REDUCING GREENHOUSE GASES & AIR POLLUTION

A Menu of Harmonized Options

Executive Summary and Case Studies

State and Territorial Air Pollution Program Administrators (STAPPA)
Association of Local Air Pollution Control Officials (ALAPCO)

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Introduction

In October 1999, the State and Territorial Air Pollution Program Administrators (STAPPA) and the Association of Local Air Pollution Control Officials (ALAPCO) released *Reducing Greenhouse Gases and Air Pollution: A Menu of Harmonized Options*, a comprehensive final report intended to serve both as an educational resource with respect to emissions of greenhouse gases (GHGs) and air pollutants and precursors, and as guidance to those wishing to pursue reductions in both. The complete, 336-page final report offers background information in the form of a primer on GHGs and, moreover, provides detailed information on a multitude of options for controlling both GHGs and air pollution from a variety of sectors, including fossil-fueled power generation, renewable power generation, transportation, energy-intensive industries (iron and steel, cement, pulp and paper, petroleum refining and chemicals), residential and commercial buildings, municipal solid waste, agriculture and forestry and carbon sequestration.

For each of the sectors addressed, the final report presents a sector profile and an overview of the regulatory framework affecting the sector, as well as a detailed discussion of the technology-based strategies available for reducing GHGs and air pollution, including a description of each strategy and information on its potential to reduce GHGs and air pollution, the associated costs and cost effectiveness and information on experiences, market penetration and obstacles. In addition, the report seeks to look beyond traditional control approaches by identifying policy- and market-based strategies for achieving harmonized reductions in GHGs and air pollution. Finally, the results of four case studies conducted specifically for this report are included to illustrate the significant benefits that can potentially result from choosing harmonized control strategies.

In this document, STAPPA and ALAPCO are pleased to reproduce two key sections of the final report: the *Executive Summary* and the final chapter, *Harmonized Strategies for Reducing Criteria Pollutants and Greenhouse Gases*, which details the four case studies and their results. Together, these two excerpts provide a concise overview of the wealth of information included in the final report and demonstrate the potential co-benefits to be achieved from the implementation of harmonized strategies. For information on obtaining the complete final report, contact STAPPA and ALAPCO.

About STAPPA and ALAPCO

The State and Territorial Air Pollution Program Administrators (STAPPA) and the Association of Local Air Pollution Control Officials (ALAPCO) are the national associations representing state and local air quality officials in the states and territories and over 165 major metropolitan areas throughout the country. The members of STAPPA and ALAPCO have primary responsibility for implementing our nation's air pollution control laws and regulations. The associations serve to encourage the exchange of information and experience among air pollution control officials; enhance communication and cooperation among federal, state and local regulatory agencies; and facilitate air pollution control activities that will result in clean, healthful air across the country. STAPPA and ALAPCO share joint headquarters in Washington, DC.

For further information, contact STAPPA and ALAPCO at 444 North Capitol Street, NW, Suite 307, Washington, DC (telephone: 202/624-7864; fax: 202/624-7863; e-mail: 4clnair@sso.org). Please visit our associations' web site at www.4cleanair.org.

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EXCERPTS FROM

Reducing Greenhouse Gases and Air Pollution: A Menu of Harmonized Options

Final Report

Executive Summary

The State and Territorial Air Pollution Program Administrators (STAPPA) and Association of Local Air Pollution Control Officials (ALAPCO) developed *Reducing Greenhouse Gases and Air Pollution: A Menu of Harmonized Options* to assess strategies that simultaneously reduce conventional air pollution and greenhouse gases or GHGs (otherwise known as "harmonized strategies"). Utilizing this document, state and local officials can identify and assess harmonized strategies and policies to reduce air pollution and address climate change simultaneously, enhancing both the environmental and economic effectiveness of these efforts.

In recent decades, a concern has emerged that the Earth's climate is being altered by increased concentrations of GHGs into the atmosphere as a result of anthropogenic (human) activity. The concern is that activities such as the burning of fossil fuels, waste disposal and agricultural and forestry practices may be accelerating the pace of climate change to a rate that natural systems, including humans and other organisms, cannot accommodate. The growing scientific consensus notwithstanding, the United States (U.S.) Environmental Protection Agency (U.S. EPA) does not currently have clear authority to regulate CO_2, and the U.S. Senate has passed a resolution blocking the ratification of the Kyoto Protocol as currently written. Meanwhile, U.S. GHG emissions rose by over 11 percent between 1990 and 1997. Although emission reductions under the Kyoto Protocol (a 7-percent GHG emission reduction from 1990 levels, on average, between the five-year "budget period" 2008 to 2012) are not required in the U.S., states and localities may wish to consider reducing GHG emissions now.

In continuing to address criteria pollutant nonattainment challenges, state and local officials have the opportunity to capture significant GHG emission reductions. The most effective path for achieving this goal is to ensure that, in obtaining emission reductions needed for criteria pollutant attainment, the applied strategies are ones that also provide GHG reduction benefits, rather than measures that are ineffective or counterproductive from a GHG perspective.

STAPPA and ALAPCO believe it is important to focus on the relationship between GHG mitigation and conventional air pollutant control, because with few exceptions, strategies that mitigate GHGs will also result in reduced emissions of other air pollutants. The most widely recognized harmonized strategies relate to fossil-fueled combustion, the major source of carbon dioxide (CO_2), as well as a source for particulate matter (PM), nitrogen oxides (NO_x), sulfur dioxide (SO_2), carbon monoxide (CO) and air toxics.

The GHGs that are of chief concern include CO_2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride. Ozone is also a GHG; therefore, ozone precursors (i.e., NO_x and non-methane volatile organic compounds or NMVOCs) have an indirect greenhouse effect.[1] This document focuses primarily on CO_2 for two reasons. First, over half of the predicted global warming impacts are expected to result from CO_2. In 1997, CO_2 emissions constituted approximately 82 percent of total U.S. GHG emissions.[2] Second, the primary source of this CO_2 is fossil-fuel combustion, an activity that state and local officials address by regulating categories of emission sources.

Each of the source categories that state and local officials address is discussed below, with a focus on effective harmonized strategies for reducing GHGs and other air pollutants simultaneously. A discussion of market-based approaches to implementing these strategies follows these sections. Finally, the implementation of several key harmonized strategies are examined in four case study areas in the U.S., to illustrate potential reductions in GHGs and other air pollutants.

Sources and Associated Harmonized Strategies

Air regulation in the U.S. targets primarily large stationary sources, area sources (groups of smaller stationary sources such as residential and commercial buildings), mobile sources (transportation) and other sources, such as municipal solid waste management and agriculture and forestry practices. There are opportunities in each of these source sectors to reduce traditional air pollutants while also achieving significant GHG reductions. In the stationary source sector, the most attractive harmonized strategies involve switching to a lower-carbon or zero-carbon fuel, increasing the efficiency of fuel use, or both. For area sources, from large commercial buildings to small homes, the key harmonized strategies are based on increasing the efficiency of fuel and electricity use. In the mobile source sector, the opportunities lie in increasing the fuel efficiency and reducing the use of motor vehicles. In the municipal solid waste sector, there are significant GHG-reduction opportunities in landfill gas to energy projects and source reduction and recycling. Finally, in the agriculture and forestry sectors, there are considerable GHG-reduction opportunities in manure management and in the sequestration of carbon, the ability of soils and plants to remove carbon from the atmosphere.

The generation of electricity is responsible for the largest portion—approximately 37 percent—of the nation's CO_2 emissions. The electric industry is also the country's largest source of SO_2 and one of the largest sources of both NO_x and airborne mercury. Thus, this industry is an important point of leverage in reducing both conventional air pollution and CO_2. The transportation industry contributes the second largest share of CO_2 and is projected to be the fastest growing sector, and the other industrial sectors are third. In terms of CO_2 emissions, the primary industrial sectors are the most energy intensive: iron and steel, pulp and paper, chemicals, petroleum refining and cement manufacture. *Figure 1* illustrates the portion of total 1997 emissions contributed by each source sector. In the chart at left, power plant CO_2 emissions are shown in a separate category; in the chart at right, emissions are allocated to end-use sectors based on the amount of electricity consumed in each sector.

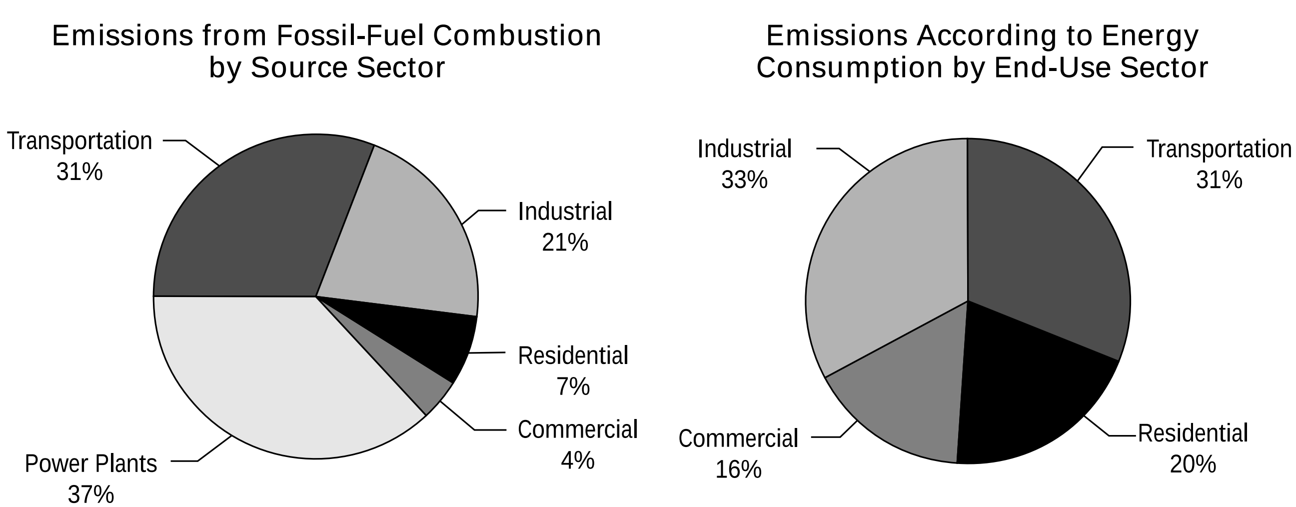
Large Stationary Sources

Large furnaces, boilers and combustion turbines constitute the majority of large stationary sources, and in general, these sources are found at power plants and industrial facilities. In both of these sectors, there is enormous potential for reducing GHG and other air pollution emissions, sometimes at a net cost savings.

Air pollutants from large stationary sources can be controlled in familiar ways. Baghouses or electrostatic precipitators can be installed to capture PM less than ten microns in diameter (PM_{10}); sulfur emissions can be reduced by switching to lower-sulfur fuels or installing flue gas desulfurization devices (scrubbers)

Figure 1

CO_2 Emissions from Fossil Fuel Combustion, 1997



Source: U.S. EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1997, 1999.

and post-combustion technologies like selective catalytic reduction (SCR) can lower NO_x emissions. Carbon, however, is a basic component of fossil fuels, not an impurity (like sulfur) or a by-product of combustion (like NO_x); therefore, removing carbon from flue gases after combustion is energy intensive and extremely expensive. Thus, for the foreseeable future, there are only two practical ways to reduce carbon emissions cost effectively from fossil-fueled combustion: switch to a lower-carbon or zero-carbon fuel or increase plant efficiency so that less fuel is combusted. Fortunately, these operational changes also result in significant reductions of other air pollutants. As a result, the above-mentioned operational changes are effective harmonized emission reduction strategies.

Many of the nation's power plants and industrial facilities are powered by coal, and coal is the most carbon-intensive fuel available. Both oil and natural gas contain less carbon per unit of energy than coal; thus switching a boiler from coal to oil or gas will result in carbon reductions. The magnitude of these reductions will depend on the efficiency of the boiler before and after the alteration. *Table 1* illustrates the combined effects of fuel switching and increased efficiency on CO_2 emissions at power plants.[3] Note that emissions in pounds per kilowatthour (lb/kWh) can be reduced by moving across the table (fuel switching), by moving down the table (increasing efficiency), or both.

Chapter II, *Fossil-Fueled Power Generation,* and *Chapter V, Energy-Intensive Industries,* review a number of specific areas in which fuel switching is an attractive option for both emission reductions and cost savings. Perhaps the best example of this opportunity is the gas-fired combined cycle (GFCC) power plant. While coal has historically been the dominant fuel in the electric industry (accounting for 57 percent of U.S. generation in 1997), falling gas prices and advances in turbine technology have made gas turbines the dominant choice for new capacity in nearly all regions of the U.S.

In addition to replacing the use of coal with gas, the use of excess heat in a heat recovery generator brings the overall efficiency of new GFCC systems to approximately 50 percent. (Existing coal-fired power plants have efficiencies in the range of 33 percent.) Together, the fuel switch and efficiency gains offer the following reductions relative to an older coal-fired plant:

- CO_2 – 66 percent;
- NO_x – 99 percent; and
- SO_2 – virtually 100 percent.

Many existing coal-fired plants could be replaced with GFCC capacity at a relatively modest cost. If the entire cost increment of a new GFCC plant were loaded onto CO_2 reductions, these reductions would cost between $0 and $39 per ton. Of course, allocating some of the costs of this fuel switch to NO_x and SO_2 reductions would lower the cost of CO_2 reductions. To put these costs in perspective, estimates of the cost of complying with the Kyoto Protocol range from $25 to $150 per ton of CO_2 (see Chapter II, *Fossil-Fueled Power Generation*).

The efficiency of a power plant or industrial boiler can also be increased without simultaneously switching fuels. One of the most attractive options for achieving increased efficiency is the use of excess heat from primary combustion. Excess heat from one process can often be captured and used in another process, removing or reducing the need for a fuel source in the second process. The term "combined heat and power" or CHP is used to describe processes in which electricity and useful heat are produced in the same combustion process (see Chapter II). These CHP strategies can:

- increase overall plant efficiency by 40 to 50 percent;
- reduce fuel use and all associated emissions considerably; and
- result in emission reductions at a negative cost (or savings) per ton.

