Climate Change & Colorado

A Technical Assessment

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of Public Health
and Environment
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Executive Summary

Many uncertainties plague the climate change debate. The scientific complexity and political sensitivity of the issue(s) only begin to touch upon the difficulty of dealing with the uncertainties associated with climate change. The potential impacts of climate change, however, cross-cut many existing environmental and public health concerns and as a result cannot be wholly ignored. In light of this and of potential federal action addressing climate change, the Colorado Department of Public Health and Environment deemed it important to compile information on the topic that can serve as a starting point for the development of a solid basis of information to support sound policy decisions concerning climate change.

This Colorado Climate Change Technical Assessment, funded by a grant from the U.S. Environmental Protection Agency, should be viewed as an informational tool that contains background, technical and policy information related to the climate change debate. Presented in the document is information on Colorado's sources of anthropogenic greenhouse gas emissions, the potential stresses climate change may have on Colorado's natural resources and public health systems, as well as an extensive "Menu of Options" list detailing existing programs at the national, state and local levels, and other potential strategies that can help to reduce Colorado's greenhouse gas emissions.

In Colorado, like most other states, fossil fuel combustion is the major source of anthropogenic greenhouse gas emissions. In 1990, fossil fuel combustion produced 78 percent of all greenhouse gas emissions in the state and in 2015 is estimated to produce 87.2 percent of Colorado's greenhouse gas emissions. Electric utilities and transportation sectors were the two largest consumers of fossil fuels responsible for 47.5 percent and 27.7 percent of emissions respectively. Production processes, in particular the production, use and disposal of chlorofluorocarbon compounds, were the next largest source of Colorado's greenhouse emissions in 1990. This source alone accounts for 10.1 percent of all greenhouse gas emissions, but is expected to be phased out by 2015 — which, in part, accounts for the increase in greenhouse gas emissions estimated in the fossil fuel combustion sector in 2015.

Total 1990 Colorado Greenhouse Gas Emissions by Major Source*

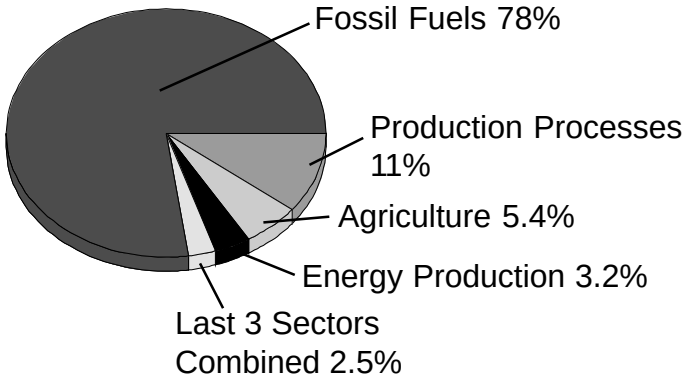

*Chart does not account for water vapor releases

Since 1990, numerous programs have been put in place at the interna-

tional, national, state and local levels that address air pollution concerns. As a result, either directly or indirectly, Colorado has realized some reduction in greenhouse gas emissions. Chlorofluorocarbons, as mentioned, are estimated to realize a 94 percent emissions reduction from 1990 to 2015 due to an international phase-out agreement. Collectively, however, measuring the success of these programs to reduce emissions from 1990 levels has not been completed. Inventorying and quantifying such reductions would be an important element in assessing Colorado's current and future greenhouse gas emission situation.

Most greenhouse gas emission reduction strategies that may be considered will have costs associated with implementation. These costs and associated benefits will be an important component of any public policy decision making process. While this document does not include a cost benefit analysis, it does list strategies such as energy efficiency and voluntary reduction programs that target the largest greenhouse gas emitting sectors and are qualitatively considered the lowest cost options for greenhouse gas emission reductions.

Project Synopsis

Under the United Nations Framework Convention on Climate Change, in 1992 industrialized nations agree to voluntary greenhouse gas reductions ...

National Efforts to address climate change begin ...

- Administration launches the Climate Change Action Plan, October 1993
- U.S. EPA begins Global Climate Change Grant Program, 1993
- Kyoto protocol presented to Congress for ratification, Spring 1998, containing legally binding targets

Colorado's efforts to investigate climate change begin via two EPA Grants...

- Colorado inventories its production of greenhouse gases, February 1997
- Colorado assesses potential state climate change impacts and mitigation strategies, and provides a report to the Governor, December 1998

Colorado Department of Public Health and Environment

Colorado's Climate Change project will provide policy makers with...

- A general discussion of climate change science
- A profile of the state's greenhouse gas production
- Identification of potential climate change impacts to the state's economic, environmental and social systems
- Identification of existing and potential mitigation strategies that can be used to address greenhouse gas emissions in Colorado

1.0 Overview of Government Involvement

Discussions regarding climate change are taking place on the international, federal, state, and local levels. At every level, a large degree of uncertainty is inherent in the debate. And, regardless of one's position on climate change, the issue is complex and polarized. If the science and climatic projections anticipated with climate change do prove true, the impacts may have a discernible influence on ecosystems, the environment and even on human health.

Recognizing this, the U.S. Environmental Protection Agency developed a climate change program to fund further study of the issue at the state and local levels. In Colorado, the Department of Public Health and Environment's Air Pollution Control Division received funding under EPA's climate change program to conduct climate change work at the state level. This document, the Colorado Climate Change Technical Assessment, in addition to the 1990 Colorado Greenhouse Gas Emissions Inventory are the final products of Colorado's grant project. Developed by the Air Pollution Control Division, these documents are designed to serve as informational tools to assist decision makers with policy and technical decisions. Given the possibility that states could eventually be mandated to implement greenhouse gas reduction strategies, it is important for Colorado to have information readily available for those who could be in the policy and decision making processes of addressing climate change. The following information is provided as background information to the development of this document.

1.1 International Activities

The climate change debate is an international issue because of its potential impact on a global scale. Both natural and anthropogenic greenhouse gas emissions occur globally, and potential impacts are also likely to occur on a global basis. At the international level, the debate about climate change, also referred to as global warming, has culminated in several significant events during the past two decades.

In 1988, the United Nations Environment Programme and the World Meteorological Organization jointly formed the International Panel on Climate Change. This scientific panel is composed of more than 150 countries and has developed a series of reports and information on climate change. The work of the panel continues and forms the basis for much of the negotiations that take place on the international level. In the United States, climate change research is overseen by the U.S. Global Change Research Program, which was established in 1989.

In 1990, the United Nations General Assembly established the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change. In June 1992, at the Earth Summit in Rio de Janeiro, the Framework was adopted and subsequently signed by more than 160 countries. The goal of the Framework was to stabilize greenhouse gas emissions "at a level that would prevent dangerous anthropogenic interference with the climate system." Initially, voluntary non-binding commitments were made by developing countries to stabilize greenhouse gas emissions at 1990 levels by the year 2000. This goal, however, is not likely to be reached by many of the participating nations.

The second Conference of the Parties was held in Geneva in July 1996. During this meeting, the United States announced for the first time that future international negotiations should focus on "realistic, verifiable and binding" emission reduction goals for carbon dioxide and other greenhouse gas emissions, such as methane and nitrous oxide. This set the agenda for the third Conference of the Parties held in December 1997 in Kyoto, Japan.

During the Kyoto Conference, the United States agreed to a binding resolution that would reduce the United States' greenhouse gas emissions by 7 percent below 1990 levels by 2012. Other developed nations also set targets for emission reductions below 1990 levels. The Kyoto Accord, however, was not signed by developing nations and as a result, does not include emission reduction targets from these countries. The issue of developing nation's participation in reduction goals is contested by many of the signatories of the Accord and by the U.S. Senate and Colorado Legislature. The U.S. Senate must approve the proposal put forth by the U.S. negotiators in Kyoto prior to implementation. This issue and other unresolved issues were addressed at a fourth Conference of the Parties held in Buenos Aires, Argentina, in November 1998, but still remain largely unresolved. Updates on future action on the international level can be found at the following internet address: http://www.cop3.de/
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1.2 National Activities

One of the largest research efforts at the national level was established by President Bush in 1989 and codified by Congress in the "Global Change Research Act of 1990" (P.L. 101-606). The fundamental purpose of the program is to increase understanding of the earth system and provide a scientific basis for national and international decision making on global climate change issues. Since its inception, a national climate change assessment has been developed, and a second assessment is currently underway and is expected to be completed by December 1999. For more information on the development of the national assessment, refer to the U.S. Global Change Research Program's internet home page at the following address: http://www.usgcrp.gov/.

In 1993, President Clinton initiated a Climate Change Action Plan based on programs already taking place in Washington, Illinois, Pennsylvania, Oregon, Indiana, Minnesota, Wisconsin and Vermont. Seeing successful programs in place at the state level, the Climate Change Action Plan was developed to encourage more states to participate in achieving the President's goal of reducing greenhouse gas emissions to 1990 levels by the year 2000.

1.3 State Activities

Involvement in climate change activities at the state level is potentially important because climate change is one of the many cross-cutting environmental and public health issues states could face. Either directly and indirectly, climate change can potentially impact air quality, waste disposal methods, water management, infectious disease rates and many other facets of environmental and public health protection.

Given these types of concerns, the Colorado Department of Public Health and Envi-

ronment received a grant from the EPA in the amount of $108,231 (including a 10 percent state match) to take a comprehensive look at the issue of climate change and its potential impacts on Colorado. The end goal of the project is the development of a 1990 Colorado Greenhouse Gas Emissions Inventory and a Technical Assessment on climate change from a Colorado perspective. The Greenhouse Gas Emissions Inventory provides data on Colorado's anthropogenic sources and natural sinks of greenhouse gases for the year 1990 with projections to 2015. The assessment includes a general description of climate science, a profile of Colorado's greenhouse gas emissions inventory, a discussion of potential impacts climate change could bring to the state and a listing of potential mitigation strategies that can serve as a starting point in discussions on ways to reduce Colorado's production of greenhouse gases. To learn more about state level greenhouse gas projects through EPA's State and Local Climate Change Program, refer to the EPA's internet address at: http://www.epa.gov/globalwarming/.

1.4 Local Activities

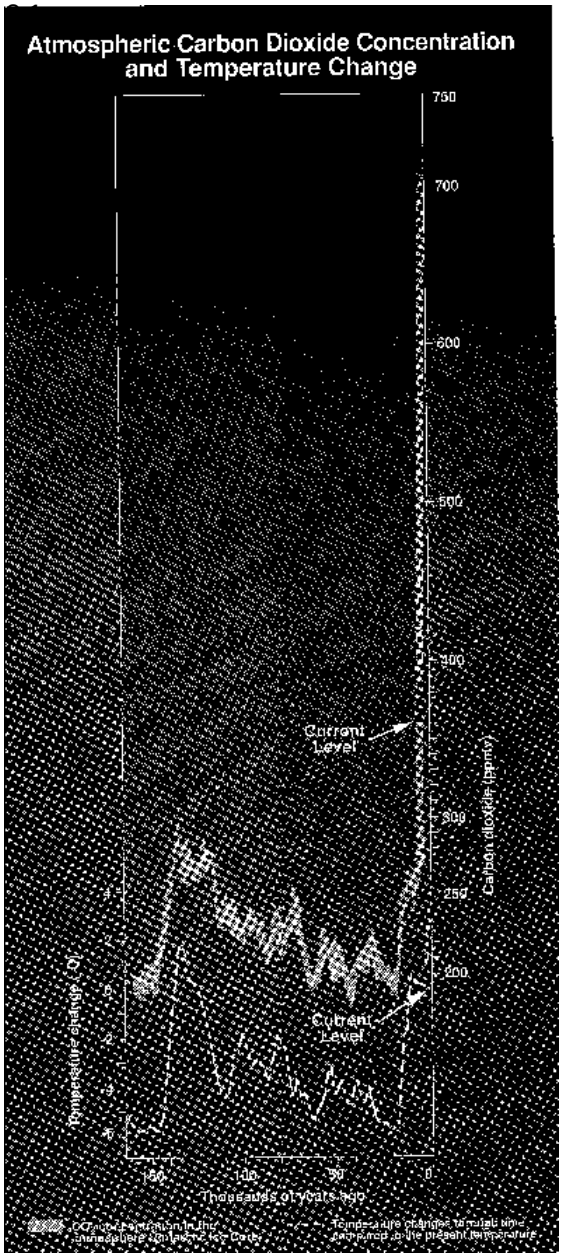
Many local governments, in partnership with communities and local businesses, are taking action to address climate change concerns. The International Council for Local Environmental Initiatives was established in 1990 through a partnership of the United Nations Environment Programme, the International Union of Local Authorities, and the Center for Innovative Diplomacy. The council's members include more than 200 local governments from around the world. Colorado's council cities include Denver, Boulder, Aspen and Fort Collins. The goal of council cities is to set a greenhouse gas emissions target and implement strategies that will reduce local emissions to agreed upon targets during a specified period of time. Additional information on Colorado's participating cities can be found on the Council's internet home page at http://www.magic.ca/iclei/#projects.

2.0 Introduction to Climate Change

2.1 Introduction

Identifying long-term trends in climate is difficult because of the variability of weather from year to year and the complexity of the earth's climate system. This system, which is not yet fully understood is influenced by many variables that affect weather patterns in different ways and on different time scales. A major factor affecting climate is the composition of the atmosphere. The presence of materials such as volcanic ash or water droplets can reflect incoming solar radiation and cool the earth's temperature, while the presence of heat-trapping gases absorb heat and warm the earth. If left to its own natural climatic processes, the atmosphere would retain a variable, but relatively consistent composition of greenhouse gases that would work in conjunction with other natural processes – like the carbon and hydrologic cycles – to regulate climate over time. However, since the beginning of the industrial revolution, an increasing amount of heat-trapping gases such as carbon dioxide, methane, nitrous oxide and chlorofluorocarbons, have been emitted into the atmosphere due to anthropogenic activities. The accumulation of these heat-trapping gases, known as greenhouse gases, raises concerns about potential global warming and climate change.

Figure



Source: Office of Science and Technology Policy, "Climate Change: State of Knowledge," October 1997, Washington, D.C.

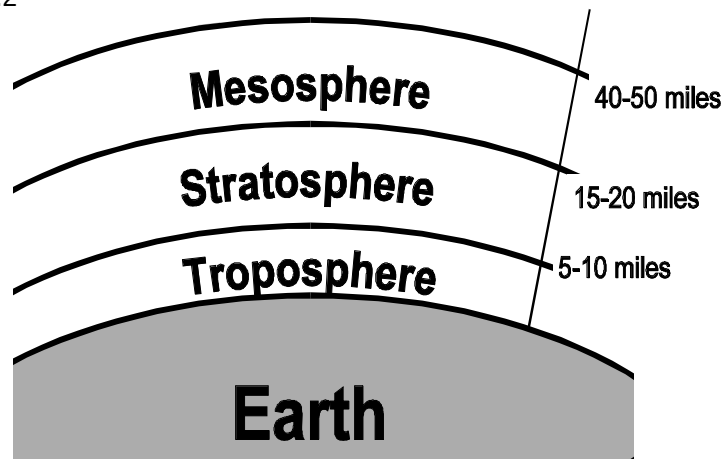
Overall, emissions of greenhouse gases are growing at about 1 percent per year. In 1860, carbon dioxide concentrations in the atmosphere equaled 280 parts per million (ppm) and since then concentrations have increased to a present day level of 360 ppm. Fluctuations in carbon dioxide levels and temperatures, however, have occurred during the last 160,000 years (Figure 2.1). The increase in carbon dioxide concentrations has been attributed to the burning of fossil fuels such as coal, oil, and natural gas to heat and cool homes and buildings, power automobiles, and manufacture a multitude of consumer goods. These activities emit carbon dioxide and other greenhouse gases as by-products. Other anthropogenic sources of greenhouse gases are produced by deforestation, agricultural processes and municipal landfills.

Developing public policy to address concerns of ris-

ing levels of greenhouse gases is complicated and politically volatile. The complex and uncertain scientific issues involved in decisions to control human-generated greenhouse gas emissions make the development and implementation of policy options extremely difficult. Integral to the political ramifications of addressing climate change policy options are the economic costs associated with greenhouse gas mitigation strategies. This document analyzes Colorado's production of greenhouse gases, the potential impacts of climate change on the state's natural and economic systems and provides a starting point for discussions to address climate change issues as may be deemed necessary for the state of Colorado both in the short- and long-term.

2.2 An Atmospheric Overview

Figure 2.2



The atmosphere surrounding the earth extends upward approximately 50 miles in height. Three main layers comprise the atmosphere including: the troposphere, the layer closest to the earth's surface; the stratosphere, and the mesosphere or upper layer (Figure 2.2). Together, these atmospheric layers are critical to the weather and climate of the earth. The interaction of atmospheric gases, including greenhouse gases with solar radiation, produce three commonly known phenomena of concern within the atmosphere, including: the depletion of the ozone layer; the greenhouse effect; and in some areas, regional and local air pollution. Each phenomena has implications for human and environmental health and well-being.

2.2.1 The Ozone Layer

Ozone is a naturally occurring three-oxygen atom, found in two layers of the earth's atmosphere. Almost 90 percent of ozone is in the stratosphere, where the "ozone layer" exists. The remaining ozone is in the lower tropospheric layer. While chemically identical, the effects associated with ozone in the two layers are very different. Tropospheric ozone is considered to be a ground-level pollutant, along with fine particulate matter and nitrogen dioxide, that leads to the formation of photochemical smog. Controlled by both federal and state governments, ground-level ozone can be harmful to public health. Depending upon an individual's condition, the impacts of ozone concentrations can vary widely. Major sources of these pollutants are motor vehicles and industry.

The stratospheric ozone layer absorbs most of the ultraviolet sunlight, allowing only a small amount to reach the earth's surface. This acts to protect us from damaging ultraviolet rays. The thickness of the ozone layer varies by about one percent to two percent due to seasonal variations and the oscillation of stratospheric winds. The depletion of stratospheric

ozone and increasing levels of ultraviolet radiation especially at the south pole has become a major environmental concern since the early 1980s.

2.2.2 Air Quality

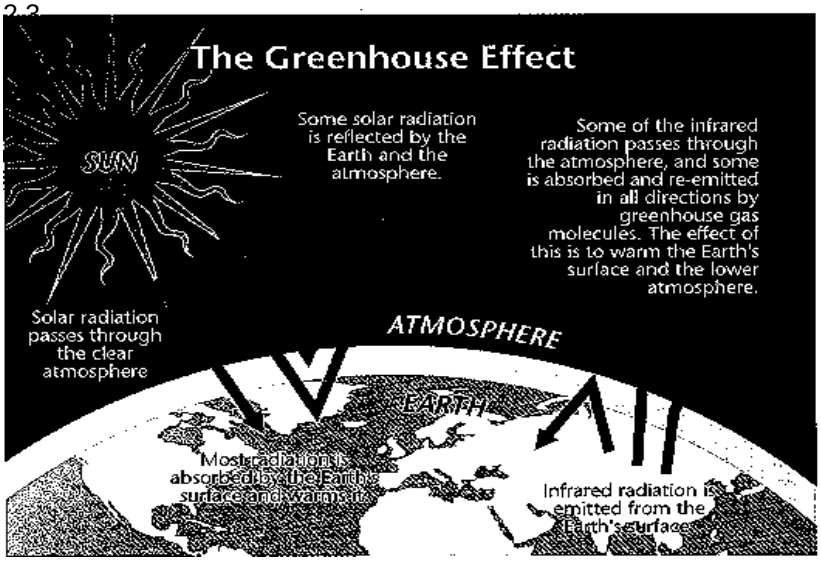
Air quality is a concern at regional, state and local levels. Pollutants such as oxides of nitrogen, particulate matter, lead, carbon monoxide and sulfur dioxide are released into the atmosphere from a range of anthropogenic and natural sources. Once in the air, some pollutants can be transported both within and between regions by wind and air currents.

Regional air quality can affect a wide ranging area many miles from the source(s), e.g., the Grand Canyon and Mount Zirkel Wilderness Area experience visibility degradation due to pollutants transported into the area from power plants and other stationary and mobile sources. State and local air quality issues occur in a more limited area and are generally more episodic in nature, e.g., Denver's Brown Cloud. In Colorado, pollutants of local concern include particulate matter, carbon monoxide and ozone.

2.3 The Greenhouse Effect & Greenhouse Gases

Approximately 98 percent of the earth's atmosphere is made up of nitrogen and oxygen, 77 percent and 21 percent respectively. Both nitrogen and oxygen allow energy from the sun to enter, as well as exit the atmosphere unimpeded. Greenhouse gases such as water vapor, carbon dioxide, methane and nitrous oxide occur in relatively minor quantities, comprising just over 1 percent of the earth's atmosphere. Although a minor percentage of the atmosphere, greenhouse gases play a significant role in keeping the earth warm and habitable. Of the small percentage of greenhouse gases, 96 percent to 98 percent, are considered natural gas molecules and make up what is termed the earth's greenhouse effect. Residing in the atmosphere, greenhouse gases radiate heat back to the earth's surface keeping it warm and habitable for living systems. In essence, this atmospheric gas layer acts as a blanket around the earth. About half of the sunlight radiated from the sun is absorbed by the earth's surface and converted into heat energy. The percentage of this heat energy, or long-wave infrared radiation, not absorbed by land and water, is radiated upward into the troposphere and trapped by water vapor, clouds and greenhouse gases which reradiate the heat back to the earth's surface. The atmosphere, without this heat trapping layer, would

Figure 2.3



Source: Office of Science and Technology Policy, "Climate Change: State of Knowledge," October 1997, Washington, D.C.

result in a much colder earth with an average temperature of -18° C (Figure 2.3).

Over time, the natural balance of water vapor and greenhouse gases has maintained consistent temperatures and climate patterns. Natural variations, however, have occurred in climate and temperatures, leading to fluctuations in the warming and cooling patterns over short periods of time. During the past two centuries, human activities have added additional greenhouse gases to the atmosphere changing the balance so that more long wave radiation is being absorbed in the lower atmosphere and re-emitted back to the earth's surface. This is referred to as the enhanced greenhouse effect, and the concern raised by climate change proponents is that by upsetting the natural balance of the earth's atmosphere, changes will occur to long-term temperatures and the hydrologic cycle.

2.3.1 Water Vapor

Water in the gaseous phase comprises water vapor. Water vapor is the key element in the atmospheric greenhouse effect and in the workings of the hydrological cycle. As an element of the hydrological cycle, water vapor moves water quickly through the atmosphere and redistributes energy associated with evaporation and condensation. As a greenhouse gas, water vapor is responsible for approximately 95 percent to 97 percent of the natural greenhouse effect. Unlike other greenhouse gases, the amount of water vapor put into the atmosphere by human activities is negligible compared to naturally occurring atmospheric water vapor. Water vapor is a concern under a global warming scenario because some scientists believe that atmospheric water vapor is likely to increase leading to further warming due to water's absorption characteristics. Potential impacts include an enhancement of the greenhouse effect, resulting in increased warming, changes to the hydrologic cycle and cloudier skies.

On the other hand, other scientists believe that the presence of more water vapor, and hence cloudier skies, might limit the amount of incoming solar radiation resulting in the cooling of global temperatures[1]. At the present time, the precise role that water vapors plays in global climate change remains uncertain and is undergoing extensive scientific research.

2.3.2 Carbon Dioxide

Carbon dioxide is essential to life, both as a greenhouse gas and as a basic element of all living organisms. As a greenhouse gas, carbon dioxide helps to warm the earth. As an essential element for organic matter, plants take in carbon dioxide and use it to make food through photosynthesis. Carbon dioxide is a colorless, odorless, noncombustible gas that is slightly more than 1.5 times as dense as air, and becomes a solid (dry ice) below –78.5ºC. It is present in the atmosphere as a result of the cyclical nature of natural systems, such as the decay of organic material and the respiration of living organisms. Human activities add carbon dioxide to the atmosphere, raising carbon dioxide levels above the natural balance inherent with the carbon cycle.

Through the carbon cycle, large amounts of carbon dioxide are constantly being removed from the atmosphere by plants and soils, by the oceans and by marine life. This carbon absorbing phenomenon is referred to as a carbon sink or as carbon sequestration.

Through the absorption and storage of carbon, soils, trees and other plants can play a role in helping to reduce carbon dioxide levels in the atmosphere.

The oceans also play a significant role in the carbon cycle. Through the process of gas exchange, carbon dioxide and seawater work together to both absorb gas from the air and/or release carbon dioxide gas back into the atmosphere. Thus the carbon cycle, like other natural processes, constantly adds to and removes carbon dioxide and other greenhouse gases from the atmosphere. This natural cycle, however, may be impacted by the human use of fossil fuels, the automobile and a number of other anthropogenic sources.

Each year more than 30 billion tons of carbon dioxide is added to the atmosphere mainly by burning fossil fuels and by cutting down and burning trees. Fossil fuels contain stored carbon; burning them releases carbon dioxide. As coal, oil and natural gas is used to generate electricity, heat homes, power factories and fuel cars, billions of tons of carbon dioxide are released every year. Fossil fuels — coal, oil, natural gas — were created chiefly by the decay of plants that flourished millions of years ago. Burning these fuels unlocks the carbon stored by these plants and releases it to the air as carbon dioxide.

As trees grow, they take carbon dioxide from the air through photosynthesis. Destroying forests releases carbon dioxide, increasing its level in the atmosphere. Until 50 years ago most of the carbon dioxide from deforestation was released from temperate zones. Now tropical deforestation is the largest source.

2.3.3 Methane

Methane is released to the atmosphere from a number of sources including: oceans, freshwater bodies, natural marshes, swamps, landfills, coal mines, gas wells, rice paddies, the burning of vegetation and, through the digestive system of ruminant animals and termites. Inversely, in natural ecosystems soil processes can act as a sink and remove methane from the atmosphere. However, some soils contain bacteria that actually produce methane.

Methane emissions and absorption processes of natural systems differ widely on a regional basis. These differences, in the release and uptake of methane, are not well understood. While methane levels in the atmosphere are documented at a global scale, considerable debate exists over the natural and regional fluctuation in atmospheric methane levels.

2.3.4 Nitrous Oxide

Nitrous oxide is a greenhouse gas. Its atmospheric concentrations have increased by about 15 percent since 1860. Less is known about the sources and sinks of nitrous oxide than carbon dioxide and methane. Some of the sources of nitrous oxide include denitrification, or the release of nitrous oxide by bacteria in soils, groundwater and the oceans. The application of nitrate and ammonium fertilizers to soils is another source of nitrous oxide. Industrial sources of nitrous oxide include the manufacture of nylon, nitric acid and the production of explosives.

In the atmosphere, nitrous oxide has 310 times the heat trapping capacity of atmospheric carbon dioxide. The removal of atmospheric nitrous oxide occurs slowly. Over time, the nitrous oxide molecule is broken down through a process called photolysis or the

chemical breakdown of nitrous oxide by the action of radiant energy. Fortunately, of the three principal greenhouse gases, nitrous oxide is the least prevalent of the gases emitted.

2.3.5 Chlorofluorocarbons

Chlorofluorocarbons are part of a larger family of compounds referred to as halocarbons. The elements bromine and chlorine in these compounds are of primary concern. Unlike the other greenhouse gases, chlorofluorocarbons are a completely human-generated pollutant. Thus, no natural sources of chlorofluorocarbons exist. They act as a greenhouse gas by intercepting outgoing radiation in the troposphere and reradiating it back to earth.

The residence time of chlorofluorocarbons in the atmosphere ranges between 50 years and 130 years. In addition to being a greenhouse gas, chlorofluorocarbons destroy atmospheric ozone in the stratosphere.

Emissions of chlorofluorocarbons are controlled through two international agreements. The Vienna Convention that addresses depletion of the ozone layer and the Montreal Protocol which bans the use of specified chlorofluorocarbons compounds. In banning chlorofluorocarbons, a related compound, hydrochlorofluorocarbon has been used as a replacement compound. Hydrochlorofluorocarbons, although a greenhouse gas, do not accumulate in the atmosphere to the same extent as chlorofluorocarbons.

