GLOSSARY[1]

Aerosol: Particulate material, other than water or ice, in the atmosphere. Aerosols are important in the atmosphere as nuclei for the condensation of water droplets and ice crystals, as participants in various chemical cycles, and as absorbers and scatterers of solar radiation, thereby influencing the radiation budget of the earth-atmosphere system, which in turn influences the climate on the surface of the Earth.

Afforestation: The process of establishing a forest, especially on land not previously forested.

Anaerobic Fermentation: Fermentation that occurs under conditions where oxygen is not present. For example, methane emissions from landfills result from anaerobic fermentation of the landfilled waste.

Anthropogenic: Of, relating to, or resulting from the influence of human beings on nature.

Atmosphere: The envelope of air surrounding the Earth and bound to it by the Earth's gravitational attraction.

Biomass: The total dry organic matter or stored energy content of living organisms that is present at a specific time in a defined unit (ecosystem, crop, etc.) of the Earth's surface.

Biosphere: The portion of Earth and its atmosphere that can support life.

Carbon Sink: A pool (reservoir) that absorbs or takes up released carbon from another part of the carbon cycle. For example, if the net exchange between the biosphere and the atmosphere is toward the atmosphere, the biosphere is the source, and the atmosphere is the sink.

Carbon Dioxide (CO_2): Carbon dioxide is an abundant greenhouse gas, accounting for about 66 percent of the total contribution in 1990 of all greenhouse gases to radiative forcing. Atmospheric concentrations have risen 25% since the beginning of the Industrial Revolution. Anthropogenic source of carbon dioxide emissions include combustion of solid, liquid, and gases fuels, (e.g., coal, oil, and natural gas, respectively), deforestation, and non-energy production processes such as cement-production.

Carbon Monoxide (CO): Carbon monoxide is an odorless, invisible gas created when carbon-containing fuels are burned incompletely. Participating in various chemical reactions in the atmosphere, CO contributes to smog formation, acid rain, and the buildup of methane (CH_4). CO elevates concentrations of CH_4 and tropospheric ozone (O_3) by chemical reactions with the atmospheric constituents (i.e., the hydroxyl radical) that would otherwise assist in destroying CH_4 and O_3.

Chlorofluorocarbons (CFCs): A family of inert non-toxic and easily liquified chemicals used in refrigeration, air conditioning, packaging, and insulation or as solvents or aerosol propellants.

[1] Some of the definitions shown here are taken from the *Carbon Dioxide and Climate Glossary* produced by the Carbon Dioxide Information Analysis Center of Oak Ridge National Laboratory.

Because they are not destroyed in the lower atmosphere, they drift into the upper atmosphere where their chlorine components destroy ozone.

Climate Change: The long-term fluctuations in temperature, precipitation, wind, and all other aspects of the Earth's climate.

Deforestation: The removal of forest stands by cutting and burning to provide land for agricultural purposes, residential or industrial building sites, roads, etc. or by harvesting trees for building materials or fuel.

Enteric Fermentation: Fermentation that occurs in the intestines. For example, methane emissions produced as part of the normal digestive processes of ruminant animals is referred to as "enteric fermentation."

Flux: Rate of substance flowing into the atmosphere (e.g. $lbs/ft^2/second$).

Global Warming Potential (GWP): Gases can exert a radiative forcing both directly and indirectly: direct forcing occurs when the gas itself is a greenhouse gas; indirect forcing occurs when chemical transformation of the original gas produces a gas or gases which themselves are greenhouse gases. The concept of the Global Warming Potential has been developed for policy-makers as a measure of the possible warming effect on the surface-troposphere system arising from the emissions of each gas relative to CO_2.

Greenhouse Effect: A popular term used to describe the roles of water vapor, carbon dioxide, and other trace gases in keeping the Earth's surface warmer than it would be otherwise.

Greenhouse Gases: Those gases, such as water vapor, carbon dioxide, tropospheric ozone, nitrous oxide, and methane that are transparent to solar radiation but opaque to infrared or longwave radiation. Their action is similar to that of glass in a greenhouse.

Hydrofluorocarbons (HFCs): HFCs are substitutes for CFCs and HCFCs which are being phased-out under the *Montreal Protocol on Substances that Deplete the Ozone Layer*. HFCs may have an ozone depletion potential (ODP) of zero, however, they are very powerful greenhouse gases. For example, HFC-23 and HFC-134a have a GWPs of 10,000 and 1,200 respectively.

Methane (CH_4): Following carbon dioxide, methane is the most important greenhouse gas in terms of global contribution to radiative forcing (18 percent). Anthropogenic sources of methane include wetland rice cultivation, enteric fermentation by domestic livestock, anaerobic fermentation of organic wastes, coal mining, biomass burning, and the production, transportation, and distribution of natural gas.

Nitrous Oxide (N_2O): Nitrous oxide is responsible for about 5 percent of the total contribution in 1990 of all greenhouse gases to radiative forcing. Nitrous oxide is produced from a wide variety of biological and anthropogenic sources. Activities as diverse as the applications of nitrogen fertilizers and the consumption of fuel emit N_2O.

Nitrogen Oxides ($NO_{x)}$: One form of odd-nitrogen, denoted as NO_x is defined as the sum of two species, NO and NO_2. NO_x is created in lighting, in natural fires, in fossil-fuel combustion, and in the stratosphere from N_2O. It plays an important role in the global warming process due to its contribution to the formation of ozone (O_3).

Nonmethane Volatile Organic Compounds (NMVOCs): NMVOCs are frequently divided into methane and non-methane compounds. NMVOCs include compounds such as propane, butane, and ethane (see also discussion on Volatile Organic Compounds).

Ozone (O_3): A molecule made up of three atoms of oxygen. In the stratosphere, it occurs naturally and it provides a protective layer shielding the Earth from ultraviolet radiation and subsequent harmful health effects on humans and the environment. In the troposphere, it is a chemical oxidant and major component of photochemical smog.

Perfluorinated Carbons (PFCs): PFCs are powerful greenhouse gases that are emitted during the reduction of alumina in the primary smelting process. Eventually, PFCs are to be used as substitutes for CFCs and HCFCs. PFCs have a GWP of 5,400.

Radiative Forcing: The measure used to determine the extent to which the atmosphere is trapping heat due to emissions of greenhouse gases.

Radiatively Active Gases: Gases that absorb incoming solar radiation or outgoing infrared radiation, thus affecting the vertical temperature profile of the atmosphere. Most frequently cited as being radiatively active gases are water vapor, carbon dioxide, nitrous oxide, chlorofluorocarbons, and ozone.

Stratosphere: Region of the upper atmosphere extending from the tropopause (about 5 to 9 miles altitude) to about 30 miles.

Trace Gas: A minor constituent of the atmosphere. The most important trace gases contributing to the greenhouse effect include water vapor, carbon dioxide, ozone, methane, ammonia, nitric acid, nitrous oxide, and sulfur dioxide.

Troposphere: The inner layer of the atmosphere below about 15 km, within which there is normally a steady decrease of temperature with increasing altitude. Nearly all clouds form and weather conditions manifest themselves within this region, and its thermal structure is caused primarily by the heating of the Earth's surface by solar radiation, followed by heat transfer by turbulent mixing and convection.

Volatile Organic Compounds (VOCs): Volatile organic compounds along with nitrogen oxides are participants in atmospheric chemical and physical processes that result in the formation of ozone and other photochemical oxidants. The largest sources of reactive VOC emissions are transportation sources and industrial processes. Miscellaneous sources, primarily forest wildfires and non-industrial consumption of organic solvents, also contribute significantly to total VOC emissions.

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CLIMATE CHANGE ACTION PLANS

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CLIMATE CHANGE ACTION PLAN FOR ILLINOIS

STATE OVERVIEW

Illinois completed the *Climate Change Action Plan for Illinois* in June 1994 as part two of a three-step program. During step one (development of emissions inventory), Illinois calculated the state's greenhouse gas (GHG) emissions and identified the largest sources of these emissions. The third step will be to implement the actions articulated in the state's plan.

Total emissions in 1990 were 242 million metric tons of carbon dioxide equivalent (MMTCDE). The greatest sources were fossil fuel combustion in the transportation and utility sectors with 58 MMTCDE each, and in the industrial sector with 53 MMTCDE.[1] The Action Plan for Illinois presents strategies for reducing emissions in these sectors as well as in the commercial energy and land use sectors. Strategies addressing sources with the highest emissions are shown in Table 1. Overall, the objective of Illinois' Action Plan is to reduce GHG emissions by 10 MMTCDE compared to a "business as usual" scenario, in order to reduce emissions to 1990 levels by the year 2000.

Table 1. Highest Emission Sources and Associated Mitigation Strategies

Source of Emissions	Mitigation Strategy
Transportation Fossil Fuel Combustion	CAFE (Corporate Average Fuel Economy) Standards (30, 35, and 45 mpg) Powering vehicles with gasohol, ethanol (E-100), or compressed natural gas
Utility Fossil Fuel Combustion	Natural gas switching
Industrial Sector Fossil Fuel Combustion	CO_2 scrubbers More efficient industrial motors More efficient industrial lighting

The Action Plan also identified the effects that climate change could have on Illinois. State officials are primarily concerned with potential effects on the state's agriculture, infrastructure, water resources, water and highway transportation, cooling energy, natural ecosystems, and human health.

STATE MITIGATION STRATEGIES

Illinois evaluated over 20 greenhouse gas mitigation actions for the fossil fuel and land use sectors, as well as one cross-sectoral action, as outlined in Table 2. Possible GHG reductions and associated costs are also shown in this table. The measures are summarized below.

[1] These values are from the summary of the Illinois greenhouse gas inventory.

Table 2. Greenhouse Gas Mitigation Strategies[a]

Sector	Strategy	Projected Annual Emission Reductions in year 2000 (MTCDE)	Cost of Reduction ($/MTCDE)
Fossil Fuel Combustion			
Residential	Residential A/C	130,637	-80
	New Housing Efficiency	1,769,947	-72
	Hot Water Heaters	582,422	-32
	Refrigerators	113,400	17
	Residential Furnaces	514,382	14
	Subtotal	**3,110,789**	**-47**
Commercial	Commercial A/C	136,080	-139
	Commercial Refrigeration	36,288	-37
	Commercial Lighting	518,011	13
	Subtotal	**690,379**	**-19**
Industrial	Industrial Motors	110,678	-36
	Industrial Lighting	163,296	-33
	CO_2 Scrubbers	44,772,134	33-110
	Subtotal[b]	**45,046,109**	**71**
Transportation	CAFE Standards (30 mpg)	409,147	0
	CAFE Standards (35 mpg)	1,696,464	63
	CAFE Standards (40 mpg)	2,969,266	116
	Gasohol	1,407,067	22-64
	Ethanol Vehicles (E-100)	8,364,384	30-82
	CNG Vehicles	2,489,357	51-67
	Subtotal[b]	**17,335,685**	**65**
Utility	Utility Transformers	54,432	-3
	Natural Gas Switching	21,954,240	42-57
	Subtotal[b]	**22,008,672**	**49**
Forestry	Pasture	6.85/acre	1.08
	Grazed Forest	7.65/acre	0.97
	Eroding Cropland	8.78/acre	0.76
	Subtotal	**not estimated**	**not estimated**
Cross-sectoral	Joint Implementation	**not estimated**	**not estimated**
Total		**88,191,634**	**60**

[a] Please note that the estimates in the table are given in metric tons of carbon dioxide equivalent.