Overall, there is tremendous potential for reducing CO_2 emissions by utilizing waste heat in industrial facilities and power plants. The U.S. Department of Energy's (U.S. DOE's) recent "Five-Labs Study" estimates that, even without CO_2 reduction

Table 1

Approximate CO_2 Emissions from Fossil Fuels

Plant Efficiency	Heat Rate (Btu/kWh)	Coal (lb/kWh)	Oil (lb/kWh)	Gas (lb/kWh)
20%	17,060	3.53	2.85	2.00
30%	11,373	2.35	1.90	1.33
40%	8,530	1.77	1.42	1.00
50%	6,824	1.41	1.14	0.80
60%	5,687	1.18	0.95	0.67

Source: STAPPA/ALAPCO, 1999.

requirements in the U.S., power generation at combined heat and power systems is likely to grow to 333,000 gigawatthours per year by the year 2010.[4] If this CHP generation had a CO_2 emission rate 40 percent below that of conventional coal-fired generation, it would result in CO_2 reductions of 102 million tons per year. This reduction is 4.6 percent of the decrease (from 1996 levels) necessary to comply with the Kyoto Protocol.

Policies to support fuel switching and increased efficiencies from power plants and other industrial sources include fuel-neutral, output-based emissions standards and comparable emission standards for all facilities.

The move to output-based emission standards, expressed in terms of the amount of pollutant emitted per unit of energy produced, usually pounds of pollution per megawatt-hour (lb/MWh) for CO_2, NO_x and possibly SO_2, would incentivize efficiency enhancements and the use of lower-carbon fuels by making it easier for efficient and cleaner facilities and more difficult for inefficient and more polluting facilities to meet emission limits. These incentives would make it more difficult to operate older, inefficient units and would enhance the value of units with very low emission rates.

Area Sources

Increasing the efficiency and reducing the use of end-use equipment (demand side management) in the residential and commercial sectors—in contrast to increasing the efficiency of electricity generating units—can vastly reduce GHGs and air pollution emissions. Over one-third of fossil-fuel energy in the U.S. is consumed by the residential and commercial building sectors via lighting, heating, cooling and the operation of appliances. Therefore, the most effective way to reduce air pollution and GHGs from these sectors is to increase end-use efficiency, thereby reducing the amount of fuel consumed directly at the building site and indirectly at the electric generating plant.

The residential and commercial sectors are characterized by a diverse array of energy uses and varying sizes and types of buildings in a wide range of climates. As a result, there is no single method to improve efficiency. Rather, a broad array of technologies are available to reduce GHGs and criteria pollutants through increasing end-use efficiency. These technologies could potentially reduce GHG emissions by approximately 20 percent, and SO_x and NO_x emissions by 20 to 30 percent in both the residential and commercial building sectors.[5]

The residential sector uses approximately 20 percent of the fossil fuel consumed in the U.S. Water heating is a main area where energy efficiency can be improved. For instance:

- new low-flow showerheads have a maximum flow rate of half that of older showerheads, and installing one can reduce hot water consumption for bathing by 30 percent. A new top-quality, low-flow showerhead costs between $10 and $20 and will pay for itself within four months;
- leaky faucets and showerheads can be repaired; a leak of one drip per second can cost $1 per month;
- high-efficiency clothes washers now on the market can reduce hot water use by 60 percent or more compared with today's average new washer, and by almost 75 percent compared to an older washer; and
- high efficiency dishwashers can cut hot-water use by about 20 percent, compared to new machines that are already using about 30 percent less water than older, existing products.

Also, new lighting technologies and the employment of existing technologies that are intelligently matched to the appropriate lighting needs can achieve significant emission reductions. High-efficiency fluorescent lamps, for example, use less than one-half the energy of incandescent fixtures. Compact fluorescent lamps are another alternative that similarly results in a reduction of energy use in the residential sector. In addition, automatic lighting controls can serve as a supplement or replacement for manual controls.

These strategies have the potential to mitigate GHGs significantly, and as the Five-Labs Study results suggest, most of the strategies will also reduce SO_x and NO_x.

Similar multiple reductions are also possible within the commercial sector. In the commercial sector, the largest potential for reducing energy use lies in motor drive systems. Motor systems include motor equipment, fans and pumps and transmissions or drivetrains. These systems consume approximately two-thirds of the total electricity in the U.S., and much of this electricity is used very inefficiently. For example, motors are often oversized for their applications, reducing their efficiency. Surveys suggest that about one-fifth of motors above five horsepower are running at or below 40 percent of rated load. Replacing these oversized motors with smaller, more efficient motors allows the new motors to maintain higher efficiency levels over a wider operating range. In general, optimizing system design, rather than simply choosing individual components, can lead to improvements of 60 percent using existing technology.[6]

Policies to support increased end-use efficiency include revised building codes and subsidies designed to help overcome market barriers to the adoption of new technologies. Many state and municipal building codes have incorporated more stringent energy requirements in their building codes as a means to reduce energy use. For example, California, Florida, Minnesota and Oregon have developed codes 5 to 30 percent more stringent than the national Model Energy Code, developed by the Council of American Building Officials.[7] California's Title 24 program is among the nation's most innovative and successful; since 1977, building and appliance efficiency programs administered by the state have saved more than $11 billion in energy costs.[8]

In addition, most states currently subsidize efficiency upgrades via a surcharge on electricity sales, and in general, these subsidies are being maintained as states move to competitive electric industries.

Mobile Sources

The mobile source sector is responsible for more than a quarter of all GHG emissions in the U.S. High levels of motor vehicle ownership, sprawling land use patterns, limited public transit service, subsidies to the oil industry and low gasoline prices have been major factors in increasing vehicle miles traveled (VMT), and as a result, GHG emissions over the past decade. Since 1990, GHG emissions from transportation have grown by almost 9 percent. In 1996, the sector was responsible for more than 30 percent of the CO_2, more than 40 percent of NMVOC, 50 percent of the NO_x and 80 percent of the CO emitted in the U.S.

Significant GHG reductions in the transportation sector will require a comprehensive approach that unites technology- and policy-based strategies. In spite of rising GHG emissions from the transportation sector in recent years, there are several reasons to be optimistic. Aggressive efforts are underway at the state and federal levels to reduce urban sprawl and constrain, if not eventually reverse, the steady growth in the use of vehicles. Fuel-efficient and advanced technologies under development by major auto manufacturers and other researchers have the potential to reduce fossil-fuel consumption considerably over time.

Strategies to reduce transportation-related GHG emissions can address either vehicle emissions per mile driven or the demand for mobility in general. Strategies to reduce emissions per mile driven are generally technology-based. Examples include improvements in fuel efficiency and shifts to new technologies that rely on lower- and zero-carbon fuels. In contrast, strategies to reduce the use of vehicles are generally policy based, such as policies to:

- limit urban sprawl;
- manage traffic; and
- promote use of public transportation.

When the distance traveled per unit of fuel is increased, CO_2 emissions decrease. The U.S. has mandatory fuel-efficiency standards for automobiles, called “Corporate Average Fuel Economy” (CAFE) standards, which require auto manufacturers to maintain a minimum fleet average fuel efficiency for all cars and light trucks sold in a given year. The average fuel economy of the total light-duty fleet has actually declined over the past decade as a result of increasing sales of light-duty trucks and sport utility vehicles, which are held to a lower CAFE standard. Largely as a result of this trend, the overall efficiency of the total light-duty fleet has deteriorated over the past decade.

U.S. DOE and the Big Three automakers have been involved in the Partnership for a New Generation of Vehicles (PNGV), a cooperative effort to develop a car with a fuel efficiency of 80 miles per gallon. In January 1998, the PNGV selected hybrid-electric vehicles, direct-injection engines, fuel cells and lightweight materials as the most promising technologies to achieve their fuel-efficiency goal.

Another opportunity to lower mobile-sector GHG emissions lies in the use of alternative fuels and advanced technologies, rather than traditional fossil-fueled internal combustion. Of the advanced vehicle technologies, the most promising for near-term commercialization are hybrid electric vehicles (HEVs). HEVs utilize two power sources, and one or both can be used depending on the amount of energy needed. Vehicles combining electric drives with fuel cells or diesel engines hold particular promise.

Progressive vehicle emission requirements at the state level can promote the development of fuel-efficient and advanced vehicle technology by increasing the pressure on automobile manufacturers to develop advanced technology vehicles. California was granted the authority to establish its own vehicle emission requirements by the Clean Air Act. As a result, since 1994, the California Low-Emission Vehicle (LEV) Program has required successively lower average annual emission rates from new vehicles sold in the state and has promoted the introduction of zero-emission vehicles (ZEVs). Other states have aggressively pursued adoption of the California LEV program. The California ZEV sales requirement has spurred tremendous technological advances in electric vehicles and hybrid drive vehicles. The ZEV mandate will require ZEVs to potentially comprise up to 10 percent of the sales of the major car companies.

Finally, policy-based strategies that reduce the use of motor vehicles are crucial to an overall GHG reduction strategy for the transportation sector. These strategies can focus on:

- land use patterns—encouraging people to live near their workplaces;
- shifting the cost of driving from indirect costs, like annual taxes, to direct costs incurred by actually driving;
- managing traffic to reduce idling time; and
- enhancing public transportation systems.

Municipal Solid Waste

Municipal solid waste (MSW) management in the U.S. is responsible for a substantial portion of the nation’s anthropogenic emissions of methane, a potent GHG. However, the emissions of criteria air pollutants from the MSW sector are relatively small. As a consequence, while there are many options for reducing GHG emissions from this sector, there are few opportunities for harmonizing these reductions with criteria air pollutant reductions. Opportunities are available, however, for co-control of other pollutants (e.g., hazardous air pollutants from landfills).

The methane emissions from MSW come from landfills, which are the largest single anthropogenic source of methane emissions in the U.S. Municipal solid waste landfills account for over 95 percent of landfill methane emissions, with industrial landfills accounting for the remainder.

There are two basic approaches for reducing emissions of methane and other gases from landfills.

- Landfill gas can be recovered and either flared or used as an energy source. A system to collect and flare landfill gas will convert virtually all of the methane in landfill gas to CO_2. Alternatively, the landfill gas may be collected and used for energy recovery. Because methane's global warming potential is 21 times higher than CO_2, most of the benefits of those systems are associated with destroying the methane emissions. Simply collecting and flaring landfill gas achieves about 95 percent of the GHG reductions that are possible by collecting landfill gas and using it for energy recovery. Energy recovery reduces GHG emissions by an additional 5 percent by displacing higher-carbon fossil-fuel combustion (i.e., oil or coal).

- The quantity of degradable organic waste that is disposed in landfills can be reduced either by limiting the quantity of waste through source reduction or recycling, or by managing the waste in other ways, notably composting. Source reduction and recycling reduces GHG emissions mainly by reducing the use of energy at the manufacturing stage. Composting of organic materials is an aerobic process that avoids the methane emissions associated with anaerobic landfills.

Policy-based strategies in the municipal solid waste sector should be designed to promote recycling, source reduction, composting and other GHG reduction strategies, such as emission trading.

Agriculture and Forestry

Although the emissions from the agriculture and forestry sectors are relatively low, there are tremendous opportunities in these two sectors to reduce GHGs. Altering farming practices and enhancing carbon sequestration provide two opportunities to reduce GHG concentrations in the atmosphere. Many sequestration opportunities represent "win–win" situations that need only to be identified, publicized and officially encouraged to make significant contributions to both climate change and pollution control efforts. As Chapters VIII, *Agriculture and Forestry* and IX, *Carbon Sequestration* discuss, carbon is constantly moving through the carbon cycle and changes in human activities can increase net storage of carbon in terrestrial systems (thereby delaying or preventing its return to the atmosphere). In many cases it is less expensive to sequester a ton of carbon in biomass than to reduce a ton of carbon emissions. Carbon sequestration can be accomplished in either of two ways:

- increase the rate and amount which carbon is sequestered by living plants; and

- decrease the rate and quantity of decomposition or combustion of existing carbon stocks in soils and forests.

Many industries convert biological waste into usable energy. The same practice can be applied to the agricultural sector. For example, biomass can be converted into gaseous fuel by covering a lagoon filled with animal waste and capturing the gas, primarily methane, as it is produced by the decomposition process. In fact, employing one of these strategies has the potential to reduce methane emissions by 80 percent on large farms (over 500 dairy cows or 2,000 hogs) in warm climates (see Chapter VIII, *Agriculture and Forestry*). Additionally, using a combination of chemicals and enzymes to break down plant cellulose to sugars that ferment into ethanol can produce liquid fuel. Biomass can also be burned directly to produce electricity, process heat or both. If the energy generated displaces fossil-fuel combustion, emissions of all pollutants, GHGs and conventional pollutants are reduced.

Forests can also be managed to maximize carbon sequestration. One study estimates that between 131 and 200 million metric tons of carbon equivalent (MMTCE) could be offset each year in the U.S. by:

- selecting trees that increase timber growth;

- encouraging longer rotations between harvest cycles;

- ensuring harvesting practices preserve carbon stored in the soil and remaining trees;

- managing forest wastes especially from forest harvests; and

- selecting appropriate uses of prescribed fire.

Policies to reduce emissions of GHGs and conventional air pollutants are only one part of a more complex mix of regulations designed to protect ecosystems. Currently, the areas of environmental regulation that could have an impact on the speed at which carbon is sequestered on U.S. lands include:

- forest management laws;

- water quality programs such as best management practices;

- land use regulation; and

- wetland protection programs.

If emission trading becomes an approved part of the implementation of the Kyoto Protocol, and mitigation credits can be earned by the creation of sequestration projects, the result could be significant financial incentives that would dramatically increase mitigation on the land. Since many sequestration projects result in reductions of both GHGs and other air pollution emissions, the development of these programs is also an important issue for air quality programs.

In order for these trading systems to be successfully adapted to agriculture and forestry programs, several challenges need to be resolved, including:

- development of acceptable methods for measuring the emission reduction values of agriculture and forestry activities; and
- creation of local institutional structures that can work with landowners to install and monitor approved practices, and assemble portfolios of project credits that will be sufficiently large, diverse and credible to attract investors.

Some of these issues will be addressed by the *Intergovernmental Panel on Climate Change Special Report on Forestry and Land Use Change*, due to be released in mid-2000. Decisions based on that report will be very important in establishing the technical framework for implementing any emissions trading or mitigation scheme in both the agriculture and forestry sectors.

Market-Based Strategies

Market-based strategies will play a key role in cost-effectively reducing GHG emissions at the local, state, national and international levels. Many state and local agencies are involved with EPA's State and Local Climate Change Program to 1) inventory their GHG emissions; 2) create State Action Plans that identify policy options to reduce those emissions; and 3) implement their state's Action Plan. The policy options recommended so far in these plans are focused on the creation of market incentives to increase energy efficiency, promote alternative fuel and renewable energy use, reduce VMT and internalize the environmental cost of CO_2 emissions.