2.3.6 Other Important Gases

There are several other gases that are not considered greenhouse gases, but can potentially effect climate. The hydroxyl radical, for example, reacts in both positive and negative ways with other greenhouse gases. It can react with methane and remove it from the atmosphere, or it can react with carbon monoxide and lengthen the time methane remains in the atmosphere. Thus, carbon monoxide can have an indirect effect on climate due to the inhibition of the hydroxyl radical to remove atmospheric methane. In addition, the hydroxyl radical can work to covert carbon monoxide to carbon dioxide, a greenhouse gas.

Other greenhouse gases in the atmosphere include nitrogen oxides and non-methane volatile organic compounds — ozone precursors. These precursors are compounds that contribute to the formation of ozone in the lower atmosphere and may play a role in the greenhouse effect. However, the full implication of this chemical process is not widely understood at this time.

3.0 Greenhouse Gas Emissions Inventory & Profile

3.1 Introduction

In order to provide policy makers and planners with the tools to understand and evaluate Colorado's role in the national and global greenhouse gas emission issue, a statewide greenhouse gas inventory was compiled. The inventory quantifies Colorado's production of greenhouse gas emissions on a gas-by-gas basis and a source-by-source basis. The gas-by-gas evaluation quantifies Colorado's greenhouse gas emissions by chemical composition. The source-by-source evaluation quantifies greenhouse gas emissions from 10 major source sectors in the state. All together, the inventory and accompanying profile descriptions provide a comprehensive analysis of source, composition and quantity of greenhouse gases produced in the state. This comprehensive analysis is intended to act as a resource for all public and private individuals engaged in addressing this issue in the future.

2000 Update

An update of the greenhouse gas emissions inventory was done in 2000 and is available on-line at www.cdphe.state.co.us/ap/down/climateupdate.pdf The update verifies that the state's projections documented in this report have thus far been on target.

3.2 Background

Colorado's Greenhouse Gas Emission Inventory is based upon emissions produced in the year 1990. This year was chosen so as to make Colorado's baseline year identical to baseline years used by other states, thus facilitating comparative and national greenhouse gas emissions analysis and planning to occur.

In developing the emissions inventory, standardize methods for estimating greenhouse gas emissions were used including: the Organization for Economic Cooperation and Development's, "Estimation of Greenhouse Gas Emissions and Sinks, February 1991;" and the EPA's, "State's Workbook: Methodologies for Estimating Greenhouse Emissions," November 1992 with subsequent revisions.

1992 Greenhouse Gas Emissions Per Capita

Colorado =	23.7 tons
Wyoming =	181.4 tons
Utah =	34.1 tons
Idaho =	12.2 tons
Nebraska =	26.6 tons
New Mexico =	42.1 tons
California =	12.1 tons
New York =	11.7 tons
Illinois =	19.1 tons
Washington =	18 tons

Source: "State Energy Data Report, 1992," Energy Information Administration

3.3 Greenhouse Gas Emissions by Gas

An inventory of the major greenhouse gases in Colorado for 1990 indicates that carbon dioxide is the most prevalent gas emitted, followed by methane, chlorofluorocarbons and nitrous oxide. Figure 3.1 shows the percentage of gases emitted and Table 3.1 quantifies emissions by carbon dioxide equivalents. In 1990, Colorado produced 105.1 million tons of carbon dioxide equivalent gases.

Figure 3.1 – Total 1990 Colorado Greenhouse Gas Emissions by Gas Percentages of Carbon Dioxide Equivalent*

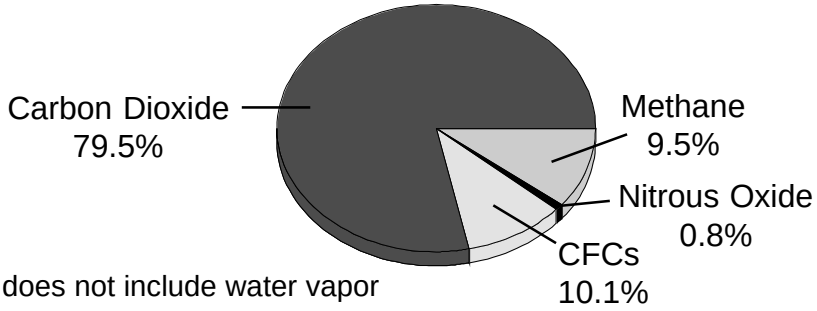


*Chart does not include water vapor

Carbon Dioxide Equivalent – Global Warming Potential

❋To make relative comparisons between gases possible, the Global Warming Potential of each gas has been indexed and equated to the global warming potential of carbon dioxide. In the equivalency calculation, the relative global warming potential of each gas is: Carbon dioxide=1, Methane=21, Nitrous Oxide=310. Chlorofluorocarbons =5,000

Table 3.1 – Total 1990 Colorado Greenhouse Gas Emissions by Gas
Tonnages & Percentages of Carbon Dioxide Equivalent

Greenhouse Gas	Global Warming Potential	Tons Carbon Dioxide Equivalent	Percent of Total
Carbon Dioxide	1	83,603,305	79.5%
Methane	21	10,033,532	9.5%
Chlorofluorocarbon	5000	10,620,000	10.1%
Nitrous Oxide	310	865,963	0.8%
Total (tons)		105,122,801	100%

3.4 Greenhouse Gas Emissions by Major Source

Ten major source categories were considered in inventorying Colorado's greenhouse gas emissions. Of the 10 sources, fossil fuel combustion created 78 percent of the state's greenhouse gas emissions in 1990, more than all other sources combined. Second in magnitude were emissions from production processes, representing 11 percent of total greenhouse gases, emissions from agricultural activities represent 5.4 percent, next came energy production activities at 3.2 percent, followed by the last three source sectors combined contributing 2.5 percent of the state's 1990 greenhouse gas emissions. Table 3.2 on the following page presents the 10 major sources and followed by their emissions profile.

Figure 3.2 – Total 1990 Colorado Greenhouse Gas Emissions by Major Source*

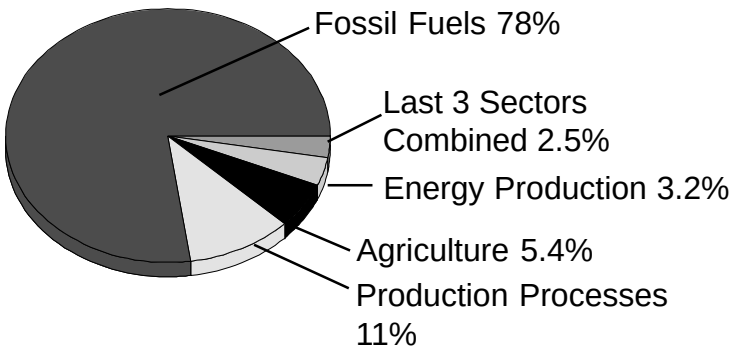


*Chart does not include water vapor

Table 3.2 – Total 1990 Colorado Greenhouse Gas Emissions by Major Source

No.	Source	CO_2 (tons) CO_2 Equiv (GWP=1)	Percent of total CO_2	CH_4 (tons) CO_2 Equiv (GWP=21)	Percent of total CH_4	N_2O (tons) CO_2 Equiv (GWP=310)	Percent of total N_4O	CFCs CO2 Equiv (GWP=5,000)	Percent of total CFCs
1.	Fossil Fuel Combustion	**81,967,736**	98.1%	0	0.0%	0	0.0%		
2.	Natural Gas & Oil Systems	0	0.0%	**1,071,704**	10.7%	0	0.0%		
3.	Coal Mining	0	0.0%	**2,319,891**	23.1%	0	0.0%		
4.	Production Processes	912,182	1.1%	0	0.0%	0	0.0%	**10,620,000**	**100%**
5.	Landfill			**1,775,109**	17.7%	0	0.0%		
6.	Domestic Animals	0	0.0%	**4,511,848**	45.0%	0	0.0%		
7.	Manure Management Systems	0	0.0%	**279,983**	2.8%	0	0.0%		
8.	Fertilizer	0	0.0%	0	0.0%	**865,963**	100.0%		
9.	Land Use Changes	723,387	0.8%	0	0.0%		0.0%		
10.	Wastewater Treatment Systems	0	0.0%	**74,997**	0.8%	0	0.0%		
11.	Totals (tons)	**83,603,305**		**10,033,532**		**865,963**		**10,620,000**	

3.5 Source Analysis

In 1992, Colorado consumed 958.9 trillion BTU's of energy, ranking 28th in the nation .

Fossil fuels supplied 98% of that energy, with petroleum suppling 36.4%, coal 34.6%, natural gas 27% and hydroelectric 1.6%.

In this section a source-by-source quantification and descriptive profile is provided. The quantification profile reports the tons of 1990 greenhouse gas emissions emitted from each major source. The descriptive profile provides a textual description of the source and offers a detailed apportionment of greenhouse gas emissions within the source.

3.5.1 Fossil Fuel Combustion

Activities involving the combustion of fossil fuels comprise the most significant portion of 1990 greenhouse gas emissions in Colorado, accounting for 81,967,736 tons of carbon dioxide equivalent emissions or 78 percent of all 1990 greenhouse gas emissions in the state. The combustion of fossil fuels accounts for most of the energy-related emissions; as fossil fuels burn they emit carbon dioxide as the carbon in the fuels is oxidized. The amount emitted is associated with the amount of fuel consumed, the portion that is oxidized and the carbon content of the fuel. A variety of fossil fuels combustion activities are responsible for the release of carbon dioxide in Colorado, including energy consumption to generate electricity, gasoline consumption in automobiles, steam production for industrial processes and heating in residential and commercial buildings. Figure 3.3 shows carbon dioxide equivalent emissions from sub-sectors' use of fossil fuels and Table 3.3 provides a fuel-by-fuel analysis of carbon dioxide equivalent emissions in the year 1990.

Figure 3.3 – Major Fossil Fuel Combustion Sectors' 1990 Carbon Dioxide Equivalent Emissions

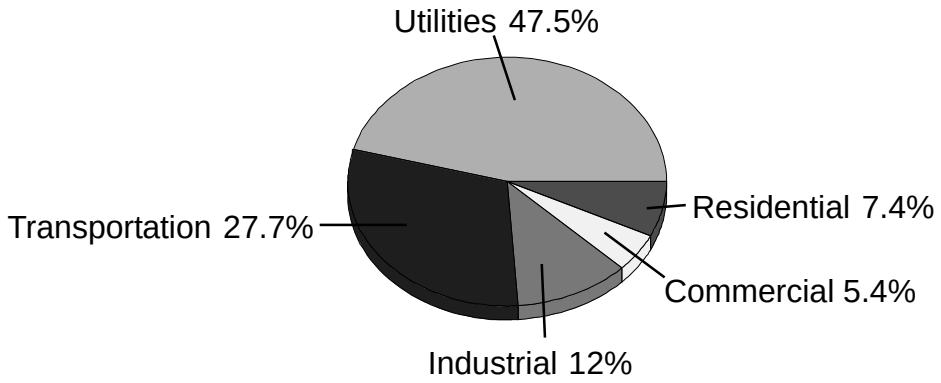


Table 3.3 – 1990 Carbon Dioxide Emissions from Fossil Fuel Types

No.	Fuel Type	CO_2 Emissions (tons)						Percent of Total
		Residential	Commercial	Industrial	Transport	Utilities	Total	
1.	Asphalt & Road Oil	0	0	1,784,893	0	0	1,784,893	2.2%
2.	Aviation Gasoline	0	0	0	63,651	0	63,651	0.8%
3.	Biomass	1,262	0	0	0	23	1,285	0.0%
4.	Coal, Anthracite	0	0	0	0	0	0	0.0%
5.	Coal, Bituminous	48,564	92,271	1,770,143	0	38,666,332	40,577,309	49.5%
6.	Distillate Fuel	12,560	203,286	1,248,090	3,337,699	0	4,801,634	5.9%
7.	Ethanol	0	-	0	1,622,947	0	1,622,947	0.0%
8.	Gasoline	0	107,321	0	14,154,908	0	14,262,229	17.4%
9.	Jet Fuel	0	0	0	2,734,759	0	2,734,759	3.3%
10.	Kerosene	9,849	4,477	8,058	0	0	22,383	.02%
11.	Liq Pet Gas	466,985	82,280	268,028	20,639	0	837,931	1.0%
12.	Lubricants	0	0	119,793	202,274	0	322,067	0.4%
13.	Natural Gas	5,514,171	3,955,819	3,955,819	539,430	299,683	14,264,921	17.4%
14.	Other Liquids	0	-	671,726	0	0	671,726	0.8%
15.	Petroleum Coke	0	0	0	0	0	0	0.0%
16.	Residual Fuel Oil	0	0	0	0	0	0	0.0%
17.	Totals	6,053,390	4,445,452	9,826,550	22,676,307	38,966,038	81,967,736	
18.	Percent of Total	7.4%	5.4%	12%	27.7%	47.5%	100%	

3.5.1.1 – Fossil Fuel Combustion Sector – Utilities Subsector

The single largest fossil fuel sector category in Colorado during the baseline year was utilities and it contributed proportionally to carbon dioxide gas emissions. Fossil fuels used by the sector include bituminous coal and natural gas. To a much lesser extent, biomass fuels are also utilized.

The total emissions from the Utility Sector represent 47.5 percent of Colorado's 1990 carbon dioxide emissions. In 1990, the sector emitted 38,966,038 tons of carbon dioxide gases, of which coal combustion produced 38,666,332 tons, natural gas combustion 299,683 tons and biomass fuels 23 tons. Figure 3.4 and Table 3.4 highlight these emission comparisons.

Figure 3.4 – Fossil Fuels Sector – Utilities: 1990 Carbon Dioxide Equivalent Emissions Apportionment

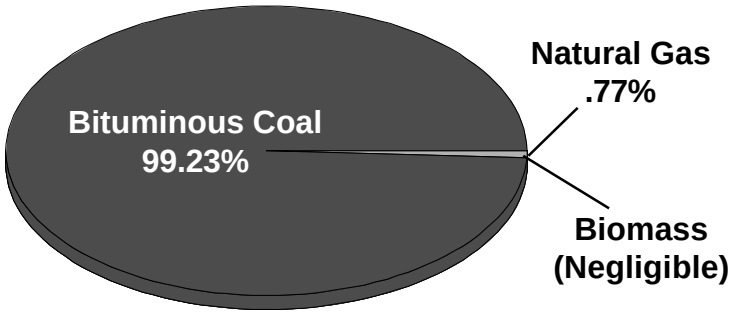


Table 3.4 – Fossil Fuels Sector – Utilities: 1990 Carbon Dioxide Equivalent Emissions Summary

Component	Carbon Dioxide (tons)	Percent of Total Categor Carbon Dioxide
Bituminous Coal	38,666,332	99.23
Natural Gas	299,683	0.77
Biomass	23	negligible
Total Carbon Dioxide Emissions	38,966,038	100

3.5.1.2 Fossil Fuel Combustion Sector – Transportation Subsector

Transportation, the second largest fossil fuel consumption category in Colorado during the baseline year, contributed significantly to Colorado's carbon dioxide emissions. Fossil fuels including gasoline, ethanol, jet and aviation fuels, natural gas, liquid petroleum gas lubricants and distillate products are consumed by this sector.

The total emissions from the Transportation Sector represent 27.7 percent of Colorado's 1990 carbon dioxide emissions from fossil fuel combustion. In 1990, the sector emitted 22,676,306 tons of carbon dioxide gases, of which gasoline combustion produced 14,154,908 tons, ethanol combustion 1,622,947 tons, distillate fuel 3,337,699 tons and jet fuel 2,734,759 tons. Figure 3.5 and Table 3.5 highlight these emission comparisons.

Figure 3.5 – Fossil Fuels Sector – Transportation: 1990 Carbon Dioxide Equivalent Emissions Apportionment

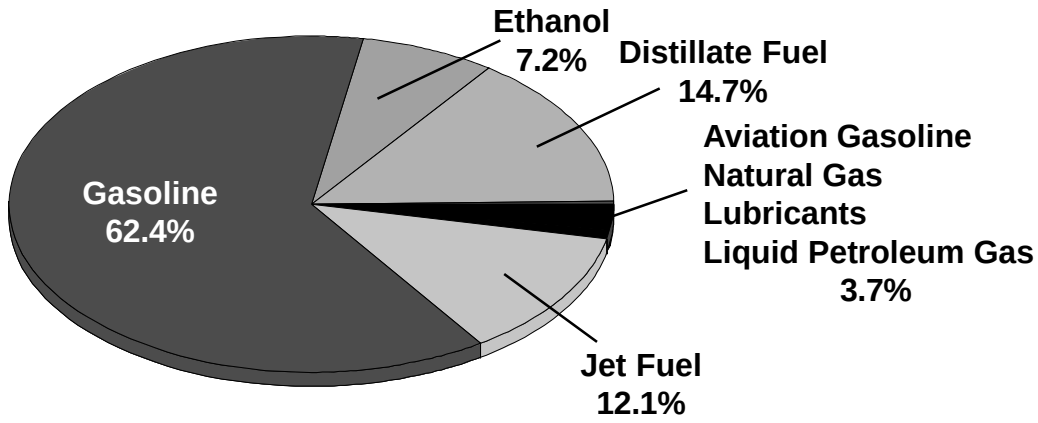


Table 3.5 – Fossil Fuels Sector – Transportation:
1990 Carbon Dioxide Equivalent Emissions Summary

Component	Carbon Dioxide (tons)	Percent Total of Sector
Gasoline	14,154,908	62.4
Ethanol	1,622,947	7.2
Distillate Fuel	3,337,699	14.7
Jet Fuel	2,734,759	12.1
Natural Gas	539,430	2.4
Lubricants	202,274	0.89
Aviation Gasoline	63,651	0.28
Liquid Petroleum Gasoline	20,639	0.09
Total Carbon Dioxide Emissions	22,676,306	100

3.5.1.3 Fossil Fuel Combustion Sector – Industrial Subsector

Industrial usage of fossil fuels was the third highest contributor of carbon dioxide emissions in the fossil fuels category in 1990. Industrial consumption or use of natural gas, asphalt and road oil, bituminous coal, distillate fuel, liquid petroleum gas, lubricants and kerosene produced carbon dioxide emissions.

The total emissions from the Industrial Sector represent 12 percent of Colorado's 1990 carbon dioxide emissions from fossil fuel combustion. In 1990, the sector emitted 9,826,550 tons of carbon dioxide gases, of which natural gas combustion produced 3,955,819 tons, asphalt and road oil use 1,784,893 tons, bituminous coal 1,770,143 tons and distillate fuel 1,248,090 tons. Figure 3.6 and Table 3.6 highlight the sector's fuel emission comparisons.

Figure 3.6 Fossil Fuels Sector – Industrial:
1990 Carbon Dioxide Equivalent Emissions Apportionment

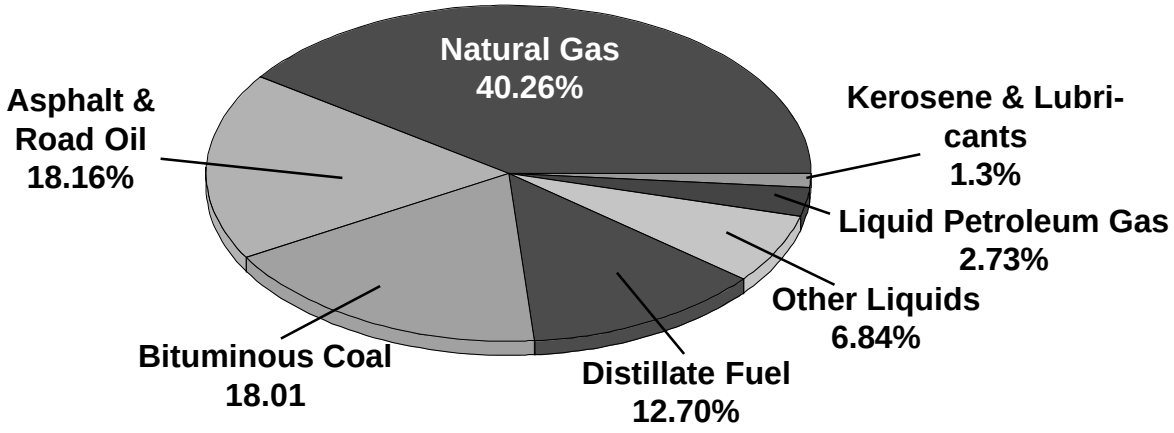


Table 3.6 Fossil Fuels Sector – Industrial: 1990 Carbon Dioxide Equivalent Emissions Summary

Component	Carbon Dioxide (tons)	Percent Total of Sector
Natural Gas	3,955,819	40.26
Asphalt & Road Oil	1,784,893	18.16
Bituminous Coal	1,770,143	18.01
Distillate Fuel	1,248,090	12.7
Other Liquids	671,726	6.84
Liquid Petroleum Gas	268,028	2.73
Lubricants	119,793	1.22
Kerosene	8,058	0.08
Total Carbon Dioxide Emissions	9,826,550	100

3.5.1.4 Fossil Fuel Combustion Sector – Residential Subsector

Residential usage of fossil fuels were the fourth highest contributor of carbon dioxide emissions from the fossil fuels category in 1990. Residential consumption or use of natural gas, liquid petroleum gas, bituminous coal, distillate products, kerosene and biomass (e.g. wood) produced carbon dioxide emissions.

The total emissions from the Industrial Sector represent 7.4 percent of Colorado's 1990 carbon dioxide emissions from fossil fuel combustion. In 1990, the sector emitted 6,053,390 tons of carbon dioxide gases, from which natural gas combustion produced most the emissions with 5,514,171 tons, liquid petroleum gas with 466,985 tons, bituminous coal with 48,564 tons and distillate fuel with 12,560 tons. Figure 3.7 and Table 3.7 highlight the sector's fuel emission comparisons.

Figure 3.7 Fossil Fuels Sector – Residential:
1990 Carbon Dioxide Equivalent Emissions Apportionment

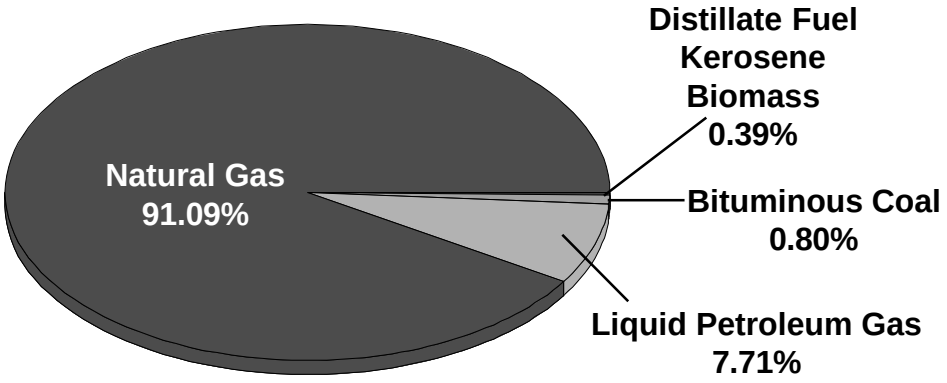


Table 3.7 Fossil Fuels Sector – Residential: 1990 Carbon Dioxide Equivalent Emissions Summary

Component	Carbon Dioxide (tons)	Percent Total of Sector
Natural Gas	5,514,171	91.09
Liquid Petroleum Gas	466,985	7.71
Bituminous Coal	48,564	0.8
Distillate Fuel	12,560	0.21
Kerosene	9,849	0.16
Biomass	1,262	0.02
Total Carbon Dioxide Emissions	6,053,390	100

3.5.1.5 Fossil Fuel Combustion Sector – Commercial Subsector

Commercial usage of fossil fuels were the fifth highest contributor of carbon dioxide emissions from the fossil fuels category in 1990. Commercial consumption or use of natural gas, liquid petroleum gas, bituminous coal, distillate products, kerosene and biomass (e.g. wood) produced carbon dioxide emissions.

The total emissions from the Commercial Sector represent 5.4 percent of Colorado's 1990 carbon dioxide emissions from fossil fuel combustion. In 1990, the sector emitted 4,445,452 tons of carbon dioxide gases, from which natural gas combustion produced most the emissions with 3,955,819 tons, distillate fuel with 203,286 tons, gasoline with 107,321 tons and bituminous coal with 92,271 tons. Figure 3.8 and Table 3.8 reiterate the sector's fuel emission comparisons.

Figure 3.8 Fossil Fuels Sector – Commercial:
1990 Carbon Dioxide Equivalent Emissions Apportionment

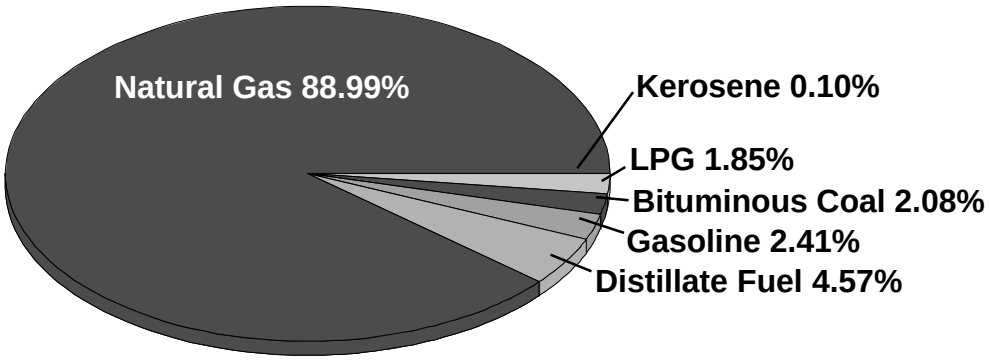


Table 3.8 Fossil Fuels Sector – Commercial: 1990 Carbon Dioxide Equivalent Emissions Summary

Component	Carbon Dioxide (tons)	Percent Total of Sector
Natural Gas	3,955,819	88.99
Distillate Fuel	203,286	4.57
Gasoline	107,321	2.41
Bituminous Coal	92,271	2.08
Liquid Petroleum Gas	82,280	1.85
Kerosene	4,477	0.10
Total Carbon Dioxide Emissions	4,445,452	100.00

3.5.2 Production Processes Sector

Greenhouse gas emissions from the processing and production of industrial materials ranked second in the state quantitatively during 1990. The predominant gas created in the Production Processes Sector is chlorofluorocarbons and carbon dioxide, although emissions of nitrous oxide, hydrofluorocarbons and perfluorinated carbons are also produced but not included in the inventory. Carbon dioxide emissions from the sector result mainly from the chemical transformation of materials from one state to another.

Colorado's carbon dioxide emissions from cement manufacturing account for 2.5% of the nation's total cement manufacturing greenhouse gas emissions.

Colorado's 1990 carbon dioxide emissions from the Production Processes Sector represent 11 percent of the state's total greenhouse gas emissions in the baseline year. In 1990, the sector emitted 11,532,183 tons of carbon dioxide. This came from emissions associated with the processing and production of industrial materials, cement and masonry cement production, lime production and limestone use. Figure 3.9 and Table 3.9 describe the sources of these emissions per production process.

Figure 3.9 Production Processes Sector 1990 Carbon Dioxide Equivalent Emissions Apportionment

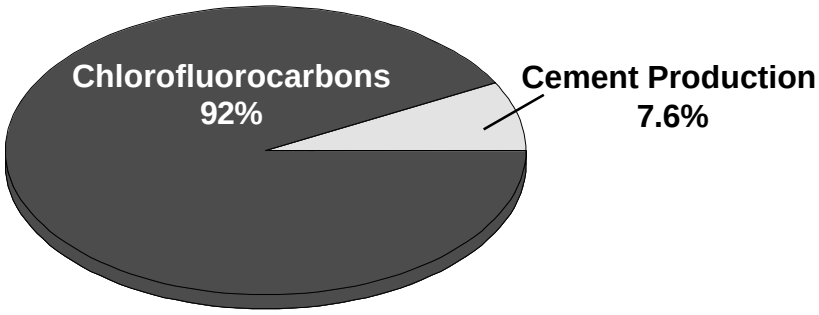


Table 3.9 Production Processes Sector: 1990 Carbon Dioxide Emissions Summary

Component	Carbon Dioxide (tons)	Percent Total of Sector
Chlorofluorocarbons	10,620,000	92.00
Cement Production	881,848	7.60
Lime Production	28,967	0.30
Limestone Use	1,368	negligible
Total Carbon Dioxide Emissions	11,532,183	100.00

3.5.3 Domestic Animals Sector

Methane emissions from Colorado's domestic animal populations rank third behind the Fossil Fuel Combustion Sector and Production Processes Sector for production of greenhouse gases. These emissions come from ruminant animals such as cattle, buffalo, sheep and goats, and non-ruminant animals such as swine, horses and mules. The majority of emissions in the sector are produced by ruminant animals during their digestion of plant material composed of cellulosic carbohydrates. Through a digestion process known as enteric fermentation, microorganisms in the animals' rumen (large fore-stomach) break down the cellulose into products usable by the animals and produce methane.

