Minnesota Pollution Control Agency

Minnesota Climate Change Action Plan: A Framework for Climate Change Action

February 2003

Foreword

This report was written under a grant received by the Minnesota Pollution Control Agency (MPCA) from the U.S. Environmental Protection Agency's Global Programs Division. More than 25 other states have developed state climate change action plans. The approach and resources devoted to developing these plans varied among the states. Some hired a consultant to conduct broad stakeholder workgroups; others were more limited in their involvement of stakeholders. Some conducted in-depth technical analyses of various greenhouse gas mitigation options; others developed more extensive inventories. In all plans, the recommended actions fall into a few key areas, with reduced greenhouse emissions from energy usage as the primary focus and an emphasis on improving carbon sequestration.

This report provides a framework for a Minnesota climate change action plan. To develop this framework we developed detailed greenhouse gas emissions information and forecasts, as well as a carbon sequestration inventory. We conducted a survey to learn what a broad group of stakeholders (e.g., industry, non-profit groups, and government) think the role of state government should be in this issue. We gathered a list of existing state programs that may be relevant to greenhouse gas control through interviews with staff from over a dozen state agencies. To aid in communicating this issue with other agencies, we also conducted a survey to learn about their attitudes and beliefs towards climate change. The ideas put forth in this report are based on a synthesis of the information we gathered.

This report does not commit any additional resources on the part of the MPCA or of others.

Throughout this paper, the term 'we' refers to the authors of this report.

Contact Information

If you would like more information about this report, please contact the authors:

Peter Ciborowski, Air Policy Unit, Majors and Remediation Division
Minnesota Pollution Control Agency
520 Lafayette Road North
St. Paul, MN 55155
Telephone: (651) 297-5822 E-mail: peter.ciborowski@pca.state.mn.us

or

Mary Jean Fenske, Air Policy Unit, Majors and Remediation Division
Minnesota Pollution Control Agency
520 Lafayette Road North
St. Paul, MN 55155
Telephone: (651) 297-5472 -- E-mail: maryjean.fenske@pca.state.mn.us

Acknowledgements

The authors thank these individuals for their assistance with the surveys described in this report:

- Ahndi Fridell, Office of Environmental Assistance (OEA)
- Jeff Ledermann, OEA
- Sherryl Livingston, MPCA
- Tom Miller, OEA
- John Seltz, MPCA

The authors thank these individuals at the MPCA and OEA for their review of the report:

- Doug Day
- Art Dunn
- Greg Pratt
- John Seltz
- David Thornton
- Ken Brown

The authors thank the participants in the various surveys from these organizations:

- 3M
- Board of Water and Soil Resources
- Cliffs Mining
- Flint Hills Resources
- Minnesota Power
- Minnesotans for an Energy Efficient Economy
- Minnesota Council of Churches
- Minnesota Chamber of Commerce
- Metropolitan Council
- Minnesota Department of Natural Resources
- Minnesota Department of Commerce
- Minnesota Office of Environmental Assistance
- Minnesota Department of Health
- Minnesota Planning
- Minnesota Department of Transportation
- Minnesota Department of Administration
- Minnesota Department of Agriculture
- Minnesota Department of Trade and Economic Development
- Northwest Airlines
- Public Utilities Commission
- Sierra Club
- Minnesota Truckers' Association
- Xcel Energy

(Although these organizations participated in one or more survey, they do not necessarily endorse the conclusions drawn by the MPCA in the report.)

In addition, the authors thank Jan Eckart for her assistance in producing this report.

Finally, the guidance and assistance of Steve Dunn and Denise Mulholland with the U.S. Environmental Protection Agency's Office of Atmospheric Programs was much appreciated.

Table of Contents

Minnesota Climate Change Action Plan: A Framework for Climate Change Action

1.0 Summary

1.1 Introduction

The global climate change issue is one of the most studied problems in the physical sciences. For the last three to four decades the underlying body of science has grown substantially. National and international scientific bodies have reviewed this science on almost an annual basis since the late 1970's. A growing climate monitoring system is documenting the warming of the earth's lower atmosphere and surface and its effects on climate. Understanding of past climates' features is now much improved, due to other research, allowing scientists to place the current warming into perspective. Scientists have gone well beyond the initial questions of whether elevated greenhouse gas levels in the atmosphere will absorb more radiation to greater understanding on how the earth's surface climate will respond.

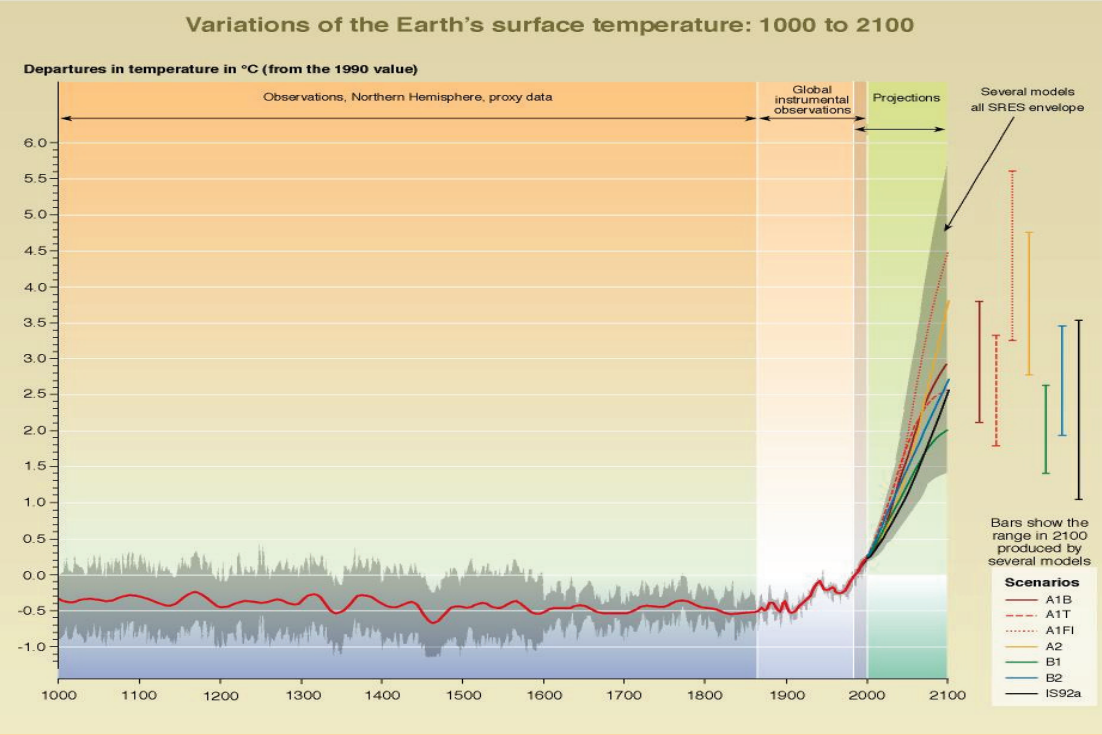
After decades-long study of the problem, we are fairly confident of the following conclusions:[1,2]

- the accumulation of greenhouse gases in the atmosphere, all other things held constant, will cause increased heating of the earth's surface and lower atmosphere leading to rising temperatures;
- from today, mean global surface temperature will rise at least 1 degree Celsius (1.5 º F) over the next century;
- the range of possible surface warming depends as much on the rate of emissions of greenhouse gases as it does on uncertainties in the response of global climate to higher atmospheric levels of greenhouse gases. On the basis of the existing peer-reviewed science, it is possible that the surface warming for the planet could be as great as 6 degrees Celsius (11º F) by 2100 or as little as 1 degree Celsius (1.5 º F);
- a mean global surface warming of 3 degrees Celsius (5 º F) or so from present levels would be a warming of about the same size as the earth underwent at the end of the last ice age (18,000 years before the present) to 10,000 years before the present;
- knowledge of how the earth's climate will respond to warming of the lower atmosphere and surface is extremely limited— scientists simply do not know how the climate will change after a large surface warming. We are told that it is possible that today's global climate could abruptly shift to something quite different in terms of global atmospheric and oceanic circulation, and that surprises are likely;[3]

[1] U.S. National Academy of Sciences, Climate Change Science: An Analysis of Key Questions (Washington, D.C.: National Academy Press, 2001).
[2] Intergovernmental Panel on Climate Change, Climate Change 2001: The Scientific Basis (Cambridge, UK: Cambridge University Press, 2001).
[3] U.S. National Academy of Sciences, Abrupt Climate Change: Inevitable Surprises (Washington, D.C.: National Academy Press, 2001).

- mean global surface temperature already has warmed about 0.6 degrees Celsius (1 º F) since 1880. Due to the lag time between emissions and global temperature increases, an additional warming of at least several tenths of a degree Celsius can be expected over the next several decades, plus whatever results from continued emissions;
- humans will have to adapt to some climatic changes because even under the most stringent long-term international greenhouse gas control regime, the surface temperature of the earth will still rise by at least 1 degree Celsius (1.5 º F) and probably more.

Figure 1.1 Projected Global Temperatures During the 21st Century Are Significantly Higher Than at Any Time During the Last 1000 Years



Source: Intergovernmental Panel on Climate Change, Climate Change 2001: Synthesis Report

Much more needs to be done and known. By definition, the effects of global climatic change are uncertain. Human economic systems can probably adapt to changing climate through slow adaptation, but some losses are inevitable. Natural ecosystems are unlikely to easily adapt to a rapidly changing climate, and, if the more extreme predictions for surface warming become reality, are likely to be substantially disrupted. This is because natural systems adjust only slowly to climatic changes, and do so primarily through migration, which human barriers in the form of cities, highways and intensively-managed landscapes make difficult.

It is often suggested that impacts will vary roughly according to the intensity of the overall rate of warming. If the overall warming remains relatively limited, in the 1 to 1.5 degrees Celsius

(1.5 - 3 º F) range over one-hundred years, future climates would not differ too much from climates of the present, suggesting more minor impacts. If large and rapid, however, the warming is more likely to involve large negative effects to natural systems, and presumably some substantial effect on economic systems.

1.2 What Is At Stake for Minnesota?

The effects of global climatic change in Minnesota probably will involve substantial warming, particularly in winter, and possibly increased precipitation. Since 1900, average annual surface temperature in Minnesota has increased about 1 degree Fahrenheit, while annual average precipitation has increased by about 15 percent. It seems possible that these trends will intensify. However, it is also possible than these trends, particularly in the case of precipitation, could reverse, perhaps many times, over the next hundred years.

Potential changes in other climatic parameters like cloudiness, relative humidity, or incidence of drought are unknown. It is thought likely that the incidence of heavy rainfall events will increase, continuing trends in the U.S. of the past fifty years. This suggests a possible increase in flooding and, paradoxically, greater likelihood of drought in summer as more moisture runs off and less is stored in soils. Warming during November/December and February/March will shorten the winter season by a month or two.

The existing ecology of Minnesota is characterized by rapid transitions in landscapes as shown in Figure 1.2. From east to west, the landscape transitions from woodland to oak savannah to prairie. From north to south, it moves progressively from boreal fir-spruce forest, to aspen and birch forest, and then to hardwoods like oak. These rapid transitions reflect the extreme diversity of climate in the state, warm enough in the south to support oak hardwood forests, cold enough in the north to support boreal forest, and dry enough in the west to support prairie. Scientists believe that much of the effect of climatic change in the continental U.S. will concentrate along vegetational boundaries like these. In Minnesota, this could involve:

- retreat of the boreal forest of the far north into Canada;
- northward expansion of grasslands and savannah into the extreme northwest and northern part of the state;
- replacement of the North Shore and Boundary Waters Canoe Area conifer forest with northeast mixed hardwoods;
- retreat of habitat for cold water species of fishes into extreme northern Minnesota;
- establishment in Minnesota of animal and plant species now found well to our south.

Figure 1.2 Minnesota's Ecological Systems in 2000 (Source: DNR)

With the exception of forestry, agriculture and tourism, the economic system in Minnesota is probably fairly well-insulated from climatic changes. Agriculture may prosper in Minnesota as cold-season constraints to production are reduced. Forestry will go the way of the forests. If these decline, so too will forestry. Of necessity, the tourist industry will need to refocus on warm season activities and activities not dependent on cold weather. It is possible that environmental protection will become more expensive, if only due to the broad array of possible future weather conditions for which wastewater treatment facilities or flood control structures will have to be designed to meet. As peak-day temperatures at the surface increase, it is also possible that air quality will decline, requiring more intensive efforts to control air pollution.

Winter heating costs will decline, but summer cooling costs will rise. Cold climate constraints to construction activities during the winter season will be relaxed. Greater expenditures on public health probably will be required to control the spread of insect-borne infectious diseases that thrive in warmer climates.

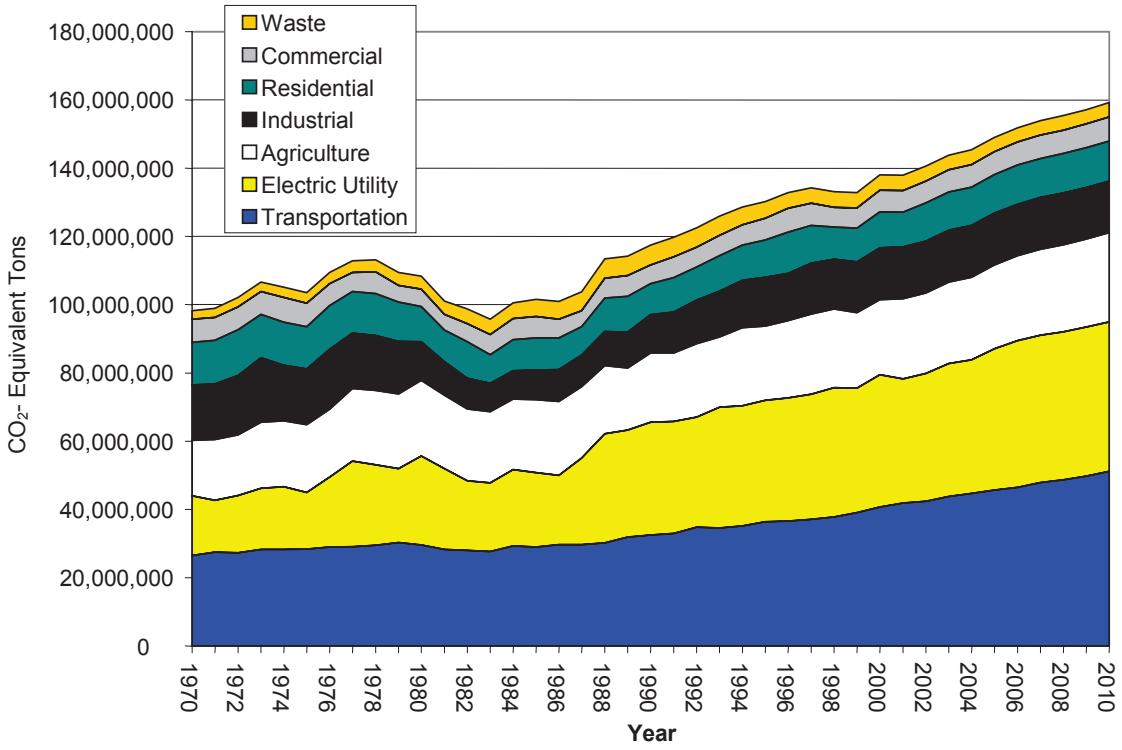
1.3 What Are Minnesota Greenhouse Gas Emission Trends and Sources?

Greenhouse gas emissions in Minnesota in 2000 were roughly 138 million CO_2-equivalent tons. This is up about 18 percent from 1990 levels, and about 40 percent from estimated 1970 levels. Emissions are increasing at a rate of about 1.7 percent per year, which is faster than the U.S. national rate of increase. Transportation and electrical generation are the largest sources of emissions in Minnesota. Together they account for about 70 percent of greenhouse gas emissions from the state. Agricultural activities, particularly those associated with field cultivation of row crops, accounts for about 20 percent of greenhouse gas emissions.

In contrast to absolute emissions, emissions of greenhouse gases from Minnesota per unit of economic production (gross state product) have declined about 50 percent since 1970. Since 1990, emissions per unit of production have declined about 15 percent. This suggests that, as the efficiency of the economic system improves, the rate of growth in emissions will remain well below the rate of growth of the economy.

Greenhouse gas emissions from Minnesota sources are expected to increase in the future. By 2010, emissions are forecast to increase to about 160 million CO_2-equivalent tons, or about 15 percent above 2000 levels. This continues the observed 30-year tendency toward progressively higher levels of annual emission.

Figure 1.3 Historic and Forecasted Greenhouse Gas Emissions from Minnesota



Offsetting the emission of greenhouse gases is the removal of greenhouse gases, mostly carbon dioxide, from the atmosphere as a result of the photosynthetic activity of plants, the growth of trees, and the expansion of Minnesota's timberland. As trees grow, carbon is withdrawn from the atmosphere and incorporated in the living biomass of the tree, where it can remain stored as wood or forest litter for hundreds of years. Carbon continues to accumulate in Minnesota's forests, in agricultural soils, in solid waste landfills, and in residential and commercial buildings. The carbon withdrawn from the atmosphere offsets about 20 million CO_2-equivalent tons of greenhouse gas emissions annually.

It is likely that the historic trend in carbon accumulation in Minnesota's forests and soils will continue, as the growing season lengthens and the climate moistens. The growing season in North America has increased about 12 days over the last few decades, and rainfall has increased. Working against this is the aging of Minnesota's forests. Older, more mature forests remove progressively less and less carbon from the atmosphere on an annual basis as they age. This will act to dampen somewhat the effect of longer growing seasons and wetter conditions.

1.4 What Minnesota State Programs Are Potentially Relevant to the Control of Greenhouse Gases?

We have inventoried and catalogued a large number of governmental programs in Minnesota that may have some relevance to any possible emissions control effort for greenhouse gases. These span the gamut from energy efficiency programs to programs in agricultural land preservation. These programs were created for purposes other than addressing climate change, such as achieving greater energy efficiency, promoting water conservation, reducing waste, or preserving forests and farmland.

Some of the more promising programs appear to be:

- SCORE program (solid waste recycling)
- MPCA closed landfill program (methane capture at landfills)
- Conservation Improvement Program (demand-side management for investor-owned utilities)
- transportation fuel formulation mandate (ethanol)
- Xcel Energy wind power mandate (wind power replacement for coal-fired generation)
- Conservation Reserve Enhancement Program (agricultural land retirement)
- Minnesota Residential Building Code (residential energy efficiency)

We have not evaluated each program that was identified for effectiveness in controlling emissions of greenhouse gases. It is possible that many only marginally influence the rate of production of greenhouse gases within the borders of Minnesota, and that at least some promote higher, rather than lower, rates of emissions from the state. As the state goes forward, it may be useful to perform this program analysis. The catalogue of programs was assembled from a survey of state agency personnel, who were asked to review a list of programs prepared by MPCA staff as potentially acting to limit the emission of greenhouse gases from Minnesota.

Some of the agency personnel in Minnesota state government have a well developed understanding of the issues involved in the climate change questions. Others have a poorer grasp of the issue. This may be a factor in any state government program to respond to the problem of global climate change.

1.5 What is a Strategy for Minnesota in the Climate Change Problem?

The global climate change problem is one with very long time-frames. It has taken many decades to induce the planetary warming that is now evident in the environment. It will take many decades to develop a truly effective response to the problem. It could certainly take many decades to direct the commercial energy sector away from fossil fuel use or, in absence of that, toward capture and sequestration of co-produced greenhouse gases. The development of a robust and effective international regulatory system will take many years.

What we think we understand about the dimensions of this problem:

- that international effort to control greenhouse gas emissions is going forward on the part of the U.S.'s major trading partners, and that trade pressures make it likely that at some point in the future the U.S. will be drawn into an international regulatory program;
- that the increasing body of biological and physical indicators (such as sea level rise, coral reef bleaching, and changing plant and animal ranges) of the apparent effect of greenhouse gas emissions will act as a continuing pressure for regulatory action, both nationally and in the state;
- that, despite this, the state probably has time to develop and implement greenhouse gas control measures—3 to 10 years—and that in the short-term, the challenge is to keep the growth in emissions from getting too far from current levels;
- that unilateral action now on the part of the state of Minnesota focused solely on reducing greenhouse gas emissions, particularly if aggressive, may place Minnesota businesses at a competitive disadvantage:
- that the economy of Minnesota is probably far from optimally invested in energy and materials-use efficiency;
- that this under-investment in efficiency may make it possible, through a strategy designed to increase the efficiency of energy and materials use in the economy, to simultaneously reduce emissions of greenhouse gases (or at least slow the rate of increase in emissions) and grow the economy; and,
- that present-day efforts to develop the energy technology that will be required nationally in future years to address the problem of global warming may yield long-term economic benefits to the state.

All of this argues for a strategy for Minnesota consisting of:

1) a 'no-regrets' short-term strategy centered on improved efficiency of the state's economy in the use of energy and materials, and
2) a longer-term effort to slowly wean the economy from its dependence on fossil fuels and their associated greenhouse gas emissions.

By aggressively pursuing opportunities to improve overall energy and materials-use efficiency in the state, it should be possible in the short-term to simultaneously grow the economy and limit the growth in emissions of greenhouse gases. By slowly going beyond energy efficiency improvements to de-couple greenhouse gas emissions from economic growth, it should be possible to minimize the economic costs of long-term emission reductions, while, at the same time, respond to a serious environmental problem. This strategy has the additional virtue in that it acts to minimize the risk to the Minnesota economy of long-term federal regulatory action.

An efficient economy would use energy at rates substantially lower than is realized under business-as-usual conditions. The average rate of improvement in the efficiency of energy use in the Minnesota economy between 1980 and 2000 was about one percent per year. This suggests

that something in the one and one-half to two percent per year range sustained over several decades might constitute a useful goal. The large apparent pool of efficiency improvements that is economically justifiable using conventional financial analysis suggests that the historic rate of improvements could be increased by at least half, with energy use reduced a commensurate 15 percent over two decades.

Thus a two-track approach has the virtue of reconciling shorter- and medium-term concerns for sustained economic growth with longer-term environmental considerations. Among other things, this would allow Minnesota's public leaders a window of time to become conversant in the question, to understand the long-term issues involved, and to bring the citizenry and the political parties in the state to a common understanding of what needs to be done. In addition, the 'no-regrets' actions focused on energy efficiency improvements can simultaneously lower emissions of criteria pollutants, thus improving air quality in Minnesota and helping to protect public health.

The Bush Administration has taken the first steps toward the development of a national policy on global climate change built around a 10-year target for U.S. greenhouse gas emissions, a voluntary program of reductions, credits for early action, and research and development. A two-track approach would align well with the Administration policy.

The kinds of things that recommend themselves for the long-term component of a dual-track policy include:

- research and monitoring to identify and track ecosystem changes
- technical assistance for farmers and small landowners
- information disclosure and education
- investigation of voluntary efforts to control methane and HFCs
- alternative energy development
- long-term planning

There are a number of ongoing efforts in the areas of pollution prevention and energy conservation. These could form the initial basis for a shorter-term 'no-regrets' efficiency strategy. Some specific MPCA actions that would be consistent with this strategy might include:

- continuation of an annual greenhouse gas inventory (tracking aggregate trends in state emissions) with annual reporting and public disclosure;
- development of a detailed state-level carbon sink inventory;
- promotion of (or possibly development of) early emission reduction credit registries and/or promotion of the Chicago Climate Exchange early reductions markets. This could include technical assistance to small businesses and farmers desiring to participate in early credits markets like the Chicago Climate Exchange;

- promotion of energy efficiency in MPCA loans and grants to public facilities for pollution control or through requirements in Supplemental Environmental Projects;
- integration of energy efficiency as a consideration in MPCA facility permitting processes. We could look at innovative ways to encourage companies to invest in energy efficiency through incentives such as flexible permitting or relaxation of recordkeeping and reporting requirements;
- participation in state energy planning processes like the Integrated Resources Planning process and Conservation Improvement Program.

MPCA efforts that support the long-term strategy component include continuing to integrate climate change information into existing outreach/education activities and reports. To this end, the MPCA is working with college and university researchers to learn what their research tells us about Minnesota's vulnerability to climate change. (A survey conducted for this report revealed that other government agencies look to us -the MPCA- for information on climate change.) Informed public and private sector decision-making depends on access to good information about this issue.

1.6 Conclusion

Minnesota's water, land, and air quality – environmental resources the MPCA is charged to protect – are likely to change more with a changing climate. The challenges involved in responding to the problem of human-induced global climate change are numerous. However, with all the pitfalls and perils, there also are substantial opportunities for Minnesota. The trick is in doing what is needed now when pursuing a no-regrets efficiency strategy, and later a more technology-based response that begins the shift of the economy from reliance on fossil fuels toward low-emitting sources of energy. The state probably has a window of three to ten years before any dramatic changes are required. During this period, it can put into place the components of a strategy that will produce a high-efficiency economy and begin to develop answers to the questions that in the long-run will need to addressed. Ultimately, it will be those answers that, in the long-term, will determine how successfully the state responds to the challenge of global climate change.

2.0 Actions That Others Are Taking

This section provides a brief description of climate change related actions at the international, national, state, business, and local levels. These actions provide the backdrop for state activities and are an important consideration in how Minnesota shapes its strategies on this issue.

2.1 International Action

Over the past decade, the most important event in shaping international climate change policy is the United Nations Framework Convention on Climate Change (UNFCCC). The stated goal was to "stabilize greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system". The signatories agreed that returning emissions to 1990 levels, as a benchmark, would be an appropriate first step. The U.S. ratified the UNFCCC in 1993. Under this, the U.S. has pledged to implement policies to stabilize greenhouse gases to 1990 levels. In 2000, the United States exceeded these levels by 14.2 percent.[4]

The Kyoto Protocol, signed in 1997 in Kyoto Japan, is a tool developed to implement the UNFCCC. It required five percent mandatory reductions of greenhouse gases in aggregate from 1990 levels by 2010 by North America, Russia, Western and Eastern Europe and Japan. Thirty-nine industrialized countries were to be governed by the original agreement, but the Bush Administration opted not to participate in March 2001.

In Bonn, Germany in June of 2001, 180 nations (the U.S. was not one of these nations) agreed to an "operational rulebook" for the Kyoto Protocol. The agreement takes effect when ratified by 55 percent of nations responsible for 55 percent of 1990 emissions. This can be accomplished without the U.S. Once Russia ratifies the necessary 55 percent will be achieved. Ratifying countries must reduce emissions of CO_2 to an average of 5.2 below 1990 levels between 2008 to 2012. Developing nation reductions can participate through the Clean Development Mechanisms outlined in the Kyoto Protocol. In Marrakesh, in November 2001, participating nations agreed on the details of implementing the Kyoto Protocol. At present, enough countries have either ratified the Protocol or have indicated their intention to ratify the Protocol that it probably will take effect in 2003.

2.2 National Action

In February 2002, President Bush announced a new climate strategy for the U.S. that sets a voluntary "greenhouse gas intensity" target, improves programs for companies to voluntarily reduce and report their emissions, and proposes increased funding for research. The strategy's target is an 18 percent reduction in emissions per unit of Gross Domestic Product by 2012. However, this target could still allow emissions to grow about 15 percent or greater by 2010 if historic rates of growth persist.

While no significant national climate legislation has passed to date, the level and intensity of the debate has increased dramatically at the national level. As an example, congressional activity on climate change has increased substantially in recent years. The number of introduced bills

[4] U.S. Environmental Protection Agency, Office of Atmospheric Programs, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2000. April 15, 2002. www.epa.gov/globalwarming/emissions/national

increased from seven in the 105th Congress (1997-1998) to 25 in the 106th Congress (1999-2000), and to over 50 in the 107th Congress (2001-2002).[5]

As a signatory to the UNFCCC, the U.S. fulfills the requirements of annually submitting a progress report with an inventory and policies. The most recent report was submitted in May 2002.[6] An Early Credits Registry was put in place under Section 1605b of the Energy Policy Act of 1990. Some firms, including many utilities, are participating in this. Since 1994, claims for roughly 1.5 billion CO_2-equivalent tons of early greenhouse gas reductions have been filed by U.S. corporations with the Department of Energy under its 1605b program. These reductions are equivalent to about one-quarter of one year's emissions from the entire U.S. economy. They have been made on the understanding that the participating firms will be able to apply these early reductions against any future obligations incurred under a Federal greenhouse gas regulatory program.

The U.S. has made significant investments in climatic research in the past and President Bush has proposed increasing these investments for the future focusing in particular on better understanding of the potential impacts of human-caused climate change.

2.3 Other States' Actions

States are leading efforts to reduce greenhouse gas concentrations through their role in land-use, transportation, utility, agriculture, taxation, and other policy areas affecting the environment. Twenty-seven states have developed strategies for reducing greenhouse gases. While these strategies for the most part have not been implemented by states, a number of states have made some significant achievements.

Most notable is California with its first-of-its-kind bill to limit CO_2 emissions from vehicles. It was signed by Governor Gray Davis on July 22, 2002. It requires the California Air Resources Board to develop carbon dioxide standards for vehicles in model year 2009 and beyond. The standards will apply to automakers' fleet averages, rather than each individual vehicle, and carmakers will be able to partially achieve the standards by reducing pollution from non-auto sources (e.g., factories, etc.).

Massachusetts set a national precedent by passing regulations in 2001 to clean up six existing power plants, which include a cap on carbon dioxide emissions. The law allows offsite reductions towards demonstration with the carbon dioxide limit. Massachusetts is part of a larger effort of six New England states. In August 2001, six states (Massachusetts, Connecticut, Rhode Island, New Hampshire, Vermont, and Maine) and five east Canadian provinces signed a pact to reduce greenhouse gas emissions. They pledged to cut emissions to 1990 levels by 2010 and by 10 percent below that level by 2020. New Jersey is on track to reach their greenhouse gas reduction goal: reduce greenhouse gases by 3.5 percent below 1990 levels by 2005.

Oregon has a limit of 0.7 lb. CO_2 per kilowatt-hour for new electrical generating units. This essentially dictates that all new electricity production be combined cycle natural gas - not coal.

[5] Pew Center on Climate Change, Climate Change Activities in the United States, June 2002. www.pewclimate.org/projects/us_activities.cfm

[6] U.S. Department of State, U.S. Climate Action Report 2002, Washington, D.C., May 2002.

In addition, more than 20,000 people signed up for the "Blue Sky Program" and pay $3.00 more a month to support electricity production from sources that do not contribute to global warming.

Voluntary state greenhouse gas registries are being developed or considered in at least 13 states. These registries are designed to help entities that are interested in reducing greenhouse gases quantify and register their emissions in order to better understand and manage them. Registries can also help raise awareness of climate change, promote success stories, and publicize low-cost mitigation opportunities. California's registry is the most advanced. It opened in fall 2002 with two dozen charter members. It is designed such that entities in other states can participate as well. Wisconsin's new registry includes greenhouse gases and criteria pollutants and has mandatory reporting rule for major sources greater than 100,000 tons CO_2 per year. The New England states are working towards a regional registry and other efforts are going on in Texas and Illinois. The Pew Center on Global Climate Change has completed several reports that discuss issues around developing greenhouse gas inventories.[7] In July 2002, the Meridian Institute based in Dillon California also completed a summary of programs involving greenhouse gas accounting.

2.4 Business Actions

Numerous companies based or operating in the United States are undertaking actions to address climate change. These actions include setting greenhouse gas targets, undertaking energy efficiency improvements, increasing carbon sequestration efforts, investing in renewables, developing energy-saving products and participating in emissions trading. A few of these companies have operations in Minnesota. Target Corporation, based in Minneapolis, recently joined the Climate Leaders Program announced by the Bush Administration in early 2002.[8] Ford Motor Company, which has a plant in St. Paul, Minnesota, has committed to improve the fuel economy of its U.S. SUV fleet by 25 percent from 2001 levels by 2005. IBM, which has operations in Rochester Minnesota, has pledged to:

- Conserve, in each year, four percent of the energy that would otherwise have been consumed.
- Reduce CO_2 emission associated with IBM's use and electricity consumption by an average annual four percent of what would otherwise have been emitted, over the period 1998 to 2004.
- Have 90 to 100 percent of the new models introduced during the year meet EnergyStar® criteria
- Reduce perflourcarbon emission from semiconductor manufacturing worldwide by 40 percent from 1995 levels by 2002 (indexed to production)
- Reduce perflourocarbon emissions from semiconductor manufacturing worldwide by 2010.[9]

A market for early reductions is developing. The Chicago Board of Trade has set up the first voluntary U.S. emissions trading pilot program called the "Chicago Climate Exchange℠" that is expected to begin operation in spring 2003. It is administered by Environmental and Financial

[7] For listing of reports by the Pew Center on Global Climate Change go to http://www.pewclimate.org/projects/index_solutions.cfm

[8] For description of Target's participation in the Climate Leader Program go to: http://www.epa.gov/climateleaders/partners.html#target

[9] Pew Center on Global Climate Change, Climate Change Activities in the United States, June 2002. Available at http://www.pewclimate.org/projects/us_activities.cfm

Products, LLC and the Kellogg School of Management under a grant from the Joyce Foundation. Firms accounting for about a fifth of the Midwest emissions, many of them utilities, are already participating. The stated goal of the program is "to design and implement a voluntary private pilot market first based in seven U.S. Midwestern states (Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio and Wisconsin), and later expanded to include national and international sources."[10] Initial propositions of the program are:

- Voluntary emissions reductions and trading for all six greenhouse gases,
- Phased-in commitments, starting with a target of two percent below 1999 levels during 2002 and declining gradually (one percent per year) thereafter,
- Monitoring, verification, tracking and reporting requirements, and
- Credits given for targeted domestic and foreign emissions offsets projects, including methane destruction, solar and wind energy projects, and certain carbon sinks.

In addition, international carbon trading brokerage firms exist for corporations and offset providers. Businesses with U.S. operations are already participating. For example, in July 2002 Ontario Power Generation purchased 6 million tons CO_2-equivalent (forward) with an option to buy 3 million more tons in the future. Blue Source, the offset provider, has clients in Texas, Wyoming and Mississippi that have installed a CO_2 pipeline to recover gases from oil production that would otherwise have been vented to the atmosphere.[11]

2.5 Local Actions

In May 2001, the City of Duluth became the 101st municipality in the United States, and one of over 500 worldwide, to make a local commitment to the reduction of greenhouse gas emissions.[12] The worldwide effort, called Cities for Climate Protection Campaign, is coordinated by the International Council for Local Environmental Initiatives (ICLEI). Duluth has pledged to:

- Take a leadership role in increasing energy efficiency and reducing greenhouse gas emissions from municipal operations;
- Develop and implement a local action plan, which describes the steps to reduce both greenhouse gas and air pollution emissions. The plan will include:
    (1) A greenhouse gas emissions analysis and forecast to determine the source and quantity of greenhouse gas emissions within the jurisdiction;
    (2) A carbon dioxide or greenhouse gas emissions reduction target;
    (3) The strategy for meeting Duluth's greenhouse gas reduction target, including an outline of the programs and measures that will be implemented to achieve the target.

Duluth was the third Minnesota city to join in the ICLEI program St. Paul[13] and Minneapolis joined the Cities for Climate Protection Campaign in 1993. In 1993, the Twin Cities pledged to reduce emissions by 20 percent from 1988 levels by 2005 or more than 6 million tons. In 2000,

[10] Information from Chicago Climate Exchange website at http://www.chicagoclimatex.com/

[11] http://www.CO2e.com

[12] For more information on Duluth's climate change actions go to http://www.ci.duluth.mn.us/city/information/ccp/index.htm

[13] For more information on St. Paul's climate change actions go to http://www.stpaul.gov/depts/tms/co2rednsumy.html

plans developed and implemented by Minneapolis and St. Paul received "Milestone Awards" from the International Council for Local Environmental Initiatives — its five stars symbolizing the highest achievement that a city can attain in its ongoing effort to improve energy efficiency and reduce greenhouse gases. (Only three others — Portland, Oregon; Chula Vista, California; and Miami-Dade County Florida — have received this honor.)

Hennepin and Ramsey Counties, whose combined population accounts for a third of all Minnesotans according to the 2000 census, also are participating in the Climate Protection Campaign. The Ramsey County Board adopted a resolution to join on April 24, 2001.[14] Hennepin County joined at the same time as Minneapolis and St. Paul.

By reducing greenhouse gas emissions these local governments are also saving money. For example, St. Paul has successfully reduced greenhouse gas emissions through energy retrofits in City buildings, increased public transportation options, urban reforestation, promoting the use of renewable energy sources, and recycling/waste reduction programs. The emissions and monetary savings from existing recycling and composting programs and waste-to-energy add up to over 155,000 tons of greenhouse gas emissions and $4,263,886 saved yearly; accounting for 35 percent of the total program greenhouse gas savings. The city of Saint Paul has documented a four percent reduction in its overall greenhouse gas emissions from 1988 to 2002, focusing primarily on partner initiatives and operations under municipal control. Saint Paul's ongoing initiative is the Environmental-Economic Partnership Project (E-EEP). The E-EEP is an overall energy conservation and CO_2 reduction strategy and implementation plan. Together, these initiatives reduced CO_2 emissions in the St. Paul area by more than 443,000 tons in 2002 and costs by $37,000,000.

[14] Resolution requires County Manager to prepare an action plan which details the steps Ramsey County will take to reduce greenhouse gases and air emissions. For text of resolution go to: http://www.co.ramsey.mn.us/cb/ma/minutes/M042401.htm

3.0 The Scientific Background

This section provides a brief background on the science behind climate change: a description of how greenhouse gases influence climate, a listing of the principal greenhouse gases and their sources, and the time-scales for their removal from the atmosphere.[15]

3.1 Relationship of the Greenhouse Gas Effect to Climate Change

Global climate change, as it is referred to today, is the change in the earth's climate that arises from the emission to and build-up in the atmosphere of greenhouse gases. Human activities are releasing large amounts of what are known as greenhouse gases into the atmosphere, and intensifying the existing background greenhouse effect, raising the surface temperature of the earth, and changing the distribution and nature of regional climates.

The earth's atmosphere contains clouds that reflect incoming sunlight, thereby cooling the planet, particles that act to scatter sunlight, also cooling the planet, and gases that absorb infrared radiation or heat. The principal infrared-absorbing gases, known as greenhouse gases, include carbon dioxide (CO_2), water vapor (H_2O) and ozone (O_3). Together they create what is known as the background greenhouse of the planet, adding roughly 60 degrees Fahrenheit to the mean surface temperature of the earth. These greenhouse gases keep the earth warm by trapping the sun's energy in the lower atmosphere and slowing its release back to space. Without greenhouse gases, the earth would not support life as we know it.

Human activities have been adding to the background greenhouse of the planet, leading to higher concentrations of existing greenhouse gases, as well as introducing new greenhouse gases to the atmosphere. The accumulation of these infrared-absorbing gases in the atmosphere act to increase the heat-trapping effect of the atmosphere – leading to more atmospheric absorption of heat and greater downward thermal emission of heat from the middle and lower troposphere (the atmospheric layer extending upward from the earth's surface about 5 miles) to the surface.

Climate, as it is experienced by people, results from, among other things, surface heating and the motions of the atmosphere. The motions of the atmosphere fall into fairly recognizable patterns that result principally from the geographical distribution of surface heating. The polar regions are cold, tropical latitudes are warm. Oceans are sometimes warmer than land masses, sometimes cooler. The earth's atmosphere acts like a giant heat engine, moving heat from areas of excess to areas of deficit, and in the process creating what people know as weather and climate.