Market strategies, for the most part, are not sector-specific. Rather, these mechanisms are typically viewed as "cross-cutting" strategies; that is, they can be applied to a variety of sectors, although with varying degrees of effectiveness. There is not a single "one-size-fits-all" market mechanism to reduce GHG that can be applied to every local area and state. Each area has a unique combination of sources contributing to its emissions inventory. As a result, a different mix of market-based strategies will be optimal in different areas. For instance, allowance trading is generally viewed as an effective form of emission trading to reduce GHG emissions from the electricity sector. However, it is less well suited for smaller sources, such as personal vehicles. A better market-based mechanism for smaller, disperse sources might include subsidies for alternative fuels and rebates for the purchase of low emitting vehicles.

Because GHG reductions have not been required in the U.S., little actual experience exists in applying market mechanisms towards the achievement of GHG reduction goals. However, experience with the application of market-based strategies to criteria pollutants provides a useful indication of the issues that are relevant to the application of each mechanism to GHGs.

From a domestic perspective, major source sectors such as electric generators are likely to be targeted with a cap-and-trade mechanism. For example, if the U.S. reduction goal for the electric generating sector were proportional to the reductions envisioned under the Kyoto Protocol, then electric generators would have average annual caps for the first budget period (2008 through 2012) set at approximately 450.68 million metric tons carbon equivalent (MMTCE), which is 7 percent below the sector's 1990 GHG emissions (484.6 MMTCE). If GHG emission levels from the generating sector continued as projected and, by 2010, were to reach a 34-percent increase over 1990 levels (or approximately 649.36 MMTCE),[9] the emission cap would represent an annual reduction of 198.68 MMTCE or a total of 993.42 MMTCE for the first five-year budget period.

Market incentives have also been used successfully to encourage energy efficiency. The federal government has sponsored energy-efficiency programs for industry and utilities have designed energy-efficiency incentives for potential commercial or industrial energy-efficiency clients.

An excellent example of this concept has been demonstrated by the Indiana Department of Commerce, Office of Energy Policy, which coordinated the design and implementation of a Home Energy Rating System/Energy-Efficient Mortgage (HERS/EEM) program. The HERS/EEM mechanism has two components. The first is a rating system that will classify new and existing homes according to their energy efficiency. This efficiency rating provides estimates of utility costs and may include recommendations for specific energy improvements. The second component allows mortgage lenders to incorporate the lower energy bill expected in a more energy-efficient house when evaluating mortgage applications. The goal of the program is to improve the energy efficiency of Indiana homes and to allow homebuyers to make informed decisions regarding the costs of operating a home.

By giving regulated sources flexibility in choosing the means of compliance, market mechanisms can allow the target environmental goals to be realized at lower costs, and can encourage innovation as well.

Harmonized Measures—Reducing Criteria Pollutants and Greenhouse Gases

As this document details and this summary has highlighted, there is an important relationship between GHG mitigation and conventional air pollutant control. To evaluate the emission impacts of harmonized strategies, an assessment model has been developed to estimate reductions of criteria pollutants and GHGs in the electricity, commercial and residential, transportation and industrial sectors. It is important to note that the assessment model has been designed to compare the relative magnitudes of emission reductions that can be expected from source sectors in different regions by implementing these strategies.

Four areas of the U.S., the state of New Hampshire; Atlanta, Georgia; Louisville, Kentucky and Ventura County, California, serve as case studies for the assessment of selected harmonized strategies. The areas that participated in these case studies are not currently implementing the strategies identified, nor have they committed to implement these strategies. The purpose of these case studies is to begin to evaluate the potential carbon reductions available from comprehensive harmonized strategies.

In most areas, the electric or transportation sector is the largest aggregate emitter of GHGs, with each one typically accounting for 35 percent to 40 percent of total emissions. Industrial sources are usually the third largest emitters, followed by the commercial/residential sector. Therefore, harmonized strategies focused on these source sectors. Each area chose its own mix of harmonized strategies, which included:

- switching to natural gas-fired steam generation at an existing coal- or oil-fired unit;
- replacing existing fossil-fueled steam cycle capacity with natural gas-fired combined-cycle capacity;
- replacing fossil-fueled power generation with renewable generation (e.g., wind, solar, hydro and biomass);
- replacing fossil-fueled power generation with primary or distributed fuel cell generation;
- reducing electricity consumption via improved end-use efficiency;
- establishing cogeneration systems at power plants and industrial sources;
- improving transportation fuel efficiency; and
- reducing vehicle use, by increasing such alternatives as carpooling, mass transit and telecommuting.

In aggregate, the results of the model for the four case study areas demonstrate that a range of effective strategies exist that can reduce GHG emissions and also contribute to criteria pollutant reduction goals. The distribution of emission reduction impacts among the four areas is a result of their different emission inventory profiles, their respective nonattainment status for criteria pollutants and the control strategies already adopted or to which the area has already committed.

This analysis indicates that the 7-percent reduction in GHG emissions targeted for the U.S. in the Kyoto Protocol is well within reach of most states and localities. The harmonized control strategies also provide additional criteria pollutant reductions required to meet current and future clean air mandates. *Table 2* summarizes the total percent reductions from baseline emissions that each area would realize with its package of harmonized control strategies.

Conclusion

Many effective opportunities exist at the federal, state and local levels to reduce GHG emissions and, at the same time, achieve substantial criteria pollutant reductions. These strategies are generally technically feasible and cost-effective and can play a substantial role in meeting current and future clean air and other environmental mandates.

Endnotes

[1] U.S. Environmental Protection Agency (U.S. EPA), *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1997,* Washington, D.C., March 1999.

[2] Ibid.

[3] This table of CO_2 emissions per unit of electrical output is derived from estimates of emissions per unit of heat input developed by the EPA and published in: U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-1993,* Washington, D.C., 1994. One figure is used in this document for CO_2 emissions from natural gas combustion (117 lb/mmBtu), and a range is given for oil combustion, reflecting different types of oil. The range is from 161 lb/mmBtu for distillate oil to 174 lb/mmBtu for residual oil. For coal, EPA provides 207 lb/mmBtu as a weighted average, reflective of the kind of coal burned in U.S. utility boilers.

[4] U.S. Department of Energy, *Potential Impacts of Energy-Efficient and Low-Carbon Technologies by 2010 and Beyond,*

Table 2

Percent Reduction from Baseline Emissions in Four Case Study Areas

Area	SO_2	NO_x	PM	VOC	CO	CO_2
New Hampshire	41%	17%	12%	3%	4%	12%
Atlanta, GA	40%	6%	1%	3%	4%	7%
Louisville, KY	26%	14%	3%	3%	4%	15%
Ventura County, CA	2%	4%	1%	4%	4%	11%

Source: STAPPA/ALAPCO, 1999.

Interlaboratory Working Group on Energy-Efficient and Low-Carbon Technologies, Energy Efficiency and Renewable Energy Program, Washington, D.C., September 1997.

[5] Ibid.

[6] Esource, *Technology Atlas Series* (Boulder, CO, 1997).

[7] Alliance to Save Energy, *Report Card on State Residential Building Codes* (Washington, D.C., 1995).

[8] California Energy Commission (*Title 24: California Energy Efficiency Standards for Residential and Non-Residential Buildings*) 1998. The regulations are available at *http://www.energy.ca.gov/title24/index.html.*

[9] U.S. Energy Information Administration, *Annual Energy Outlook 1999*, Washington, D.C., December 1998.

Harmonized Strategies for Reducing Criteria Pollutants and Greenhouse Gases

Introduction

As other chapters in this document have shown, there are a variety of methods by which a wide range of air pollutants can be reduced from stationary and mobile sources. Many states and local areas have grappled for years with the challenges of reducing emissions of criteria pollutants in an effort to comply with provisions of the Clean Air Act (CAA). However, in recent years, a growing consensus on the science and impacts of climate change has led to the realization that efforts to reduce emissions of criteria pollutants may need to be coordinated with efforts to reduce greenhouse gases (GHGs). As a result, many states and metropolitan areas have become interested in the opportunities available for meeting criteria pollutant reduction goals in ways that also maximize GHG reductions. These dual goals can be met by requiring or incentivizing "harmonized" emission reduction strategies; that is, strategies that maximize reductions in emissions of criteria pollutants and GHGs.

Strategies that reduce criteria pollutants do not necessarily yield GHG reductions; in fact, some strategies may increase GHG emissions. In contrast, all GHG reduction strategies that affect fuel combustion (the largest source of GHG emissions) also reduce criteria pollutants. Only an informed assessment of a wide range of emission reduction options will reveal to regulators and policy makers the best opportunities to maximize reductions of both criteria pollutants and GHG emissions.

When taken together, the transportation, electric and industrial sectors account for the vast majority of anthropogenic emissions of criteria pollutants and GHGs in the U.S. While this document presents dozens of harmonized strategies for these and other sectors, this chapter examines a limited number of effective emission reduction strategies for these source sectors and evaluates the combined emission reduction benefits associated with these strategies. Four areas of the U.S. have been selected to serve as case studies for the assessment of these strategies. In each of these areas, the strategies are assessed in terms of their potential impact on both criteria pollutant emissions and GHG emissions.

The four case study areas used to illustrate the potential impact of these strategies are the state of New Hampshire (NH); Atlanta, Georgia (GA); Louisville, Kentucky (KY); and Ventura County, California (CA). These areas were selected because they differ in terms of criteria pollutant nonattainment status, economic growth and industrial profile, and therefore are useful in demonstrating the different potential emission reduction impacts of the harmonized strategies being assessed. The areas that participated in these case studies are not currently implementing the strategies identified, nor have they committed to implement (or even consider) these strategies. The purpose of these case studies is to evaluate the potential for reductions to occur if such strategies were to be pursued.

This chapter first describes the current State Implementation Plan (SIP) process for criteria pollutants and the logic of including GHGs in a harmonized process. Next, the relevant aspects of each of the case study area are described along with the strategies selected for that area and the modeled results of implementing the strategies. Finally, conclusions about the use of harmonized approaches to achieve emission reductions are presented.

Harmonized State Implementation Plans

Why Focus on State and Local Efforts for GHG Reductions?

In the U.S., the prevention and control of air pollution at its source is the primary responsibility of states and local governments. Although the landmark 1970 CAA and its 1990 amendments greatly expanded the authority and responsibility of the federal government in the regulation of air pollution, these statutes explicitly preserved the principle of primary state responsibility. Whether or not the nation as a whole moves in the direction of reducing emissions of GHGs, some state and local governments are already doing so. These state and local governments that act to curb emissions of GHGs must accommodate their efforts within their legal obligation to attain and maintain the National Ambient Air Quality Standards (NAAQS), as required by the CAA.

Throughout this document, options have been identified that can simultaneously reduce emissions of both GHGs and criteria pollutants, such as ozone—through its precursor pollutants, oxides of nitrogen (NO_x) and volatile organic compounds (VOCs)—sulfur dioxide (SO_2), carbon monoxide (CO) and particulate matter (PM). Because harmonized options, by definition, reduce both conventional pollutants and GHGs, they are manifestly more effective than adopting pollutant-specific strategies in terms of both economic goals and pollution reduction goals.

The air pollution control strategies developed by state and local regulators to attain and maintain a federal air quality standard are embodied in a planning and implementation document commonly referred to as a SIP. Revisions of or modifications to a previously approved SIP are known as SIP revisions. SIPs and SIP revisions are prepared by state and local governments, and then submitted to the U.S. Environmental Protection Agency (U.S. EPA) for review and approval. The SIP can be thought of as the blueprint that guides state and local efforts to comply with the requirements of the CAA. An area that exceeds the NAAQS for a pollutant is known as a nonattainment area for that pollutant and must develop a SIP that contains several elements, including:

- an attainment demonstration that includes an acceptable modeling analysis;
- a baseline and attainment year emissions inventory for the nonattainment pollutant (at a minimum) that was used in the modeling analysis that supports the attainment demonstration;
- a list of the new control strategies that will achieve the required reductions in baseline emissions of pertinent pollutants by the attainment year, by strategy; and
- a list of statutes or regulations that must be enacted or adopted to assure that the state has the legal authority to enforce the new control strategies.

Once a SIP revision has been approved by U.S. EPA, the subsequent adoption by the state of any new air pollution control program, such as one to control emissions of GHGs, creates the risk of disrupting SIP-directed efforts to attain the air quality standards. Some GHG reduction strategies might increase emissions of a nonattainment pollutant or precursor in the attainment year or change the temporal or spatial characteristics of emissions and/or speciation,[1] resulting in modeled or projected exceedances of the applicable standard. If this were to occur, the state would have to revise its SIP to compensate for any increases in emissions or changes in emission patterns.

An alternative approach would be to evaluate the effect that any new GHG control strategy would have on efforts to attain a criteria pollutant standard before adopting such new strategies. With an effective evaluation undertaken first, GHG reduction strategies could be implemented with the knowledge that they would not jeopardize efforts to attain a criteria pollutant NAAQS. Moreover, such an analysis would show which strategies are likely to provide reductions in criteria pollutants and roughly how large those reductions might be. To demonstrate how this type of analysis can be done, an assessment model has been developed to characterize the impact of selected harmonized strategies on GHGs and criteria pollutants. This assessment model has been applied for the four case study areas.

Overview of the Assessment Model

As noted, the electricity, transportation and industrial sectors account for most of the anthropogenic emissions of criteria pollutants and GHGs in the U.S. In most areas, the electric or transportation sector is the largest aggregate emitter of GHGs, with each one typically accounting for 35 percent to 40 percent of total emissions. Industrial sources are usually the third largest emitters, followed by the commercial/residential sector. Note that the electric sector supplies electricity for the residential and commercial and industrial sectors

The harmonized strategies assessment model that has been developed to estimate reductions of criteria pollutants and GHGs in the electricity, commercial/residential, transportation and industrial sectors has been designed to compare the relative magnitudes of emission reductions that can be expected from source sectors in different regions by implementing harmonized strategies. As such, it allows regulators and policy makers to evaluate at the broadest level the relative benefits of these control options. However, more sophisticated techniques with more refined data inputs must be used to generate more precise emission projections; dispersion modeling will be needed to support an attainment demonstration.