[b] This subtotal was calculated based on the midpoint of the range of costs for each measure in this sector.

Fossil Fuel Combustion

Most of the measures evaluated by Illinois involve energy efficiency. Improved efficiency in the residential, commercial, transportation, and utility sectors were all estimated to offer cost savings as well as greenhouse gas reductions. Use of biofuels (gasohol and ethanol vehicles) offer possible reductions of more than 10 MMTCDE per year. The two actions with the greatest potential reductions are use of CO_2 scrubbers (45 MMTCDE) and switching from coal to natural gas for power generation (22 MMTCDE). Both of these options would require significant expenditures — costs per MTCDE are on the order of $27 to $91 for scrubbers and $34 to $47 for fuel switching.

Land Use

Afforestation is presented in the Illinois Action Plan as a low-cost, "no regrets" option that provides benefits beyond emission reductions. Tree seedlings are supplied by the state's nursery program and planted by landowners on marginal land. The 40 year levelized cost of sequestering CO_2 in Illinois is between $0.69-0.89 per metric ton, while the CO_2 offset ranges from 6.8-8.8 metric tons/acre/year. Currently, the demand for tree seedlings exceeds the supply; expansion of the state's nursery program could yield higher CO_2 sequestration at a very low cost.

Cross-sectoral

Joint implementation projects (i.e., projects whereby one country assists another in reducing greenhouse gas emissions through technology transfer or other means, and in return receives emission reduction credits) are presented in Illinois' Action Plan. These projects may be more cost-effective than domestic reductions. The Action Plan provides an example of the potential benefits of joint implementation: reducing emissions in China by 18 million short tons of carbon dioxide through *cost saving* measures is compared to spending $500 million dollars annually to achieve the same reductions in Illinois.

RECOMMENDATIONS

The *Climate Change Action Plan for Illinois* recommends the following framework for the state's policy-makers for developing a response to global climate change:

1. Make energy efficiency and forestation, which are relatively low-cost and have other environmental, social and economic benefits, the centerpiece of Illinois' climate change policy.

2. Expand the state's rural and urban tree planting programs and increase forest management assistance to private forest landowners.

3. Provide cost sharing and technical assistance to landowners and communities for tree planting and management.

4. Assist Illinois companies in meeting their commitments under the Climate Wise and Climate Challenge programs.

5. Partner with the federal government to implement energy efficiency programs under the U.S. Climate Change Action Plan.

6. Test joint implementation as an option for cost effective emissions reductions and, where efficient, promote the option for meeting long term emissions reduction requirements by utilities and industry.

7. Partner with the federal government to capture and use methane gas from landfills.

8. Promote research, development, and adoption of renewable fuels and biomass including ethanol fuel and soy-based fuel.

CLIMATE CHANGE ACTION PLAN FOR IOWA

STATE OVERVIEW

Iowa completed the *Iowa Greenhouse Gas Action Plan* (the Action Plan) in December 1996 as part two of a three-step program. During step one (development of emissions inventory), Iowa calculated the state's greenhouse gas (GHG) emissions and identified the largest sources of emissions. The third step will be to implement the actions specified in the state's plan.

Total GHG emissions in 1990 were 70.7 million metric tons of carbon dioxide equivalent (MMTCDE). The greatest sources were electric utilities with 25 MMTCDE, and agriculture with 15 MMTCDE.[2] The Action Plan for Iowa presents options for (1) reducing emissions from these sources (as shown in Table 1), as well as in the residential, commercial, industrial, and transportation sectors, and (2) increasing forest carbon sequestration. Overall, the objectives of Iowa's Action Plan are to reduce GHG emissions to 1990 levels by the year 2000 — which will require a reduction of 5.7 MMTCDE below projected baseline emissions, and to achieve further reductions by 2010.

Table 1. Highest Emission Sources and Associated Mitigation Strategies

Source of Emissions	Mitigation Strategy
Electric utilities	State & Federal voluntary programs for end users of electricity Growing energy crops Developing wind power Emissions trading (i.e., financing emission reductions in other sectors, or outside Iowa) Reporting facility-level GHG emissions
Agriculture	Reducing N_2O from fertilizers Improved manure management Continued improvement of farm efficiency

The Action Plan also identified the effects that climate change could have on Iowa. State officials are primarily concerned with the potential effects on the state's agriculture, water supply, and energy demand.

STATE MITIGATION STRATEGIES

Iowa has identified greenhouse gas mitigation measures for 7 sectors, as described below. The Action Plan discusses 34 options, and selects 16 as the most cost-effective and easily achievable. If the 16 options are implemented, the state projects that GHG emissions would be

[2] These values are from the summary of the Iowa greenhouse gas inventory.

reduced to 1990 levels by 2000.[3] The GHG reductions expected from each option are shown in Table 2.

Fossil Fuel Combustion

Residential

State and Federal programs: Residential energy efficiency options include (1) ongoing energy efficiency education programs for builders and building officials to improve compliance with requirements to construct new homes in conformance with the Model Energy Code (MEC), and (2) using Iowa's Home Energy Rating System (HERS) to indicate which homes merit energy efficient mortgages (EEMs).

Transportation

Improve vehicle fleet efficiency: The emission reduction estimates in this sector rely on implementing a revenue-neutral rebate system whereby there is a rebate for vehicles with a relatively high fuel efficiency and a fee for those that achieve fewer miles per gallon.

Discourage single occupancy trips: Options include cashing out employer provided parking in urban areas, and promoting transit use and telecommuting.The emission reduction estimates in this sector rely on implementing a revenue-neutral rebate system whereby there is a rebate for vehicles with a relatively high fuel efficiency and a fee for those that achieve fewer miles per gallon.

Commercial

State and Federal energy efficiency measures: Several programs are in force or are to be implemented in Iowa. These programs, described below, include (1)Rebuild Iowa, (2) Building Energy Management Programs (includes Iowa Energy Bank program and the Iowa Facilities Improvement Corporation), (3) Energy Star Buildings, and (4) Green Lights.

(1) The Rebuild Iowa program is an opportunity for communities to invest in cost-effective energy improvements in their schools, hospitals, local governments, colleges, commercial and industrial facilities, and multi-family dwellings. At present, with the help of a federal grant, five communities have been selected to participate in the program. As buildings become more efficient through the program, they will serve as examples for managers of similar facilities in other communities.

(2) The Building Energy Management Program provides advice, and helps identify and finance the installation of energy improvement measures for state facilities, schools, hospitals, private colleges, and local governments. Financing is structured so that energy savings cover the cost of lease or loan payments for the measures, and the payback is six years or less.

(3) Energy Star Buildings is a federal program designed to improve efficiency in heating, cooling, and air handling equipment.

(4) Green Lights, another federal program, promotes efficiency in facility lighting.

[3] The Action Plan also specifies the maximum feasible extent to which these policy options could be implemented. At the maximum feasible levels, additional GHG reductions of 19 MMTCDE would be achieved by 2010.

Table 2. Greenhouse Gas Mitigation Strategies

Sector	Strategy/Action	Annual Emissions Reductions (MTCDE) in 2010 (Priority Options)	Cost Per MTCDE
Fossil Fuel Combustion			
Residential	Improved Efficiency Measures		
	State and Federal voluntary programs	610,000	not estimated
	Sub-total	**610,000**	
Industrial & Commercial			
	Improved Efficiency Measures		
	State voluntary programs	70,000	not estimated
	Federal voluntary programs	1,900,000	not estimated
	Emissions Trading	1,810,000	not estimated
	Reporting Facility GHG Emissions	1,270,000	not estimated
	Sub-total	**5,050,000**	
Transportation			
	Improved Efficiency Measures		
	Revenue neutral fee/rebate	2,630,000	not estimated
	Economic Incentives		
	Discourage single occupancy trips	160,000	not estimated
	Sub-total	**2,790,000**	
Electricity Generation			
	Improved Efficiency Measures		
	Demand side management	180,000	not estimated
	Production of energy crops	80,000	not estimated
	Wind power development	250,000	not estimated
	Emissions trading	1,810,000	not estimated
	Reporting Facility GHG Emissions	1,270,000	not estimated
	Sub-total	**3,590,000**	not estimated
Forestry			
	Tree Planting Program	2,450,000	not estimated
	Sub-total	**2,450,000**	not estimated
Agriculture			
	Reducing N_2O from Fertilizers	360,000	cost savings
	Improved Manure Management	90,000	not estimated
	Continued Improvement of farm efficiency	90,000	not estimated
	Sub-total	**540,000**	not estimated
TOTAL		**15 million**	**Annual cost saving of $300 million**

Please note that the estimates in the table are given in metric tons of carbon dioxide equivalent (MTCDE).

Industrial

State and Federal energy efficiency measures : Voluntary programs that are currently in place include (1) Climate Wise, (2) Total Assessment Audit (TAA), and (3) Motor Challenge. These programs are explained in turn:

> (1) The Climate Wise program provides information and assistance on a range of emission reduction opportunities. Companies are encouraged to reduce emissions by measures such as altering production processes, switching to lower carbon content fuels and renewable energy, implementing employee mass transit, and tracking energy use for efficiency improvements.
>
> (2)The TAA works in conjunction with the Climate Wise Program by analyzing waste and productivity operations. The audits help firms enhance their competitive position and improve their economic success.
>
> (3) Motor Challenge promotes energy efficient electric motor systems; motor systems account for 75 percent of the electricity used in industry. The aims of the program are to increase the use of efficient motors and drive systems, improve industrial competitiveness and productivity, save energy, and decrease industrial waste and pollution.

Electricity Generation (Wind Power, Demand Side Management, and Production of Energy Crops)

Wind Power: Iowa has good potential for wind power, but at present it is not cost-effective compared to conventional energy sources, because coal fired power plants can produce electricity at less than $0.02/kW-hr. A state program developed under the 1991 Energy Efficiency Act requires utilities to purchase 105 megawatts (MW) of alternate-energy which will be provided by wind power or other sources. The Iowa Utilities Board has given investor-owned utilities a 1997 deadline for meeting this goal; the Action Plan anticipates that wind power will supply the majority of this energy supply.

Demand Side Management: Utilities are investing millions of dollars in programs to improve their customers' energy efficiency; these programs will continue and may expand by the year 2010. Spending on energy efficiency programs by Iowa utilities topped $76 million in 1994. Outreach efforts targeted 226,000 residential and business customers and encouraged improved lighting efficiency and installation of more efficient heating, ventilation, and air conditioning (HVAC) equipment.

Production of Energy Crops: Programs are underway to determine the feasibility of growing switchgrass in Iowa as a renewable biofuel that would also sequester carbon dioxide. One study has indicated that co-firing switchgrass with coal would be the most practical and economical way to establish a biomass energy industry. It further projected that with relatively low cost modifications at an existing utility, a biomass capacity of 35 MW could be achieved. This would require an estimated 200,000 tons of biomass annually.

Cross-sectoral (Commercial, Industrial and Electricity Generation)

Emissions Trading: A global, national, or regional CO_2 trading system could be used effectively to reduce overall GHG emissions while making pollution control a less expensive effort. Iowa estimated its emission reduction potential on the basis of a system similar to the sulfur dioxide allowance system in which allowances are allocated to each emitter based on their baseline CO_2 emissions.

