Emissions Forecasting for the Southern Appalachian Mountain Initiative

Jay Hall, ICF Consulting
Tom Elmore, Land of Sky
Matt Howes, ICF Consulting

ABSTRACT

The Southern Appalachian Mountain Initiative (SAMI) funded a project to assess the potential role of incentives to reduce energy use and emissions from the buildings sectors of the SAMI region. This paper presents a summary of this SAMI study, including: a baseline energy use and emissions assessment, the most cost-effective upgrade measures and strategies for the residential and commercial building sectors, and the potential emissions reductions achievable under several penetration scenarios through the year 2040.

The SAMI Region is composed of eight states: Alabama, Georgia, Kentucky, Tennessee, North Carolina, South Carolina, Virginia, and West Virginia. The scope of work includes both residential and commercial buildings. Industrial facilities are not addressed. Packages of energy efficient technologies are evaluated in this study. These packages include a broad range of technologies addressing the different energy end-use sources: space heating, space cooling, ventilation, hot water heating, and lighting. The energy efficiency measures in each package vary with each of three adoption rates: (1) **passive**: voluntary market transformation programs with no incentives; (2) **active**: voluntary market transformation programs with moderate incentives; and (3) **aggressive**: voluntary market transformation programs with large incentives. The results of this study include the estimated aggregate energy savings by fuel for each state, and related SO_2, NO_x, and CO_2 emissions reductions. Energy use and related emissions are projected for each of these three scenarios in the years 2000, 2010, 2020, 2030, and 2040. Program costs and incentives are also defined for each scenario to ensure the cost-effectiveness of the upgrades.

This study shows that annual emission reductions from energy efficiency upgrades in buildings range from 10 to 25% in the year 2020. In aggregate, only the aggressive adoption scenario neutralizes the effects of growth in demand and ensures a decline in missions (relative to current emissions levels) in the SAMI region. More detailed analyses are needed to assess the impact of custom initiatives targeted at specific local markets.

Introduction

The Southern Appalachian Mountain Initiative (SAMI) funded a project to assess the potential role of incentives to reduce energy use and emissions from the buildings sectors of the SAMI region. SAMI's primary reason for conducting this study was to find ways of reducing atmospheric pollution to better preserve the natural resources in the eight state SAMI region, and thereby to protect the valuable tourism industry that is dependent on these natural resources.

The SAMI Region is composed of eight states: Alabama, Georgia, Kentucky, Tennessee, North Carolina, South Carolina, Virginia, and West Virginia. The scope of work includes both residential and commercial buildings. Industrial facilities are not addressed. Energy use and related emissions are projected for a variety of scenarios involving voluntary (incentive driven) implementation of energy efficiency packages in the years 2000, 2010, 2020, 2030, and 2040.

More comprehensive emissions forecasts have been performed at the national level (Interlaboratory Working Group 2000). This paper is a summary of one aspect of a regional study (E.H. Pechan 2001). This ambitious goal of this project is to estimate energy use in residential and commercial buildings over the next forty years. The general approach is to (1) develop preliminary estimates using simplified calculation methods, and (2) as appropriate, conduct more detailed analyses. This paper summarizes the initial phase (i.e., simple spreadsheet analysis) of this project. The analysis is based on end-use estimates of energy use in a typical residential building and a typical commercial building. The typical home is assumed to be a 2,000 square foot two story building with a basement. The commercial building is assumed to be 25,000 square foot retail store. The specifications for these buildings were based on 10 years of modeling experience of real buildings for the EPA's ENERGY STAR initiatives. The residential and commercial buildings were each modeled in two climates as well. A hot and humid climate was selected to represent the more southern states, and a temperate climate for the more northern states.

Baseline Energy Use and Emissions Assessment

The annual emissions reductions in this project are based on estimates of difference between the annual energy use in a "business as usual" case (without energy efficient technologies) relative to the case when energy efficient technologies are used. As a starting point, it was necessary to develop an estimate of the "business as usual" case (i.e., what if voluntary energy efficiency programs did not exist).

As indicated above, a simple spreadsheet model was developed. The purpose of this model was to make all algorithms and assumptions transparent to all stakeholders. Key assumptions included in the model include: energy-related building characteristics (U.S. Department of Energy, Energy Information Administration, 1998), penetration rate of energy efficient technologies, annual new construction growth rate, emission factors, energy costs. It is expected that the each of the states in the SAMI region will review these assumptions and refine them over time.