Emissions Data Sources

The 1996 emissions of criteria and GHG pollutants for each case study area were used as the baseline, and the emission impacts of the selected strategies were calculated from this baseline. Although the baseline is largely composed of emission estimates, this does not compromise this assessment's ability to demonstrate the relative impact of the harmonized strategies on criteria pollutant and GHG emissions in the different case study areas.

For criteria pollutant emission levels, the modeling analysis relies upon two sources, as follows:

- For all areas, electric sector emission information was obtained from U.S. EPA's 1996 Acid Rain Program.[2]
- For non-electric criteria pollutant emissions for all areas, U.S. EPA's 1996 Emission Trends database was used in combination with 1996 date provided by the state or local air agency for each case study area.[3]

For CO_2 emissions, the modeling analysis relies upon three methods for estimating the needed data:

- For New Hampshire, the only area that comprises an entire state, CO_2 emissions were obtained from the data reported to U.S. EPA's State and Local Climate Change Program.
- For Atlanta and Louisville, CO_2 emissions were estimated by the air agency in each area based on reported fuel consumption and the U.S. EPA guidelines for estimating CO_2 emissions for each fuel, by sector.
- In Ventura County, CO_2 emission information was available only for power plants, as reported in the Acid Rain database for 1996. For the other sectors in Ventura County, the ratio of CO_2 to CO in the other case study areas was used to estimate CO_2 emissions based on CO emissions from each sector in Ventura County.

Electric Generation and Use

The electric component of the analysis addresses emissions from large electric generators. It also assesses the impact of energy efficiency strategies that reduce electricity consumption in the industrial, commercial and residential sectors.

Total emissions from electric generation and use in an area are modified by adopting one or more of the following five strategies:

- switching to natural gas-fired steam generation at an existing coal- or oil-fired unit;
- replacing existing fossil-fueled steam-cycle capacity with natural gas-fired combined-cycle capacity;
- replacing fossil-fueled power generation with renewable generation (e.g., wind, solar, hydro and biomass);
- replacing fossil-fueled power generation with primary or distributed fuel cell generation; and
- reducing electricity consumption via improved end-use efficiency.

Note that because of enhanced efficiency and, in some cases, new equipment, unit conversions to combined-cycle systems can increase generating capacity. When a new combined-cycle system is constructed, some portion of the existing capacity in the area is displaced. For each case study area, a mix of these five strategies is adopted, based on the existing electric generating system in the area. The impact of this mix of strategies on SO_2, NO_x, PM and CO_2 emissions is then modeled using the unit- and area-specific data discussed above.

The utility electric generation portion of the model contains 1996 reported emissions data for 677 utility plants. Each record contains the plant name and plant number (ORIS), National Electric Reliability Council region, state, county, capacity (kilo-watt), utilization, heat input, generation, NO_x tons, SO_2 tons, CO_2 tons, NO_x rate, SO_2 rate, CO_2 rate, heat rate, plant age and primary fuel type.

Output-based emission rates, in terms of pounds per Megawatt hour (lb/MWh), for the units after the fuel switch are assumed by the model and can be changed by the user in the control types spreadsheet. The assumptions used for this analysis are outlined in *Table 1* below.

Table 1

Assumed Output-Based Emission Rates

Type	Heat Rate	NO_x (lb/MWh)	SO_2 (lb/MWh)	CO_2 (lb/MWh)	PM (lb/MWh)
Natural gas-fired steam generator	9300	0.93	0.00	1088	0.023
Natural gas combined-cycle	6800	0.08	0.00	796	0.017
Fuel cell	4551	0.00	0.00	532	0.000
Wind	3413	0.00	0.00	0	0.000
Solar	3413	0.00	0.00	0	0.000
Improved end-use efficiency (Demand side management)	3413	0.00	0.00	0	0.000

Source: STAPPA/ALAPCO, 1999.

Within the assessment model, these emission factors are applied to the 1996 generation MWh of the affected units and the total emissions are calculated. The emission reduction is simply the emissions emitted by the current facilities minus the projected emissions associated with the new (in this case, gas-fired) facilities.

Commercial/Residential Heating and Cooling

Increases in the efficiency of residential and commercial heating and cooling systems are also adopted. At the residential level, these increases are likely to occur through enhanced insulation and windows and the replacement of older heating systems with highly efficient systems, such as ground source heat pumps. In the commercial sector, these same strategies would be applied, but on a larger scale, and the efficiency of fossil-fueled chilling systems could be improved with strategies such as cogeneration. In each of the case study areas, a 4-percent reduction in commercial/residential emissions is assumed to result from these efficiency gains.

Industry

The industry component of the analysis gauges the emission impacts of establishing cogeneration systems at power plants and industrial sources whose relative locations meet certain proximity criteria. In areas where plant locations make cogeneration feasible, excess heat from 5 percent of local electric generation is assumed to be used at industrial facilities, displacing fossil-fuel combustion there. While individual industrial facilities can install cogeneration systems onsite, the overall penetration of cogeneration in a given area is limited by electricity use. Thus, this analysis simply assumes that in the case study areas, a 5-percent penetration of cogeneration can be achieved at industrial facilities in close proximity to electric generators.

For the industrial sector portion of the model, a given level of heating was modeled to be displaced by electric generating station cogeneration of power and heat. Potential cogeneration energy available was determined based on the current electric generation in the region. The cogeneration model contains 1996 data for all utility electric generators, including heat input, emissions of NO_x, SO_2 and CO_2, as well as location information, such as state and county. The model also includes census data for 1996 that identifies the number of business establishments by Standard Industrial Classification (SIC) code within each county of the U.S. The remaining inputs include the penetration percentage and the overall efficiency of a plant where heat is co-generated (typically 75 percent).

When the model is run, manufacturing establishments are cross checked against the utility plant database by county to determine if both a sufficient number of establishments and a utility plant are located in the same county. The amount of waste heat at the target facilities is then calculated, adjusted according to the cogeneration penetration percentage and displayed as the total available waste heat.

Because the emissions offset by industrial cogeneration are that of the industry, not that of the utility, the emission benefit of cogeneration strategies are calculated based on user-provided emission rates. This is necessary because the type of heat and fuel consumption is generally industry specific and may consist of anything from a gas-fired unit heater, to an oil-fired boiler, to a coal-fired boiler, to a scrap wood- or paper pulp-fired furnace. In this analysis, the following emission rates for natural gas-fired unit heaters were generally used:

- 0.1 lb NO_x/million British thermal units (mmBtu), (except in Ventura County, where 0.05 was used);
- 117 lb CO_2/mmBtu;
- 0.015 lb PM/mmBtu;
- 0.01 lb VOC/mmBtu; and
- 0 lb SO_2/mmBtu.

Transportation

The transportation component of the analysis is designed to develop projection-year emission inventories of criteria pollutants and GHG emissions for light-duty gasoline vehicles (LDGV) and diesel vehicles in order to assess the relative effectiveness of various control options. The transportation component relies on the base-case emission information found in the 1996 U.S. EPA Emission Trends database. It is configured to assess the emissions reductions resulting from a mix of two strategies:

- improved fuel efficiency and
- changes in vehicle use, such as carpooling, mass transit and telecommuting.

The transportation component calculates emissions from a given area's fleet by multiplying the population of the fleet (e.g., light-duty vehicles, heavy-duty trucks and school buses) by the appropriate activity rate and emission factor. Emissions from 1996 are used as baseline emissions, and reductions from the strategies adopted are calculated from this baseline. The first strategy, improved fuel efficiency, is being implemented at the national level, and thus is applied to all four areas.

Time Frame

It is important to bear in mind that the assessment results shown for each areas do not reflect any given period of time; rather, assessment results simply show the difference between emission levels prior to implementation of the strategies and emission levels after implementing the strategies. This fact may be most relevant to transportation strategies, whose effectiveness is directly proportional to fleet turnover. Emission reductions from increased fuel efficiency will have important benefits over the long-term, due to growth in the total number of vehicles in an area and vehicle miles traveled. However, for the case study areas examined in this chapter, the percent penetration used for the strategies is assumed to be realistic in the near-term (i.e., within the next four years).

As discussed in Chapter IV, *Transportation*, an efficiency improvement of 1 percent per year in the light-duty gasoline fleet could be expected to decrease CO_2 emissions 10 percent below current levels by the year 2020. This estimate takes into consideration the fleet distribution of vehicle miles traveled and the pace of fleet turnover. Near-term emission reductions from improving new vehicle fuel efficiency would be much smaller than 10 percent.

Harmonized Strategies

The harmonized strategies included in this assessment are derived directly from the recommendations identified in the previous sections. For example, in the two chapters on power generation, the recommendations for harmonized strategies fall into three main categories: fuel switch to lower-carbon fuels, improved energy generating efficiency and the use of renewable fuels. Strategies to achieve cleaner generation at utilities are briefly explained in *Table 2*. Strategies for renewable energy generation and fuel cells are summarized in *Table 3*, while *Table 4* shows measures to improve energy efficiency. Strategies to reduce emissions from the transportation sector are presented in *Table 5*. Industrial strategies are shown in *Table 6*.

These strategies have been selected for their effectiveness in achieving harmonized emission reductions. Some will be widely implemented in the near-term (i.e., fuel switch and demand side management, or DSM); others will require longer implementation periods before having substantial impacts on air quality (e.g., improved vehicle fuel efficiency). However, in most cases, state and local regulators and policy makers have the ability to either require such strategies or to implement incentives that lower market barriers and accelerate implementation. Incentive options that are widely applicable include market mechanisms, such as tax incentives and subsidies for new technologies (such as wind, solar and fuel cells), whose limited market penetration renders them relatively expensive. Alternatively, performance-based emission requirements for suppliers of electricity in competitive markets may drive the need to reduce emissions from generating plants further, providing increased demand for combined-cycle conversions and eventually increased use of wind and solar, as well. The previous chapters provide discussion on policy options for implementing each of these strategies, as well as many others.

The emission reductions realized from these strategies will depend a great deal on current fuel used and the extent of controls present during the baseline year. For example, the first four GHG reduction strategies (fuel switch to natural gas, combined-cycle conversions, renewable power and fuel cell penetration) are all essentially various forms of fuel switching that can also be expected to reduce emission rates of SO_2, NO_x, PM and CO_2. The other two strategies (reduced gas and electricity consumption through DSM will reduce the activity level of the relevant electric generating source, thus reducing its emissions of both GHGs and criteria pollutants.

Similarly, the strategies included for the transportation sector adhere to the strategies identified in the transportation chapter: 1) mass transit, 2) transportation control strategies and 3) cleaner fuels and improved fuel economy. The first and third strategies will reduce gasoline use and should therefore reduce emissions of NO_x, VOCs and CO and formation of secondary PM. The second strategy will reduce the use of diesel fuel, affecting

Table 2

Harmonized Strategies—Cleaner Electric Generation at Utilities

Gas-Fired Capacity Converted to (or Displaced by) Gas Combined-Cycle	This strategy assumes that a percentage of the electric generating capacity fueled by natural gas in the area is converted to combined-cycle generation to increase efficiency, or is displaced by newly constructed gas combined-cycle capacity. Output-based emission rates decrease as a result of increased plant efficiency, yielding lower emissions for the same output.
Fuel Switch to Natural Gas	This strategy is a simple fuel switch of oil or coal-fired capacity to natural gas, which generally allows for summer combustion of natural gas and winter combustion of fuel oil and coal. This is consistent with ozone control strategies where sources may choose to switch to natural gas during the summer season to comply with more stringent emission rates. Retaining dual-fuel capability is also a strategy for obtaining more favorable gas prices during the summer months when gas supply is plentiful and demand is low.
Coal Displaced by Natural Gas Combined-Cycle	This strategy assumes that new natural gas combined-cycle plant construction will displace existing conventional coal generation in the restructured electricity markets. Small combined-cycle and combined-cycle cogeneration facilities are assumed to penetrate the market.

Source: STAPPA/ALAPCO, 1999.

Table 3

Harmonized Strategies—Cleaner Electric Generation Sources

Renewables	A combination of biomass, solar, hydro and wind power generation is assumed to displace a percentage of the power generation.
Fuel Cells	Fuel cell power generation is assumed to penetrate niche markets where it is economical. In addition to commercial-sized fuel cells, residential-sized fuel cells are also anticipated to enter the market within the next three to five years. Existing generation will be displaced.

Source: STAPPA/ALAPCO, 1999.

Table 4

Harmonized Strategies—Increased Energy Efficiency

Reduced Residential Energy Demand	A reduction of residential energy demand is assumed for each area. These reductions are primarily achieved as a result of improved water heater designs and reduced hot water consumption (e.g., low volume shower heads, more efficient home heating systems and better insulated homes and windows).
Reduced Commercial and Residential Electricity Demand	Implementation of improved lighting, electric motor efficiency, variable frequency drives and building efficiency strategies are assumed to reduce residential and commercial electricity demand by a given amount for each area.

Source: STAPPA/ALAPCO, 1999.

Table 5

Harmonized Strategies—Transportation

Light-Duty Gasoline Vehicle Emission Reduction Strategies Other Than Efficiency	Emission reductions are applied to the entire light-duty gasoline vehicle inventory for each area. Light-duty gasoline vehicle use is assumed to decrease by a given amount through increases in a combination of strategies, such as mass transit use, carpools, telecommuting, the use of alternative lower carbon fuel and advanced technology vehicles and urban sprawl initiatives.
Improved Light-Duty Vehicle Fuel Economy	Improved average annual light-duty vehicle fuel economy is modeled to reflect assumptions for the area. This per-year improvement is based on either incremental increases in vehicle fuel economy as a result of Corporate Average Fuel Economy (CAFE) requirements, or moderate penetration of high efficiency automobiles from the Partnership for a New Generation of Vehicles (PNGV) which would raise the annual average fuel economy by the percentage predicted. It should be noted that this would occur notwithstanding the growing popularity of sport utility vehicles, which is steadily decreasing the average fuel economy of the urban fleets.

Source: STAPPA/ALAPCO, 1999.

Table 6

Harmonized Strategies—Industrial

Reduced Industrial Process Emissions	For each area, industrial process emissions are assumed to be reduced by a given percent. These reductions could be achieved via a combination of fuel switching, updating of process methods and revised product compositions (e.g., blended cement) that would, in combination, reduce the overall process emissions.
Increased Industrial Cogeneration	For the industrial sector, a given level of heating is predicted to be displaced by electric generating station cogeneration of power and heat. Potential cogeneration energy available was determined based on the current electric generation in the region. Cogeneration was assumed to achieve a specified level of availability.