CO_2 Emission Inventory: Under this strategy, a reporting system is proposed for greenhouse gas emissions. Like the 1986 Toxic Release Inventory (TRI) reporting program, the top ten emitters of GHGs within the state would be published. The state hopes that, as in the case of the TRI, most industries would take actions to reduce emissions to get their facilities off the list and to improve public relations. Because the program could only be implemented a few years prior to 2000, annual reductions of only 1 percent have been estimated for this strategy in the industrial and utility sectors.

Agriculture (Fertilizer Use, Manure Management, and Improvement of Farm Energy Efficiency)

Reducing N_2O from Fertilizers: A number of programs have been in effect in Iowa since 1982 to improve nitrogen management on Iowa farms. The programs include the Big Spring Demonstration project, the Integrated Farm Management Demonstration Project, the Integrated Crop Management Project, and the Model Farms Demonstration project. The education programs were funded by oil overcharge revenues at a cost of $26 million, with savings to farmers of $363 million.

Improved Manure Management: Iowa has the largest number of hogs of any state (14 million). Under the priority option, state legislation would require large producers (those with more than 5,000 animals) to have methane capture facilities by the year 2000.This will reduce emissions by 0.02 MMTCDE per year after the year 2000.

Continued Improvement of Farm Energy Efficiency: Total farm energy consumption in 1989 was only 60 percent of 1975 consumption, despite little change in acreage farmed. For this strategy it is assumed that further efficiency gains will be made, without the need for state action.

Forestry

Tree Planting Program: As a priority option, a total of 200,000 acres should be reforested with poplar and native trees by the year 2015. This would be accomplished by voluntary efforts, “free-trees” programs, Conservation Reserve Program conversion to permanent forest land, and land purchases.

RECOMMENDATIONS

The options summarized in the Action Plan are largely voluntary in nature and many have already been underway for several years. To help implement additional options that are not currently underway, the Iowa Greenhouse Gas Action Plan also recommends actions at the federal level. These are:

- Beyond adopting public policies that directly affect those within its borders, Iowa can work with other states to influence the adoption of federal policies to conserve energy and reduce CO_2 emissions.
- Emissions trading is a difficult program for Iowa to enact alone. Rather, the state should encourage the federal government to adopt an innovative CO_2 emission allowance system

that would reduce CO_2 emissions equitably and efficiently.

CLIMATE CHANGE ACTION PLAN FOR OREGON

STATE OVERVIEW

Oregon completed the *Report on Reducing Oregon's Greenhouse Gas Emissions* (the Action Plan) in March 1995, as part two of a three-step program. During step one (development of emissions inventory), Oregon calculated the state's greenhouse gas (GHG) emissions and identified the largest sources of emissions. The third step will be to implement the actions specified in the state's plan. The Action Plan describes Oregon's strategy, which consists of near-term actions (i.e., a five year action plan) and longer term actions, as well as a scenario of what it might take to stabilize Oregon's greenhouse gas emissions at 1990 levels. This scenario is presented in Appendix A of the Action Plan, and is summarized at the end of this Action Plan summary. The Oregon Department Of Energy (ODOE) does not propose that Oregon stabilize GHG emissions, because of the economic losses the state would incur in doing so. Nonetheless, the Action Plan evaluates the type and magnitude of measures required to meet a stabilization goal.

Total GHG emissions in 1990 were 56 million metric tons of carbon dioxide equivalent (MMTCDE). The greatest sources were fossil fuel combustion for transportation with 20 million MMTCDE, and electric utilities with 16 MMTCDE. [4] Oregon's strategy presents options for (1) reducing emissions from these sectors (as shown in Table 1), (2) reducing emissions from fossil fuel combustion in the residential, commercial, and industrial sectors, (3) reducing emissions from solid waste management, and (4) increasing forest carbon sequestration. Oregon predicts that its GHG strategy will reduce GHG emissions by "at least 2 million tons" (presumably, 2 million short tons of carbon dioxide equivalent) in 2015, compared to a "business as usual" scenario.

Table 1. Highest Emission Sources and Associated Mitigation Strategies

Source of Emissions	Mitigation Strategy
Transportation	Implement the Oregon Transportation Plan (including telecommuting)
Electric utilities	Consider GHG emissions in integrated resource plans. Find new ways to fund and achieve energy efficiency.

The Action Plan also identified the effects that climate change could have on Oregon. State officials are primarily concerned with the potential effects of sea-level rise on Oregon's coast.

STATE MITIGATION STRATEGIES

Oregon has identified greenhouse gas mitigation strategies for six sectors, as described below. The Action Plan does not project the GHG reductions that will be achieved by each strategy, nor the cost of the various strategies.

[4] These values are from the summary of the Oregon greenhouse gas inventory.

Residential

If extended, the Residential Tax Credit program will continue to provide loans, rebates and tax credits to households to fund energy effficiency improvements, while the Home Oil Weatherization Program will continue to fund home weatherization. In addition, the Oregon Department Of Energy (ODOE) (1) has developed standards for homes and appliances; (2) provides technical information to consumers on ways to save energy; and (3) supports pricing strategies and environmental costing policies that signal to consumers the need to conserve energy and reduce GHG emissions.

Industrial and Commercial

The ODOE has a range of energy efficiency programs for this sector, including (1) codes and standards for appliances, (2) training for building operators to run their equipment efficiently, and (3) demonstration projects for new energy saving technologies. The Oregon Resource Efficiency and Waste Prevention Program helps businesses, schools, industry, and cities use energy efficiency measures to save money and reduce GHG emissions. The program helps reduce costs by proposing ways to increase energy efficiency and decrease the production of solid waste. The state also provides incentives for the recycling of waste.

Transportation

The five year action plan calls for implementing the Oregon Transportation Plan (OTP), which would result in construction of more bike lanes and walkways. However, additional sources of state, federal, and local funding will be needed to implement this plan. As part of the OTP and in harmony with the state's "20 x 2000" executive order (which directs Oregon state government to reduce its energy use in facilities and transportation 20 percent by 2000), the ODOE is also collaborating with public and private employers to implement telecommuting; particularly in the Portland area, to meet federal air quality standards. The Business Energy Tax Credit program offers an incentive for purchasing telecommuting equipment.

The Plan also calls for the Oregon Department Of Transportation (ODOT) to develop an integrated management system that guarantees compatibility of intermodal facilities and systems. For example, it calls for rail mainlines to have convenient ramp, terminal, and reload facilities for transfers from truck to rail for longhaul movement of freight.

In addition to the OTP, the Action Plan suggests educational efforts to inform state residents about ways to save fuel when maintaining and operating their cars and trucks. The Action Plan also calls for study of the potential for encouraging the purchase of efficient cars and trucks through market-based incentives.

Utility

The Oregon Public Utility Commission requires utilities to consider CO_2 emissions as they design their integrated resource plans. Oregon recognizes that the most efficient way to limit damage is to ensure that prices signal the full costs of energy. The state continues to seek ways to incorporate environmental consequences into energy decisions. As a result of electric utility deregulation, it is hard for utilities to finance efficiency measures; because of this, the Action Plan calls for finding new ways to fund energy efficiency.

Forestry

The Oregon Forest Resources Trust (FRT), administered by the Oregon Department of Forestry, aims to plant trees in 250,000 acres of damaged, non-productive and under-productive forest lands over 15 years. Within the next five years, the state plans to fulfill a substantial portion of the goals of the FRT. The state makes low interest loans to private, non-industrial landowners for initial reforestation and rehabilitation costs. The landowners then repay the loans by paying a percentage of the after-tax receipts when they harvest the timber.

Municipal (Recycling and Solid Waste Management)

The five year action plan seeks to implement the Oregon State Integrated Resource and Solid Waste Management Plan. The solid waste plan calls for a continuous decrease in per-capita solid waste disposal, and for using recycled materials in production and manufacturing. It has a goal of a 50 percent recovery rate. As an incentive, the State's Business Energy Tax Credit program offers a 35% tax credit for purchasing equipment to recycle materials and to incorporate recycled materials into new products. By reducing the amount of waste that goes into landfills and capturing or flaring landfill gases, methane emissions from landfills will be reduced by 0.04 million tons by 2015 (beyond the reductions from the capture or flaring of methane from large landfills due to EPA's landfill gas regulation).

Cross-sectoral

Additional aims of the five year action plan include helping the Portland metropolitan area achieve the goals of its CO_2 reduction strategy. The Action Plan also calls for research on (1) the effects of climate change on water, fisheries, agricultural and forestry resources; (2) sea level rise on Oregon's coast; and (3) climate change adaptation and mitigation.

Recommendations

The five year action plan includes existing plans and regulations that are in the early stages of implementation as well as supplementary actions that could be implemented in the near term. Because of the scope of the changes and the economic consequences for a state acting alone, ODOE does not recommend actions that would stabilize emissions. In particular, ODOE found no way to achieve sufficient reductions from transportation emissions through state actions alone. Also, the state could not find a way to meet new demand in the electricity sector solely with energy efficiency and renewable energy.

In light of this, the Action Plan suggests that the following national actions should be implemented:

- Focus federal research and development, standards, incentives, collaborations, and promotion activities to give priority to reducing greenhouse gas emissions, and use pricing mechanisms to incorporate climate change externalities into the marketplace.

- Take leadership in areas where the federal government has pre-empted the states from acting (e.g., vehicle and appliance efficiency standards). Leadership would involve (1) setting standards, (2) sponsoring collaborative efforts with industry, states and other parties, and (3) achieving significant advances in research and development.

- Institute pricing mechanisms such as a carbon tax or tradable permits for carbon emissions, which would be most effective as part of a national, and probably international, effort.
- Institute a national gas-guzzler fee / gas-sipper rebate (“feebate”) program. This would be an incentive to consumers to purchase efficient vehicles, and a disincentive to purchase inefficient ones. A national program could have a greater impact than a state program in that it could influence manufacturers to provide more choices for efficient vehicles.

- Support research, development, and demonstration (RD&D) of new renewable resource technologies and efficient energy conversion technologies such as fuel cells, and re-direct RD&D funds away from fossil fuels and nuclear power and toward renewable resources and efficient technologies.

- Collaborate with other stakeholders to develop an overall appliance and equipment efficiency strategy to link new standards to RD&D and commercialization efforts.

- Revise alternative fuels policy for vehicles, to develop and promote only those fuels that reduce greenhouses gas emissions.

Additional strategies, beyond those specified in Oregon’s Climate Change Strategy, that would need to be implemented to stabilize GHG emissions in Oregon include the following:

<u>Pay-as-you-drive insurance</u> - This would involve charging an extra 50 cents per gallon of gasoline for insurance, instead of the driver paying monthly or annually. Ideally this would have to be a federal program so that people living near the state border did not have an incentive to buy fuel in other states.

<u>Corporate Average Fuel Economy standards (CAFE)</u> The GHG reductions projected for this measure assume that cars achieve 50 miles per gallon (MPG) by 2015 and light trucks 40 MPG. At present the federal government forbids states from setting energy efficiency standards. The current federal CAFE standard for cars is 27.5 MPG and for light trucks is 20.5 MPG.

<u>Feebates</u> - This is a cash incentive for consumers of efficient vehicles, combined with a surcharge to discourage consumers from buying inefficient vehicles.