Global warming is altering the geographical distribution of surface heating. If the underlying science is correct, this will result in a broad redistribution of climates across the surface of the earth in as little as 100 years. The Intergovernmental Panel on Climate Change (IPCC) in its latest assessment concluded that the average global surface temperature has already increased more than one degree F, although the increase is unevenly distributed. The IPCC reconstructions of climate data from the past 1000 years suggest that it is unlikely that this degree of warming

[15] Numerous sources exist for learning more about climate change science. Suggested sources include the Intergovernmental Panel on Climate Change (http://www.ipcc.ch/) and EPA's global warming website (http://www.epa.gov/globalwarming/).

was due to natural forces alone. The IPCC projects average global temperature to further increase 2.5 to about 11 degrees F from 1990 to 2100 based on a number of climate models. According to the IPCC, this projected warming is far in excess of the warming seen in the 20th century and is likely without precedent for at least the past 10,000 years based on paleoclimate records.

3.2 Principal Greenhouse Gases

Principal greenhouse gases that are emitted by or formed in the atmosphere as a result of human activities include:

- carbon dioxide (CO_2),
- methane (CH_4),
- nitrous oxide (N_2O),
- tropospheric ozone (O_3), and
- CFC-12 (in the family of chlorofluorocarbons -CFCs).

A partial listing of human-caused greenhouse gases of lesser significance includes: other CFCs, HCFC-22, HFC-134a, carbon tetrachloride (CCl_4), methyl chloroform (CH_3CCl_3), carbon tetrafluoride (CF_4), perfluoroethane (C_2F_6), and sulfur hexafluoride (SF_6). HCFC-22 is of a class of compounds known as hydrochlorofluorocarbons. HFC-134a is of a class of chemical compounds corporately known as hydrofluorocarbons. C_2F_6 and CF_4 are part of a class of compounds known as perfluorocarbons.

Greenhouse gases are emitted during a variety of activities from energy production to agriculture. Section 5.0 quantifies the sources and sinks of greenhouse gases in Minnesota. Table 3.1 lists the primary sources the various greenhouse gases and a description of each follows.

Table 3.1 Principal Human Sources of Greenhouse Gases
(Arrow direction indicates whether concentrations are increasing or decreasing)

Carbon Dioxide ↑
Fossil Fuel Production and Combustion
Deforestation
Limestone Consumption
Cement Manufacture

Methane ↑
Rice Cultivation
Enteric Fermentation in Livestock
Manure Management
MMSW Landfills
Coal Mining
Natural Gas Production and Transmission
Biomass Burning

Chlorofluorocarbons ↑↓-depending on CFC
Cooling and Refrigeration
Plastic Insulating Foams
Manufacture of Plastic Cushioning Foams
Solvent Uses

Ozone Precursors ↑
Fossil fuel combustion
Industrial Processes
Biomass Burning
Soils Nutrient Management

Nitrous Oxide ↑
Soil Nutrient Management
Manure Management
Biomass Burning
Coal Combustion

Perfluorocarbons ↑
Aluminum Manufacture
Semiconductor Manufacture

Hydrofluorocarbons ↑
Cooling and Refrigeration

Hydrochlorofluorocarbons↑
Cooling and Refrigeration
Solvent Use
Plastic Insulating Foams

Chlorocarbons ↓
Metal Cleaning

Sulfur Hexafluoride ↑
Electrical Equipment

Carbon Dioxide (CO_2)

The principal source of emitted CO_2 is fossil fuel combustion. Some emissions are cycled back into natural "sinks", such as the soil, growing forests, and the oceans. Thus, the clear-cutting of forests and the sustained cultivation of agricultural soils also can contribute to rising atmospheric CO_2 levels. The manufacture of cement using limestone also results in a measurable emission of CO_2 to the atmosphere.

Methane (CH_4)

Methane (CH_4) derives from the anaerobic decay of organic matter in oxygen-deprived reducing environments, and from a number of fossil fuel sources, including underground and surface coal mines, oil and natural gas production, and natural gas transmission and distribution. Anaerobic decay of organic matter leading to the production of CH_4 takes place in swamps, marshes, peat bogs, lake sediments, and, in the case of managed human systems, in mixed municipal solid waste landfills, the digestive tract of ruminant cattle, liquid manure storage ponds and pits, and rice paddies. Biomass burning also can produce CH_4.

Nitrous oxide (N_2O)

Nitrous oxide (N_2O) is produced principally in soils by bacteria. Available nitrogen for bacterial activities derives from the preexisting pool of organic nitrogen found in soils, which upon mineralization is made available to bacteria. Large amounts of available nitrogen also are added

to soils through the application of commercial fertilizers and livestock manure used as a soil amendment. Additional sources of added soil nitrogen include leguminous crops, crop residues, and atmospheric deposition.

Non-soil sources of N_2O emissions include biomass burning and coal combustion and emissions from stacked solid livestock manure.

Chlorofluorocarbons (CFCs)

Chlorofluorocarbons (CFCs) are synthetic compounds that do not exist in nature. They are emitted upon the intentional use and leakage or venting of the compounds. CFCs are greenhouse gases and also known stratospheric ozone depleters. Ozone depletion acts to cool the atmosphere whereas, acting as greenhouse gases, CFCs warm the atmosphere. On the whole, the net effect of CFCs favors warming.

As such, the production of CFCs in the U.S. was banned as of 1995 under the Vienna Convention and the Montreal Protocol. Small quantities continue to be emitted from pre-1995 stocks, particularly slow-release insulating foams. In the developing world, production and use of CFCs remains permissible.

Hydrochlorofluorocarbons (HCFCs)

Hydrochlorofluorocarbons (HCFCs) were developed in the 1970s and 1980s as substitutes for the CFCs in industrial, commercial and residential applications. While not as effective as the 'hard' CFCs (CFC-12, CFC-11, CFC-113) in depleting stratospheric ozone, an effect on stratospheric ozone levels has been identified. Under international agreements, the production and use of these compounds in developed economies is to be phased-out by 2030. As in the case of the CFCs, emissions result from intentional use and subsequent leakage or venting to the atmosphere. HCFCs are primarily used as cleaning solvents, insulating gases in plastic foams, and refrigerants. Within this class of compounds, the most important greenhouse gas is HCFC-22. Other HCFCs that may grow slightly in importance include HCFC-142b and HCFC-141b.

Hydrofluorocarbons (HFCs)

Hydrofluorocarbons are another class of substitutes for CFCs. At present, the most important of these is HFC-134a and HFC-152a, substitutes for CFC-12 with widespread applications in motor vehicle air conditioning, refrigeration and cooling, and other applications. Unlike the CFCs and HCFCs, in the atmosphere HFCs do not negatively impact stratospheric ozone. However, like the HCFC-22 and CFC-12, HFC-134a is a potent greenhouse gas.

Chlorocarbons

Carbon tetrachloride and methyl chloroform belong to a class of chemical compounds known as chlorocarbons. These compounds have had primarily industrial applications, notably in metal cleaning. Like the CFCs, they are potent ozone depleters, and like the CFCs, the production and use of these compounds was banned in developed economies under the terms of the Montreal Protocol on Substances that Deplete the Ozone Layer. Use in industrial applications continues in developing economies.

Perfluorocarbons (PFCs) and SF_6

C_2F_6, C_2F_{10}, and CF_4 belong to a class of synthesized compounds known as perfluorocarbons (PFCs). C_2F_6 and CF_4 are produced principally as byproducts of the refining of aluminum. C_2F_6 also has industrial applications in the etching of semiconductor chips. Sulfur hexafluoride (SF_6) is used in circuit breakers and during the manufacture of semiconductor and related electronics components. It is released to the atmosphere through inadvertent leakage or purposeful venting during the servicing of equipment.

Ozone Precursors (VOCs and NO_x)

Ozone (O_3) in the troposphere (the layer of atmosphere that extends upward about 5 miles from the earth's surface) is produced from the photochemical interaction of volatile organic compounds (VOCs) with nitrogen oxides (NO_x) – called ozone precursors. Sources of VOCs are varied. In Minnesota, most VOC emissions result from the combustion of petroleum-based fuels in internal combustion engines and industrial solvent use. Fugitive losses from gasoline service stations and residential wood combustion also contribute. In addition, carbon monoxide influences levels of ozone in that it acts to suppress the hydroxyl radical (OH) for both NO_x and ozone, leading to elevated levels.

Nitrogen oxides are produced during high temperature combustion of fossil fuels. The combustion of petroleum-based fuels in internal combustion is a large emitter of NO_x. Stationary source coal combustion is also a large emitter of NO_x. NO_x is also produced in soils by facultative soil bacteria following the input to soils of commercial fertilizer and other sources of nitrogen. Biomass burning also contributes to global NO_x emissions.

Water Vapor

Finally, water vapor, while naturally occurring like many of the compounds listed above, is temperature dependent. Its tropospheric concentration is largely a function of lower tropospheric and surface heating. In the stratosphere, water vapor is a very potent greenhouse gas. Water vapor accumulates in the stratosphere through the atmospheric build-up of methane and its oxidation at high altitudes. Jet aircraft are an additional source of stratospheric water vapor.

3.3 Residence Times and Global Warming Potential of Greenhouse Gases

Greenhouse gases persist in the atmosphere for between five years and thousands of years, depending on removal mechanisms for a particular gas. For a gas like CO_2, multiple removal mechanisms are involved, some acting rapidly, and some over periods of hundreds years. Human activities – mainly burning fossil fuels and removal of forests - have increased CO_2 concentrations about 30 percent, an unprecedented amount, since the beginning of the industrial age. The rate of increase of growing emissions has outpaced the balancing uptake ability of natural "sinks". Thus, increases in greenhouse gas emissions do not immediately translate into corresponding temperature and climate changes. Temperature and climate changes are a function of greenhouse gas concentrations, and occur much more slowly- on the order of decades- because of the inertia built into the climate system, e.g. the ability of oceans to warm and natural sinks to absorb CO_2. So, even if human greenhouse gas emissions were eliminated today, the earth would still continue warming for years before the trend was reversed.

Atmospheric residence times for some principal greenhouse gases are assembled in Table 3.2. For CO_2, this is an adjustment time, the amount of time for an atmospheric concentration to decline to about one-third of initial levels. It is dependent on an assumed long-term background concentration. At concentrations that are thought likely to prevail in the next century, this adjustment time is long, more than 500 years.

For N_2O, the estimated atmospheric lifetime is 114 years, and for CFC-12, about 100 years. CH_4 remains in the atmosphere for less time, 12 years, HFC-134a slightly more than that (13.8 years). SF_6 has an estimated atmospheric lifetime of 3,200 years, and CF_4 an estimated 50,000-year atmospheric lifetime.

Also shown in Table 3.2 are global warming potentials. The concept of global warming potential was developed to have a common measure for the comparison of the effect of different gases. This is a measure of the relative effect of an emission of any of the greenhouse gases, accounting for both the intensity of infrared absorption of each and their respective atmospheric lifetimes. Greenhouse gases differ in their absorption of infrared radiation. By accounting for the atmospheric lifetimes and infrared absorption characteristics of each of the greenhouse gases, it is possible to develop an index of relative effect of emissions.

The values given in Table 3.2 are referenced to equivalent emissions of CO_2. Thus, accounting for both radiative absorption and atmospheric lifetime, one ton of emitted methane is said to have roughly the same effect on surface temperature as 23 tons of CO_2. A one ton emission of N_2O would be equivalent to 296 tons of CO_2. For a compound like SF_6, the equivalent of one ton of emissions would be some 22,200 tons of CO_2. Other compounds fall intermediate between these two levels of equivalent CO_2-effect.

Table 3.2 Atmospheric Lifetimes and Global Warming Potentials of Principal Greenhouse Gases[16]

Chemical Compound	Current Atmospheric Lifetime (years)	Global Warming Potential (100 Year Time Horizon)
CO_2[a]	>500	1
CH_4	12	23
N_2O	114	296
CFC-11[b]	45	4,600
CFC-12[b]	100	10,600
CFC-113[b]	85	6,000
HCFC-22[b]	11.9	1,700
Carbon Tetrachloride	35	1,800
Methyl chloroform	4.8	140
HFC-134a	13.8	1,300
CF_4	50,000	5,700
C_2F_6	10,000	11,900
SF_6	3,200	22,200

[a] for an atmospheric concentration increase leading to ultimate stabilization at 650 ppmv
[b] direct radiative effects only

[16] Intergovernmental Panel on Climate Change, Third Assessment Report. Climate Change 2001: The Scientific Basis. Cambridge University Press. 2001.

4.0 Climate Change Impacts in Minnesota

Stratus Consultants prepared this summary of climate impacts in Minnesota for the MPCA. This summary is based on what the published science tells us today and touches on these areas: water resources, ecosystems, and recreation.

4.1 Introduction

Humanity is facing an unprecedented environmental problem in the 21st century: because of human activities, humans may be changing the very climate they have come to depend on. Energy from the sun heats the earth's surface and the earth's surface radiates energy back into space. Atmospheric greenhouse gases (water vapor, carbon dioxide, and other gases) trap some of the outgoing energy and retain some of this radiated energy. This phenomenon, known as the greenhouse effect, has kept the earth's average temperature at approximately 60°F. Without the greenhouse effect, the earth's average temperature would be about 0°F, making life virtually impossible. However, the climate system can become unbalanced when the atmospheric concentration of greenhouse gases increases and additional energy is retained.

Over the last century, atmospheric concentrations of carbon dioxide have increased nearly 30 percent, methane concentrations have more than doubled, and nitrous oxide concentrations have risen by about 15 percent. These increases have resulted mainly from increased burning of fossil fuels, and have enhanced the heat-trapping capability of the earth's atmosphere.[17]

Average surface air temperatures across the earth increased by 1°F in the 20th century and are projected to increase by 2 to 10°F in the 21st century. The Intergovernmental Panel on Climate Change (IPCC) concluded that most of the global warming over the last 50 years is attributable to human activities that have altered the chemical composition of the atmosphere through the buildup of greenhouse gases[18]. Their findings, however, only apply to global changes; they did not draw conclusions about specific regions. While regional climate changes may result from changes in greenhouse gas concentrations, they may also result from natural climate variability. While efforts to reduce greenhouse gas emissions may slow further warming, they will not eliminate it[19]. The areas that are likely to see the greatest change in average climate conditions are high latitude areas. In addition, midcontinental areas are more likely to experience summer drought than areas closer to the oceans. Thus, in the United States, outside of Alaska, the upper Midwest is likely to see some of the greatest changes in climate.

This sector briefly addresses the current climate and economic conditions in Minnesota, how the state's ecological systems and economy have been affected by climate change in the 20th century, and how they may be affected by future climate change. The discussion of projected changes covers potential impacts on three critical sectors: water resources, ecosystems and biodiversity, and recreation and tourism. Other sectors will also be affected, some

[17] U.S. EPA. 2002c. Global Warming – Climate. http://yosemite.epa.gov/oar/globalwarming.nsf/content/climate.html. Accessed October 21, 2002.

[18] Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, D. Xiaosu, and K. Maskell (eds.). 2001. *Climate Change 2001: The Scientific Basis*. Cambridge University Press, New York.

[19] Hansen, J. (and 27 co-authors). 2002. "Climate Forcings in GISS SI2000 Simulations." *Journal of Geophysical Research — Atmospheres* 107:4347-4384.

positively, some negatively. For example, agriculture in Minnesota would probably expand because a warmer climate will increase Minnesota farmers' competitive advantage over lower latitude farmers. On the other hand, with warmer temperatures, new pests and diseases could migrate into the state and expanded agriculture can result in additional nonpoint source runoff and other environmental concerns. This section also briefly considers adaptation options to impacts on the three sectors, identifying win-win approaches, and discusses costs of action and inaction in terms of economic impact and irreversibility.

4.2 Current Conditions

Minnesota's climate is characterized by cold winter temperatures, mild to cool summer temperatures, and moderate rainfall. The statewide average temperature, based on data from 1971 to 2000, is 7.9°F in January and 69.1°F in July; average annual temperature is 41.2°F, with a standard deviation of 1.91°F. The average annual precipitation is 27.4 inches, with a standard deviation of 3.74 inches.[20]

The state can be divided into three primary ecological regions: the prairie parkland in the southeastern corner of the state, Laurentian mixed forests in the northeastern portion of the state, and eastern broadleaf forests dividing the two (see Figure 4.1). Northern parts of Minnesota also fall within the southern edge of the boreal forest range.[21]

Figure 4.1 Minnesota ecological systems in 2000.

Source: Used with permission of Minnesota DNR.

The change between prairie in the southwest and forest in the northeast is primarily the result of increasing rainfall amounts caused by proximity to moist air masses coming from the Gulf of Mexico. Southeastern Minnesota, because it is closer to the Gulf of Mexico, receives 32 inches of precipitation a year, on average. Northwestern Minnesota, however, only receives 19 inches per year.[22]

Seasonal variation in precipitation results from different air flow patterns that bring either dry, cold polar air masses from the north or warmer, moist air masses from the Gulf of Mexico. Almost 66 percent of Minnesota's annual precipitation falls during the summer growing season (May-September), when the moist, tropical air mass is present. Only eight percent of annual rainfall falls during the winter months (December-February).[23]

Despite generally wet summers and drier winters, it is not unusual for Minnesota's climate to differ from these averages. For instance, droughts tend to occur in the summer when high evapotranspiration rates, brought on by high temperatures, are accompanied by low rainfall. The

[20] NCDC. 2002. National Climatic Data Center. Minnesota Climate Summary. http://lwf.ncdc.noaa.gov/oa/climate/research/cag3/MN.html. Accessed September 10, 2002.
[21] Minnesota Department of Natural Resources (DNR). 2002b. "Ecological Classification System." http://www.dnr.state.mn.us/ecological_services/ecs/index.html. Accessed October 10, 2002.
[22] Minnesota Department of Natural Resources (DNR). 2002a. "Climate's Impact on Water Availability." http://www.dnr.state.mn.us/climate/water_availability.html. Accessed October 14, 2002.
[23] Ibid.

northwestern and western portions of the state, which are farther away from the moist Gulf air masses, are particularly susceptible to drought. When deep snowpack, frozen ground, rapidly warming temperatures, and heavy early spring precipitation combine, floods occur in late winter and early spring.[24]

The predominant land use in Minnesota is cultivated land (42 percent), followed by forested land (26.7 percent), wetlands (10.9 percent), and grassland (9.2 percent). Urban and rural developed land only comprise 2.7 percent of Minnesota's land use.[25] The difference in rainfall amounts across the state corresponds with primarily agricultural use in the south and primarily forestry in the north.

Minnesota's gross state product in 2000 was $184.7 billion, and is dominated by the service industry (22 percent), closely followed by finance, insurance, and real estate (19 percent), and manufacturing (18 percent). Figure 4.2 shows the percentage of gross state product by sector. Agriculture comprises a small but important portion of the economy: farms alone generated $2.5 billion in revenue in 2000, and associated agricultural services generated $864 million.[26] Approximately five percent of all farm acres in the United States are in Minnesota. The primary crops in Minnesota are corn, soy, and wheat, and roughly two percent of these crops are irrigated.[27]

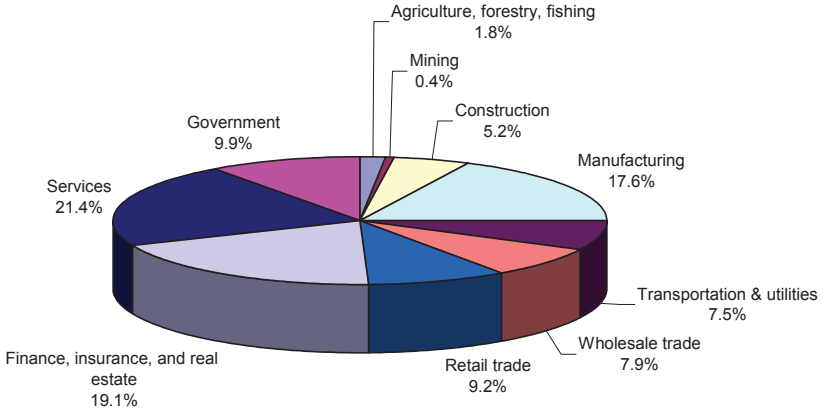


Figure 4.2. Minnesota gross state product in 2000.

Source: BEA, 2002.

[24] Minnesota Department of Natural Resources (DNR). 2002a. "Climate's Impact on Water Availability." http://www.dnr.state.mn.us/climate/water_availability.html. Accessed October 14, 2002.

[25] Minnesota Land Management Information Center. 1999. "Minnesota Land Use and Cover: 1990s Census of the Land." http://mapserver.lmic.state.mn.us/landuse/. Accessed October 14, 2002.

[26] BEA. 2002. Gross State Product Data. Bureau of Economic Analysis. http://www.bea.doc.gov/bea/regional/gsp. Accessed September 10, 2002.

[27] U.S. EPA. 2002b. Great Lakes 5-Year Strategy. http://www.epa.gov/glnpo/plans/5yrstrat.html. Accessed September 10, 2002.

Tourism comprises a relatively small but vital part of Minnesota's economy. In 2000, tourism and travel generated $9 billion in gross receipts and $1 billion in state and local tax revenue.[28] Outdoor activities, including hunting, fishing, and visiting state and national parks, were the primary purpose for 40.3 percent of visitor trips in 1999. The number of outdoor-related trips declined between 1998 and 1999, potentially due to mild winter conditions.[29] Fishing, hunting, and wildlife viewing generated $2.553 million, $477,000, and $524,000 in expenditures, respectively — a total of $3.6 million. Recreational expenditures account for about two percent of Gross State Product for Minnesota.

Fishing, hunting, and other outdoor recreation are very popular activities for Minnesotans, and are important components of the state's culture. According to U.S. Fish and Wildlife Services, 36 percent of Minnesota residents fish, compared with 16 percent nationally.[30] Overall, Minnesota attracted 1.62 million anglers and 597,000 hunters in 2001, including residents and nonresidents. In addition, 1.93 million people participated in wildlife viewing around the home and 634,000 participates in wildlife viewing away from home.

4.3 Observed Changes

Minnesota has already experienced some changes in climate over the last century, including increased average temperature, increased precipitation amounts, increased flooding severity, and shorter winters. Although these changes are consistent with changes in global climate, they are not necessarily a result of increased greenhouse gas concentrations and may reflect regional climate variability. However, they do indicate the kinds of changes that may occur in the future.

Figure 4.3 depicts the change in average annual temperature and average winter temperature (December – February) over the last century. The equation for a trendline fitted to these data points reveals that average winter temperatures are increasing more than twice as fast as average annual temperatures: winter temperatures are rising at 2.3°F per 100 years while annual temperatures are increasing at 1°F per 100 years.[31]

The impacts of these warmer temperatures are already noticeable. According to the U.S. National Assessment (NAST, 2000), the length of the snow season in the Great Lakes region has decreased by roughly 6 days over the last 50 years. Anecdotal evidence points to species shifts that are already occurring, potentially in response to these observed climate changes. For example, opossums and true katydids are now spotted in Minnesota. Cardinals have moved into northern cities such as Duluth.[32] Warmer weather also causes migratory birds to stay longer in their summertime range: in the 2000 Christmas Bird Count, Duluth logged a record 74 species.[33]

---

[28] Minnesota Department of Trade and Economic Development. 2002. "Department of Trade and Economic Development Home Page." Accessed October 14, 2002.

[29] Ibid.

[30] U.S. Fish and Wildlife Service. 2002. 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation State Overview. U.S. Fish and Wildlife Service, Washington, DC.

[31] NCDC. 2002, op cit.

[32] Minnesota Department of Natural Resources (DNR). 2001. "The Crossroads of Climate Change." http://www.dnr.state.mn.us/volunteer/articles/warming.html. Accessed October 17, 2002.

[33] Audubon Science. 2002. Christmas Bird Count. http://www.audubon.org/bird/cbc/. Accessed October 18, 2002.

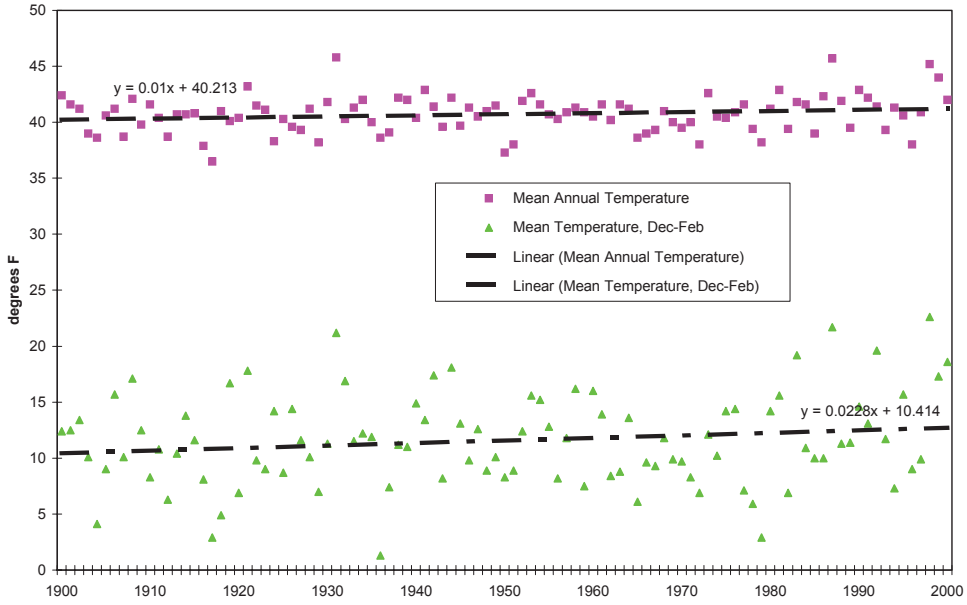
Figure 4.3 also shows that total annual precipitation has increased over the last 100 years. Total annual precipitation has increased from 26.5 inches (1941-1970 average) to 27.4 inches (1971-2001 average).[34] The equation for the trendline fitted to the precipitation data shows that annual precipitation is increasing at a rate of 2.9 inches per 100 years. As a percentage increase, this is consistent with the increase in national average precipitation of approximately 10 percent.[35]

Olsen et al.[36] examined trends in flood volumes over time in the Upper Mississippi and Lower Missouri River basins, based on gauge records. They found that gauges on the St. Croix, Minnesota, and Upper Mississippi rivers all showed statistically significant increases in flood flows over time. They hypothesized that a combination of increased precipitation, land use changes, and river channel modifications may be affecting peak flows. They also noted that this trend may correspond with changes in the timing of precipitation events: earlier snowmelt and major rainfall events may be occurring while the ground is still frozen, thereby decreasing the moisture absorbed by soils, increasing surface runoff and the volume of water in river channels.

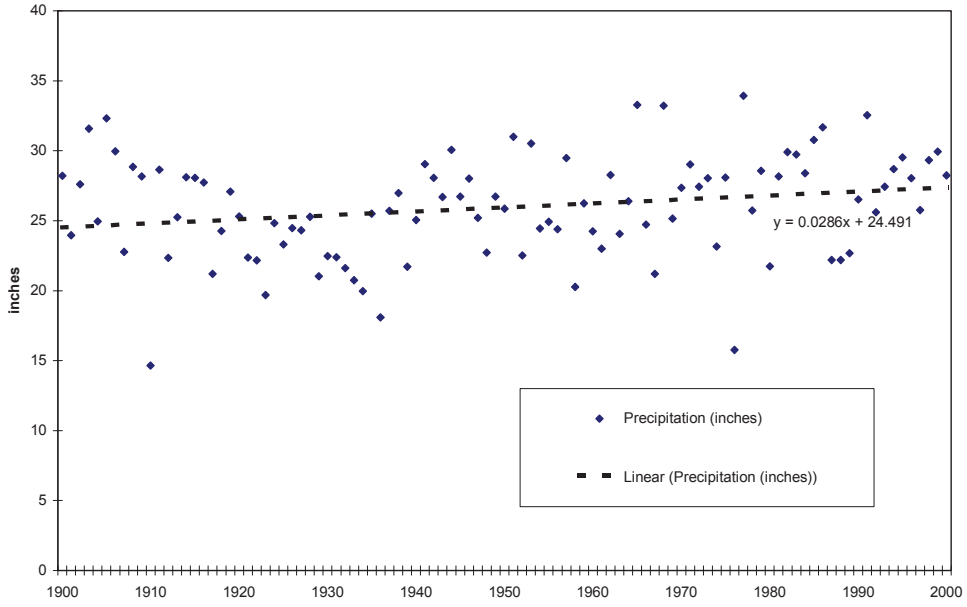
[34] NCDC. 2002, op cit.

[35] Karl, T.R., R.W. Knight, D.R. Easterling, and R.Q. Quayle. 1996. "Indices of Climate Change for the United States." *Bulletin of the American Meteorological Society* 77:279-292.

[36] Olsen, J.F., J.R. Stedinger, N.C. Matalas, and E.Z. Stakhiv. 1999. "Climate Variability and Flood Frequency Estimation for the Upper Mississippi and Lower Missouri Rivers." *Journal of the American Water Resources Association* 35:1509-1523.



(a)



(b)

Figure 4.3. (a) Temperature and (b) precipitation trends for Minnesota, 1900-2000.

Source: NCDC, 2002.

The economic impact of floods in Minnesota has also been increasing in recent years. Figure 4.4 shows annual flood damages, in 1995 dollars, from 1955 to 2000. There were five major flooding events (over $100 million in damages) between 1965 and 1980, with average damages

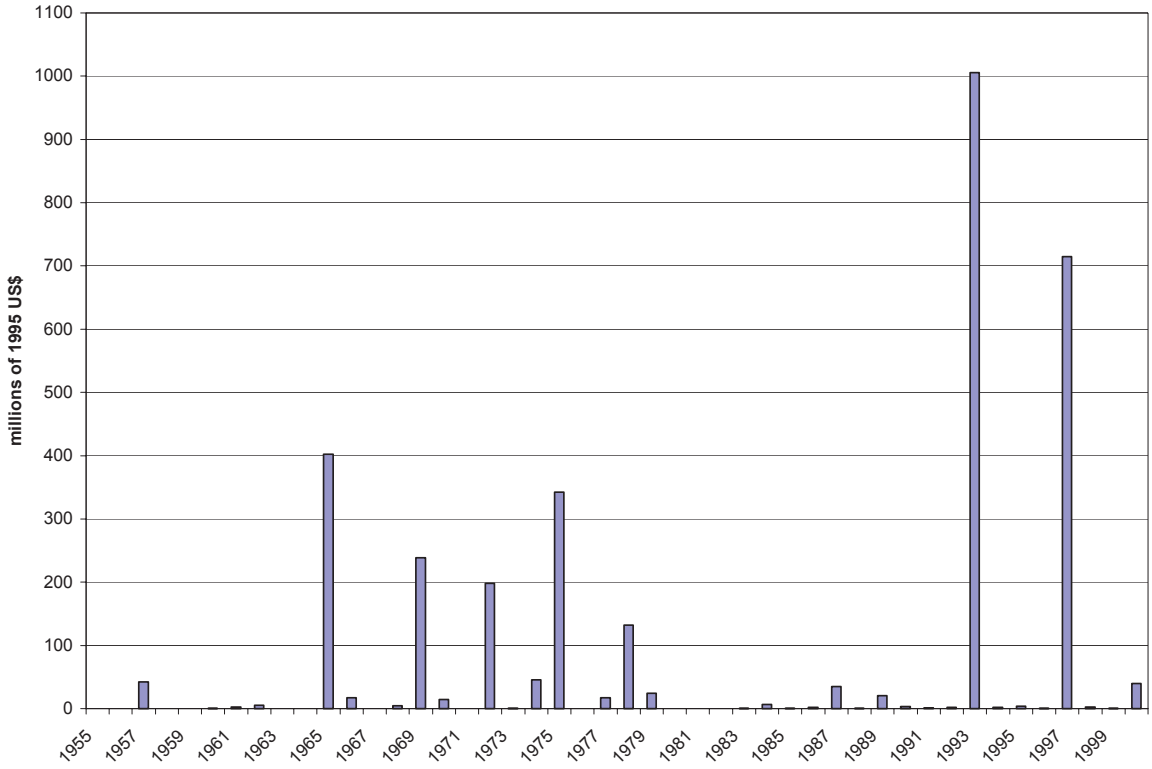


Figure 4.4. Annual flood damages in Minnesota, 1955-2000, in millions of 1995 US$.

Source: UCAR, 2002.

of $263 million. Since 1990 there have only been two major flooding events, but the average damages from these two events was $860 million.[37] These numbers may also include other socioeconomic factors, such as increases in property covered by insurance and insurance claim amounts, and changes in development patterns (more urbanization causes more runoff), but it does suggest a trend toward more costly floods.

Flooding can also affect human health. Not only do they directly threaten health, but they also degrade water quality. The floods of 1993, for example, washed animal waste from agricultural operations into surface water near Milwaukee's treatment water inflow on Lake Michigan. A combination of engineering problems and overwhelmed treatment plants due to major flooding resulted in an outbreak of *Cryptosporidiosis* that infected 400,000 people and resulted in 100 deaths.[38] Flooding also affects human health when basements and homes are inundated and

[37] UCAR. 2002. Flood Damage in the United States. States Data Set. http://www.flooddamagedata.org/. Accessed October 16, 2002.

[38] NAST. 2000. *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change Foundation and Overview*. National Assessment Synthesis Team, U.S. Global Change Research Program, Washington DC.

mold grows within the homes. Major mold growth can cause serious respiratory and allergic reactions if left untreated.[39]

The flood of 1997 illustrates the disastrous impacts floods can have on the state, as well as the conditions that precede major flooding events. The spring floods in 1997 were brought on by unusually high precipitation, combined with springtime temperature fluctuations, that exacerbated the saturated soils. Conditions leading to the flood began in fall of 1996, when the amount of precipitation that fell in October and November was in the 95th percentile for most of Minnesota, thereby saturating the soil before it froze. Over the winter, many of the affected areas had two to three times the normal snowfall amounts; most parts of the Minnesota and Red River basins had over 6 feet of snow. This heavy snowfall was compounded by few warm mid- and late-winter days, so the snowpack melted very little during the winter and was exceptionally deep. April brought unusually warm days (10 degrees above normal) the first week, followed by exceptionally cold days (20 degrees below normal) the following week. Thus when heavy precipitation fell at the end of the first warm week, it was compounding the high runoff from snowmelt and soils thawing. The freezing that followed prevented water from being absorbed into soils, thus creating the conditions for massive flooding.[40] These floods affected the Upper Minnesota and Red rivers, and 58 of Minnesota's 87 counties were declared federal disaster areas. The economic damage to public infrastructure alone approached $300 million,[41] and overall damages totaled over $700 million.[42]

4.4 Predicted Changes

The projections of changes in temperatures and precipitation in this section are based on two general circulation models (GCMs) that simulate global climate: the Hadley and the Canadian models. These are the same GCMs used in the U.S. National Assessment. Because these models are created to model large-scale climate changes, regional detail is sacrificed and these interpolations of global results should be treated with caution.

Based on a visual inspection of maps showing GCM results, the Hadley climate model shows temperatures increasing 5-10°F in Minnesota in the 21st century, and the Canadian model shows temperatures increasing 7-12°F.[43] The Hadley model also shows an increase in the number of extremely hot summer days.[44] Mean daily temperature is projected to rise more rapidly than maximum daily temperature,[45] suggesting higher minimum daily temperatures.

---

[39] Federal Emergency Management Agency. 2002. "Mold Can Damage Home and Health." http://www.fema.gov/diz02/d1419n40.shtm. Accessed October 18, 2002.

[40] Minnesota Department of Natural Resources (DNR). 2002c. "1997 Record Spring Floods." http://www.dnr.state.mn.us/climate/floods/1997/index.html. Accessed October 17, 2002.

[41] Ibid.

[42] UCAR. 2002. Flood Damage in the United States. States Data Set. http://www.flooddamagedata.org/. Accessed October 16, 2002.

[43] NAST. 2000, op cit.

[44] U.S. EPA. 1997. EPA Global Warming: State Impacts – Minnesota. http://www.epa.gov/globalwarming/impacts/stateimp/minnesota/index.html. Accessed September 10, 2002.

[45] Ibid.

According to both the Hadley and Canadian climate models, precipitation is projected to increase by 20-40 percent by 2100 in the upper Midwest. However, the Canadian model estimates a reduction in precipitation over northern Minnesota.[46] The Hadley model predicts an increase in the amount of precipitation on extremely wet summer days as well.[47] Both models predict that much of the increased precipitation will fall on days already receiving the heaviest rainfall.[48] Even though these climate models estimate that precipitation will increase in Minnesota, the possibility cannot be ruled out that it could decrease or that there could be dry periods amidst a general trend toward increased precipitation.

Changes in temperature and precipitation also affect soil moisture. In the Hadley model, the drying effects of the increases in temperature are outweighed by the effects of the increases in precipitation, thus creating small increases in soil moisture by 2100. The Canadian model, however, predicts decreased summer precipitation and a greater temperature increase, and therefore decreased soil moisture. Under the Canadian model, drought frequency and severity increase by 2100, but they decrease slightly under the Hadley model.[49]

In addition to absolute changes in temperature, both models predict changes in temperature variability, including less interannual variability of annual mean temperatures and more extreme high temperatures.[50]

4.5 Sectoral Impacts and Adaptation Options

These estimated changes in temperature and precipitation are likely to affect many aspects of Minnesota's ecology and economy, including human health, air and water quality, biodiversity, recreation and tourism, species migration, and vegetation shifts. Some of these sectors deserve further exploration because of their potential economic importance, irreversibility, risks, or importance to quality of life. For these reasons, this section explores water resources, terrestrial and aquatic ecological changes, and recreation in depth.

In light of potential impacts on these sectors, steps can be taken to reduce the adverse effects on natural and human systems. These may not reverse or offset all of the adverse effects, but they can reduce their severity.

Identifying and implementing adaptation options, however, should be done with care. Decision-makers need to find a balance between three key criteria: the uncertainty of future impacts, the potential level of risk associated with these impacts, and whether the adaptation option would still be beneficial or benign to human or natural systems if the impact does not occur as predicted. The first set of adaptation options to consider are those that are win-win: these are justified under current climate and make the system less vulnerable to potential impacts of climate change. It is also important to keep in mind that many human systems are highly adaptable, whereas natural ecosystems have much more limited capacity to adapt. Finally, a

[46] NAST. 2000. op cit.

[47] U.S. EPA. 2002b. Great Lakes 5-Year Strategy. http://www.epa.gov/glnpo/plans/5yrstrat.html. Accessed September 10, 2002.

[48] NAST. 2000, op cit.

[49] Ibid.

[50] Ibid.

discussion of potential economic impacts and irreversibilities may help elucidate which sectors and options to focus on. This section identifies win-win adaptation options, followed by a brief discussion of the economic impacts and irreversibility of climate change impacts on each sector.

4.5.1 Water Resources

Climate change will likely have a substantial impact on Minnesota's water quality, hydrologic cycle, and floods and droughts. This in turn will have significant effects on ecological systems and societal activities such as agriculture, recreation, and shipping. Maintaining the quality and quantity of water resources is imperative to human and ecosystem health, and is of cultural and aesthetic importance to Minnesotans.

Water quality in Minnesota lakes may be diminished by the combined effects of increased precipitation and temperatures. Warmer summers and longer ice-free seasons would decrease the amount of dissolved oxygen in water and increase algae growth and eutrophication. It would also reduce favorable habitat for trout, whitefish, and other cold water species. For example, a 4.5°F increase in water temperature would reduce habitat for these species one-quarter to one-third, nationwide.[51] This suggests that cold water fish populations in Minnesota would decrease by a similar amount. Warmer waters would decrease the rate of overturning in lakes, thereby decreasing the amount of dissolved oxygen available for fish in deepwater habitats.[52]

Research is inconclusive on how levels of Lake Superior will change. In the Canadian climate model, increased precipitation is offset by increased evapotranspiration resulting from higher summer temperatures. One recent study found that this increased evapotranspiration rate could lower Lake Superior levels by 0.3 meters to 0.9 meters.[53] Using the Hadley climate model, which estimates smaller temperature increases and smaller increases in evapotranspiration rates, the study estimated there would be up to a one-foot increase in lake levels.[54] However, another study using results from 10 GCMs consistently estimated a decrease in inflows to the Great Lakes due to high evapotranspiration rates, resulting in lowered lake levels.[55] Lower lake levels would lead to increasing shoreline exposure to erosion, lower inputs to hydroelectric power facilities, increased concentration of pollutants, and more dredging required for ship channels or reduced loads that could be carried on each ship.[56]

Although water levels may decrease, the frequency and magnitude of heavy precipitation events is likely to increase, thereby increasing the likelihood of flooding. Given the potential increases in precipitation mentioned above, flood levels and events could increase substantially. Although the literature identifies increased flooding as a possibility, little analysis has been done to estimate the degree to which flood intensity or frequency would increase. Currently most floods

[51] U.S. EPA. 2002a. EPA Global Warming Case Studies: Great Lakes and Upper Midwest. http://www.epa.gov/globalwarming/impacts/water/cs_gluml.html#gmlr. Accessed Sept. 10, 2002.