Source: STAPPA/ALAPCO, 1999.

NO_x, PM and SO_2. Note that the third strategy, improved fuel efficiency for light-duty vehicles, represents a national strategy, implementation of which is not within the authority of a state or local agency.

Finally, as recommended in Chapter V, *Energy-Intensive Industries*, industrial sector strategies assessed include improved efficiency in on-site power generation and reduced on-site emissions. Because the first strategy improves energy efficiency of on-site power generation, it should deliver NO_x, PM, CO_2 and possibly SO_2 benefits; the second strategy affects process emissions and therefore yields the bulk of its benefits in CO_2, VOC and CO reductions.

These strategies have the ability to deliver significant reductions in both GHG emissions, as well as criteria pollutants. However, the extent of the projected reductions varies among the four case study areas depending on several factors, such as the specific set of strategies selected, as well as the area's emission inventory, land area, population, economic profile and base-case control strategies.

The Four Case Studies

Each of the strategies summarized in *Tables 2–6* were modeled for the case study areas at varying levels of penetration. *Table 7* summarizes the extent of implementation for each of the strategies across all areas. Following *Table 7*, each area is discussed in detail, with references to *Table 7*, as needed. The areas that participated in these case studies are not currently implementing the strategies identified, nor have they committed to implement (or even consider) these strategies. The purpose of these case studies is to evaluate the potential for reductions to occur if such strategies were to be pursued.

Area 1: New Hampshire

Area Description. New Hampshire, one of the six New England states, is bordered to the west by the state of Vermont, to the south by the Commonwealth of Massachusetts, to the east by both the Atlantic Ocean and the state of Maine and to the north by the province of Quebec, Canada. The state is 9,304 square miles (sq. mi) in total area. This area can be broken down into two components: land area of 9,024 sq. mi and inland surface water area of 280 sq. mi. New Hampshire ranks 46th in size among the 50 states. There are 18 miles of coastal waterfront and forests cover 5 million acres of the state, which represents 87 percent of the total area of the state. The population is approximately 1.15 million (42nd in the U.S.).

Over 70 percent of New Hampshire's population and industry are located in four counties in the southeastern portion of the state. Much of southeastern NH can be characterized as

Table 7

Harmonized Strategy Summary for the Four Case Study Areas

	Level of Penetration Modeled for Each Area			
Harmonized Strategies by Sector	**NH**	**Atlanta, GA**	**Louisville, KY**	**Ventura County, CA**
Electric Generation				
Gas-fired generation converted to gas combined-cycle	0%	0%	0%	100%
Fuel switch from oil or coal to natural gas	25%	20%	0%	0%
Coal-fired capacity displaced by natural gas combined-cycle capacity	50%	30%	25%	0%
Fossil-fuel generation displaced by renewables	1%	1%	1%	1%
Fossil-fuel generation displaced by fuel cells	1%	1%	1%	1%
Commercial and Residential				
Fossil-fuel (oil and gas) consumption reduction through energy efficiency strategies	4%	4%	4%	4%
Commercial and residential energy consumption reduction through increased demand side management	5%	5%	5%	5%
Transportation				
Light-duty gasoline vehicle strategies other than efficiency	5%	5%	5%	5%
Annual increase in light-duty vehicle fuel efficiency	1%	1%	1%	1%
Industrial				
Industrial energy consumption reduction through increased demand side management	2%	2%	2%	2%
Reduced process emissions	1%	1%	1%	0%
Reduced heating energy consumption through cogeneration	5%	5%	5%	5%

Source: STAPPA/ALAPCO, 1999.

relatively urban or suburban, with economic growth that is currently among the highest east of the Mississippi River. Much of this growth is attributable to industrial and residential expansion from the metropolitan Boston area occurring over the past three decades. The remainder of the state is much less densely populated and less industrialized.

The industrial infrastructure of the state consists primarily of small to medium-sized manufacturing facilities, with high technology and electronics predominating in the heavily populated southeastern counties. Lumber is NH's main natural resource. Coos County, over 100 miles to the north of the industrial southeast, is the center of the timber industry and contains three large paper mills. Forestry and logging are important in northern NH, and the entire state has the second highest percentage of forest cover in the U.S. The timber is used to manufacture pulp and paper products, railroad ties, furniture and fence posts.

New Hampshire has depended on manufacturing as a major source of income and employment for over 100 years. The principal industrial products are electrical and electronic goods, industrial machinery and precision instruments. Other leading industries include rubber and plastics, instruments (measuring devices), printing and publishing, fabricated metal goods and paper and paper products. Most of NH's industry is located in the Merrimack River Valley, primarily in Manchester and Nashua.

The state of NH is essentially continental in climate. This means cold winters and warm summers are marked by 17 temperature extremes with variability from month to month, year to year, and region to region. The state is divided into two climatic regions. The northern division includes the northern and west-central part of the state, approximately one-third of NH. The southern division is made up by the remainder of the state. The northern division's higher elevation tends to hold temperatures lower, with a regional average 41 degrees Fahrenheit (°F) and 25 to 50 sub-zero days each year. The southern division's lower elevation results in higher temperatures, averaging 46°F with only 10 to 25 sub-zero days each year. The average normal temperature for a year ranges from a low of 9°F to a high of 83°F.

The state is currently in attainment for SO_2, lead, CO and PM. Portions of the more densely-populated and industrialized southeastern counties of NH are designated as serious nonattainment for the 1-hour ozone standard. A second area, in the interior southeast and consisting of greater Manchester and Concord metropolitan areas (the state's largest and third largest cities, respectively), was designated as marginal nonattainment for the 1-hour ozone standard until July 1998, when the standard was revoked by U.S. EPA for this area. A third area, Cheshire County in the state's southwest corner, had been designated nonclassifiable nonattainment prior to July 1998 when U.S. EPA revoked the 1-hour NAAQS for this area, as well. Based on the most recent monitoring data, it appears likely that the 1-hour ozone standard will also be revoked for the (currently) serious nonattainment portions of the state.

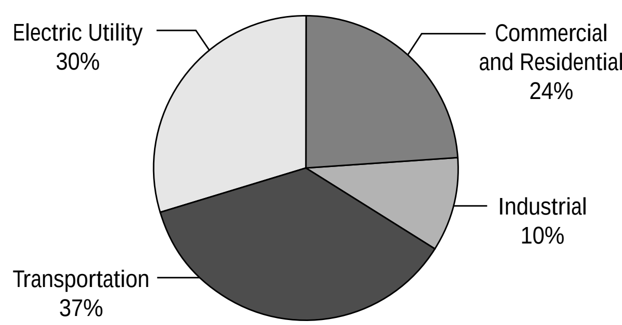
New Hampshire is one of 12 states that comprise the Ozone Transport Region (OTR).[4] Therefore, as required by the CAA, its ozone attainment areas are subject to stricter ozone control strategies that do not apply to ozone attainment areas in other regions of the country.[5]

Photochemical modeling has demonstrated that with the NO_x and VOC reduction strategies NH has implemented, those it is scheduled to implement, and appropriate reductions from upwind jurisdictions, all areas of the state will attain the one-hour ozone standard by 2003. This is the projected U.S. EPA deadline for areas in the state violating the 8-hour NAAQS to attain this new standard.

Area Emission Inventories. As shown in *Table 8* on the next page, in 1996 power plants emitted 83 percent of the state's SO_2, 31 percent of its NO_x, 24 percent of its PM and 30 percent of its CO_2 (1993).[6] The state contains three large power plants, all located in ozone nonattainment areas. In 1996, total generation at these plants was approximately 4,148,000 MWhs. The primary fuel for two of the plants is coal, which contributes 63 percent of the total generating capacity. *Figure 1* shows the fossil-fuel contribution to CO_2 emissions by source sector in 1993.[7]

Figure 1

Area 1: New Hampshire CO_2 Emissions, 1993



Source: State of New Hampshire, New Hampshire State Greenhouse Gas Inventory, 1993.

The commercial and residential CO_2 emissions are only significant in fuel consumption for heating (24 percent), which is logical given the state's northern climate. New Hampshire's NO_x, CO and CO_2 inventories are dominated, however, by the transportation sector (59, 95 and 37 percent respectively) and, as a result, harmonized strategies for highway vehicles result in large reductions of these pollutants on a statewide level.

Considering these factors, CO_2 emissions in NH are relatively evenly distributed between electric generation, transportation and end-use consumers (industrial, commercial and residential). Because the CO_2 breakout is evenly distributed, applying CO_2 reduction strategies across a variety of source sectors has a pronounced effect on the entire state CO_2 inventory.

Table 8

Area 1: New Hampshire 1996 Annual Criteria Pollutant Emissions and 1993 CO_2 Emissions (tons and % contribution to total)

Sector	SO_2	NO_x	PM	VOC	CO	CO_2
Electric Generation	47,224	17,895	2,017	118	1,865	4,860,000[a]
	83%	*31%*	*24%*	*<1%*	*1%*	*30%*
Commercial/Residential	1,751	1,822	165	7,055	1,034	3,850,000
	3%	*3%*	*2%*	*13%*	*1%*	*24%*
Transportation	1,477	33,962	1,779	25,391	189,186	5,960,000
	3%	*59%*	*22%*	*48%*	*95%*	*37%*
Onroad	1,477	31,200	1,359	19,950	159,000	5,639,765
Offroad	0	2,762	420	5,441	30,186	320,235
Industrial	6,012	2,751	1,243	18,897	5,087	1,649,939
	11%	*5%*	*15%*	*36%*	*3%*	*10%*
Other (anthropogenic sources only)	519	794	3,029	1,423	2,123	2,269
	1%	*1%*	*37%*	*3%*	*1%*	*<1%*
Total	56,983	57,224	8,223	52,884	199,295	16,322,208

[a] Electric generation CO_2 is from 1996 Acid Rain Database.

Sources: U.S. EPA, Acid Rain Database, 1996; U.S. EPA, Emission Trends Report, 1996; State of New Hampshire, New Hampshire Greenhouse Gas Inventory, 1993.

Area-Specific Harmonized Strategies. Based on New Hampshire's mix of electric generation, industry and transportation, harmonized strategies were modeled to maintain needed reductions in criteria pollutants while maximizing reductions of GHGs. These strategies are shown in *Table 7* above.

Based on the availability and relatively low cost of natural gas, and the need to reduce seasonal NO_x emissions under the Ozone Transport Commission (OTC) Memorandum of Understanding (MOU), NH estimated that 25 percent of the state's annual oil-fired electric generation could be switched to natural gas.[8] Gas would be utilized in the summer ozone season when prices are low due to low demand for space heating. NH also indicated that several new, gas-fired combined-cycle power plants have been proposed for construction. At least one of these facilities has indicated that it would co-generate heat for a proposed industrial site nearby. Based on the size of the new gas-fired units proposed, NH indicated that it would be possible for 50 percent of annual electric generation to shift to these newer, cleaner units over the next several years. There is currently no gas-fired electric generation in NH; thus shifting existing gas generation to combined-cycle generation was not an option.

In addition, a modeled strategy was analyzed for a 1-percent market penetration by renewable power generation and an additional 1-percent penetration by fuel cells. Thus, under this scenario, 2 percent of the electricity currently generated in NH by fossil-fueled power plants would be expected to be displaced by new fuel cells and generating units using renewable fuels. The state is likely to complete the deregulation of its electric industry by the end of 1999, thus the development of fuel cells and renewable resources in NH is likely to be driven by electricity supply companies marketing these resources to consumers. In addition, renewable resources will be supported by funds collected from all electricity consumers to subsidize renewable technologies. These funds will be available for several years during the transition of competitive electricity markets. Given the state's renewable resources and the current costs of different technologies, hydroelectricity, biomass and wind energy are likely to constitute the majority of this renewable energy.

The state also included residential, commercial and industrial energy efficiency investments designed to reduce peak electric demand and reduce overall use. Like renewable resources, "demand-side" efficiency investments will be supported through the transition to competitive electricity markets by a surcharge collected on all electricity sales. The types of investments expected to result in reduced electricity use include high-efficiency lighting and heating systems and improved windows and insulation. Over time, competitive energy service companies are expected to provide efficiency services, reducing the need for this subsidization.

Transportation represents the highest percentage of CO_2 emissions in NH. Over time, the estimated 1-percent improvement in new fuel efficiency annually is expected to provide moderate CO_2 reductions; however, these reductions are much smaller than those expected from the power generation sector.

Industrial process emissions are expected to decrease as both new regulations and greater compliance with existing regulations are achieved over the next several years.

Model Results From Harmonized Strategies. Harmonized strategies to reduce CO_2 from the electric generation, transportation and industrial sectors have a cumulative impact on other criteria pollutant emissions. However, reductions from any one sector do not dominate statewide averages for reductions, as shown in *Table 9*.

Benefits for both GHGs and criteria pollutants are most pronounced in the electric and transportation sectors. In the electric sector, the largest reductions are realized from the displacement of coal-fired generation with gas-fired combined-cycle generation. Together, the electric sector strategies yield SO_2 reductions of over 23,200 tons per year (49 percent), NO_x, reductions of over 8,200 tons per year (46 percent), PM reductions of 972 tons per year (48 percent) and CO_2 reductions of over 1.5 million tons per year (31 percent).

In the transportation sector, the harmonized strategies yield CO reductions of over 7,800 tons per year (5 percent), NO_x reductions of over 1,100 tons per year (4 percent) and CO_2 reductions of over 256,000 tons per year (5 percent).

Overall, NH would reduce approximately 2.0 millions tons of CO_2 per year (12 percent), over 23,000 tons of SO_2 per year (41 percent), over 9,500 tons of NO_x per year (17 percent) and over 1,000 tons of PM per year (12 percent).