<u>Better tires</u> - Driving with under-inflated tires increases fuel consumption and makes the tires wear out faster. The Action Plan relies on the US Department of Transportation to establish tire standards. An education campaign could also alert the public to the potential savings.

<u>Electric cars</u> - The scenario forecasts the potential CO_2 emission reductions from having up to 15% of new car purchases being electric cars by 2010. It further assumes that the increase in electric load will be met by renewable-based generation.

<u>Gasohol</u> - As an alternative fuel, the scenario assumes that low CO_2 gasohol will provide 20% of the gasoline market by 2000, increasing to 65% by 2010. It also assumes that gasohol will only be used in the winter months because of air quality concerns about using it in the summer.

Non-transportation petroleum fuels efficiencies - efficiency measures for commercial and industrial equipment, such as improved operations and maintenance, and boiler efficiency improvements, could reduce CO_2 emissions from such equipment by 10 percent.

SUMMARY OF APPENDIX A OF OREGON'S CLIMATE CHANGE ACTION PLAN

Hypothetical Greenhouse Gas Mitigation Strategies and Associated Emission Reductions in 2000 and 2010 (for Oregon's Stabilization Scenario)

Sector	Strategy / action	Potential annual emission reductions (MTCDE) in 2000	Potential annual emission reductions (MTCDE) in 2010
Residential	**Subtotal**	**-**	**-**
Commercial	**Subtotal**	**0**	**0**
Industrial	Improved efficiency measures		
	non-transportation petroleum efficiencies	97,070	317,520
	natural gas efficiencies	199,584	654,998
	Improved industrial processes		
	Inert anodes for alumina reduction	0	73,483
	Subtotal	**296,654**	**1,046,001**
Transportation	Improved efficiency measures		
	Freight hauling efficiency improvements	229,522	554,299
	Fuel switching		
	Cellulose and waste biomass based gasoh	213,192	509,393
	New regulations		
	Oregon transportation plan	0	684,936
	Economic incentives		
	Pay-as-you-drive insurance, High MPG cars and light trucks (CAFE), Feebates, better tires & electric cars.	1,075,939	4,093,286
	Subtotal	**1,518,653**	**5,841,914**
Electricity generation	Renewables / nuclear		
	Renewable resources and energy efficiency	233,150	2,747,909
	Subtotal	**233,150**	**2,747,909**
Forestry	Tree planting program		
	Forest Trust resources timber offsets	54,432	296,654
	Additional In state timber offsets	0	766,584
	Subtotal	**54,432**	**1,063,238**
Agriculture	***Subtotal***	**0**	**0**
Municipal	***Subtotal***	**-**	**-**
Cross - sectoral	***Subtotal***	**-**	**-**
TOTAL		2,102,890	10,114,243

Please note that the estimates in the table are given in metric tons of carbon dioxide equivalent. No cost data are provided in Oregon's Action Plan.

A dash indicates that the data are not available. Oregon also provides emission reduction estimates for 2005 and 2015***.***

Timber offsets - the stabilization plan reflects an additional 400,000 acres of Douglas fir and 350,000 acres of ponderosa pine. The cost would be about $25 - $45 per ton of carbon sequestered.

Inert anodes for alumina reduction - Technology is available to reduce perfluorocarbon emissions in the aluminum industry by 30 to 60 percent. Using an inert anode would reduce both carbon and perfluorocarbon emissions. The US Department of Energy and EPA are supporting research in this area.

Natural gas efficiencies - the stabilization scenario reflects a decrease in natural gas consumption of 10 percent as a result of new equipment standards and better design of equipment for space conditioning, water heating, cooking and commercial and industrial processes. The reductions could be greater if the federal government introduced more stringent standards for new furnaces and water heaters.

Freight hauling - reductions in diesel fuel emissions could be achieved by more aerodynamic designs; improved tires, transmissions, and engines; electronic engine controls; scheduling improvements; and reductions in empty back hauling. The stabilization scenario assumes that diesel is used mostly for freight hauling by truck and train, and that there would be a 10 percent reduction in GHG emissions as a result of the above measures.

Even with all these measures in force, Oregon would still have excess CO_2 emissions of 5 million tons above the target in 2000, and excess CO_2 emissions of 2.6 million tons in 2015. To achieve these additional GHG reductions, Oregon states that a national carbon tax or tradable emission allowances would be needed.

CLIMATE CHANGE ACTION PLAN FOR PENNSYLVANIA

STATE OVERVIEW

Pennsylvania completed *Phase II of the Greenhouse Gas Inventory: Reducing Pennsylvania's Anthropogenic Greenhouse Gas Emissions* (the Action Plan) in January 1995 as the second phase of a three-phase program. During step one (development of an emissions inventory), Pennsylvania calculated the state's greenhouse gas (GHG) emissions and identified the largest sources of these emissions. The third step will be to implement the actions specified in the state's plan.

Total GHG emissions in 1990 were 278 million metric tons of carbon dioxide equivalent (MMTCDE). The greatest sources of emissions were fossil fuel combustion in (1) the utility sector with 89 MMTCDE, (2) the industrial sector with 62 MMTCDE, and (3) the transportation sector with 57 MMTCDE.[5] The Action Plan for Pennsylvania presents strategies for reducing emissions from these sources as well as from commercial and residential fossil fuel combustion, mining and extraction, landfills, agriculture, and land use. Strategies addressing two of Pennsylvania's three highest emission sources are shown in Table 1. Overall, the objective of the Action Plan is to reduce GHG emissions "through viable mechanisms that do not inhibit the state's economy." The Pennsylvania Energy Office (PEO) did not set a target emissions level in the Action Plan, nor a target date for implementing the plan. The Action Plan does not address the effects that climate change could have on the state.

Table 1. Highest Emission Sources and Associated Mitigation Strategies

Source of Emissions	Mitigation Strategy
Utility Fossil Fuel Combustion	Clean Coal Projects Demand Side Management
Transportation Fossil Fuel Combustion	Employer Trip Reduction Enhanced Vehicle Inspection and Maintenance Program

STATE MITIGATION STRATEGIES

Pennsylvania identified more than 15 GHG mitigation strategies in the areas of fossil fuel combustion, mining and extraction, landfills, agriculture, and land use sectors, as well as five cross-sectoral actions, as outlined in Table 2. The plan identified programs currently in place as well as proposed actions to further reduce GHG emissions. The Action Plan does not provide specific emission reduction potentials for most actions, nor does it estimate costs for individual actions. The GHG reduction measures are summarized below.

[5] These values are from the summary of the Pennsylvania greenhouse gas inventory.

Table 2. Greenhouse Gas Mitigation Strategies

Sector	Strategy	Projected Annual Emission Reductions in 2010 (MTCDE)
Fossil Fuel Combustion		
Residential	Building Energy Conservation Act	not estimated
	Community Action and Resources for Energy Savings	not estimated
	Subtotal	**not estimated**
Commercial	Green Lights Program	not estimated
	Building Energy Conservation Act	not estimated
	Subtotal	**not estimated**
Transportation	Enhanced Vehicle Inspection and Maintenance Program	not estimated
	Employer Trip Reduction	not estimated
	Subtotal	**not estimated**
Utility	Clean Coal Projects	not estimated
	Demand Side Management	2,721,600
	Subtotal	**not estimated**
Mining/Extraction	Coalbed Methane Recovery and Use	**not estimated**
Landfills	Landfill Gas Recovery	not estimated
	Grants for Landfill Gas Capture	not estimated
	Subtotal	**not estimated**
Agriculture	Nutrient Management Program	not estimated
	Deep-Pit Manure Systems	not estimated
	Information Dissemination	not estimated
	Subtotal	**not estimated**
Land Use	Cool Communities	not estimated
	Stabilization of Forest Lands	not estimated
	Subtotal	**not estimated**
Cross-Sectoral	State Agency Task Force	not estimated
	PEO Partnerships	not estimated
	PEO Educational Outreach	not estimated
	Grant Programs	not estimated
	Extension of Cool Communities Program (outreach to local officials)	not estimated
	Subtotal	**not estimated**
Total		**not estimated**

Fossil Fuel Combustion

Residential

Building Energy Conservation Act (BECA) - Pennsylvania enacted BECA, Pennsylvania's Act 222, to require that design and construction of new residential buildings meet minimum energy conservation standards. This also applies to additions and renovations to existing buildings.

Community Action and Resources for Energy Savings (CARES) - Project CARES is designed to implement various energy efficiency measures in specific communities. One such activity involved weatherization improvements in a low to moderate income apartment complex.

Commercial

Green Lights Program - PEO encourages small businesses to participate in EPA's ongoing *Green Lights* Program, which promotes energy efficiency in lighting.

Building Energy Conservation Act (BECA) - BECA, described above for the residential sector, also applies to commercial buildings.

Transportation

Enhanced Vehicle Inspection and Maintenance Program - This program requires automobiles to operate at "standardized efficiencies" that reduce emissions.

Employer Trip Reduction Program - This program reduces the number of vehicles traveling to and from employment sites by promoting measures such as "high occupancy vehicles, enhanced transit services, and improved parking management measures for companies [with more than 100 employees] in areas of severe ozone nonattainment." In addition, "each large employer in the five-county area around Philadelphia is required to achieve a commuting employee passenger occupancy of approximately 25% more than that of the area-wide average occupancy per commuting vehicle."

Utility

Clean Coal Projects - The Pennsylvania Energy Authority has designated nearly $13 million dollars for research projects focused on environmental enhancement, energy efficiency, and conservation. To date, 58 Clean Coal Projects have been supported.

Demand Side Management Plans - These plans will evolve into programs that prevent emissions of carbon dioxide by over 2.7 MMTCDE per year by 2010. All Pennsylvania utilities are required to submit demand side management plans to the Pennsylvania Public Utility Commission.

Mining/Extraction

Coalbed Methane Recovery and Use - The plan proposes that PEO and the Department of Environmental Quality should work collaboratively to implement a program to encourage the capture and use of coalbed methane.

Landfills

Landfill Gas Recovery - Seven of the landfills in Pennsylvania are already recovering landfill methane or are planning to do so. The PEO and the Department of Environmental Regulation (DER) participate in EPA's Landfill Methane Outreach Program as State Allies.

Grants for Landfill Gas Capture - The Pennsylvania Economic Development Financing Authority (PEDFA) makes low-interest loans for landfill gas recovery projects. PEDFA makes loans for up to 100% of project costs, at 75 percent of the prime interest rate, for a term of up to 30 years.

Agriculture: Manure Management

Nutrient Management Program - the Department of Agriculture operates a Nutrient Management Program that provides information to farmers and others, and sponsors programs on issues such as alternative uses for manure.

Deep-Pit Manure Systems - The Pennsylvania Department of Agriculture and the Pennsylvania Department of Environmental Resources are actively pursuing the enhancement of deep-pit manure systems to collect methane for use in near-site electricity generation.

Information Dissemination - The plan proposes that the PEO and the Department of Agriculture should provide farmers with information about energy-efficient sustainable farming practices.

Land Use

Cool Communities - This program, organized by PEO and the DER, creates local partnerships to reduce the urban heat island effect through strategic tree planting and surface color lightening.

Forest Lands - Pennsylvania forest growth exceeds harvests; as a result, the state's 17,000,000 acres of forest lands sequester approximately 141 MMTCDE a year.