[52] Ibid.

[53] Chao, P. 1999. "Great Lakes Water Resources: Climate Change Impact Analysis with Transient GCM Scenarios." *Journal of the American Water Resources Association* 35:1499-1507.

[54] Quinn, F.H., B.M. Lofgren, A.H. Clites. R.A. Assel, A. Eberhardt, and T. Hunter. 1999. Great Lakes Water Resources Sector Report. Great Lakes Environmental Research Laboratory, Ann Arbor, MI, as sited in NAST, 2000.

[55] Chao, P. 1999, op cit.

[56] U.S. EPA. 2002a, op cit.

in Minnesota result from snowmelt, but changes in timing and quantities of winter precipitation, as well as the rate and timing of spring thaws, could dramatically change flooding patterns in the state.[57] Increased flooding could also increase agricultural runoff and storm sewer overflows, thereby compromising surface water quality.

With increasing temperatures, ice cover on Lake Superior is expected to decrease by approximately one to two months by 2100. Ice cover on smaller lakes is expected to last half of its normal season. A shorter ice-free season would alter the timing of peak spring stream flow, thereby affecting habitats. It could also have feedback effects on lake-effect snowfall events. However, it could extend the shipping season by one to two months, thereby potentially offsetting the deleterious effects of lowered lake levels during summer months (i.e., the reduced cargo each ship could carry).[58]

Adaptation options for maintaining water quality include increasing the ease of shifting water between consumers, using pricing and market methods to improve water use efficiency, including changes in supply and demand in long-term allocation and infrastructure planning, creating incentives to move residents out of floodplains, and focusing on sustainable management of existing ground- and surface water supplies.[59] With the exception of incorporating climate change into long-term planning, these options are ones that make sense without considering climate change. However, considering the potential effects of climate change increases the benefits of these adaptation options.

There is no published information on the costs of these adaptation options. Options that involve changes to infrastructure can involve substantial costs, unless the infrastructure is modified while new projects or reconstruction is being done anyway. Administrative changes such as pricing methods may not have high financial costs (unless infrastructure such as meters needs to be installed), but can be politically difficult to implement.

4.5.2 Ecosystems

Minnesota's terrestrial and aquatic ecosystems are likely to experience significant changes because of temperature and precipitation changes. The fundamental stress imposed by climate change is that many plants and animals will no longer be in climates they are best adapted for. The warmer climate may exceed thermal tolerances of many species, result in insufficiently cold temperatures for some species, or enable predators or competitors migrating into habitats of many species. Species affected this way will need to migrate to new locations, which will mean changes in the composition and productivity of ecosystems. Existing stresses such as habitat fragmentation, eutrophication, acid precipitation, and invasion by exotic species are likely to make these species even more vulnerable to climate change. It is likely that many species would no longer exist in parts of the state they now inhabit or in the entire state. These results are likely to be irreversible.

[57] Olsen, J.F., J.R. Stedinger, N.C. Matalas, and E.Z. Stakhiv. 1999. "Climate Variability and Flood Frequency Estimation for the Upper Mississippi and Lower Missouri Rivers." *Journal of the American Water Resources Association* 35:1509-1523.
[58] NAST. 2000, op cit.
[59] NAST. 2000, op cit.

Minnesota's forests, for example, are made up of hardwood deciduous forests to the south and coniferous forests to the north. The current combination of soil type and climate conditions makes northern Minnesota ideal for conifer growth. Changes in climate are likely to affect these growing conditions, leading to a decline in coniferous forests. In Voyageurs National Park, for instance, by 2010 to 2040, the climate suitable for the boreal forests that characterize this far northern landscape could have changed.[60] Vegetation models forecast a major poleward shift of boreal forests, with a 25 percent net reduction in boreal forest area globally. The southernmost edges of the boreal forest are likely to see the most rapid migration rate.[61] Disruptions in boreal forests may also mean losing species such as moose, pine marten, and fisher that are specific to that ecosystem.[62] Although it is likely that temperate deciduous forests would expand northward, it is also possible that a combination of current stresses, the relatively rapid rate of climate changes, and impediments to species migration (e.g., human settlements and agricultural land) could cause a decline in both coniferous and deciduous species.[63] Figure 4.5 shows results from two climate scenarios run through the Mapped Atmosphere Plant Soil System (MAPSS) model,[64] which estimate that boreal (conifer) forests will no longer be in Minnesota, while grasslands will expand farther north into Minnesota, and temperate deciduous forests and savanna woodlands will expand northward and southwesterly.

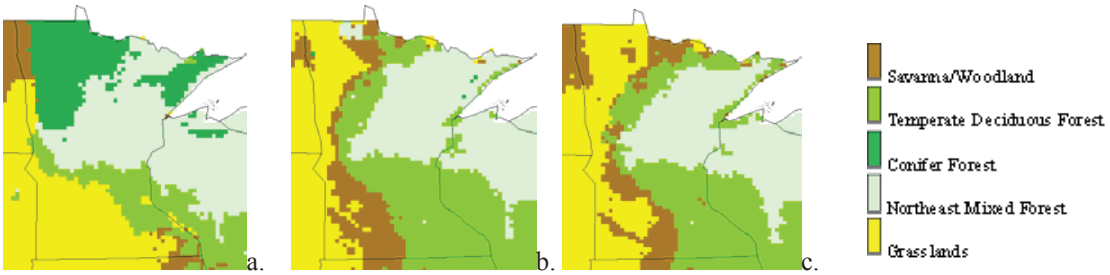


Figure 4.5. MAPSS-simulated vegetation distribution for 2061-2099 under current a) climate conditions, b) HADCM2SUL (Hadley CM2 with sulfates), and c) CGCM1 (Canadian) at 10-km resolution.

Source: Figure provided by R. Neilson, U.S. Forest Service, October 23, 2002.

Figure 4.6 shows how leaf area index (LAI) may change by the end of the next century. LAI measures the density of leaf coverage with higher LAI indicating greater leaf coverage. In Figure 4.6, green means increasing LAI and brown means decreasing LAI. As these maps show, most of Minnesota is estimated to have decreased LAI ranging anywhere from one percent to 75 percent. The northern and northwest portions of the state are most likely to have reduce LAI, while the southwestern and southeastern parts of the state are likely to have increased LAI.

[60] U.S. EPA. 2002a, op cit.

[61] Intergovernmental Panel on Climate Change. 1997. *The Regional Impacts of Climate Change: An Assessment of Vulnerability.* Cambridge University Press, Cambridge, UK.

[62] Minnesota Department of Natural Resources (DNR). 2001, op cit.

[63] NAST. 2000, op cit.

[64] Personal communication by Stratus personnel with R. Neilson, U.S. Forest Service, October 23, 2002.

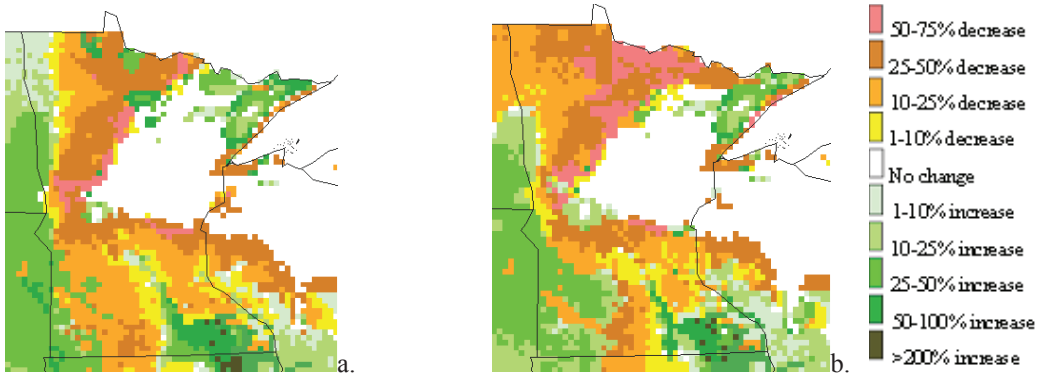


Figure 4.6. MAPSS-simulated percentage changes in LAI for a) HADGCM2SUL and b) CGCM1 at 10 km resolution.

Source: Figure provided by R. Neilson, U.S. Forest Service, October 23, 2002.

Bachelet et al.[65] modeled the change in biomass consumed by fire under the Hadley and Canadian models. The Hadley model, with higher potential for excessive wet periods, forecasts a decrease in biomass consumed by fire. Overall the Canadian model results show smaller decreases in biomass consumed and small increases in the northwestern portion of the state, where precipitation may decrease. Overall, results from these models show biomass consumed by fire in Minnesota decreasing by 2100.

Wildlife populations are particularly vulnerable to climate change. Changes in temperature and precipitation patterns affect both food and habitat availability, leading to lower reproduction rates and population sizes.[66] Birds, which are likely to migrate most easily to more suitable habitat, may be some of the first species to disappear from Minnesota. Thirty-six species of birds, including dark-eyed juncos, evening grosbeaks, white-throated sparrows, black-headed vireo, and the mourning warbler, may no longer be found in Minnesota.[67]

The prairie potholes in Minnesota, for example, are the most important North American breeding area for mallards, pintails, and blue-winged teals. These shallow wetlands are highly vulnerable to drought, which would compromise water quality and food availability. If precipitation remains constant or is lacking during critical seasons, the size and number of these potholes are expected to diminish because of higher temperatures and increased evaporation, thereby affecting the primary reproductive habitat for many species. Poiani and Johnson[68] simulated the potential effects of climate change on the hydrology and vegetation of semipermanent wetlands

[65] Bachelet, D., R.P. Neilson, J.M. Lenihan, and R.J. Drapek. 2001. "Climate Change Effects on Vegetation Distribution and Carbon Budget in the U.S." *Ecosystems* 4:164-185.

[66] NAST. 2000, op cit.

[67] Price, J. 2002. "Global Warming and Songbirds: Minnesota." American Bird Conservancy and the National Wildlife Federation. http://www.nwf.org/climate/PDFS/minnesota.pdf. Accessed October 18, 2002.

[68] Poiani, K. and W.C. Johnson. 1993. "Potential Effects of Climate Change on a Semi-Permanent Prairie Wetland." *Climatic Change* 24:213-232.

such as potholes across a range of sensitivity simulations (+3.6 and +7.2°F temperature changes, -20, -10, 0, +10, +20 percent precipitation changes). For 9 of the 10 sensitivity simulations, they found that maximum water depth decreased significantly and surface vegetation increased significantly, decreasing open-water area. They concluded that these changes could significantly affect habitat quality for breeding waterfowl. The number of ponds containing water in the spring in the north-central United States could drop from 1.3 million to 0.6-0.8 million, assuming +2.7°F to +4.5°F temperature increases by 2060, with no change in precipitation. This could, in turn, reduce the number of breeding ducks in the area from 5 million to 2.1-2.7 million.[69]

As a result of lower water levels, diminished water quality, and changes in water temperature, aquatic species could be severely impacted as well. Thermal habitat for cold water fish could be eliminated in lakes less than 40 feet deep, whereas warm and cool water fishes would have increased habitat.[70] Brown trout could subsequently lose much of their habitat.[71]. Changes in water quality could also decrease the amount of suitable habitat for crayfish and snails, and drought could decrease the supplies of silica in groundwater, which is essential for diatoms.[72]

Wetland ecosystems are quite likely to be affected by changes in the annual precipitation and temperature cycle. Lower water levels caused by evapotranspiration rates exceeding precipitation increases could affect system recharge and ecosystem services the wetland provides, such as waterfowl habitat, fish breeding areas, and water filtration. If uneven topography prevents migration, many wetlands could be diminished or be lost. Current stresses such as land development could exacerbate these stresses.[73] Lower lake levels could also reduce the number and size of lakeside wetland areas.[74]

One study conducted on bog and fen communities found significant changes resulting from climate changes.[75] Altered resource dynamics, trophic structures, and disturbance regimes would significantly affect plant community composition and productivity. Because species diversity tends to be much lower at northern latitudes than at lower latitudes, these communities are already more vulnerable to slight changes in species composition, which could have dramatic ecosystem-level effects.

Adaptation options for ecosystems generally focus on minimizing existing stresses by improving or maintaining habitat and creating more effective management strategies. The flora and fauna of terrestrial ecosystems face substantial impacts from climate change on top of pressures already exerted by habitat fragmentation and invasive species. Creating or maintaining undeveloped migration corridors would allow wildlife and plants to migrate should their existing

[69] Sorenson, L.G., R. Goldberg, T.L. Root, and M.G. Anderson 1998. "Potential Effects of Global Warming on Waterfowl Populations Breeding in the Northern Great Plains." *Climatic Change* 40:343-369.

[70] NAST. 2000, op cit.

[71] U.S. EPA. 1997, op cit.

[72] U.S. EPA. 2002a, op cit.

[73] NAST. 2000, op cit.

[74] Mortsch, L.D. 1998. "Assessing the Impact of Climate Change on the Great Lakes Shoreline Wetlands." *Climatic Change* 40:391-416.

[75] Weltzin, J.F., et al. 2000. "Response of Bog and Fen Plant Communities to Warming and Water Table Manipulations." *Ecology* 81:3464-3478.

habitat become unsuitable. This may be particularly important for species with limited geographic ranges. However, the effectiveness of migration corridors in enabling species to migrate is not clear. Improved understanding of ecosystem functions and their resident species would allow for more effective management. To be sure, given the slow rates of migration of some terrestrial species and the natural and human barriers to migration, the potential for adaptation to substantially reduce adverse effects of climate change on ecosystems appears to be quite limited.

Another set of options focuses on improving the health of ecosystems and restoring watersheds that have been damaged by development and pollution. An example of these kinds of options is the Great Lakes Five Year Strategy,[76] a plan developed jointly between EPA, fishery management agencies of states bordering the Great Lakes, and other federal agencies. The plan is intended to improve environmental protection and resource management of the Great Lakes by reducing toxic substances, protecting and restoring important habitats, and protecting human and ecosystem health by restoring and maintaining natural populations of aquatic and terrestrial organisms. Therefore, this plan will improve current conditions as well as make the Great Lakes ecosystem less vulnerable to climate change.

4.5.3 Recreation

The impacts of climate change on recreational activities may have significant effects on the economy and welfare of Minnesota residents and visitors alike. Outdoor recreation in Minnesota, including snowmobiling, skiing, fishing, and boating, is highly sensitive to weather and climate. Less winter precipitation and warmer temperatures would reduce opportunities for snowmobiling, skiing, ice fishing, and other cold weather activities. These changes may be offset by a longer ice- and snow-free season, which would increase opportunities for boating, fishing, and other warm weather activities.

As discussed above, there may be a net loss of prairie potholes in Minnesota, which as prime breeding groups for a number of waterfowl. While reductions of waterfowl populations would directly impact recreational hunting in Minnesota, the losses would be felt in many areas across the country because many waterfowl species migrate great distances. For instance, Pennsylvania duck hunters were found to have significant willingness to pay values for prairie pothole preservation in the upper Midwest, including Minnesota.[77]

The literature on how recreation may be affected by climate change is limited. Loomis and Crespi[78] estimate that nationwide days devoted to snow skiing would decrease by 50 percent with an average temperature increase of about 5°F. On the other hand, they found that days spent golfing and fishing, swimming, and boating on streams and reservoirs would increase. Given that relatively larger temperature increases are projected for Minnesota compared to the nation as a whole, these changes may be more pronounced in Minnesota.

---

[76] U.S. EPA. 2002b, op cit.

[77] Kinnell, J., J.K. Lazo, D. Epp, A. Fisher, and J. Shortle. 2002. "Perceptions and Values for Preventing Ecosystem Change: Pennsylvania Duck Hunters and the Prairie Pothole Region." *Land Economics* 78:228-244.

[78] Loomis, J. and J. Crespi. 1999. "Estimated Effects of Climate Change on Selected Outdoor Recreation Activities in the United States." In *The Economic Impacts of Climate Change on the U.S. Economy,* R. Mendelsohn and J. E. Neumann (eds.). Cambridge University Press, Cambridge, UK, pp. 289-314.

Revenue from recreation and lodging totaled $2.8 billion in 2000, roughly 1.5 percent of Minnesota's total gross state product in 2000.[79] (Status Consultants was unable to determine what share is from cold weather activities and what share is from warm weather activities.) Whether net expenditures on recreation or time devoted to recreation increases, decreases, or stays the same is difficult to determine. Loomis and Crespi[80] estimated a small increase in nationwide recreation expenditures. It is reasonable to expect that individuals and communities would experience great differences in how they are affected, with some communities facing losses as winter recreation opportunities decline.

Changes in recreation can have the most impact on smaller, more remote communities because much of the local economy is based on providing services for outdoor recreation. In Lake Mille Lacs, for example, ice fishing and snowmobiling are critical to the local economy, generating $23-$27 million of the $40 million total that outdoor recreation contributes annually to the local economy.[81] The 2001-2002 winter was unseasonably warm, and the late freeze shortened the season for ice fishing and snowmobiling, reducing the revenue for local businesses. Late freezes can have an added impact if there is inadequate snow and ice for the week between Christmas and New Year's, which is usually the biggest week of the year for many businesses.[82]

Late freezes can also affect the safety of winter recreation because of extended periods of thin or unpredictable ice. Quick freezes, accompanied by impatient enthusiasm brought on by a late winter, can create hazardous conditions. The winter of 1998-1999, with mild temperatures, saw 10 deaths from people falling through ice. This was the highest total in 12 years.[83]

Adaptation options for the recreation sector are likely to involve shifts in when activities occur, like boating earlier and later in the year than previously possible. Reductions in winter recreation opportunities could be offset by increases in summer recreation opportunities. What may be critical is whether areas currently offering cold weather recreation opportunities can also offer warm weather opportunities. Local outfitters and other services may have to adjust to different clientele and different activities.[84]

4.5.4 Conclusions

Climate change will result in increased temperatures and could result in wetter winters and springs and drier summers and falls. These changes are likely to affect many sectors, including water resources, natural ecosystems, and recreation. Soil moisture and lake levels are likely to change substantially, flooding could increase, the location of species is likely to generally shift northward, and winter recreation opportunities will shrink while opportunities for summer recreation will expand. Because the sectors most likely to be impacted constitute relatively small portions of the economy, the economic impacts of these changes may not be devastating to the

[79] BEA. 2002. Gross State Product Data. Bureau of Economic Analysis. http://www.bea.doc.gov/bea/regional/gsp. Accessed September 10, 2002.

[80] Loomis, J. and J. Crespi. 1999, op cit.

[81] McCormick, T.J. 2001. "Mild Winter is Hurting Mille Lacs Resort Owners." *Star-Tribune.* December 12.

[82] Ibid.

[83] Kaszuba, M. 1999. "A Late Winter, and Quick Freeze-up, Bring Thin-Ice Fear." *Star-Tribune*, December 24.

[84] NAST. 2000, op cit.

state. However, communities dependent on natural resources such as rural agricultural communities and communities dependent on recreation could see more substantial economic impacts. In addition, the impact on Minnesota's culture may be significant, because a state that prides itself on its northern forests, many lakes, and cold, snowy wintertime activities may see these attributes considerably diminished.

These affected sectors have numerous adaptation options that would improve existing conditions while also reducing vulnerability. Considering climate change in long-term planning and in decisions with long lifetimes, such as construction of infrastructure, can reduce the potential harm from climate change.

It is also important to note that these changes projected to happen within the next century will not happen suddenly in 2100. Rather, the changes, some of which are already becoming evident, will become more noticeable and will affect more locations and regions as time goes on.

5.0 Greenhouse Gas Emissions from Minnesota

5.1 Introduction

The principal greenhouse gases implicated in global climate change include: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), stratospheric water vapor, chlorofluorocarbons (CFC-12, CFC-11, CFC-113), hydrochlorofluorocarbons (HCFC-22, HCFC-141b, HCFC-142b, HCFC-123), hydrofluorocarbons (HFC-134a, HFC-152a, HFC-43-10mee), other chlorocarbons (CH_3CCl_3, CH_2Cl_2, CH_3Cl, $CHCl_3$, CCl_4), perfluorocarbons (C_2F_6, C_2F_8, C_4F_{10}), carbon tetrafluoride (CF_4), and sulfur hexafluoride (SF_6). Common to these gases is an ability to absorb radiation in the infrared, making them potent climate warming gases.

Most of these gases are directly emitted from the surface to the atmosphere. However, some of these greenhouse gases are formed in the atmosphere from other gases or as a result of chemical interactions of other emitted compounds. Ozone, for example, is formed photochemically in the troposphere by the interaction of volatile organic compounds and sunlight in the presence of nitrogen oxides (NO_x). Some water vapor in the stratosphere is directly injected by jet aircraft, but most anthropogenic water vapor in the stratosphere derives from the oxidation of emitted CH_4. In the case of CO_2, some CO_2 results from the oxidation of carbon monoxide (CO) in the atmosphere.

The chemistry can be quite complex. In the case of a compound like O_3, atmospheric concentrations are controlled not only by rates of ozone formation, but also by removal rates. Emissions of carbon monoxide (CO) and CH_4 act to slow the rate of tropospheric removal of O_3, leading to longer atmospheric lifetimes for ozone and increased effect on climate. Emissions of CO have similar effect on tropospheric levels of CH_4 and some of the other short-lived greenhouse gases.

Some sources of these gases are natural in origin. Under natural conditions, sources of emissions and removal mechanisms balance, leading to stable atmospheric concentrations. Human activities unbalance sources and removal mechanisms or sinks, leading to changed atmospheric concentrations. CO_2, CH_4 and N_2O are examples of greenhouse gases that are found naturally in the atmosphere, but which are increasing in concentration in the atmosphere due to human created imbalances between sources and sinks. Synthetic greenhouse gases like the CFCs, HCFCs, PFCs and HFCs are not found in nature.

In the case of some greenhouse gases, it is possible to remove them from the atmosphere through human activities, thereby lowering concentrations. The most obvious instance of this is CO_2, which can be removed from the atmosphere through forest growth and expansion, and agricultural tillage practices that build soil organic carbon. Thus, in addition to inventorying CO_2 emissions, it is useful also to inventory carbon sinks.

Trends in greenhouse gas emissions are presented in this section for Minnesota. Not all greenhouse gases are treated. Omitted are the CFCs and HCFCs, as well as tropospheric ozone precursors. In addition to being greenhouse gases, the CFCs, HCFCs and chlorocarbons are ozone-depleting compounds. After a residence time of typically decades in the atmosphere, they are oxidized or undergo photolysis, which frees chlorine to catalytically destroy ozone in the

lower stratosphere. As ozone depleters, these compounds are regulated under the U.N. Vienna Convention on Substances that Deplete the Ozone Layer, rather than the U.N. Framework Convention on Climate Change. Because of this, it has become something of a convention not to treat CFCs and HCFCs in greenhouse gas inventories.

NO_x and VOC emissions also are not treated due to the difficulties in developing an agreed to measure of their effect on climate.

The greenhouse gases that are treated in the Minnesota emission inventory are listed in Table 5.1 along with their global warming potential. A global warming potential (GWP) is a measure of the relative effectiveness of any greenhouse gas in raising mean global temperature. Expressed in CO_2-equivalent tons, the GWP converts the emission of a unit emission of any one greenhouse gas to the approximate amount of emitted CO_2 needed to realize the same effect on climate. Thus a one ton emission of CH_4 is equivalent in its effect on global climate as 21 tons of emitted CO_2; one ton of N_2O is equal to 310 tons of CO_2, one ton of SF_6 to 23,900 tons of CO_2. For CO, which is treated in the inventory, the scientific literature gives a GPW of 1 to 3. To be conservative, the MPCA uses a value of one.

Table 5.1 Greenhouse Gases Treated in Minnesota Emissions Inventory and Global Warming Potentials*

Chemical Compound	GWP (100 year time horizon)	Chemical Compound	GWP (100 year time horizon)
CO_2[a]	1	SF_6	23,900
CH_4	21	CO	1
N_2O	310	C2H4	1
HFC-134a	1300	HFC-152a	140
PFCs	6000 – 12,000	HFC-43-10-mee	1300

*Global warming potentials used are from the Second Assessment Report of the Intergovernmental Panel on Climate Change. They do not differ significantly from those presented in the Third Assessment Report.

In developing the inventory presented below, an effort was made to limit the types of emissions treated to those actually occurring within the borders of Minnesota. However, in the case of aviation, emissions were calculated on the basis of fuel consumed by flights originating in Minnesota. An effort also was made to locate emissions from continuously emitting sources like landfills in the year in which they were likely to have occurred.

Greenhouse gas emissions from Minnesota sources totaled 138 million CO_2-equivalent tons in 2000. By emitting sector, nearly 70 percent originated from transportation and electric generation. Figure 5.1 shows the calculated 30-year trend in emissions between 1970 and 2000. Over this period, emissions from Minnesota sources increased from about 99 million CO_2-equivalent tons to the present 138 million tons, or by about 40 percent. Since 1990, greenhouse gas emissions have increased by about 21 million tons, growing at a rate of 1.7 percent per year.

Aggregate carbon storage on timberlands and in landfills and housing is shown graphically in Figure 5.2 for Minnesota for the period 1970 to 1990. By the early 1990s, the annual rate of increase in the amount of carbon stored in these reservoirs was about 7 million tons, or 20 million CO_2-equivalent tons. This is a measure of the rate of biospheric removal of CO_2 from

the atmosphere. In the early 1990s, this would have acted to offset about one-sixth of greenhouse gas emissions from all sources in Minnesota.

Figure 5.1 Greenhouse Gas Emissions from Minnesota

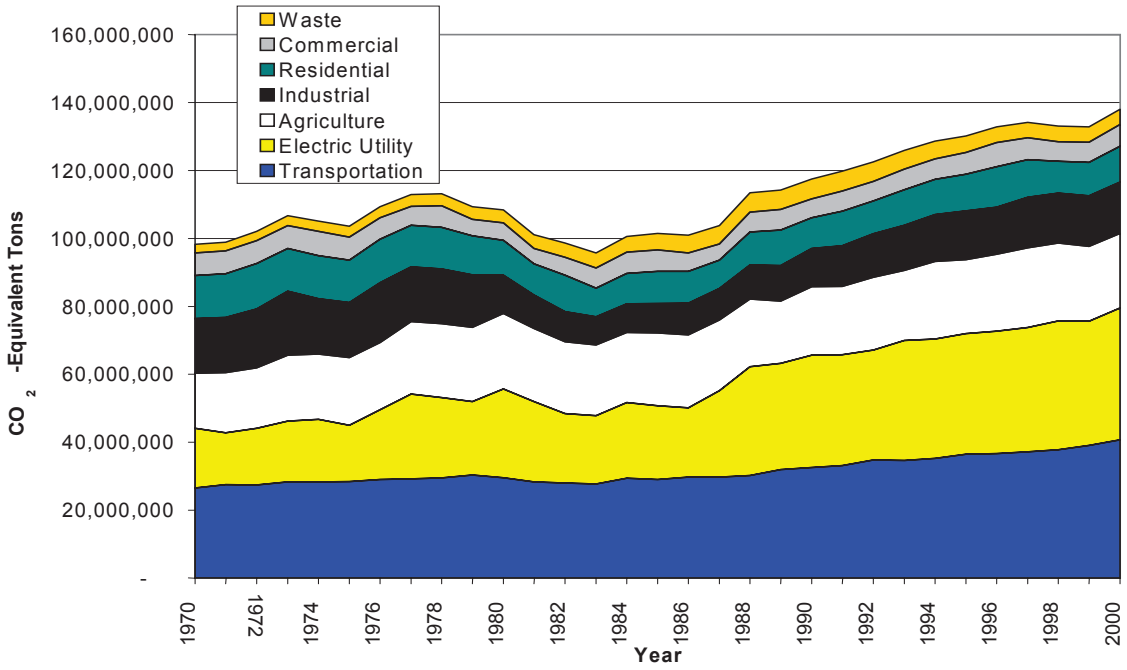


Figure 5.3 shows forecasted trends in greenhouse gas emissions out to the year 2010. Emissions are expected to increase to about 160 million CO_2-equivalent tons by 2010, continuing past trends in emission. This will leave emissions roughly 35 percent higher than the targets laid out in 1992 in the UN Framework Convention on Climate Change. Due to the difficulty in projecting economic change in the industrial sector, emissions from industrial activity were left at 2000 levels. The history of emissions from this sector suggest that, due to fluctuating industrial sector emissions, the 2010 forecast level could be higher by several million tons or, given past volatility in emissions, lower by 5 to 10 million tons. The short-term effects of the economic recession of 2001/2002 are not treated.

Figure 5.2 Carbon in Place on Tiberland and in Landfills and Housing in Minnesota

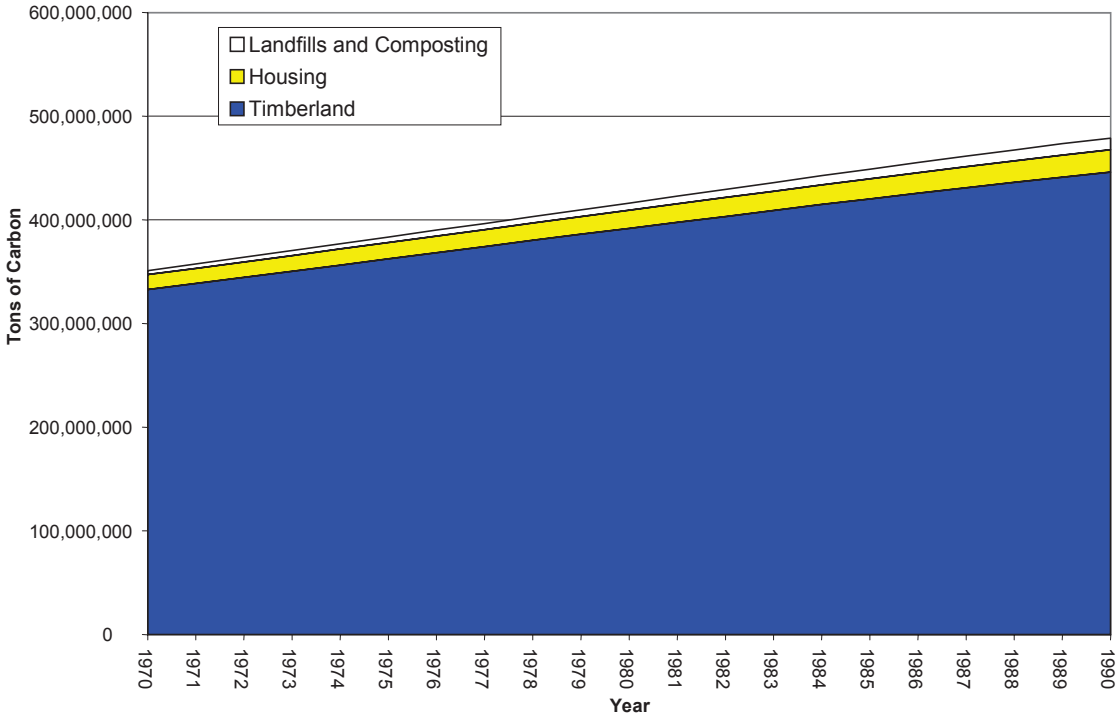
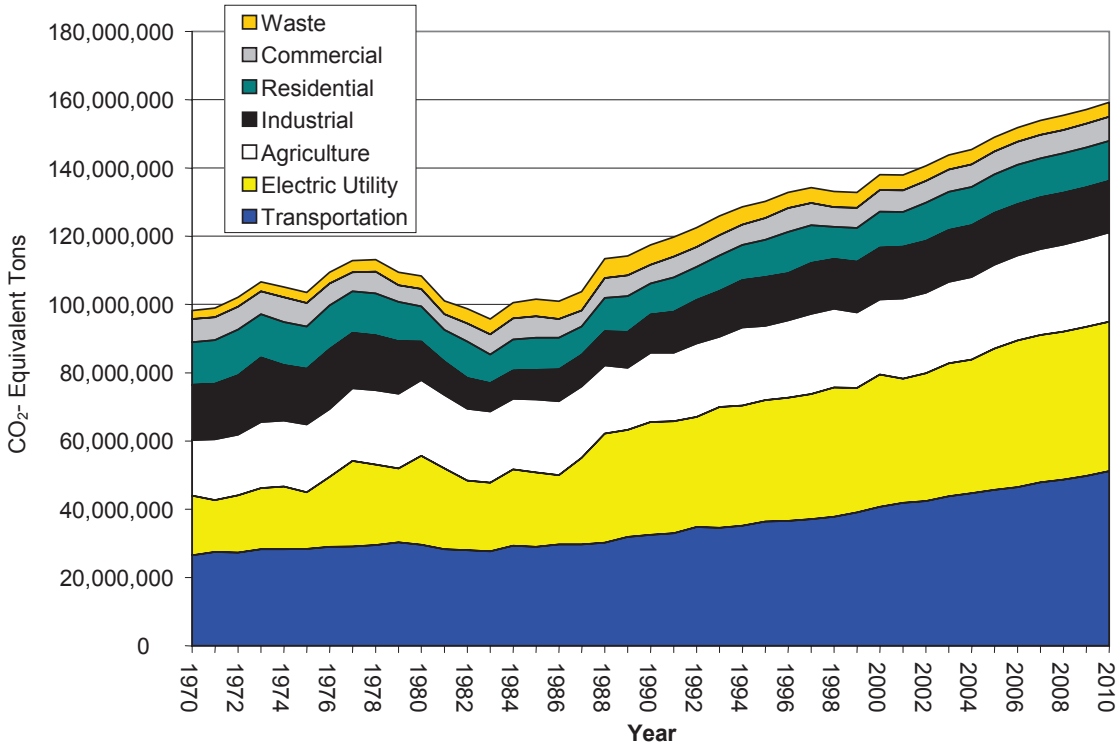


Figure 5.3 Historic and Forecasted Greenhouse Gas Emissions from Minnesota



5.2 Transportation

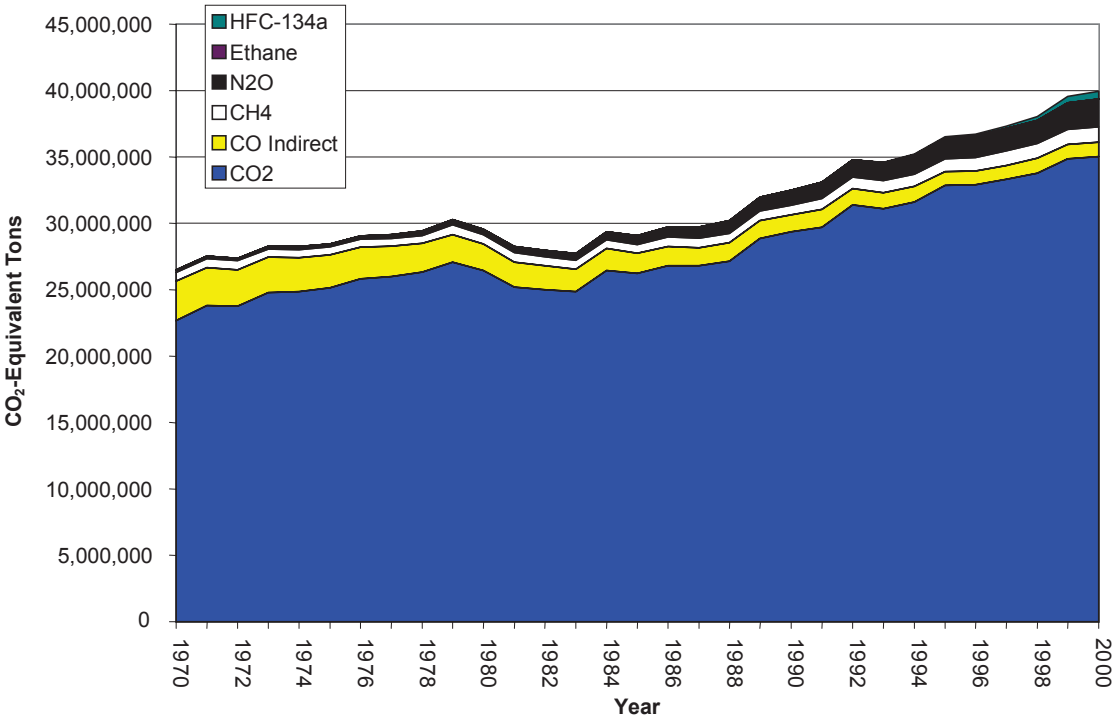
Transportation emissions of greenhouse gases totaled an estimated 40 million CO_2-equivalent tons in 2000. Since the early 1980's, emissions have increased by about 50 percent, increasing at an annual rate of about 1.8 percent per year.

Greenhouse gases that are emitted from Minnesota transportation include: CO_2, N_2O, CH_4, CO, ethane, and HFC-134a. In addition, jet aircraft can have an indirect effect on climate through high altitude effects on cirrus cloud formation, stratospheric ozone and water vapor amounts. These, however, are uncertain, and so are not included in this inventory. CO_2 is produced during the combustion of fossil fuels, mostly refined petroleum products in highway vehicles, aircraft, boats, and rail locomotives, as well as some natural gas used in the engines that push natural gas through the natural gas transmission system. N_2O is produced by the catalytic converters installed in most light-duty vehicles to control other types of pollution. Smaller amounts are produced at the point of combustion. CH_4 is also produced during combustion, but most CH_4 emitted from the Minnesota transportation system is leaked from natural gas transmission and distribution pipelines. Most emitted ethane derives from the gas transmission system.

CO is produced during the incomplete combustion of fossil and biomass fuels. As discussed above, it has an indirect climatic effect, photochemically elevating tropospheric levels of ozone, an important greenhouse gas. Within months of emissions, CO is oxidized to CO_2, and thus acts as the source of an additional release of CO_2 to the atmosphere. Finally, HFC-134a is a refrigerant used in mobile air conditioning in cars, light-duty and heavy-duty trucks and buses. Small amounts of HFC-134a are released to the atmosphere upon air conditioning servicing, vehicle retirement, and leakage associated with routine vehicle operation.

The historical trend in greenhouse gas emissions from Minnesota transportation is shown in Figure 5.4. In 1970, emissions were some 26 million CO_2-equivalent tons, remaining largely unchanged through the early 1980's. Beginning in the mid-1980s, emissions from transportation expanded dramatically, reaching 33 million CO_2-equivalent tons in 1990, and 40 million tons in 2000.