The general analytic approach used in the spreadsheet model is a heating and cooling degree day algorithm. State level annual residential energy use is estimated by multiplying the "per home" energy estimates by the number of homes in the state. The SAMI regional energy use is an aggregate of the energy use estimates for the eight SAMI states. Similar calculations are performed for the commercial sector. Emissions are calculated by multiplying the energy use by the appropriate emissions factors.

The baseline electric use in the SAMI region is summarized in Table 1. Similarly, the baseline on-site fossil fuel use is summarized in Table 2. In these tables, the baseline estimates from the spreadsheet model are compared to data from the U.S. Department of Energy, Energy Information Agency (U.S. Department of Energy, Energy Information Administration, 2001), on energy use on a state-by-state basis. In aggregate, the spreadsheet model agreed with the Energy Information Administration data to within 5 and 7 % for

Table 1. Comparison of Baseline Energy Consumption Estimates Electricity Consumption in Buildings (in TWh) for SAMI

Yr	Stat	Residential			Commercial			Total for Residential Commercial Building		
		EIA	ICF	% Difference	EIA	ICF	% Difference	EIA	ICF	% Difference (EIA - ICF)
199	AL	21	19	-8%	12	15	26	32	34	4%
	GA	30	34	14	24	26	10	54	60	12
	KY	17	16	-8%	12	13	11	29	29	0%
	NC	33	30	-	26	25	-1%	59	55	-6%
	SC	18	17	-7%	13	13	0%	31	30	-4%
	TN	29	21	-	13	18	39	42	40	-5%
	VA	28	27	-5%	28	23	-	56	50	-
	WV	8	7	-7%	5	6	17	13	13	3%
	Sub-	183	171	-7%	132	139	5%	315	310	-2%

Table 2. Comparison of Baseline Energy Consumption Estimates Non-Electric Consumption in Buildings (in Trillion Btu)

Yr	Stat	Residential			Commercial			Total for Residential Commercial Building		
		EIA	ICF	% Difference	EIA	ICF	% Difference	EIA	ICF	% Difference (ICF - EIA)
199	AL	57	62	9%	38	33	-	95	95	0%
	GA	107	111	3%	64	59	-8%	171	170	-1%
	KY	71	56	-	41	38	-7%	112	95	-
	NC	80	109	35	52	74	42	133	183	38
	SC	34	55	63	22	29	35	56	85	52
	TN	57	78	36	53	53	1%	110	131	19
	VA	98	97	0%	63	67	7%	160	164	2%
	WV	41	26	-	28	18	-	69	43	-
	Sub-	545	594	9%	361	372	3%	906	965	7%

electric energy use, and between 3 and 9 % for the non-electric energy use. For the purposes of the first phase of this project, this level of overall alignment was adequate. Note however, that the energy use estimates for some of the individual states values vary from the model by as much as 63%. These discrepancies are largely due to the overly simplified assumptions and modeling approach. In the next phase of this project, adjustments will be made in the model to minimize these state-level discrepancies.

Potential Building Upgrade Technologies And Policies

Nine promising energy efficient technologies for residential buildings (new and existing) were identified for inclusion in this study. These technologies were selected primarily based on ICF Consulting's experience in implementing residential energy efficiency programs (e.g., the ENERGY STAR® Homes and Labeled Product initiatives) over the last 5 years. Working closely with builders, contractors, and manufacturers, we have developed a deep understanding of how homes are constructed, and the design changes that can most effectively improve energy performance (Carrie, Webber, Brown 1998). These technologies are briefly described in Table 3 below.

The EPA's ENERGY STAR initiatives for commercial buildings have been in place for as long as ten years, providing energy efficiency-related marketing and implementation assistance to building owners and operators. ICF drew from their experience supporting thousands of the ENERGY STAR program partners to identify the most effective energy efficient technologies for both new and existing commercial buildings (including offices, retail, education, warehouses, hospitality, health care, etc.). These technologies are listed in Table 4, below, in approximate order of energy savings potential.

Packaging of Energy Efficient Technologies

The most cost-effective energy efficiency technologies were selected for inclusion in "technology packages". These technology packages are defined for four levels of energy efficiency, including:

Typical: the typical set of energy efficiency measures in an existing building.

Efficient: a moderate improvement of the existing home, or a typical newly constructed building (i.e., code compliant).

High Efficiency: a substantial improvement of a typical existing building, or a new building built moderately above code.

Very High Efficiency: a major improvement of a typical existing home, or a new building built substantially above code.

The energy efficiency measures in each of these technology packages are defined in Table 5. Technologies are identified for both residential and commercial buildings in the Table.