Cross-sectoral

State Agency Task Force - Pennsylvania established a task force of state agencies (PEO, Public Utilities Commission, Department of Agriculture, Department of Transportation, and Department of Commerce) to formulate state policies to reduce greenhouse gas emissions.

PEO Partnerships - PEO will continue to engage in partnerships with private sector firms and local governments to establish energy conservation practices and promote the use of alternative sources of energy.

PEO Educational Outreach Programs - The plan proposes that the PEO should perform more education and outreach activities in order to make state residents more energy- and environmentally-literate. PEO staff have met with various interest groups, including the Council of Boroughs, to make progress towards achieving this goal.

Grant Programs - Pennsylvania has a number of grant programs that could reduce the emissions of greenhouse gases. These programs include the Energy and Environmental Grants Program, the Recycling Grants Program, and the Alternative Fuels Program.

Expansion of the Cool Communities Program - The plan proposes an expansion of the Cool Communities program to include an educational and technical assistance program for local officials and also an improved training program for urban foresters.

Recommendations

The Pennsylvania Action Plan suggests future actions concentrated on education and technical assistance, the adoption of environmentally sound technologies, and the establishment of a cooperative public-private approach to addressing GHG emissions. These recommendations, taken verbatim from the Action Plan, are listed below:

1. Community Action Programs, consisting of direct technical assistance, public information programs, and the development of tailored energy and environmental programs, have been proposed. These multi-phased community energy efficiency programs would focus the attention of local leaders on the greenhouse gas issue and provide these leaders with information and assistance on energy and environmental issues.

2. Expansion of the Cool Communities Program to include an educational and technical assistance program for local officials and also an enhanced training program for urban foresters. This enhanced training in cool community concepts will better equip urban foresters to provide on-site assistance to communities interested in implementing the program.

3. As an extension of the Cool Communities Program, the Commonwealth should organize and implement a program of outreach and technical assistance to local governments in the area of energy efficiency. This type of program could be developed by the PEO and delivered to local governments through existing training and outreach services conducted by the Pennsylvania Department of Community Affairs.

4. The PEO and the DER should work together to implement a program to facilitate the capture and use of coalbed methane. Such a program could be modeled after the Landfill Gas Outreach Program. A potential mechanism for this program may involve the DER which, through its Bureau of Oil and Gas Management, has held a series of meetings to pursue a coalbed methane program.

5. The Commonwealth, through the PEO and the Department of Agriculture, should expand information to farmers about sustainable farming practices which not only are energy efficient, but which are also beneficial to the local environment. This could be accomplished through the use of existing mechanisms such as the Nutrient Management Program. This could also include developing a joint strategy to develop cost effective designs for small scale on-farm digesters that would collect methane and turn it into a usable energy source for the farm. A mechanism of this could be financial assistance for the design of such systems offered through the Commonwealth programs, such as the Agricultural Technology Loan program in the Department of Agriculture or from other sources, such as the Center for Rural Development. In addition, the Department of Agriculture, in conjunction with the PEO, should develop Pennsylvania’s electrofarming potential through use of crops like C-4 switchgrass.

CLIMATE CHANGE ACTION PLAN FOR WASHINGTON STATE

STATE OVERVIEW

Washington State completed the *Greenhouse Gas Mitigation Options for Washington State* (the Action Plan) in April 1996 as part two of a three-step program. During step one (development of emissions inventory), Washington calculated the state's greenhouse gas (GHG) emissions and identified the largest sources of emissions. The third step will be to implement the actions specified in the state's plan.

Total GHG emissions in 1990 were 61 million metric tons of carbon dioxide equivalent (MMTCDE).[6] The greatest sources were fossil fuel combustion for transportation with 42 MMTCDE; land use (especially forest changes including land conversion and slash burns) with 38.1 MMTCDE;[7] and industrial processes (especially aluminum production) with 6 MMTCDE. The Action Plan presents strategies for reducing emissions from these sources as well as from fossil fuel combustion in the residential, commercial, and utility sectors. Strategies addressing sectors with the highest emissions are shown in Table 1. In order to reach the goal of returning GHG emissions to 1990 levels, Washington would need to reduce emissions by 16.3 MMTCDE by the year 2010 (the target year for the Action Plan), in comparison with emissions under a "business as usual" scenario.

Table 1. Highest Emission Sources and Associated Mitigation Strategies

Source of Emissions	Mitigation Strategy
Fossil Fuel Combustion for Transportation	Increased Parking Fees Tire Pressure Check Gasoline Tax Feebate More Efficient Airplane Engines
Land Use: Forest Changes	Afforestation
Industrial Processes: Aluminum Production	Aluminum Manufacturing Process Improvements

The Action Plan also identified the effects that climate change could have on Washington. State officials are primarily concerned with potential effects of sea-level rise, especially for the central-south Puget Sound and central coastal areas.

STATE MITIGATION STRATEGIES

Washington evaluated more than 35 GHG mitigation strategies for fossil fuel combustion, industrial processing, and land use sectors, as outlined in Table 2. It should be noted that the potential programs identified in this report did not undergo highly detailed review and the

[6] This value is from the summary of the Washington greenhouse gas inventory.
[7] These land use emissions are offset by 46.4 MMTCDE sequestered through Washington's net annual forest growth.

estimated emission reductions and costs only identify the most promising programs. Flexibility, economic efficiency, and feasibility were considered in determining promising programs. One of the criteria for selecting mitigation strategies was cost-effectiveness: actions with costs higher than $100 per metric ton of GHG controlled were rejected. The GHG reductions expected from each strategy, and associated costs, are shown in Table 2. It is very important to note that in terms of greenhouse gas emissions, there is often overlap between sectors. For example, little is gained from reduced residential electricity use if the electricity displaced is from a renewable resource. Therefore, the emission reduction estimates presented herein can not be added across sectors. Washington's GHG strategies are summarized below.

Fossil Fuel Combustion

Residential

Existing Home Retrofits: Potentially, large reductions of GHG emissions may result from efficiency measures, conservation, and fuel switching in existing homes. Washington has a large inventory of homes built before 1970 which lack adequate insulation. These homes provide a great opportunity for energy savings; it is cost effective to retrofit insulation in the ceiling and crawl space to an R-19 level and in exterior walls to an R-11 level. Other possibilities for reductions include: converting to electric space and/or water heating to natural gas, installing low-flow shower heads, and installing compact fluorescent light bulbs. A program aimed at replacing incandescent bulbs with fluorescent bulbs could result in as much as a 130 megawatt reduction in the state's average electricity demand.

New Building Practices: Upgrading the residential energy codes to class 35 windows (e.g., windows with an insulation value of U-3.5) for new construction is one cost-effective option to reduce GHG emissions through energy conservation, because the energy savings exceed the cost of the upgraded windows. In addition, emission reductions can be obtained through upgrading the residential energy codes for insulation used in new construction (see Table 2).

Commercial

Food Refrigeration Efficiency Improvements: Several measures for commercial food refrigeration systems offer large energy savings. For example, multiple compressors in parallel reduce energy use 13 to 27 percent, and glass doors for supermarket display cases lower energy use 30 to 60 percent.

Fluorescent Lighting Retrofits: Implementing commercially available lighting technologies could lower lighting electrical use by 40 percent. Potential efficiency improvements include: fluorescent lamps, ballasts, lighting fixtures, and lighting control switches.

Improvements for Public Buildings: There is the potential for improving the energy efficiency of many public buildings, such as schools, recreational facilities, prisons, etc. Conservation measures would include lighting (e.g., controls that reduce hours of operation), heating, ventilating and air conditioning systems (e.g., improved controls and operation), building envelopes (higher insulating windows), and improved appliances (e.g., low-flow faucets).

Transportation

More Efficient Airplane Engines: Commercial jet fuel is one of the fastest growing areas of fossil fuel consumption. Between 1990 and 2010 consumption in Washington is projected to almost double and carbon dioxide emissions are estimated at over 17.2 MMTCDE. The *Ultrahigh* bypass high-efficiency, unducted fan engine is one way to reduce these emissions.

Table 2. Greenhouse Gas Mitigation Strategies[a]

Sector	Strategy/Action	Potential Annual Emission Reductions (MTCDE) in 2010	Cost per MTCDE
Fossil Fuel			
Residential	Existing Home Retrofits		
	Install Fluorescent Lighting	417,312	not estimated
	Hot Water Tank Upgrade	3,629	$3
	Direct Use of Natural Gas	226,800	cost savings
	R-19 Attic Insulation, Electrically Heated Homes	189,605	cost savings
	R-11 Wall Insulation	102,514	cost savings
	R-19 Floor Insulation for Natural Gas Homes	105,000	cost savings
	R-30 Attic Insulation for Natural Gas Homes	13,608	cost savings
	Low Flow Shower Heads	6,350	cost savings
	R-11 Duct Insulation for Natural Gas Homes	9,979	$18
	Caulking Joints in Natural Gas Homes	4,536	$3
	New Building Practices		
	Class 35 Windows Code	96,163	cost savings
	R-30 Floor Insulation Code for Natural Gas Homes	15,422	$65
	R-38 Attic Insulation Code for Natural Gas Homes	5,443	$82
	R-21 Wall Insulation Code	22,680	$86
	Subtotal	**1,219,042**	**insufficient data**
Commercial	Fluorescent Lighting Retrofits	4,898,880	cost savings
	Food Refrigeration Efficiency Improvements	498,960	cost savings
	Improvements for Public Buildings	397,354	cost savings
	Subtotal	**5,795,194**	**cost savings**
Transportation	More Efficient Airplane Engines	725,760	cost savings
	Tire Pressure Check	31,752	cost savings
	Parking Restrictions	not estimated	not estimated
	FeeBate ($100/MPG off baseline)	3,991,680	$0
	Gas Tax ($1.00/gallon)	7,711,200	$17
	Vehicle Mileage Tax (0.04/mile)	7,439,040	$50
	Diesel to Electric Train Conversion	199,584	not estimated
	Truck to Train Mode Shift	1,524,096	not estimated
	Subtotal	**21,623,112**	**insufficient data**
Utility	Chemical Boiler Cogeneration	371,952	cost savings
	Landfill Gas Combustion	448,157	$0
	Animal Manure	9,979	$2
	Wood Waste Combustion	136,080	$88
	Agricultural Waste Combustion	255,830	$103
	Wind	408,240	not estimated
	Nuclear Power	2,685,312	$28
	Subtotal	**4,315,550**	**insufficient data**
Industrial	Petroleum Refining Process Improvements	121,565	not estimated
	Pulp and Paper Process Improvements	95,165	not estimated
	Aluminum Process Improvements	1,074,125	not estimated
	Subtotal	**1,290,855**	**not estimated**
Land Use - Forest	Afforestation	**4,989,600**	**$4**
Total[b]		**39,233,352**	**insufficient data**

[a] Please note that the estimates in the table are given in metric tons of carbon dioxide equivalent.
[b] Please note that the emission reduction estimates are not additive. See text for further explanation.

Given the mobile nature of airplanes and interstate commerce issues, the Action Plan noted that an individual state can do little to promote acquisition and use of these engines. Progress will depend upon federal action.

Increased Parking Fees: Many commuters do not bear the full costs of parking and, as a result, drive more frequently than is socially optimal. Increasing the cost of employee parking to reflect its full costs would correct this inefficiency. However, it will be difficult to persuade commuters who currently receive free parking to accept this change. Unless other salary or benefit adjustments were made, commuters would bear the costs while employers would reap the benefits. Under one option, the state could require employers to pay a parking fee for every employee using a single occupant vehicle to get to work.