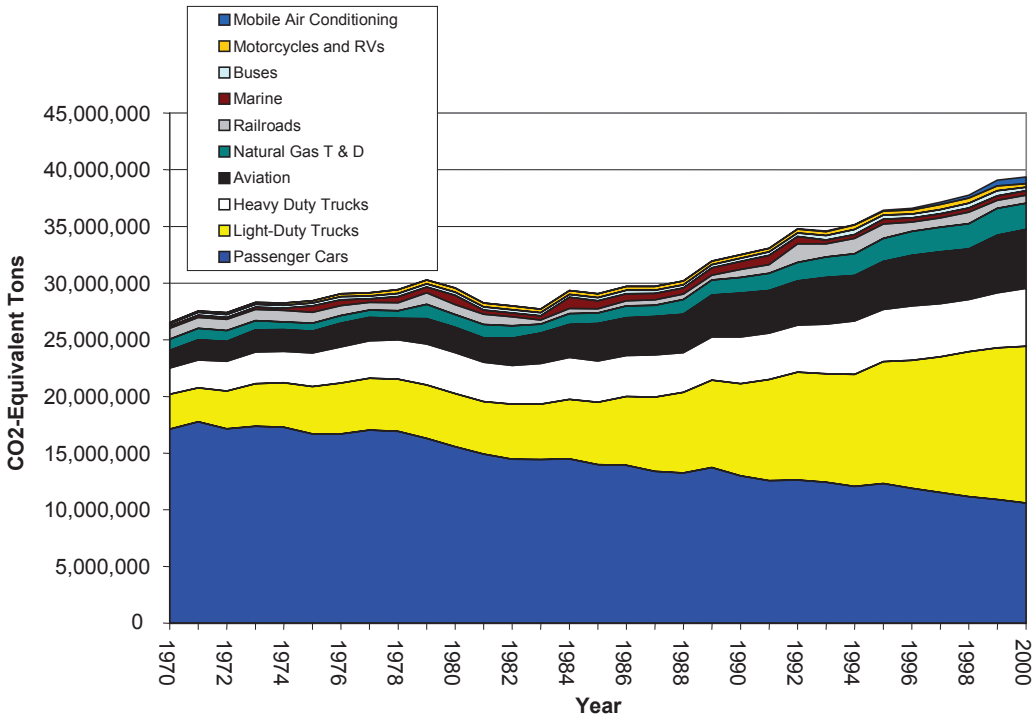
Figure 5.4 Greenhouse Gas Emissions from Minnesota Transportation



Currently, emissions of CO_2 account for about three-quarters of all greenhouse gas emissions from Minnesota transportation. Of the other greenhouse gases emitted from transportation, emissions of N_2O account for about 5 percent of releases, CH_4 4 percent, CO 3 percent, and HFC-134a one percent.

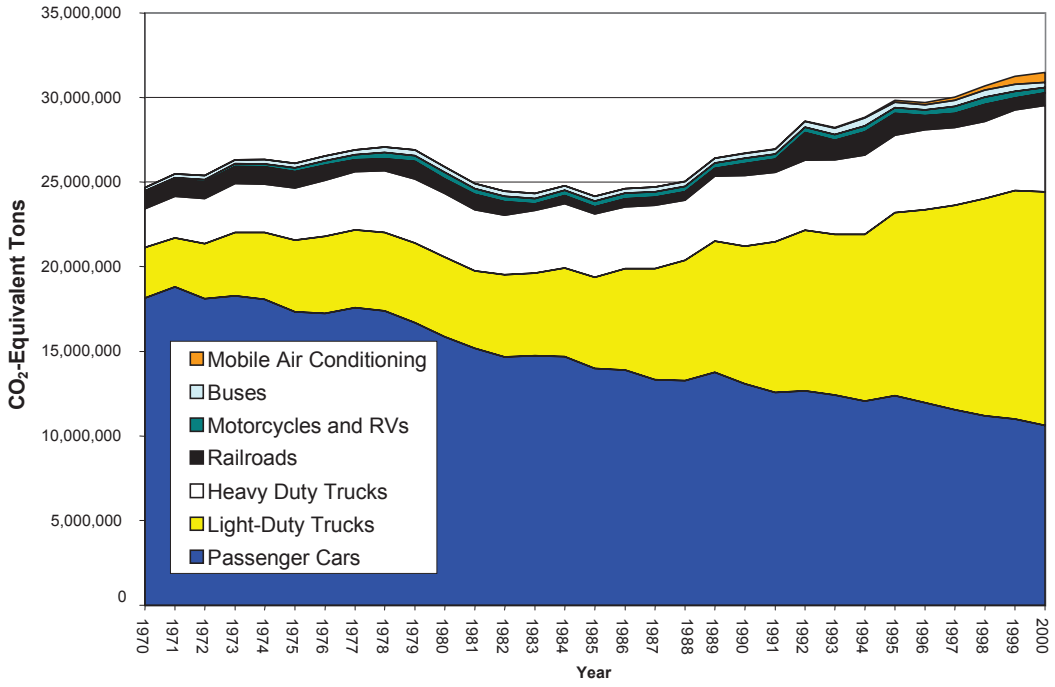
By emission source, light-duty vehicles account for about half of all greenhouse gases emitted from Minnesota transportation. Aircraft account for another one-quarter of emissions; heavy-duty trucks for one-tenth. Natural gas transmission and distribution accounts for about one twentieth of greenhouse gas emissions, while the remaining five percent derives from smaller railroad, marine, bus, RV, motorcycle and mobile air conditioning sources. Figure 5.5 shows the trend in greenhouse gas emissions from 1970 to 2000 by emission source.

Figure 5.5. Greenhouse Gas Emissions from Minnesota Transportation



Highway vehicles account for about two-thirds of all greenhouse gas emissions from transportation, some 32 million CO_2-equivalent tons. The historic trend in emissions from highway sources is shown in Figure 5.6. Over the initial part of this period, 1970 to 1987, greenhouse gas emissions were flat or declining, due to a combination of rising light-duty vehicle fuel economy and high fuel prices. Since 1987, emissions have increased at a rate of about 1.7 percent per year, fueled by a dramatic growth in emissions from light-duty trucks. Over this period, emissions from light-trucks more than doubled, while emissions from cars declined by one-fifth. Over this same period, emissions from heavy-duty trucks, the next largest highway source, increased by one-third, but in absolute terms by only 1.5 million tons.

Figure 5-6. Greenhouse Gas Emissions from Minnesota On-Road Transportation



Underlying the growth in emissions from highway vehicles has been a more than doubling of the number of vehicle miles traveled (VMTs) on Minnesota roadways since 1970 and a 50 percent increase in fuel consumption in highway vehicles over the same period. Historic trends in VMTs on Minnesota roadways and in fuel consumption by highway vehicles are shown in Figures 5.7 and 5.8, respectively. About 90 percent of the growth in vehicle miles traveled on Minnesota roadways since 1980 has resulted from growth in light truck VMTs. Over the same period, virtually all of the growth in fuel consumption by highway vehicles was accounted for by increased fuel use in light trucks.

After highway vehicles, the next two largest sources of emission of greenhouse gases from Minnesota transportation are civilian aircraft and natural gas pipelines. Emission trends for these nonhighway sources of emission are shown in Figures 5.9 and 5.10. Since the early 1970s, two large natural gas pipelines have been constructed in Minnesota, and capacity on the largest pipeline system in the state, Great Lakes Gas Transmission, has more than doubled. Over this same period, greenhouse gas emissions from pipelines have increased from about 1 million CO_2-equivalent tons in 1970 to an estimated 2.3 million tons in 2000. Over this same period, emissions from aviation increased from an estimated 1.5 million CO_2-equivalent tons to over 5 million CO_2-equivalent tons with the growth of Minneapolis-based Northwest Airlines into one of the nation's largest air carriers.

Figure 5.7 Vehicle Miles Traveled on Minnesota Highways

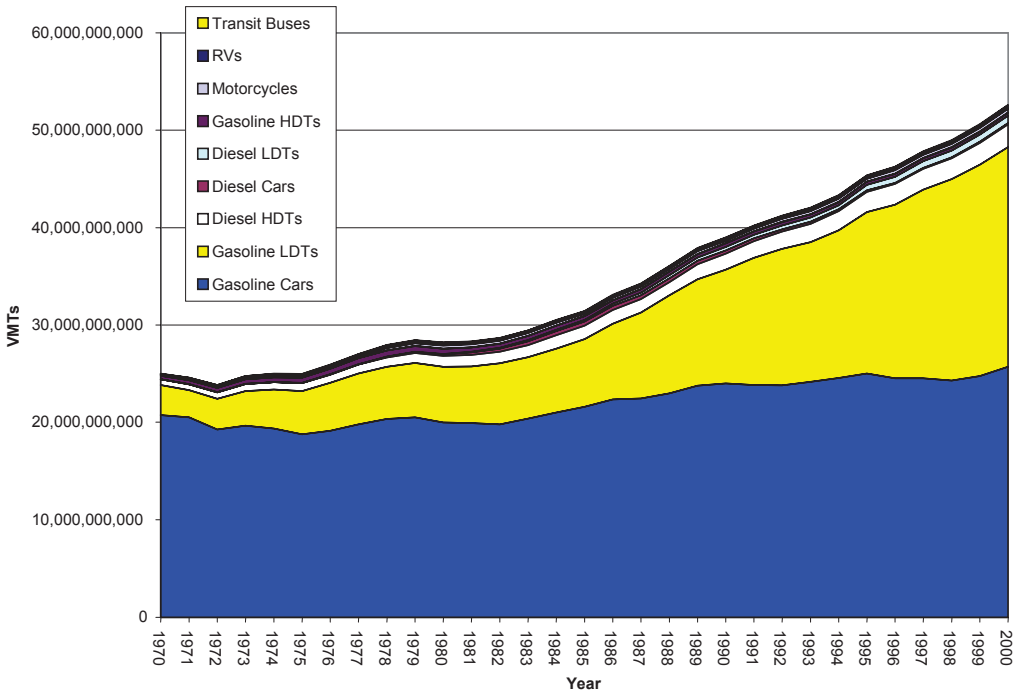


Figure 5.8 Energy Content of Fuels Used by Highway Vehicles in Minnesota

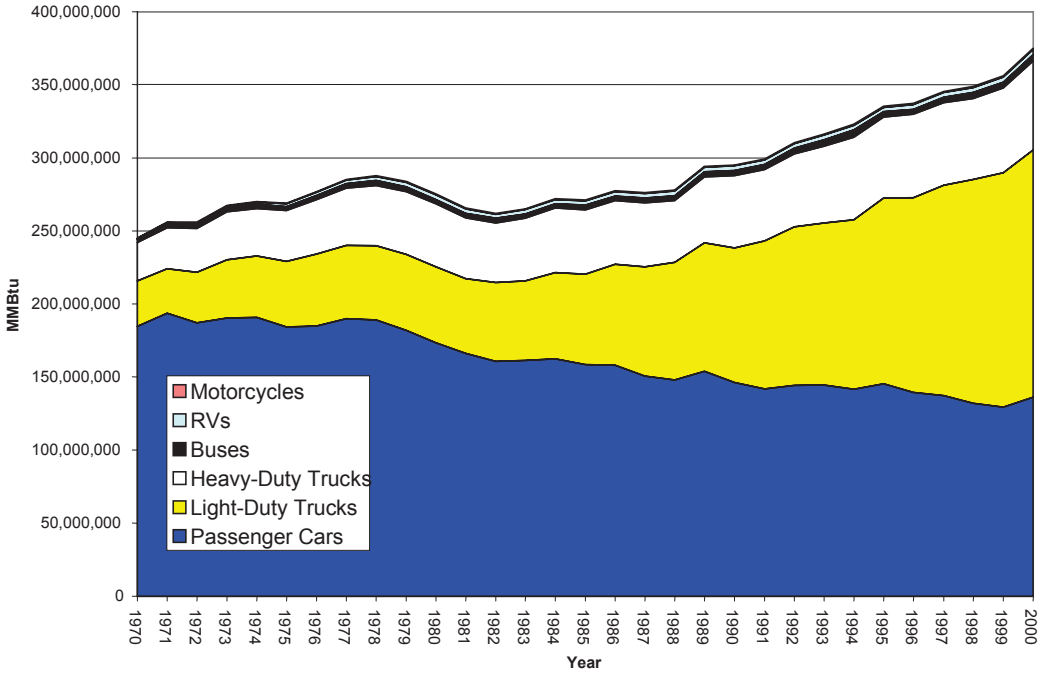
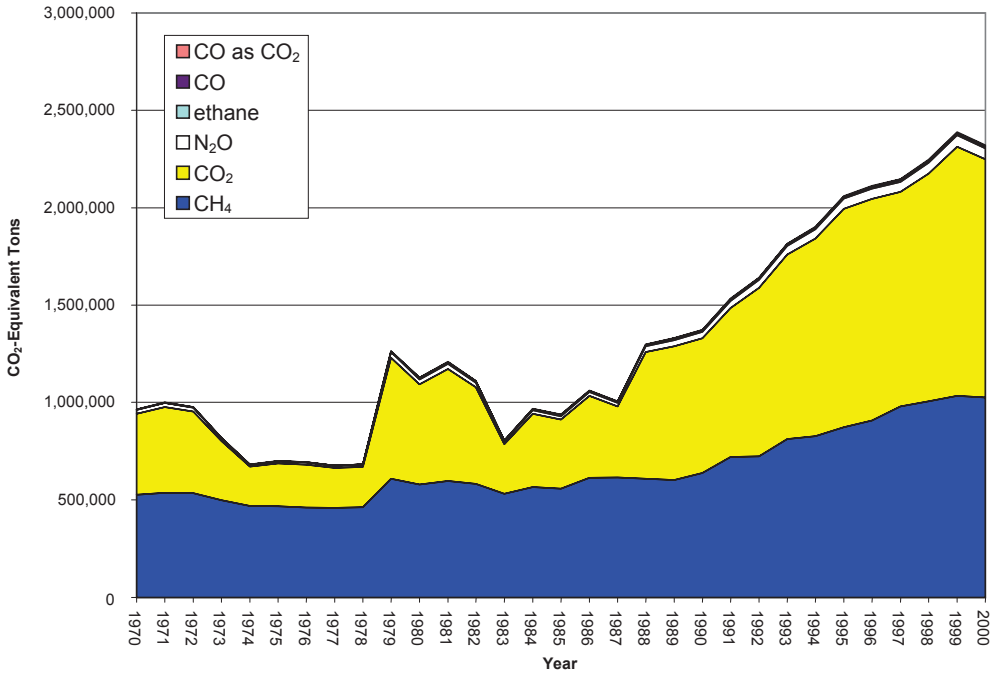


Figure 5.9 Greenhouse Gas Emissions from Natural Gas Transmission and Distribution in Minnesota



Since, with the exception of HFC-134a usage and CH_4 leakage from transmission pipelines, all greenhouse gas emissions from transportation derive from fuel combustion, the principal underlying driver of emissions is transportation energy use. The trend in energy use in the Minnesota transportation sector since 1970 is shown in Figure 5.11. From 1970 to 2000, total energy use in transportation has increased from about 290 million to 475 million MMBtu, most of it since the mid-1980s.

The methods used to calculate highway, rail, marine and aviation emissions of greenhouse gases were taken from USEPA (1995), IPCC (1998), and USEPA (2001). Emissions from the natural gas transmission and distribution system were estimated using the methods and emission factors given in Radian (1997). CO emissions from 1985 to 2000 were taken from USEPA (2002). Emissions of CO prior to 1985 were calculated using mean per mile traveled emission factors for the mid1980s reported in USEPA (2002). HFC-134a use and emissions were modeled using a stock model of vehicles in Minnesota and emission factors from USEPA (1987).

Emissions from railroad locomotives and barges were estimated based on reported fuel use, rather than ton-miles of travel in the state. In the future, it would be useful for emissions to reestimated on a ton-mile basis. Emissions from commercial air travel are also calculated on the basis of fuel purchases in the state, hence represent fuel use associated with air travel originating in Minnesota, rather than air travel within Minnesota airspace.

Figure 5-10. Greenhouse Gas Emissions from Air Travel Originating in Minnesota

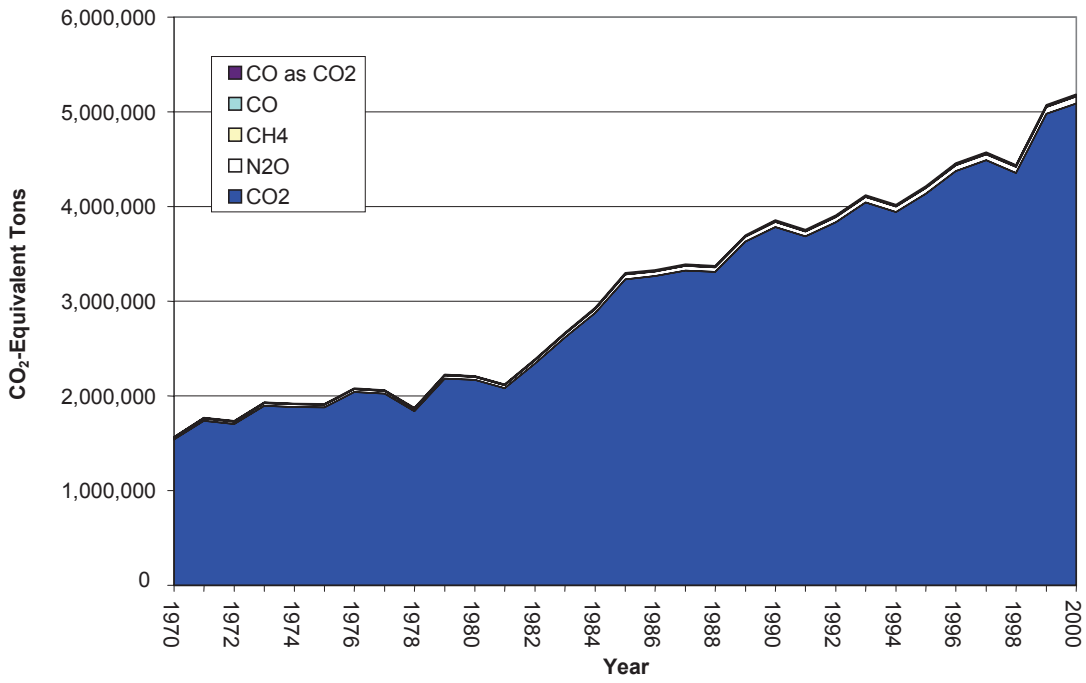
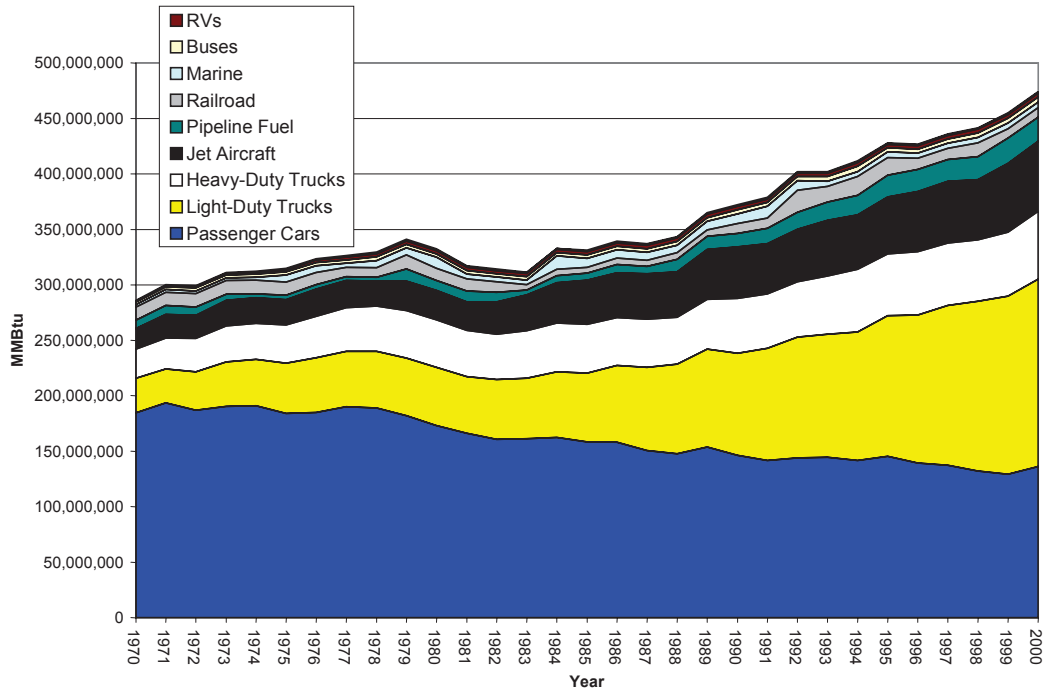


Figure 5.11 Energy Use in the Minnesota Transportation Sector

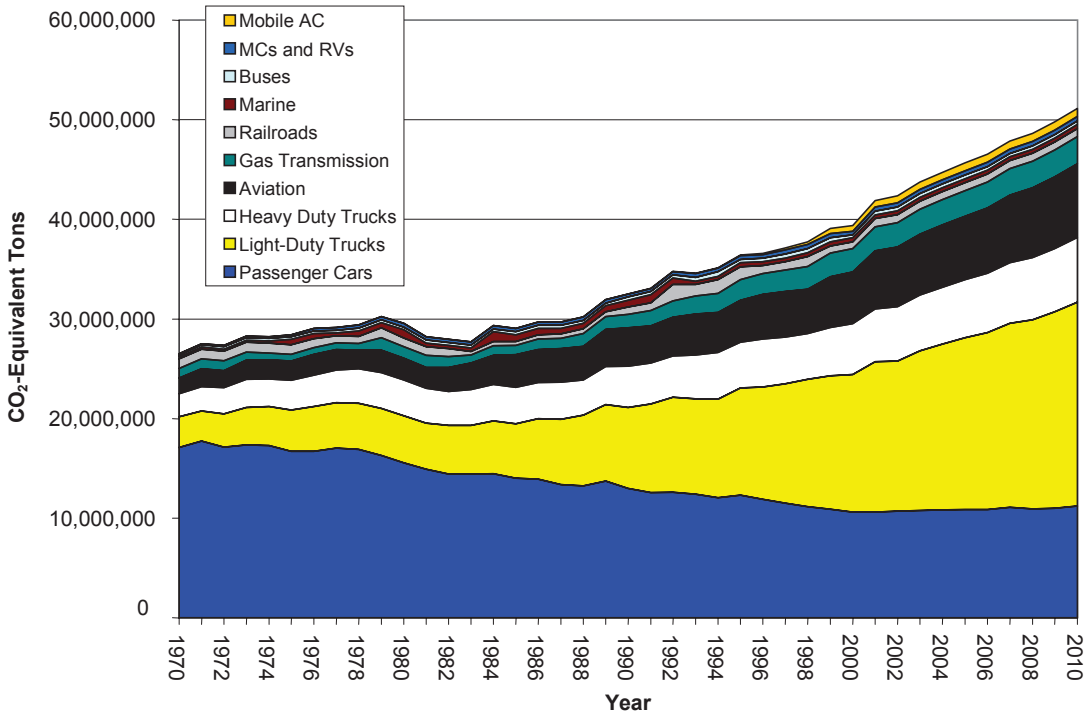


Historic and forecasted trends in greenhouse gas emissions from transportation in Minnesota are shown graphically in Figure 5.12. Emissions from highway vehicles are forecast from trends in the underlying factors that determine the demand for travel. These include: population, per capita disposable income, fuel price, the distribution of drivers with age, and elasticities of demand for travel with respect to income, fuel price, and fuel economy improvements. The vehicle population in the state is modeled using empirically derived scrappage rates for cars and light-duty trucks, trends in per capita vehicle ownership in Minnesota, and the forecast distribution of new light-duty vehicle purchases by vehicle type and fuel. On-road fuel economy is calculated from new vehicle fuels economies, as adjusted for the effects of vehicle age, highway speeds and observed differences in new vehicle fuel economy between the U.S. EPA test estimates and actual on-road performance.

Emissions from heavy-duty trucks are calculated from forecasted VMTs and forecasted improvement in fleet fuel economy for the U.S. VMT growth is linearly extrapolated from trends in Minnesota in heavy-duty truck VMTs since 1980.

Greenhouse gas emissions from aviation are forecast principally on the basis of forecasted enplanements at Minneapolis-St. Paul airport, and trends in average trip length and energy consumption per passenger-seat mile. Emissions from natural gas transmission and distribution are forecast on the basis of completed or already planned expansions in the transmission system, and only slow growth in already existing components of the system. The distribution system is assumed to expand linearly with the forecast expansion in the customer base.

Figure 5.12 Historic and Forecasted Greenhouse Gases from Minnesota Transportation



Emissions of HFC-134a are calculated using a stock model of vehicles, refrigerant charge, and leakage rates for servicing, normal operations and retirement. Emissions from rail and barge operations are assumed to remain constant at the 1996-2000 average annual emission level.

Forecasted greenhouse gas emissions follow the long-term trajectory of emissions, increasing to 52 million CO_2-equivalent tons by 2010 (See Figure 5.12.). Emissions from passenger cars stabilize, following a long decline. Emissions from light-duty trucks increase by about 5.5 million tons to 20.5 million CO_2-equivalent tons, or by more than one-third from the present. Emissions from heavy-duty trucks increase from the present by 1.3 million CO_2-equivalent tons to 6.5 million tons. Emissions from gas transmission increase only slightly, while forecast emissions from aviation increase from the present by 1.5 million CO_2-equivalent tons to 6.7 million tons.

The principal determinants of emissions growth from highway vehicles are VMT growth and the light-duty vehicle fleet composition. Forecasted trends in VMTs on state roadways are shown in Figure 5.13. VMTs are forecast to increase by about one-fifth by 2010, from the current 52 million to 63.6 million. This continues the observed trajectory of growth. The growth mirrors the forecasted rate of growth in income in the state. It long has been observed that travel demand increases almost linearly with income.

Figure 5.14 shows the distribution of light-duty vehicles among passenger cars and light-duty trucks for the period 1970 to 2000 and the forecast period. The observed penetration of light trucks into the fleet is forecast to continue to 2010. Since the average fuel economy of the average light truck is one-quarter to one-third lower than that of the average passenger car, this translates to a rapidly rising trajectory of emissions.

Figure 5.13 Historic and Forecasted Vehicle Miles Travelled on Minnesota Highways

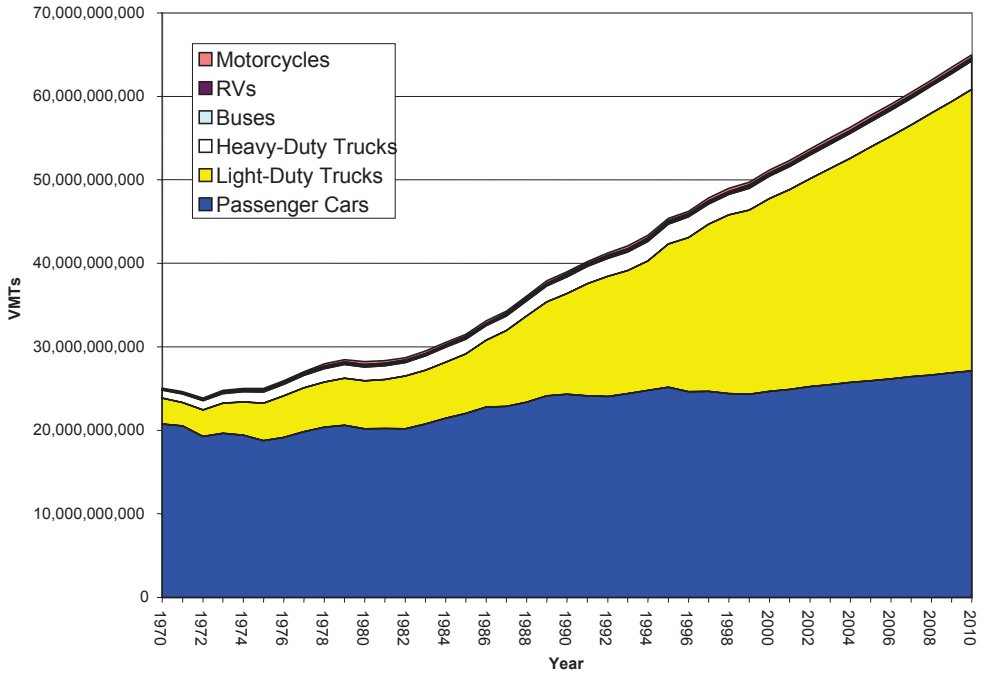
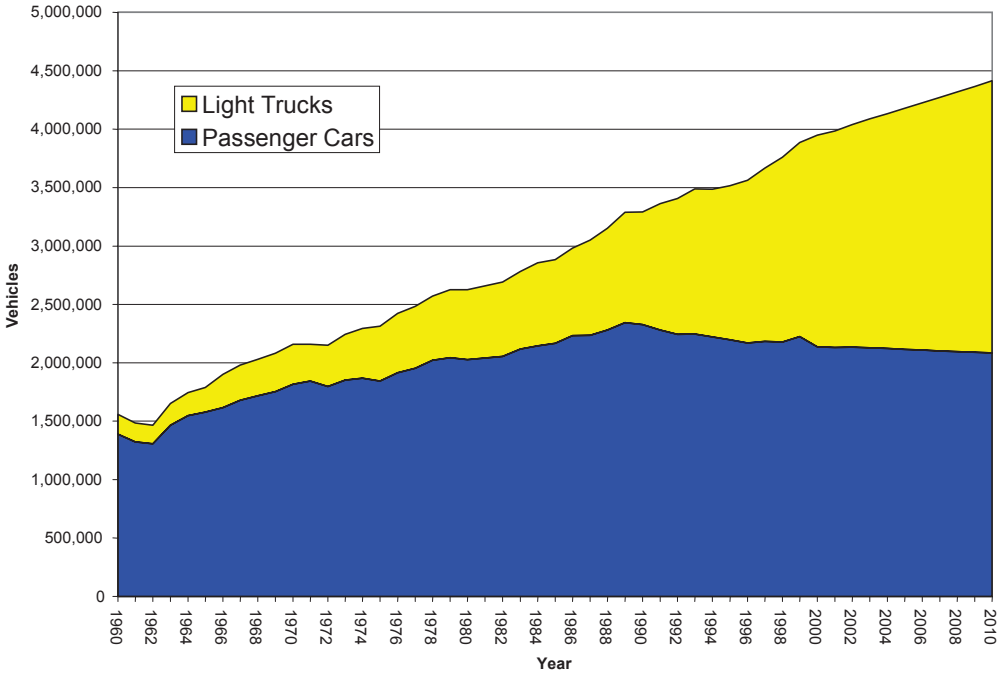
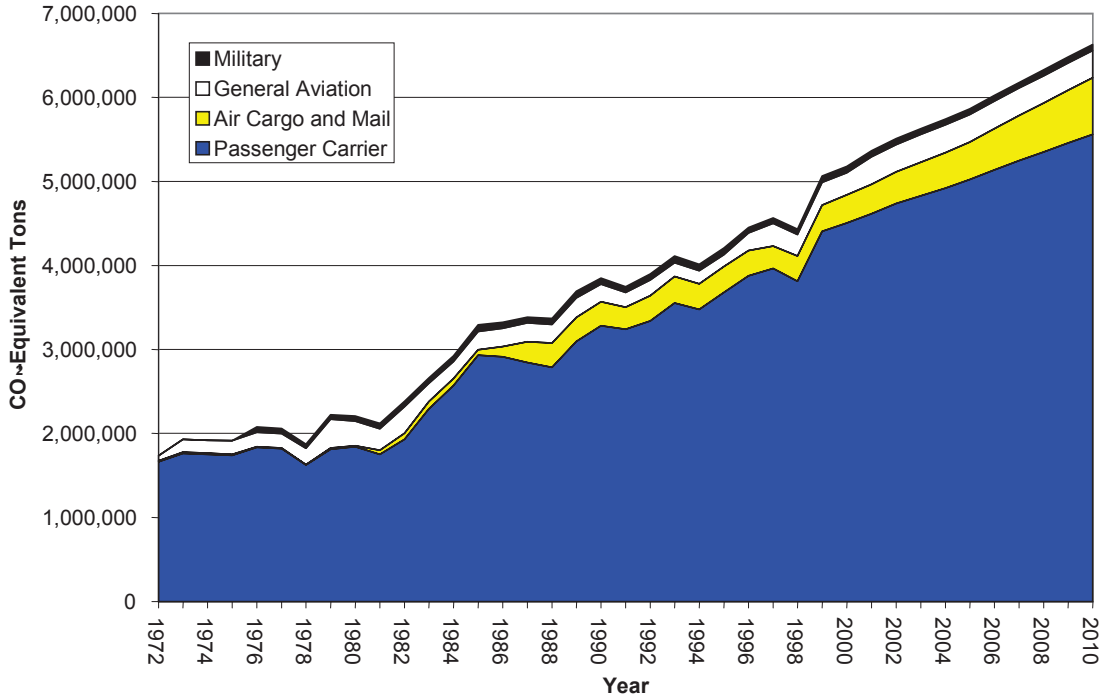


Figure 5.14 Historical and Forecasted Light-Duty Vehicle Population



Of forecasted nonhighway emissions, those from aviation are the most important. Figure 5.15 shows historic and forecasted greenhouse gas emissions from aviation by type of aviation service. Passenger service is the principal driver of emissions, accounting for more than half of the forecast 1.5 million CO_2-equivalent ton increase to 2010.

Figure 5.15 Historic and Forecasted Emissions of Greenhouse Gases from Aviation Originating in Minnesota



5.3 Electricity Generation

The electric generating sector includes all facilities in Standard Industrial Classification (SIC) codes 4911, 4931, 4961 and 4953 that are generating electricity or steam for sale off-site. This includes municipal waste combusters that generate electricity or raise steam for off-site use. Also included are industrial facilities in SIC codes 10 or 26 (iron ore mining and paper/pulp production) that are committed to some extent to servicing the electric grid. In apportioning emissions from these facilities between the electric generating and industrial and mining sectors, care was taken to ascribe to electric generation only those emissions that were associated with reported sales.

Greenhouse gas emissions from electric generation are dominated by emissions of CO_2. 38.5 million CO_2-equivalent tons of greenhouse gases were emitted in 2000, 99% of which were in the form of CO_2. The combustion of coal accounts for most emissions of greenhouse gases from electric generation, about 95 percent of all emissions from this sector. The combustion of natural gas, oil and solid waste each account about equally for the remainder.

A detailed record of emissions has been assembled on a facility-by-facility basis for the period 1983 through 2000. This includes all small and large base-load and intermediate-load facilities and most peaking plants, including small kilowatt-scale plants. The trend in greenhouse gas emissions from these facilities is shown in Figures 5.16 and 5.17 by gas and source of emission, respectively. Since 1983, greenhouse gas emissions from electric generation have increased from 20 million CO_2-equivalent tons to the current 38.5 million tons, growing at a rate of about 3.9 percent per year.

Figure 5.16 Greenhouse Gas Emissions from the Electricity Generation Sector in Minnesota

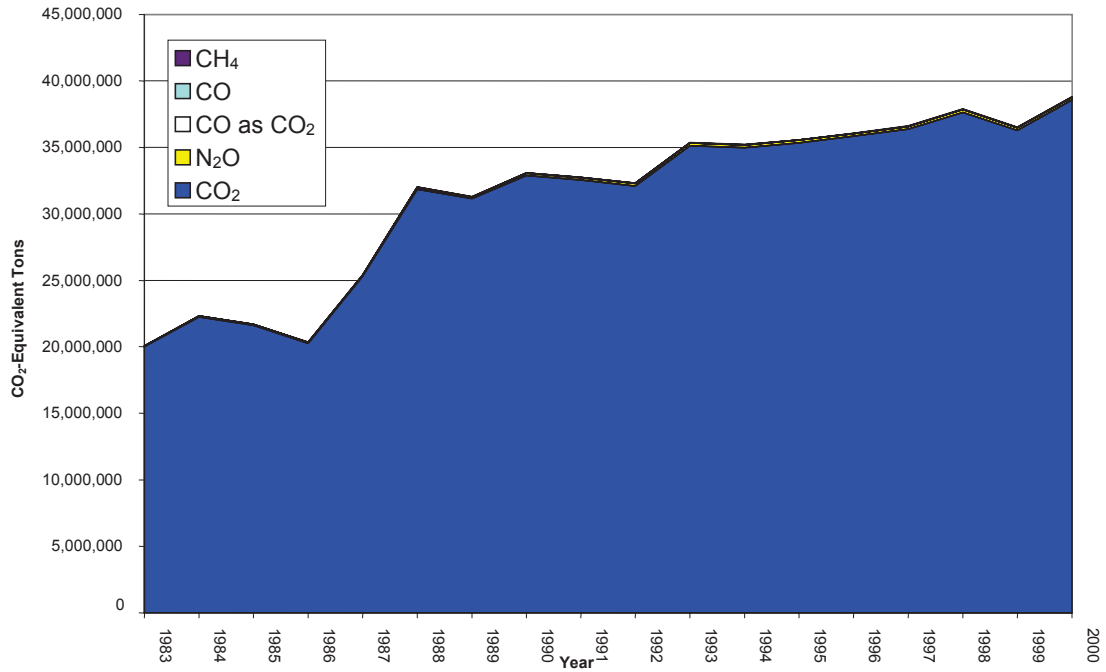
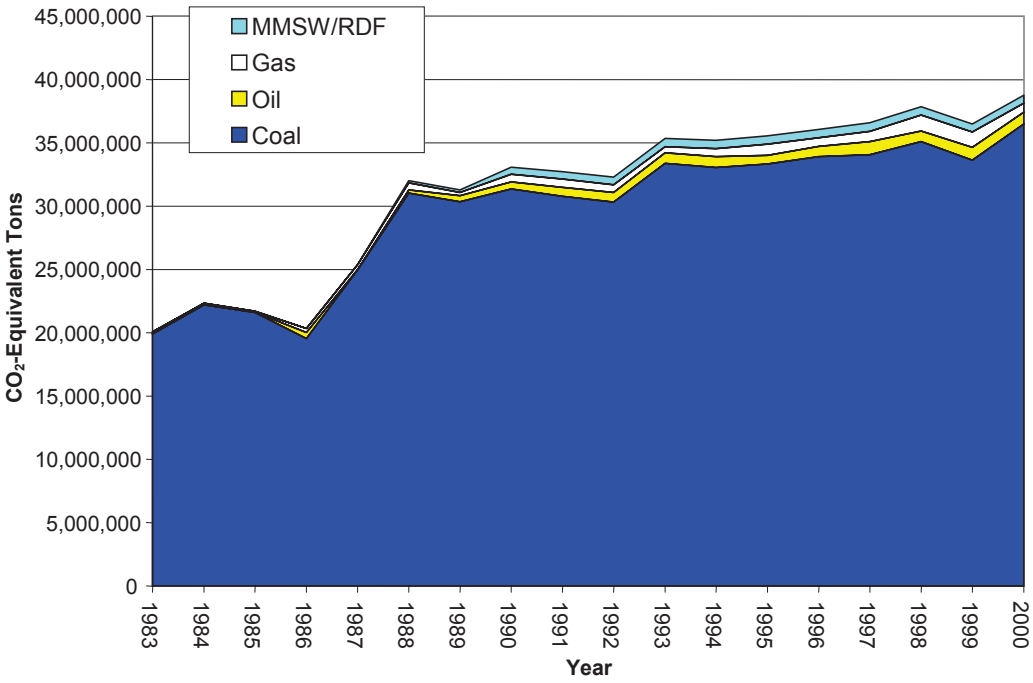


Figure 5.17 Greenhouse Gas Emissions from Electricity Generation in Minnesota



Primary inputs of energy to electric generation have increased more slowly than greenhouse gas emissions. This is due to the role of civilian nuclear power in electric generation in Minnesota, which was instituted in the early-to-mid 1970s and have not been expanded significantly since. Primary energy inputs to electric generation in Minnesota are shown in Figure 5.18. In terms of percentage distribution of primary energy inputs, coal combustion accounts for about 60 percent of primary inputs to electric generation in Minnesota, civilian nuclear power about 30 percent. The remainder derives from the combustion of petroleum coke, natural gas and solid waste in baseload steam turbine facilities and natural gas in gas-fired turbines.