In 1990, Colorado was home to roughly 2.2% of the nation's domestic animals and produced more than 12% of the nation's methane emissions associated with

The total methane emissions from the Domestic Animals Sector represent 4.3 percent of Colorado's total 1990 carbon dioxide emissions. In 1990, the sector emitted 214,850 tons of methane emissions which equal 4,511,846 tons of carbon dioxide equivalent gases. These emissions come from livestock used in the production of meat, hides, fiber and draft power. Figure 3.10 and Table 3.10 highlight the sources of these emissions.

Figure 3.10- Domestic Animals Sector: 1990 Methane Emissions Apportionment

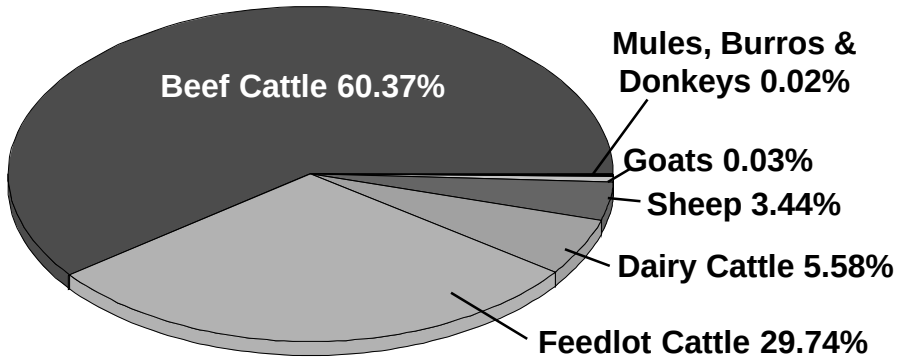


Table 3.10 Domestic Animals Sector: 1990 Methane & Carbon Dioxide Equivalent Emissions Summary

Component	Methane (tons)	Percent Total of Sector
Beef Cattle	129,702	60.37
Feedlot Cattle	63,900	29.74
Dairy Cattle	11,994	5.58
Sheep	7,392	3.44
Horses	1,374	0.64
Swine	380	0.18
Goats	65	0.03
Mules, Burros & Donkeys	45	0.02
Total Methane Emissions	214,850	100.00
Total Carbon Dioxide Equivalent Emissions	4,511,848	100.00

3.5.4 Coal Mining Sector

Methane emissions from coal mining and processing were the fourth largest source of greenhouse gas emissions in Colorado during 1990, producing 2.2 percent of the state's greenhouse gas emissions. Methane trapped in coal seams is released during mining, milling and transportation operations. The methane is a by-product of chylification, the long-term geologic process that creates coal. Methane is usually trapped within coal seams until natural or anthropogenic activity expose the seams or relieve the pressure which traps the gas.

Colorado produced 19 million tons of coal in 1990 from 14 underground and 5 surface mines. Mining activities released 110,471 tons of methane in 1990, less than 1% of the nation's coal mining activities.

In 1990 coal mining activities released 110,471 tons of methane or 2,319,891 tons of carbon dioxide equivalent gases. This quantity includes releases of methane from surface and subsurface coal mining, and releases from post-mining processing activities (e.g. breaking, crushing, thermal drying and transportation). Figure 3.11 and Table 3.11 highlight the sector's apportionment and emission comparisons.

Figure 3.11 Coal Mining Sector: 1990 Methane Emissions Apportionment

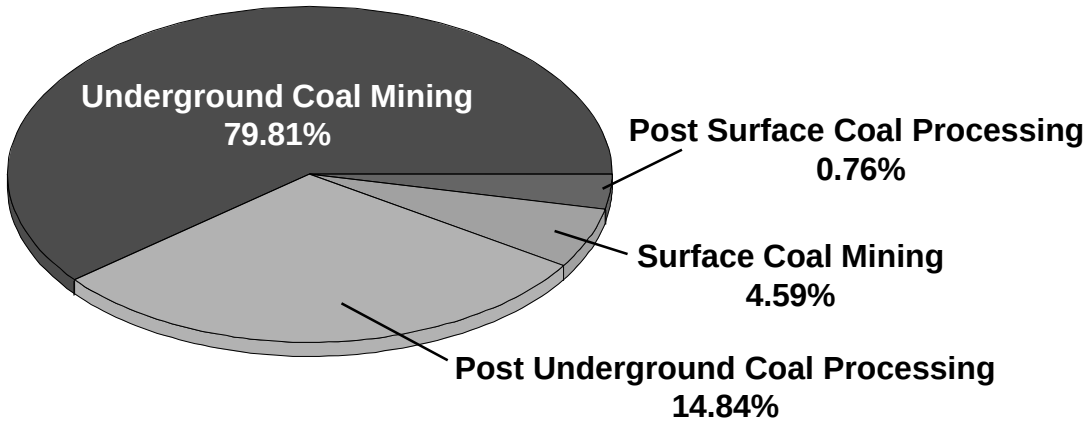


Table 3.11 Coal Mining Sector: 1990 Methane & Carbon Dioxide Equivalent Emissions Summary

Component	Methane (tons)	Percent Total of Sector
Underground Coal Mining	88,168	79.81
Post Underground Coal Processing	16,390	14.84
Surface Coal Mining	5,069	4.59
Post Surface Coal Processing	845	0.76
Total Methane Emissions	110,471	100.00
Total Carbon Dioxide Equivalent Emissions	2,319,891	100.00

3.5.5 Landfill Sector

Greenhouse gas emissions from Colorado's landfills rank fifth in the state quantitatively. Anaerobic decomposition of organic materials in landfills by bacteria result in emissions of methane and carbon dioxide. In particular, materials such as yard waste, household garbage, food waste and paper decompose and produce methane. Methane production in landfills typically begins one or two years after waste placement and may occur for 10 to 60 years. Carbon dioxide emissions produced from landfills are not included in greenhouse gas inventories because the organic matter which produces the gases is assumed to absorb carbon dioxide during its growing cycle. This "uptake-release" scenario is assumed to work in equilibrium from a net carbon dioxide production standpoint.

Colorado's 1990 methane emissions from the Landfill Sector represents 1.7 percent of the state's total greenhouse gas emissions in the baseline year. In 1990, the sector emitted 84,529 tons of methane emissions which equal 1,775,109 tons of carbon dioxide equivalent gases. These emissions come from large, small and industrial landfills. Figure 3.12 and Table 3.12 highlight the sources of these emissions.

Figure 3.12 Landfill Sector: 1990 Methane Emissions Apportionment

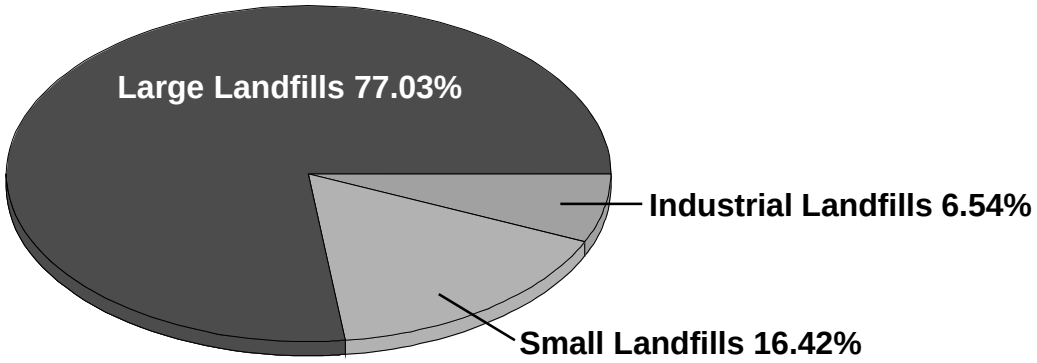


Table 3.12 Landfills: 1990 Methane & Carbon Dioxide Equivalent Emissions Summary

Component	Methane (tons)	Percent Total of Sector
Large Landfills	65,117	77.03
Small Landfills	13,882	16.42
Industrial Landfills	5,530	6.54
Total Methane Emissions	84,529	100.00
Total Carbon Dioxide Equivalent Emissions	1,775,109	100.00

3.5.6 Natural Gas & Oil Production Sector

Greenhouse gas emissions from oil and gas production, storage, transportation and distribution ranked sixth in the state quantitatively during 1990. The primary greenhouse gas emitted by the sector is methane, although it also produces minor emissions of non-methane volatile organic compounds, carbon dioxide and carbon monoxide. For inventory purposes, only methane gas is considered.

Colorado's 1990 methane emissions from the Natural Gas and Oil Production Sector represent 1.0 percent of the state's total greenhouse gas emissions in the baseline year. In 1990, the sector emitted 51,033 tons of methane emissions which equal 1,071,704 tons of carbon dioxide equivalent gases. This came from emissions associated with venting, flaring, chronic leaks or discharges from process vents, emissions during routine maintenance and emissions during system upsets and accidents. Figure 3.13 and Table 3.13 describe the sources of these emissions per fuel type and activity.

Figure 3.13 Natural Gas & Oil Production Sector: 1990 Methane Emissions Apportionment

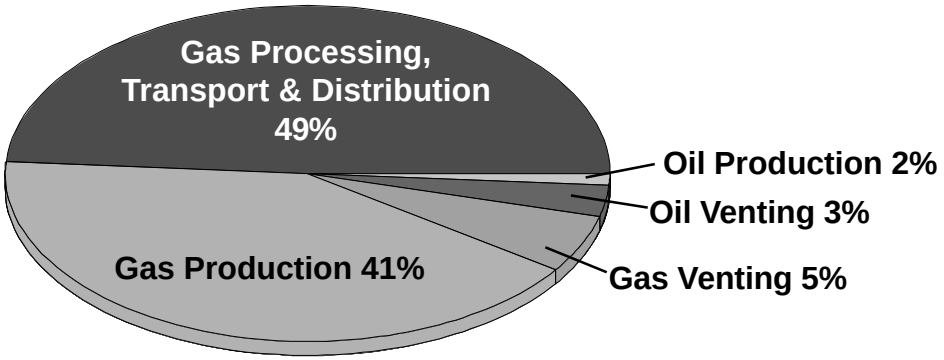


Table 3.13 Natural Gas & Oil Production: 1990 Methane & Carbon Dioxide Equivalent Emissions Summary

Component	Methane (tons)	Percent Total of Sector
Gas Processing, Transport & Distribution	25,004	49
Gas Production	21,119	41
Gas Venting	2,760	5
Oil Venting	1,636	3
Oil Production	512	2
Total Methane Emissions	51,033	100
Total Carbon Dioxide Equivalent Emissions	1,071,704	100

3.5.7 Fertilizer Use Sector

Greenhouse gas emissions from commercial fertilizer use ranked seventh in the state quantitatively during 1990. Nitrous oxide is produced from the application of commercial fertilizer to soil. While nitrous oxide is naturally produced in soils from microbial processes, the application of commercial nitrogen fertilizers increases soil's nitrogen source and thus increases nitrogen oxide emissions.

Colorado's 1990 nitrous oxide emissions from the Fertilizer Use Sector represent 0.8 percent of the state's total greenhouse gas emissions in the baseline year, ranking seventh quantitatively. In 1990, the sector emitted 2,793 tons of nitrous oxide, which equated to 865,963 tons of carbon dioxide equivalent emissions. These emissions were produced from two main types of fertilizers – anhydrous ammonia and nitrogen solution fertilizers. Figure 3.14 and Table 3.14 describe the sources of emissions from the sector according to fertilizer type.

Figure 3.14 Fertilizer Use Sector: 1990 Nitrous Oxide Emissions Apportionment

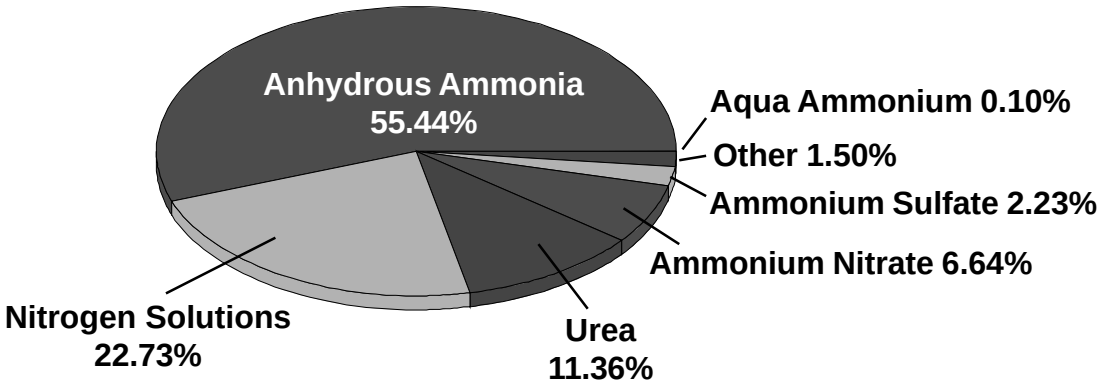


Table 3.14 Fertilizer Use Sector: 1990 Nitrous Oxide Emissions Summary

Component	Nitrous Oxide (tons)	Percent Total of Sector
Anhydrous Ammonia	1,549	55.44
Nitrogen Solutions	635	22.73
Urea	317	11.36
Ammonium Nitrate	185	6.64
Ammonium Sulfate	62	2.23
Other	42	1.50
Aqua Ammonia	3	0.10
Total Nitrous Oxide Emissions	2,793	100.00
Total Carbon Dioxide Equivalent Emissions	865,963	100.00

3.5.8 Land Use/Forestry Sector

Emissions from land use activities that altered the state's quantity of biomass resources ranked eighth in the state for greenhouse gas production during the 1990 baseline year. Biomass resources includes organic material both above and below ground, both living and dead. Unlike other sector's emissions, greenhouse gas emissions from the Land Use/Forestry Sector are considered to be kept in equilibrium due to the natural cycle of plants which uptake (sequester) carbon dioxide during plant growth and release it during decay or burning.

In examining Colorado's Land Use/Forestry Sector, it is therefore important to consider land uses which cause emissions of carbon dioxide and the potential for the state's forests to act as a "sink" and sequester carbon dioxide. Colorado's forest sink capacity on an annual basis is 76,918,806 tons. On the inverse, during the baseline year anthropogenic land use practices caused the emission of 723,387 tons of carbon dioxide. Figure 3.15 and Table 3.15 detail this activity below.

Figure 3.15 Land Use/Forestry Sector: 1990 Carbon Dioxide Emissions

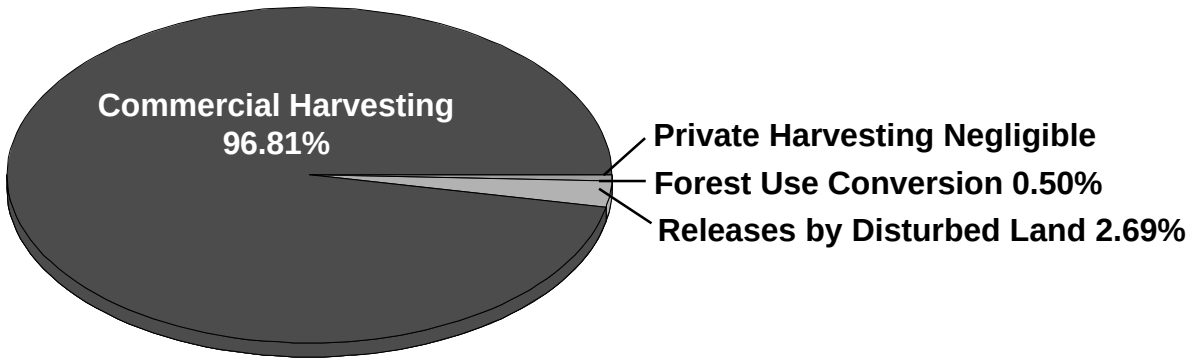
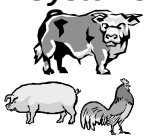


Table 3.15 Land Use/Forestry Sector: 1990 Carbon Dioxide Emissions

Component	Carbon Dioxide (tons)	Percent Total of Sector
Commercial Harvesting	700,278	96.81
Distrubed Land Releases	19,485	2.69
Forest Use Conversion	3,622	0.50
Private Harvesting	2	negligible
Total Carbon Dioxide Emissions	723,387	100.00



3.5.9 Manure Management Systems Sector

Emissions from manure management systems ranked ninth in the state for producing greenhouse gases during the 1990 baseline year. Manure management systems in Colorado vary in complexity between anaerobic lagoon systems to simple pasture and range systems. The primary gas emitted by manure decomposition in these systems is methane. Methane is produced as microorganisms derive energy and material for cellular growth by metabolizing organic material in the manure. The specific methane producing capacity of manure depends upon the particular composition of the manure, which is in turn dependent upon the composition and digestibility of the animal's diet. Contributing to emissions in this sector are all the animals included in the Domestic Animals Sector plus nearly 4.5 million poultry.

Colorado's 1990 methane emissions from the Manure Management Sector represent 0.3 percent of the state's total greenhouse gas emissions in the baseline year. In 1990, the sector emitted 13,332 tons of methane emissions which equal 279,983 tons of carbon dioxide equivalent gases. Figure 3.16 and Table 3.16 describe the sources of these emissions per animal species.

Figure 3.16 Manure Management Systems 1990 Methane Emissions Apportionment Per Animal

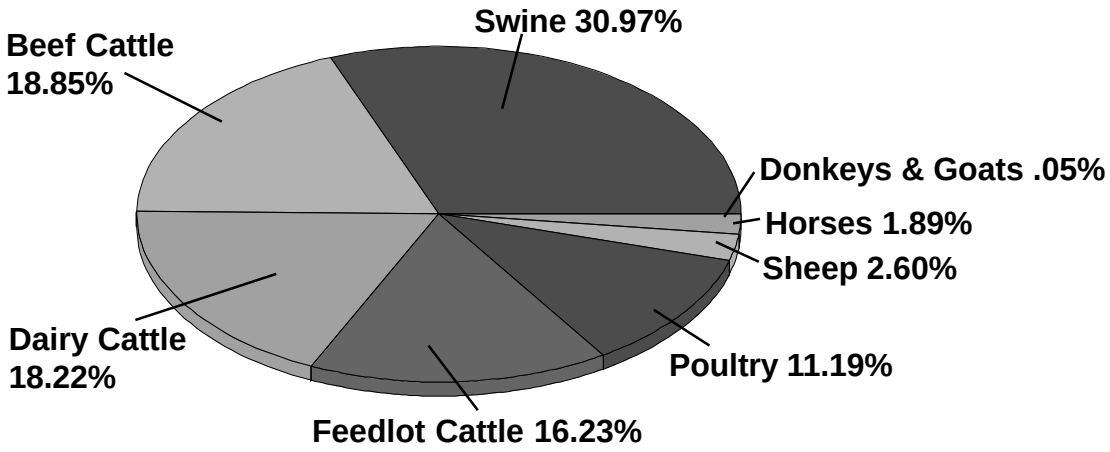


Table 3.16 Manure Management Systems Sector: 1990 Methane & Carbon Dioxide Equivalent Emissions Summary Per Animal

Component	Methane (tons)	Percent Total of Sector
Swine	4,129	30.97
Beef Cattle	2,513	18.85
Dairy Cattle	2,429	18.22
Feedlot Cattle	2,163	16.23
Poultry	1,492	11.19
Sheep	346	2.60
Horses	252	1.89
Donkeys & Goats	7	0.05
Total Methane Emissions	13,332	100.00
Total Carbon Dioxide Equivalent Emissions	279,983	100.00

3.5.9.1 Manure Management Systems Sector

How livestock manure is managed is can make a big difference on the amount of methane emitted from the livestock manure management sector. Depending on the type of animal being managed and the preference of the operator, a number of manure management systems can be used. In Colorado, the most commonly used systems include: lagoons, dry-lots, slurry, short and long-term storage, daily spreading, litter and other methods. Figure 3.17 and Table 3.17 tabulate the relative contributions of each manure management system to Colorado's greenhouse gas production. Across these management systems, nearly 30 billion pounds of manure is disposed. Methane emissions in 1990 were estimated to be more than 13,000 tons or roughly 2.8 percent of Colorado's methane emissions. Lagoon management methods alone contribute to 38 percent of the volume being released as methane. Management of cattle manure represents the single largest component of this sector, accounting for more than 50 percent of the methane releases.

Figure 3.17 Manure Management Systems 1990 Methane Emissions Apportionment Per System

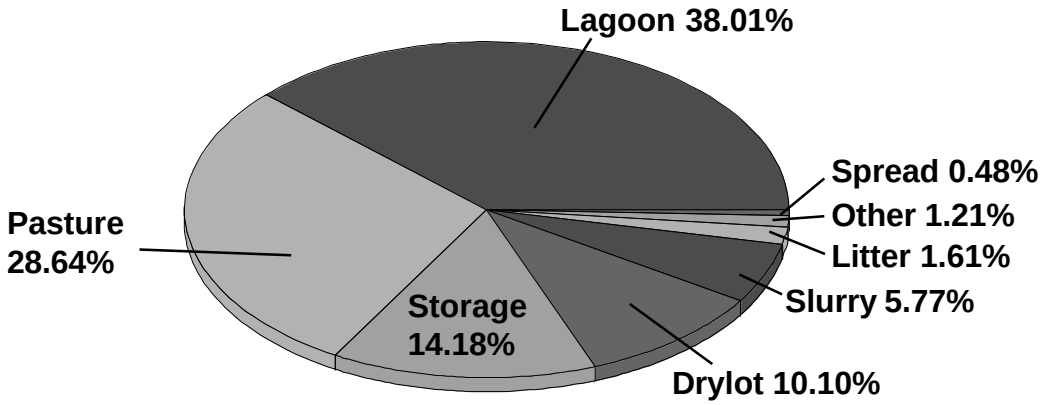


Table 3.17 Manure Management Systems Sector: 1990 Methane & Carbon Dioxide Equivalent Emissions Summary Per System

Component	Methane (tons)	Percent Total of Sector
Lagoon	5,067	38
Pasture	3,819	28.6
Storage	1,890	14.2
Drylot	1,347	10.1
Slurry	769	5.8
Litter	214	1.6
Other	162	1.2
Spread	64	0.48
Total Methane Emissions	13,332	100
Total Carbon Dioxide Equivalent Emissions	279,983	100

3.5.10 Wastewater Treatment Systems Sector

Colorado's industrial and municipal wastewater treatment systems produce methane gas as a result of anaerobic decomposition. Highly organic wastewater streams such as waste streams from food processing operations rapidly deplete available oxygen in the water stream during decomposition. This oxygen depletion is termed biochemical oxygen demand, or "BOD." Biological oxygen demand represents the amount of oxygen taken up by the organic matter in the wastewater during decomposition. Under the same conditions, wastewater with relatively high biological oxygen demand concentrations will produce more methane than wastewater with lower biological oxygen demand concentrations. Most industrial wastewater has a low biological oxygen demand, while food processing facilities such as fruit, sugar, meat processing plants and breweries can produce untreated wastewater with high biological oxygen demand.

In 1990, the Wastewater Treatment Systems Sector ranked tenth in terms of greenhouse gas production. Approximately 3,571 tons of methane were emitted from the systems during the baseline year, equaling 74,997 tons of carbon dioxide.

Table 3.18 Wastewater Treatment Systems Sector: 1990 Methane & CO_2 Equivalent Summary

4.0 Potential Climate Change Impacts to Colorado

This section is intended to evaluate what might occur if pro-climate change predictions occur. It is expressly not intended to imply that such predictions will occur.

Assessing potential climate change impacts to the state is complicated by general uncertainties in climate change science and climate change modeling. Scientists and modelers' foremost attempts to predict climate change impacts to the state involve the use of global and regional computer models. These models inherently contain substantial margins of error which increase as the scale of the area being modeled decreases. Thus, there is more certainty in predicting potential climate change impacts to an area the size of North America, as opposed to an area as small as the state of Colorado.

Despite the modeling uncertainty, there is a large amount of knowledge in existence about the potential responses of Colorado's natural and anthropogenic systems to stress. This knowledge can be used to evaluate these systems' sensitivities and vulnerabilities to potential changes in climate. Once these sensitivities and vulnerabilities are characterized, potential climate change scenarios can be applied and system responses inferred. In essence, if done correctly this evaluation can empirically answer the question of "What could happen in Colorado?" This question can be addressed with far greater certainty than the "What will happen ...? question. The end result in completing such an evaluation is to give policy makers and the public a sense of the potential risk involved.

Natural & Anthropogenic Systems

In assessing responses to potential climate change in the state, this study considered a cross section of natural ecosystems, socioeconomic systems and infrastructure systems. These systems include:

- Forests
- Snow and Ice
- Rangelands
- Hydrologic Cycle
- Industry
- Tourism, Insurance

4.1 Assessing Potential Stresses to Colorado's Natural and Anthropogenic Systems

In evaluating the response of Colorado's natural and anthropogenic systems's response to potential climate change induced stresses, it was vital to first characterize those potential stresses. To accomplish this task, ReCom Applied Solutions, Inc., completed a literature review to ascertain what experts are predicting will happen as a result of climate change. To this end, reviews of pubic and private publications, web sites, traditional scientific literature and consultations with scientists at the National Center for Atmospheric Research took place. A listing of the literature research is located in Appendix 7.0 of this document.

The next step in the evaluation was to adopt an approach to describe the sensitivities and vulnerabilities of Colorado's systems to those potential stressors. For this report, the approach used by the Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change was adopted. This approach focuses on assessing the sensitivity and vulnerability of systems to potential climate changes. After having identified the response functions and/or potential thresholds of particular systems to climate change induced stress, the approach then applies theoretical climate change scenarios and infers climate change induced impacts to the natural and anthropogenic systems.

For Colorado, this meant initially clarifying what was known and unknown about three distinct issues involving systems before applying regional climate scenarios to estimate potential impacts. The three issues were:

- How sensitive is a particular system to climate change? In essence, how will a system respond to given changes in climate?

- How adaptable is a particular system to climate change? To what degree are adjustments possible in practices, processes, or structures of systems in response to projected or actual changes in climate?

- How vulnerable is a system to climate change? How susceptible is a system to damage or harm due to potential changes in climate?

To further provide a basis of objective qualification of the impact evaluation, a ranking method was used to signify with what degree of confidence subjective statements were made concerning the potential impacts to different systems. This allows readers to qualitatively weigh statements made concerning the sensitivity, adaptability and vulnerability projections made in the evaluation.

The three-tiered confidence level structure used the following delineations:

- High Confidence - Denotes wide agreement, based on multiple findings through multiple lines of investigations.

- Medium Confidence - Denotes agreement, but not a strong one, in support of the conclusion.

- Low Confidence - Denotes a high uncertainty about a particular conclusion which could reflect a lack of agreement or the existence of serious competing hypotheses.

The confidence levels of many statements contained in this report are qualified by the existence of one of these high, medium or low delineations. The delineations follow the appropriate sentences and are placed in parenthesis.

4.1.1 Climate Change Scenario

After characterizing Colorado's natural and anthropogenic systems' sensitivity, adaptability and vulnerability to changes in climate, the evaluation posed a theoretical climate change scenario to each system and predicted what the impacts of the climate scenario would be on the system. In assessing what climate change scenario to apply to Colorado, a multitude of choices arose, from climate change scenarios that predicted little if any change to scenarios which predicted significant change. The scenario chosen for the evaluation utilized the Intergovernmental Panel on Climate Change's projections for climate change, the same projections that drove much of the Kyoto negotiations in December 1997. These

projections are based upon general circulation model estimates to the year 2100.

From these projections, a relatively conservative scenario was adopted for the Colorado evaluation in which the doubling of carbon dioxide concentrations occurred by the year 2100, going from 350 to 700 parts per million by volume. Equilibrium global warming for this scenario ranges from 1.0°C to 3.5°C (1.8°F to 6.3°F) with a best estimate of about 2°C (3.6°F), with significant variation by region.