Tire Pressure Check: A slight modification of the Inspection and Maintenance (I&M) program could improve automobile efficiency. At any given time, approximately half the motor vehicles have under-inflated tires. These vehicles suffer an efficiency loss of about one mile per gallon. Incorporating tire check/inflation into the I&M procedure would reduce gasoline consumption and carbon dioxide emissions.

Gasoline Tax: Higher fuel prices due to a gasoline tax would result in improved vehicle efficiency and lower vehicle miles traveled. Commuters would acquire more fuel efficient vehicles and adopt behaviors which lower transportation demand, such as moving closer to work or using alternatives to single occupancy vehicles. The reduction in travel and the improvement in fuel efficiency could save 900 million gallons of gasoline.

FeeBate: A feebate system sets a standard level of motor vehicle efficiency against which each new motor vehicle is compared. A fee is charged to purchasers of vehicles below the efficiency standard and a rebate is awarded to those who purchase vehicles above the standard.

Vehicle Mileage Tax: A vehicle mileage tax raises travel costs in order to reduce vehicle miles traveled. Data from the Washington State Department of Transportation suggest that a $0.04 per mile tax could lower vehicle travel by approximately 18.6 billion miles in the year 2010. This would result in a reduction of 866 million gallons of gasoline and thus would lower GHG emissions.

Diesel to Electric Train Conversion: In Washington, trains consume significant quantities of energy. Electric trains emit 15 percent less carbon dioxide per ton-mile than do diesel trains. Thus, conversion of diesel trains to electric trains would reduce GHG emissions.

Truck to Train Mode Shifts: Trains consume much less energy per ton-mile than trucks. Assuming a conservative in-use energy consumption truck-to-train ratio of 3:1, approximately 330 pounds of carbon dioxide emissions are reduced for every 1,000 ton-miles of freight diverted from trucks to trains. The feasibility of such a shift depends on both the proximity of current rail facilities to cargo origination and destination points, and the capacity of rail facilities to absorb the new load. Absorbing the new load does not appear to pose a problem because the national rail network operates at about 20-25 percent of capacity. However, the extent to which truck cargo may be diverted to trains is uncertain.

Utility

Chemical Boiler Cogeneration: Washington has 19 paper mills, nine of which have chemical recovery boilers. Chemical recovery boilers recycle chemicals used to pulp wood into fiber, reduce wastewater discharges, and create excess steam which is used to produce electricity. Washington State Energy Office (WSEO) estimates that upgrades to four boilers along with new generating equipment at five other boilers would increase the electricity generating capacity in this sector to over 203 aMW (average megawatt).

Landfill Gas Combustion: Landfills in Washington are projected to produce 369,775 metric tons of methane in 2010. WSEO projects that a collection system will capture about 75 percent or 277,331 metric tons of methane. At a conversion rate of 9.4 MW/trillion Btu for internal combustion engines, landfill methane could produce about 140 aMW of electricity in 2010.

Animal Manure: Dairy cows provide the major recoverable animal manure resource in Washington. In 1992, the manure generated by about 242,000 dairy cows had the potential to produce 26 aMW of electric power. A cost per kWh of 0.039 and 0.041 is estimated for herd sizes of 1500 and 750 head, respectively. Assuming a size cut off of 750 head, a 5.5 aMW generation potential exists from manure methane recovery and electricity generation. The climate change benefits of this strategy not only include the displacement of electricity from other generating sources, but also includes a reduction in methane emissions.

Wood Waste Combustion: Woody residues include two potential biomass fuels — forest residues and mill residues. Forest residues include material left after a timber harvest, stagnant and dying timber, hardwood stand conversions, and pre-commercial thinnings. Washington projects that 2,350 Mbtu of forest residues will be economically available for energy production each year beginning in 2010. Mill residues are generated when timber is converted into lumber and plywood. A projected 5,500 Mbtu of mill residues are assumed to be economically available to produce electricity in 2010. Alternative wood-fired power plants could supply approximately 43.5 aMW of electricity in 2010.

Agricultural Waste Combustion: Crop residue burning as a source of electricity generation in Washington has the potential to offer important GHG reduction benefits. Approximately 50,000 MBtu of residues are annually left on Washington fields. Washington does not currently practice agricultural waste combustion to produce power, however other areas such as California do utilize this resource.

Wind: Using current wind turbines, Washington's estimated wind resources are approximately 900 MW. The potential for wind energy in Washington State is limited by the windiness of an area, competing land uses, and the cost of project development. The intermittent nature of wind gives rise to concerns about its ability to supply base-load needs. However, for Washington, it is an attractive complement to the regional hydroelectric energy system.

Nuclear Power: There is one nuclear powered electricity generation facility operating in Washington, WNP-2. In 1994, it operated at a capacity factor of 71.8 percent and generated about 840 aMW of electricity. Because no fossil fuel was combusted, the 840 megawatts generated by WNP-2 reduced GHG emissions by 2.69 MMTCDE.[8]

Industrial Processes

Petroleum Refining Process Improvements: The adoption of available state-of-the-art technologies can reduce energy consumption in the petroleum sector by about one-third. For example, improvements could be made to the distillation method which is one of the most energy-intensive steps in the refining process. Distillation is the primary process for breaking down crude oil into its constituent hydrocarbons. Technologies such as vapor recompression, staged crude preheating, and air condensers can reduce energy use in distillation by 55 percent.

[8] Note that the Action Plan takes no position on the environmental issues surrounding nuclear power.

Pulp and Paper Process Improvements: The adoption of state-of-the-art technologies by the pulp and paper industry could reduce energy consumption by 29 percent below that of current average practices. For example, improvements could be made to drying and stock preparation which are the most energy-intensive activities of paper production. Modern technologies such as top-wire formers and improved mechanical and thermal water removal techniques can reduce the energy use of this stage by approximately 32 percent.

Aluminum Process Improvements: The adoption of state-of-the-art technologies in the aluminum industry would reduce energy consumption by 16 percent below that of current average practices. Smelting consumes about 65 percent of the energy used in aluminum production. Using the latest technology for smelters would result in a 11 to 18 percent efficiency improvement.

Land Use

Forest Changes

Afforestation: This strategy will sequester carbon dioxide by planting idle cropland with trees. The 1992 Department of Commerce Agricultural Census reports approximately 450,000 acres of idle cropland in Washington. A study cited in the Action Plan estimates that newly planted Pacific coast forests sequester 12.2 tons of carbon dioxide per acre.

Recommendations for Federal Action

Washington's Action Plan emphasized that major progress in reducing GHG emissions in many of the areas of the transportation sector depends on action by the federal government. Several of the state's recommendations for federal action follow.

- Washington suggested that the federal government implement more stringent standards for motor vehicle fuel efficiency. The U.S. government is the sole regulator of motor vehicle fuel efficiency and federal statutes prohibit states from establishing motor vehicle efficiency standards. Federal regulation began in 1976 through Corporate Average Fuel Efficiency (CAFE) standards. Proponents of fuel efficiency standards argue that currently available technologies could markedly improve motor vehicle efficiency. The Congressional Office of Technology Assessment (OTA) projected that regulatory pressure could raise average new car fuel efficiency by about 13 percent in 2000 and 22 percent by 2005.
- The federal government could support FeeBate programs. The U.S. Department of Transportation (DOT) blocked Maryland's effort to enact a FeeBate program. DOT held that fuel economy incentive programs are preempted by federal statute. Maryland's Attorney General, while conceding that certain aspects of the Maryland law violated the federal preemption, otherwise affirmed the state's right to enact a FeeBate. Presently, the legality of a feebate based on fuel efficiency is uncertain.
- Washington can do little to promote acquisition and use of the *Ultrahigh* bypass high-efficiency airplane engine because of the mobile nature of airplanes and interstate commerce issues. Progress in the adoption of this engine technology depends upon federal action.
- Federal government policies could directly promote rail transportation in the form of subsidies or tax breaks.

RECOMMENDATIONS

The Washington Action Plan offers the following framework for policy-makers developing a response to global climate change:

1. Actively pursue those mitigation strategies that are cost effective for reasons other than their greenhouse gas reduction benefits.

2. Efforts to reduce greenhouse gas emissions are investments in the future of the state and nation. As an investment, the mitigation program must compete with other claims on state resources (e.g., education, welfare programs, police and fire protection, etc.).

3. The use of cost effectiveness criteria to develop a mitigation program is essential. The cost of changing energy, industrial, land use, agriculture, and forestry practices range from cost savings to very expensive. Obtaining the largest emission reduction at the lowest cost is sensible.

4. The expected consequences of global climate change should drive the scope and stringency of a mitigation program.

5. Any mitigation program should consist of a diverse portfolio of programs to protect against unexpected economic and emission effects.

6. Given the uncertainties surrounding climate change, the state should consider carbon dioxide controls as insurance against as yet unknown consequences.

7. The state should commit to better understand the effects of climate change and to further develop greenhouse gas mitigation options. A better understanding of climate change reduces the need to hedge against the uncertainty and improved GHG mitigation technologies will enhance our ability to deal with surprises should they occur.

8. With regard to specific concerns within Washington, perhaps the best policy-makers can do is to identify and develop response plans for those activities/environments most sensitive to climate change. In this way the state can help minimize adverse climate change consequences should they occur.

Estimating GHG Reductions From State Actions to Improve Solid Waste Management Practices

This appendix contains three sections: (1) Background, (2) A Life Cycle Approach: Evaluating and Incorporating Solid Waste Management Actions in a Statewide GHG Mitigation Plan, and (3) Example Plan for Waste Management Mitigation Actions. The background section sketches some national trends in solid waste management actions, identifies solid waste management actions which may yield GHG reductions, and discusses the importance of integrating solid waste management actions into a statewide GHG mitigation action plan. The next section discusses the importance of using a life cycle approach for evaluating the GHG impacts of current and future solid waste management actions. In the last section of this appendix, an example MSW management scenario is presented for a hypothetical state looking to evaluate its current and future solid waste management actions from a GHG perspective. The example establishes a baseline scenario of solid waste management actions and compares it to a future scenario; the future scenario uses solid waste management as part a statewide GHG mitigation action plan.

Background

To achieve statewide source reduction and recycling goals, many states and municipalities develop municipal solid waste (MSW) management plans which include a variety of measures such as curbside collection and recycling programs, recycling drop-off centers, and yard trimmings composting facilities. According to a recent nationwide survey, 45 states have waste reduction and/or recycling goals in place.[1] Nationwide, approximately 51% of the US population has access to curbside recycling, and the number of drop-off recycling programs continues to grow.[2]

Additional MSW management measures provide opportunities for states to meet and exceed their source reduction and recycling goals. Such measures include introducing "Pay As You Throw" (PAYT) pricing for waste collection, increasing the service area or improving collection efficiency of curbside recycling programs, increasing commercial sector recycling, and banning landfilling of organic wastes such as yard trimmings. Note that in most states, the role of state government is to develop plans and standards; local governments implement solid waste policy. Thus, any state actions addressing solid waste should start with full coordination and consultation with local officials.