Table 3. List of Energy Efficiency Technologies Included in Residential Building Model

1. **Duct Tightening**. Duct leakage is the most significant cause of energy losses in most houses.
2. **Air Sealing & Weatherization**. Air leakage through the home's envelope is the second largest cause of energy losses in most residential buildings.
3. **Increased Attic Insulation.** One of the more effective (and easy) energy efficiency upgrades is to add insulation to the attic of a home, especially older poorly insulated homes. This upgrade reduces both space cooling and heating energy use.
4. **High Efficiency A/C Equipment / Systems.** Space cooling is one of the largest energy end-uses in the southern states. Thus, high efficiency air conditioning equipment is one of the more effective upgrades.
5. **High Efficiency Heating Equipment** Systems. Space heating is a significant energy end-use, even in some southern states. High efficiency space heating equipment offers a significant potential to reduce energy use.
6. **High Efficiency Window**s. Solar heat gain through windows is one of the most significant causes of space cooling energy use in southern states. High efficiency (i.e., low-E) windows can reduce solar gains by more than 50%.
7. **Water Heating System Improvements.** Hot water energy use can be the second largest energy end-use in some homes. There are several effective upgrades for water heating systems, including: low flow faucets and shower heads, insulated water heater tank wrap, and reduced hot water temperature.
8. **High Efficiency Appliances.** There are several high efficiency appliances available in the market. Refrigerators and clothes washers are two of the more significant energy consuming appliances in homes. High efficiency models can reduce energy use by as much as 50%.
9. **High Efficiency Lighting.** Lighting is a relatively small energy end-use in homes. However, compact fluorescent lamps (CFLs) use less than 20% of the energy consumed by incandescent lamps. Thus, in selected applications, CFLS are highly effective in reducing energy use.

Policies Chosen For Analysis

Three general types of policies to promote the voluntary adoption of energy efficiency have been evaluated in this report. These policies/strategies may include both programmatic activities (e.g., marketing and implementation support and tracking) and incentives. The incentives would be targeted at consumers and/or businesses that are promoting energy efficient technologies. A detailed market assessment is needed to determine the best mix for any given market. These three general policies are summarized below.

Passive Strategies

Program administrative costs are low (100 $/home for residential programs, and 0.10 $/SF for commercial programs). Primary program activities include: consumer outreach; contractor education; no consumer incentives; and no contractor incentives. Residential technologies promoted include: duct tightening, air sealing, increased attic insulation, and whole house design. Commercial technologies promoted include: commissioning, high efficiency lighting, and envelope improvements. Example programs include: regional utility programs (with limited funds), and national programs like ENERGY STAR®.

Active Strategies

Program administrative costs are moderate (400 $/home for residential programs, and 0.35 $/SF for commercial programs). Primary program activities include: consumer outreach; contractor education; multi-media advertising campaign; marketing and technical training; no consumer incentives; and moderate contractor incentives (e.g., 250 $/home for residential programs, and 0.20 $/SF for commercial programs). Residential technologies promoted include: duct tightening, air sealing, increased attic insulation, high efficiency HVAC; whole house design, and water heating system improvements. Commercial technologies include: commissioning, high efficiency lighting, envelope improvements, high efficiency motor systems, and high efficiency HVAC equipment. Example programs include: regional utility programs (moderately funded); and state programs with Public Benefits Funds (moderately funded).

Table 4. List of Energy Efficiency Technologies in the Commercial Building Model

1. **Commissioning, Auditing, and Baseline Benchmarking**. The process of testing the energy performance of newly installed energy end-use equipment is called “commissioning”. This process ensures that energy efficient equipment is installed properly and is performing as intended. The term “commissioning” is also used to describe a longer term process whereby the energy use of the building is closely tracked over time, and the efficiency of the energy systems is continuously refined. An assessment of current and historical energy use is an effective starting point in an energy efficiency program. When historical energy use is compared to “industry-average benchmarks”, the potential for energy saving upgrades becomes immediately apparent. Further, when a building is audited for energy use, many obvious causes of energy waste / losses are readily identifiable. Many of these “problems” are easy one-time fixes that result in significant energy savings.
2. **High Efficiency Lighting Systems**. High efficiency fluorescent lighting systems (i.e., T-8 lamps, electronic ballasts, with reflectors) are the most cost effective upgrade for most commercial buildings. Compact fluorescent lamps (CFLs) are also recognized as an effective alternative to incandescent lighting in commercial buildings. Occupant sensors have been proven to reduce lighting energy use in some facilities by as much as 30%.
3. **Envelope Improvements**. Some commercial buildings have relatively large amounts of surface area. Improvements to roof insulation and windows can significantly reduce energy use in these facilities.
4. **High Efficiency Fan, Pump & Motor Systems**. Fan energy use is the third largest energy end-use in many commercial buildings. High efficiency motors with variable speed drives can reduce fan energy use by as much as 50%.
5. **High Efficiency A/C Equipment / Systems**. Space cooling is the second largest energy end-use in most commercial buildings. Further, high efficiency space cooling equipment is readily available and cost effective. Thus, cooling systems upgrades are effective means of reducing energy use, especially in the southern states.
6. **High Efficiency Heating Equipment Systems**. Significant improvements are available in space heating equipment. These technologies are effective in the southern states with colder climates.
7. **Control Strategies.** The on-off operation of every piece of energy end-use equipment must be controlled. Numerous control strategies are available for each type of equipment. A careful review of available control strategies for the primary energy-use equipment usually reveals significant opportunities for improvement. Common controls upgrades include: optimal HVAC start and stop, improved outdoor air damper controls, and enthalpy controlled economizers.