Under the Intergovernmental Panel's scenario, in the United States and high latitudes it is projected that warming will be greater than the global average. For Colorado's impacts evaluation a conservative approach was used which operated in the lower ranges and did not expect warming values of more than .6°C (1.1°F) by the year 2015 and 2°C (3.6°F) by 2100. It should be noted that changes of this magnitude would be greater than recent natural fluctuations and would be occurring at a rate significantly faster than any observed changes in the last 10,000 years. Accompanying these increases in temperature under this scenario is an assumed increase in the frequency and magnitude of extreme meteorological events.

The atmosphere since the pre-industrial era has seen atmospheric levels of carbon dioxide increase by almost 30 percent, nitrous oxide levels rise by 15 percent and methane concentrations effectively double. These increases lead to a heat-trapping of energy (termed radiative forcing) that now stands at about 2.8 watts per square meter (WM^{-2}). By the year 2100, the general circulation models used by the Intergovernmental Panel on Climate change predict additional radiative forcing of about 3 WM^{-2} to 8 WM^{-2}.

Scientifically, it is possible to predict with fairly high certainty what the resulting increase in radiation should be for a given concentration of greenhouse gases. However, predicting the resulting impact on climate, especially regionally in Colorado is much more

Table 4.1 Regional Climate Change Scenario Assumptions

• The largest temperature changes will occur in high latitudes
• Mid-latitude changes will be more pronounced in the Northern Hemisphere
• Frostline will move 150 to 250 miles north
• Temperature will change more in winter than in summer
• Food-producing belts will shift 200 miles to the north
• In predicting Colorado impacts from this regional scenario, most impacts can only be predicted at medium to low confidence levels (High Confidence).

uncertain. In order to develop an overall sense of the potential regional impacts of global warming as it pertains to this evaluation, a simple list of assumptions for the climate scenario was compiled (Table 4.1). The list was derived from large scale General Circulation Models.

Changes in temperature, storm intensity, storm frequency and precipitation driven by climate change can add to existing stresses on Colorado's natural resources. The stresses include impacts from land-use changes, population growth and pollution (all human-induced). Under the Intergovernmental Panel warming scenario, natural ecosystems in Colo-

rado could potentially be degraded as individual species respond to these changes. Degradation could affect the basic composition and productivity of these ecosystems (Medium Confidence). Reduction in biological diversity could be a direct spin-off of this degradation. Definitive impact statements about specific Colorado ecosystems, however, are difficult to make at present with any significant confidence. Presented below are the findings from the assessment/scenario comparisons for selected systems in the state.

4.2 Natural & Anthropogenic Systems: Vulnerability/Impacts of Climate Change

Colorado's natural ecosystems, socioeconomic systems and infrastructure systems are varied and vast. Overlap and interaction frequently occur between the systems. For example, the condition of Colorado's natural hydrologic system is directly linked to the state's agricultural system. For simplicity and clarity, this evaluation grouped the natural ecosystems and anthropogenic systems into nine large systems. While not all-inclusive of every natural and anthropogenic system or activity within the state, the evaluation of these nine systems' response to the theoretical warming scenario can provide a sense of the potential risk of climate change in Colorado.

4.2.1. Mountain Regions – Forest System, Snow & Ice Systems

The potential climate change impacts on the Colorado Rocky Mountains as a physical system are highly uncertain and impossible to predict at this time with any significant level of confidence (High Confidence). However, the mountain systems are highly sensitive to climate change (High Confidence). There is an inherent difficulty in predicting the impacts of potential climate change on the mountains areas because of the poor resolution of most general circulation climate models. This makes the models difficult to use in investigating the potential impacts of climate change. There is also a general lack of comprehensive multi-disciplinary data for impact assessment (Parry et al., 1992). The many complex systems that make up the Colorado mountain environment present major problems for assessing with confidence the potential impacts of climate change (High Confidence). However, an evaluation of the vulnerability of the mountains' forest systems and snow and ice systems in comparison to the theoretical climate change scenario is pertinent in attempting to characterize the potential impacts involved.

4.2.1.1 Forest Systems

The forests in Colorado are highly sensitive to climate change (High Confidence). Sustained temperature increases of as little as 1°C in mean annual air temperature can be sufficient to cause changes in regeneration capacity and growth of almost all forest species

in Colorado. This could alter the composition and function of forests and cause forest cover in some areas to disappear completely (Medium Confidence).

In the theoretical climate change scenario, the impact affecting Colorado forest species the most include increases in both summer and winter mean temperatures of about 1°C, decrease in summer and winter precipitation and drier soils in the summer. Projections under the theoretical warming scenario imply longer and warmer growing seasons, more summer droughts and less extreme sub-zero temperatures in winter. Probably the most important aspect, however, is the speed with which these climate change events might occur. Projections from the theoretical scenario suggest it might take less than a century for these climate changes to significantly impact the forested areas of Colorado. This rate of change is significantly faster than any in the preceding 10,000 years and could represent a significant to major climate-induced stress on Colorado's forests (High Confidence).

Colorado forests contain approximately 80 percent of all above ground carbon in vegetation and about 40 percent of all soil carbon. Hence, forests and forest soils play a significant role in the carbon cycle as source (e.g. deforestation, and forest degradation) and sinks (e.g. reforestation, afforestation). In some cases, the forests' sink role might enhance forest growth due to carbon dioxide fertilization. As a general rule, forest productivity and the diversity of species will increase with temperature, nutrient availability and precipitation. However, under extreme changes in water availability associated with the theoretical climate change scenario, as from periodic waterlogging or drought, Colorado forests could become vulnerable to degradation and could decline rapidly.

For Colorado, an average global warming of 1°C to 3.5°C during the next 100 years would be equivalent to shifting isotherms poleward approximately 150 kilometers to 550 kilometers, or an altitude shift of 150 meters to 550 meters. When compared to past tree species migration rates of 4 kilometers to 200 kilometers per century, there is the potential that entire forest types may disappear across the state (Medium Confidence). The potential northward shift in the ideal range for Colorado forests might exceed the ability of forests and other ecological communities to migrate. (Medium Confidence).

Under this theoretical scenario, the greatest potential impact would occur to Colorado's unmanaged forests and related ecosystems. This would include large tracts of private and public forests where virtually no forestry management is possible or does not occur. In contrast, Colorado's managed forests, which tend to include smaller manageable tracts owned by both private and public entities, could be managed to a greater degree to respond to climate change.

In examining potential impacts of change, the response of forests and ecosystems to elevated concentrations of atmospheric carbon dioxide has been considered in this study. Higher atmospheric carbon dioxide concentrations have been shown to increase the net primary productivity of plants at the plant level in controlled experiments. In essence, carbon dioxide can act as a form of fertilizer. This in turn could alter species composition by changing the competitive balance among different plants. These effects are currently being studied at the ecosystem level and the magnitude and persistence of the carbon dioxide fertilization effect remains unquantified. It is believed that carbon dioxide fertilization can be limited by saturation, adaptation and nutrient limitations, among other factors (Bazzaz,

et al., 1996). Although it is possible that the net primary productivity could increase as a direct result of elevated concentrations of atmospheric carbon dioxide, the standing forests in Colorado could suffer an overall decline in the theoretical scenario from several accompanying and competing side effects. Warming-induced water shortages, marked shifts in pest speciation and activity, increased disease and forest fires would likely cause decreased net primary productivity leading potentially to significant changes in forest distribution across the state (Medium Confidence).

Although elevated carbon dioxide concentrations along with potential warming could increase net primary productivity in many of Colorado's forests, net carbon storage may not increase because of the associated stimulation of soil organic matter decomposition by soil warming. Increases in net primary productivity could be offset by increased soil respiration due to the warmer temperatures (Kirschbaum, 1993; Thornley et al., 1991). Hence, net ecosystem productivity may not change, and likely could decrease (Medium Confidence).

Many Colorado species that are growth limited by water shortages for at least part of the year could be adversely affected by intensification of summer soil water deficits (Greco et al.,1994), as predicted in the theoretical scenario. In addition, warmer winters which potentially lead to less precipitation falling as snow could lead to reduced regional snow packs as a direct result. This, in turn, could result in less carry over of water from the winter to the growing season (Mitchell, et al. 1990). A large fraction of Colorado forests could be lost in response to increased summer droughts resulting from decreased water availability (Medium Confidence).

In addition, since water shortages during part of the year already impact Colorado forests, this effect could be amplified by intensification of summer soil water deficits. The overall impact could be an increase in the incidence of summer drought and an increase in forest disease, pest outbreaks and mortality. (Medium Confidence). A direct result of this could be to increase the probability of forest fires and extend the hazard to areas that are not now affected. In areas of the state with large quantities of built up fuel, particularly Colorado's Front Range forests, the risk of increased forest fires may be exacerbated. (Medium Confidence).

4.2.1.2 Snow & Ice Systems

Colorado's snow and ice systems constitute a major source of fresh water for the state. They are comprised of snow, ice and discontinuous permafrost, including seasonal snow, mountain glaciers, ice sheets, seasonally frozen soils, river ice and lake ice. The systems are very sensitive to climate change (High Confidence).

Using the climate change scenario of doubled carbon dioxide adopted for this report, the disappearance of up to 25 percent of the presently existing mountain glacial mass could be realized (Medium Confidence). Even with less than a 1^{o}C temperature increase by 2015 in Colorado, there could be significant glacier mass reduction. It should be noted that there has been a very obvious thinning, mass-loss and retreat of mountain glaciers worldwide including mountain glaciers within the Rocky Mountains during the 20th century (High Confidence).

Under the theoretical warming scenario, pronounced reductions are possible in sea-

sonal snow fall along with an accompanying loss in soil moisture (Medium Confidence). The reduced snow cover would cause reduction of the seasonal flow regime of rivers statewide. Since Colorado is home to the headwaters of five major rivers, a reduction in the seasonal flow of the state's rivers could have local and regional impacts (Medium Confidence). River and lake ice reductions are probable under the theoretical scenario with freeze up dates potentially being delayed and breakup beginning significantly earlier. The river ice season could be shortened by up to 30 days. Many lower elevation streams, lakes and rivers could become ice-free or develop only intermittent or partial ice cover (Medium Confidence). Reduced snow cover could cause changes in the seasonal flow regimes of rivers and streams, so that spring runoff decreases and winter runoff increases (Medium Confidence).

In Colorado, both lower elevation and alpine snow covers are very sensitive to changes in climate (High Confidence). A 1°C increase in the annual temperature of the Northern Hemisphere has been shown to result in a 20 percent reduction in Northern Hemisphere snow cover (Karl et al., 1993). Other studies have indicated that large increases in precipitation on the order of 50 percent are necessary to offset even a 0.5°C warming (CSIRO, 1994).

Under the theoretical climate scenario, Colorado's snow cover could be diminished in extent, duration and depth (Greco et al., 1994). The actual snow season could be shortened by more than 30 days, depending on snow depth. For Colorado's eastern plains, snow coverage duration and depth could be reduced significantly. (Medium Confidence).

Since snowfall could begin later, according to the climate scenario, and snowmelt could be earlier than at present, the snow-free season will be extended. The snow line could rise by between 100 meters and 400 meters depending on the precipitation. In two studies (Martinec et al., 1994; Rango and Martinec, 1994) an examination was made of the behavior of a snowmelt-runoff model in various catchments for different climate scenarios. With a rise of 1°C, snow cover would be depleted in winter due to the conversion of precipitation to rainfall and increased snowmelt. Under this warmer scenario, five days into the melt season, snow depth could be depleted to the equivalent of nine days under the present climate regime. With a 1°C warming in Colorado and a reduction in precipitation, it is probable that the net amount of snow available for snowmelt annually could decrease between at least 10 percent to 20 percent (Medium Confidence).

Changes to Colorado's snow and ice systems could change seasonal snow cover and melting rates which could reduce slope stability and increase the incidence of natural hazards for people, vehicles and structures. A tendency toward an increase in avalanche and mudslide intensity and frequency exists (Low Confidence), but the magnitudes are impossible to predict at this time (High Confidence).

For Colorado's mountains, less snowfall could have a negative impact on alpine tourism and could limit the ski industry to higher alpine areas than at present (Medium Confidence). The annual number of ski-days could decline over time. Snow seasons could tend to be shorter and less reliable (Medium Confidence). Because of the size of Colorado's ski industry, mountain communities that depend on winter tourism could experience detrimental socioeconomic impacts to a significant degree (Medium Confidence).

4.2.2 Rangeland Systems

Colorado's rangelands are used primarily for grazing by domestic livestock and wildlife. The amount and timing of precipitation are the two major limiting factors of rangelands' community plant functions and basic plant structure. Secondary driving forces that determine plant community distribution, productivity and composition include temperature, soil type, fire and herbivory. As a general rule, most Colorado rangelands do not exist in a state of equilibrium nor do they exhibit linear successional trends. Typically they fluctuate over time from one state to another depending on rain, grazing, fire and other anthropogenic factors (Westoby et al., 1991; Hobbs et al., 1991; Stafford Smith, 1994). Therefore, Colorado rangelands taken as a whole, are fairly well adapted to a wide range of climate, grazing intensities and fire frequencies.

For Colorado rangelands, the doubling of carbon dioxide concentrations assumed in the theoretical scenario could result in reductions of forage quality and palatability mainly due to increasing carbon to nitrogen ratios. Fundamental questions surrounding edibility of forage for domestic livestock and wildlife could result and lead to compounding feed problems. Under this scenario, wildlife migration and die-off are possible especially if this ratio increases rapidly and is coupled with such extreme events as drought. Where low nutritional production from rangelands is already a chronic problem, this effect could be pronounced (Medium Confidence).

Decreases in rangeland productivity could result in a decline in the overall contribution of the livestock industry to Colorado's economy. Because of the sheer size of this component within Colorado's economy this could detrimentally affect not only the livestock industry but many related industries as well.

4.2.3 Hydrologic Cycle Systems

Water availability is a critical issue to all facets of Colorado life. It has been characterized as one of the cornerstones of economic growth for the state. Across Colorado the hydrological system is very sensitive to changes in climate (High Confidence). Even a small change in precipitation and temperature, along with non-linear effects on soil moisture and evapotranspiration, can have a profound impact on runoff. Under the theoretical climate change scenario, it is probable that a changing climate associated with global warming will lead to an intensification of the hydrologic cycle in Colorado (High Confidence).

Since the hydrologic cycle directly affects how precipitation is partitioned between ground and surface water storage, particularly with snow cover, any intensification could affect the timing, intensity and magnitude of droughts and floods. More intense rainfall is probable under the theoretical scenario, but its distribution and intensity across Colorado remain difficult to predict with any significant degree of certainty. This impact would not necessarily point to a net increase in the total annual precipitation. Some evidence suggests that while precipitation events may be more intense, the total delivery of water to Colorado could be decreased. Based on global and regional data (IPCC, 1995) to date, however, it can not be clearly defined for Colorado what hydrologic cycle intensification may actually mean (High Confidence).

Typically the effects of climate change on hydrological regimes are estimated by start-

Figure 4.2.3 Impacts of Potential Climate on the Hydrologic System

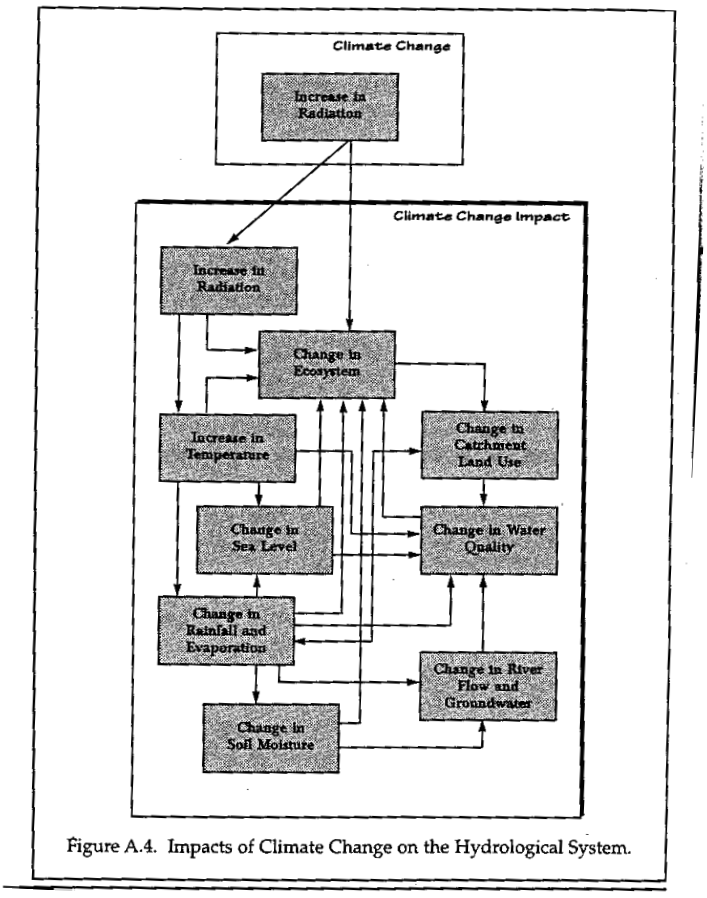


Figure A.4. Impacts of Climate Change on the Hydrological System.

ing with climate change scenarios determined from general circulation models and combining this output with catchment-scale hydrological models. This melding process has many uncertainties and three major problems with regional-scale output: (1) presenting scenarios at a scale appropriate for hydrological modeling; (2) the considerable errors inherent in climatic and hydrological data used for validation; and (3) converting the climatic inputs into hydrological responses (High Confidence). Figure 4.3.2 shows a schematic representation of the complexity of climate change on the hydrological system (Arnell, 1994).

In the theoretical climate change scenario with a doubling of carbon dioxide, the increase in greenhouse gas levels results in an increase in net radiation at the Earth's surface, which could lead to changes in temperature, precipitation and evaporation, which could in turn drive soil moisture regimes, groundwater runoff and recharge. Concurrently, soil moisture, precipitation, temperature and evaporation affect vegetation growth, as do changes in incoming solar radiation and greenhouse gas concentrations. All components of the hydrologic system are linked in a complex web of nonlinear feedback-interactions. At this point in time, this system is only roughly approximated in the broadest sense for Colorado (High Confidence).

In considering the theoretical climate change scenarios's on Colorado's hydrologic cycle, assuming decreased snowpack and a reduction in annual precipitation, it becomes probable that Colorado is likely to experience significant water shortages (Medium Confidence). Considering the catchment characteristics of the Rocky Mountains, with storm intensity and storm frequency increasing under the scenario, it is significantly probable that the number and severity of flooding events will likely increase (Low Confidence). Accordingly, the danger of flash floods, especially along the Front Range, can be expected to increase. As Colorado's population grows and the number of home and home values increase, it could be expected that property damage and loss of life will likely increase (Me-

dium Confidence). Overall annual precipitation amounts may decrease (Medium Confidence) but localized storm intensity and frequency may increase (Low Confidence). Since winter snowfall and spring snowmelt drive the flow rates of rivers and streams in Colorado, this could translate into widespread reductions in spring runoff, coupled to increases in winter runoff (Medium Confidence). The consequences for Colorado could be significant for water storage and delivery systems, flood prevention, irrigation and agro-water management, and the availability of drinking water supplies (Medium Confidence).

4.2.4 Agricultural Systems

Unlike natural unmanaged systems, agricultural systems are highly managed through crop and animal selection, fertilizer and feed selection, tillage and husbandry methods, and pest and disease control. Relative to unmanaged natural systems, this gives agricultural systems more adaptability in the face of potential climate change.

In considering potential impact on Colorado's agricultural system from climate change, two broad areas of effects are of concern:

• Direct effects on agriculture from climate change that alter temperature, precipitation, water balance, atmospheric composition and extreme events

• Indirect effects on agriculture from climate change that alter the frequency, distribution and severity of disease and pest outbreaks, changes in the incidence of fire and weed infestation and changes in basic soil properties.

Under the theoretical climate change scenario, it is suggested that Colorado's climate will change towards drier and warmer conditions (Medium Confidence). With these conditions and lower mean annual precipitation, crop yields could be lower than they are presently (Medium Confidence). There is historical precedence for this from past extreme weather events such as the droughts of the 1930s and 1950s. Laboratory experiments and computer crop growth simulations also support this yield reduction scenario. However, according to some agronomists the detrimental effects from a drier hotter climate could be offset or mitigated via appropriate application of advances in genetics and husbandry (Council for Agricultural Science and Technology, 1992) (Medium Confidence).

The frequency and intensity of drought conditions across Colorado could increase as net precipitation levels decrease and soil moisture drops, according to the climate change scenario (Medium Confidence). The consequences to selected Colorado crops and livestock could be moderate to severe, especially along the western slope and eastern plains (Low Confidence).

A major consideration in current agronomic and economic models is the effect on productivity of atmospheric compositional changes, specifically the doubled-equivalent carbon dioxide equilibrium condition. Most modeling results are built on the assumption of increased productivity of crops due to elevated concentrations of atmospheric carbon dioxide. Their applicability to Colorado is still speculative since these studies at present do not include changes in weeds, diseases and insects, or changes in water supply and soils. Soil-management practices also are not folded into current predictive models and the direct effect on Colorado livestock is missing. Since the models are lacking these fundamental

components, the ability to deal with regional, transient climate change scenarios or to fully address impacts, costs and adaptation potential remains very limited (High Confidence).

Research focusing on crops such as wheat, soybeans, potatoes and trees illustrates these shortfalls but also points to a potential positive feature to rising carbon dioxide concentrations in the atmosphere. Carbon dioxide is a necessary ingredient in photosynthesis and actually helps plants use water more efficiently. Some experiments are now showing that certain crops like small grains and soybeans are likely to benefit greatly from increasing carbon dioxide levels in the atmosphere. Other crops, like corn and sorghum, however appear to benefit much less. The mean value crop response under experimental conditions shows a 30 percent increase in productivity for many small grain and soybean crops under doubled-carbon dioxide conditions, but the range is minus 10 percent to plus 80 percent. This high variability reflects the fact that the carbon dioxide doubling response is critically dependent on plant species, precipitation, temperature, plant nutrient availability as well as a host of other unmodeled variables. Differences in experimental technique also are likely to play a significant role in their variability (High Confidence). Recent and on-going crop-yield studies may clarify this complex picture.

4.2.5 Socioeconomic Systems

In this evaluation the major economic sectors within the state's economy were considered. Those sectors included a variety of elements ranging from residential and commercial property capital and assets, to industrial entities, to communications and education, to energy and transportation across the state. Because of the high degree of uncertainty, impact variability and complexity involved with these sectors, the evaluation only considered these elements in a broad fashion. Due to the interconnections of economic activity between these sectors, most of the potential climate change influences to them such as industrial activity, transportation and energy could be indirect and transmitted by market changes. These market changes could be sensitive to changes in resources which are sensitive to climate (e.g. energy demand for space cooling and heating) or changes in resources sensitive to climate (e.g. water, relative to the ski and tourist industry). In the course of the evaluation, no studies were found that addressed the monetary value of potential indirect climate change impacts to Colorado.

4.2.6 Industry, Energy and Transportation Sectors

Very few studies exist on potential climate change impacts and adaptation options for the industrial, energy and transportation sectors across the United States (IPCC, 1995). No studies on this topic were found for Colorado. This reflects a perception of low vulnerability to climate change for these sectors in general (Medium Confidence). Additionally, compared to agriculture or natural ecosystems, the climate sensitivity of most activities in the industrial, energy and transportation sectors is low (IPCC, 1995) (Medium Confidence).

Quantitative impacts studies are lacking in the energy sector. In Colorado hydroelectric power generation is very small, thus changes in precipitation and evaporation will not have a significant impact on the state's power production. Power generation elsewhere in

the west, however, could be adversely impacted. Under the theoretical climate change scenario, peak winter demand for primary energy is projected to decrease due to an overall reduction in space heating needs. Conversely, peak summer electricity loads could increase in response to greater cooling requirements, especially in larger metropolitan areas such as Denver. The net effects of such changes in energy, however, have not been quantified (High Confidence).

In evaluating the impacts to the industry, energy and transportation sectors in Colorado, it would be amiss not to consider the possibility of mitigation impacts to the sectors.

Under the theoretical climate change scenario, the nation and Colorado could look to mitigate greenhouse gas emissions from these sources. Such activity could spawn an increase in research and development of mitigation methods, such as increasing the efficiency of fossil fuel combustion processes. Also spawned from such activity could be an increase in the development of alternative energy resources and technology. This could expand Colorado's economy into this energy-related field.

4.2.7 Tourism, Financial and Insurance Sectors

The tourism industry in Colorado, especially all outdoor winter activities such as skiing, would be impacted by a climate shift likely involving lower precipitation, later first snow fall, earlier springs, reduced snowpacks and rising transient permafrost levels, as predicted in the theoretical climate scenario. However, quantitative studies and estimates are lacking to enable a definitive conclusion to be drawn on the impacts to this industry. It is likely that the winter sports and touring industry in Colorado, together with its support industries, will be significantly impacted by regional climate change affects (Medium Confidence).

The increased risk for extreme weather events in Colorado, as predicted in the theoretical scenario, could likely impact the property insurance component of the financial services sector (Low Confidence). This potential risk could lead to higher insurance premiums or the withdrawal of coverage for certain vulnerable areas or sectors of the Colorado economy. However, this link is weak at present and is not perceived to be an issue of concern within the financial services sector (Medium Confidence).

4.2.8 Public Health Systems

Any significant climate change disturbance of Colorado's natural systems (e.g. weather patterns, water supplies) and ecosystems (e.g. disease-vector habitats, agro-ecosystems) could pose risks to public health (High Confidence).

Under the theoretical climate change scenario, most of the health impacts associated with an altered climate are negative (High Confidence). In Figure 4.2.8, direct and indirect impacts to public health are explained. The direct impacts on Colorado could be significant but are impossible to quantify at this time (High Confidence).

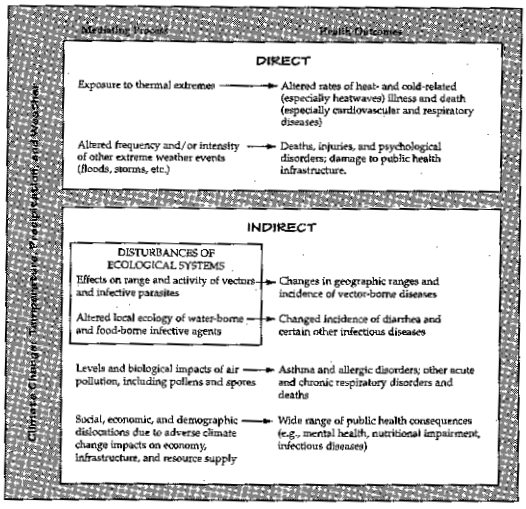
With an increased frequency and severity of heat waves, as foreshadowed in the theoretical scenario, mortality and illness rates could rise (High Confidence). The number of cardiorespiratory problems, especially in vulnerable populations such as the elderly and

young, could increase. Across Colorado, the heat-related increase in deaths may be partially offset by fewer cold-related deaths, but at present there is insufficient data to quantify this trade-off (High Confidence).

The direct, health-related impacts of extreme weather events in Colorado such as droughts, floods and storms, as outlined in the theoretical scenario, could lead to increases in rates of death, injury, infectious diseases and other related psychological disorders (Medium Confidence).

Insects are especially tuned to temperatures changes and could be expected to shift their ranges rapidly in response to changing weather patterns and rising temperatures. Disease-borne insect problems now present in northern Mexico and New Mexico may be transported to Colorado during fairly short time periods. For example, the climate-driven movement of the Edith's Checkerspot Butterfly in the western United States appears to have shifted northward by about 150 kilometers during the past century (Parmesan, 1996). While this study occurs during a 100-year time period, a warming trend of .6^{0}C is associated with the time period. Many vectors move much faster in response to temperature and other related environmental influences.

Figure 4.2.8 Possible Climate Change Impacts on Human Health in Colorado



As highlighted in Figure 4.2.8, there are many indirect effects that include respiratory and allergic disorders directly related to climate-enhanced increases in some air pollutants, mold spores and pollens. Air pollution intensification in some areas of Colorado is plausible in the theoretical scenario as a result of increase in mean annual temperature (Low Confidence).