Many states are in the process of reevaluating their MSW management goals. This reevaluation process provides the opportunity for state and local authorities to consider the GHG reduction benefits of different MSW management strategies currently in place, and identify opportunities to further achieve GHG reductions in the MSW sector. Viewing MSW management actions from a GHG perspective provides the basis for including and integrating these management actions into a statewide GHG mitigation action plan.

A Life Cycle Approach: Evaluating and Incorporating MSW Management Actions in a Statewide GHG Mitigation Plan

To incorporate MSW management actions into a statewide GHG mitigation action plan, one must first identify the impacts of MSW management actions on GHG emissions. Heretofore, most of the focus on GHG emissions associated with waste management has been on methane emissions from landfills.

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[1] BioCycle, *The state of garbage in America*, April, 1997.
[2] Ibid.

There are, however, many emissions and sinks upstream of the point of disposal that are affected by MSW management. A life cycle approach provides an analytic framework for evaluating the full range of GHG emissions and sinks. Major GHG sources associated with MSW include carbon dioxide from fossil fuel burning associated with raw material extraction manufacturing processes, and transportation; process non-energy emissions; landfill methane; and waste combustion. These emissions are offset to some degree by energy recovery at municipal waste combustors and landfill gas collection systems, and enhanced carbon sequestration by forests and landfills.

For MSW management, EPA has conducted a streamlined life cycle inventory (LCI) focusing on the GHG impacts of ten MSW components (e.g., paper, plastics, metals) in various ways. The EPA draft working paper *Greenhouse Gas Emissions from Municipal and Solid Waste Management*[3] and the EPA's Waste Reduction Model (WARM)[4] provide GHG emission factors, for waste stream components, that are based on an LCI framework. EPA's research indicates that for many materials, the effect of recycling or source reduction on net GHG emissions is more closely related to upstream energy emissions and forest carbon sinks than to landfill methane emissions, and so a life cycle approach is able to capture the benefits of solid waste management options in a more holistic way.

EPA recognizes that LCIs have limitations. Data vary with respect to quality, quantity, validity, and robustness. For example, data may vary seasonally, regionally, and locally as a result of changes in economic activity, demographics, different state and local waste regulations, or different waste accounting practices. When state or local data are not available, it is possible to use averaged national data. Application of averaged national data may not accurately reflect state or local conditions. However, in the absence of state or local data, averaged national data are a good proxy. The EPA research to date, has very wide error bounds and is based on average national conditions; nevertheless, the information it provides on GHG emissions from waste management is suitable for estimating the impacts of voluntary GHG reduction activities.

Example Plan for Waste Management Mitigation Actions

The objective of this example is to demonstrate to developers of State Action Plans the value of incorporating waste management activities in their plans. This example uses averaged national data to estimate GHG emissions resulting from the baseline and future MSW management scenarios for a hypothetical state. The initial (baseline) scenario is based on some simple assumptions about MSW management activities in the current year. This baseline scenario provides the starting point from which to consider future changes in MSW management actions. The future scenario is based on the successful implementation of a variety of waste management activities which result in increases in overall recovery and a reduction in GHG emissions.

The hypothetical scenarios focus on a set of ten materials[5] present in the MSW stream for which EPA has estimated GHG emission factors. EPA is conducting research to develop emission factors for additional materials such as glass and wood.

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[3] EPA 530-R-97-010. March 1997. USEPA Office of Solid Waste and Emergency Response.
[4] Available through the USEPA Office of Solid Waste.
[5] These materials include paper (office paper, newsprint, corrugated cardboard), metals (aluminum cans, steel cans), plastics (HDPE, LDPE, and PET), food scraps, and yard trimmings.

Methodological Approach and Assumptions

To establish a baseline and future scenario for the hypothetical state, the following assumptions were made.

Waste Generation:

Total waste generation is the product of the per-capita waste generation rate and the state population. In both the baseline and future scenarios, this analysis assumes a state population of 5 million people and a per-capita waste generation rate of 4.3 pounds of waste/person/day.[6]

Baseline Scenario Assumptions:

The baseline scenario assumes the state currently landfills most of its waste, and also uses waste-to-energy as a management option. Recycling actions include curbside recycling programs in major residential areas, some recycling collection centers, some yard waste composting facilities, and a limited industrial/commercial recycling program. These assumptions are based largely on *BioCycle's* "The State of Garbage In America" which reported the number and types of MSW management programs in place for each state (April, 1997).[7]

The baseline scenario assumes these programs reflect common MSW management actions at the state and local level within the US, and that these actions result in a recovery rate of 27 percent, a combustion rate of 15 percent and a landfill rate of 58 percent.[8] The baseline data are presented in Table 1.

The baseline scenario assumes 20 percent of the waste destined for landfills is managed in landfills with landfill gas (LFG) recovery systems, and that these systems have a LFG collection efficiency of 75 percent. In addition, the baseline scenario assumes an overall waste-to-energy (WTE) efficiency rate (i.e., electrical energy output divided by energy value of waste inputs) of 17 percent.

Future Scenario Assumptions:

The future scenario assumes the state implements a set of MSW management activities designed to achieve a higher total recovery rate by the year 2005 in response to state solid waste recovery goals (see Exhibit 1). The future scenario assumes these MSW management activities result in a waste recovery rate of 50 percent, a combustion rate of 15 percent, and a landfill rate of 35 percent. The future scenario data are presented in Table 2.

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[6] Calculated based on an estimated total US population of 260 million and a total amount of waste generated as reported in *Characterization of MSW in the United States 1996 Update*, EPA530-R-97-015.

[7] *BioCycle* reported approximately 49 of 51 states have curbside recycling programs, 40 of 51 states have recycling drop-off sites, and 48 of 51 states have yard waste composting facilities (for reporting purposes the District of Columbia was counted as a state).

[8] The total and material specific generation, recovery, and disposal rates are comparable to the national average rates for 1995 reported in EPA's *Characterization of Municipal Solid Waste in the United States: 1996 Update*.

Exhibit 1
Example of Future Scenario MSW Management Goals and Activities

Future Goals	Future Activities
Increase newspaper recovery rate to 67 percent.	Increase collection efficiency of curbside collection.
Increase office paper and corrugated cardboard recovery rates to 67 percent.	Expand the commercial collection of mixed paper and corrugated cardboard.
Increase yard trimmings recovery rate to 40 percent.	Promote the benefits of composting. Create yard waste drop-off centers in addition to offering seasonal curbside collection of yard waste. Ban yard waste from landfills.
Increase food waste diversion rate to 25 percent.	Expand the commercial and institutional collection of food waste discards.

Specifically, the future scenario assumes a statewide recovery rate of 67 percent for newspaper, office paper, and corrugated cardboard; 25 percent for food scraps; and a landfill ban on yard trimmings. The material-specific recovery rates for the remaining materials were adjusted upward to achieve a total recovery rate of 50 percent.

The future scenario assumes 60 percent of the waste destined for landfills is managed in landfills with landfill gas (LFG) recovery systems, and that these systems have a LFG collection efficiency of 85 percent. In addition, the future scenario assumes the overall waste-to-energy (WTE) efficiency rate improves to 19 percent.

In an actual state report, the future scenario for the total and material-specific recovery, combustion, and landfill rates would be based on the state's MSW management goals and activities.

The Waste Reduction Model (WARM)

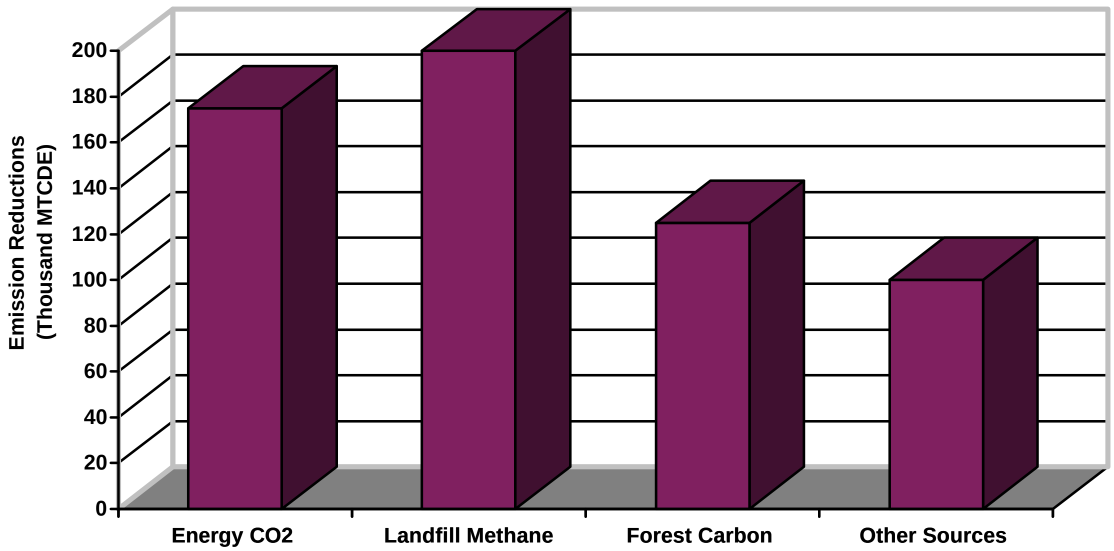
WARM, an EPA software model for estimating GHG emissions from the waste management sector, was used to estimate GHG emissions for this analysis. Table 3 presents the GHG emission estimates for the baseline scenario, and Table 4 presents the GHG emissions for the future scenario. Table 5 compares the estimates from the two scenarios.

Results of Example Analysis and Relationship to Other Mitigation Activities

WARM estimates of annual GHG emissions in the baseline and future scenarios are summarized in columns "b", "c", and "d" of Table 5. The estimated GHG emissions are 1.5 million MTCDE per year in the baseline scenario and 930,000 MTCDE per year in the future scenario. The future scenario thus reduces emissions by about 600,000 MTCDE per year.

The largest reductions in GHG emissions were for office paper (224,000 MTCDE per year), corrugated boxes (153,000 MTCDE per year), newspaper (114,000 MTCDE per year), and food waste (103,000 MTCDE per year). Most of the reductions are attributable to reduced energy-related carbon dioxide emissions, reduced landfill methane emissions, and increased forest carbon sequestration. (Exhibit 2)[9]

Exhibit 2: GHG Emission Reductions by Source



The estimated 600,000 MTCDE emission reduction predicted in this exercise is comparable in magnitude to some of the most significant tools available to states for reducing GHG emissions. For comparison, examples of policy and technology options that reduce GHG emissions by similar levels are found in several state action plans. One such option can be found in Illinois' action plan, which estimated that efficiency improvements to hot water heaters and residential furnaces have the potential to reduce GHG emissions by approximately 582,000 and 514,000 MTCDE, respectively, by the year 2000. In Oregon, improved natural gas efficiencies have the potential to reduce GHG emissions by approximately 655,000 MTCDE by the year 2010. Washington estimates that improved food refrigeration may reduce GHG emissions by approximately 500,000 MTCDE by the year 2010.

MSW management options thus represent significant opportunities for states to further reduce their GHG emissions. Because these options have other environmental benefits as well, they deserve careful consideration in Action Plans.

[9] Potential exhibit comparing the "breakout" by source for the baseline and future scenarios.