Table 5. Overview of List of Recommended Technologies for Energy Efficient Upgrades to Buildings in the SAMI Region

Fuel	End-Use	Technology	Unit	Typical Technology	Efficient Technology		High Efficiency Technology		Very High Efficiency Technology	
				Specification	Specification	% Change	Specification	% Change	Specification	% Change
Residential Buildings										
Neutral	Envelope	Insulation (Attic/Walls/Basement)	R-Value	8/8/3	16/11/3	50%	24/14/3	67%	30/18/11	73%
		Windows	Uo	0.75	0.50	33%	0.33	56%	0.25	67%
		Envelope Air Leakage	ACH	0.80	0.60	25%	0.46	43%	0.35	56%
		Duct Leakage	%	20%	10%	50%	5%	75%	2.5%	88%
	Controls	Programable Thermostat (10 F Setback)	(% of Time)	0%	15%	15%	50%	50%	80%	80%
Electric	Appliances	Refrigerators	KWh/Yr	1200	900	25%	750	38%	600	50%
		Other	KWh/Yr	5500	5000	9%	4500	18%	3500	36%
	HVAC	Space Heating	HSPF	1.0	1.2	17%	1.6	38%	2.0	50%
		Space Cooling	SEER	9.0	11.0	18%	13.0	31%	16.0	44%
	Water Heating	HE Heater	E-Factor	0.80	0.84	5%	0.88	9%	0.92	13%
		Distribution Temperature / Flow Rate	(F / GPM)	140/5	140/4	0%	130/3	7%	120/2	17%
	Lighting	CFLs & Fluorescent	KWh/Yr	1000.0	800.0	20%	600.0	40%	400.0	60%
Gas	HVAC	Space Heating	%	78%	84%	7%	90%	13%	95%	18%
	Water Heating	HE Heater	E-Factor	0.52	0.56	7%	0.60	13%	0.6	19%
Commercial Buildings										
Neutral	Envelope	Insulation (Attic/Walls/Basement)	R-Value	8/8/3	16/11/3	50%	24/14/3	67%	30/18/11	73%
		Windows	Uo	0.75	0.50	33%	0.33	56%	0.25	67%
		Envelope Air Leakage	ACH	0.80	0.60	25%	0.46	43%	0.35	56%
		Duct Leakage	%	20%	10%	50%	5%	75%	2.5%	88%
	Controls	Programable Thermostat		0%	15%	15%	50%	50%	80%	80%
Electric	Lighting	Indoor	W/SF	2.0	1.6	20%	1.2	40%	0.8	60%
		Outdoor	W/SF	0.20	0.16	20%	0.13	35%	0.10	50%
	HVAC Equip	Space Heating	HSPF	1.0	1.2	17%	1.6	38%	2.0	50%
		Space Cooling	COP	2.5	3.5	29%	4.0	38%	5.0	50%
	Office Equip.		W/SF	1.0	0.8	20%	0.6	40%	0.5	50%
	Water Heating		E-Factor	0.80	0.84	5%	0.88	9%	0.92	13%
Gas	HVAC	Space Heating	%	78%	84%	7%	90%	13%	95%	18%
	Water Heating		E-Factor	0.52	0.56	7%	0.60	13%	0.6	19%

Aggressive Strategies

Program administrative costs are high (1000 $/home for residential programs, and 0.75 $/SF for commercial programs). Primary program activities include: consumer outreach; contractor education; multi-media advertising campaign; marketing and technical training; large consumer incentives; and large contractor incentives (e.g., 800 $/home for residential programs, and 0.55 $/SF for commercial programs). Residential control system improvements. Example programs include state programs with Public Benefits Funds (well funded).