Area 2: Atlanta, Georgia

Area Description. Georgia is located in the southeastern U.S. and is bordered by Tennessee and North Carolina to the north,

Table 9

Area 1: New Hampshire Emission Reductions from Modeled Harmonized Strategies (tons per year)

Harmonized Strategy	SO_2	NO_x	PM	VOC	CO	CO_2
Electric Generation						
Oil-fired electric generation to natural gas (25%)	2,132	161	25	0	0	118,396
Coal-fired generation displaced by natural gas combined-cycle (50%)	19,220	7,430	873	0	0	1,145,015
Renewables penetration (1%)	256	85	10	1	5	33,660
Fuel cell penetration (1%)	256	85	10	1	5	22,625
Electricity consumption DSM[a] (5% Commercial/Residential)	1,255	418	48	6	25	165,484
Electricity consumption DSM[a] (2% Industrial)	166	55	6	1	3	21,844
Total Electric Generation Emission Reductions[b]	23,285	8,234	972	9	38	1,507,024
% Reduction	49%	46%	48%	8%	2%	31%
Commercial and Residential[a]						
Heating/cooling consumption DSM (4%)	70	73	7	282	41	154,000
Total Commercial/Residential Emission Reductions[b]	70	73	7	282	41	154,000
% Reduction	4%	4%	4%	4%	4%	4%
Transportation						
Increase in LDGV fuel efficiency (1%)	5	107	2	90	723	23,512
LDGV strategies other than efficiency (5%)	47	1,063	21	887	7,163	232,788
Total Transportation Emission Reductions[b]	52	1,171	23	976	7,886	256,299
% Reduction	4%	4%	1%	4%	5%	5%
Industrial						
Industrial cogeneration (5% utility availability)	0	27	8	5	0	62,742
Industrial process emission reductions (1%)	0	0	0	151	0	699
Total Industrial Emission Reductions[b]	0	27	8	156	0	63,441
% Reduction	0	10%	6%	8%	0	4%
Total Emission Reductions in NH[b]	23,408	9,505	1,009	1,423	7,965	1,980,764
Total % Reduction in NH	41%	17%	12%	3%	4%	12%

[a] Increases in end-use efficiency results in reduced emissions at the electric generating plant.
[b] Numbers may not add up exactly due to independent rounding.

Source: STAPPA/ALAPCO, 1999.

Alabama to the west, Florida to the south and by both South Carolina and the Atlantic Ocean to the east.

Atlanta is the capital and largest urban area of GA; it is also the economic engine of GA. According to *Business Week*, the state has 4.6 major corporate headquarters per million population, the 11th highest ratio in the nation. In addition, there are 14 Fortune 500 firms headquartered in the Atlanta area.

The manufacture of transportation equipment, mainly motor vehicles and aircraft, is concentrated in the Atlanta metropolitan area. The state also has many paper mills, as well as plants manufacturing cellophane and rayon from the cellulose of pine trees. Much pine lumber and hardwood flooring is also produced, and an important furniture industry is centered at Toccoa. Other fabricated goods made in GA include industrial machinery, electronic equipment, chemicals, metal products, bricks and tiles.

The Atlanta area is a major rail hub, as well as the site of the William B. Hartsfield International Airport. One of the busiest airports in the country, Hartsfield ranks second in domestic flights behind Chicago's O'Hare International Airport. In addition, GA's principal seaports are Savannah and Brunswick; along the coast is a section of the Atlantic Intracoastal Waterway.

The Atlanta area is located in what is known as the Georgia Piedmont. The Piedmont comprises nearly one-third of the area of the state of GA. The major climate condition affecting the region is the clock-wise airflow prevailing over the mid-Atlantic ocean, known as the Azores high-pressure system. Temperatures annually average 74°F. Summers are hot (89°F) and winters are cool (57°F).

The Atlanta area is classified as serious nonattainment for ozone. This classification applies to 13 metro-Atlanta counties (Cherokee, Cobb, Coweta, Clayton, Dekalb, Douglas, Fayette, Forsyth, Fulton, Gwinnet, Henry, Paulding and Rockdale counties).

In accordance with the CAA, serious ozone nonattainment areas, like the metro-Atlanta area, were required to submit a revised SIP for ozone by November 15, 1994 which demonstrated attainment by 1999.

Area Emission Inventories. Base-case annual emissions for the greater-Atlanta nonattainment area are shown in *Table 10*. The transportation sector dominates the inventories for CO and NO_x and is also the largest contributor of PM, VOC and CO_2. Electric utilities contribute the most SO_2 (74 percent). The greater-Atlanta area has a total of three electric utility power plants, with 1996 generation of about 6,139,000 MWhs.[9] The primary fuel for the two larger plants is coal, and natural gas is the primary fuel for the smaller plant.

Electric sector CO_2 emissions are 11 percent of Atlanta's CO_2 inventory, as shown in *Figure 2*.[10] This is because over 99 percent of the area's power generation is coal-fired, resulting in extremely high CO_2 emissions per unit of electricity. Transportation sources dominate the percent contribution of all criteria pollutants except SO_2, due to the significant level of mobile source activity in the Atlanta area. On a typical weekday, residents in the metro Atlanta region travel an average of 34 miles, farther than residents of any other major metro area in the country. Also, older cars in the Atlanta area are responsible for 70 percent or more of the region's automobile-related air pollution.

Table 10

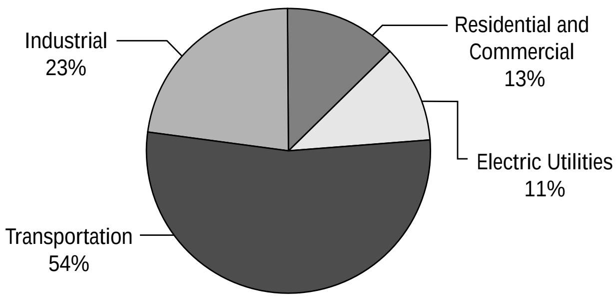
Area 2: Atlanta, GA 1996 Annual Criteria Pollutant Emissions and 1996 CO_2 Emissions (tons and % contribution to total)

Sector	SO_2	NO_x	PM	VOC	CO	CO_2
Electric Generation	42,785	12,881	641	90	777	5,651,134
	74%	*6%*	*3%*	*<1%*	*<1%*	*11%*
Commercial/Residential	1,503	14,603	1,857	3,693	19,730	6,601,287
	3%	*7%*	*8%*	*2%*	*1%*	*13%*
Transportation	7,625	159,711	11,527	138,511	1,255,557	27,587,391
	13%	*78%*	*52%*	*61%*	*95%*	*54%*
Onroad	5,152	119,626	4,299	109,716	1,056,021	22,886,852
Offroad	2,474	40,085	7,228	28,795	199,536	4,700,538
Industrial	5,395	14,922	953	75,406	2,201	11,664,310
	9%	*7%*	*4%*	*33%*	*<1%*	*23%*
Other (anthropogenic sources only)	272	1,981	7,224	9,591	41,260	0
	<1%	*1%*	*33%*	*4%*	*3%*	*0%*
Total	57,580	204,098	22,202	227,291	1,319,525	51,504,122

Sources: U.S. EPA, Acid Rain Database, 1996; U.S. EPA, Emission Trends Report, 1996; Georgia Air Protection Branch, Greenhouse Gas Assessment (unpublished), 1999.

Figure 2

Area 2: Atlanta, GA CO_2 Emissions, 1996



Source: Georgia Air Protection Branch, GHG Assessment (unpublished), 1999.

The industrial sector contributes significantly to the VOC (33 percent) and CO_2 (23 percent) emissions.

Area-Specific Harmonized Strategies. Harmonized emission reduction strategies were modeled based on the Atlanta area's mix of transportation, industry and electric generation. These strategies are shown in *Table 7* above.

Like NH, a broad array of strategies was modeled for the Atlanta area. In light of available supplies of relatively low-cost gas, and the need to reduce seasonal NO_x emissions for Georgia's ozone attainment plan, the Atlanta area power plants are assumed to switch to natural gas during the summer. New combined-cycle generation is also assumed to replace a percentage of the existing coal-fired generating plants. But, because there is currently no gas-fired generating capacity in the Atlanta area, the switch from gas steam generation to combined-cycle is not an option.

Strategies were also modeled in the Atlanta area to replace 1 percent of its current generating capacity with renewable capacity, and an additional 1 percent with fuel cell capacity over the next several years. To date, the electric industry in Georgia has not been restructured, so Georgia Power remains the supplier of all customers in the Atlanta area. Thus, this new renewable and fuel cell capacity would be developed by the utility in response to incentives or mandates from the state utility commission and/or state environmental agency. Once electric customers in the Atlanta area are allowed to chose their supplier, competing supply companies would likely begin marketing renewable power to customers.

Energy efficiency programs are expected to continue mitigating growth in electricity use and electricity-related emissions in the Atlanta area. Currently, the utilities in Georgia collect fees from ratepayers to fund energy efficiency investments and, as in other states, this is expected to continue after the industry is restructured. Together, these supply and demand-side strategies are expected to reduce emissions significantly.

In addition, the Atlanta area modeled strategy includes increases in the efficiency of residential and commercial heating and cooling systems, resulting in a 4-percent reduction in all emissions from this sector.

Mobile sources are responsible for over half of the CO_2 emissions in the Atlanta area. Therefore, national strategies (such as an estimated 1-percent improvement in fuel efficiency, and the enhancement of public transportation) are assumed to provide large CO_2 reductions.

As in New Hampshire, industrial process emissions are assumed to decrease as both new regulations and greater compliance with existing regulations are achieved over the next several years.

Model Results From Harmonized Strategies. The Atlanta area's model results are shown in *Table 11*. The largest reductions are from the utility sector, with the CO_2 inventory reduced by over 2 million tons per year (38 percent), CO emissions reduced by over 45 tons per year (6 percent) and the VOC inventory reduced by approximately 6 tons per year (5 percent).

In the transportation sector, the strategies modeled yield CO_2 reductions of over 1.1 million tons per year (5 percent), CO reductions of over 52,000 tons per year (5 percent), VOC reductions over 5,000 tons per year (5 percent) and NO_x reductions of over 4,000 tons per year (4 percent).

Industrial sources in Atlanta are responsible for 33 percent of the area's VOC inventory and less than 9 percent of other criteria pollutants. However, industry is the second largest consumer of fossil fuels (after transportation) and it contributes 23 percent of the CO_2 emissions in the Atlanta area. The package of industrial harmonized strategies yielded small CO_2, SO_2 and VOC reductions and more substantial NO_x reductions.

Efficiency gains in residential/commercial heating and cooling yield annual CO_2 reductions of over 260,000 tons, and CO reductions of roughly 790 tons per year (4 percent).

Total reductions of CO_2 emissions are 7 percent, with over 2 million tons per year coming from the utility sector. Substantial reductions in SO_2 (40 percent) are primarily the result of summertime fuel switching at the area's two coal-fired power plants and displacement of coal-fired generation with gas combined-cycle technology. Relatively high reductions in VOC (3 percent) and CO (4 percent) emissions reflect the unusually large influence of mobile sources on the Atlanta inventory.

Area 3: Louisville, Kentucky

Area Description. Located in the south central U.S. along the west side of the Appalachian Mountains, KY is the 37th largest state, with 39,732 square miles. Kentucky is bordered by seven states: Indiana, Ohio, West Virginia, Virginia, Tennessee, Missouri and Illinois. It is the 24th most populous state in the nation, with a 1996 population of 3,882,071. The Ohio River flows over 650 miles along the northern and western borders of the state.

The Louisville metropolitan area, located on the Ohio River between St. Louis and Cincinnati, has a population of over 270,000. It is composed of seven counties: Jefferson, Oldham and Bullitt counties in KY, and Clark, Floyd, Harrison and Scott counties in Indiana.

Table 11

Area 2: Atlanta, GA Emission Reductions from Modeled Harmonized Strategies (tons per year)

Harmonized Strategy	SO_2	NO_x	PM	VOC	CO	CO_2
Electric Generation						
Oil/coal generation to natural gas (up to 20%)[a]	8,528	2,005	39	0	0	702,181
Coal displaced by natural gas combined-cycle (30%)	12,792	3,686	62	0	0	1,245,457
Renewables penetration (1%)	215	72	5	1	8	37,035
Fuel cell penetration (1%)	215	72	5	1	8	20,706
Electricity consumption DSM[b] (5% Commercial/Residential)	694	233	17	3	25	120,310
Electricity consumption DSM[b] (2% Industrial)	139	47	3	1	5	24,062
Total Electric Generation Emission Reductions[c]	22,582	6,114	133	6	46	2,149,750
% Reduction	53%	47%	21%	5%	6%	38%
Commercial/Residential[b]						
DSM heating/cooling consumption (4%)	60	584	74	148	789	264,051
Total Commercial/Residential Emission Reductions[c]	60	584	74	148	789	264,051
% Reduction	4%	4%	4%	4%	4%	4%
Transportation						
Increase in LDV fuel efficiency (1%)	20	438	9	502	4,843	103,730
LDGV strategies other than efficiency (5%)	193	4,334	86	4,967	47,948	1,027,027
Total Transportation Emission Reductions[c]	213	4,772	95	5,469	52,791	1,130,756
% Reduction	4%	4%	2%	5%	5%	5%
Industrial						
Industrial cogeneration (5% utility availability)	0	37	11	7	0	86,357
Industrial process emission reductions (1%)	18	42	7	752	2	42,737
Total Industrial Emission Reductions[c]	18	79	18	759	2	129,094
% Reduction	3%	5%	2%	1%	<1%	1%
Total Emission Reductions in the Atlanta Area[c]	22,873	11,549	320	6,381	53,628	3,673,652
Total % Reduction in the Atlanta Area	40%	6%	1%	3%	4%	7%

[a] Strategy chosen by the Georgia Air Protection Branch
[b] Increases in end-use efficiency results in reduced emissions at the electricity generating plant.
[c] Numbers may not add up exactly due to independent rounding.

Source: STAPPA/ALAPCO, 1999.

The largest industries in the area, as a percentage of 1996 earnings were; services (22.3 percent), durable goods manufacturing (13.6 percent) and state and local government (11.6 percent). In 1994, Kentucky had more than 4,400 manufacturing firms, which added over $30 billion to the state's economy. Principal manufacturing industries are: industrial machinery 36,000; transportation equipment 34,300; textiles and apparel 34,100; printing and publishing 33,500; and electric and electronic equipment 26,100. However, between 1986-1996, the service sector was the fastest growing sector, expanding at an average rate of 8.3 percent per year.

The total value of KY's mineral production in 1995 was $4.4 billion. Major minerals and by-products produced in order of value are coal, crushed stone, natural gas, and petroleum. Kentucky is the nation's third largest coal producer—153.7 million tons in 1995.

Kentucky is home to 88,000 farms, averaging 159 acres. Cash receipts from farm marketing in 1995 were almost $3.1 billion; the principal products were tobacco, horse and mule sales, cattle and calves, corn, dairy products and soybeans. The state also has 12.7 million acres of commercial forestland, 50 percent of the state's land area. The state ranks third among hardwood producing states.