A longer record of greenhouse gas emissions going back to 1970 is shown by gas in Figure 5.19. For the period 1970-1982, emissions are calculated using state-level fuel use data for the electric generation sector developed from surveys and emission rates for coal-fired, natural gas-fired and oil-fired generation capacity that were common for the mid-1980s. In the early 1970's, greenhouse gas emissions from electric generation in Minnesota were about 15 million tons, increasing two and one-half fold by 2000. Increased CO_2 emissions account for most of this.

The historic record of primary fossil fuel and wood inputs to electricity generation since 1970 is shown in Figure 5.20. Primary energy inputs have increased from about 200 million MMBtu in 1970 to about 380 million MMBtu in 2000. In the early 1970's, natural gas and oil accounted for more than one-third of all nonnuclear primary energy inputs to electric generation, coal about two-thirds. Today coal combustion accounts for about 95 percent of nonnuclear energy inputs.

Figure 5.18 Energy Input in Minnesota to Energy Production in the Electricity Generation Sector in Minnesota

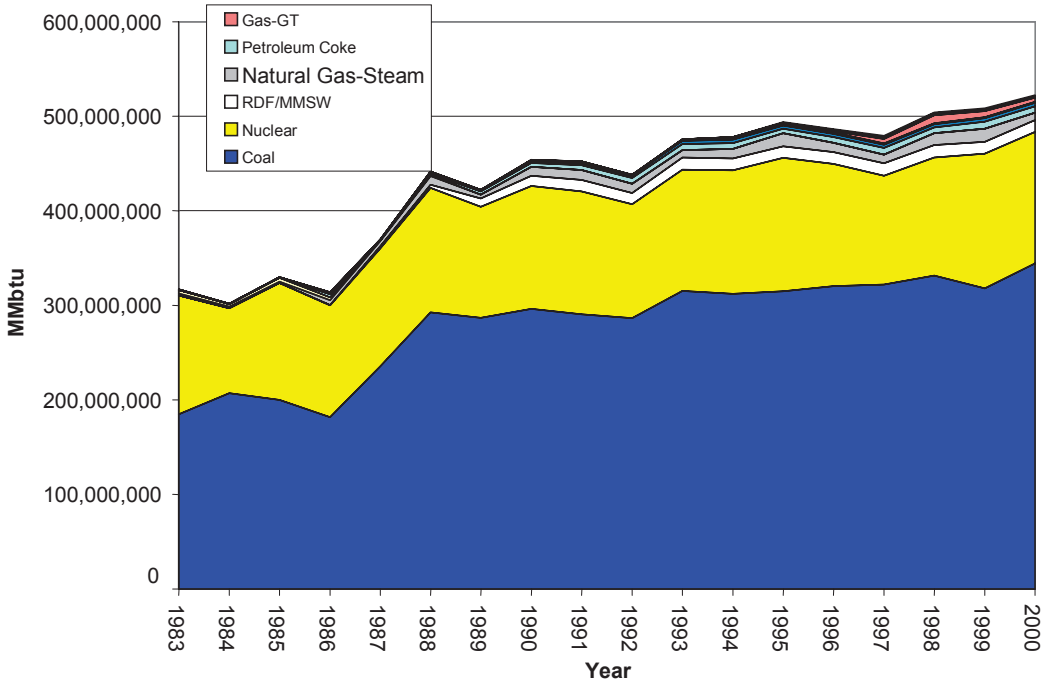


Figure 5.19 Greenhouse Gas Emissions from the Minnesota Electricity Generation Sector, 1970-2000

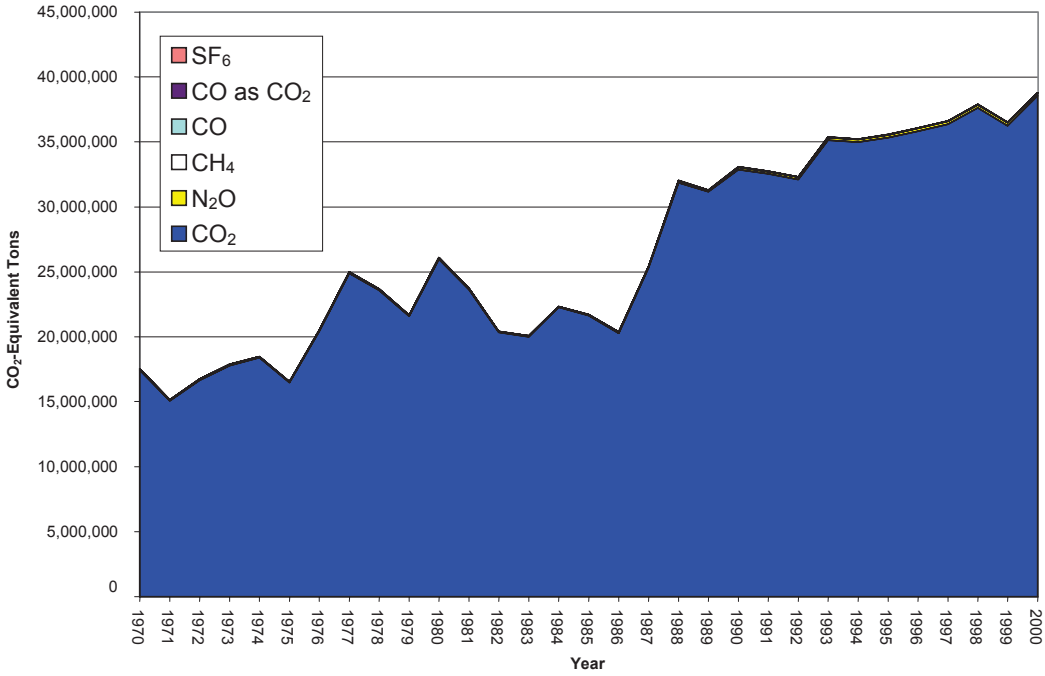
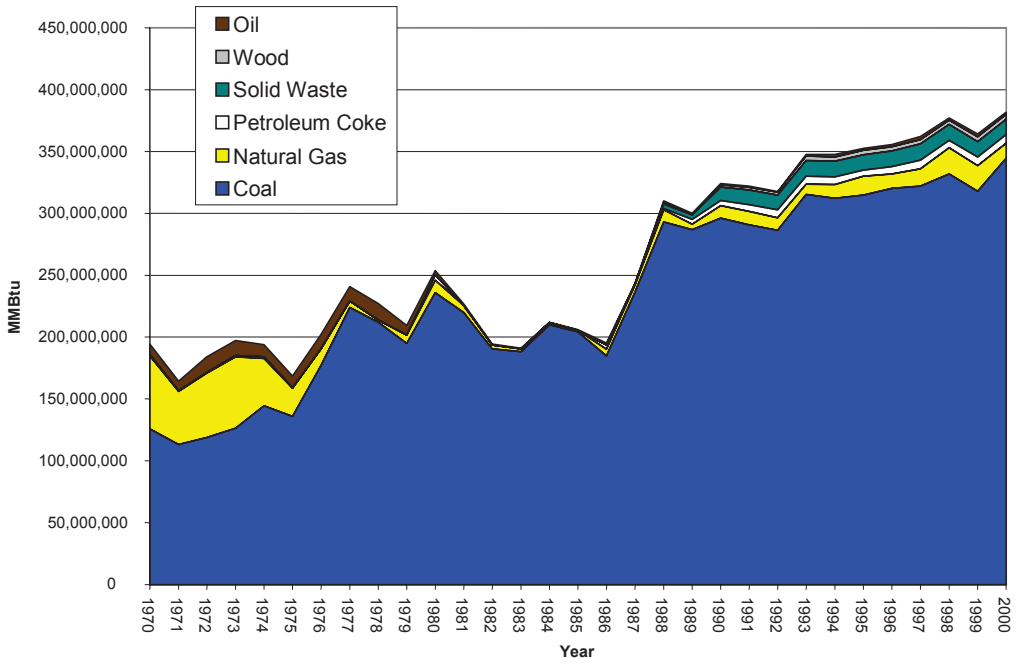


Figure 5.20 Primary Fossil Fuel and Wood Energy Input to the Electricity Consumption Sector in Minnesota



The long-term trend in emission rates in Minnesota per kilowatt-hour (kwh) of electric generation is shown graphically in Figure 5.21 for the period 1970-2000. About 1.6 CO_2-equivalent pounds of greenhouse gases are emitted to the atmosphere from Minnesota electric generating facilities per kwh of electricity generated. This is down from about 2 lbs. per kwh in the early 1970s, but up from about 1.3 to 1.4 lb. per kwh the middle 1970's, when civilian nuclear power became an important source of electric generation in Minnesota. Since the middle 1980's, and increased reliance on coal, emissions rates per kwh of generation have risen about 20 percent to the present 1.65 to 1.7 pounds per kwh.

Underlying the growth in greenhouse gas emissions from electricity generation is long-term growth in generation in Minnesota. The historical record of net generation in Minnesota going back to 1970 is shown in Figure 5.22.

The methods used to calculate current and historical greenhouse gas emissions were taken from U.S. EPA (1995) and IPCC (1998). Omitted from the emissions inventoried were those of SF_6 from the electric transmission and distribution system. This source probably contributes between several tens of thousands to several hundreds of thousands of tons of emissions to the inventory totals given above. The results shown above for CO_2 agree well with the independent but parallel record of CO_2 from large baseload and intermediate-load plants taken from the U.S. EPA's continuous emission monitoring system database.

Figure 5.21 Emissions of Greenhouse Gases from the Minnesota Electricity Generation Sector per Kilowatt-Hour of Electricity Generated

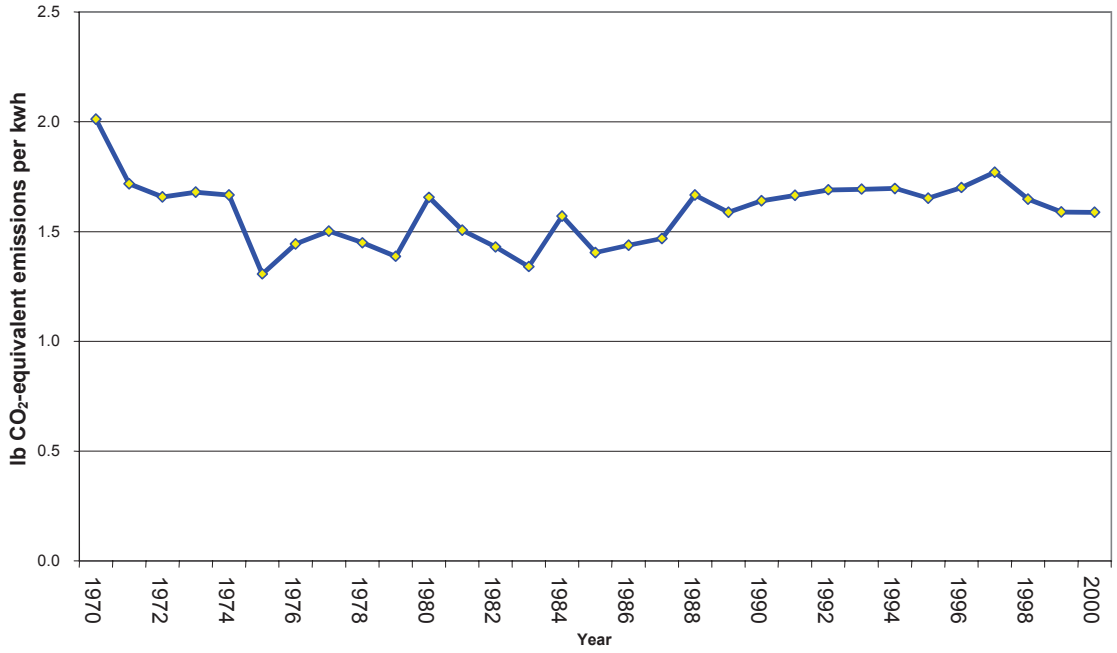
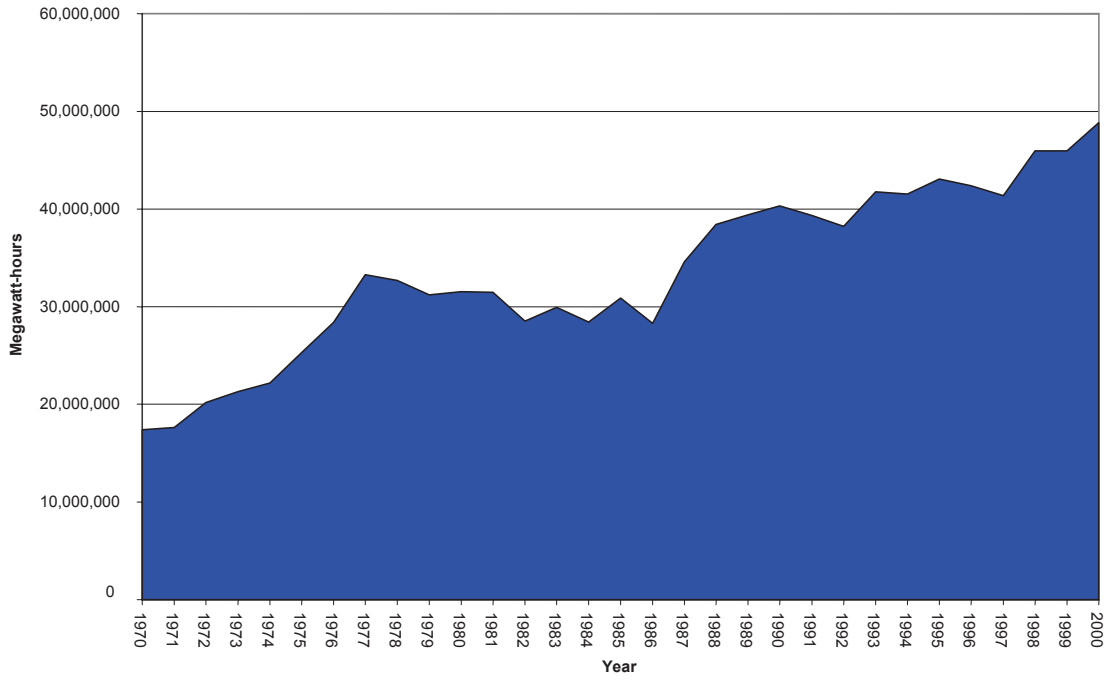
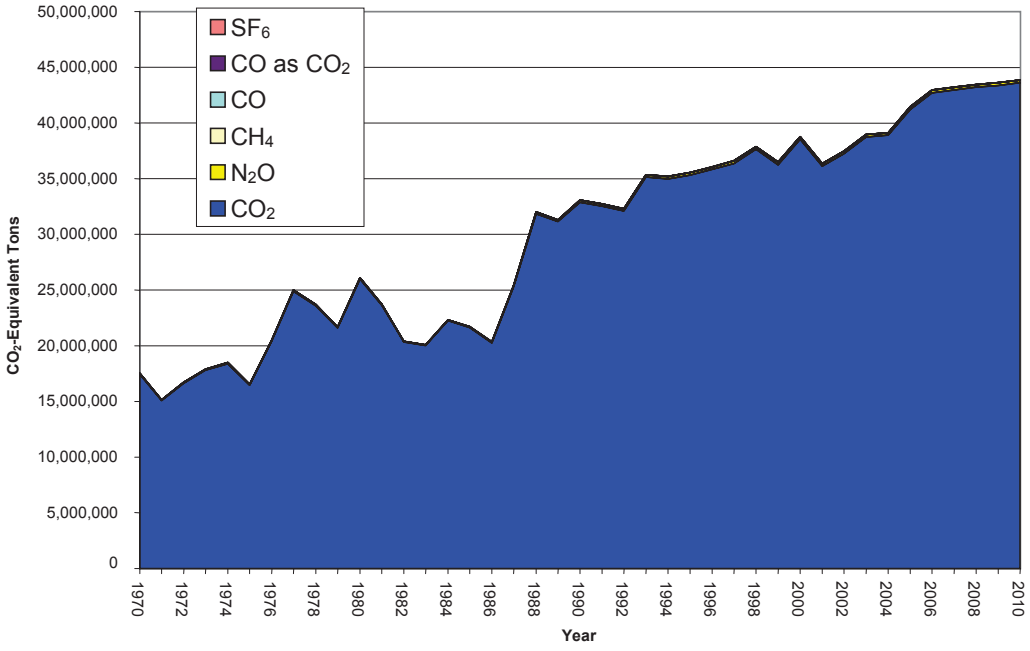


Figure 5.22 Net Generation of Electricity in Minnesota



In the future, greenhouse gas emissions from electric generation in Minnesota are expected to increase to about 44 million CO_2-equivalent tons, or about 15 percent. This is shown graphically in Figure 5.23. This derives both from enhanced utilization existing power plants and from the construction and operation of new plants.

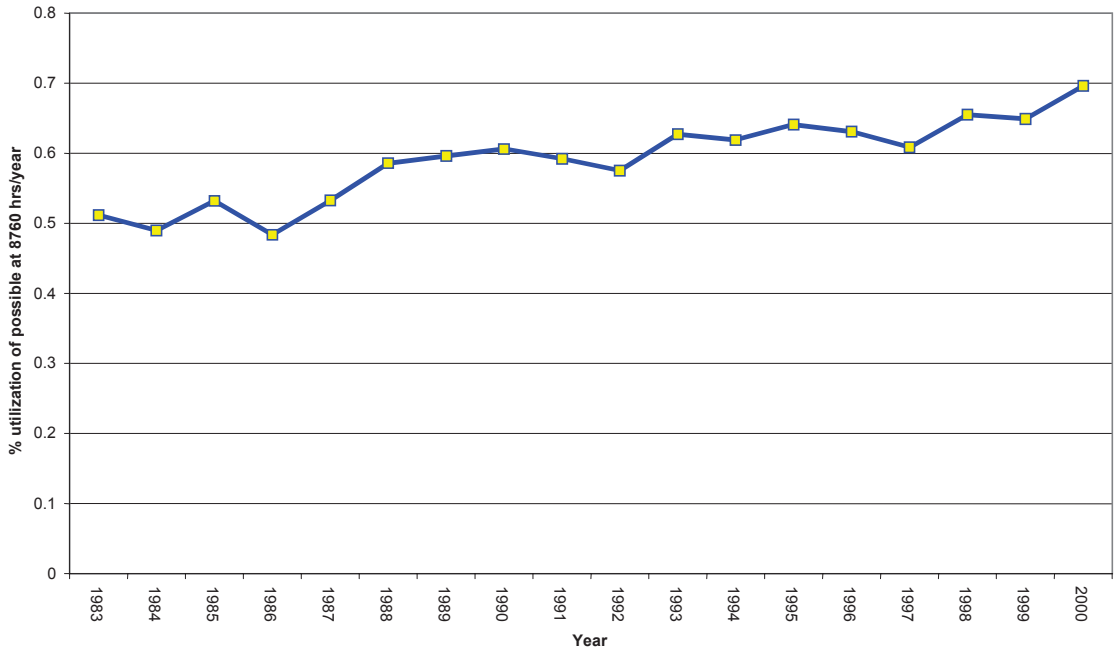
Figure 5.23 Historic and Forecasted Emissions of Greenhouse Gases from the Minnesota Electricity Generation Sector



The trend in utilization rates for large baseload and intermediate-load facilities is shown in Figure 5.24. Utilization rates have risen from about 50 percent in 1983 to about 70 percent in recent years. There appears to be room for a further increase of perhaps 5 percent.

Regarding installed electric generation capacity, about 9,500 MW of capacity currently are installed within the borders of Minnesota. Most analysts have projected that this total will increase, but there is debate about how much and what type of capacity will and should be added to the existing stock. In 1999, the Minnesota Department of Commerce (Commerce) forecast the need for 3,500 to 5,000 MW of new capacity between 2005 and 2010. It is now generally understood that this forecast probably overstated the need for new capactiy. Since the

Figure 5.24 Capacity Factor for Large Base- and Intermediate-load Electric Generation Units in Minnesota



Commerce forecast was developed, demand nationally has flattened, electricity prices on wholesale markets have plummeted, and a multitude of expansion projects, thought needed only a few years before, have been cancelled. Plans to build a new baseload coal-fired power plant in Minnesota have been shelved. Figure 5.25 shows the historic record for installed electric generation capacity in Minnesota going back to the early 1970s. Over that period, installed capacity increased about 3,500 MW or at a rate of 1,300 MW per decade.

Since Commerce made its forecast, roughly 1,500 MW of new capacity have been constructed or permitted for construction by state regulatory agencies. This alone would bring electric generation capacity in-line with what would be expected with a continuation of long-term historical trends. An additional 500 MW of new capacity has been proposed for the period out to 2010. Given the historic record of capacity additions, and prevailing market conditions, this added 2,000 MW is probably an upper limit of what reasonably constitute future capacity additions. Due to the economics of dispatch, this new capacity could be expected to operate at lower levels of utilization than existing plants, 45 to 60 percent of capacity for baseload and intermediate-load facilities.

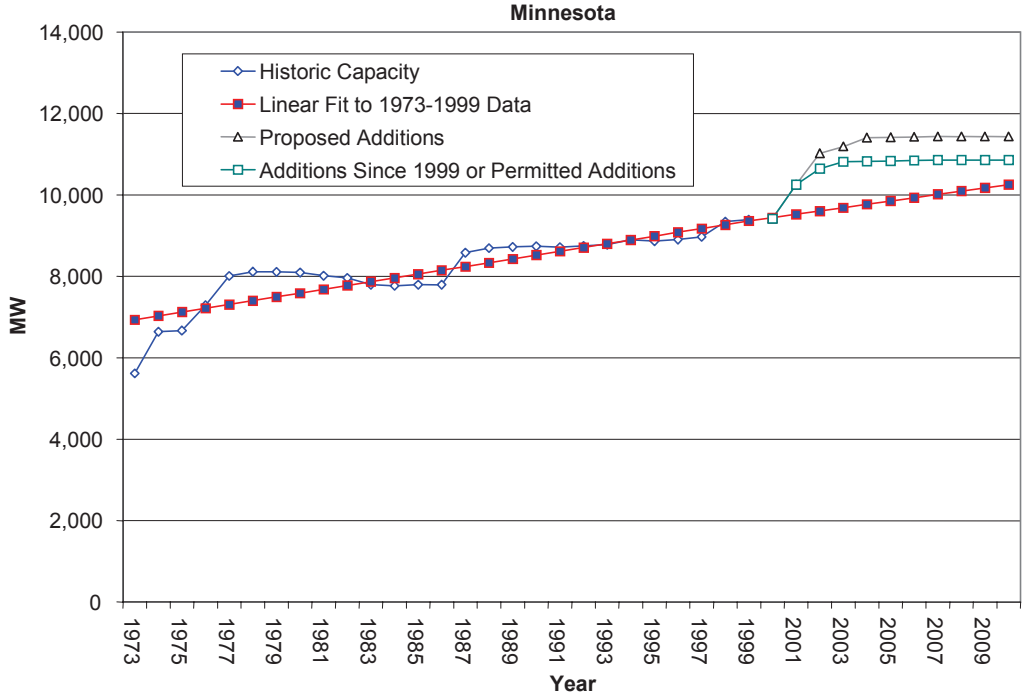
The forecasted trend in greenhouse gases shown in Figure 5.23 was developed assuming that:

1. all facilities currently under construction or in permitting are completed;
2. new natural gas-fired combined cycle turbines are operated as intermediate-load plants;
3. new coal-fired and other solid fuel-fired plants are operated as baseload plants at a 65 percent utilization rate;

4. and, future coal use at existing facilities follows the forecasts provided by the principal investor-owned utilities in the state in the Integrated Resource Plans.

It also allocates emissions from the Taconite Harbor plant to the electric generation sector following its purchase by Minnesota Power.

Figure 5.25 Historic and Forecasted Installed Summer Electricity Generation Capacity in Minnesota



Based on the forecast shown in Figure 5.23, greenhouse gas emissions grow at a rate of 1.3 percent per year to 44 million CO_2-equivalent tons by 2010. Most of the calculated emissions growth occurs between 2004 and 2005, when the bulk of the new facilities that are planned or under construction begin operation. Emissions from new facilities account for about one-third of the new emissions above present levels; the remainder comes from increased coal use at existing facilities.

Finally, it might be noted that Xcel Energy has proposed a repowering project at three of its metropolitan area plants that, if implemented, would lower annual emissions from these plants by about 2 million CO_2-equivalent tons. The repowering project, which would cost an estimated $1 billion, has yet to be considered or approved by the Minnesota Public Utilities Commission (PUC). Depending on PUC action, the emission reductions envisioned under the proposal might or might not be realized.

5.4 Agriculture

Agricultural emissions of greenhouse gases include: N_2O, CH_4, CO_2, and CO. CH_4 is produced through the decomposition of organic matter in oxygen-poor or anaerobic environments like those found in manure storage ponds, wild rice paddies, or the digestive tracts of animals, particularly ruminants like cattle. Small amounts of CH_4 also are emitted during the combustion of liquid petroleum fuels in agricultural machinery. Waterlogged agricultural soils can be another source of agricultural CH_4. Natural sources in Minnesota include wetlands, marshes and peat bogs.

CO_2 is produced during fossil fuel combustion. The liming of fields and the use of urea-based fertilizer result in the release of small amounts of CO_2 to the atmosphere. The erosion of topsoils from agricultural fields and the oxidation of soil organic matter in displaced soils also can be a source of CO_2.

N_2O is produced in soils and sediments by bacteria that reduce nitrites and nitrates to simple nitrogen compounds. Depending on soil conditions, those bacteria reduce nitrate to either N_2O or, through further reduction, to N_2, either of which is then emitted to the atmosphere. N_2O is also produced in soils during the nitrification of nitrogen, principally in an ammonium form, to nitrite and nitrate.

Sources of ammonium include ammonium-based fertilizers, like anhydrous ammonia, livestock manure, and atmospheric deposition of ammonium ion. Sources of nitrate can be direct or indirect. Nitrate is made available for N_2O-producing soil bacteria through the mineralization of organic forms of nitrogen, such as is found in livestock manure or incorporated crop residues. Small amounts of nitrate are added directly to soils as fertilizer in the form of ammonia nitrate. Larger amounts of nitrogen are fixed in a nitrate form by legumes like soybeans and alfalfa. Nitrification of ammonia-based fertilizers like anhydrous ammonia constitutes the largest single source of nitrate for use by soil bacteria. Mineral fertilizers of this type are applied in large amounts to raise soil fertility. Once added to soils, nitrogen undergoes multiple transformations, leading finally to the emissions of N_2O associated with nitrification and denitrification, as well as the emission of other nitrogen species like N_2 and NO_x.

Some N_2O is also produced in stored manure. Other minor sources include fuel combustion in internal combustion engines, and open burning of agricultural residues or forestry slash.

CO is formed through the incomplete combustion of fuels. As noted earlier, CO influences the rate of destruction of tropospheric ozone. Its global warming potential currently is estimated to be between 1 and 3 (below we conservatively utilize a value of one).

By gas, about one-half of all greenhouse gas emissions from Minnesota agriculture are in the form of N_2O, about one-third in the form of CH_4, and the rest are in the form of CO_2. By source, about one-third of emissions are associated with animal agriculture, a little less than one half result from nitrogen applications to agricultural soils, about one-tenth comes from energy use in agriculture, and the rest derives from a miscellany of sources.

The reconstructed trend in greenhouse gas emissions from agricultural activities in Minnesota going back to 1970 is shown in Figures 5.26 and 5.27 by gas and by source, respectively. In 2000, agricultural activities are estimated to have resulting in the emission of about 22 million CO_2-equivalent tons of greenhouse gases to the atmosphere. This is down slightly from peak years of emission in 1996 and 1997. A prior peak was reached in the late 1970s, followed by a decline until the late 1980's and early 1990's, and recovery to 1996/7. Taken as a whole, the 1990's saw emission levels that were elevated above those of the two preceding decades, but only marginally.

Figure 5.26 Greenhouse Gas Emissions from Minnesota Agriculture –By Gas

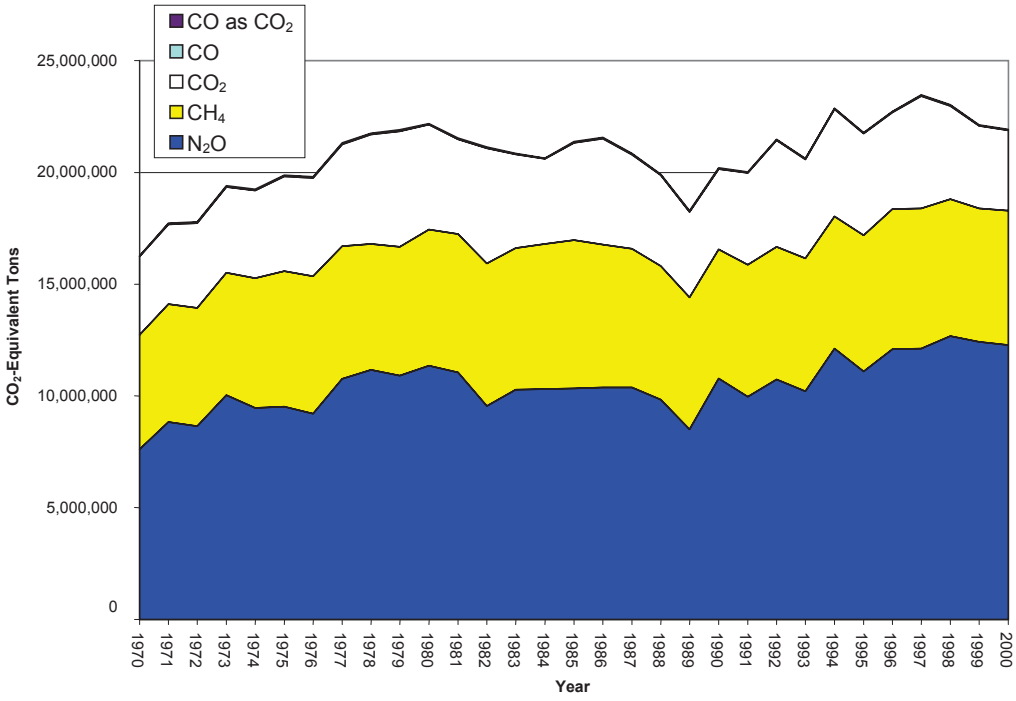
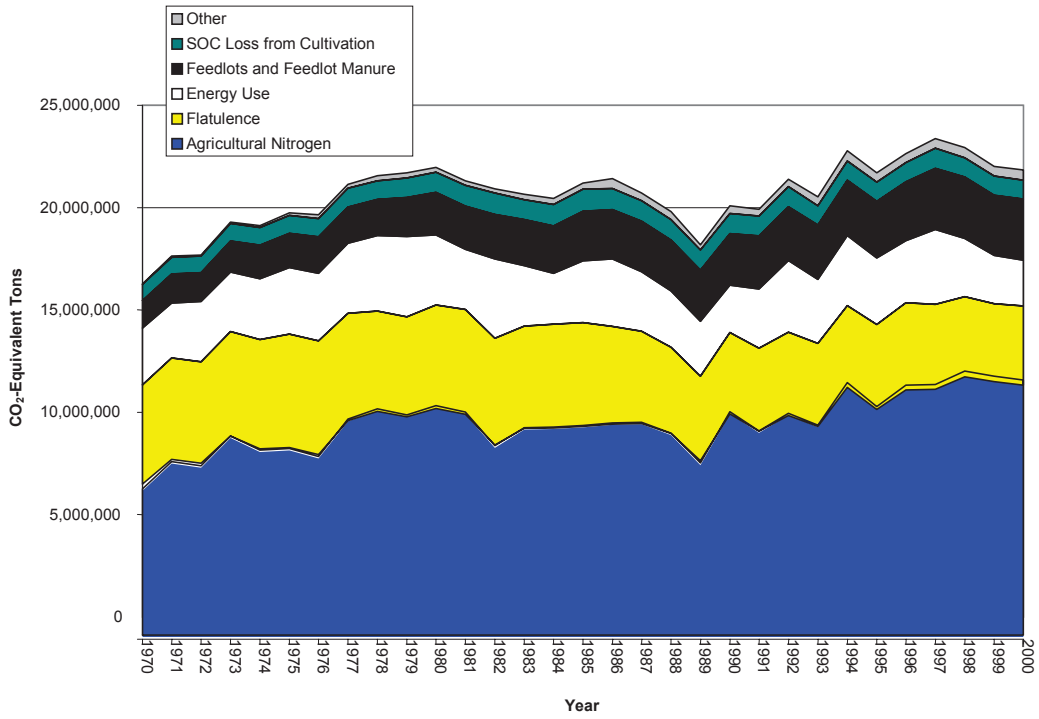


Figure 5.27 Greenhouse Gas Emissions from Agriculture in Minnesota - By Source



Greenhouse gas emissions from agriculture result from crop production and animal husbandry. The respective trends in greenhouse gas emissions from these two subsectors going back to 1970 are shown in Figures 5.28 and 5.29. Emissions from crop production, now about 15 million CO_2-equivalent tons, experienced two periods of rapid run-up of emissions, 1970-1980 and 1993-2000, with a period of slow decline interspersed between. By contrast, emissions from the livestock sector have been relatively flat at about 7 million CO_2-equivalent tons. Large reductions in emissions from flatulence in livestock, particularly cattle, have been off-set by proportionally larger increases in emissions from feedlot manure storage.

Soil nitrogen applications constitute the dominant source of greenhouse gas emissions from crop production. 2000 emissions were about 10 million CO_2-equivalent tons, up from about 5 million tons in 1970 and 9 million tons in 1990. The corresponding trend in nitrogen inputs to soils and water over this same period is shown in Figure 5.30. Fertilizer and crop residues constitute the two largest sources of nitrogen in Minnesota. Legumes are also a large source of nitrogen into soils. Nitrogen run-off from fertilizer and manure is a smaller calculated source of nitrogen input to the biosphere. Atmospheric deposition is a small source. Total annual inputs of nitrogen to soils and waters in the state are an estimated 1.85 million tons.

Figure 5.28 Greenhouse Gas Emissions from the Production of Field Crops in Minnesota

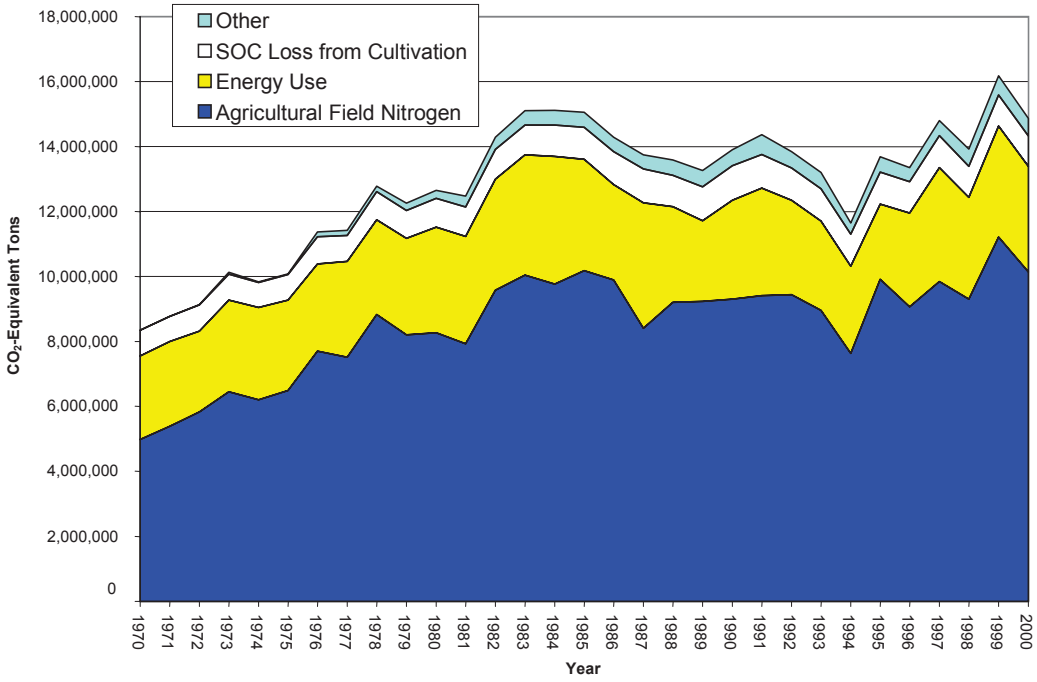


Figure 5.29 Greenhouse Gas Emissions from Animal Agriculture in Minnesota

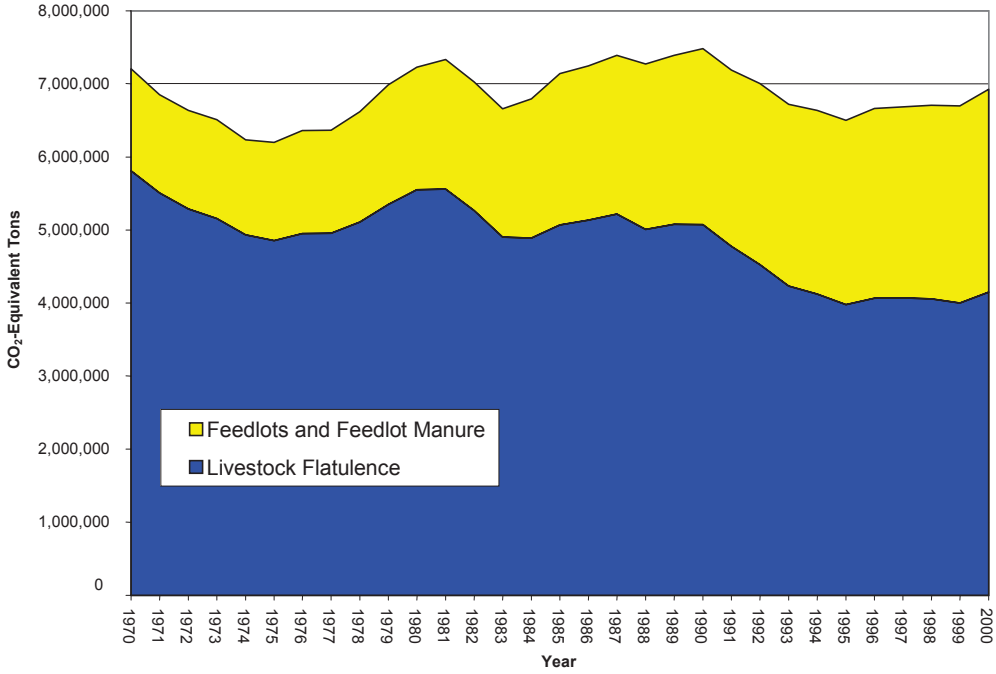
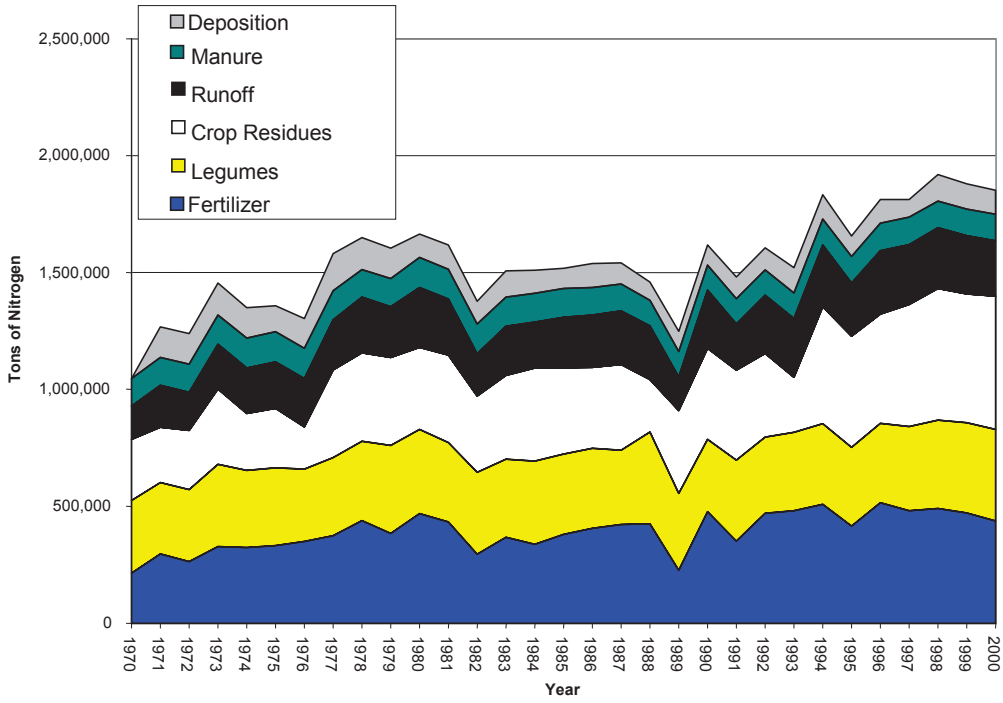


Figure 5.30 Agricultural Inputs of Nitrogen to Soils and Waters in Minnesota



About 60 percent of greenhouse gas emissions from animal husbandry derive from livestock flatulence. Flatulence results in the emission of about 4 million CO_2-equivalent tons of emissions per year. Due to the peculiar digestive tract of cattle, as well as animal size, these are dominated by emissions from beef cattle and milk cows. This is shown graphically in Figure 5.31. Due to the decline of the Minnesota dairy and beef industry, emissions of greenhouse gases from livestock flatulence have declined consistently between 1970 and 2000. Further contraction is expected as the centers of national milk production continue to shift to western and southern states. The overall trends in the number of farms animals between 1970 and 2000 is shown in Figure 5.32 by animal type in animal units (1 animal unit = 1 1000 lb. cow).

