to produce technology improvements that bring brighter LEDs and provide light equivalent to existing fluorescent fixtures with 25 to 45 percent less electricity usage.	*Super Boiler.* A combination of enhanced design features could increase industrial package boiler efficiency from 75 percent to 95 percent. Many boilers used today are more than 40 years old, suggesting a large energy-savings opportunity.	

2.4 ALTERNATIVE FUTURES

In keeping with Peter Schwartz's *The Art of the Long View* (1991) and other advocates of scenario analysis, the project's analytic team undertook a systematic assessment of alternative possible futures for the Appalachian Region. Our goal was to consider the range of drivers and change agents that could cause energy efficiency in the Region to play a role quite distinct from simply imposing an aggressive energy-efficiency campaign on an otherwise ―business-as-usual" trajectory. The process involved identifying possible drivers of change, brainstorming a wide range of possible futures they could create, and then down-selecting to a small number of scenarios for further consideration.

Because it seems likely that some form of national climate or carbon policy will be announced early during the study's 25-year time horizon, we assume that in any alternative future a price will be placed on greenhouse gas emissions. We also model the impact of this possible future policy, at least partially, by conducting a sensitivity analysis of the policy bundle's cost-effectiveness. Specifically, we consider a range of carbon prices (from $25 to $100 per metric ton of carbon dioxide) beginning in 2011. These carbon ―adders" result in higher retail prices for fossil-based fuels, as shown in Table 2.5 with respect to today's retail energy prices. Using these higher prices, we calculate alternative net

present benefits from the energy saved by the policy bundles, resulting in a range of higher benefit/cost ratios. The results of this sensitivity analysis are summarized in Chapter 8 and detailed in Appendix G for each of the study's fifteen policies.

Table 2.5 Range of Impacts of a Carbon Cap-and-Trade System on Fossil Energy Prices
(Source: Brown and Atamturk, 2008)

Carbon Tax/Penalty ($/MtC)	Natural Gas ($/ccf)	Coal ($/short ton)	Distillate Fuel Oil ($/gal)	Motor Gasoline ($/gal)	Electricity ($/MWh)		
					Average	CCGT	Coal
$25	$0.04 (0.49%)	$13.00 (52.20%)	$0.07 (3.13%)	$0.06 (2.77%)	$4.43 (4.17%)	$2.50 (2.36%)	$6.50 (6.13%)
$50	$0.07 (0.98%)	$26.00 (104.39%)	$0.14 (6.26%)	$0.12 (5.55%)	$8.85 (8.35%)	$5.00 (4.72%)	$13 (12.26%)
$100	$0.15 (1.96%)	$53.00 (208.79%)	$0.28 (12.52%)	$0.24 (11.09%)	$17.70 (16.70%)	$10.00 (9.43%)	$26 (24.53%)

In addition, two scenarios emerged from our brainstorming session that appeared to bracket distinct futures for the Region: a "region-at-risk" scenario and a "high-tech investment boost" scenario. As with any scenario analysis, we do not expect that either of these alternatives will exactly come to pass. Rather, we assume that they characterize a range of plausible possibilities.

2.4.1 Region-at-Risk Scenario

In the region-at-risk future, a national climate policy is assumed to be promulgated early in the time frame (perhaps in 2011), initiating a shift in the way energy is produced and used. However, in this scenario the shift takes place without the aid of fundamentally different technologies. For example, there is no great leap forward in cellulosic ethanol, clean coal, or hydrogen fuel cell vehicles.

In this alternative reference scenario, the Region faces economic troubles due to the higher cost of operating coal plants and the subsequent reduced demand for coal across the country. The Region's annual GRP growth is significantly dampened in this scenario, especially in counties where coal mining dominates. Counties near metropolitan areas or with a more varied economic base may not be impacted as heavily.

Overlaying on this scenario a set of vigorous deployment policies would result in public-private investments that are able to cushion these negative economic impacts and could help the Region adapt to a low-carbon future. With a premium on the price of fossil fuels, energy-efficient technologies are highly cost-effective; however, the difficult economic conditions dampen investments.

2.4.2 High-Tech Investment Boost Scenario

In the high-tech investment boost scenario, a national climate policy is assumed to be promulgated early in the time frame, identical to the policy assumed in the Region-at-risk case. But in this case, by 2015-2020 the country produces significant material, technology, and process advances in the performance and cost competitiveness of clean energy supply technologies, most notably clean coal. The ability to cost-effectively capture and sequester carbon allows the Region to maintain its economic base in industrial and coal sectors even in the face of public concern over climate. Technological breakthroughs also allow coal to be gasified and used to produce hydrogen for the growing demand for fuel cell technologies, and cellulosic ethanol becomes cost-competitive in the 2015-2030 timeframe. This future offers a picture of optimism for the Appalachian Region as coal retains its value and receives a new use for producing vehicle fuels. The Region‘s annual GRP growth rate is expected to rise as a result.

Without the advancement of energy-efficient technologies and vigorous deployment policies in combination with more cost-competitive low-carbon supply options, energy-efficiency investments may have more difficulty gaining market share. In contrast, overlaying on this more prosperous high-tech boost, a set of vigorous deployment policies would result in public-private investments that can significantly decrease the Region‘s energy intensity. With capital made available from the successful launch of clean coal and other low-carbon fuels and motivated by effective energy-efficiency policies, consumers are able to trim their energy consumption and cut their energy bills. The successful investment climate can thus greatly enhance the role energy efficiency plays in the Region.

2.5 DEEPER MODELING

The ACEEE model – *Dynamic Energy Efficiency Policy Evaluation Routine* (DEEPER) – was used to assess the macroeconomic impacts of the policy scenarios. This includes estimates of the net employment and income effects as well as the impact on GRP. DEEPER is a dynamic input-output model that adapts the policy scenario results into a form that enables us to provide a richer assessment of economic impacts that would result from the policy suite. See Appendix F for a detailed description of the DEEPER model.