Kentucky's highest point is Black Mountain in Harlan County, 4,145 feet (1,264 meters) above sea level; its lowest point, the Mississippi River in Fulton County, 257 feet (78 meters) above sea level. In the average year, the average summer temperature is 88°F; the average winter temperature is 37°F; and 43 inches of precipitation fall.

The Louisville ozone nonattainment area was designated as moderate pursuant to the CAA. The Louisville ozone nonattainment area consists of Jefferson County and parts of Bullitt and Oldham Counties, Kentucky and Floyd and Clark Counties, Indiana. Only the three counties in the Louisville, KY area are included in this case study. This area was designated as a multi-State Moderate ozone nonattainment area. The Air Pollution Control District of Jefferson County, Kentucky is responsible for designing programs to attain the NAAQS for inclusion in the KY SIP.

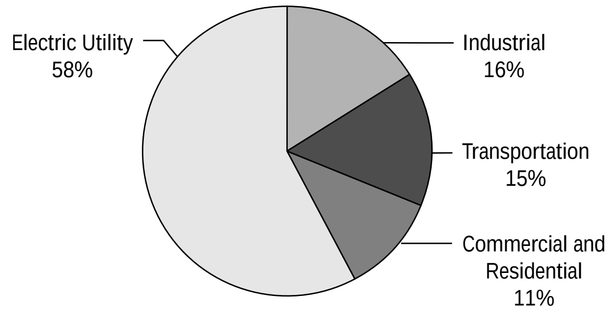
Area Emission Inventories. *Table 12* shows 1996 emission levels for conventional pollutants. The electric and transportation sectors are the most significant sources of emissions in the Louisville area. The electric sector dominates the inventory of both SO_2 (88 percent) and CO_2 (58 percent). The electric sector also emitted more NO_x (43 percent) than any other sector. The transportation sector emits the most PM (36 percent), VOCs (44 percent) and CO (81 percent) in Louisville.[11] The Louisville area has three power plants, two located in Kentucky, one in Indiana (excluded from this analysis). In 1996, the total generation at these plants was over 14 million MWhs. The primary fuel for all three plants is coal.

Figure 3 shows 1996 CO_2 emissions from the major sectors in the Louisville, KY area.[12]

Area-Specific Harmonized Strategies. The dominance of power plant emissions in Louisville's SO_2, NO_x and CO_2 inventories led to a focus on strategies in this sector. The mix of strategies modeled is shown in *Table 7* above. The primary electric sector strategy is the replacement of 25 percent of the area's coal-fired capacity with gas-fired combined-cycle capacity. Other electric sector strategies include replacing 1 percent of existing coal-fired generation with generation from renewable sources and an additional 1 percent with generation from fuel cells. Since Kentucky has not yet introduced competition into its electric industry, this renewable and fuel cell capacity would be developed by the local utility, Louisville Gas & Electric, as opposed to competitive energy suppliers. When the state's electric industry is restructured, competitive electricity suppliers could be expected to participate in this development of low-emission generating resources. In addition, energy efficiency strategies implemented by the industrial sector

Figure 3

Area 3: Louisville, KY CO_2 Emissions, 1996



Source: Jefferson County Air Pollution Control District, 1996 Emission Inventory (unpublished), 1999.

Table 12

Area 3: Louisville, KY 1996 Annual Criteria Pollutant Emissions and 1996 CO_2 Emissions (tons and % contribution to total)

Sector	SO_2	NO_x	PM	VOC	CO	CO_2
Electric Generation	60,215	29,940	365	163	1,385	16,530,640
	88%	*43%*	*6%*	*<1%*	*1%*	*58%*
Commercial/Residential	2,337	8,109	589	11,364	21,969	3,101,774
	3%	*12%*	*10%*	*26%*	*16%*	*11%*
Transportation	1,563	25,044	2,049	19,154	112,961	4,214,068
	2%	*36%*	*36%*	*44%*	*81%*	*15%*
Onroad	823	18,261	869	13,928	90,992	3,856,591
Offroad	740	6,783	1,180	5,226	21,969	357,477
Industrial	3,473	6,896	1,270	12,354	1,850	4,453,565
	5%	*10%*	*22%*	*28%*	*1%*	*16%*
Other (anthropogenic sources only)	767	249	1,391	473	1,998	0
	1%	*<1%*	*25%*	*1%*	*1%*	*0%*
Total	68,356	70,238	5,663	43,508	140,163	28,300,047

Sources: U.S. EPA, Acid Rain Database, 1996; U.S. EPA, Emissions Trend Report, 1996; Jefferson County Air Pollution Control District, 1996 Emission Inventory (unpublished), 1999.

were assumed to reduce electric sector emissions by 2 percent, and efficiency strategies implemented by the commercial/residential sectors were assumed to reduce emissions by another 5 percent.

In the commercial/residential sector, emissions from non-electric energy consumption were assumed to be reduced by 4 percent through more efficient heating and cooling systems. Cogeneration in the industrial sector were assumed to reduce process emissions by 1 percent and emissions from heating by 5 percent.

As in the other areas, national auto efficiency standards are assumed to deliver a 1 percent reduction in emissions from the LDGV fleet. The conversion of diesel vehicles to CNG is assumed to deliver an additional 1 percent reduction in emissions, and incentives to reduce vehicle use provide a 5-percent reduction.

Model Results From Harmonized Strategies. These modeled strategies provided the emission reductions shown in *Table 13*. The replacement of 25 percent of the area's coal-fired power generation achieves significant SO_2, NO_x PM and CO_2 reductions. The electric-sector inventory of SO_2 was reduced by over 17, 700 tons per year (29 percent). This sector's NO_x inventory was reduced by over 8,600 tons per year (29 percent). The sector's PM inventory was reduced by 23 percent and the sector's CO_2 inventory was reduced by over 3.6 million tons per year (22 percent). Although considerably lower than the supply-side reductions, energy efficiency efforts that reduce electricity use also have a significant impact on SO_2 (over 1,600 tons per year) and CO_2 (over 500,000 tons per year).

Strategies in the transportation sector provided the largest reductions in VOC and CO of any strategies. The transportation sector's VOC inventory was reduced by over 660 tons per year (4 percent) and its CO inventory was reduced by over 4,300 tons per year (4 percent). Transportation strategies also reduced CO_2 emissions

Table 13

Area 3: Louisville, KY Emission Reductions from Modeled Harmonized Strategies (tons per year)

Harmonized Strategy	SO_2	NO_x	PM	VOC	CO	CO_2
Electric Generation						
Coal-fired generation displaced by natural gas combined-cycle (25%)	15,054	7,276	65	0	0	2,911,701
Renewables penetration (1%)	452	227	3	2	14	136,189
Fuel cell penetration (1%)	452	227	3	2	14	105,769
Electricity consumption DSM[a] (Commercial/Residential 5%)	1,461	733	10	5	45	441,440
Electricity consumption DSM[a] (Industrial 2%)	292	147	2	1	9	88,288
Total Electric Generation Emission Reductions[b]	17,710	8,609	83	10	81	3,683,388
% Reduction	29%	29%	23%	6%	6%	22%
Commercial/Residential[a]						
DSM heating/cooling consumption (4%)	93	324	24	455	879	124,071
Total Commercial/Residential Emission Reductions[b]	93	324	24	455	879	124,071
% Reduction	4%	4%	4%	4%	4%	4%
Transportation						
Increase in LDGV fuel efficiency (1%)	3	63	2	61	396	18,944
LDGV strategies other than efficiency (5%)	32	620	24	601	3,924	187,561
Total Transportation Emission Reductions[b]	35	683	27	662	4,320	206,504
% Reduction	2%	3%	1%	4%	4%	5%
Industrial						
Industrial cogeneration (5% utility availability)	0	68	20	14	0	159,848
Industrial process emission reductions (1%)	11	31	11	116	8	5,627
Total Industrial Emission Reductions[b]	11	99	31	130	8	165,475
% Reduction	3%	1%	2%	8%	<1%	3%
Total Emission Reductions in the Louisville Area[b]	17,849	9,715	164	1,256	5,289	4,179,438
Total % Reduction in the Louisville Area	26%	14%	3%	3%	4%	15%

[a] Increases in end-use efficiency results in reduced emissions at the electric generating plant.
[b] Numbers may not add up exactly due to independent rounding.

Source: STAPPA/ALAPCO, 1999.

by over 206,000 tons per year (5 percent). Overall, the strategies implemented in the Louisville, KY area achieved significant reductions in SO_2 (26 percent), NO_x (14 percent) and CO_2 (15 percent), driven largely by reductions in the electric sector.

Area 4: Ventura County, California

Area Description. With approximately 33.5 million people, CA is the most populous state, with 12 percent of the U.S. population. California generates 13 percent of the U.S. gross domestic product and is the nation's leading agricultural state.

Ventura County, with an area of 1,843 square miles and a total of 43 miles of coastline, is located adjacent to, and northwest of, Los Angeles County. The majority of the county's population is in its southern half. Ventura County is home to 740,000 people and contains ten incorporated cities, with the City of Ventura as the county seat. Ventura County's Port of Hueneme is the only deep-water port between Los Angeles and San Francisco. The port has recently been granted Port of Entry status for Foreign Trade Zone status.

Ventura County is one of three coastal counties comprising the Los Angeles region, along with Los Angeles and Orange counties. With 16.3 million residents, the Los Angeles region accounts for nearly one-half of the statewide population.

Ventura County's largest (non-agricultural) employment sectors include services, government, trade and manufacturing. Manufacturers who formerly depended on defense contracts are now producing cleaner, more energy-efficient transportation equipment and environmental technology. Exporting is expected to grow, along with electronics, apparel and biotechnology.

The northern half of Ventura County is mountainous with elevations ranging from 3,000 to 8,800 feet. This part of the county is sparsely populated. The climate is a mix of Alpine and Mediterranean. The southern half of the county's landscape ranges from the beaches of Ventura and Oxnard to the valleys and coastal mountains of Piru, Simi and Thousand Oaks. This climate is classified as Mediterranean. The vast majority of the population resides in the southern half of the county where Ventura County Air Pollution Control District's monitoring efforts are focused. The Ventura County Air Pollution Control District has divided the south county into six air basins (coastal shore, inland coastal plain, Ojai Valley, Fillmore-Piru, Simi Valley-Moorpark and the Conejo Valley). The basis for these divisions is the variety of micro-climates and topography.

The climate of the coastal shore region is dominated by the Pacific Ocean. From the spring through the fall, temperatures and humidity levels are relatively constant. Minimum and maximum temperatures are no more than 10°F apart and relative humidity ranges from 80 to 100 percent. The inland coastal plain is also greatly affected by the proximity of the ocean, but as the distance from the ocean increases, so do the heating effects of the land mass. The solar heating of the land erodes the stable marine layer of air during the late mornings, but the coastal plain is protected by hills on three sides, thus "fencing in" the marine environment and moderating temperature and humidity levels.

The California Air Resources Board (CARB) oversees on-road vehicle emission standards, fuel specifications, some off-road sources and consumer product standards throughout the state of CA. At the regional level, local air pollution control districts are primarily responsible for stationary sources and some mobile source air quality issues. In addition, the districts have lead responsibility for developing local air quality management plans, which are then submitted to CARB as part of the CA SIP.

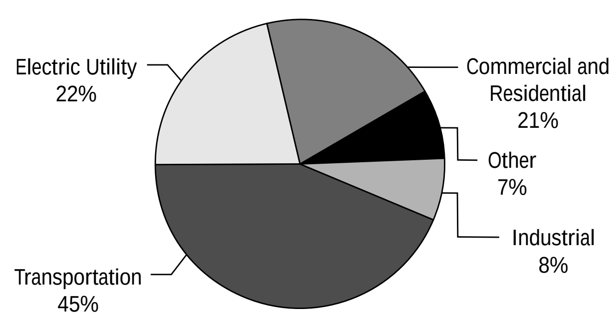
Ventura County is classified as serious nonattainment for ozone, with an attainment date of November 15, 2005. Ventura is in attainment for PM, CO, lead and SO_2.

Area Emission Inventories. Ventura County's 1996 emission profile, illustrated in *Table 14*, is notable for the lack of criteria pollutant emissions from the electric sector. This is due to the fact that the generating units in the area are fueled by natural gas, with NO_x controls bringing power generation emissions to just 2 percent of the area's total. Despite the criteria pollutant benefits of natural gas, its use is responsible for 19 percent of the area's CO_2 emissions. The largest source of both CO_2 and criteria pollutant emissions for the area is the transportation sector, contributing the majority of NO_x and CO emissions and just over half of the SO_2 and VOC emissions. The transportation portion of SO_2 is from off-road vehicles, while the remainder is residential emissions. The single largest impact of industrial sector emissions is its 8 percent contribution to CO_2 emissions. Similarly, the commercial/residential sector's largest impact is 38 percent of the SO_2 emissions.

Emissions of SO_2 in 1996 were 1,242 tons. Forty-four percent of these emissions were from non-road sources. The two Ventura County power plants both use natural gas for primary fuel. In 1996, their total generation was 2,508,997 MWhs. Transportation contributes 87 percent of the area's NO_x, 52 percent of VOC, 87 percent of CO and 45 percent of CO_2 emissions.[13] CO_2 emissions by sector for Ventura County are shown in *Table 14* and *Figure 4*.

Figure 4

Area 4: Ventura County, CA Estimated CO_2 Emissions, 1996



Source: STAPPA/ALAPCO, 1999.

Table 14

Area 4: Ventura County, CA 1996 Annual Criteria Pollutant Emissions and 1996 Estimated CO_2 Emissions (tons and % contribution to total)

Sector	SO_2	NO_x	PM	VOC	CO	CO_2[a]
Electric Generation	0	365	37	0	840	1,530,953
	0%	*2%*	*<1%*	*0%*	*6%*	*19%*
Commercial/Residential	475	1,497	4,818	6,242	5,512	1,653,600
	38%	*8%*	*30%*	*27%*	*4%*	*21%*
Transportation	694	16,462	657	11,826	109,610	3,511,680
	56%	*87%*	*4%*	*52%*	*87%*	*45%*
Onroad	146	12,775	401	10,220	94,171	2,841,015
Offroad	548	3,687	256	1,606	15,439	670,665
Industrial	73	585	402	1,497	1,570	635,995
	6%	*3%*	*2%*	*7%*	*1%*	*8%*
Other (anthropogenic sources only)	0	0	10,147	1,350	7,848	542,558
	0%	*0%*	*63%*	*6%*	*6%*	*7%*
Total	1,242	18,909	16,061	20,915	125,381	7,874,786

[a] CO_2 Inventory estimated based on CO to CO_2 ratio except electric generation CO2 from 1996 Acid Rain Database.