By contrast, since 1970 emissions of greenhouse gases from stored manure have almost doubled. Emissions of methane have increased by an estimated 7- to 8-fold from a relatively small value to 2 million CO_2-equivalent tons, while emissions of N_2O have decreased about 15 percent, from about 1.1 to about 0.9 million CO_2-equivalent tons. The large increase in CH_4 emissions was due to changes in the way in which manure is managed in Minnesota. In the early 1970's, most manure was managed as a solid. Since then, longer-term storage of manure in a liquid or slurry form has become the norm. In a solid form, manure generates relatively little methane. However, in a liquid or slurry form, in which anaerobic conditions dominate, livestock manure generates large amounts of CH_4.

Approximate trends in emissions from livestock manure are shown in Figures 5.33 and 5.34 for CH_4 and N_2O, respectively. The associated 30-year trend in manure production is shown in Figure 5.35.

Figure 5.31 Methane Emissions from Livestock Flatulence in Minnesota

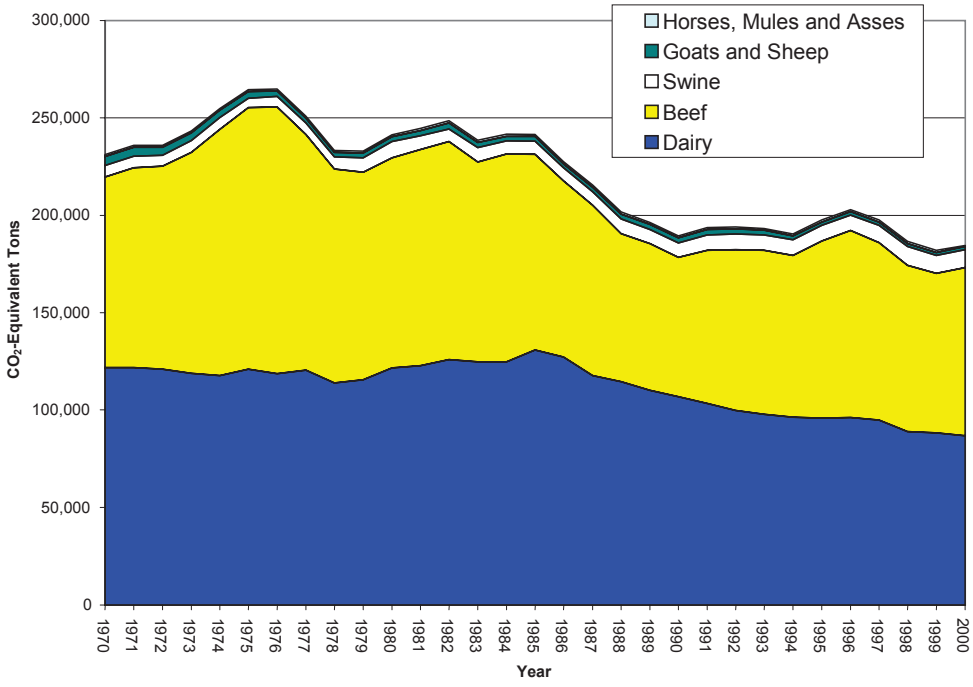


Figure 5.32 Livestock on Minnesota Feedlots

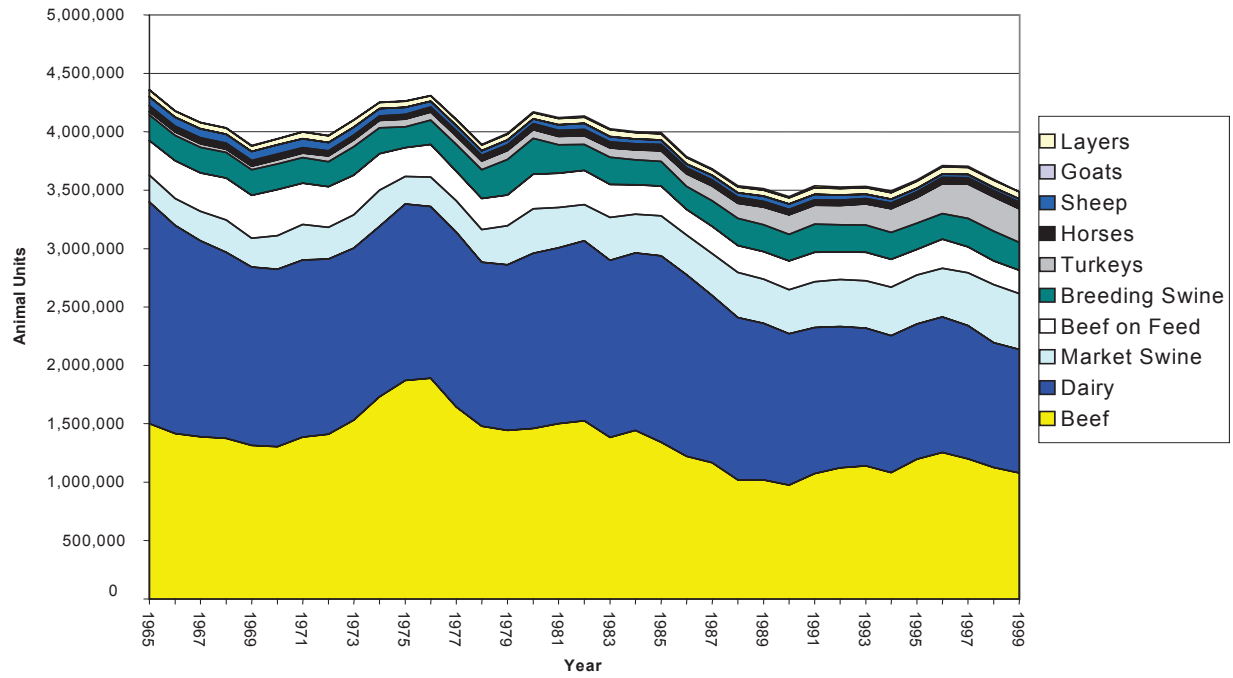


Figure 5.33 Methane Emissions from Manure Storage at Minnesota Feedlots and Farms

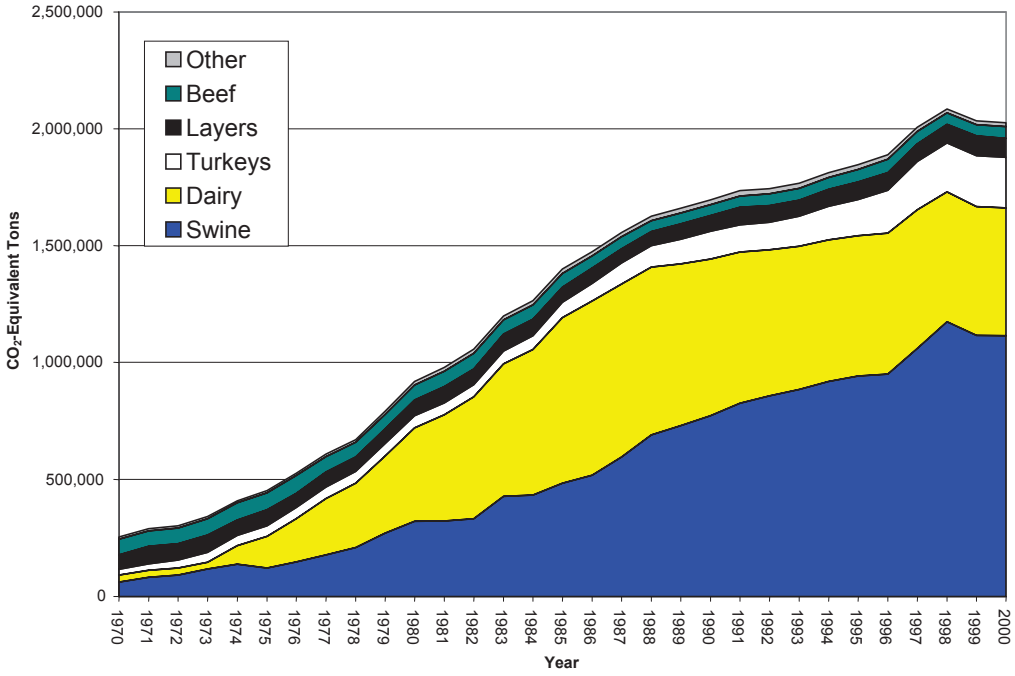


Figure 5.34 Nitrous Oxide Emissions from Minnesota Feedlots

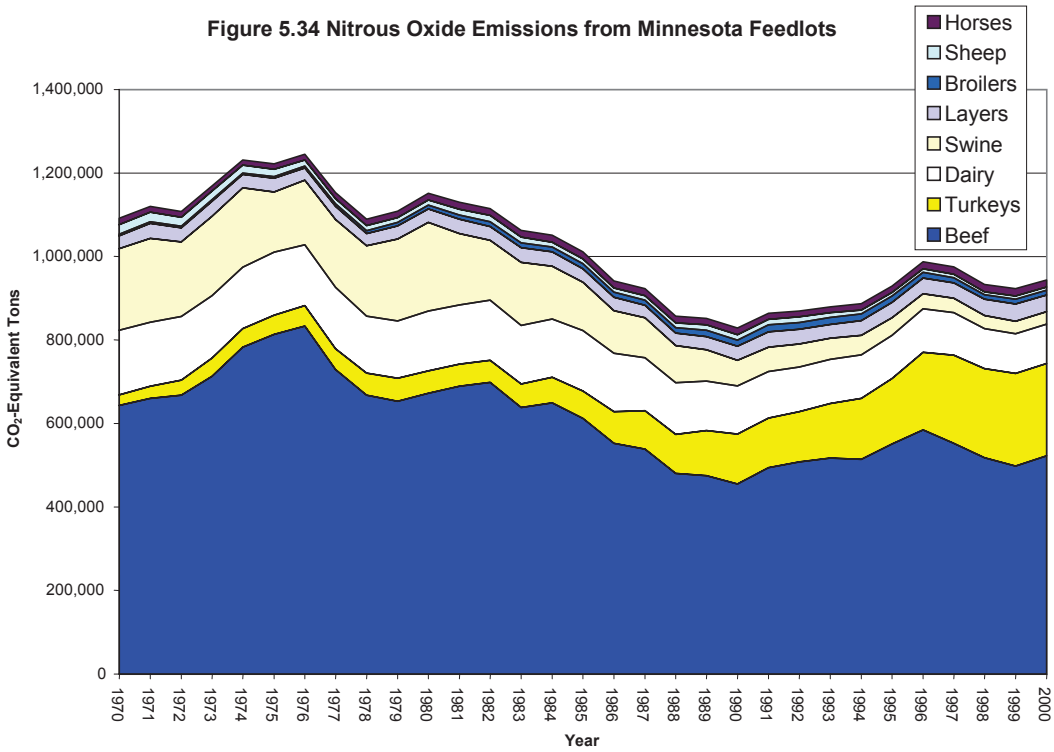
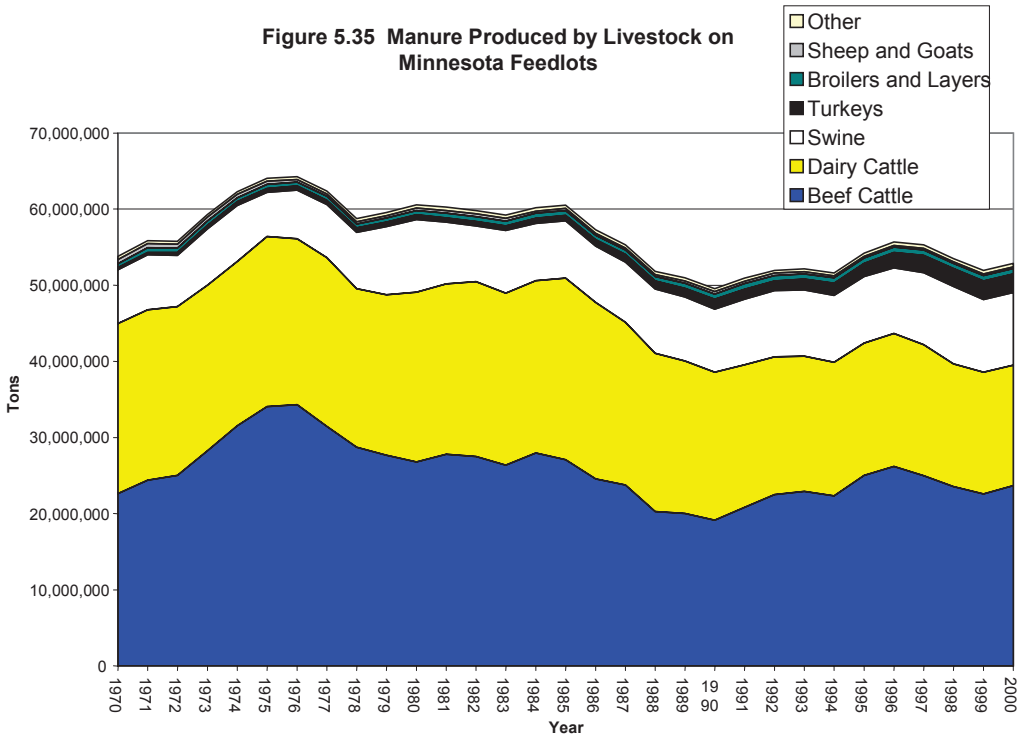


Figure 5.35 Manure Produced by Livestock on Minnesota Feedlots



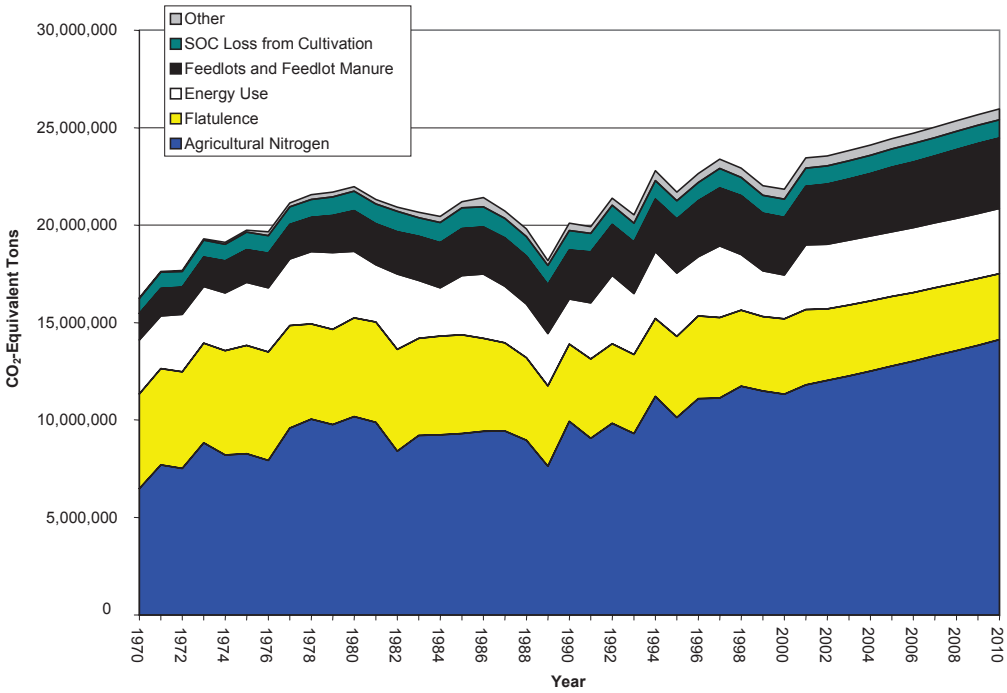
The methods used to calculate emissions were taken from USEPA (1995), IPCC (1998), USEPA (2001), and USDOE (1998). The emission of CO_2 urea applications was calculated on the basis of the carbon content of the fertilizer by weight, and an assumed emission in the year of application. CO_2 releases from soil erosion were calculated on the basis of an assumed 5 percent loss of carbon from eroded soils.

Not treated in this emission inventory are emissions of CO_2 from following cultivation, particularly of highly organic wet mineral soils, and emissions of CH_4 avoided from the draining of wetlands and waterlogged fields.

Forecast emissions from the agricultural sector are shown graphically in Figure 5.36. Emissions from livestock husbandry are forecast on the basis of livestock numbers and historical trends in animal liveweight. Forecast livestock numbers are developed from long-term trends in on-farm numbers of each livestock type, in liveweight produced, or both. From these are derived annual levels of production of livestock manure, manure nitrogen and volatile solids. Emissions are calculated from forecast levels of production of volatile solids and manure nitrogen or, in the case of flatulence emissions, animal numbers adjusted for projected changes in liveweight. It is assumed that for all livestock types other than diary cattle, current management practices remain constant from the present. For dairy cows, the long-term trend away from labor-intensive daily scrape-and-haul systems is assumed to continue, in favor of longer-term storage in outdoor liquid/slurry pits, ponds, tanks or basins and lagoons.

Emissions from crop production are forecast assuming a continuation of historic trends in per acre commercial fertilizer applications, per acre dry matter productivity, and acreage committed

Figure 5.36 Historic and Forecasted Greenhouse Gas Emissions from Minnesota Agriculture



to leguminous crops like soybeans and alfalfa. Total cultivated acres are assumed to remain constant at 20.8 million acres. Per acre atmospheric deposition of nitrogen is assumed to decrease slightly from the present. Manure nitrogen inputs to soils, calculated from forecast livestock populations, increase less than 5 percent; atmospheric deposition of nitrogen to soils is assumed to decline slightly from the present. CO_2 emissions from farm energy use are calculated on the basis of historic fuel inputs to different farm activities from Tiffany and Fruin (1998).

Based on these assumptions, greenhouse gas emissions over the forecast period increase to 26 million CO_2-equivalent tons. Over the forecast period, emissions increase at an annual rate of 1 percent per year. Most of the increase result from increasing nitrogen inputs to soils from fertilizers, manure, and crop residues. N_2O emissions from these sources continue their long-term trajectory of increase evident in the record since the early 1980's. Flatulence emissions continue to decline, again continuing trends in play for several decades. CH_4 emissions from manure storage increase, but only marginally effect the overall trend in emissions from agriculture.

Underlying trends in livestock numbers and manure production are shown in Figures 5.37 and 5.38. Forecasted trends in nitrogen inputs to agricultural soils are shown in Figure 5.39. All continue pre-existing trends.

Figure 5.37 Historic and Forecast Number of Flatulating Livestock on Minnesota Feedlots

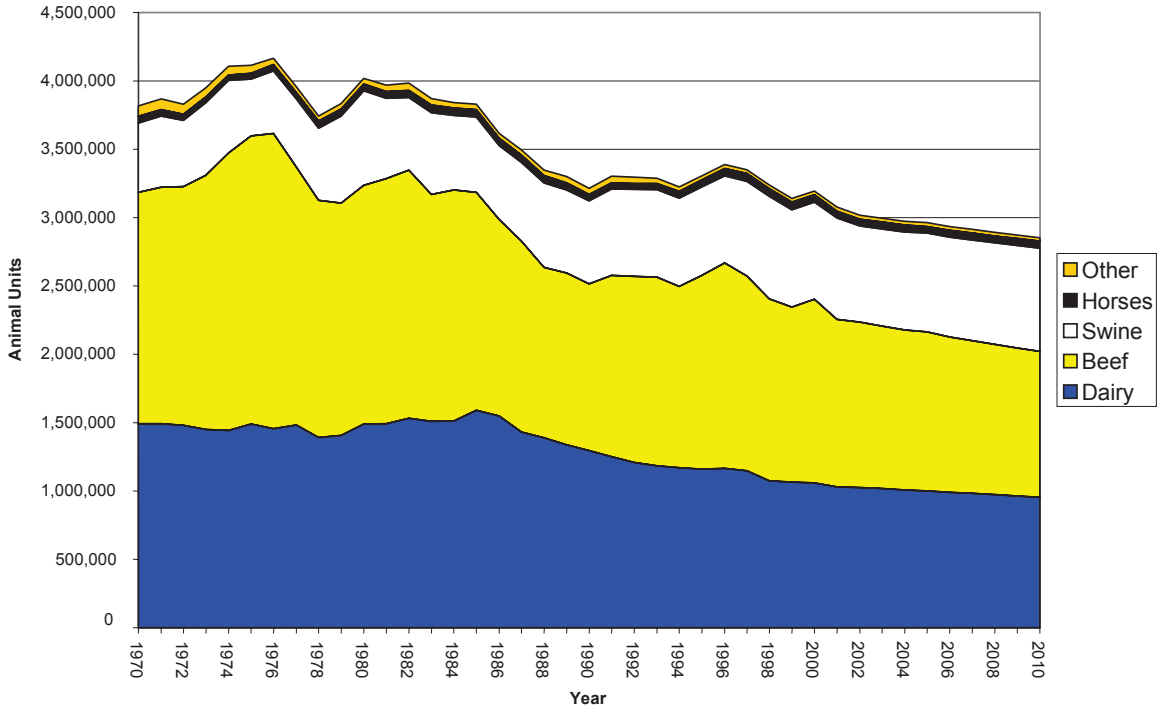


Figure 5.38 Historic and Forecasted Livestock Production of Manure in Minnesota

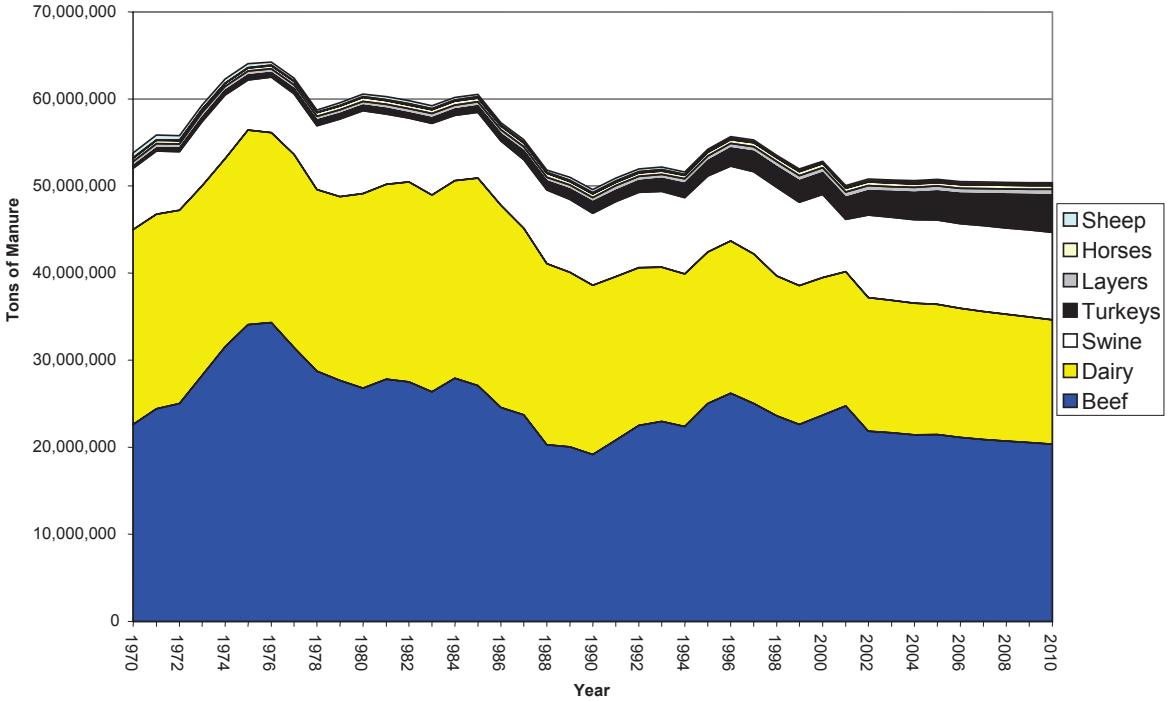
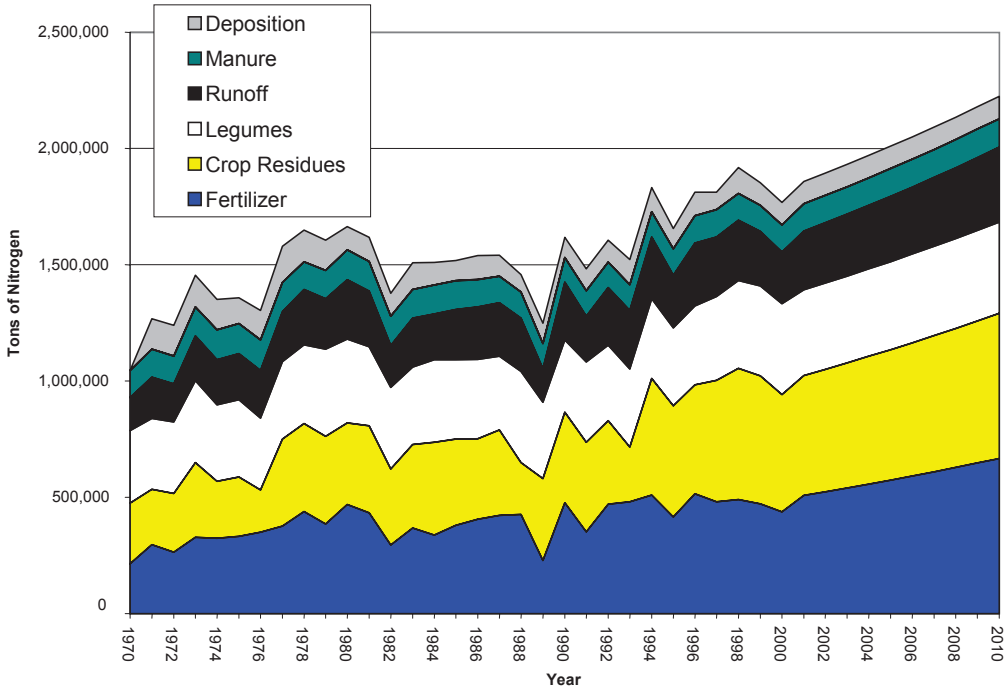


Figure 5.39 Historic and Forecasted Nitrogen Inputs to Soils and Water in Minnesota

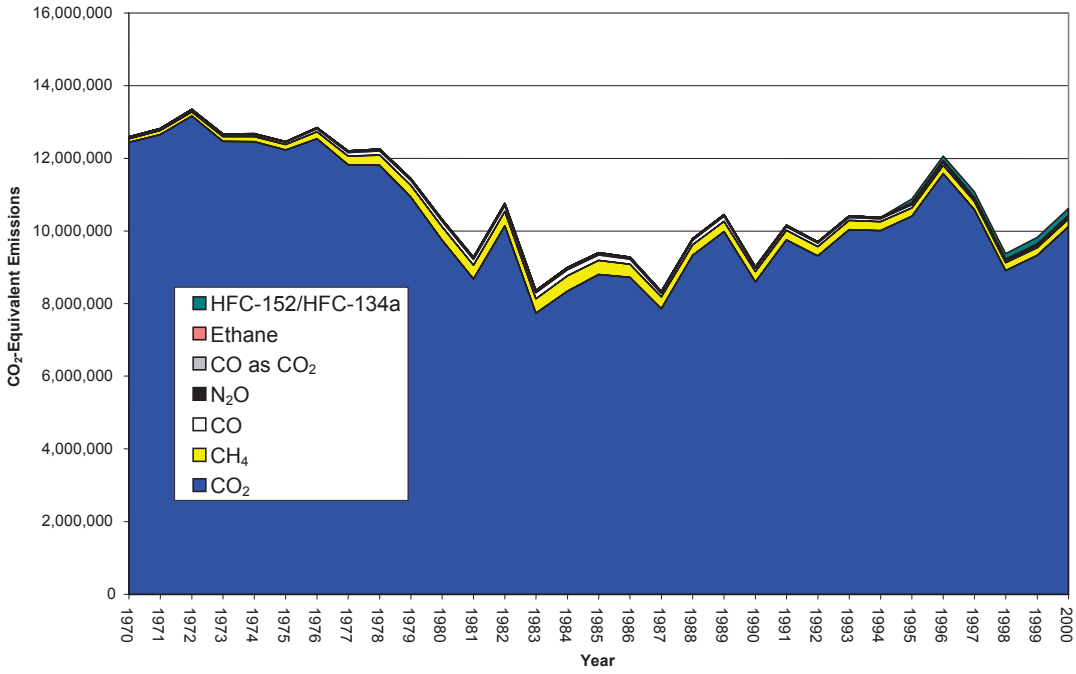


5.5 Residential Sector

Greenhouse gas emissions from the Minnesota residential sector derive principally from fossil fuel combustion, mostly natural gas and liquid petroleum heating fuels. Most of these are in the form of CO_2, although small amounts of N_2O, CO and ethane, a weak greenhouse gas, are emitted upon the combustion of fossil fuels. Other greenhouse gases emitted from the Minnesota residential sector include: CH_4, which in the Minnesota residential sector is produced principally during wood combustion, and HFC-152a and HFC-134a, which are used as aerosol propellants and released upon use. A small amount of CO_2 is also added to the atmosphere annually from the oxidation in the atmosphere of CO released during fossil fuel combustion.

10.7 million CO_2-equivalent tons of greenhouse gases annually are emitted to the atmosphere from the Minnesota residential sector. The estimated trend in emissions since 1970 is shown in Figure 5.40. Emissions declined dramatically between 1970 and 1982, by about one-quarter, but have since trended upward at a rate of about 1.5 percent per year.

Figure 5.40 Emissions of Greenhouse Gases from the Minnesota Residential Sector



Since 1970, natural gas has come to dominate fuel use in the residential sector. As of 2000, about 70 percent of all fuel use in the residential sector was natural gas-based, up from about 50 percent in 1970. Natural gas is the lowest emitting of the fossil fuels. The combustion of natural gas releases about 25 percent less CO_2 per unit of energy released as does the combustion of distillate fuel oil. This largely accounts for the roughly one-fifth reduction in greenhouse gas emissions from the residential sector from 1970 to the present. Trends in greenhouse gas emissions by fuel type and in residential fuel use in the Minnesota residential sector are shown in Figures 5.41 and 5.42, respectively.

The trend in residential fuel use since 1970 for different energy end-use applications is shown in Figure 5.43. The corresponding trend in greenhouse gas emissions is shown in Figure 5.44. Approximately 70 percent of fuel used in the Minnesota residential sector is committed to space heating; most of the rest is committed to water heating applications. Greenhouse gas emissions are similarly distributed among applications (see Figure 5.44).

Figure 5.41 Greenhouse Gas Emissions from the Minnesota Residential Sector by Fuel and Activity Source

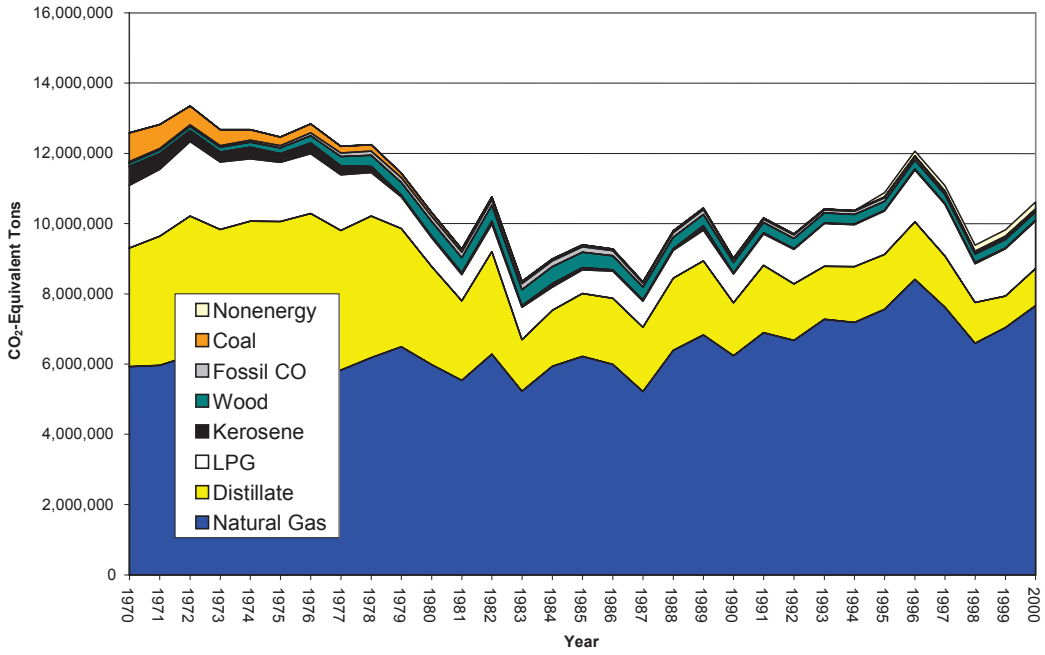


Figure 5.42 Nonelectric Energy Use in the Minnesota Residential Sector

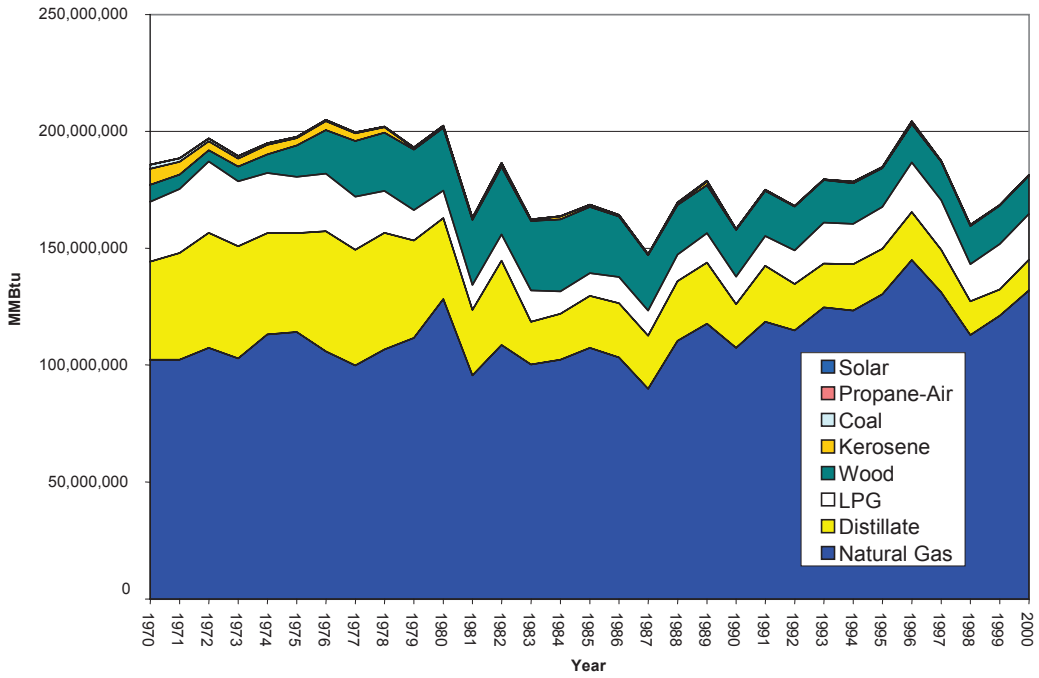


Figure 5.43 On-Site Fossil Fuel and Wood Use in the Minnesota Residential Sector

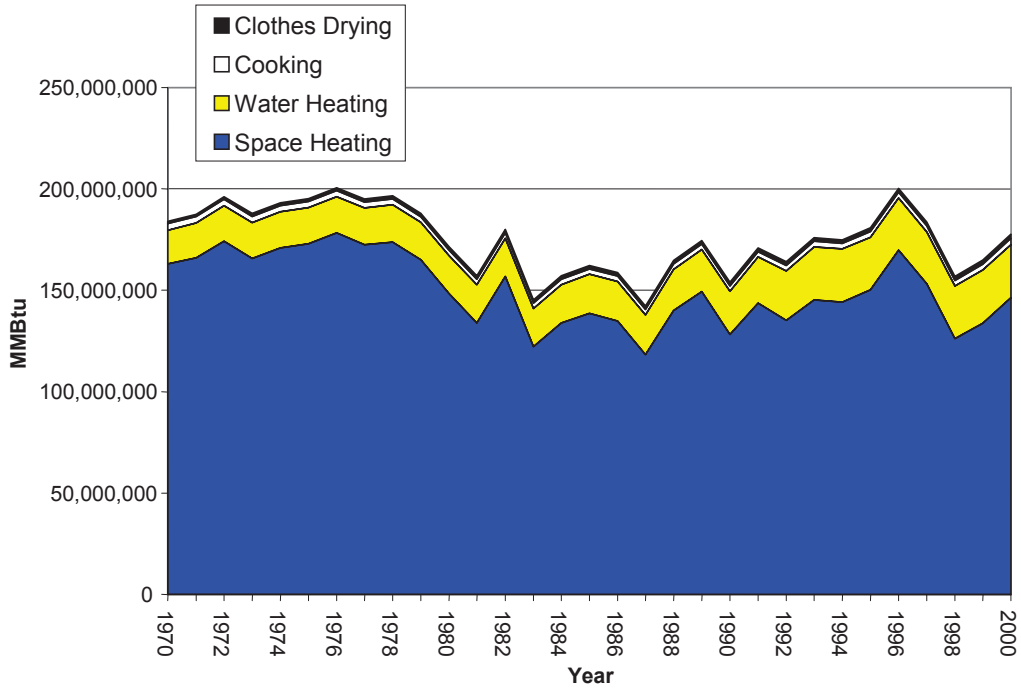
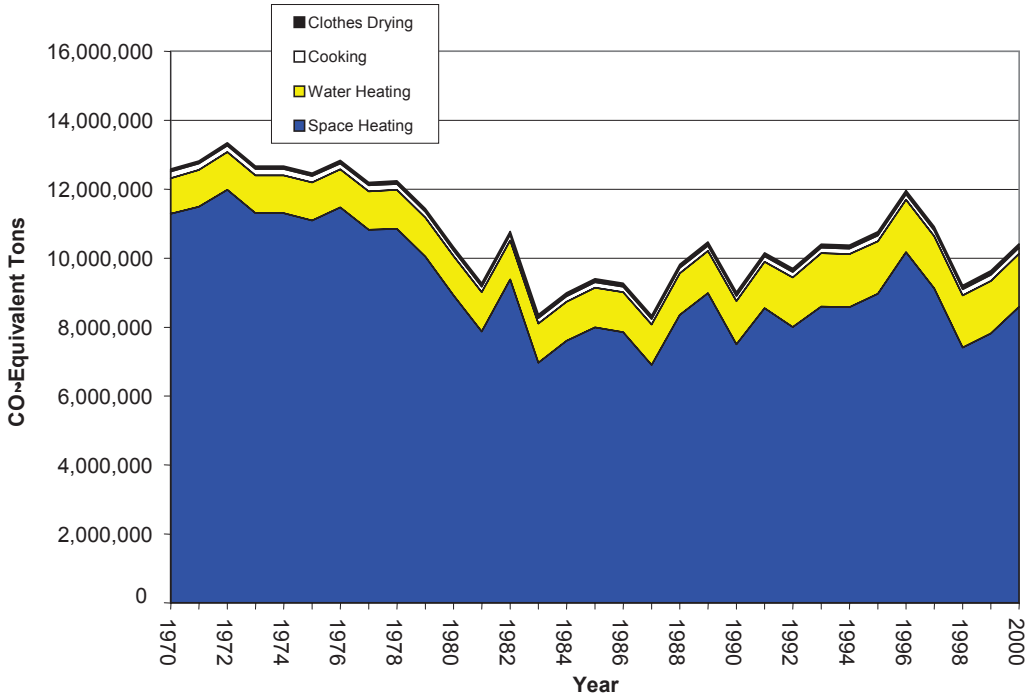
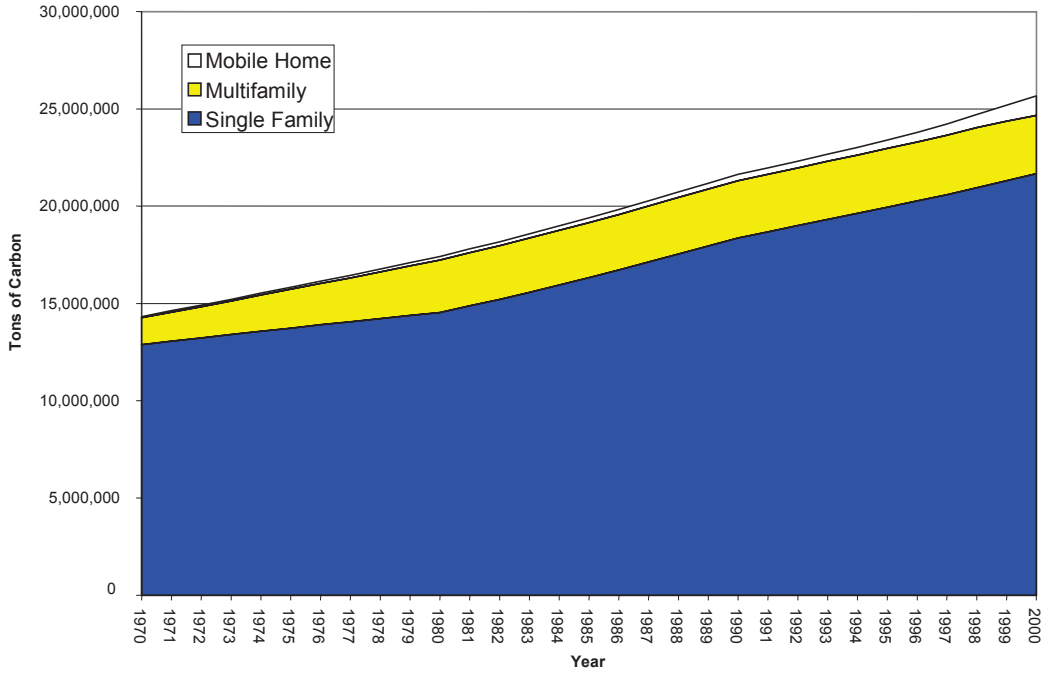


Figure 5.44 Estimated Emissions of Greenhouse Gases from Residential Fuel Use in Minnesota by End-Use



Large amounts of carbon are stored in the structural parts and other wooden components of housing. Approximately 15 tons of carbon is stored in the typical single family residence in Minnesota. As of 2000, an estimated 26 million tons of carbon was stored in all residences in Minnesota, up from about 14 million in 1970. This is shown graphically in Figure 5.45. About 400,000 tons annually of carbon is placed into long-term storage in the residential housing sector in the form of the wooden components of housing, offsetting about 1.5 million CO_2-equivalent tons of greenhouse gas emissions from other sources.