Developing a quantified picture of projected health impacts attributable to climate change across Colorado is an illusive task. Climate induced disorders depend on numerous coexistent and interacting factors that characterize the vulnerability of Colorado's population. They can include nutritional and immune status, population density, access to quality health care services and a vast array of environmental and socioeconomic factors (IPCC, 1995). At present, there is very little research available that attempts to pull this spectrum of factors together in terms of climate change impacts.

In summary, climate change as outlined in the theoretical scenario could have wide-ranging and mostly adverse impacts on human health (High Confidence). However, the magnitude of these impacts remains unknown at present (High Confidence).

5.0 Greenhouse Gas Mitigation, Adaptation & Sequestration Strategies

A key component of any future state climate change strategy involves the potential use of mitigation and adaptation strategies to reduce Colorado's greenhouse gas production. If required, the selection of mitigation and adaptation strategies will ultimately fall to state law makers and decision makers to meet greenhouse gas reduction goals. A general list of mitigation and adaptation options that can serve as a starting point for policy development are provided below, followed by background information. Included in the list are programs currently in place as well as possible strategies to further reduce greenhouse gas emissions in Colorado. Further consideration of these strategies should include a thorough examination of costs, economic impacts, feasibility, etc., as part of the decision making process. This list provides no predefined emission reduction goals and is considered to serve as a reference tool for discussions on potential greenhouse gas mitigation strategies for the state of Colorado.

5.1 National Level Initiatives and Programs

At the national and international levels, there are several programs being developed that will provide opportunities for Colorado businesses and government agencies to participate.

5.1.1 Energy Consumption and Fossil Fuel Combustion

Sectors included in the energy consumption and production section include under the energy consumption sector: residential, commercial, industrial, transportation, and utilities. Under the production sector are emissions from natural gas and oil production processes and from coal mining.

5.1.1.1 Residential

The average household in the United States uses 10,000 kilowatts of electricity per month, producing 7.5 tons (15,000 pounds) of carbon dioxide and .03 tons (55.13 pounds) of nitrogen oxides during the production process. Contributing to a households energy demands are an estimated 125 million refrigerators and freezers in homes across the United States. The energy requirement for these appliances alone is equivalent to the entire output of 43 large power plants. If the current stock of refrigerators was replaced with the newest efficient models, it would be possible to eliminate almost 20 power plants.[1] Programs already in place at the national level include the following:

Rebuild America

The Rebuild America program is sponsored by the U.S. Department of Energy's En-

ergy Partnership for a Strong Economy. The program strives to stimulate capital investments that reduce pollution and save energy in multifamily residential and commercial buildings. DOE provides technical assistance to its partners, who set their own goals and implement programs at the community level. DOE estimates that the Rebuild America program will reduce greenhouse gas emission levels by the year 2000 by 1.7 million metric tons of carbon equivalent. Other benefits include: reductions in utility bills, service contracts, maintenance and supplies; increased worker comfort and better process control.

Energy STAR Program

The energy used to power small household appliances and consumer electronics, including televisions and video cassette recorders, is one of the largest and fastest growing household energy costs in the United States - responsible for about 30 percent of residential electricity use. DOE and EPA are working together to promote the use of energy-efficient products by awarding the Energy STAR label to products that save energy. Products carrying the Energy STAR label are more energy efficient, reduce pollution and save money on home utility bills. Products such as light fixtures, household appliances, heating and cooling systems, televisions and video cassette recorders that carry the Energy STAR label meet federal energy-efficiency and quality guidelines, without sacrificing performance. Televisions, video cassette recorders and other small household appliances still use energy even when they are turned off. In the United States, for example, nearly $1 billion is spent each year to run televisions and video cassette recorders that are switched off - the equivalent to the annual output of eight power plants. An Energy STAR labeled television, on the other hand, consumes up to 75 percent less energy than the average television that is switched off. An Energy STAR video cassette recorder consumes up to 70 percent less energy than the average video cassette recorder that is switched off.

Cool Communities

Many local governments are working in partnership with DOE and EPA to introduce measures that will help cool cities and reduce pollution. These measures include planting shade trees and installing reflective surfaces such as light colored roofs and pavement.

Weatherization Assistance Program

The Weatherization Assistance Program was created by DOE in 1976 to increase energy efficiency and reduce the burden of energy costs to low income Americans. To accomplish these goals, DOE works in partnership with state and local weatherization programs throughout the United States. In Colorado, the Denver Regional Support Office issues grants to state governments which subsequently award subgrants to local agencies which actually perform the weatherization services. The Support Office also monitors the grants to the states and provides specialized technical assistance on a variety of administrative issues.

5.1.1.2 Commercial

Energy STAR Buildings

Energy efficiency upgrades can save more than $.50 per square foot annually at com-

mercial or industrial buildings. The EPA Energy Star Buildings program helps businesses plan and implement a step-by-step strategy that takes advantage of system interactions within buildings to achieve energy efficiency and economic savings. Participants commit to completing all profitable energy upgrades within 7 years of enrollment. The average rate of return from initial investments is 30 percent or more.

The Jefferson County school district has participated in EPA's Energy Star Buildings Program since 1993. The end result to date, is a reduction in the school district's energy needs by 21 percent, at a savings of about $2 million a year. The savings have come from a combination of energy efficient appliances, ranging from light bulbs to air conditioners and the installation of remote control monitors to control lighting.

Energy STAR Office Equipment

Energy efficient equipment, such as computers, printers, copiers, and fax machines, can save commercial businesses and industry money through lowered electrical bills. The equipment retains all of the performance features of regular machines, but powers down when not in use to save energy and money.

Green Lights Program

The Green Lights Program is a voluntary EPA-sponsored program that encourages participants to upgrade lighting wherever it is profitable, while improving or maintaining lighting quality. The EPA provides technical assistance including decision support software package, lighting upgrade workshops, manuals and a financing registry. As of Aug. 3, 1998, The Green Lights Program had 2,537 members, including the city of Boulder, Boulder Community Hospital, Boulder Valley Public School District, Breckenridge School District R1, Colorado State University System Office, the University of Denver and ARCO.

Federal Buildings

If all federally-owned and operated buildings made energy efficiency improvements in their lighting systems, 5,000 gigawatt hours (a gigawatt is equal to 1 billion watts) would be saved — enough electricity to power half a million average households a year.

5.1.1.3 Industrial

Climate Wise Program

Climate Wise is a voluntary program sponsored by DOE and the EPA to help businesses turn energy efficiency and environmental performance into a corporate asset. Originally, the program was designed to help the United States meet its international commitment to reduce greenhouse gas emissions to 1990 levels by the year 2000. Today, the program continues to position businesses to play a role in improving performance at the process and environmental stewardship levels. Participants in the program receive assistance from EPA and DOE to develop a portfolio of innovative, energy-efficient actions. Technical, financial and public recognition are additional elements available throughout the program. Nationally, the Climate Wise program has almost 400 partners that by the year 2000 are estimated to save more than $300 million annually and reduce greenhouse gas emis-

sions by more than 20 million metric tons of carbon dioxide equivalent.

Motor Challenge

Motor systems, including motors, drives, pumps, fans, compressors, and their control-system and mechanical-load components, account for nearly 75 percent of the electricity used by industry. The Motor Challenge, sponsored DOE, provides technical assistance and independent performance validation to participating companies who convert motor systems to energy efficient, electric motor systems.

Steam Challenge

Patterned after the motor challenge program, DOE, in partnership with the Alliance to Save Energy and several private companies and associations, are implementing a program to improve the efficiency of industrial steam systems. Industrial steam is used in the production of most goods that are relied on each day. Steam systems are also very energy intensive and highly inefficient. By improving industrial steam systems, significant savings in energy, production cost, and air emissions are possible. According to the DOE, projected efficiency gains of 30 percent to 40 percent are possible through actions such as:

- improving boiler performance;
- insulating and upgrading steam delivery systems;
- recovering waste heat to preheat boiler feedwater;
- reducing capital outlays for new steam generation capacity; and,
- decreasing industrial energy consumption.

Early Emissions Reduction Credit Program

A voluntary early emissions reductions credit program can provide larger sources, such as utilities, industry and commercial businesses an opportunity to build credit for early greenhouse gas reductions.

Emissions Trading

Emissions trading is a market based approach which enables participants to minimize the costs of achieving an environmental objective through the market system. If mandatory controls on greenhouse gas emissions are adopted, some form of a trading system is likely to be implemented. A trading system could apply to both producers and combustors of fossil fuels. Allowance trading, emissions credit trading, or a combination of both could be incorporated into the trading system. The design of an emissions trading system could allow the system to exist solely as a trading program or be combined with regulatory standards, such as emissions standards. Regardless of the final design of a trading program, it will be important to accurately account for the sources of greenhouse gas emissions from fossil fuel combustion.

Currently at the international level, representatives from the United States and seven other industrialized nations have begun to draft a proposal detailing how an international greenhouse gas emissions trading system might work. The proposed system would create tradable emissions reduction credits equal to one (1) metric ton of carbon dioxide for six gases — carbon dioxide, methane, nitrous oxide, perfluorocarbons, hydrofluorocarbons and

sulfur hexafluorides. Under the proposal, governments, companies, brokers, business associations, and environmental groups would be allowed to participate in the system, but each country's federal government would have the right to remain the sole trader within its boundaries. It is anticipated that there would be no limit on the percentage of a nation's emissions target that could be met through trading, however, the ultimate responsibility for meeting any predetermined reduction targets would rest with the federal government.[2]

Joint Implementation

Joint implementation is a strategy that allows developed countries to meet emission reduction goals in part by obtaining emission credits that can be traded on an international emissions trading market. Credits are obtained by a firm or other organization financing a greenhouse gas emissions project or sequestration project in other countries. Projects might involve renewable energy power plants, retrofits to existing plants and equipment, forest management projects, or other projects that either reduces net emissions or sequesters carbon.

Clean Development Mechanism

The Clean Development Mechanism will enable industrialized countries, such as the United States, to finance emissions-reduction projects in developing countries and receive credit for doing so.

National Industrial Competitiveness through Energy, Environment, and Economics (NICE^3)

NICE^3 is a cost-sharing grant program sponsored by DOE's Office of State and Community Programs which advances industrial competitiveness through energy efficiency, clean production, and waste reduction. The NICE^3 program provides financial assistance and encourages cooperation between states and industry.

5.1.1.4 Transportation

Enhanced Vehicles

The big three automakers; Ford, General Motors and Chrysler, have joined forces with the federal government to create the Partnership for a New Generation of Vehicles. This partnership is focused on developing an affordable midsize vehicle that will achieve 80 miles per gallon. The Partnership announced four technologies that promise to meet this goal: hybrid-electric vehicles; direct-injection engines; fuel cells and lightweight materials. The hybrid-electric vehicle and direct-injection engines rely heavily on electronics technology.[3]

In addition to participating in the Partnership, automakers have improved their manufacturing processes for electronic components to avoid or reduce use materials and energy. Ford, for example, has cut energy use in printed circuit board manufacturing in half by adopting new technologies to eliminate the use of chlorofluorocarbons. The new process has also reduced lead by 98 percent and volatile organic compound emissions by 70 per-

cent. Ford has realized savings of $19 million per year at eight plants throughout the world.[4]

Alternative Fuel Vehicles

The National Ethanol Vehicle Coalition is an ad hoc group created by the National Corn Growers Association and the Governors' Ethanol Coalition to establish a national program to promote the use of 85 percent ethanol fuel as an alternative fuel while concurrently, enhancing agricultural profitability and environmental stewardship. Through a cooperative effort between the National Corn Growers Association, the Office of Energy Conservation and DOE, the National Ethanol Vehicle Coalition provides loans for the installation of public ethanol fueling stations.

Transportation Partners

EPA sponsors a nationwide Transportation Partners program to help improve air quality in communities by reducing traffic congestion and resulting pollution. Transportation Partners offers communities the information, technical assistance, financial advice, and the public recognition they need to reduce vehicle miles traveled, while enhancing mobility, boosting the economy and preserving natural resources. Local governments, regional authorities and municipalities are EPA's primary partners under this program.

Clean Cities Program

DOE's Office of Transportation Technologies is responsible for carrying out the alternative fuels section of the Energy Policy Act. Stemming from this Act is a program called Clean Cities. This program seeks to accelerate and expand the use of alternative fuel vehicles in communities throughout the country and simultaneously provide refueling and maintenance facilities for their operation. The Clean Cities Program focuses on the importance of forming public/private partnerships, and represents an innovative approach to coalition building.

Currently, 14 cities have joined the Clean Cities Program, including Denver; Colorado Springs; Atlanta; Austin; Albuquerque; Boston; Chicago; Las Vegas; Long Beach; Miami; Milwaukee; Philadelphia; Washington, D.C.; and Wilmington. Colorado's Weld and Larimer counties/Rocky Mountain National Park also participate in the program. In Denver, the Clean Cities Program supported a proactive alternative fuels ordinance that mandates the conversion of 10 percent of fleets with greater than 30 vehicles to clean fuel technologies. At the time of Denver's Clean Cities designation in 1993, 5,000 alternative fuel vehicles existed with 184 alternative fueling stations across the city. The projected goal for the year 2000 is to have 53,800 alternative fuel vehicles in the vehicle fleet, supported by 333 refueling stations.

5.1.1.5 Utilities

Climate Challenge Program

The Climate Challenge Program is a joint, voluntary effort of DOE and the electric utility industry. The program links electric utilities with technical assistance through the DOE to implement strategies to reduce, avoid, or sequester greenhouse gas emissions. The

program works with utility partners to identify implementation strategies, barriers, and solutions for generation, delivery, and end-use options. A voluntary written agreement and final report of achievements are required under the program. At the national level, participation numbers 487 utility partners that represent more than 56 percent of 1990 U.S. electricity generation and carbon emissions.

The Lower Colorado River Authority is an example of one partnership that has committed to reduce greenhouse gases through the implementation of reduction and sequestration strategies. The specific projects or actions selected by the Lower Colorado River Authority include:

- expanding the use of coal combustion by-products from the Fayette Power Project;
- expanding commercial and residential demand-side management programs;
- completing a wind-power project anticipated to provide 90 gigawatt hours of energy form a 25 megawatt installation; and,
- expanding supply-side energy efficiency improvements in existing electric generating and transmission systems.

These projects alone, have the potential to achieve annual greenhouse gas emission reductions of approximately 400,000 tons in fiscal year 2000 under the current economic and regulatory environment.[5] Other strategies not quantified but anticipated for further greenhouse gas reductions include:

- continue expansion of educational programs;
- rehabilitate and modernize turbines/generators and other equipment at two hydroelectric generating stations to increase power generation capacity and extend facility life by 50 years;
- convert up to 90 percent of the Lower Colorado River Authority's fleet vehicles to alternative fuels and purchase dual fuel or electric vehicles; and,
- continue to expand recycling and pollution prevention programs.

Energy STAR Transformers Program

Every year, more than 2 percent, or 61 billion kilowatt hours of electricity produced in the United States is lost because of transformer inefficiencies. Transformers are essential to the delivery of electricity, because they convert voltage to a safe level for electric consumers. In an attempt to promote the development and purchase of energy efficient transformers, EPA launched the Energy STAR Transformers program in 1997. Under this voluntary program, electric utilities enter into agreements with the EPA to purchase high-efficiency distribution transformers, and manufacturers commit to produce and market Energy STAR distribution transformers. To date, about 10 percent of electric utilities have joined the program.

Renewable Energy

In the area of renewable energy, DOE's Renewable Energy Commercialization program sponsors cost-shared pilot and demonstration projects with utility and industry partners. Renewable technologies covered by the program include geothermal, photovoltaics, wind, and biomass.

Rebuild America

The Rebuild America program works with community partners nationwide to develop and execute large-scale programs devoted to investing money to complete energy efficient renovations in building and utilities. In the electric power industry, utilities are partnering with Rebuild America to better serve their customers through; implementing energy efficiency programs that focus on building renovations to cut energy demand and help reduce the need for new generating capacity; improving the environment by providing reductions in the amount of pollutants emitted during the power generation process; improving the community by improving the quality of life in the area and supporting local development and community revitalization; and improving customer retention by providing good public relations and saving customers' money.

5.1.2 Production Processes and Area Sources

5.1.2.1 Natural Gas and Oil Production

Natural Gas STAR Program

Sponsored by the EPA, the Natural Gas STAR program aims to reduce methane emissions during the production, transmission and distribution of natural gas by introducing and promoting cost-effective technologies and practices throughout the natural gas industry. The program provides implementation guidelines, technical assistance, and an information sharing network for gas companies. The goal of the Natural Gas STAR program is to reduce emissions by 11 million metric tons carbon dioxide equivalent, or about 524,000 metric tons of methane, by 2000. According to the EPA, Natural Gas STAR reduced methane emissions by 205,000 metric tons in 1994 and an additional 290,000 metric tons in 1995 — a savings of $75 million in the cost of gas alone.

5.1.2.2 Coal Mining

Coalbed Methane Outreach Program

EPA developed a program to encourage methane recovery through the voluntary Coalbed Methane Outreach Program. This program works with coal mines and related industries to encourage the recovery and use of methane that would otherwise be emitted to the atmosphere during mining operations. Program activities include profiling conditions at the gassiest coal mines; conducting site-specific assessments; and working with government agencies to reduce barriers to project development. The Coalbed Methane Outreach Program seeks to reduce emissions by 8.1 million metric tons carbon dioxide equivalent, or almost 400,000 metric tons of methane, by 2000.

Methane Recovery and Utilization

DOE is supporting research at five mines located in Alabama, Ohio, Pennsylvania, and West Virginia to demonstrate the feasibility of alternate ways to recover and utilize

methane released during the underground coal mining process. The projects will demonstrate the productive use of low methane ventilation gas as well as gob gas of irregular methane content for pipeline sales, small-scale electric power generation, and other uses.[6] The difference in altitude in Colorado, however, may impact the ability to use many recovery technologies that are used in other areas of the country.

Clean Coal Technology Demonstration Program

DOE has forged a unique partnership with industry to demonstrate new technologies that show the most promise of success for coal-based processes in the domestic and international marketplace. As of September 1996, 40 projects have been funded through the Clean Coal Technology Program. For more information on this program, see http://www.lanl.gov/projects/cctc/program/program_txt.html

Clean Coal Technology Compendium

This compendium is sponsored by DOE's Office of Fossil Energy and serves as an informational vehicle for successful demonstrations coming out of the Clean Coal Technology Demonstration Project. The compendium is designed for ease-of-use and contains a broad collection of different types of data and information on clean coal technologies. The compendium is in a data base format accessible via the internet at http://www.lanl.gov/projects/cctc/compend/compend_txt.html

5.1.2.3 Chlorofluorocarbon Production

Chlorofluorocarbons are manufactured chemicals that release chlorine and bromine in the atmosphere that deplete the ozone layer in the stratosphere and contribute to the greenhouse effect in the troposphere. These chemicals are used in a wide variety of products common to industrialized societies, including air conditioning, home insulation, refrigerators, cleaning solvents and fire extinguishers. Chlorofluorocarbon molecules released during the manufacturing, use and disposal of these products remain in the atmosphere for decades.

1987 Montreal Protocol

The Montreal Protocol is an international agreement that went into effect on Jan.1, 1989. The protocol established a list of ozone depleting substances. The production and consumption of these substances must be progressively eliminated. At the time of the protocol's ratification, 29 countries and the European Economic Community ratified the agreement. Since then, 155 countries have ratified the Protocol, which represent more than 100 developing countries. Legislation is now in place in most countries to phase out chlorofluorocarbons.

Perfluorocompounds Emissions Reduction Partnership for the Semiconductor Industry

EPA has partnered with the semiconductor manufacturers industry to reduce emissions of perfluorocompounds and hydrofluorocarbons used in the manufacture of semicon-

ductors. Based on the accomplishments of the program, the atmospheric accumulations of these greenhouse gases is unknown, but is expected to significantly reduce emissions of chlorofluorocarbons.

Significant New Alternatives Policy (SNAP)

The EPA administers the Significant New Alternatives Policy program to review and identify alternatives for ozone-depleting chlorofluorocarbon compounds. The program has published several new decisions regarding acceptable and unacceptable alternatives. These recommended alternatives can be found on EPA's web site at www.epa.gov/ozone/title6/snap/lists/, or call the SNAP hotline at (800)-296-1996.

5.1.3 Landfills/Solid Waste Reduction

Landfills are the largest source of anthropogenic methane emissions in the United States, constituting almost 40 percent of these emissions each year. Methane is a potent greenhouse gas; each pound of methane emitted from a landfill is about 25 times more effective at trapping radiation in the atmosphere than a pound of carbon dioxide. Recovery and use of methane from landfills substantially reduces these emissions while capturing their energy value. EPA estimates that up to 750 landfills could economically recover their methane for energy, yet only about 130 methane recovery projects are in place.

Landfill Methane Outreach Program

EPA sponsors a voluntary Landfill Methane Outreach Program which works with municipal solid waste landfill owners and operators, states, tribes, utilities, and other federal agencies to promote the use of landfill gas to generate electricity or to use as fuel. Among the program’s primary targets are those landfills affected by new federal regulations mandated by EPA. The new regulations will require large landfills to recover and combust methane. By selling the energy from recovered methane, landfill operators may recover some of the capital cost incurred in complying with the new regulations. The Landfill Methane Outreach Program is expected to reduce methane emissions by 4 million metric tons carbon dioxide equivalent, or almost 200,000 metric tons of methane, by 2000.

Methane Recovery Regulation

Landfill gas emissions contain methane, carbon dioxide, and numerous non-methane organic compounds, including volatile organic compounds, hazardous air pollutants and odorous compounds. Concerned about greenhouse gas emissions and health effects from exposure to hazardous air pollutants, the EPA published regulations for air emissions at new and existing municipal waste landfills in March of 1996. According to the new regulation, municipal landfills with design capacities of 2.5 million cubic meters or greater, are required to track emissions of non-methane organic compounds on an annual basis. Landfills within the 2.5 million cubic meter design capacity that emit more than 50 megagrams of non-methane organic compounds per year are required to install controls to capture emissions of non-methane organic compounds and methane. According to EPA, methane emissions are expected to drop by 21 percent for new landfills and 40 percent for existing land-

fills that capture or flare emissions on an annual basis.

WasteWi$e Program

Waste Wi$e is a voluntary EPA program where members commit to waste prevention, recycling collection, and buying or manufacturing recycled products in return for technical assistance from EPA. Since the start of the WasteWi$e program in 1994, member companies have recycled more than 10 million tons of material and purchased more than 7 million tons of recycled-content products. In addition, more than 10 million tons of material have been recovered in manufacturing processes.

5.1.4 Agriculture, Forests and Land Use

5.1.4.1 Domestic Animals

Ruminant Livestock Efficiency Program

The federal government sponsors the Ruminant Livestock Efficiency Program, a cooperative effort of the U.S. Department of Agriculture (USDA) and the EPA, that focuses on research and demonstration projects aimed at reducing methane emissions from dairy and beef cattle due to enteric fermentation. Initiatives are aimed at improving nutrition through mechanical and chemical feed processing and strategic supplementation, genetic improvements, and disease control. The program is slated to reduce emissions by 6.6 million metric tons carbon dioxide equivalent, or more than 300,000 metric tons of methane, by 2000.

Ruminant Livestock Methane Program

A collaborative effort between the EPA and USDA to improve efficiency in the dairy and beef industries. The program works with livestock producers to improve livestock production, thereby reducing methane emissions.

5.1.4.2 Manure Management

AgSTAR Program

To encourage the capture and use of methane produced from the anaerobic decomposition of animal waste EPA, DOE, and USDA jointly sponsor the AgSTAR program. As part of this program, participating producers voluntarily commit to survey their facilities to identify profitable options for capture and use of methane as an on-site power source. The program includes demonstration projects and decision support software. AgSTAR is expected to contribute reductions of 5.5 million metric tons carbon dioxide equivalent, or about 260,000 metric tons of methane by the year 2000.

5.1.4.3 Forests and Land Use

Forestry Incentives Program

The 1996 Farm Bill extended the Forestry Incentives Program which authorizes the

USDA to share up to 65 percent of the costs of tree planting, timber stand improvements, and site preparation for natural regeneration. Benefits of the program include reduced wind and soil erosion, a reliable future supply of timber, and enhanced water quality and wildlife habitat. Both tree planting and timber stand improvements help to sequester greenhouse gases. To be eligible for assistance under the Forestry Incentives Program, the land area can be no more than 1,000 acres and must be a nonindustrial privately owned forest.

Stewardship Incentives Program

The Stewardship Incentive Program provides technical and financial assistance to encourage non-industrial private forest landowners to keep their lands and natural resources productive and healthy. Qualifying land includes rural lands with existing tree cover or land suitable for growing trees and which is owned by a private individual, group, association, corporation, tribes, or other legal private entity. Eligible landowners must have an approved Forest Stewardship Plan and own 1,000 or fewer acres of qualifying land. Authorizations may be obtained for exceptions of up to 5,000 acres.

Conservation Reserve Program

Recognizing the problems associated with erodible land and other environmental-sensitive cropland, the USDA included conservation provisions in the 1996 Farm Bill. Among other things, the Farm Bill created the Conservation Reserve Program to address these concerns through conservation practices aimed at reducing soil erosion, improving water quality and wildlife habitat.

Through the Conservation Reserve Program, farmers are encouraged to enter into contracts with USDA to place erodible cropland and other sensitive land into long-term conservation practices for 10 to 15 years. In exchange, landowners receive annual payments for the land and cost-share assistance for establishing conservation practices.

On a national level, the Conservation Reserve Program has enrolled 30.5 million acres of cropland during the 1998 crop year. In Colorado, over 1.8 million acres are set-aside in the program. Native grasses or trees have been planted to improve soil quality and reduce its sensitivity to environmental stresses. Through a quantification processes, Colorado's Conservation Reserve Program lands could provide an opportunity for farmers to participate in a greenhouse gas reduction strategy by serving as a sink for carbon emissions.

Conservation Reserve Enhancement Program

The Conservation Reserve Enhancement Program is a state-federal conservation partnership program targeted to address specific state and nationally significant water quality, soil erosion and wildlife habitat issues related to agricultural use. Using financial incentives, the program seeks voluntary enrollment of agriculturally productive land for 10 to 15 years in duration. The Conservation Reserve Enhancement Program is a refinement of the Natural Resource Conservation Services' Conservation Reserve Program and is limited to 100,000 acres for each state. Projects must address resource issues of state and national significance and must be cost effective in comparison to other conservation programs at the

state and local level. Enrollment is offered on a continuous basis.

Like the Conservation Reserve Program, the Conservation Reserve Enhancement Program can provide opportunities to reduce the level of atmospheric carbon dioxide through the sequestration of carbon in the 100,000 acres of land enrolled in this conservation program.

Conservation Buffer Program

Conservation buffers can provide a number of environmental benefits, including carbon sequestration. Buffers are strips of vegetation, often grasses or trees, installed where one kind of land use ends and a different one begins. The USDA, through the Natural Resources Conservation Service, administers the Conservation Buffer Program. There are sixteen conservation practices that fit the category of buffers. Often times a practice installed for one purpose will provide several benefits, such as blocking movement of soils, reducing wind erosion by acting as a windbreak, and minimizing drift from ground and aerial spraying. Nationwide, USDA's goal is to establish two million miles of conservation buffers by the year 2002.

Conservation Technical Assistance

The purpose of USDA's Conservation Technical Assistance program is to assist land-users, communities, state and local government, and other federal agencies in planning and implementing conservation systems. The purpose of the conservation systems are to reduce erosion, improve soil and water quality, improve and conserve wetlands, enhance fish and wildlife habitat, improve air quality, improve pasture and range condition, reduce upstream flooding, and improve woodlands.

Assistance is provided to land users voluntarily applying conservation and to those who must comply with local or state laws and regulations. Given the broad range of issues and constituencies that are addressed by the Conservation Technical Assistance program, this program could provide an opportunity to educate the agricultural community on the role conservation programs can play in sequestering and storing carbon.