Source: U.S. EPA, Acid Rain Database, 1996; U.S. EPA, Emissions Trend Report, 1996; Ventura County Air Pollution Control District, 1996 Emissions Inventory (unpublished), 1999.

Area-Specific Harmonized Strategies. Given Ventura's mix of transportation, industry and electric generation, harmonized strategies were modeled to maintain needed reductions in criteria pollutants and to realize reductions of GHGs as shown in *Table 7* above.

Ventura County's gas-fired power plants make it an ideal candidate for conversion to the gas combined-cycle strategy, which was modeled at 100 percent penetration. The remaining strategies were assessed at the standard level used for the other areas.

The harmonized strategy for the penetration of renewable energy generation and fuel cells, with implementation of 1 percent each, was modeled for Ventura County. Accordingly, the siting of fuel cells would displace 1 percent of the electricity currently generated in Ventura by natural gas power plants and 1 percent would be displaced by renewable fuel generating units. The development of this renewable and fuel cell capacity is expected to be driven largely by the activity of power marketers and state funding of these technologies. California's electricity consumers currently have a choice of suppliers, who are actively marketing renewable power. In addition, the state's three largest utilities will devote nearly $150 million to the development of renewable resources through the year 2001.

Residential, commercial and industrial electricity consumption strategies can be implemented to reduce demand. The state's utilities are collecting funds from ratepayers to fund energy efficiency investments. The reductions associated with residential fuel consumption would come as a result of improved building heating and cooling strategies, with either high efficiency heating systems, thermal windows or improved wall and ceiling insulation.

Transportation represents the highest percentage of CO_2 emissions in Ventura. National strategies, such as an estimated 1-percent annual improvement in fuel efficiency applied to the current year, and the implementation of public transportation, carpooling, telecommuting and other strategies that reduce the populations' dependency on personal automobiles are expected to have a significant effect on the Ventura inventory.

Industrial process emissions were not expected to decrease in the near future because of the high concentration of natural gas use in the county, therefore the industrial process strategy was not modeled.

Model Results from Harmonized Strategies. Results of the model assessment for Ventura County are shown in *Table 15*. The power plants in Ventura County are fueled by natural gas, thus while 22 percent of the area's CO_2 inventory comes from two power plants, less than 6 percent of all other pollutants are generated at these plants. In Ventura County, strategies implemented in the electric sector provide minimal reductions in pollutants other than CO_2; for example, the electric sector strategies provide no SO_2 reductions and only 22 tons per year of NO_x reductions. The emission inventories of SO_2, NO_x and CO are dominated by transportation sources; as a result, the harmonized strategies could result in significant cuts in CO, VOC, CO_2 and NO_x emissions in

Table 15

Area 4: Ventura County, CA Emission Reductions from Harmonized Strategies (tons per year)

Harmonized Strategy	SO_2	NO_x	PM	VOC	CO	CO_2
Electric Generation						
Gas-fired generation to combined-cycle (100%)	0	0	0	0	0	532,874
Renewables penetration (1%)	0	4	.5	0	8	9,981
Fuel cell penetration (1%)	0	4	.5	0	8	3,310
Electricity consumption DSM[a] (5% Commercial/Residential)	0	12	1	0	27	32,498
Electricity Consumption DSM[a] (2% Industrial)	0	2	0	0	5	6,500
Total Electric Generation Emission Reductions[b]	0	22	2	0	49	585,163
% Reduction	0%	6%	5%	0%	6%	38%
Commercial/Residential[a]						
DSM heating/cooling consumption (4%)	19	60	193	250	220	66,144
Total Commercial/Residential Emission Reductions[b]	19	60	193	250	220	66,144
% Reduction	4%	4%	4%	4%	4%	4%
Transportation						
Increase in LDGV fuel efficiency (1%)	0	52	1	50	460	13,808
LDGV strategies other than efficiency (5%)	4	518	13	495	4,557	136,712
Total Transportation Emission Reductions[b]	4	518	14	544	5,017	150,519
% Reduction	7%	4%	2%	5%	5%	7%
Industrial						
Industrial cogeneration (5% utility availability)	0	13	4	3	0	31,466
Total Industrial Strategy Reductions[b]	0	13	4	3	0	31,466
% Reduction	0%	2%	10%	2%	0%	5%
Total Emission Reductions in Ventura County[b]	23	665	213	797	5,287	833,292
Total % Reduction in Ventura County	2%	4%	1%	4%	4%	11%

[a] Increases in end-use efficiency results in reduced emissions at the electric generating plant.
[b] Numbers may not add up exactly due to independent rounding.

Source: STAPPA/ALAPCO, 1999.

the transportation sector. Reductions of CO in that sector are over 5,000 tons per year (5 percent); VOC reductions are over 500 tons per year (5 percent); CO_2 reductions are over 150,000 tons per year (7 percent); and reductions in NO_x are over 570 tons per year (4 percent).

The major impact from the strategies in Ventura County is an overall reduction in CO_2 emissions of 11 percent. The largest single reduction of CO_2 emissions comes in the electric sector, through the switch from gas-fired steam generation to combined-cycle generation. The transportation sector has the greatest impact on total reductions of NO_x, VOCs and CO, achieving over half of the total reduction amount realized for each pollutant.

Overall Results

In aggregate, the model results for the four case study areas demonstrate that a range of effective strategies exist that can reduce both GHG emissions and criteria pollutants in significant amounts. The varying distribution of emission reductions among the four areas can be explained by their different emission inventory profiles, their respective nonattainment status for criteria pollutants and the control strategies already adopted, or to which the area has already committed. *Table 16* summarizes the total percent reductions from baseline emissions that each area would realize with its set of harmonized control strategies.

The level of emission reductions that can be achieved by states and localities through the implementation of harmonized control strategies equal or exceed the target envisioned (i.e., 7%) by the Kyoto Protocol. The harmonized control strategies also provide additional criteria pollutant reductions beyond those required under the CAA.

For each of the criteria pollutants assessed, significant emission reductions are projected beyond the reduction targets currently committed to in SIPs. The one pollutant that exhibited limited reduction benefit was direct particulate matter. In contrast, fine particulate matter, in large part resulting from secondary NO_x and SO_2 formation into nitrates and sulfates respectively, will be

Table 16

Percent Reduction from Baseline Emissions in Each Case Study Area

Area	SO_2	NO_x	PM	VOC	CO	CO_2
New Hampshire	41%	17%	12%	3%	4%	12%
Atlanta, GA	40%	6%	1%	3%	4%	7%
Louisville, KY	26%	14%	3%	3%	4%	15%
Ventura County, CA	2%	4%	1%	4%	4%	11%

Source: STAPPA/ALAPCO, 1999.

reduced significantly as a result of the relatively substantial reductions projected for SO_2 and NO_x. The pollutant-specific results are set forth below.

- **SO_2**—The bulk of the SO_2 emission reduction benefits is the result of electric sector fuel switching and advanced technology strategies. The SO_2 reduction benefits range from 2 percent in Ventura County to 40 percent in the Atlanta area and 41 percent in New Hampshire. The minimal impact in Ventura County is due to the fact that current electric generator SO_2 emissions are already very low from the use of natural gas.

- **NO_x**—The projected NO_x reduction benefits range from a 4-percent reduction in Ventura to a 17-percent reduction in New Hampshire. NO_x reduction benefits, unlike the other criteria pollutants, result from a variety of control strategies, including fuel switching at electric generators and advanced technology strategies, transportation and industrial control strategies.

- **Fine PM**—While the projected fine particulate matter reduction benefits are not specifically quantified, the substantial projected reductions of SO_2 and NO_x achieved with the implementation of the various control strategies represent a clear indication that the reduction of sulfates and nitrates will also be substantial.

- **VOC**—The projected VOC reduction benefits are, in general, smaller than the projected SO_2 and NO_x emission reduction benefits, but remain very meaningful in terms of SIP reduction targets. Major components of the VOC inventory, such as industrial and area sources, are not directly affected by the harmonized control strategies analyzed. The projected VOC reduction benefits range from 3-percent in New Hampshire, Atlanta and Louisville, to a 4-percent reduction in Ventura County.

- **CO**—In each of the case study areas, CO emission inventories are dominated by the transportation sector. As a result, the projected CO reduction benefits result almost entirely from the transportation-related control strategies analyzed. The projected CO reduction benefits are 4 percent for each case study area.

- **CO_2**—While the CO_2 reduction benefits projected for the four case study areas should be viewed as rough estimates, this analysis indicates that substantial CO_2 reductions (e.g., 7-15%) can be attained by employing an integrated, or harmonized approach to meeting criteria pollutant reduction goals and simultaneously achieving meaningful CO_2 reductions in the electricity, transportation and industrial sectors.

Conclusion

The harmonized strategy analysis among the four case study areas indicates that meaningful criteria pollutant reductions and GHG reductions can be achieved using the integrated implementation approach. The areas that participated in these case studies are not currently implementing the strategies identified, nor have they committed to implement these strategies. The purpose of these case studies is to evaluate the potential for reductions to occur if such strategies were to be pursued.

While the combination of strategies included in the harmonized scenario is capable of delivering useful reductions of GHG and criteria pollutant emissions, individual state and local areas will need to consider different combinations of strategies that can best address their respective needs. In doing so, the emphasis for policy makers and the private sector should be on the fact that many of the control strategies commonly considered for reductions in criteria pollutants would have little or no impact on GHG emissions. In particular, post-combustion controls for NO_x and SO_2, such as selective catalytic (or non-catalytic) reduction strategies for NO_x, are not capable of reducing CO_2 from the exhaust stream, and, when used to control conventional pollutants, in many cases will increase GHG emissions. In essence, once GHGs have been formed as the product of fuel combustion, they cannot effectively be reduced without expending the use of a level of energy that approaches or exceeds the energy production that formed the

GHG emissions in the first place. Therefore, control programs or incentives must be implemented that will minimize the combustion of fuel that contains carbon. This fact results in the need to implement the types of strategies identified above, and in the previous sections, demonstrating that a limited set of strategies deliver substantial CO_2 reductions while also achieving meaningful criteria pollutant reductions. A more comprehensive analysis that evaluates a broader set of strategies for specific areas has the potential to deliver even higher levels of GHG reductions. The strategic implementation of market-based strategies (e.g., tax and/or subsidies and emissions trading) will enhance or accelerate achieving these reductions.

The assessment of the strategies included in the harmonized scenario has assumed their application in addition to the existing control strategies for each area. These additional strategies will allow agencies to continue to improve air quality with regard to criteria pollutants while also addressing GHG concerns. In some cases, the harmonized strategies may be more expensive than non-harmonized options. Where this occurs, the implementation of market incentive mechanisms can effectively shift the economics in favor of the harmonized strategy. Alternatively, where GHG emission reductions are required, the motivation to implement harmonized strategies becomes internalized for the affected sources, lessening the need for market incentives to encourage the implementation of harmonized strategies.

The actions of state and local regulators are central to achieving GHG emission reductions. In continuing to address criteria pollutant nonattainment challenges, these regulators have the opportunity to obtain GHG emission reductions concurrently. The most effective path for achieving this harmonized goal is to ensure that in obtaining emission reductions needed for criteria pollutant attainment, the applied strategies should be those that also provide GHG reduction benefits rather than those that are ineffective or counterproductive from a GHG perspective.

Endnotes

[1] Speciation refers to the composition of compounds within a class of emissions, such as the mix of individual VOCs within the general VOC category.

[2] The data is available on U.S. EPA's Acid Rain Program web site at *http://www.epa.gov/acidrain* [hereinafter, *U.S. EPA Acid Rain, 1996*].

[3] U.S. EPA, *Emission Trends Viewer CD (1985-1996) Version 2.0*, Washington, D.C., July 1998 [hereinafter, *Emission Trends, 1996*].

[4] OTR states include Connecticut, Delaware, the District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont and the northern counties of Virginia.

[5] To address the regional NO_x problem, the Clean Air Act (CAA) required reasonably available control technology (RACT) rules for NO_x in the OTR in SIP revisions by November 15, 1992, with compliance required no later than May 1995. Further, SIP revisions, including an ozone attainment demonstration, were due by November 15, 1994, with compliance dates no later than May 1999.

[6] See *U.S. EPA Acid Rain, 1996, supra* note 2; *Emission Trends, 1996, supra* note 3; State of New Hampshire, *New Hampshire Greenhouse Gas Inventory* (Concord, NH: Department of Environmental Services, 1993) [hereinafter, *NH Inventory, 1993*].

[7] *NH Inventory, 1993, supra* note 6.

[8] On March 10, 1992, the Ozone Transport Commission (OTC) adopted a memorandum of understanding (MOU) committing to RACT on major stationary sources of NO_x in the OTR to control emissions of NO_x during the summer-time ozone season (May 1 through September 30 of each year). Under the MOU, states in the OTR committed to achieve reductions in NO_x emissions from large stationary sources by up to 65 percent from 1990 baseline emissions by 1999. Also OTR states are committed to adopting additional regulations by May 1, 2003, establishing a NO_x emission rate of no greater than 0.15 lb/mmBtu or a 75-percent reduction from 1990 baseline emissions.

[9] See *U.S. EPA Acid Rain, 1996, supra* note 2; *Emission Trends, 1996, supra* note 3; Georgia Air Protection Branch, *Greenhouse Gas Assessment* (unpublished) (Atlanta, GA: Georgia Air Protection Branch, 1999) [hereinafter, *GA Inventory, 1999*].

[10] *GA Inventory, 1999, supra* note 9.

[11] See *U.S. EPA Acid Rain, 1996, supra* note 2; *Emission Trends, 1996, supra* note 3; Jefferson County Air Pollution District, *1996 Emission Inventory* (unpublished) (Louisville, KY: Jefferson County Air Pollution Control District, 1999) [hereinafter, *KY Inventory, 1999*].

[12] *KY Inventory, 1999, supra* note 11.

[13] See *U.S. EPA Acid Rain, 1996, supra* note 2; *Emission Trends, 1996, supra* note 3; Ventura County Air Pollution Control District, *1996 Emissions Inventory* (unpublished) (Ventura County, CA: Ventura County Air Pollution Control District, 1999).