Figure 5.45 Tons of Carbon Stored in the Structural Parts of Minnesota Housing



The methods used to estimate current and past greenhouse gas emissions from the Minnesota residential sector were taken from USEPA (1995) and IPCC (1998). Aerosol uses and emissions of HFC-134a/HFC-43-10mee were calculated on a per capital basis. Per capita usage and emissions of HFC-134a/HFC-152a were taken from USEPA (2001). All major emissions sources were treated. Small emission sources that were not treated include: yard chemical usage, HFC-134a/HFC-43-10mee emissions from insulating foams, HFC-134a from home central air conditioners, and home solvent usage. Emissions of HCFC-22 from room air conditioners, CFC-12 from home refrigeration and central air conditioning, and CFC-11 and HCFC-141b from home insulating foams are likely to of an interesting size, but, as non-UNFCCC gases, are not inventoried in Minnesota.

Over the next ten years, greenhouse gas emissions are expected to increase by about 15 percent. The expected trend is shown graphically in Figure 5.46 by fuel end-use application. Emissions from space heating are forecast on the basis of forecasted total heated floor space in the Minnesota residential sector and trends in energy intensity of space heating per square foot of

heated floor space. The 30-year mean for population-weighted heating degree days for Minnesota is assumed. The water heating, clothes drying and cooking components of the forecast were derived from analyses of trends in Minnesota population, household formation, and available housing type, as well as trends in the intensity of energy use for each application developed at a national level. The trend in weather-adjusted energy intensity of space heating in Minnesota is shown graphically in Figure 5.47.

The trends in floor space in the housing sector in Minnesota since 1970 is shown graphically in Figure 5.48. The estimated amount of floor space in Minnesota residences is some 3.5 billion square feet.

Primary energy use is forecast to increase by 15 percent from 2000 to 2010, giving rise to the estimated 15 percent increase in greenhouse gas emissions shown in Figure 5.46.

Figure 5.46 Historic and Forecasted Greenhouse Gas Emissions from the Residential Sector in Minnesota

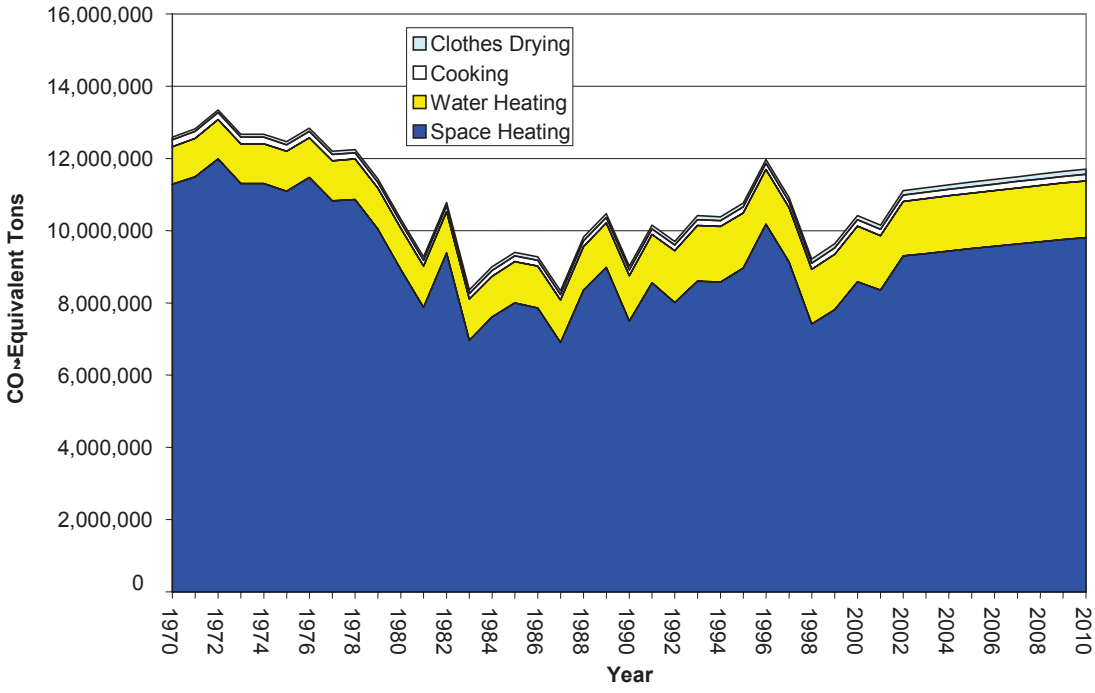


Figure 5.47 Estimated Trend in Energy Intensity of Nonelectric Space Heating in Minnesota

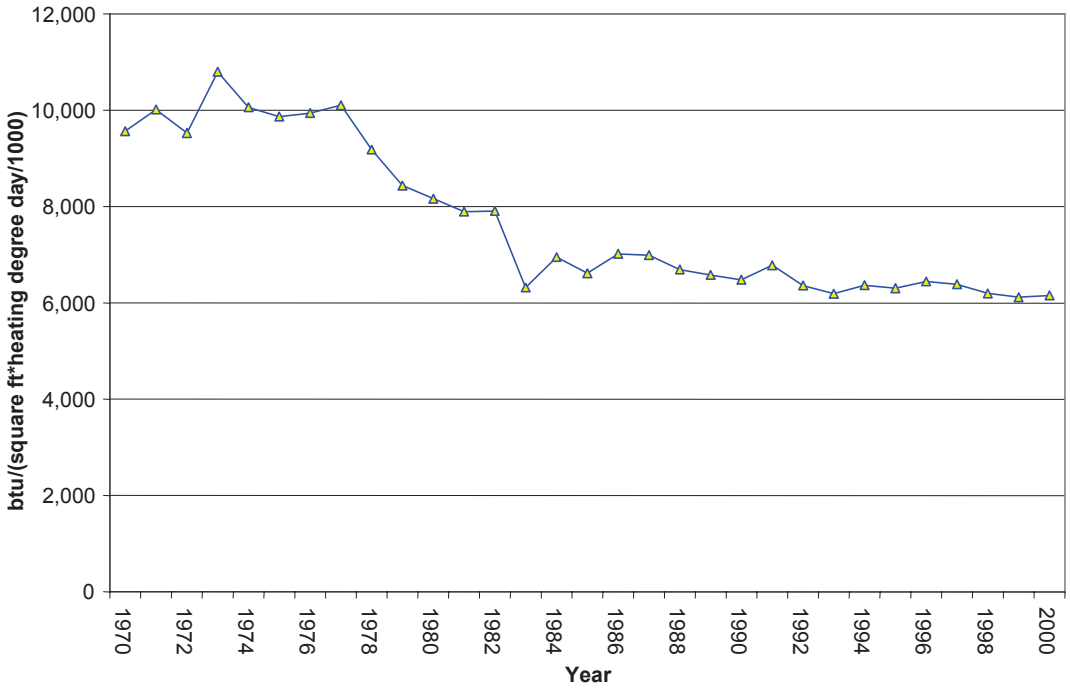
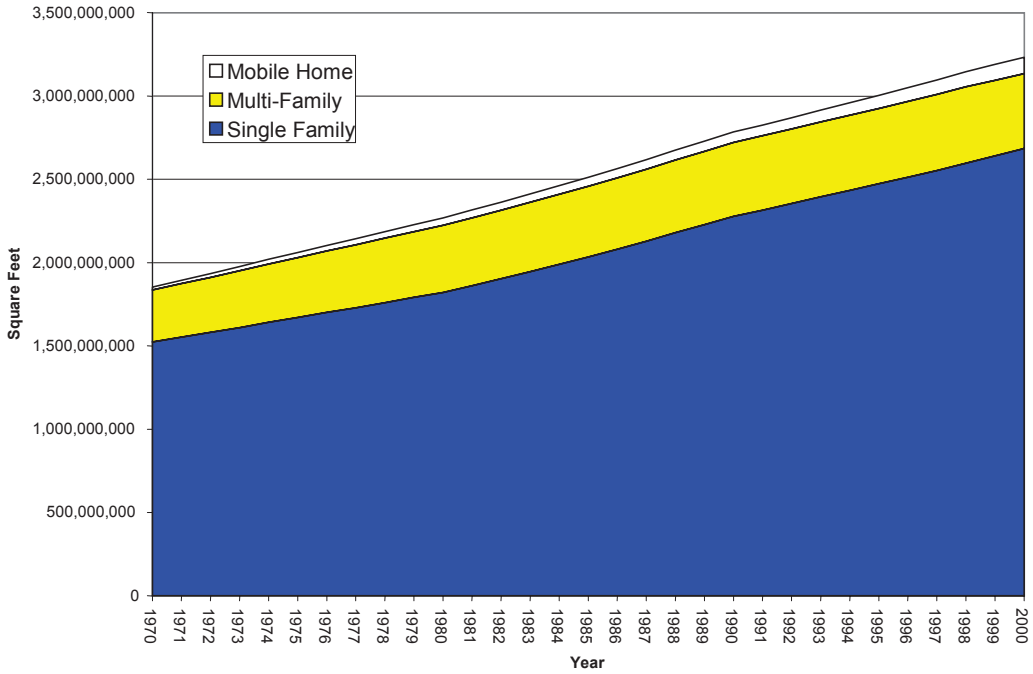


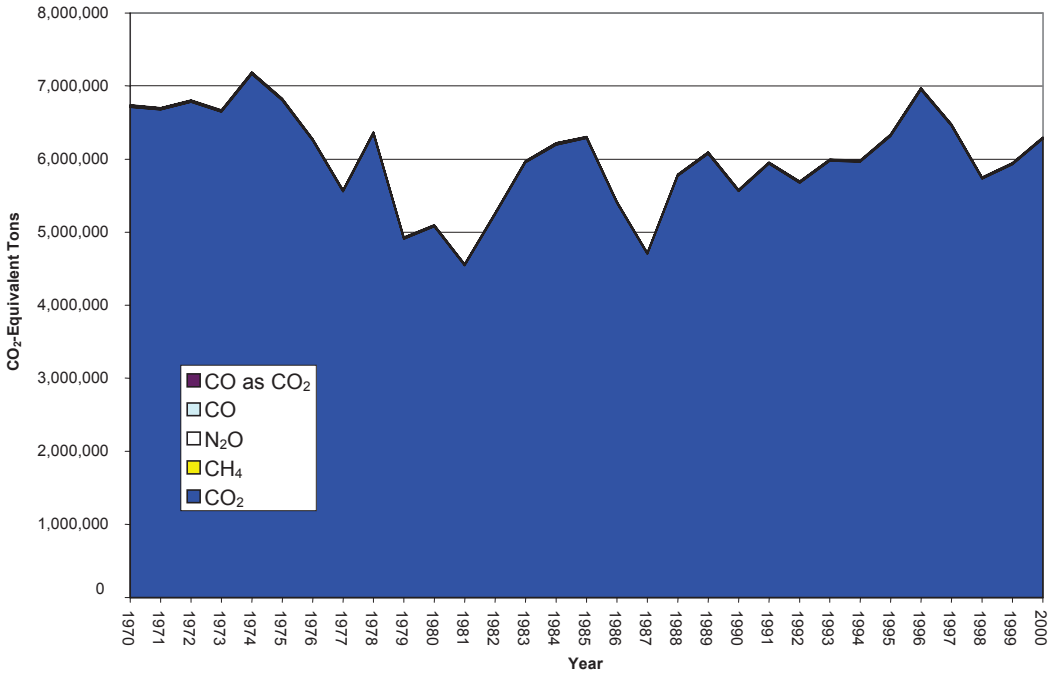
Figure 5.48 Approximate Trend in Square Feet of Floor Space in Minnesota Residences



5.6 Commercial Sector

The historical trend in greenhouse gas emissions from the commercial sector of the Minnesota economy—standard industrial classification codes 50 through 99-plus – from 1970 through 2000 is shown in Figure 5.49 by greenhouse gas. Most greenhouse gas emissions from this sector are in the form of CO_2 emitted to the atmosphere upon the combustion of natural gas, oil or coal. The direct emission of N_2O, CH_4 and CO, and the decay in the atmosphere of emitted fossil CO to CO_2, constitutes a small additional source. As discussed above, while carbon monoxide is not a greenhouse gas per se, its release to the atmosphere does act photochemically to elevate concentrations of other greenhouse gases.

Figure 5.49 Greenhouse Gas Emissions from the Minnesota Commercial Economic Sector



Annual emissions of greenhouse gases from the commercial sector of the Minnesota economy are an estimated 6.3 million CO_2-equivalent tons, up from about 6 million tons in 1990 and 5 million tons in 1980, but down from about 6.8 million tons in 1970.

Figure 5.50 shows the 30-year tend in emissions since 1970 by fuel type. Most emissions of greenhouse gases from this sector derive from the combustion of natural gas and oil. Emissions from the combustion of coal have steadily declined. Additionally, a small emission derives from wood combustion, as well as, indirectly, from solvent use in the services sector. Most of the increase in greenhouse gas emissions from the commercial sector since 1980 is from an increase in natural gas use, only partially offset by a decline in emissions from coal and distillate oil. Of UNFCCC-gases, HFC-134a was not inventoried with respect to emissions. HFC-134a is a substitute for CFC-12 in refrigeration and cooling applications.

Figure 5.50 Greenhouse Gas Emissions from the Minnesota Commercial Sector

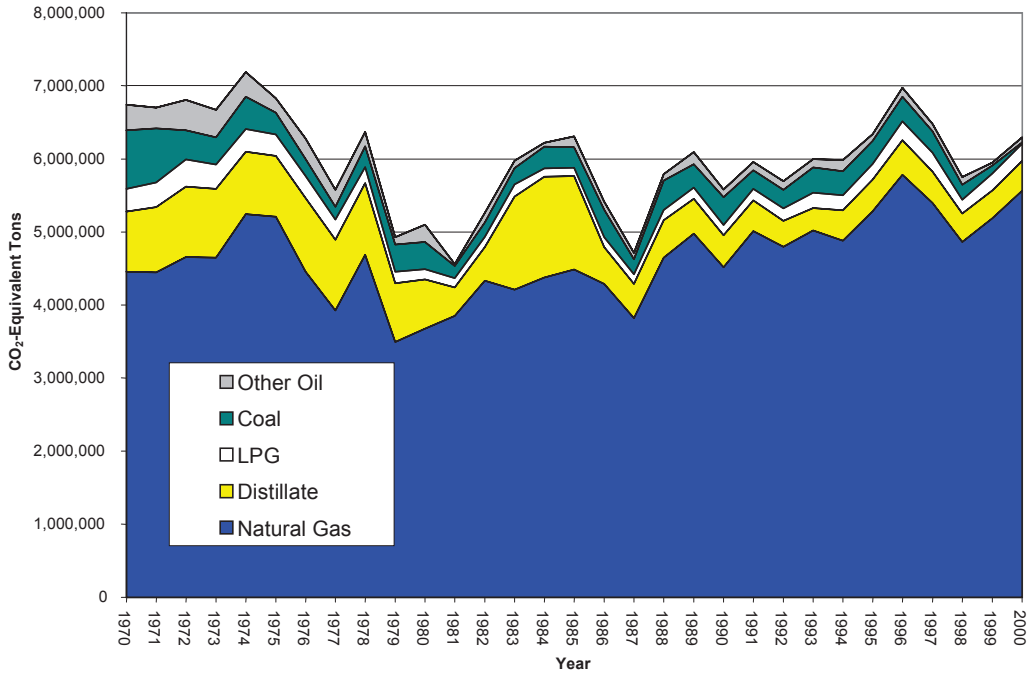
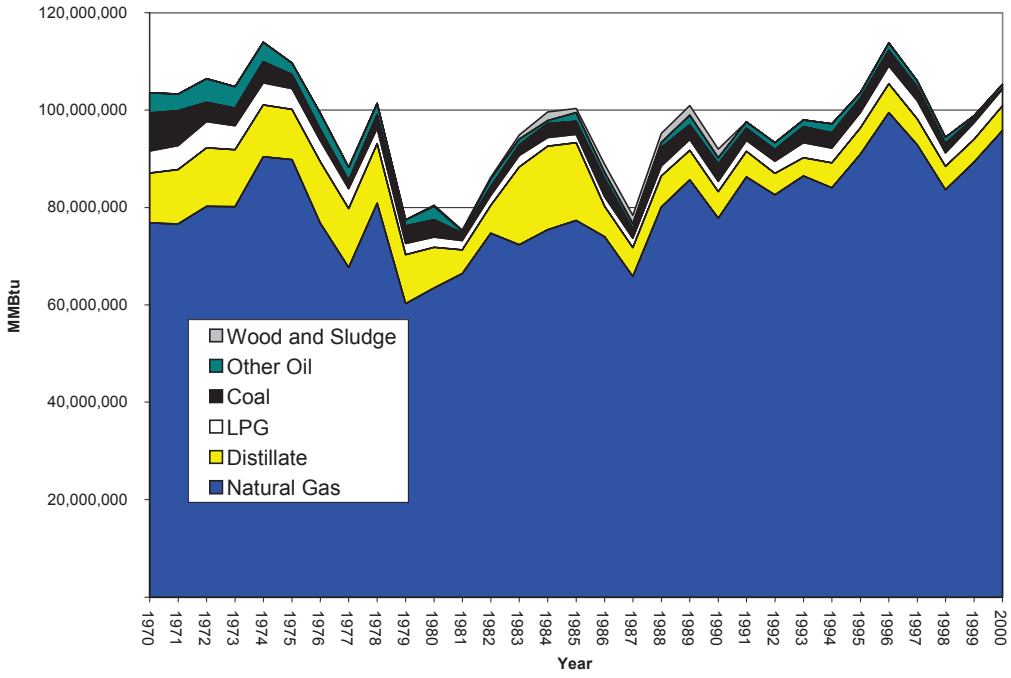


Figure 5.51 Primary Energy Use in the Minnesota Commercial Sector



The underlying trend in primary energy use in the Minnesota commercial sector is shown in Figure 5.51. Roughly 0.1 quads of primary energy are consumed annually in the Minnesota commercial sector in the form of natural gas, distillate fuel oil and liquid petroleum gas. The pattern of annual fluctuations in primary fuel use closely mirrors the 30-year trend in emissions of greenhouse gases from this sector.

Employment, sales and economic activity generally in the commercial sector of the Minnesota economy have increased substantially since 1970. Output from this sector, as measured by GSP (gross state production) from this sector, have increased at a rate of about 6 percent per year since 1970, roughly tripling in real terms. This is in contrast to greenhouse gas emissions from this sector, which have increased only slightly over the same period. This is due to a substantial decline in the intensity of emission per real dollar of commercial sector economic activity, declining by 2000 to about one-quarter of its 1970 value. Figures 5.52 and 5.53 show historic trends in real commercial sector GSP in Minnesota and associated greenhouse gas emissions, respectively. The trend in Figure 5.52 is calculated the using weather-normalized trend in emissions to account for the effect of weather variations on heating needs and hence fuel use in these SIC codes. In Figure 5.53, the historic trend-line for economic output in the Minnesota commercial sector is continued out to 2010.

Figure 5.52 Weather-Normalized Emissions of Greenhouse Gases Per Dollar of Commercial Sector Gross State Product

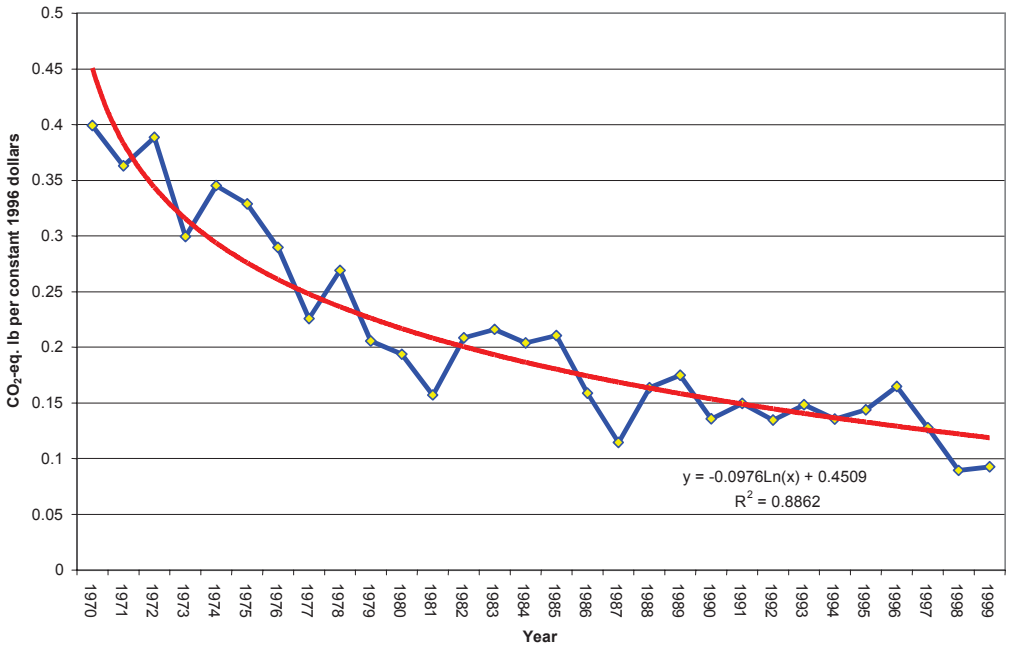
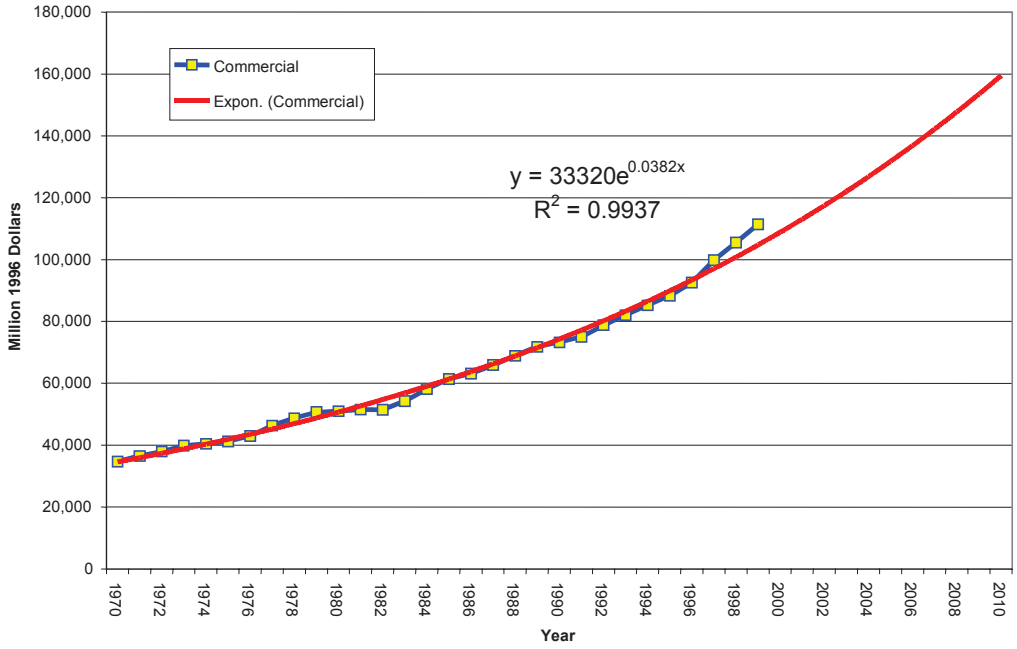


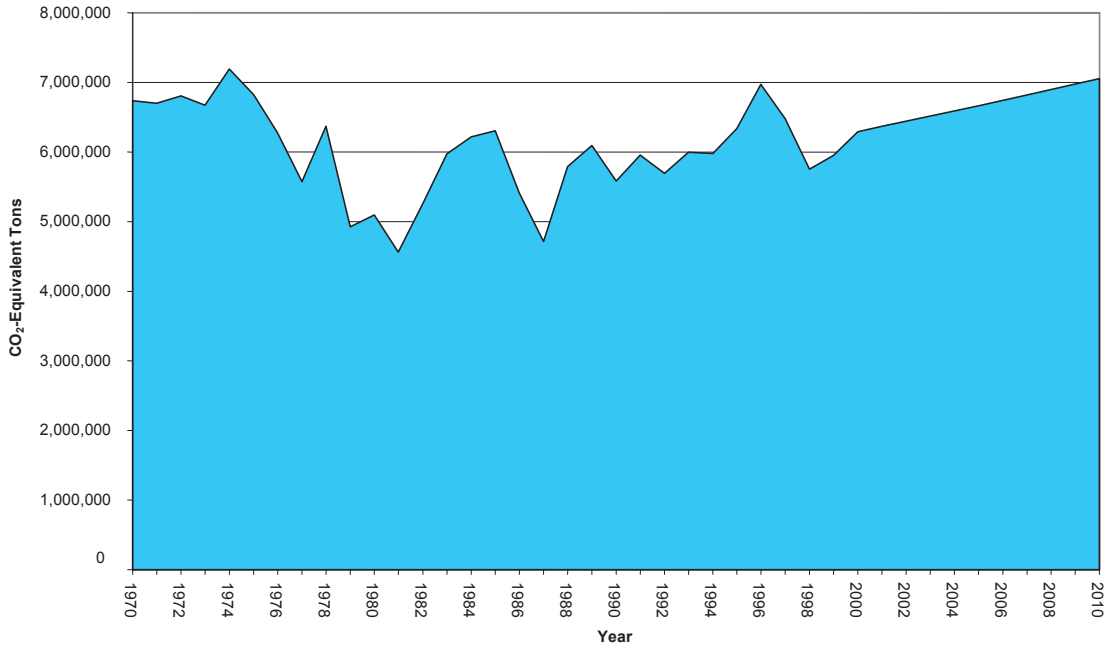
Figure 5.53 Historic and Forecasted Growth in Gross State Product in the Minnesota Commercial Sector



As for other emitting sectors, the methods used to estimate emissions from the commercial sector follow the guidelines suggested by the IPCC and the U.S. EPA for preparing greenhouse gas emissions inventories, as well as the methods utilized by the U.S. EPA and U.S. DOE in preparing U.S. national greenhouse gas emission inventories.

The forecasted trend in emissions is shown in Figure 5.54. Emissions out to 2010 are forecast using observed trends in economic activity in the Minnesota commercial sector, in combination with long-term trends greenhouse gas emission intensity per unit of economic activity (see Figures 5.52 and 5.53). GSP in the commercial sector is forecast to increase by about one-third from current levels by 2010, continuing the 30-year trend in growth since 1970. Weather-normalized greenhouse gas emission intensity is forecast to decline by about one-fifth. Greenhouse gas emission are forecast to increase slightly to 7 million CO_2-equivalent tons by 2010, or by less than 10 percent, continuing the shallow trajectory of growth experienced since 1980.

Figure 5.54 Historic and Forecasted Emissions of Greenhouse Gases from the Minnesota Commercial Economic Sector



5.7 Waste Management

The waste management sector is comprised of landfills, incinerators, solid waste collection and processing facilities, composting facilities, waste water treatment facilities and discharges, and land application of treated wastes. Managed in this system are: mixed municipal solid waste, industrial solid waste, demolition and construction waste, yard waste, medical waste, hazardous waste, and human waste.

Mixed municipal solid waste is recycled, landfilled, incinerated or shipped out-of-state for disposal. Most industrial solid waste is landfilled, although a small amount of industrial solid waste is incinerated. All demolition and construction waste is landfilled. Medical waste is either incinerated or sterilized and landfilled. Hazardous waste is incinerated in the state or shipped out of Minnesota for disposal. Most yard waste is composted, though some still is landfilled.

Human waste is treated at wastewater treatment plants or in septic systems. Sludge from wastewater treatment either is land-applied, incinerated or landfilled.

Associated with waste management in Minnesota are annual emissions of about 4.6 million CO_2-equivalent tons of greenhouse gases. Large amounts of CH_4 are produced in and emitted from landfills containing mixed municipal solid waste (MMSW). Smaller amounts of CH_4 are emitted from industrial landfills, and from wastewater treatment plants. Some CH_4 also is formed during combustion associated with waste processing and incineration.

CO_2 is produced from the combustion of solid waste in municipal waste combusters and industrial and medical incinerators. CO_2 is also produced from the combustion of solid waste in burn barrels in rural areas lacking garbage collection, and from the incineration of hazardous waste.

N_2O is produced primarily in surface waters following the discharge to rivers and streams of wastewater from wastewater treatment facilities. Some N_2O is also produced in soils following land application of sewage sludge and during sludge composting. N_2O is also probably produced during the composting of yard waste. Large amounts of CO are produced from rural open burning of solid waste. Smaller amounts are emitted from commercial and industrial incinerators.

Of estimated year 2000 emissions from waste management, about 85 percent derive from landfills, and most of the rest from wastewater treatment facilities or related wastewater discharges. More than 90 percent of emissions are in the form of CH_4.

The historical trend in emissions from waste management in Minnesota is shown in Figures 5.55 and 5.56 by gas and source, respectively. Estimated emissions in 1970 were about 2.6 million CO_2-equivalent tons, but rose rapidly to an estimated peak in 1990 of about 5.8 million tons, before declining to the current 4.6 million tons. Most of the growth in emissions from 1970 to 1990 was the result of growing emissions of CH_4 from mixed municipal solid waste landfills. Similarly, most of the estimated decline in emissions since 1990 was due to declining emissions from landfills receiving MMSW. These emission totals, it might be noted, do not include

emissions from the combustion of solid waste at municipal waste combusters that produce energy for sale off-site. These are treated below in the electric generation sector.

Figure 5.57 shows the historic trend in greenhouse gas emissions from landfills receiving mixed municipal solid waste. Emissions were estimated on a landfill-by-landfill basis from records of annual landfill receipts. Eight landfills currently account for about 40 percent of CH_4 emissions from MMSW landfills. Most of the rest comes from a large number of closed landfills, and from city dumps, where most MMSW was disposed between 1950 and 1980.

Figure 5.55 Greenhouse Gas Emissions from Waste Management by Gas (without energy production facilities)

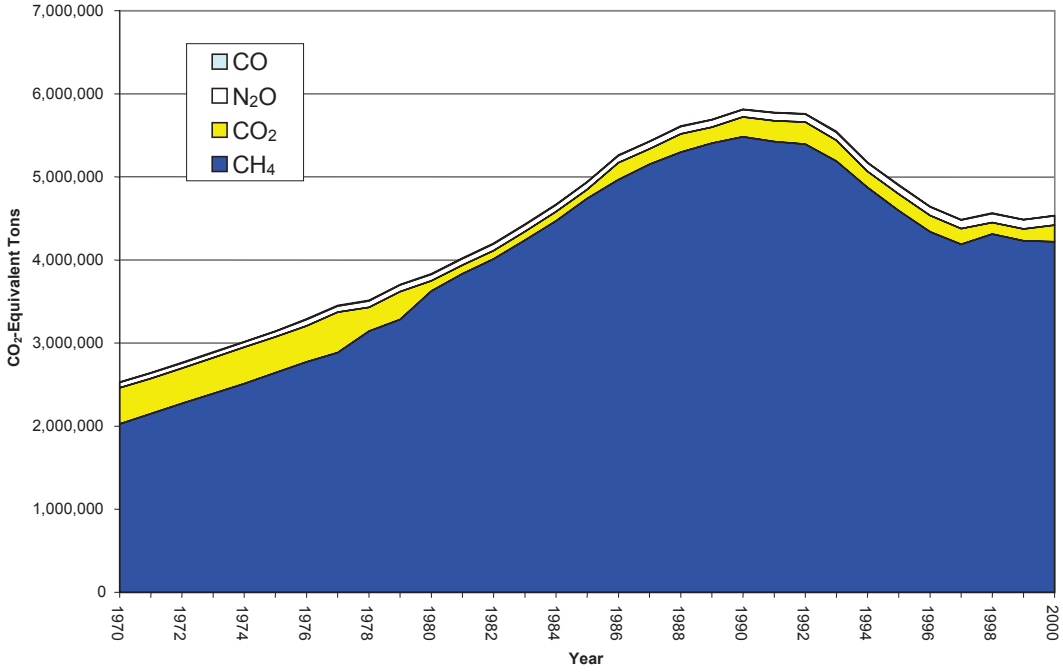


Figure 5.56 Greenhouse Gas Emissions from Waste Management by Source (Without Energy Production)

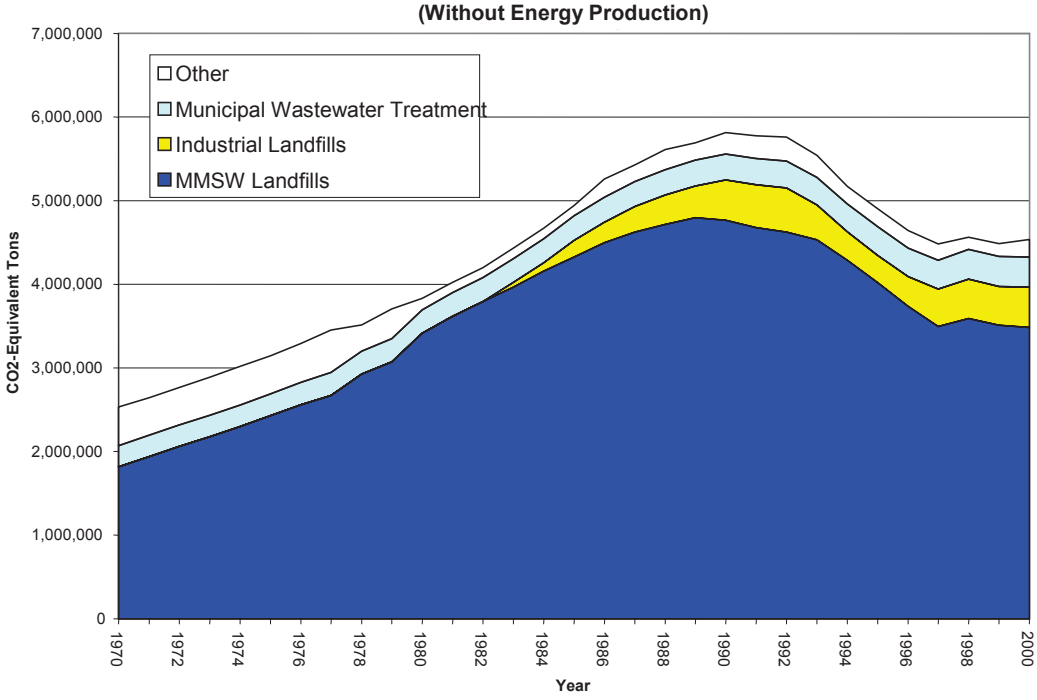
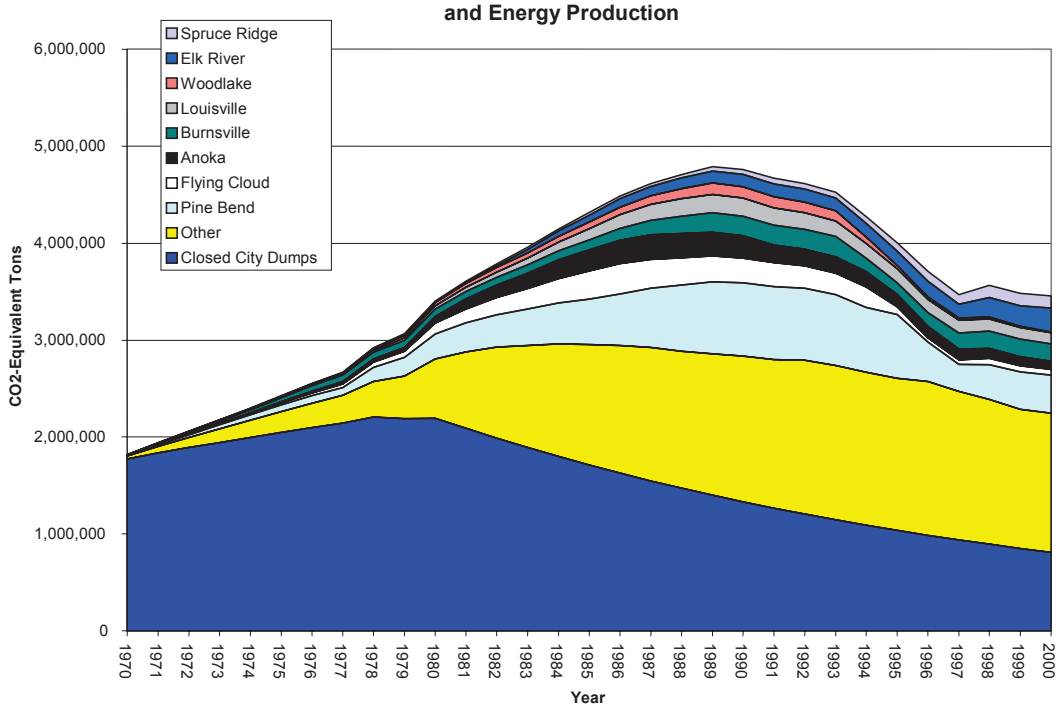


Figure 5.57 Methane Emissions from MMSW Landfills in Minnesota: Mid-Case with Flaring and Energy Production



CH_4 is generated in landfills from the anaerobic decomposition of waste organic matter. Once placed in a landfill, solid waste will produce CH_4 for 25 to 70 years or longer. The carbon in landfilled organic waste that is not emitted goes into temporary below ground storage, where it is sequestered from the atmosphere. Since most of this carbon was originally removed from the atmosphere during photosynthesis, and in absence of landfilling would be returned to the atmosphere as CO_2 through processes of respiration, this represents a net withdrawal of CO_2 from the atmosphere. Figure 5.58 shows the balance of landfill greenhouse gas emissions, including both directly emitted CH_4 and offsetting storage of plant-based carbon. Accounting for both effects, net landfill emissions peaked in 1992 or 1993 at about 4.9 million CO_2-equivalent tons, declining to the present 3.5 million tons.