Each of these different scenarios has different technology mixes and different penetration rates (the rate of technology diffusion in the building sector). The assumed penetration rate of these technology packages into residential buildings in the SAMI region is presented in Table 6. Similarly, assumed penetration rates for these technology packages into commercial buildings in the SAMI region are presented in Table 7.

The energy savings reduction from the energy efficiency packages defined for each of these three levels of energy efficiency is evaluated relative to the business-as-usual (or baseline) case. The evaluation process for the emission reductions from these technology packages is presented below:

Step 1: Calculate energy use for the baseline and each of the 3 energy efficiency scenarios.

Step 2: Determine the emissions factors for the 3 main pollutants: SO_2, NO_x, and CO_2.

Step 3: Calculate the emissions from the baseline and each energy efficiency scenario by multiplying the energy use by the appropriate emission factors (i.e., lbs NO_X/kWh, lbs SO_X/Btu, etc.).

Step 4: Calculate the emissions reductions of NO_X, SO_2 and CO_2 for each of these scenarios as the difference between the emissions of the baseline and the given energy efficiency scenario.

Note that the emissions of SO_2, NO_x, and CO_2 are each directly proportional to the energy savings achieved. In the remainder of this paper, the emissions results will be reported for CO2 emission reductions achieved. Similar percentage reductions will be achieved for all three pollutants (SO_2, NO_x, and CO_2).

Energy Efficiency Program Costs and Incentives

For this study, energy efficiency incentives and program costs were assumed for the three forecast scenarios. The incentive values are largely based on the minimum level of financial support required to make these scenarios viable (i.e. cost effective). For residential buildings, the incentives range from 0 to 250 to 800 dollars per home for the passive, active, and aggressive scenarios, respectively. For commercial buildings, the incentives range from 0.00 to 0.20 to 0.55 dollars per square foot of floor area for each of the forecast scenarios. The program costs assume a minimal incremental level of investment above the incentives to recruit program participants, market the program, and track the programs progress. For residential buildings, the program costs are assumed to range from 100 to 400 to 1,000

Table 6. Assumed Penetration Rates of Energy Efficient Technology Packages into Residential Buildings

Year	Construction Type	New Homes				Existing Homes			
		Baseline	Passive	Active	Aggressive	Baseline	Passive	Active	Aggressive
2000	Typical					0.90			
	Efficient	0.90				0.10			
	High Efficiency	0.10							
	Very High Efficiency								
2020	Typical					0.35	0.20	0.15	
	Efficient	0.40	0.20			0.40	0.35	0.20	0.20
	High Efficiency	0.50	0.60	0.70	0.50	0.20	0.35	0.45	0.60
	Very High Efficiency	0.10	0.20	0.30	0.50	0.05	0.10	0.20	0.20
2040	Typical					0.15			
	Efficient					0.35	0.25		
	High Efficiency	0.90	0.50	0.25		0.30	0.40	0.30	
	Very High Efficiency	0.10	0.50	0.75	1.00	0.20	0.35	0.70	1.00

Table 7. Assumed Penetration Rates of Energy Efficient Technology Packages into Commercial Buildings

Year	Construction Type	New Homes				Existing Homes			
		Baseline	Passive	Active	Aggressive	Baseline	Passive	Active	Aggressive
2000	Typical					0.9			
	Efficient	0.9				0.1			
	High Efficiency	0.1							
	Very High Efficiency								
2020	Typical					0.35	0.225	0.15	
	Efficient	0.4	0.2			0.4	0.375	0.35	0.2
	High Efficiency	0.5	0.6	0.7	0.5	0.2	0.275	0.3	0.6
	Very High Efficiency	0.1	0.2	0.3	0.5	0.05	0.125	0.2	0.2
2040	Typical					0.15			
	Efficient					0.35	0.25		
	High Efficiency	0.9	0.5	0.25		0.3	0.4	0.3	
	Very High Efficiency	0.1	0.5	0.75	1	0.2	0.35	0.7	1

dollars per home for the passive, active, and aggressive scenarios, respectively. For commercial buildings, the program costs are assumed to range from 0.10 to 0.35 to 0.75 dollars per square foot of floor area for each of the forecast scenarios.

Emissions Rates

The emissions factors used in this analysis are provided in Table 8. These emissions rates were developed by EPA for evaluation of the ENERGY STAR programs.