Conservation Farm Option

The Conservation Farm Option is a voluntary pilot program for producers of wheat, feed grains, cotton, and rice. The purpose of the program is to include conservation of soil, water, and related resources, water quality protection and improvement, wetland restoration, protection and creation, wildlife habitat development and protection, or other similar conservation purposes. Eligibility is limited to owners and producers who have contract acreage enrolled in the Agricultural Market Transition Act program. The Conservation Farm Option may provide another opportunity for agriculture to play a role in reducing emissions of atmospheric carbon dioxide through soil conservation efforts. In addition, if the crops included under the Conservation Farm Option program serve as carbon sinks, farmers may have an opportunity to market carbon credits should a greenhouse gas emissions trading program be developed.

Conservation of Private Grazing Land Initiative

The Conservation of Private Grazing Land initiative ensures that technical, educational, and related assistance is provided to those who own private grazing lands. It is not a cost share program. This technical assistance offers opportunities for better grazing land management, protecting soil from erosive wind and water, using more energy-efficient ways to produce food and fiber, conserving water, providing habitat for wildlife, sustaining forage and grazing plants, using plants to sequester greenhouse gases and increase soil organic matter, and using grazing lands as a source of biomass energy and raw materials for industrial products.

5.1.5 Sequestration and Adaptation

Carbon Sequestration in Soils

Collaborative research efforts in the field of soil carbon research are taking place between numerous Canadian and United States governments and corporate sponsors. In Colorado, the Natural Resource Ecology Laboratory at Colorado State University is taking a lead role in much of the research on the ability of agricultural soils to remove and store greenhouse gas from the atmosphere. Through this collaborative effort, a number of measures have been identified to improve the ability of soil to sequester carbon. Additional benefits from improved soil carbon strategies include improving the sustainability and productivity of agricultural lands; prevention of erosion; preservation of soil productivity; enhancement of profitability of farming systems through increased yields and reduced production costs. Strategies for the main agricultural land types include the following:

Cultivated land:

- reduce the intensity of tillage practices by increasing reduced or no till methods;
- increase cropping systems through implementation of winter cover crops and the reduction or elimination of summer fallow.
- adopt yield-promoting practices, including improved nutrient amendments to the soils; and, re-established permanent perennial vegetation, such as perennial grasses, grassed waterways, shelterbelts and trees.

Rangelands and pastures:

- reduce grazing intensity and frequency;
- improve the vegetative cover on range and pasture lands; and,
- irrigate and reseed using improved species or varieties of vegetation.

Degraded land:

- restoration of degraded soils by reversion of land to natural vegetation cover;
- establish rapidly growing perennials and annuals; and,
- apply inorganic fertilizers and organic amendments.[7]

5.2 State Level Initiatives and Programs

5.2.1 Long-Range Plans

Blueprint for Clean Air

The Blueprint for Clean Air is a comprehensive, locally-driven, long-range air quality plan spearheaded by the Regional Air Quality Council to meet these challenges. The plan provides citizens with a series of choices for improving regional air quality during the next 20 years. Throughout the Blueprint process, field studies, technical analysis and modeling have formed the scientific framework for evaluating possible pollution control options considered in the plan.

Vision 2020 Plan

Growth, especially along Colorado's front range, will continue to be a challenge for the state. The Metro Vision 2020 plan serves as a comprehensive planning guide for the future development of the region. The long-range plan incorporates growth, development, transportation, and water quality management into a single integrated plan.

Colorado Ski Industry Comprehensive Grant Project

The Colorado Department of Public Health and Environment, in partnership with Aspen Skiing Company, has been awarded three grants from EPA totaling $174,650 to address pollution prevention/climate change issues in the ski industry. The goal of the project is to develop a comprehensive, multimedia based environmental management strategy for the ski industry. The project will strive to achieve this goal by deriving actual measurable environmental benefits through an assessment of the ski industry's generation of: solid waste-including paper, plastic, fabric, paperboard, aluminum, glass, construction materials, scrap metals, landscaping and restaurant green waste; hazardous waste materials; energy requirements from lodging facilities, restaurants, office space, and on-mountain lift, snowmaking and maintenance equipment/vehicles; and, water requirements from landscaping, snowmaking operations, hospitality operations, and golf course management. Both summer and winter season assessments will be conducted to determine the best comprehensive pollution prevention/climate change mitigation strategies that will reduce solid and hazardous wastes and energy and water demands in the ski industry.

5.2.2 Energy Consumption and Fossil Fuel Combustion

5.2.2.1 Residential

Energy Rated Homes of Colorado

Funded by the Office of Energy Conservation, the Energy Rated Homes of Colorado program uses the Energy Star rating system to evaluate a home's energy efficiency on a 100-point scale, which translates into scores of 1 star to 5+ stars — the rating sheet includes

a calculation of carbon dioxide emission reductions. A low score indicates a poor performance and a high score indicates a home that keeps you comfortable while using very little energy. The Energy Rated Homes program is operated by the Colorado Housing and Finance Authority. In addition to support from the Office of Energy Conservation, the program receives assistance from the Colorado Association of Realtors, Colorado Mortgage Lenders Association, utilities throughout the state and a coalition of other groups committed to enhancing the value of Colorado homes.

Residential Incentives Program

Tax credits, low-interest loans, rebates, credits to households to fund energy efficiency improvements.

Energy Saving Partners

This program provides free weatherization services to help low-income Coloradans reduce their energy bills and improve home safety and comfort.

5.2.2.2 Commercial

New Commercial and Public Buildings

A survey conducted by the Governor's Office of Energy Conservation in 1994 shows that 73 percent of Colorado's jurisdictions do not rely on commercial energy codes to ensure that new commercial buildings are built efficiently. Even at a voluntary level, the Office of Energy Conservation estimates that practical guidelines could reduce energy use in new commercial buildings by up to 25 percent.

In January 1996, the Office of Energy Conservation began working with developers, architects, engineers, building officials, planning departments and other professionals to encourage energy efficiency in new buildings. A Technical Advisory Committee was convened to develop a set of voluntary energy efficiency guidelines for new commercial buildings in Colorado. Ten members, representing all segments of the commercial building community, form the committee. The goal of the committee is to reach consensus on a set of guidelines that make practical and economic sense for Colorado.

Commercial and Public Buildings Program

The Office of Energy Conservation oversees a Commercial and Public Buildings Program in order to provide information, training and technical support to owners, managers, engineers and other professionals looking to improve building energy efficiency and cut operating costs. By introducing building professionals to performance contracting, a concept that lets future energy savings pay for conservation measures, the program is helping to overcome barriers with making energy efficient building improvements. An initiative with state buildings may help Colorado save between $4 and $6 million annually through simple, cost-effective conservation projects.

Geothermal Heat Pump Program

The goal of DOE's Geothermal Heat Pump Program is to install 400,000 Geothermal Heat Pump units per year by the year 2000. To reach this goal, DOE must expand its educa-

tion and outreach, technology transfer, and technical assistance programs.

Rebuild Colorado

The Governor's Office of Energy Conservation received a $202,000 grant in September 1995, from DOE's Rebuild America program to help other state agencies and local governments take advantage of the benefits of performance contracting. Rebuild Colorado launched a campaign last fall to promote performance contracting and offer engineering and financial expertise to help building managers achieve success.

Rebuild Colorado offers assistance during each step of a performance contracting project. Services range from providing a sample contract to furnishing an on-site expert in performance contracting to helping monitor the energy improvements. Overall energy savings could reach $25 million annually, helping state agencies, cities, counties, schools, hospitals and multifamily building owners throughout the state.

Energy Analysis Diagnostic Center

Colorado State University's Department of Mechanical Engineering provides a free program for qualifying businesses to help manage energy costs, optimize existing equipment, and set realistic targets through site visits and reports on potential savings.

Bid 2000

Public Service Company of Colorado announced several new energy-efficiency incentives for qualified business customers. The program, called Bid 2000, is designed to connect interested businesses with local energy services companies who can help install more efficient lighting equipment. Approximately $5 million in incentives are available through the year 2000.

The incentives are available for projects at colleges, hospitals, office buildings open 24 hours, retail stores, warehouses, and elementary, middle and high schools. To qualify, businesses must purchase their retail electric service from Public Service Company of Colorado and each individual site must have a potential demand reduction of 20 kW to be eligible. New construction projects, lighting controls, exterior lighting and ongoing projects are not eligible. More information, including a list of participating energy services companies, can be obtained by calling: (303) 294-2558.

State Buildings

The Governor's Office of Energy Conservation launched an effort to save millions of dollars in Colorado's state buildings through efficient use of electricity and natural gas. This effort is supported by state legislation, HB 93-1052, and by a report prepared by the State Auditor's office in June 1996.

The State Buildings Programs with support from an Office of Energy Conservation engineer will provide technical assistance to state agencies, including the following:

• information on energy-saving projects and technologies;

- software and training to help agencies better track energy use (including assistance in metering or tracking energy use in individual buildings); and
- a guidebook to walk agency staff through an energy audit.

The initiative is based on recommendations included in "Cutting Energy and Costs at State Buildings: Opportunities for Saving Millions," a report provided to the state legislature in January 1996. The report outlines problems and barriers to energy efficiency in state buildings, and recommends practical ways to make improvements.

Federal Energy Management Program

Federal agencies can achieve substantial savings in energy use and cost through activities under funding sources that are not specifically earmarked for energy efficiency. New building design and construction, as well as major renovation of existing buildings are two prime examples. Operations, management, and repair funds can also be leveraged.

The mission of the Federal Energy Management Program is to reduce the cost of government by advancing energy efficiency, water conservation, and the use of solar and other renewable energy. A long-term goal of the program is to institutionalize sound energy management as a way of doing business in the federal government. Helping federal agencies gain the awareness, develop the policies and commitment, and obtain the knowledge, tools, and equipment to reduce the use and cost of energy in their facilities are all aspects of capacity building.

Business & the Environment Program

The national organization, Business for Social Responsibility, manages an Education Fund's Business & the Environment Program to assist its members and the general business community in developing cost-effective policies and practices which enhance corporate environmental performance. The program's mission is to help companies integrate environmental considerations into strategic business decisions and to help create more environmentally sustainable systems of commerce. The program's current initiatives include projects relating to global climate change, green product design, green building design, sustainable business practices, and "closing the loop" with customers and suppliers.

Through the Climate Wise Initiative, the Business & the Environment Program is working with DOE and EPA to help approximately 150 businesses identify and implement cost-effective and productivity-enhancing measures to reduce energy use, natural resource consumption, minimize waste, and prevent pollution. In addition to the Climate Wise Initiative, the program is addressing the issue of climate change by helping companies invest in projects that offset greenhouse gas emissions. The Climate Program is also initiating a Green Power Project to help companies purchase power produced by renewable resources and invest in cost-effective renewable energy projects at their own facilities. (For further information, contact the Business for Social Responsibility at 303-433-1020.)

5.2.2.3 Industrial

The Environmental Leadership Program

The Colorado Environmental Leadership Program was created by the state legislature in 1998 (H.B. 98-1058). Managed by the Colorado Department of Public Health and Envi-

ronment, the Environmental Leadership Program creates a pollution prevention revolving loan fund and provides incentives for pollution prevention, toxic use reduction, source reduction, resource recovery, energy efficiency, and innovative environmental technologies. Qualified businesses which are accepted into the Environmental Leadership Program participate on a voluntary basis to reach environmental goals that go beyond goals that would be achieved by compliance with environmental laws and permits alone.

To be eligible for participation in the Environmental Leadership Program, a facility or business must meet mandatory program requirements including:

- no serious violations of all applicable state and federal environmental laws and permits three years prior to the date of application to participate in the program;
- the existence and maintenance of an environmental management system;
- the existence and maintenance of an environmental compliance audit program to assess compliance with environmental laws, correct noncompliance within a reasonable period of time, and report audit findings as required by law;
- the existence and maintenance of a pollution prevention program or plan with specific goals and actions to significantly reduce releases of pollutants or the use of resources beyond the reductions required by law or permit; and,
- the existence and maintenance of verifiable, quantifiable and qualitative measures or methods that document compliance with environmental requirements, resource conservation goals and pollution prevention goals.

Climate Wise Program

Climate Wise is a voluntary government-industry partnership sponsored by DOE and EPA that is available at the state and local level. Since the programs inception, more than 450 partners have taken advantage of the program's technical, financial assistance and peer exchange opportunities. In Colorado, approximately 35 companies are participating in the Climate Wise program which is being managed by the organization, Business for Social Responsibility.[8]

After joining the Climate Wise program, a company has six months to develop an Action Plan. The Action Plan identifies what projects the company will implement during the coming year(s). The plans are open-ended and can be updated on an annual basis as needed. Within a year of implementation, a report quantifying savings and emissions reductions is required.

Customized Industrial Process Efficiency Solutions

Available through the Public Service Company of Colorado, the Customized Industrial Process Efficiency Solutions provides incentives for improving the overall energy efficiency of production processes for eligible businesses.

Chilled Water Plant

In late 1997, Public Service Company of Colorado began construction of a central chilled water plant in downtown Denver. The project will allow replacement of individual refrigeration systems on buildings in downtown. Replacements will reduce ozone-deplet-

ing gases as well as increase energy efficiency by reducing and flattening the demand for electricity in the metro area.

Denver International Airport

Three engine-driven natural gas centrifugal chillers have been installed for cooling at the Denver International Airport. Total system electrical demand savings are estimated to be 7.8 megawatts of energy per year.

Industry Partnerships Project

The Industry Partnerships Project has been designed to identify specific obstacles to industrial recycling and provide technical expertise to address them. The primary goal of the project is to develop a sustainable technical assistance program for Colorado industries. Key project activities include:

Organizing an advisory group composed of industry, nonprofit, trade association and government representatives to assist with: 1) creating a vision for how best to provide long-term technical assistance; 2) developing a program to achieve that vision; and 3) forging partnerships so that the program will be implemented.

Researching extension service models throughout the nation and developing an approach that will work in Colorado to provide helpful, cost-effective assistance to businesses on the use of recycled feedstock and waste minimization.

Waste Minimization Assessment Center

The Colorado State University's Department of Mechanical Engineering offers a free program for qualifying businesses to help reduce costs for raw materials and waste disposal, and set priorities for pollution prevention. The program provides site visits and reports on potential savings.

Recycling Development Incubator

The Colorado Recycling Development Incubator is a long-term, local market development project designed to increase the use of secondary materials in existing and new Colorado businesses. Funded by EPA's Jobs Through Recycling Grant, the Governor's Office of Energy Conservation and Eco-Cycle, Inc. in Boulder will coordinate the project.

Rocky Mountain Materials Exchange

The Colorado Center for Environmental Management, a non-profit organization, developed and implemented the Rocky Mountain Materials Exchange, to improve environmental management through innovation and collaboration. The Exchange serves as a regional clearinghouse for a variety of industry, business, manufacturing companies, construction firms, federal, state and local governments, chambers of commerce, trade associations, professional organizations, school districts, colleges and universities, non-profit organizations, and citizen groups to exchange both solid and hazardous materials as a means of pollution prevention, waste minimization and recycling. The Exchange utilizes the Internet, and existing state and regional electronic bulletin boards to exchange information on technologies and materials considered by one company to be waste, and to another company

considered a raw material. Other benefits derived from the Exchange include: natural resource conservation, waste minimization, pollution prevention, environmental protection, sustainable economic development and increased profitability. Additional information on the Exchange can be found at: http://www.rmmex.com/about.html

Joint Center for Energy Management

The Joint Center for Energy Management is a research center in the Department of Civil Environmental, and Architectural Engineering at the University of Colorado at Boulder. This research center is dedicated to improving energy efficiency and improved mechanical systems for buildings and industries. The program focuses on the design and technology of cost-effective, energy efficient buildings and industrial processes, as well as the application of renewable resources. The Center is supported by grants and contracts with industrial firms, state and federal agencies, and private organizations and foundations. For more information on the Center, please refer to: http://bechtel.colorado.edu/Research_Groups/Jcem/jcemover.html

5.2.2.4 Transportation

Alternative Fuel Rebates

The Alternative Fuel Rebates Program is a public/private partnership between the Governor's Office of Energy Conservation, alternative fuel providers in Colorado and DOE. Under this program, a rebate of $1,500 to $6,000 is given per vehicle for the purchase of an alternative fuel vehicle(s). In addition, the state offers a 50 percent state tax credit to vehicle owners who make the switch to alternative fuels such as propane, compressed natural gas, methanol, ethanol, electricity, or any other alterative fuel approved by the Colorado Air Quality Control Commission. As of May 1998, the program has given more than $525,000 in rebates to small and large businesses, city, county and state governments, and individuals.

The Colorado Interstate Gas Company provides incentive funding on a case-by-case basis and offers technical assistance to customers who convert vehicles to run on natural gas.

Alternative Fuels Financial Incentive Program

In addition to the Alternative Fuel Rebates Program, the Alternative Fuels Financial Incentive Program offers all public and private sector fleets and individuals an opportunity to receive cash for a converted vehicle or factory produced alternative fuel engine vehicle.

Denver Alternative Fuels Ordinance

The City and County of Denver adopted an Alternative Fuel Ordinance in 1990. The ordinance applies to vehicle fleets of 30 or more light-duty gasoline-powered vehicles weighing under 8,500 pounds. Fleets of this size or larger are required to convert 10 percent of the fleet to alternative fuel vehicles. Alternative fuel conversions in Denver number 800 to 1,000 city-wide with 200 to 250 of this number from the city fleet.

Alternative Technology Vehicles

Colorado has two innovative-technology transportation initiatives underway; an electric vehicle grant project for an electric shuttle-bus, and efforts to secure an electric vehicle for the Department of Public Health and Environment.

The Department of Public Health and Environment, in partnership with the Cherry Creek/Colorado Boulevard Transportation Management Association, received a grant from the Office of Energy Conservation to study the feasibility of an electric shuttle bus project to promote the use of a cleaner-burning transportation system to move people through heavily congested areas of a city. The route currently being considered would run through the Colorado Boulevard and Cherry Creek Shopping Districts. The Department also received a grant from EPA to study the life-cycle benefits of an electric vehicle demonstration project within the state's vehicle fleet. The goal of this project is to bring three electric vehicles into the Department's vehicle fleet and analyze the cost and environmental benefits derived from the vehicles.

Transportation Partnerships Program

Transportation Partnerships began in October 1995, to help communities better understand available innovative transportation options and how these options can be used to respond to community concerns. With a series of grant cycles, the Office of Energy Conservation has granted nearly $1.5 million to fund projects in half of Colorado's 63 counties.

Alternative Fuel Vehicles

Started in 1981, the Public Service Company of Colorado began an Internal Natural Gas Vehicle Program. Through the program, Public Service Company operates a number of natural gas vehicles in the corporate fleet. Since 1981 the natural gas powered vehicles have driven more than 24 million miles, and as of late 1997, 338 natural gas vehicles have operated from 12 locations in Colorado. Public Service Company also operates the "Clean Air Machine"— a natural gas powered bus that carries 14 passengers.

The Natural Fuels Corp. formed in 1990 to develop the market for, and to sell compressed gas, for use as domestic transportation fuel for clean vehicles. Natural Fuels has converted approximately 1,100 vehicles to run on natural gas and has built or supported the installation of approximately 40 public natural gas fueling stations in Colorado. Twenty private fueling stations and 25 fuel maker sites have also been added.

5.2.2.5 Utilities

E-Star Utility Partners

Energy Rated Homes of Colorado's E-Star program provides utilities with a program that can be tailored to meet the needs of each utility partner and their customers. Services provided by the E-Star program include: energy ratings, energy efficient mortgages and industry partnerships and rebates for efficient equipment. Currently, eight utilities participate in the program, serving more than 80 percent of residential customers in the state. The Public Service Company of Colorado, for example, offers low-cost energy ratings and energy improvements to its more than one million customers statewide. E-Star lenders Uni-

versal Lending and GMAC Mortgage Corporation offer energy mortgages, energy improvement and energy equity loan incentives up to $500 to utility customers needing to finance energy improvements.

Regulatory Advocacy Program

The Governor's Office of Energy Conservation created the Regulatory Advocacy Program to present information and evidence about energy efficiency and renewable energy sources to the Public Utilities Commission. The mission of the Regulatory Advocacy Program is to encourage the Public Utilities Commission to adopt regulatory decisions that allow and encourage utilities to promote clean energy from renewable sources and cost-effective energy efficiency.

Integrated Resource Plan Process

For electric utilities, the Integrated Resource Plan (IRP) process integrates supply- and demand-side resources into a flexible resource portfolio. By assessing a variety of resource options that meet consumer energy-service requirements, the Integrated Resource Planning process helps utilities to be responsive to external changes such as economic conditions, resource prices, new technologies, and changes in regulatory or tax policies. During the Integrated Resource Planning process consideration is given to risk and diversity of supply, maintenance of system reliability, and to environmental and other external impacts. The Integrated Resource Planning process provides an opportunity for emissions of greenhouse gases to be included in the portfolio planning and development process.

Demand-Side Management

Electric utilities utilize a management strategy known as demand side management to implement energy efficiencies and reduce load demand for energy. The primary objective of demand-side management programs is to provide cost-effective energy and capacity resources and strategies to help defer the need for new energy sources of power/energy, including generating facilities, power purchases, and transmission and distribution capacity. Utilizing a demand-side management planning and selection process, strategies are identified and evaluated for consumer acceptance, response and cost effectiveness. The implementation of demand-side management programs should save the utilities money, as well as improve the environment through reductions in energy demand. During 1994-1997, Colorado's Public Service Company saved $80 million through the implementation of collaborative demand-side management strategies and programs, with an additional $5 million (28 megawatt reduction) planned in future demand-side management projects.

The Public Service Company established two separate demand-side management bid programs, one from energy service companies and second from the company's own electric customers. The first bid resulted in combined reductions of 50.1 megawatts of demand reductions. While the second bid realized an additional 50 megawatt of demand reduction. The third bidding program during 1997-1998, is expected to result in 145 megawatts of demand reduction during non-peak periods.

Efficiency Replacement Partnership

Available through the Public Service Company of Colorado, the Efficiency Replacement Partnership provides rebates for lighting products, premium efficient motors, and "custom" measures, such as upgrading entire heating/cooling systems. Rebates can help eligible businesses replace old equipment with energy efficient alternatives.

Public Service Company Energy Efficiencies

Public Service Company has implemented a number of energy efficiency improvements at existing Colorado power plants. Some of the strategies include: replacing feedwater heaters with new higher efficiency heaters on Cameo Unit 2, Cherokee Units 1,2, & 3, Comanche Unit 2, and Valmont Unit 5; replacing the re-heater on Cherokee Unit 4; replacing circulating water cooling towers for Cherokee Units 2,3,4, and Arapahoe 4; installing new variable speed fan drivers at Comanche and Pawnee; replacing low pressure turbine blading on Arapahoe Unit 4 and Cherokee Unit 4; replacing turbine seal strips on Cherokee Unit 3; and, upgrading boiler controls on Cherokee Unit 3.

In addition, Public Service Company has rebuilt and upgraded many transmission lines throughout the service territory. For example, a new 230 kilovolt transmission line was built between Fort St. Vrain generating station and Barr Lake substation. Such improvements reduce the amount of energy lost through the lines.

State Energy Program

DOE's State Energy Program was established in 1996, the program combines the former State Energy Conservation Program and the former Institutional Conservation Program. This program provides core funding to the states to enable them to maintain a state energy office and to undertake state specific energy conservation projects. The program also has a Special Projects module which provides competitive grants to the states for proposed projects which reflect their perceived needs and capabilities. Special projects support DOE end-use buildings, transportation, industry, and utility programs.

5.2.2.6 Renewable Energy

Wind Power

The Public Service Company of Colorado has entered the wind power market by installing the first 240 foot-tall-turbine in Colorado. This single turbine can generate enough energy to meet the needs of approximately 225 homes. During phase one of Public Service Company's wind project, seven turbines will be installed. Phase two of the project is planned for late 1998-1999, and will add an additional 10 turbines to the Colorado wind facility for a total of more than 12 megawatts of power. To date eight towns and cities have signed on to the Public Service's WindSource wind project. More than 115 businesses and over 10,000 households are also participating. It is estimated that together these participants will reduce carbon dioxide emissions by more than a million tons a year.

Wind Resource Assessment Project

The Office of Energy Conservation, in partnership with the Public Service Company of Colorado, Tri-State Generation and Transmission Association, Inc., of Denver, Colorado Springs Utilities, Platte River Power Authority of Fort Collins, West Plains Energy of Pueblo, and Arkansas River Power Authority of Lamar, completed a study that identifies 10 sites in Colorado as having the highest potential to be utility wind development sites. Nine of the 10 sites are spread across the eastern half of Colorado. The only exception, was one site located near Grand Junction.[9] According to study, suitable sites could be developed with 20 to 50 megawatts capacity each - some equally in size the capacity of a mid-sized coal plant.[10]

Hydropower

In Colorado Springs, 25 megawatts of hydropower have been brought on-line.

Governor's Renewable Energy Task Force

In November 1997, the Governor's Renewable Energy Task Force presented to Governor Romer a 10-point plan that incorporates 33 recommendations to significantly increase the use of renewable energy in Colorado. The Governor has directed the Office of Energy Conservation to begin implementing some of the recommendations included in the report. Some of the recommendations include:

- encouraging state and local governments to adopt policies to purchase green power;
- establish a definition and a standard for green power;
- adopt "net metering" for small photovoltaic systems on homes and businesses;
- adopt local ordinances that promote the use of renewable energy technologies;
- lease state lands for renewable energy production;
- offer renewable energy production tax credits;
- reduce property taxes for renewable energy facilities;
- build a Colorado Renewable Energy Industries Center;
- support renewable energy technologies through a surcharge;
- create disclosure and labeling for electric power;
- ensure long-term support for renewable energy at the state level.

Renewable Energy Forum

Supported by the Office of Energy Conservation, the Colorado Renewable Energy Forum meets to address barriers to the increased use of renewable energy resources. Forum members work together to promote the increased use of renewable energy by Colorado utilities. Members include government, consumer protection agencies, industry, environmental groups, and concerned citizens.

Renewable Energy Trust

The Renewable Energy Trust was developed in 1993. The Trust is a customer-driven fund to help develop renewable energy sources in Colorado. To date, the program has helped to install approximately 14.3 kilowatts of solar energy products throughout the state. An advisory group comprised of Public Service Company customers select the projects to be

funded. The Public Service Company provides administrative and marketing support to the fund, in addition to contributing $1,000 per kilowatt to selected project(s). Projects to date include: installation of a photovoltaic restroom and boat ramp lighting at Colorado State Parks, a thermal mass classroom at Carbondale Middle School, solar lighting and call boxes for the Stapleton Development Corp., solar heating and cooling at the Boulder Conservation Center, and many others. One of the noteworthy current projects being funded through the Trust include the installation of 1.4 kilowatt photovoltaic system on top of Mount Evans.

Renewable Energy and Energy Efficiency Education Program

The Office of Energy Conservation has introduced a new program that offers financial assistance to schools to offset the initial costs of incorporating renewable energy and energy efficiency concepts into existing curricula.

Million Solar Roofs Initiative

On June 26, 1997, President Clinton announced the Million Solar Roofs Initiative. The goal is to install one million solar energy systems on buildings across the United States by the year 2010. DOE is supporting teams from the building industry, local governments, state agencies, the solar industry, electric utilities, and other organizations to remove market barriers, foster incentives, and strengthen the grassroots demand for solar energy technologies. The Million Solar Roofs Initiative will include photovoltaic and solar water heating systems that provide energy to homes or commercial or government buildings.

Colorado Solar Schools Program

This program provides financial assistance for half of the costs, up to $9,000, to help schools purchase and install small grid-tied solar electric (photovoltaic) systems as a way to demonstrate renewable energy concepts. It is offered by the Office of Energy Conservation.

Photovoltaic Services Network

The Photovoltaic Services Network is an independent, nonprofit organization of utilities sponsored in part by the Office of Energy Conservation. The goal of the Network is to assist utilities in using off-grid photovoltaic systems by:

- providing education, training and installation support to customers as required by member utilities;
- establishing a forum for information exchange on photovoltaic program implementation and marketing methods;
- creating standardized photovoltaic system specifications for a variety of applications;
- negotiating volume discounts for group photovoltaic product purchases; and,
- pursuing alliances with other organizations interested in photovoltaic technologies.[11]

Commercialization Ventures Program

The Commercialization Ventures Program provides financial assistance to state energy offices in teaming arrangements with private-sector organizations for the purpose of

accelerating the commercialization of emerging renewable energy technologies. The Program was established by the Renewable Energy and Energy Technology Competitiveness Act of 1989 as amended by the Energy Policy Act of 1992, to assist entry into the marketplace of newly emerging renewable energy technologies or innovative applications of existing technologies. A competitive solicitation was issued in June of 1996 and resulted in nine cooperative agreement awards. The Commercialization Ventures Program activities must be performed within the United States of America and substantial manufacturing and reproduction must occur within the Unites States. The Program is not entertaining any new requests for financial assistance; however, the post-award administration of existing projects continues.