Table 1
Baseline Scenario for the Management of Municipal Solid Waste in the Current Year for a State "Mock-Up"

Baseline Scenario Assumptions

State's Population	Annual MSW Generation[1] (tons)	Percent of Total MSW Recovered	Percent of Total MSW Combusted	Percent of Total MSW Landfilled	Percent of Landfilled Waste Managed at Landfills with LFG Systems	Collection Efficiency of LFG Systems	Conversion Efficiency of Waste-to-Energy (WTE) Systems
5,000,000	4,015,000	27%	15%	58%	20%	75%	17%

Generation and Management of MSW in Current Year

	Current Waste Generation		**Current Waste Recovery**					
(a) **Material**	**(b)** **Percentage of MSW Generation[2] (by weight)**	**(c)** **Amount of Waste Generated[3] (tons)**	**(d)** **Percentage of Waste Recovered[4] (by weight)**	**(e)** **Amount of Waste Recovered (tons)**	**(f)** **Amount of Waste Discarded[5] (tons)**	**(g)** **Amount of Waste Combusted (tons)**	**(h)** **Amount of Waste Landfilled with no LFG System (tons)**	**(i)** **Amount of Waste Landfilled with LFG System (tons)**
Newspaper	6.3%	252,945	53.0%	134,061	118,884	24,428	75,565	18,891
Office Paper	3.3%	132,495	44.3%	58,695	73,800	15,164	46,908	11,727
Corrugated Cardboard	13.8%	554,070	64.2%	355,713	198,357	40,758	126,079	31,520
Aluminum Cans	0.8%	32,120	62.7%	20,139	11,981	2,462	7,615	1,904
Steel Cans	1.3%	52,195	56.8%	29,647	22,548	4,633	14,332	3,583
HDPE	1.9%	76,285	10.8%	8,239	68,046	13,982	43,251	10,813
LDPE	2.7%	108,405	1.7%	1,843	106,562	21,896	67,733	16,933
PET	0.5%	20,075	22.7%	4,557	15,518	3,189	9,863	2,466
Food Scraps	6.7%	269,005	4.1%	11,029	257,976	53,009	163,974	40,993
Yard Trimmings	14.3%	574,145	30.3%	173,966	400,179	82,229	254,360	63,590
SUBTOTAL	51.6%	2,071,740	38.5%	797,889	1,273,851	261,750	809,681	202,420
Other Materials	48.4%	1,943,260	14.7%	286,161	1,657,099	340,500	1,053,279	263,320
TOTAL	100.0%	4,015,000	27.0%	1,084,050	2,930,950	602,250	1,862,960	465,740

[1] Assuming 5 million people generate 4.4 lbs of waste/person/day.

[2] Franklin Associates, Ltd. *Characterization of Municipal Solid Waste in the United States: 1996 Update*, EPA 530-R-97-015.

[3] The product of total MSW generation and percent of MSW generation for each material. For example, 4,015,000 tons/yr x 0.063 = 252,945 tons/yr of newspaper.

[4] Percentage recovery for each material based on national average from Franklin Associates, Ltd., EPA 530-R-97-015. Yard waste recovery means back yard composting.

[5] The difference between the amount of waste generated and the amount of waste recovered.

Table 2

Future Scenario for the Management of Municipal Solid Waste by Year 2005 for a State "Mock-Up": Assuming Increased Material Recovery

Future Scenario Assumptions

State's Population	Annual MSW Generation[1] (tons)	Percent of Total MSW Recovered	Percent of Total MSW Combusted	Percent of Total MSW Landfilled	Percent of Landfilled Waste Managed at Landfills with LFG Systems	Collection Efficiency of LFG Systems	Conversion Efficiency of Waste-to-Energy (WTE) Systems
5,000,000	4,015,000	50%	15%	35%	60%	85%	19%

Generation and Management of MSW in Year 2005

	Future Waste Generation		Future Waste Recovery					
(a) Material	(b) Percentage of MSW Generation[2] (by weight)	(c) Amount of Waste Generated[3] (tons)	(d) Percentage of Waste Recovered[4] (by weight)	(e) Amount of Waste Recovered (tons)	(f) Amount of Waste Discarded[5] (tons)	(g) Amount of Waste Combusted (tons)	(h) Amount of Waste Landfilled with no LFG System (tons)	(i) Amount of Waste Landfilled with LFG System (tons)
Newspaper	6.3%	252,945	67.0%	169,473	83,472	25,042	23,372	35,058
Office Paper	3.3%	132,495	67.0%	88,772	43,723	13,117	12,243	18,364
Corrugated Cardboard	13.8%	554,070	67.0%	371,227	182,843	54,853	51,196	76,794
Aluminum Cans	0.8%	32,120	65.0%	20,878	11,242	3,373	3,148	4,722
Steel Cans	1.3%	52,195	60.0%	31,317	20,878	6,263	5,846	8,769
HDPE	1.9%	76,285	15.0%	11,443	64,842	19,453	18,156	27,234
LDPE	2.7%	108,405	5.0%	5,420	102,985	30,895	28,836	43,254
PET	0.5%	20,075	25.0%	5,019	15,056	4,517	4,216	6,324
Food Scraps	6.7%	269,005	25.0%	67,251	201,754	60,526	56,491	84,737
Yard Trimmings	14.3%	574,145	40.0%	229,658	344,487	51,673	9,646	14,468
SUBTOTAL	51.6%	2,071,740	48.3%	1,000,458	1,071,282	321,385	299,959	449,939
Other Materials	48.4%	1,943,260	51.8%	1,007,042	936,218	280,865	262,141	393,211
TOTAL	100.0%	4,015,000	50.0%	2,007,500	2,007,500	602,250	562,100	843,150

[1] Assuming the state population of 5 million people and the waste generation rate of 4.4 lbs of waste/person/day have not changed by the year 2005.

[2] Franklin Associates, Ltd. *Characterization of Municipal Solid Waste in the United States: 1996 Update* , EPA 530-R-97-015.

[3] The product of total MSW generation and percent of MSW generation for each material. For example, 4,015,000 tons/yr x 0.063 = 252,945 tons/yr of newspaper.

[4] Assuming these are the recovery rate goals achieved by the year 2005. Yard waste recovered includes back yard and centralized composting.

[5] The difference between the amount of waste generated and the amount of waste recovered.

Table 3
Estimated GHG Emissions from MSW Management Actions in the Baseline Scenario
(Estimated Using WARM)

(a)	(b)	(c)	(d)	(e)	(f)			(g)	(h)	(i)	(j)	(k)
Material	**Baseline Generation of Material (Tons)**	**Estimated Recycling (Tons)**	**Annual GHG Emissions from Recycling (MTCDE)**	**Estimated Landfilling (Tons)**	**Annual GHG Emissions from Landfilling (MTCDE)**			**Estimated Combustion (Tons)**	**Annual GHG Emissions from Combustion (MTCDE)**	**Estimated Composting (Tons)**	**Annual GHG Emissions from Composting (MTCDE)**	**Total Annual GHG Emissions (MTCDE)**
					LFs without LFG recovery	**LFs with LFG recovery**	**Total**					
Newspaper	252,945	134,061	-185,829	94,456	107,922	11,639	119,561	24,428	33,254	0	0	-33,014
Office Paper	132,495	58,695	-52,950	58,635	280,253	25,656	305,908	15,164	26,154	0	0	279,113
Corrugated Box	554,070	355,713	-405,678	157,599	301,554	22,292	323,846	40,758	42,499	0	0	-39,334
Aluminum Cans	32,120	20,139	112,359	9,519	153,774	38,444	192,218	2,462	49,764	0	0	354,341
Steel Cans	52,195	29,647	59,380	17,915	59,866	14,967	74,833	4,633	19,416	0	0	153,629
HDPE	76,285	8,239	10,230	54,064	116,933	29,233	146,166	13,982	59,954	0	0	216,351
LDPE	108,405	1,843	2,705	84,666	230,652	57,663	288,315	21,896	109,256	0	0	400,275
PET	20,075	4,557	9,087	12,329	43,149	10,787	53,937	3,189	18,023	0	0	81,047
Food Waste	269,005	0	0	204,967	142,889	-7,334	135,555	53,009	-2,212	11,029	0	133,343
Yard Waste	574,145	0	0	317,950	22,122	-32,603	-10,480	82,229	-5,694	173,966	0	-16,175
Total	2,071,740	612,894	-450,696	1,012,101	1,459,114	170,744	1,629,858	261,750	350,414	184,995	0	1,529,576

Table 4
Estimated GHG Emissions from MSW Management Actions in the Future Scenario
(Estimated Using WARMl)

(a) Material	(b) Baseline Generation of Material (Tons)	(c) Projected Recycling (Tons)	(d) Annual GHG Emissions from Recycling (MTCDE)	(e) Projected Landfilling (Tons)	(f) Annual GHG Emissions from Landfilling (MTCDE)			(g) Projected Combustion (Tons)	(h) Annual GHG Emissions from Combustion (MTCDE)	(i) Projected Composting (Tons)	(j) Annual GHG Emissions from Composting (MTCDE)	(k) Total Annual GHG Emissions (MTCDE)
					LFs without LFG recovery	LFs with LFG recovery	Total					
Newspaper	252,945	169,473	-234,916	58,430	33,380	21,435	54,815	25,042	32919	0	0	-147,183
Office Paper	132,495	88,772	-80,082	30,606	73,143	39,770	112,913	13,117	22098	0	0	54,930
Corrugated Box	554,070	371,227	-423,372	127,990	122,450	53,558	176,008	54,853	54924	0	0	-192,439
Aluminum Cans	32,120	20,878	116,481	7,869	63,563	95,345	158,908	3,373	68182	0	0	343,571
Steel Cans	52,195	31,317	62,726	14,615	24,419	36,628	61,046	6,263	26255	0	0	150,027
HDPE	76,285	11,443	14,208	45,390	49,086	73,628	122,714	19,453	81274	0	0	218,196
LDPE	108,405	5,420	7,956	72,089	98,195	147,293	245,488	30,895	150763	0	0	404,207
PET	20,075	5,019	10,008	10,539	18,442	27,664	46,106	4,517	25273	0	0	81,387
Food Waste	269,005	0	0	141,228	49,227	-15,677	33,550	60,526	-3369	67,251	0	30,181
Yard Waste	574,145	0	0	24,114	839	-8,676	-7,837	51,673	-4429	498,358	0	-12,266
Total	2,071,740	703,548	-526,991	532,871	532,744	470,968	1,003,711	269,712	453,890	565,609	0	930,610

Table 5
Comparison of Total Estimated GHG Emissions For the Baseline and Future Scenarios

(a) Material	(b) Baseline Scenario: Estimated Total Annual GHG Emissions* (MTCDE)	(c) Future Scenario: Estimated Total Annual GHG Emissions** (MTCDE)	(d) Difference Between Baseline and Future Scenario Estimates of Annual GHG Emissions (MTCDE)
Newspaper	-33,014	-147,183	-114,169
Office Paper	279,113	54,930	-224,183
Corrugated Boxes	-39,334	-192,439	-153,106
Aluminum Cans	354,341	343,571	-10,770
Steel Cans	153,629	150,027	-3,602
HDPE	216,351	218,196	1,846
LDPE	400,275	404,207	3,932
PET	81,047	81,387	340
Food Waste	133,343	30,181	-103,162
Yard Waste	-16,175	-12,266	3,909
Total	1,529,576	930,610	-598,966

* These data were copied directly from Table 3, column k.
** These data were copied directly from Table 4, column k.