Table 8. Emissions Factors for the SAMI Region

State	Electric Emissions Factors			Gas Emissions Factors		
	SO_2 (Lb/MWh)	NO_x (Lb/MWh)	CO_2 (Lb/KWh)	SO_2 (Lb/MBtu)	NO_x (Lb/MBtu)	CO_2 (Lb/MBtu
AL	10.17	3.81	2.215	1.0	0	116.4
GA	9.63	3.35	2.215	1.0	0	116.4
KY	14.56	8.31	2.215	1.0	0	116.4
NC	9.07	5.31	2.215	1.0	0	116.4
SC	5.28	2.89	2.215	1.0	0	116.4
TN	11.56	5.81	2.215	1.0	0	116.4
VA	6.78	3.66	1.68	1.0	0	116.4
W VA	6.78	3.66	1.68	1.0	0	116.4

Results - Residential Buildings

There are three primary types of results generated for the residential buildings in the eight state SAMI region. The first is the total estimated SO_x, NO_x, and CO_2 emissions from all of the residential buildings in the SAMI region for each of the three penetration scenarios. An example output for CO_2 emissions is provided in Figure 1. Relative to the baseline emissions in the year 1900, the emissions are fairly stable in time with the “active” energy efficiency scenario. Reductions from the 1990 reference point are only achieved with the “aggressive” energy efficiency scenario. These general trends are similar for the SO_x, and NO_x results (not shown).

The second type of result produced in this study is the percent reduction in SO_x, NO_x, and CO_2 emissions from the residential baseline in any given year. An example output for CO_2 emissions is presented in Figure 2. For any given energy efficiency scenario (e.g., “passive”), the percent value of the reductions increases over time since the penetration rate of upgrades in the building stock will increase in time. As expected, the greatest percent reductions in CO_2 occur in the “aggressive” energy efficiency scenario – approaching 40 percent by the year 2040. These general trends are similar for the SO_x, and NO_x results (not shown).

The third type of result in this study is the assessment of the cost-effectiveness of the energy efficiency scenarios. A summary graphic of the relative cost effectiveness of the three levels of energy efficiency is presented in Figure 3. Note that although the more active and aggressive levels of energy efficiency provide greater savings, they are not more cost-effective. Fairly substantial incentives (up to $800 per home) are required to make these options attractive to consumers.

Figure 1. Estimated Annual CO_2 Emissions From Residential Buildings in the SAMI Region

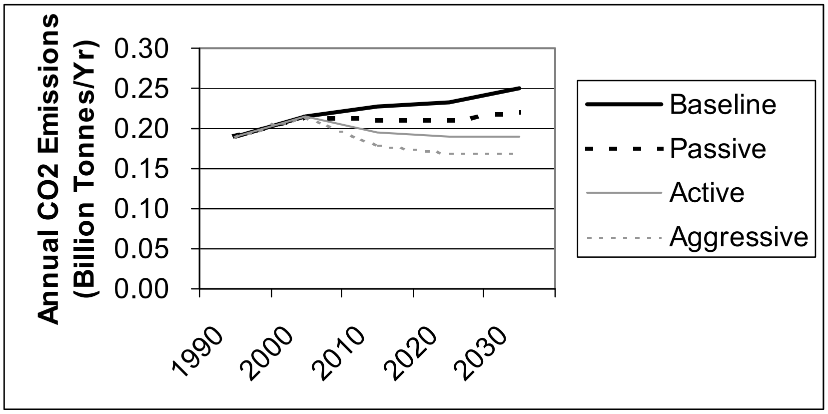


Figure 2. Estimated Annual Percent Reduction in CO_2 Emissions from Residential Buildings in the SAMI Region (Relative to Baseline)