Green Power Marketing Grant Program

The Office of Energy Conservation is offering a small grant, up to $5,000, to nonprofit organizations to support recruitment of green power to customers for utility wind programs in Colorado.

5.2.3 Production Processes and Area Sources

5.2.3.1 Natural Gas and Oil Production

Gas Distribution System

Public Service Company has implemented operation practices and replaced some equipment to reduce emissions of methane during normal operations. Other strategies include routinely lowering pressure in pipelines during normal operations, specifically prior to venting a pipeline to conduct maintenance operations. In addition, thousands of feet of old steel pipe have been replaced with new plastic pipe - reducing loss due to leakage.

5.2.3.2 Chlorofluorocarbon Production

State Strategies for Ozone Depleting Compounds

Colorado's stratospheric ozone program to address the statutory requirement of 25-7-105(11)(a-h) C.R.S., is detailed in Regulation No. 15, "Regulation to Control Emissions of Ozone Depleting Compounds." Regulation No. 15 regulates the use of all ozone depleting compounds (chlorofluorocarbons and hydrofluorocarbons) during the service, repair and disposal of refrigeration and air conditioning appliances by the automotive and stationary industries throughout the state. The program was developed as an inspection and compliance program to ensure that emissions of such compounds are controlled pursuant to state and federal requirements.

With the assistance of twelve local agency health departments, the Chlorofluorocarbon Program performs approximately 2,200 inspections of automotive and stationary sources each year. In addition to the federal requirements found in Title VI of the Clean Air Act Amendments 1992, Colorado's program requires that all automotive sources perform mandatory leak checks of air conditioning systems prior to the addition of ozone depleting

compound refrigerants. Certain stationary sources must register with the program, e.g., all businesses that perform air conditioning/refrigeration service and all owners of air conditioning/refrigeration systems rated at 100 compressor horsepower or greater, and businesses that own refrigeration equipment that is used in food sales.

Although Colorado's Chlorofluorocarbon program only regulates ozone depleting compounds that are used for refrigerant applications, significant national gains have been made as a result of the Clean Air Act requirements. Specifically, ozone depleting compound usage in the solvent, foam blowing, insulation/packaging and fire extinguishing industries have either been entirely eliminated or greatly reduced. This can be directly attributed to two major factors; 1) the discontinuance of the more harmful ozone depleting compound production at the end of 1995, and 2) an Internal Revenue Service tax on the compounds at the point of initial manufacture and a subsequent floor stock tax levied for each year certain quantities are held for future use for manufacture or sale. Consequently, escalating prices for these compounds have forced users to look at other options including non-ozone depleting compounds or compounds that are less harmful to the stratosphere and are not affected by the production phaseout.

5.2.3.3 Landfills

Methane Recovery Regulation

On Feb. 20, 1997, the Colorado Air Quality Control Commission adopted the landfill revision to Regulation No. 6, titled "Standards of Performance for New Stationary Sources" (40 CFR 60, Subpart WWW). Pending EPA approval, Colorado's new and existing landfills with capacities greater than or equal to 2.5 million cubic meters which emit more than 50 megagrams of non-methane organic compounds, will need to install a collection and control system to capture methane and non-methane organic compounds for resale (alternative energy) or flaring. Once a landfill is deemed to meet or exceed the regulations criteria, it will have one year to submit a design plan to the Colorado Air Pollution Control Division. Control systems must be installed within 18 months from the date of submittal of the design plan. In Colorado, it is anticipated that 8 to 10 municipal landfills will be subject to the new landfill standards. Tracking of methane emissions, however, are not required by the current regulation.

Recycle Colorado

Recycle Colorado is an office recycling program that helps to promote, develop and advance recycling throughout state agencies. In response to Governor Romer's challenge to cut in half the amount of waste going to Colorado landfills, the Governor's Office of Energy Conservation has worked to institutionalize office recycling programs in many state agencies. The Office of Energy Conservation, the lead recycling agency in the state, has designed the Recycle Colorado program to be a model for other state agencies and the private sector to emulate.

Recycle Net

RecycleNet serves as an information clearinghouse by providing links to recycling and solid waste resources on the Internet. It can assist in finding national recycling news and events, state and federal government resources, publications, solid waste legislation, waste exchanges, trade associations and nonprofit organizations. To continue its important role of providing information to Colorado and surrounding states, RecycleNet also includes a listing of Colorado events, links to community home pages, and links to the markets and manufacturers databases.

RecycleNet can be accessed through the Office of Energy Conservation's home page at http://www.state.co.us/gov_dir/oec/, or through the Internet at the following address: http://governor.state.co.us/gov_dir/oec/recyclenet/

5.2.4 Agriculture, Forests and Land Use

5.2.4.1 Forests and Land Use

Western Regional Biomass Program

DOE has developed a Western Regional Biomass Energy Program to support biomass technologies and the transformation of current and reliable information to potential biofuel energy users. The program focuses primarily on existing and emerging technologies demonstrated from case studies or second generation designs. Colorado is in the Western Region along with Arizona, California, Kansas, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Utah and Wyoming. For more information, contact the Western Regional Biomass Energy Program at (303) 275-4821.

5.3 Local Initiatives and Programs

5.3.1 Climate Change Programs

Cities for Climate Protection

Cities for Climate Protection is a global campaign of the International Council for Local Environmental Initiatives (ICLEI). More than 170 local governments worldwide participate in the Campaign, including over 50 cities and counties in the United States. In Colorado, four cities are participating in the Cities for Climate Protection Campaign: Denver, Boulder, Aspen and Fort Collins.

The Cities for Climate Protection Campaign offers grants, technical assistance, training, publications and marketing tools to support the implementation of programs and policies which improve energy efficiency and result in greenhouse gas emissions reductions in all sectors: buildings, manufacturing and industrial facilities, municipal fleets, waste management, land-use planning, renewable energy applications, transportation and local government operations.

Once enrolled in the Cities for Climate Protection Campaign, cities and counties pledge

to reduce greenhouse gas emissions from their local government operations and throughout their communities. Local governments pass a resolution and undertake the following tasks or milestones:

• determine the base year emissions by developing a greenhouse gas emissions inventory;

• forecast emissions growth for the target year of 2005 or 2010;

• adopt an emissions reduction target;

• develop an action plan outlining the activities that will be pursued to achieve the emissions reduction target; and,

• implement the recommendations included in the action plan.

Clean Cities

Clean Cities is a locally-based government/industry partnership, coordinated by DOE. The goal of Clean Cities is to expand the use of alternatives to gasoline and diesel fuel in city fleets. By combining local decision-making with voluntary action of partners, the grass-roots approach of Clean Cities creates an effective transportation plan that is carried out at the local level. DOE will be working with national Clean Cities coalitions to:

• create new jobs and commercial opportunities;

• facilitate the production and conversion of alternative fuel vehicle technologies;

• advance clean air objectives and increase public awareness;

• provide greater fuel choices and develop cleaner transportation corridors;

• expand refueling infrastructure and support regulated fleets.

5.3.2 Energy Consumption and Fossil Fuel Combustion

5.3.2.1 Residential

Implementing energy efficiency technologies at the residential level can provide many benefits to households, the community and to the environment. Through the implementation of increased residential efficiencies, public and household budgets can realize improvements, freeing up money for other priorities.

Two years ago Rocky Mountain National Park insulated the walls, attics and crawl spaces of all 66 National Park Mission homes. Several homes were converted from all electric to natural gas hydronics with domestic hot water makers. Some of the homes converted underground fuel oil heating systems to high efficiency spark ignited forced air furnaces. Eighteen apartments have also been converted from underground fuel oil to two high efficiency hydronic boilers. All underground fuel oil storage tanks have been removed. In addition, most wood stoves have been removed and replaced with pellet stoves.

Green Builder Program

The Home Builders Association of Metropolitan Denver sponsors a Green Builder Program that requires builders to meet one of two energy standards. Both standards exceed Colorado's Energy Code. The goals of the requirements include: reduced energy costs for the homeowner, reduced air pollution emissions, and preservation of natural resources. The program is available to all builders and remodelers in the six-county metropolitan Denver area.

The criteria used to voluntarily qualify homes under the Green Builders Program was developed by the Home Builders Association of Metropolitan-Denver and termed the Built Green Program. To be eligible for certification as a "green" builder, homebuilders must incorporate certain efficiency technologies into their homes. A list provides potential green building practices considered acceptable to the Home Builders Association and the Office of Energy Conservation. McStain Enterprises, Inc., one of 40-plus builders participating in the Built-Green Program, is a large production home builder in the Denver-Metropolitan area. McStain homes are built to a higher standard of energy efficiency than most local codes require. Many of the building materials used by McStain have less embodied energy than more commonly used products, e.g., cellulose insulation versus fiberglass. The higher standards utilized by McStain are estimated to reduced greenhouse gas emissions during the manufacturing process and from on-site energy consumption. It is estimated that each home in the Boulder Greenlee Park subdivision emits about 1 ton less of carbon dioxide per year than homes built in the average Boulder subdivision, and 2-3 tons less than similarly-sized homes built in the Denver-Metropolitan area.

Any builder of the Built-Green standard must meet or exceed the Council of American Building Officials' 1992 Model Energy Code. Builders meeting this standard should reduce annual emissions of carbon dioxide (per home) by a minimum of one (1) ton. The Denver Home Builders Association estimates that approximately 500 homes built during 1997 met the Built-Green standard. It is anticipated during 1998 that three times as many will meet the standard.

Boulder Green Points Program

The Green Points Program is a mandatory city-wide program that specifies a minimum number of green measures for new homes and additions as a requirement for getting a building permit. Under this program, Green Points are earned for energy and resource efficiency features that are available in eight categories including: land use, framing, plumbing, electrical, insulation, solar energy, and indoor air quality. The larger the home, the more Green Points needed to be considered resource or energy efficient. For more information on Boulder's Green Points Program, access:

http//environmentalaffairs.ci.boulder.co.us/residential/gp_overview.html

5.3.2.2 Commercial

Energy Efficiency Retrofits

Energy efficiency upgrades can save businesses money and reduce greenhouse gas emissions. For example, at the Boulder Bookstore in Boulder, upgrades to the 20,000 square

foot historic building is saving the bookstore owners $4,800 annually, resulting in a payback within three years. Upgrades included the installation of more efficient lighting, low-emissive super-insulated window, and an evaporative cooler have helped improve the bookstores business, cut energy costs, reduced its share of greenhouse gas emissions, and improved comfort and light levels in the store.

5.3.2.3 Industrial

Partners For A Clean Environment (PACE)

The Partners For A Clean Environment or PACE, is a program of the city of Boulder, Boulder County, Boulder Chamber of Commerce and Boulder Energy Conservation Center that assists local businesses in saving money through the implementation of environmental efficiency programs. Autobody and auto repair shops, dry cleaners, local manufacturers, printers and the hospitality industry are examples of some of the participants in Boulder's PACE program. This voluntary program helps businesses customize pollution prevention programs in order to reduce emission of air pollutants, as well as providing cost-savings through measured results.

Programs like Boulder's PACE program provide no-cost voluntary environmental certification opportunities for businesses and can be used as models for similar programs designed to reduce emissions of greenhouse gases.

Financial Energy Management

Financial Energy Management, a Denver-based energy service company, conducts energy efficiency improvement projects for commercial buildings.

CLEAN Business Program

The CLEAN Business Program is sponsored by the Clean Air Campaign of the Pikes Peak Region and encourages businesses in the Pikes Peak Region to implement strategies for conserving energy through energy audits and surveys.

5.3.2.4 Transportation

Denver Clean-City Fleets Survey

The Denver Clean-City Fleets Survey is a 1995 survey of private companies and local governments in the Denver/Boulder area operating 10 or more vehicles. The survey is part of an alternative-fuel vehicle data collection program conducted by the Energy Information Administration as mandated by the 1992 Energy Policy Act. Alternative Fuel Vehicles are vehicles that operate on fuels other than gasoline and diesel, such as electricity, ethanol, methanol, natural gas, and propane. Denver has been designated a Clean City by DOE because it fosters the wider use of Alternative Fuel Vehicles.

The survey produced information about the number of Alternative Fuel Vehicles and identified factors likely to promote the use of alternative fuel vehicles in commercial fleets. Survey results included:

• five percent of the commercial fleets surveyed operate some type of alternative fuel

vehicle, those vehicles represent 2 percent of the area's fleet vehicles;

- more than half of the Denver-area fleets purchase fuel at public stations, while only 8 percent fuel on-site at company facilities. Fleets that use company fueling facilities are considered to be prime targets for conversion to Alternative Fuel Vehicles be cause there is little public infrastructure for the purchase of alternative fuels.

Fifty-nine percent of gasoline and diesel vehicles were less than 4 years old. High vehicle turnover creates the opportunity for fleet operators to expand the use of Alternative Fuel Vehicles to non-fleet owners, but it also means a shorter time in which to recover the investment cost of the vehicles.

Travel Reduction Incentive Program

Sponsored by Clean Air Campaign of the Pikes Peak Region, the Travel Reduction Incentive Program provides employer-based travel reduction action plan development for businesses in the Pikes Peak Region through survey and site analysis.

RideArrangers

In the Denver-Metropolitan area, RideArrangers provides a carpool and vanpool matching service for Front Range businesses, transit information, and technical assistance for businesses wanting to set up alternative transportation programs. In the Pikes Peak Region RIDEFINDERS conducts the same program for businesses in the region.

Commuter Pool

Commuter Pool provides a carpool and vanpool matching service for businesses in the Northern Front Range area, especially Fort Collins, Greeley and Loveland. Also provided are site visits for businesses wanting to start alternative transportation programs.

Ethanol and Biodiesel Vehicles

The Rocky Mountain National Park uses ethanol gasoline for all unleaded vehicles and is currently analyzing biodiesel trucks and road equipment. If deemed successful, biodiesel equipment will be purchased for use in the park.

5.3.2.5 Utilities

Solar Energy

In 1994 the Public Service Company of Colorado installed an 18 kilowatt, grid-connected photovoltaic system on the roof of the Public Service Company warehouse facility.

In 1996 the largest renewable energy source was installed at Cherry Creek State Park. This 22 kilowatt, grid-connected photovoltaic system supplies energy to Public Service Company's electrical power system.

*Solar*source is a special solar power pilot program sponsored by the Public Service Company of Colorado. Under this program, the Public Service Company is offering a limited number of grid-connected roof-top photovoltaic systems for customers to purchase at reduced cost. Systems range from 1580 watts to 2600 watts. Based on response, Public Service Company will determine if it will market the *Solar*source program on larger scale.

Wind Power

Wind power was first offered in Colorado to Fort Collins electric customers this spring. Two 750 kilowatt turbines located in Medicine Bow, Wyoming began commercial operation in April 1998. The Wyoming facility will supply 600 residential customers and 13 business customers with wind power. In fact, Fort Collins Light and Power and Platte River Power Authority won the Governor's Smart Growth Award and the 1997 Energy Innovator Award from the American Public Power Association for the Wind Power Pilot Program of the year.

*Wind*Source

The first wind power facility is under development in Colorado. Offered by the Public Service Company of Colorado, seven wind turbines will be constructed at the Ponnequin Wind Facility in northeast Colorado. Each turbine is capable of generating up to 700 kilowatts of power - enough energy to meet the needs of approximately 225 homes. The second phase of the wind project will add 10 more turbines later in 1998 for a total of more than 12 megawatts of windpower.

The wind farm is located along the Colorado and Wyoming state line, between highways I-25 and U.S. 85. This site was chosen because the wind at this location blows steady and strong, and is environmentally appropriate for wind energy. One of the main environmental issues associated with wind power is its effect on birds. The area is not an attractive habitat due to lack of water and nesting sites.

5.3.3 Forests and Land Use

Rocky Mountain National Park

Rocky Mountain National Park received a grant from the National Renewable Energy Laboratory to convert vehicles to natural gas and propane. The goal of the grant program was to convert 70 percent of the park vehicle fleet from gasoline to cleaner burning fuels by the year 2005. To date, two vehicles have been converted to natural gas, 14 vehicles converted to propane and two vehicles are electric. Altogether, these alternative-fuel vehicles represent about 17 percent of the Rocky Mountain National Park's service fleet. The cost for making these conversions was approximately $3,000 per vehicle to convert from gas to natural gas or propane. The National Park service will continue to budget natural gas/propane vehicles into their existing fleet.

Tourism

Most visits to Rocky Mountain National Park occur between May and October. During this time two bus shuttle systems are used. One bus runs throughout the day during the summer months on the east side of the park. During the fall buses are used for elk viewing.

Mass Transit

A mass transit system is being discussed for the Rocky Mountain National Park. Ideas

include: establishing a Trail Ridge Road Corridor starting at the Hidden Valley parking lot; operating a shuttle to run along Trail Ridge Road and other parts of park; and developing a collaborative effort with Estes Park that would operate from the city of Estes Park into the park, connecting with other shuttle systems.

Education and Outreach

Rocky Mountain National Park receives more than 3 million visitors per year. Of that number, it is estimated that more than half are in contact with a park ranger or park volunteer. The park provides environmental education to park visitors on climate change and related greenhouse gas information. One person works full time in Community Outreach Programs with Front Range Schools. In 1996, 7,720 school children visited, 1,790,240 visitors at park through evening programs, guided walks, information desk and/or kiosks.

Within the Rocky Mountain National Park system, there have been discussions about creating a formal climate change program in the future, especially in the context of impacts on the resources of the park and how visitors can minimize those impacts to the park.

5.3.4 Landfills/Waste Minimization

Stamp Out Unwanted Mail

Paper makes up more than 40 percent of America's solid waste stream. Each year millions of Americans make one or more purchases through the mail. To lessen the amount of unwanted mail, the Office of Energy, Boulder Energy Conservation Center, and EPA Region VIII, sponsor a statewide "Stamp Out Unwanted Mail" campaign. Through the campaign names from mailing lists across the country can be removed. Instructions on how it is done can be obtained from the free "Stamp Out Unwanted Mail" kit available through the Boulder Energy Conservation Center at (303) 441-3278.

Recycling

Colorado Recycles is a non-profit organization that educates consumers about recycling, and buying recycled materials, including green building materials and composting.

5.4 Menu of Options

5.4.1 Energy Consumption and Fossil Fuel Combustion

Energy consumption in Colorado is projected to grow at an average rate of 1.5 percent annually through 2010.[12] Improving energy efficiency in residential, commercial, industrial and transportation sectors can provide reductions in greenhouse gas emissions, reduce demand for electric power, improve air quality, as well as provide other environmental and

productivity benefits. Many programs promoting efficiency standards are already in place in Colorado. Finding ways to remove existing barriers and to fund continued research and development of energy efficiency technologies will be important for bringing these technologies into the Colorado marketplace. The following lists are provided by sector and include other potential strategies that can work to reduce greenhouse gas emissions produced during the combustion of fossil fuels. No one strategy is being suggested, but numerous ideas are presented to serve as a starting point for future discussions on the type of technologies and opportunities that are available in the energy and combustion sectors.

5.4.1.1 Residential

Energy use in the residential and commercial sectors result primarily from activities that take place in homes and other buildings.

Energy Efficiency/Conservation

A number of states promote residential efficiency through the use of Home Energy Rating Systems. This efficiency program rates homes not only for existing energy efficiency, but also for a number of measures that could reduce energy consumption through cost-effective actions. A rating system typically provides consumers with a menu of retrofit options and the estimated cost and savings. Only those measures that offer a pay back through energy savings on a cash flow basis, assuming the measures are financed, are recommended. The Home Energy Rating System is intended to complement energy efficiency financing.

Energy Efficient Building Codes

New construction, once built inefficiently, is expensive and difficult to change. By developing a statewide building code, a floor for efficient building and home standards can incorporate efficiencies into new structures. The advantages of consistent building codes allow energy and pollution savings to be predicted, measured, and if necessary, adjusted. A basic structure for a model code could include minimal standards for insulation, window performance, equipment efficiency, or other performance-based methods.

Model Energy Code

Colorado is among more than 20 states that has not adopted the International Code Council's 1993 Model Energy Code. This model building code is estimated to save American home buyers $81 million and almost 226,000 tons of air pollution annually — enough energy savings to serve the energy needs of all the new homes built in a typical year in Michigan and Pennsylvania combined.[13] Energy bill savings for a typical homeowner are about $122 per year with a positive payback within two years.

Improving Heating and Cooling Systems

Many furnaces can be 90 percent efficient, but due to leaky duct work can result in heat losses of up to 30 percent. Improvements to heating and cooling systems could include

plugging leaks in heating and air conditioning ducts by injecting airborne sealants into these systems.

Incentive Programs

Incentives usually involve rebates or low-interest loans to consumers purchasing efficient devices or undertaking building retrofits. Financial incentives, such as point-of-purchase rebates to customers who replace existing electric water heaters with natural gas, liquid propane, or solar powered water heaters, for example, can encourage early replacement of systems and promote specific efficiency technologies.

Cool Communities

Reflective roofs, white pavement and tree planting can provide savings from both the direct effect of sunlight being reflected or by blocking sunlight and heat from entering the building envelope.

Information Programs

Information or educational programs can be used to promote energy conservation in homes. Programs can consist of labeling devices with efficiency information, utility bill stuffers, booklets listing efficient devices and appliances, radio and television advertisements, handbooks for building designers, developers, architects and others.

5.4.1.2 Commercial

The commercial sector, i.e. buildings, produce the vast majority of emissions from the energy (electricity) used in buildings. Building structures represent a market in the United States of more than $70 billion per year. Primarily it is the buildings themselves that are highly inefficient in conserving energy, e.g., poor insulation and windows. Another key component of buildings includes the equipment in buildings that transforms fuel or electricity into end-uses, such as delivered heat or cooling, lights, fresh air, vertical transport, cleaning of clothes or dishes, information management, or entertainment.

During the past decade, energy consumption in the commercial sector has grown at about the same rate as Gross Domestic Product. Technologies that increase energy efficiency is the key to achieving reductions in greenhouse gas emissions produced by this end-use sector. Improving energy efficiency in buildings will also provide benefits to urban and regional air quality, energy security, and sustainable development goals.

Improving the Building Envelope

The building envelope provides thermal load control for a building. Walls, roofs, and floors block or delay the flow of heat between a building’s interior and exterior. Windows can also block heat flow, provide daylight, and transmit solar energy. Improvements in the energy performance of these building elements can reduce energy use in buildings and thereby reduce greenhouse gas emissions. Major benefits other than energy savings and reduced greenhouse gas emissions, include improved comfort, health and productivity; an increase in recycled materials; reduced ozone depleting potential with non-chlorofluorocar-

bon foam insulations; and, reduced air pollutants emissions.

Decreasing a buildings thermal load reduces the need for energy for heating and cooling. Building envelope technologies include:

- super insulation;
- high efficiency foam insulation that is chlorofluorocarbon free;
- gas-filled, multiple-glazing, low-emitting windows and electrochromic glazing;
- light colored, self-drying roofs;
- passive solar components;
- durable high-reflective coatings; and,
- thermal storage materials.

Utility Rebates

A utility rebate program can be a cost-effective opportunity to encourage more efficient lighting or equipment in commercial businesses. A rebate program such as this could be supported through a utility energy efficiency budget to promote building efficiency retrofits.

Intelligent Building Systems

Intelligent building systems would use data from design, together with building-sensed data, to automatically configure controls and start up and shut down building operations. An intelligent building system would optimize operation across building systems, inform and implement energy purchasing, guide maintenance activities, and report building performance, while ensuring that comfort, health and safety needs are met at the lowest possible costs. Savings from an intelligent building system is estimated to be more than 30 percent of the annual energy costs of existing commercial buildings.

Solar Electric & Solar Thermal Systems

Solar electric and solar thermal systems can be used for both residential and commercial buildings to provide radiant heat, domestic hot water and provide electricity for all needs.

Equipment and Appliances

Building equipment and appliances can vary in efficiency by 20 percent to 40 percent from the least efficient on the market to the most efficient. The annual market in the United States for equipment and appliances is more than $200 billion. Technological improvements during the past 20 years have improved the efficiency of many types of equipment by 15 percent to 20 percent. Continued technical innovation could at least match these efficiency gains during the next 20 years. Some of the major benefits, aside from energy savings and greenhouse gas reductions include better control of indoor comfort conditions; improved health and productivity; and reduced air pollution emissions. An equipment and appliance standard can ensure that commercial businesses replace old equipment and appliances with more efficient units as they are replaced during natural turnover.

Minimum efficiency standards could apply to appliances and other equipment and to

new buildings or to those undergoing substantial renovations. Efficiency standards can take two forms: prescriptive standards, which mandate specific technologies, and performance standards, which mandate a specific level of energy consumption.[14] A standard could provide a choice between either the prescriptive or performance standard.

Heating and Cooling Systems

Heating and cooling systems provide numerous opportunities to improve energy efficiency in buildings through integrated systems design, right sizing modular/multiple equipment configurations and better integration of the process for distributing space heating and cooling within buildings. Energy efficient air filtration and humidity and temperature control could be incorporated into heating and cooling systems to reduce indoor concentrations of airborne particulate matter such as pollen and other allergens, and infectious agents that cause health effects. This type of integrated technology can be applied to residential as well as commercial buildings.[15]

Better use of thermal storage technologies would increase the ability of passive solar heating and cooling systems to offset the use of mechanical systems. Improved distribution of natural heating and cooling uniformly during the day can decrease the need for both heating and cooling from mechanical systems.[16]

Incentives for purchasing recycling equipment to recycle materials from daily operations

Incentives could be used to encourage commercial businesses to do on-site recycling of materials produced during daily operations.

Energy Efficient Buildings

Designing buildings with advanced technology can reduce energy consumption by 25 percent to 50 percent with extra costs offset by the smaller heating and cooling requirements and smaller systems. Changes to building codes and to appliance/equipment requirements can help the commercial sector reduce production of greenhouse gas emissions by encouraging owners to develop “smart buildings” that regulate areas based on occupancy, hours of operation and daily activities can reduce building maintenance needs in addition to providing emission reductions.

Elevator systems are an example of an energy intensive operating building system - accounting for as much as 5 percent to 8 percent of a building’s energy consumption.[17] United Technologies Corporation’s Otis Elevator Company has developed several technologies that improve service and save energy in elevator systems. By changing the speed at which elevators are dispatched and adding regenerative drives that recover a portion of the electrical energy that would be otherwise lost as heat, elevator systems can reduce energy needs by 5 percent to 20 percent.[18] At Xerox’s research center, engineers have developed “active badging” systems that key employees’ identification badges to heating and cooling systems, copiers, or other office equipment which will turn on only when they sense someone is approaching. The result of this badging system was that the energy-management system reduced energy consumption by 45 percent.[19]

Hospitality Industry

Every day tons of detergent, millions of gallons of water, and significant quantities of energy are used to wash towel and sheets that have been used only once at hotels, motels, and other overnight accommodations. Many hotels on the west coast encourage guests to reuse towels and sheets through an educational program provided upon arrival to the room. Brochures, placards, etc., are placed on bathroom doors or racks and bed pillows explaining the environmental concerns and what a guest can do to minimize wasteful practices, such as reusing towels and requesting that sheets not be washed each day.