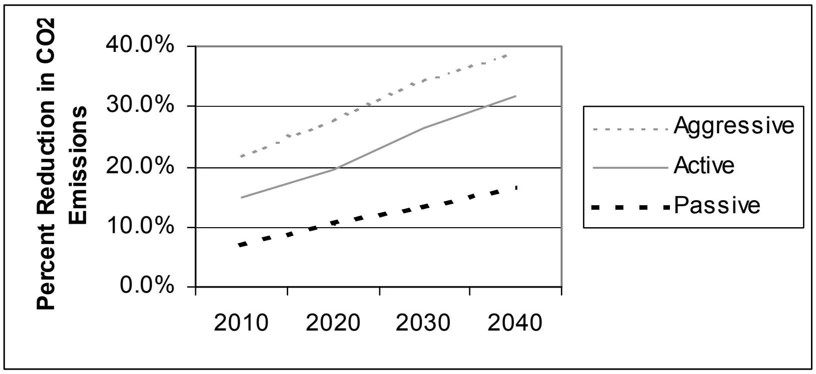
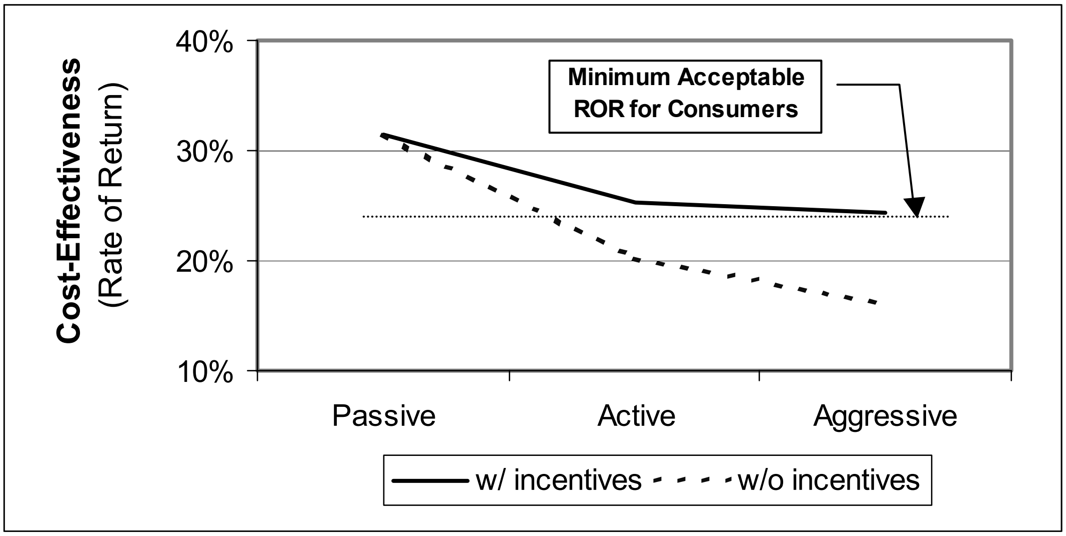


Figure 3. Costs and Impacts of Adopting Energy Efficiency Measures In Residential Buildings



Results - Commercial Buildings

Similar to the residential results above, there are three primary types of results generated for the commercial buildings in the eight state SAMI region. The first is the total estimated SO_x, NO_x, and CO_2 emissions from all of the commercial buildings in the SAMI region for each of the three penetration scenarios. An example output for CO_2 emissions is provided in Figure 4. Relative to the baseline emissions in the year 1900, the emissions are fairly stable in time with the "active" energy efficiency scenario. Reductions from the 1990 reference point are only achieved with the "aggressive" energy efficiency scenario. These general trends are similar for the SO_x, and NO_x results (not shown).

The second type of result for commercial buildings produced in this study is the percent reduction in SO_x, NO_x, and CO_2 emissions from the commercial baseline in any given year. An example output for CO_2 emissions reductions is presented in Figure 5. These results largely mirror the trends in the residential emissions reductions. The percent value of the reductions increases over time due to the increase in the penetration rate of the upgrades in the building stock over time. As expected, the greatest percent reductions in CO_2 occur in the "aggressive" energy efficiency scenario – approaching 30 percent by the year 2040. These general trends are similar for the SO_x, and NO_x results (not shown).

Again, similar to the residential results, the third type of result from this study is the assessment of the cost-effectiveness of the energy efficiency scenarios. The relative cost effectiveness of the three levels of energy efficiency implemented in commercial buildings is presented in Figure 6. Note that although the more active and aggressive levels of energy efficiency provide greater energy savings and emission reductions, they are not more cost-effective. Fairly substantial incentives (up to $0.75 per square foot of floor area) are required to make these options attractive to consumers.

Figure 4. Annual CO_2 Emissions From Commercial Buildings in the SAMI Region

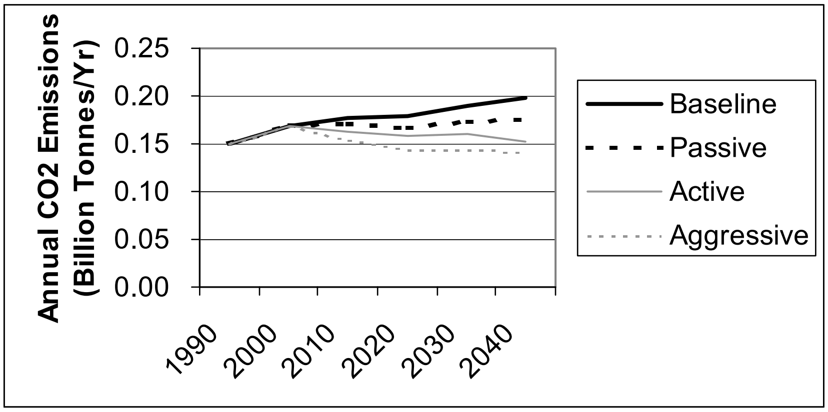


Figure 5. Estimated Annual Percent Reduction in CO_2 Emissions from Commercial Buildings in the SAMI Region (Relative to Baseline)

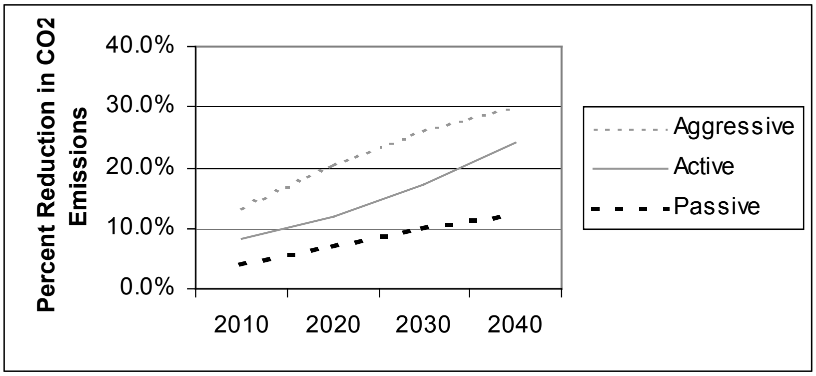
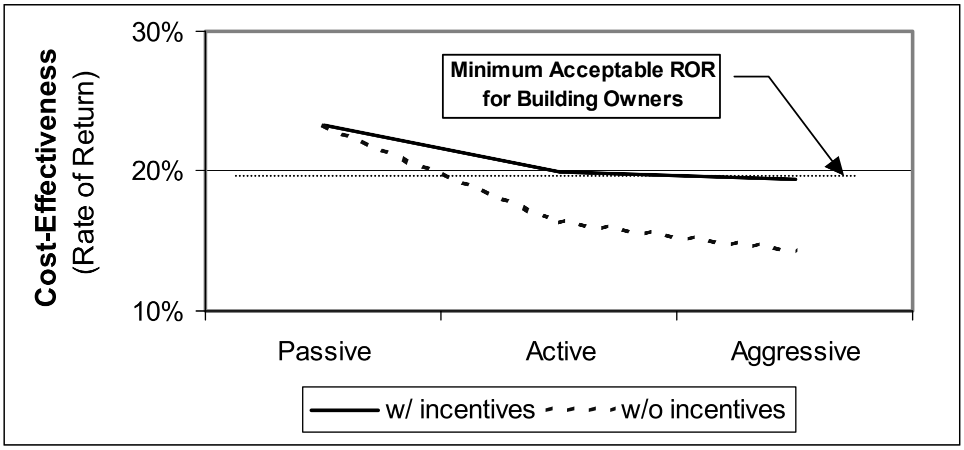


Figure 6. Costs Effectiveness of Adopting Energy Efficiency Measures in Commercial Buildings in the SAMI Region.



Recommended Future Activities

1. **Improve Analytical Model.** The current model is based on only two prototypical buildings and two climate regions. Further the analytical engine is weak. The reliability of the results of this project can be significantly enhanced (especially at the local market level) by upgrading the analytical engine for this model.
2. **Refine Assumptions**. Several key assumptions underlie the results of this analysis, including assumed values for: new construction growth rates, technology diffusion (penetration rates), and emission factors. Each of these assumptions contributes to the uncertainty in the estimated energy savings and emissions reductions. These assumptions need to be carefully reviewed for ***each state*** in the SAMI region.
3. **Develop a User-Friendly Front-End for the Model**. The development of a Visual Basic front end will allow greater user interaction with the model, thereby allowing further scenario analysis and model updates over time. This would allow SAMI members to examine the emission reductions under a number of different

assumptions about penetration rates, housing growth, emission factors, and other variables.

4. **Expand the Model to Include Other Sources of Emissions**. This study was based on emissions from only residential and commercial buildings. The analytical model should be expanded to include the industrial and transportation sectors.

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