5.4.1.3 Industrial

In Colorado, the industrial sector produces approximately one-third of total greenhouse gas emissions. Improvements in energy efficiency can reduce emissions from the industrial sector with a short-term payback. Mitigation opportunities in the industrial sector, however, differ from other sectors because increases in energy efficiency often come from pursuing other goals such as improved product quality and lower production costs versus from direct efforts to reduce energy consumption. Industry also has different incentives to improve efficiency, mainly, to reduce costs while maintaining profitability. Thus, it is important to develop mitigation strategies within the industrial sector that can build upon and enhance efforts that may already be underway and, in addition, improve the bottom-line. Thus, it is important to work closely with the industrial sector and allow them the flexibility to choose effective strategies for their particular industry. Potential mitigation strategies that can reduce greenhouse gas emissions from energy use include minor operational changes, such as housekeeping and maintenance. These strategies are the cheapest, easiest to implement and the least risky, but usually provide the smallest energy and cost-savings. Production equipment changes and energy conservation technologies involve larger investments. Major process changes are often justified only by strategic market development concerns.[20] In addition, policies that lessen the demand for energy-intensive commodities can reduce industrial energy consumption.[21]

Energy Audits

The industrial sector is complicated by the vast array of processes taking place in the course of its daily operations. Conducting energy audits provide a systematic approach to determining the most cost-effective and energy efficient strategies for improvement. The benefit of energy efficient strategies is that an industry can realize a high return on the initial capital investment, as well as realize reductions of greenhouse gas and other pollution emissions. Motors, for example, consume 70% of industrial electricity used and opportunities for improved efficiency of motors exist. Pumps, lights, and boilers, once identified, are other equipment needs that consume large amounts of energy and can be improved through efficiency measures.

Housekeeping and Maintenance

Good housekeeping practices, such as routine inspections that focus on conservation,

turning off equipment that is not in use, installing and using energy-monitoring equipment, wrapping pipes and tanks with insulation and repairing leaks provide low-cost ways to increase energy efficiency. Regular equipment repair and maintenance provides additional opportunities to conserve energy.

Integrated Systems Analysis

Utilization of an integrated systems analysis would allow industrial sources to assess the entire process of their energy use, identify opportunities to improve efficiencies, implement improvements and track energy use and diagnostic procedures that will assure proper performance of the strategies during its life cycle. This approach would lead to pollution prevention opportunities as well as cross-media and multiple pollutant benefits in daily operations of the industrial source.

Energy Management Systems

Automated systems that turn off or turn down process equipment, lights, fans, etc. throughout the day and on weekends can be used to conserve energy throughout a site.

Incentives to recycle materials during production and manufacturing

Creating incentives for the purchase of recycling equipment will encourage the industrial sector to recycle materials produced on-site during the production and manufacturing processes.

Motor Drive System Improvements

Electrical motors are major consumers of industrial electricity. Several studies in the United States conclude that approximately two-thirds of electricity is consumed by electrical motors, with the industrial sector accounting for between 26 percent to 30 percent of the total. Motors are used primarily to drive pumps, compressors and fans. Major opportunities exist to improve the efficiency of the motors and supporting systems, such as connecting shafts and belt drives.[22]

Energy Efficiency Codes and Standards

The development of codes and standards for energy efficient equipment will help ensure that old industrial equipment is replaced with more efficient units during natural turnover of the equipment.

Cogeneration (Combined Heat and Power)

Industrial cogeneration allows the substitution of waste heat from electricity generation for steam that would otherwise be raised in a boiler using fuel. Cogeneration is particularly attractive for large industries that have large process heat requirements such as pulp and paper, chemicals and food processing. New technologies are available to capture waste heat that industrial sources currently throw away. Industrial cogeneration of natural gas or biomass could reduce carbon emissions by 2015. Advanced turbines developed by DOE and industry will be available in 2001. They have an efficiency rating of 80 percent to 90 percent and produce steam together with electricity and significantly reduce emissions of

nitrous oxides.

Heat Recovery

Recovering heat from industrial processes may involve transferring heat from high-temperature waste heat sources to more useful media such as steam or raising the temperature of low-temperature streams so they can be useful as heat sources.[23]

Demonstration Projects

Demonstration projects of new innovative technologies need to be encouraged and well documented. Attracting new technologies to Colorado will be important to long-term improvements in addressing greenhouse gas emissions, in addition to realizing other environmental benefits.

5.4.1.4 Transportation

The transportation sector produces approximately one-third of Colorado's greenhouse gas emissions. Over the long-term, the most effective initiatives to reduce transportation energy locally will be require changes in local land use management that foster more compact communities, mixture of residential and commercial uses in the same neighborhoods, and transit-oriented development. Some of the technologies that can reduce greenhouse gas emissions from the transportation sector include:

- high efficiency cars and light trucks;
- high efficiency heavy trucks; and,
- advanced efficient aircraft and rail.

High Efficiency Cars and Light Trucks

A number of lighter weight more efficient technologies are under development for cars, light trucks, and sport utility vehicles. Technologies such as hybrid vehicle design, advanced engines, regenerative braking and lightweight materials are anticipated to produce cars that are three times more efficient than current vehicles.

Alternative Fuel Vehicles

Alternative fuels include compressed and liquefied natural gas, biomass ethanol, liquefied petroleum gas, and biodiesel. Domestic automobile manufacturers have been producing alternative fuel vehicles since 1991. Most alternative fuel vehicles use flexible-fuel, dual-fuel, and dedicated fuel sources. Additional benefits from use of alternative fuel vehicles include reductions in nitrogen oxides, carbon monoxide, hydrocarbons, and fine particulate matter, yielding improvement in air quality, especially in urban areas.

High Efficiency Heavy Trucks

Advanced technologies for diesel engines and lightweight materials for heavy duty

trucks are projected to be available in 2003. Improvements in engine design and lighter materials have the potential to substantially reduce greenhouse gas emissions from this segment of the transportation sector as well as improve fuel mileage (a truck typically gets 7 to 8 miles to the gallon and travels more than 50,000 miles a year) and lessen damage to road surfaces.

Improve System Efficiency

Improvements in traffic flow, such as improved traffic signalization can make small contributions to reducing emissions from automobiles on urban area streets.

Lower Emission Modes

Promote walking, bicycling, public transportation and railroad freight relative to automobile and truck traffic. Avoid creating barriers to alternative modes of transportation when developing, managing, or operating infrastructure for motor vehicles and developing new communities. Promote alternative modes of transportation via public information campaigns or improvements in the quality of service, such as dedicated right-of-ways for buses, bicycles or pedestrians.

Advanced Efficient Aircraft and Rail

Ongoing federal research and development on advanced aircraft engines, improved airframes, and air traffic control have the potential to improve aircraft energy efficiency by 35 percent with small reductions coming from efficiency improvements of trains. Switching the travel-mode of container freight from road to rail can reduce primary energy consumption by 30 percent.[24]

Better Tires

Education and outreach on proper inflation of tires and routine engine maintenance can provide small reductions in greenhouse gas emissions through improved operation and improved gas mileage of vehicles.

Community Design

The way communities are designed and built determines the diversity of travel options available. Strategies include pedestrian and transit oriented development; mixed-use development; and revitalization of traditional downtown neighborhoods that combine transportation choices, economic development, mobility, employment and livability.

Mode Switching

Switching the way people travel, primarily from car to bus or alternative modes, is estimated to result in a primary energy use of 30 percent to 70 percent.[25]

Market-based Strategies

Congestion pricing, reductions to parking lot subsidies, zoning changes, et. al., can be used to encourage the use of alternative modes of transportation.

5.4.1.5 Utilities

Among utilities, energy losses associated with transmission and distribution typically fall in the 5 percent to 10 percent range, with an average of about 7 percent. The carbon dioxide emissions associated with this energy loss is about 127 million metric tons. Hence, a one percentage point reduction in transmission losses for the United States as a whole would yield an annual reduction in emissions of 18 million metric tons.

By increasing the efficiency of the generation process, efficiency improvement projects at fossil-fuel-fired power plants reduce the plants' heat rate, defined as the amount of fossil energy (measured in Btu) needed to produce each kilowatt-hour of electricity. The result is a reduction in the amount of fuel that must be burned to meet generation requirements, and hence a reduction in carbon dioxide (and other greenhouse gas) emissions. Efficiency improvements at non-fossil-fuel power plants (e.g., hydroelectric plants) can also reduce greenhouse gas emissions. Emissions reductions occur if the efficiency improvement leads to an increase in the amount of electricity generated by the affected plant, with a consequent reduction in the amount of electricity that must be generated by other (fossil fuel) plants to meet demand.

5.4.1.5.1 Coal-Fired Power Plants

Improving the efficiency of coal-fired power plants has the potential to reduce carbon emissions in the near, mid, and long terms. In Colorado, coal generates about 92.66 percent of the state's electric generation — a percentage that during the next 15 to 20 years is not likely to change much. During a coal-fired power plant's normal operation, the plant converts about 33 percent to 38 percent of the energy potential of coal into electricity. The rest is lost primarily as waste heat. Boosting a power plant's coal-to-electricity efficiency means that less fuel will be consumed to generate the same amount of electricity. During the past two decades considerable research and development has been dedicated to the development of efficiency improvements for coal-fired power plants. Some of the high-efficiency technologies that are targeted for deployment beginning around the year 2000 include[26]:

- low emission boiler systems;
- pressurized fluidized bed combustion;
- integrated gasification combined cycle.

Power-System Efficiency Maximization Technologies

Improving existing technology systems can help maximize energy efficiency. Grounded in the second law of thermodynamics, power-system efficiency maximization takes advantage of the fact that waste heat is always produced and can be reduced or reused, increasing efficiency. Through the development of technologies to utilize waste heat created at coal-fired power plants, efficiencies can be elevated from approximately 30 percent to 60 percent or more. Finding a permanent use for the waste heat may be a greater challenge than developing the technology to do so.

Low Emission Boiler Systems

A conventional coal-burning power plant generates electricity using a single-cycle process. During this process, heat from the burning of coal boils water to create steam which spins a steam turbine-generator. A low emission boiler system pushes single-cycle generation into higher efficiencies due to the ability of the system to pack more energy into the steam that is released from power plant boilers. Implementing a low emission boiler system would increase fuel-to-electricity efficiency to 42 percent and reduce carbon dioxide emissions 25 percent.

Pressurized Fluidized Bed Combustion

In a pressurized fluidized bed combustion system, coal is burned at elevated pressures (6 to 16 times atmospheric pressure) to produce a high-pressure exhaust gas stream. The exhaust gas has enough energy to spin a gas turbine-generator. At the same time this process is taking place, the boiler heats water to produce steam for a conventional steam cycle. A pressurized fluidized bed combustion system is estimated to improve fuel-to-electric efficiency to 45 percent during the first generation cycle (2000-2010) and up to 50 percent during the advanced generation period (post 2010). Carbon dioxide emission reductions would be approximately 27 percent during the initial start-up time period and 36 percent as the technology advances and becomes more widespread in its application.

Integrated Gasification Combined Cycle

An integrated gasification combined cycle system would convert coal into a combustible gas. The gas is burned in the combustor of a gas turbine to produce one source of electricity. Exhaust gases from the gas turbine remain hot enough to boil water for a conventional steam cycle. Fuel-to-electricity efficiency using an integrated gasification combined cycle system is estimated to be 45 percent during the first generation and up to 52 percent as technology continues to advance. Carbon dioxide reductions from this system would be 30 percent initially, and 39 percent in the advance generation period.

Coal Combustion By-Product Recycling

Coal combustion by-products can be recycled into building and construction materials, road base, soil stabilization projects, and many other materials. In Texas, the Lower Colorado River Authority's Fayette Power Project recycles coal combustion by-products, as well as fly ash. The recycled fly ash is used as a substitute for Portland Cement. In 1994, the Lower Colorado River Authority recycled about 80 percent of the fly ash it produced. In fiscal year 2000, an estimated 226,000 tons of fly ash will be recycled as a substitute for Portland Cement — resulting in a 64 percent emissions reductions or approximately a 145,000 tons reduction of carbon dioxide.

Cogeneration

Only a portion of the heat generated during the combustion of fossil fuels can be converted into electrical energy; the remainder is generally lost. Cogeneration involves the recovery of this thermal energy, for use in subsequent applications. Cogeneration facilities

typically employ either topping or bottoming cycles. In a topping cycle, thermal energy is first used to produce electricity and then recovered for subsequent applications. Topping cycles are widely used in industry as well as utility power plants that sell electricity and steam to customers. In bottoming cycles, the thermal energy is first used to provide process heat, from which waste heat is subsequently recovered to generate electricity. Bottoming cycle applications are less common and are usually associated with high-temperature industrial processes. Because cogeneration involves the recovery and use of thermal energy that would otherwise be wasted, it reduces the amount of fossil fuel that must be burned to meet electrical and thermal energy requirements, hence reducing greenhouse gas emissions.

Distributed Power Generation

The concept of distributed power generation places small power plants closer to customers. Distributed generators can be connected to either smaller electrical distribution systems serving multiple customers, or can be linked directly to homes, offices buildings, or factories. Typically, a 30 kilowatt distributed power system can generate enough electricity to supply six homes. A 50 megawatt system can power 25,000 homes. Generally, the cost for distributed power generators to deliver electricity is approximately 3 cents per kilowatt-hour, given the close proximity of generators to its customers[27] .

5.4.1.5.2 Natural Gas Power Plants

Worldwide, the use of natural gas to generate electricity is projected to increase from 16 percent of fuel consumed for electricity generation in 1995 to 23 percent in 2015. Although coal is projected to remain the dominant fuel for power plants.

Natural gas emits half the amount of carbon dioxide than coal for the same energy produced. New technologies, however, can enhance natural gas-to-electric efficiencies, further reducing greenhouse gas emissions.[28] These technologies include:

- Advanced Turbine Systems;
- Advanced Fuel Cells.

Advanced Turbine Systems

Natural gas turbines provide more power generating capacity in smaller increments with fewer greenhouse gas emissions than coal-fired power plants. The fuel-to-electricity efficiency of gas turbines is around 30 percent. Advanced turbine technology is being developed that can raise the fuel-to-electricity efficiency to 60 percent or greater with nearly a 20 percent reduction in carbon dioxide emissions.

Advanced Fuel Cells

Fuel cells can use natural gas to generate electricity. The advanced fuel cell uses an electrochemical reaction of hydrogen (from fuel) and oxygen (from air) to produce electricity, water and heat. The generation of electricity from fuel cell technology does produce some emissions of carbon dioxide, but fuel cells are capable of attaining high fuel-to-electricity efficiencies of 50 percent to 70 percent with reductions of carbon emissions of 32 percent. By 2010, hybrid fuel cells and advanced gas turbine systems should be adapted to

operate on gases made from coal and biomass. Efficiencies from these hybrid systems are expected to have efficiencies of close to 60 percent for coal systems.

5.4.1.5.3 Power Distribution Systems

Transmission and Distribution Projects

The purpose of the electricity transmission and distribution system is to deliver electrical energy from the power plant to the end user. Due to resistance to the flow of the electrical current in the cables, transformers, and other components comprising the transmission and distribution system, a portion of the energy (typically about 7 percent) is lost in the form of heat. Improving the efficiency of the various system components can reduce line losses, reducing the amount of generation required to meet end-use demand and, thus, power plant fossil fuel consumption and greenhouse gas emissions.

High-Efficiency Transformers

Transformers are used to change the voltage between different segments of the transmission and distribution systems and are a major source of system losses. Transformer losses occur as a result of impedance to the flow of current in the transformer windings, and because of hysteresis and eddy currents in the steel core of the transformer.[29] When existing transformers are replaced with high-efficiency transformers (including improved silicon steel transformers and amorphous core transformers) transformer losses are reduced.

Conductors

Like transformers, conductors (including feeders and transmission lines) are a major source of transmission and distribution system losses. In general, the smaller the diameter of the conductor, the greater its resistance to the flow of electric current, and the greater the consequent line losses. Reconductoring involves the replacement of existing conductors with larger diameter conductors.

Distribution Voltage Upgrades

Line losses are dependent, in part, on the voltage at which the various segments of the transmission and distribution system operate. By upgrading the voltage of any segment, line losses can be reduced.

5.4.1.5.4 Renewable Energy

Using energy from sunlight, wind, rivers, oceans, biomass, and geothermal energy, electricity can be produced without significant emissions of greenhouse gases. All regions of the United States have renewable resources of one type or another. Currently, renewable energy accounts for about 8 percent to 10 percent of the energy consumed in the United States.

Hydropower

Electricity generated from rivers and dams currently produces approximately 10 percent of the nation's electricity. Adverse environmental effects of ecosystems downstream

of the generation of power are a significant concern to many.

Geothermal Energy

Geothermal technologies use energy from within the earth to produce electricity or provide heat for industrial processes. Geothermal heat pumps use the thermal mass of the earth as a heat sink for air-conditioning and heating. In the United States, geothermal reservoirs produce about 2,100 megawatt equivalent and about 6,000 megawatt equivalent worldwide.

Solar Photovoltaic

Solar technology uses semiconductor-based cells and modules to convert energy from the sun into electricity. Photovoltaics can be used on a number of different scales, depending on how many PV modules are connected together.

Renewable Energy Portfolio

Expand the current energy portfolio to include increased renewable energy technologies in the portfolio. One avenue of achieving this type of goal is through the Integrated Resource Planning process. During the Integrated Resource Planning process consideration is given to risk and diversity of supply, maintenance of system reliability, and to environmental and other external impacts.

5.4.1.5.5 Emissions Trading Program

A voluntary, market-driven greenhouse gas "cap-and-trade" program would reward reductions of greenhouse gases through a profitable trading program. The creation of a flexible market trading mechanism would let sources determine how to reduce emissions either through the purchase or sale of emission credits. Additional benefits of an emissions trading program would be improved efficiencies and savings on materials, fuels, and other operational systems.

State Banking and Trading Program

An emissions bank establishes a mechanism for recognizing and awarding "credit" to sources that make reductions in advance of any potential mandatory requirements. Operating as an incentive, a banking and trading program provides a number of benefits for early emissions reductions while promoting voluntary reductions taken by industry.

In New Jersey, the New Jersey Department of Environmental Protection is designing a trading bank that will provide credits for voluntary early reductions of greenhouse gas emissions from changes in practices or technologies that result in a decrease in emissions. The program calculates the associated early reduction credits and deposits them in the bank. A program participant can withdraw banked credits for future regulatory compliance or market them to other sources. New Jersey's goal is to reduce greenhouse gas emissions to 3.5 percent below 1990 levels by the year 2005.

5.4.2 Production Processes and Area Sources

5.4.2.1 Coal Mine Production Processes

Due to differing circumstances (altitude) in the Rocky Mountain region, it is essential that any potential strategies in the coal mining industry be coordinated in collaboration with the mining industry to assure that technologies are appropriate at higher altitudes and colder climate conditions.

5.4.2.2 Chlorofluorocarbon Production

Recovering and recycling ozone depleting chemicals and use of alternative products are the best ways in the short-term to minimize emissions of chlorofluorocarbon chemicals. Items that provide the best opportunity for recovery and recycling are automobile air conditioners, chillers, and home and retail food refrigerators. The following is a list of steps that can be taken to minimize emissions including:

- establishing recycling centers for reclamation of chlorofluorocarbons;
- recover chlorofluorocarbon chemicals when refrigerators and automobiles are disposed;
- promote better air conditioner and refrigerator standards;
- improve automobile air conditioner recharge units;
- prevent automobile air conditioner leaks;
- use alternative home insulation; and,
- promote use of alternative testing agents in fire extinguishers.

5.4.2.3 Landfills/ Waste Minimization

Measures that reduce methane emissions from waste, such as initiatives to reduce, reuse and recycle solid waste, can provide significant reductions to greenhouse gas emissions at the local level.

Methane Recovery

Landfills produce methane gas as a by-product of the natural degradation of the waste within the landfill. Capturing landfill methane gas significantly reduces landfills' air pollution, odor and safety impacts. By using the captured gas as an energy source, local governments can convert a community liability into an asset.

Source Reduction

A general approach to waste management can be called source reduction. This means solving waste and other pollution problems as close to their generation point as possible. In short, waste that is never created, never needs be disposed and when generated, waste recognized as a resource can be used over in one form or another.

In practice, source reduction means reducing the amount of potential trash and hazard-

ous wastes entering the household as well as reducing the toxicity of that waste. A simple reduction in the overall volume of waste will mean fewer materials to be disposed in landfills — reducing methane emissions, and less incinerator ash will be created — including fewer hazardous materials.

Composting

Increasing backyard and commercial level composting activities will decrease a large amount of yard and green waste currently dumped into dumpsters and trash cans.

Recycling

Research at the national level shows that the benefits of recycling can be quite large. At the national level, increasing recycling from the current rate of 27 percent to a goal of 35 percent would reduce greenhouse gases by 12 million metric tons of carbon. A benefit roughly equivalent to the greenhouse gas emissions from 8 million cars.

Reuse of Second-Hand Products

Reuse of products contributes to reduced waste going into landfills. At the same time, reusing materials and products reduces production needs at all stages of manufacturing, from initial material extraction to final production. Promoting widespread use of returnable and refillable containers, for example, would reduce waste generation for businesses, households and industry.

5.4.3 Agriculture, Forest and Land Use

In 1990, agricultural-related activities accounted for 5.9 percent of Colorado's greenhouse gas emissions. Activities such as fertilizer use, domestic animal manure systems and emissions from domestic animals emit nitrous oxide and methane are estimated to grow by 9 percent by 2015.

In 1995 there were 25,000 farms in Colorado with an average size of farms and ranches being 1,327 acres. Total agricultural land area in farms and ranches is more than 32 million acres with almost 11 million acres in cropland. Because of the size of the industry and the nature of its operations, agriculture can play an important role in reducing concentrations of greenhouse gases through carbon sequestration in soils and croplands, as well as through changes in other management practices. Presently, the extent to which agriculture can contribute to emissions reductions through sequestration processes is not clearly defined. Ongoing research efforts, however, are trying to accurately quantify sequestration benefits from natural living systems.

5.4.3.1 Animal Manure Management Systems

Improve management practices of animal manure waste and if possible trap or process methane for its energy and nutrient content.

5.4.3.2 Fertilizer Use

Reduce use of nitrogen fertilizer application to crops. Apply only when needed and in quantities and forms needed by crops.

5.4.3.3 Forest Land

According to the USDA, during the past 40 years, forest land in the United States has stored the equivalent of 25 percent of the nation's carbon emissions. Through the process of reforestation of harvested acres and afforestation of new acres, the sequestration process can continue and be used to offset emission targets. In Colorado, forest woodlands comprise 21.5 million acres of land. An additional 34 million acres is classified as land without trees. Much of this land is considered farm, rangeland and grassland. Of this land, the state owns and manages more than 3 million acres of Colorado's land.

Mitigation options for the forestry sector may be classified into two basic types. One option involves expanding the pool of carbon in soils, vegetation, and wood products. Expansion of soils and vegetation would draw carbon from the atmosphere and sequester it. The second option involves maintaining the existing carbon sinks in soils, vegetation and forested areas. Maintaining existing stands keeps stored carbon from entering the atmosphere through deforestation activities or wildfire.

Forest Protection and Conservation

Protection and conservation strategies protect the carbon in both vegetation and soil. Typically, such measures are put into place for non-carbon resource management purposes, such as wildlife protection, soil conservation, water catchment and recreational reserves.

Increased Efficiency in Forest Management

Measures to increase efficiency include natural forest management with selective harvesting, and harvesting for multiple end-uses.

5.4.3.4 Land Use

Rangelands and Grasslands

Rangelands cover approximately 47 percent of the earth's surface and are generally characterized by low and/or erratic precipitation, poor drainage, rough topography and low soil fertility.[30] On a global basis, methane production by wild and domestic animals has been estimated to be around 15 percent of the world's total methane emissions. Greenhouse gas reduction strategies in the rangeland sector primarily involve the reduction of methane production by wild and domestic ruminant grazers, and increasing carbon storage through improved rangeland conditions. Some mitigation strategies could include:

- rehabilitation of degraded rangelands, including afforestation, reforestation, grass and shrub establishment;
- improve the quality of the diet by increasing native grasses and planting other adapted plant species for wild and domestic ruminant consumption.

5.4.4 Sequestration and Adaptation

Carbon Sequestration

Natural systems such as trees, plants and soils can help offset carbon dioxide emissions through the sequestration of carbon in these living systems. In the agricultural sector, soil, cropland and woodland areas are important systems that can be utilized as carbon sinks, as well as provide other environmental benefits. By sequestering carbon in soils, for example, the organic carbon levels in soils increase, resulting in improved tilth and soil moisture and a reduction in soil erosion processes. In general, increased carbon storage in agricultural soils improves soil quality.

Urban Forestry

Developing urban and rural tree planting programs on private land and in communities could help sequester carbon statewide, and provide benefits at the local level. Increase forest management assistance (cost-sharing and technical assistance) to private landowners and communities to encourage tree planting on private and public lands.

Reforestation

Replanting and/or natural regeneration of deforested areas.

Agroforestry

Common practices of agroforestry include inter-cropping for the purpose of producing both agricultural and forest products, and boundary and contour planting for wind and soil protection, as well as for providing agricultural and wood products.

Conservation Tillage

Increase conservation tillage (low- and no-till) and other crop residue management practices to lower emissions from equipment and increase soil organic matter content;

Plant/Crop Engineering

Plant/crop engineering involves improving plant productivity and the ability for plants and crops to capture solar energy and perform photosynthesis. Genetic engineering of plants and crops can help increase biomass production, increase carbon fixation, improve nitrogen utilization and recycling, and increase carbon storage abilities. Other benefits of plant/crop engineering include improved nutritional quality and extended storage life.

Biomass Fuels

Biomass stores carbon and releases it when it is burned. The balance, however, between stored (sequestered) carbon and that which is released, provides no net change in emissions. Growing biomass crops can serve multiple purposes such as the ability to grow and stabilize fragile lands, filter fertilizer and pesticide runoff, and serve as a carbon sink. Biomass crop production can also benefit farmers by adding energy crops to traditional

production processes.

5.5 Other Opportunities

Education and Outreach

A vast array of energy-efficiency technologies currently exist. This information may not be readily available to the average consumer or the companies that may choose to implement efficiency technologies. Thus, it is important to make the information available, including the financial and environmental benefits that can be realized through implementation.

Electronic Technologies

Electronic technologies touch many aspects of daily life and as a result have changed the world. The Information Age that is upon us can be a key to addressing environmental challenges such as climate change. Three technologies in particular hold promise for enabling electronics and communication products to reduce greenhouse gases. These technologies include improving display technologies; bandwidth technologies; and, sensors and controls.[32]

Display technology affects the quality of visual communication - they are also consumers of energy. Technologies that produce lighter weight displays with lower energy consumption requirements, will save energy and increase portability of the systems. Improvement to bandwidth refers to increasing how fast the networks can transmit visual data images. In short, how many bits of information that can be transmitted per second over a given channel such as optical fiber or copper wire.[33] These type of technological advancements can help make appliances, buildings, vehicles and industrial processes more efficient by reducing energy intensity through technology development and application. Benefits from improved electronic and communication technologies can mean provide reductions to greenhouse gas emissions and improve productivity.

Partnerships

Partner with federal, state, and local government agencies and educational institutions to implement greenhouse gas mitigation strategies or demonstration projects and studies that lead to reductions of greenhouse gas emissions. This partnership could serve as a clearinghouse for information, tied together via the internet or some other form of electronic technology for ease of access and to help keep the information timely and accurate.

Mitigation Assessment

A mitigation assessment would involve a state-level analysis of the potential costs and impacts of various technologies and practices that have the capacity to mitigate climate change impacts. The goals of an assessment are two-fold: (1) to provide policy makers with an evaluation of those technologies and practices that can both mitigate climate change and

also contribute to national development objectives, and (2) to identify policies and programs that could enhance their adoption. An initial assessment should be followed by a more detailed evaluation of specific policies, programs, or projects designed to address greenhouse gas reduction technologies and practices.[34]

Research & Development

Promote research, development, and the adoption of innovative technologies that establish as a goal the reduction of emissions of greenhouse gases from anthropogenic sources.

Grant/Loan Program

A grant and loan program could be established to help fund state/local projects designed to reduce greenhouse gas emissions.

Demonstration Projects

One way to disseminate information about the capability and reliability of new or successful technologies is to conduct demonstration projects. An added benefit of demonstration projects is the opportunity to correct unanticipated problems with new technologies.

Government Purchase Programs

State and local governments can create a market for new efficiency technologies through their purchasing choices - encouraging production processes, economies of scale and more rapid adoption of efficiency technologies. Establishing standards for new government construction projects or certain efficiency or performance levels, are examples of the leading role government can take in reducing emissions of greenhouse gases and other pollutants.

6.0 Endnotes

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7.0 Appendix – Literature Review

Separate document available by request. See “Acknowledgments” section in the front of this document for contact information.

7.1 Appendix – Peer Review

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