Also shown on Figure 5.58 is the profile of what emissions would have been had landfill operators not installed systems to capture a part of emitted CH_4 emissions. At some landfills in Minnesota, landfill gas is captured and either destroyed in flares or used for energy production. The emissions of not quite one million CO_2-equivalent tons of CH_4 are avoided annually through active gas capture in Minnesota.

Contributing to the decline in landfill emissions has been a dramatic slowing in the rate of landfilling in Minnesota since the mid-1980s. This is shown graphically in Figure 5.59.

Figure 5.58 Emissions Balance for Minnesota MMSW Landfills: Mid-Case

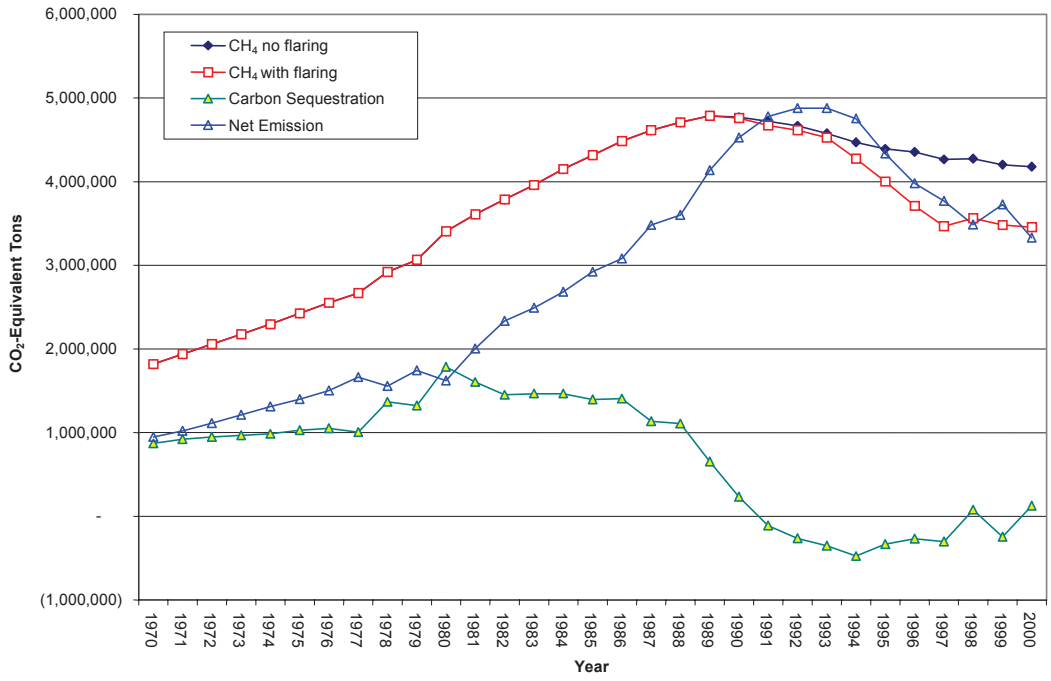
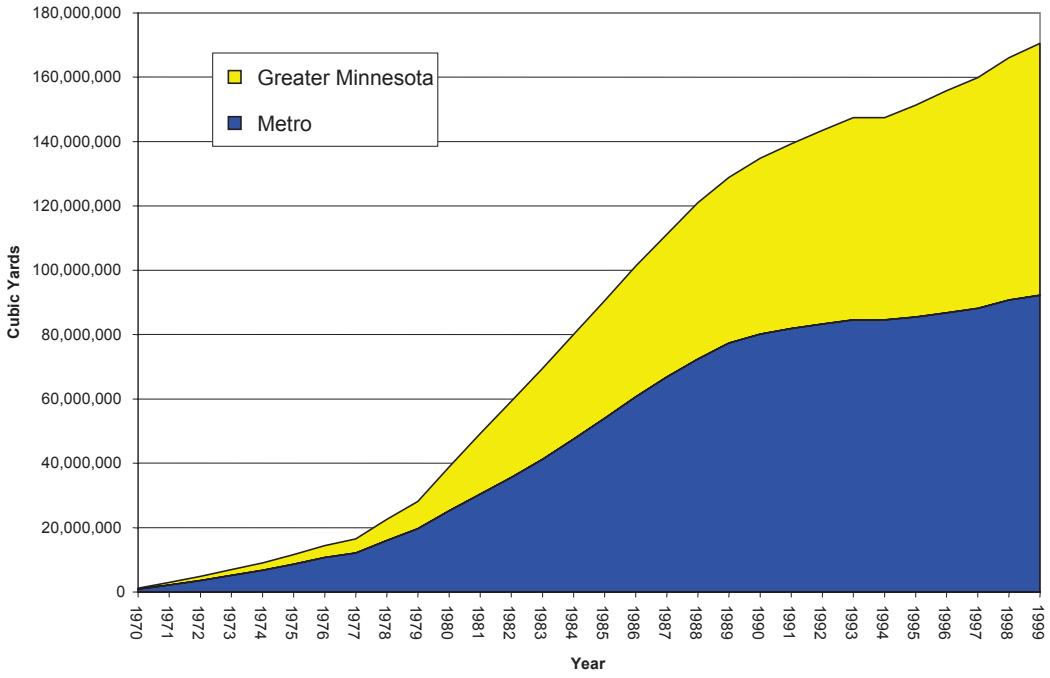


Figure 5.59 Mixed Municipal Solid Waste Landfilled in Sanitary Landfills in Minnesota



In addition to sanitary landfills, other sources of emission from solid waste management include: industrial landfills and demolition/construction landfills, open burning in rural locations and, in decades past, at city dumps, and commercial and industrial incineration. The reconstructed trend in emissions of greenhouse gases from the management of all nonagricultural solid waste in Minnesota going back to 1970 is shown in Figure 5.60. Carbon storage in all landfill types and in soils through composting is shown in Figure 5.61. Beginning in the early 1980s, demolition and construction (D/C) waste was diverted from sanitary landfills to landfills dedicated solely to D/C waste. Since wood, the principal biogenic component of D/C waste, is resistant to degradation, most or all of the carbon in wood disposed in D/C landfills is assumed to go into permanent storage.

The reconstructed trend in greenhouse gas emissions from the management of human waste is shown in Figure 5.62. Greenhouse gas emissions from the management of human waste are small in comparison to those from solid waste, about 350,000 tons in 2000. CH_4 emissions from wastewater treatment plants (WWTPs) comprise more than two-thirds of emissions from the management of human waste. Most of the rest results from discharges from wastewater treatment plants. Underlying the pattern of growth in emissions shown in Figure 5.62 is a parallel pattern of growth in amounts of human waste to be managed. This is shown in Figure 5.63.

Figure 5.60 Greenhouse Gas Emissions from Solid Waste Management in Minnesota

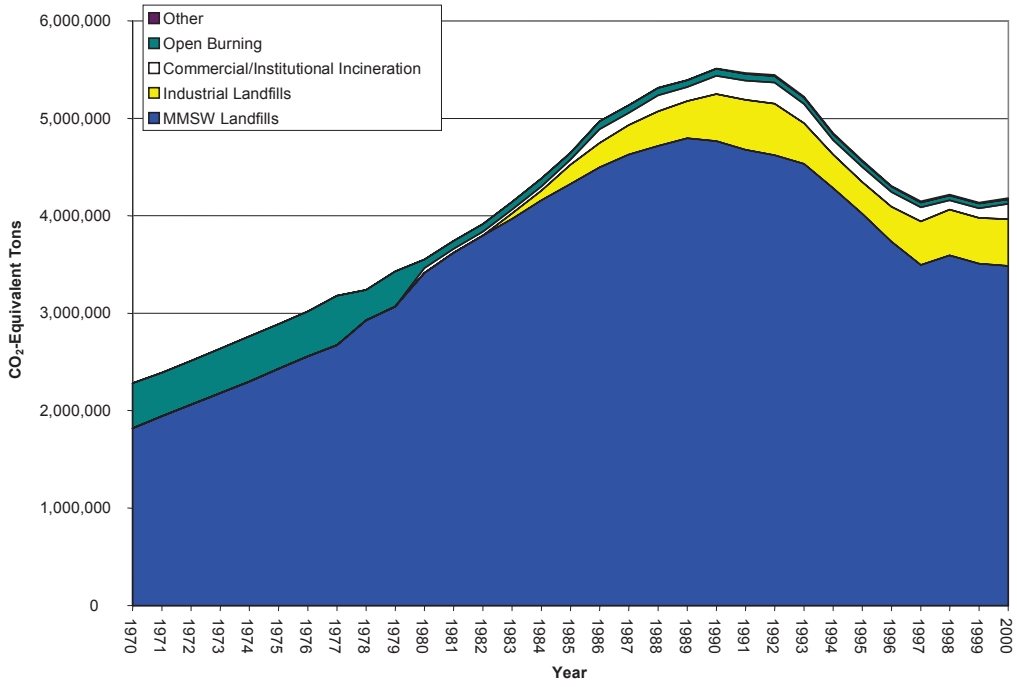


Figure 5.61 Biogenic in Landfills and Compost in Minnesota

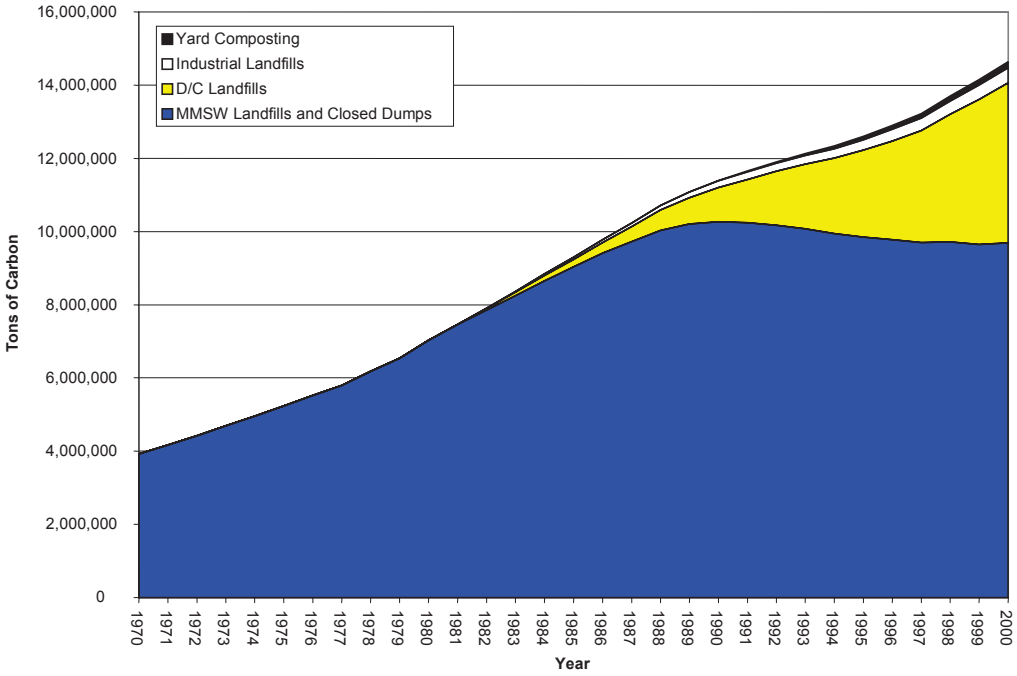


Figure 5.62 Greenhouse Gas Emissions in Minnesota from the Management of Human Waste

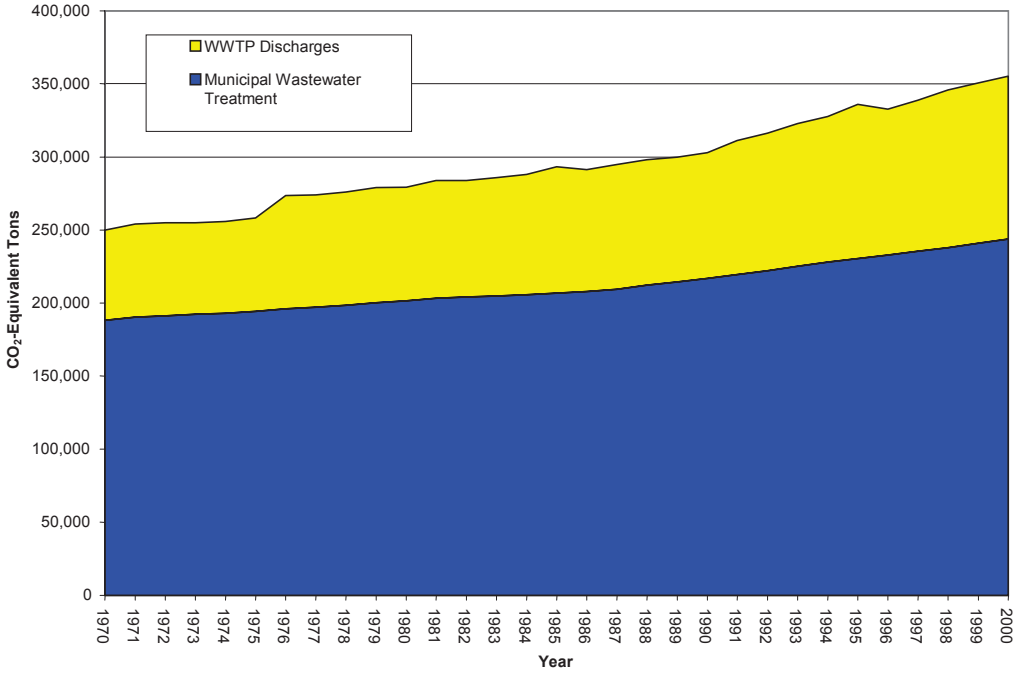
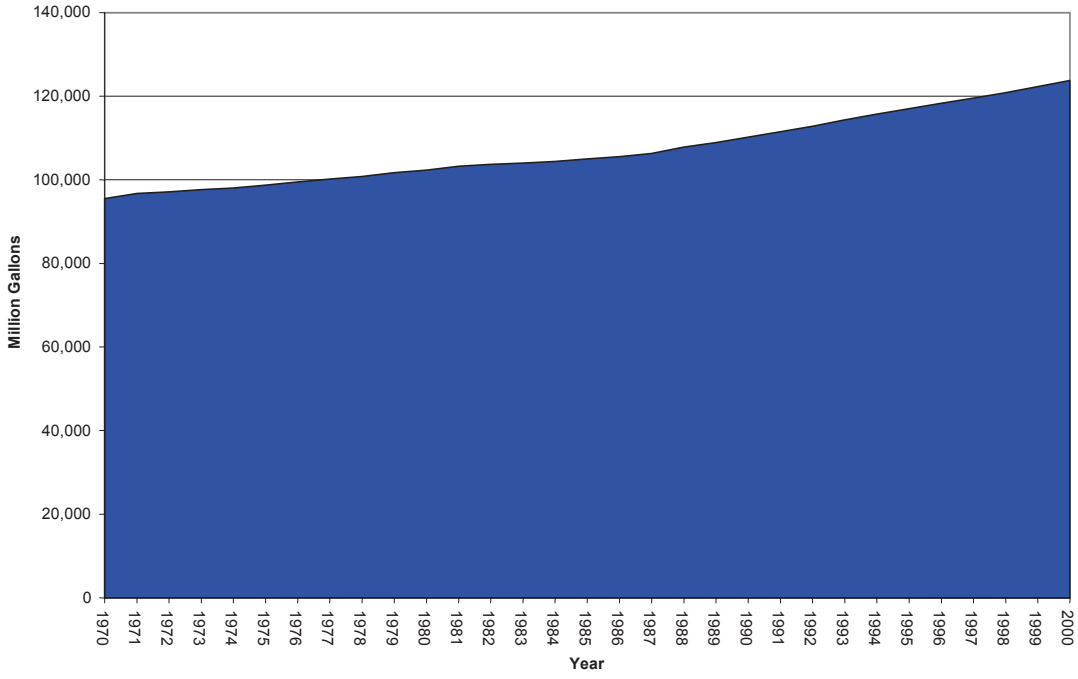


Figure 5.63 Production of Human Waste in Minnesota



The methods used to estimate emissions from human waste management were taken from USEPA (1995), IPCC (1998), USDOE (2000) and USEPA (2001). Emissions from sanitary landfills were estimated using the USEPA landfill gas model and records of annual waste receipts. Flare amounts were taken from MPCA (2001). Emissions from industrial landfills were calculated using a first-order decay model calibrated to produce observed gas production at industrial landfills in Minnesota. Emissions were estimated solely for industrial landfills receiving wood sludge from the paper and pulp industry. Destruction of CH_4 in flares or reciprocating engines was subtracted from emission totals. Emissions from other sources were calculated using emission factors taken from Ciborowski (1995), R.W. Beck/Ecobalance (1999), IPCC (1998), and USEPA (2001).

Carbon sequestration in landfills was calculated from waste receipts and their carbon content and calculated emissions of CH_4 and CO_2. Omitted from the inventory are landfill emissions of CFCs, chlorocarbons like methyl chloroform, and HCFCs, for reasons discussed above. It is possible that emissions, particularly of CFC-11 and CFC-12 from D/C landfills could become substantial as structured built in the 1960's and 1970's are retired.

Forecasted emissions from waste management in Minnesota are shown in Figure 5.64. The forecast assumes that trends in per capita MMSW waste generation and Minnesota population follow historical patterns, and that no new waste incineration capacity is added in the state. Further, it assumes that MMSW exports to other states rise slightly to 800,000 tons per year. MMSW exports have increased from an estimated 425,000 tons in 1995 to an estimated 700,000 tons in 2000. Recycling rates in the state are assumed to increase to 50 percent from the prevailing 40 percent rate. No change is assumed in amounts of MMSW managed through composting. It is also assumed that active gas capture is implemented at two additional closed landfills between 2002 and 2010.

Industrial landfill emission are forecast assuming a continuation of landfilling trends in the paper/pulp sector, plus planned landfill retirement and construction for the period 2000-2005.

Emissions from the management of human waste are forecast on the basis of historic trends in Minnesota population, per capita waste generation, and per capita protein in-take, and a continuation of reliance on land application and incineration for management of WWTP sludge. Greater planned reliance in the Metropolitan Twin Cities Area of land application of sludge is taken into account.

Emissions in the forecast period decline slightly, to a level of about 4.1 million CO_2-equivalent tons. This is driven by a slight forecasted reduction in CH_4 emissions from MMSW landfills (see Figure 5.65). Emissions from human waste management increase, but are small relative to emissions from landfills, and so have only a minor effect on the forecasted trend in emissions.

Components of forecasted net emissions from MMSW landfills are shown in Figure 5.65. Forecasted net annual carbon sequestration is slightly negative over most of the forecast period, finally reaching zero at 2010. The trend in net emissions approximate very closely to the forecasted trend in gross landfill emissions of CH_4, declining slightly from 3.6 to 3.2 million tons

by 2000. By 2010, 1 million CO_2-equivalent tons of emissions are destroyed during energy production and flaring, up about 30 percent from 2000 levels.

Figure 5.64 Historic and Forecasted Greenhouse Gas Emissions from Waste Management in Minnesota

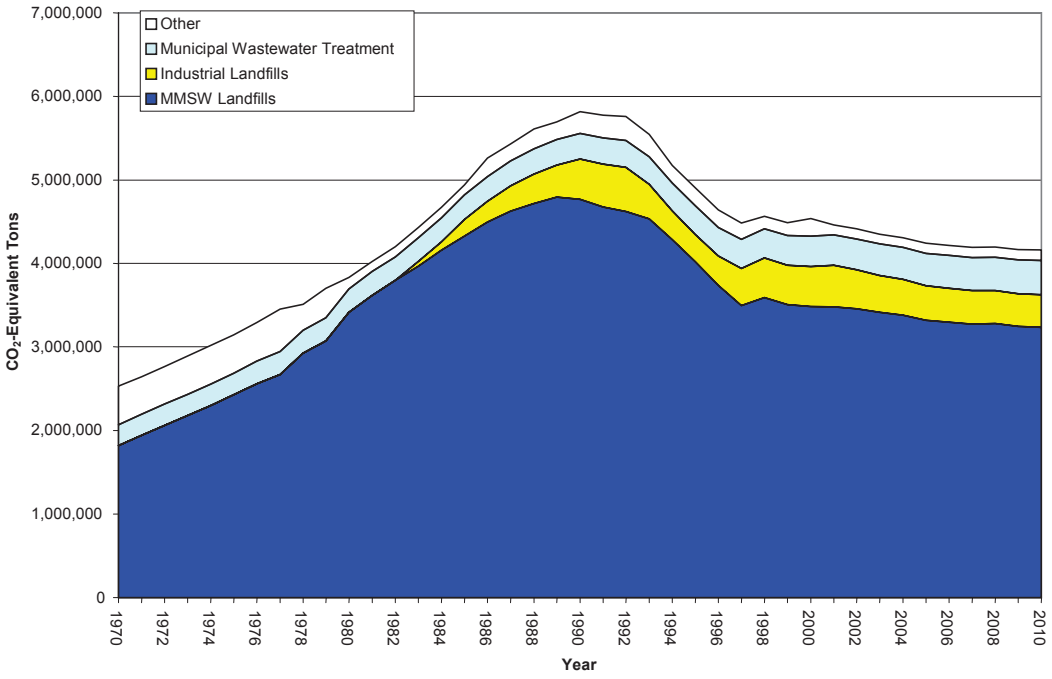
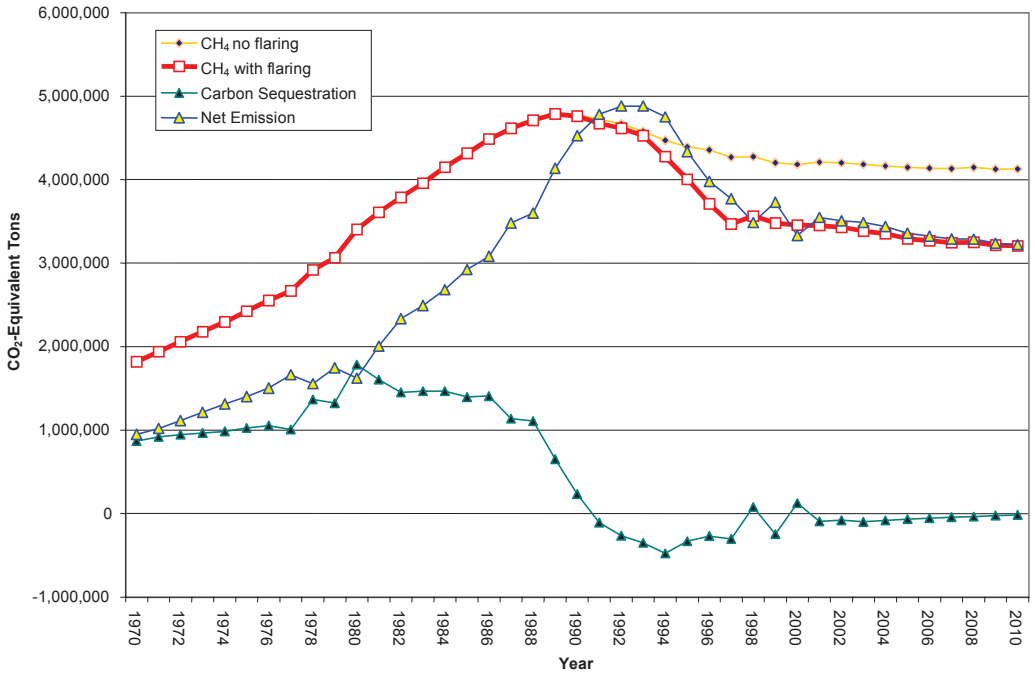


Figure 5.65 Historic and Forecasted Emissions Balance for Minnesota MMSW Landfills: Mid-Case



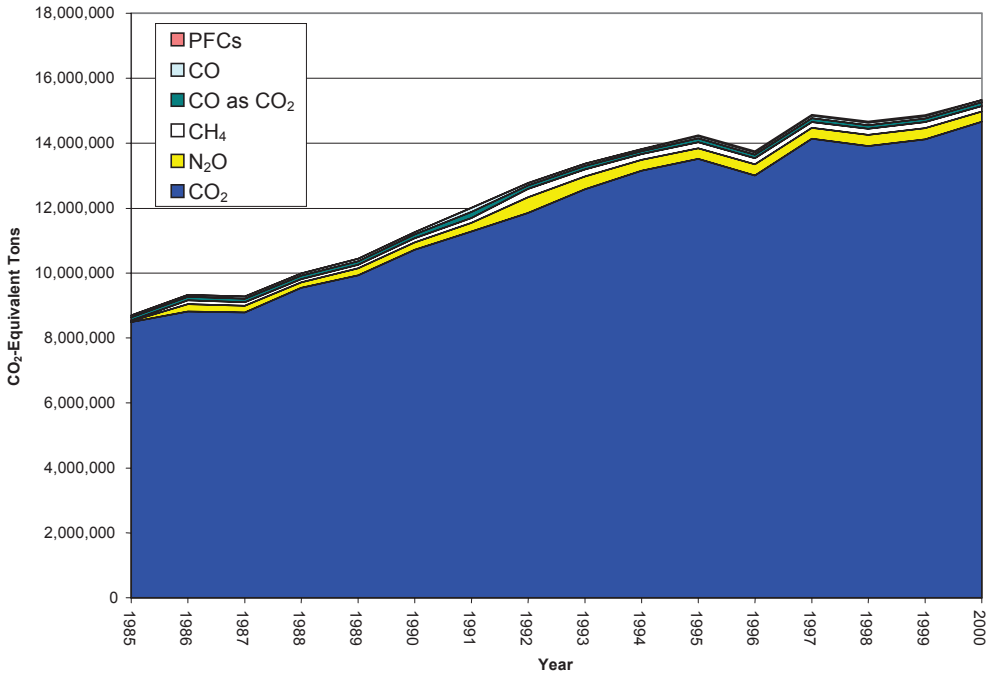
5.8 Industrial and Mining Sector

Greenhouse gases are emitted from a variety of activities in the industrial and mining sector of the Minnesota state economy. CO_2, N_2O and CH_4 are directly emitted to the atmosphere during fossil fuel combustion. CO is also produced during combustion. Additionally, CO_2 is formed in the atmosphere as a result of the oxidation of CO. CO_2 deriving from CO formed during the combustion of a fossil fuel is counted as a net emission of CO_2.

Small amounts of CH_4 also are emitted from petroleum refining and storage. Substantially larger amounts of CH_4 are produced during industrial wood combustion. CF_4 and SF_6 are emitted to the atmosphere during the manufacture of semiconductor and related electronics components, as are other perfluorocarbons. CO_2 is released to the atmosphere as a result of industrial consumption of limestone during glass manufacture and the manufacture of various building products. Small amounts of CO_2 also are emitted from the consumption of peat harvested from Minnesota peatlands.

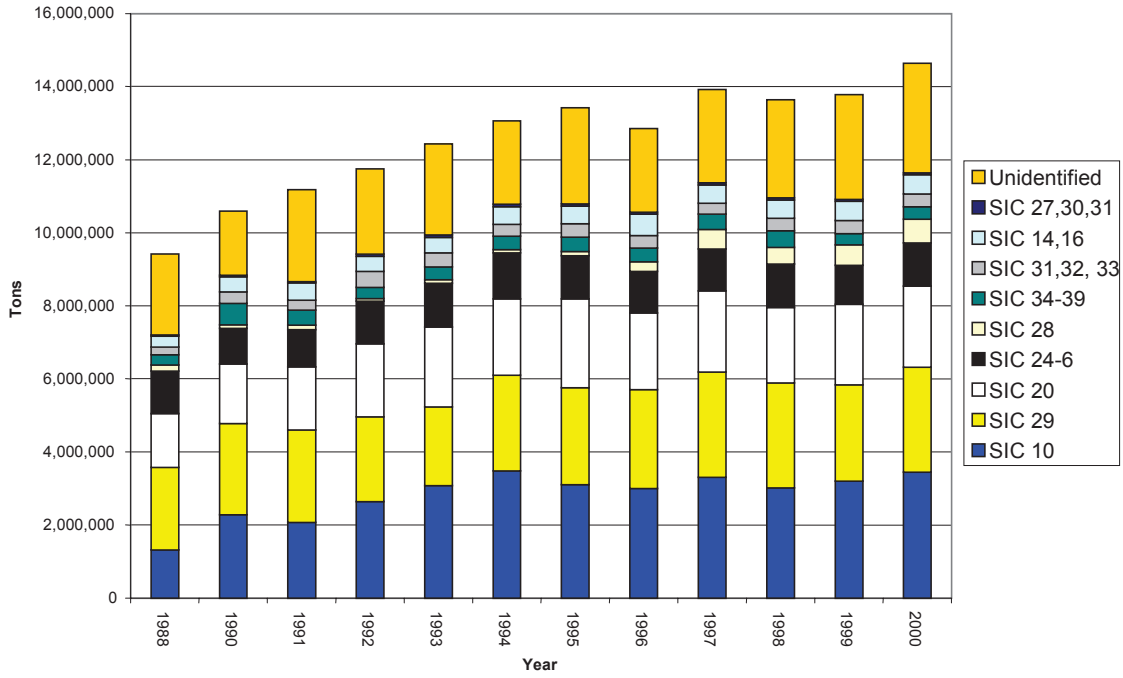
Figure 5.66 shows the estimated trend in emissions of greenhouse gas emissions from the Minnesota industrial and mining sector since 1985. The industrial and mining sector comprises SIC codes 10-39. Current emissions are about 15.5 million CO_2-equivalent tons, up from about 11 million in 1990 and 9 million tons in 1985. Estimated emissions from the industrial sector are dominated by emissions of CO_2 directly released during fossil fuel combustion. Of the remainder, much of this is accounted for by direct combustion emissions of CH_4 and N_2O. Emissions of CF_4 and the PFCs account are on the order of several hundred thousand CO_2-equivalent tons; those from peat consumption several tens of thousands of tons.

Figure 5.66 Greenhouse Gas Emissions from the Minnesota Industrial Sector, 1985-2000



The trend in CO_2 emissions from the industrial and mining sector since 1985 is shown in Figure 5.67 by SIC code. CO_2 emissions are dominated by emissions from five industrial groupings: metal mining (SIC 10), petroleum refining and related (SIC 29), food processing (SIC 29), wood and paper products (SICs 24-6), and ethanol production (SIC 28). Together, these industrial groupings account for more than 70% of CO_2 emissions from the industrial and mining sector. Sources for approximately 15 percent of emissions are unidentified.

Figure 5.67 CO_2 Emissions from the Industrial Sector by Standard Industrial Classification Code



Emissions estimates for non-CO_2 releases are available only for the period staring in 1985. Prior to that, the data on activities are adequate only for the estimate of emitted CO_2. The 30-year trend in emissions of CO_2 from fossil fuel combustion is shown in Figure 5.68. Over this period, emissions have varied widely, from the 18 to 19 million ton level early in period, to lows in the 8 to 9 million ton range in the middle 1980s, and, following a rapid recovery, to the current 15 million tons. From the late 1970's through about 1985, substantial amounts of industrial capacity was either idled or closed, leading to the large emissions reductions evident in the record.

The trend in underlying primary fuel use in the Minnesota industrial and mining sector is shown in Figure 5.69. The general trend in fuel use follows the same basic pattern as the trend in CO_2 emissions.

Figure 5.68 CO_2 Emissions from Fossil Fuel Combustion in the Minnesota Industrial Mining Sector

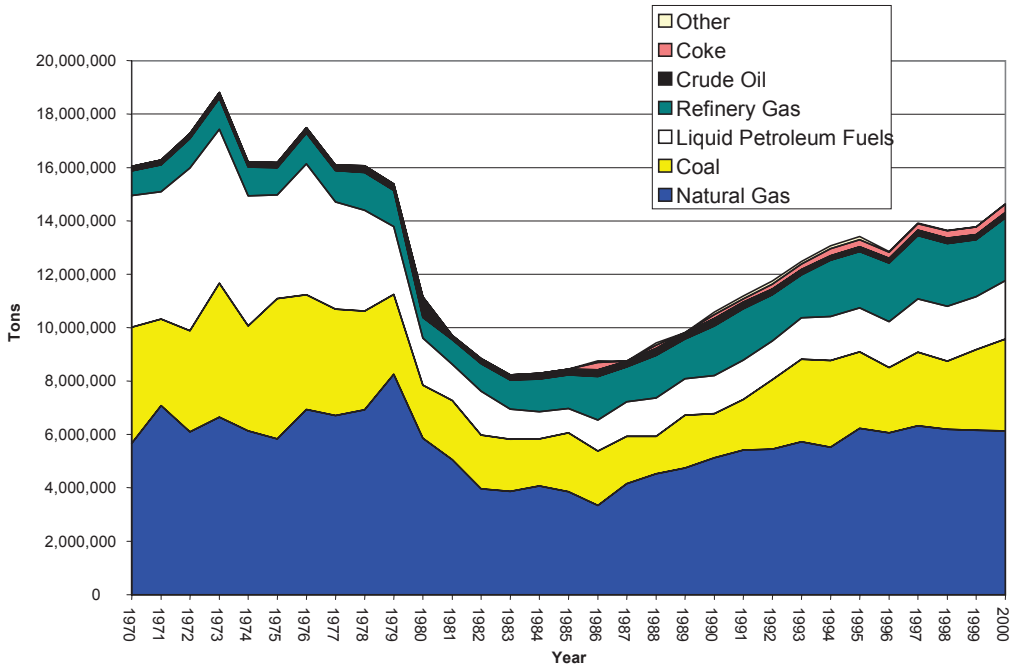
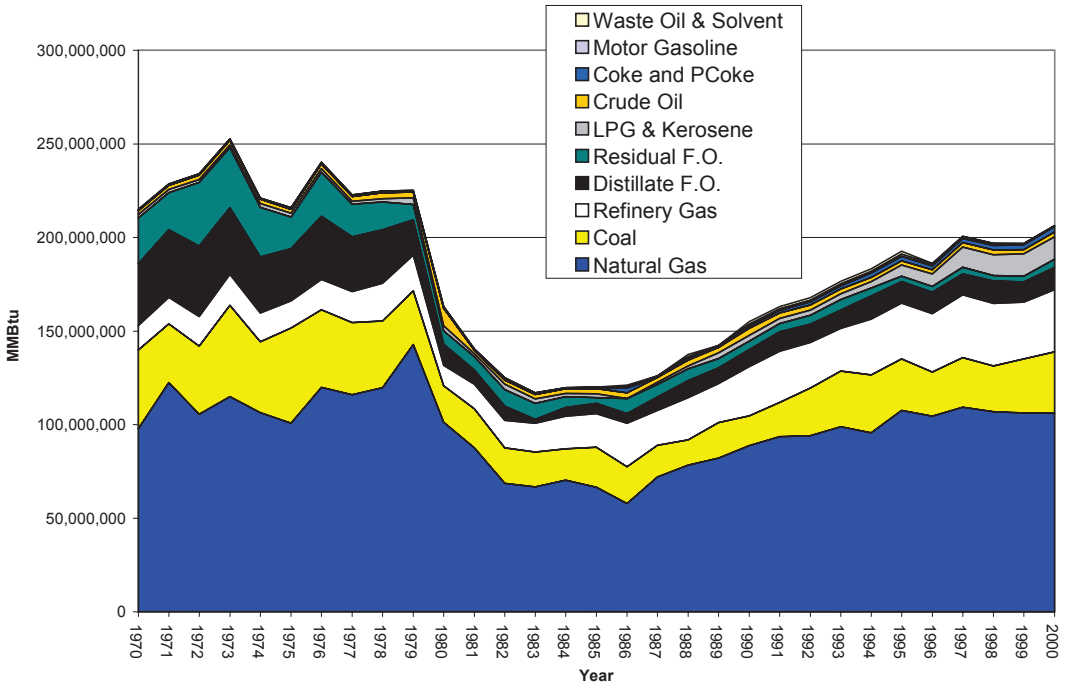


Figure 5.69 Primary Energy Input to the Minnesota Industrial Sector



5.9 Forestry Carbon Sink

Through forest growth and regrowth, substantial amounts of carbon dioxide can be withdrawn from the atmosphere and stored on land in biomass and soils. During photosynthesis, carbon, absorbed from the atmosphere in the form of CO_2, is used, along with hydrogen, oxygen and other elements, to form the complex carbohydrates that comprise plant biomass. In Minnesota, large-scale forest clearing between 1880 and 1910 resulted in the release of large amounts of CO_2 to the atmosphere. Forest regrowth since has resulted in the removal of some of this from the atmosphere.

Figure 5.70 shows the approximate trend in carbon storage on Minnesota timberlands since 1936. As of 1990, the last year for which have information on growing volumes on Minnesota timberlands, approximately 450 million tons of carbon was stored in trees and the floor of the forest, up from about 380 million tons in 1977. Between 1977 and 1990, rates of annual carbon storage averaged 5.4 million tons, or about 20 million CO_2-equivalent tons. This is equal to about one-fifth of emissions from all Minnesota sources of greenhouse gases.

Figure 5.71 shows trends in carbon storage over time for the different components of the forest. Carbon storage in the nonmerchantable parts of growing stock, in the forest floor and in below-ground biomass was estimated as a constant multiple of carbon storage in harvestable growing stock. The trend in harvestable growing stock was estimated from US Forest Service (USFS) forest inventory assessment estimates of growing stock on Minnesota timberlands. The estimated trend in growing stock from these USFS assessments going back to 1936 is shown in Figure 5.72 on a volumetric basis.

Figure 5.70 Carbon Storage on Minnesota Timberlands

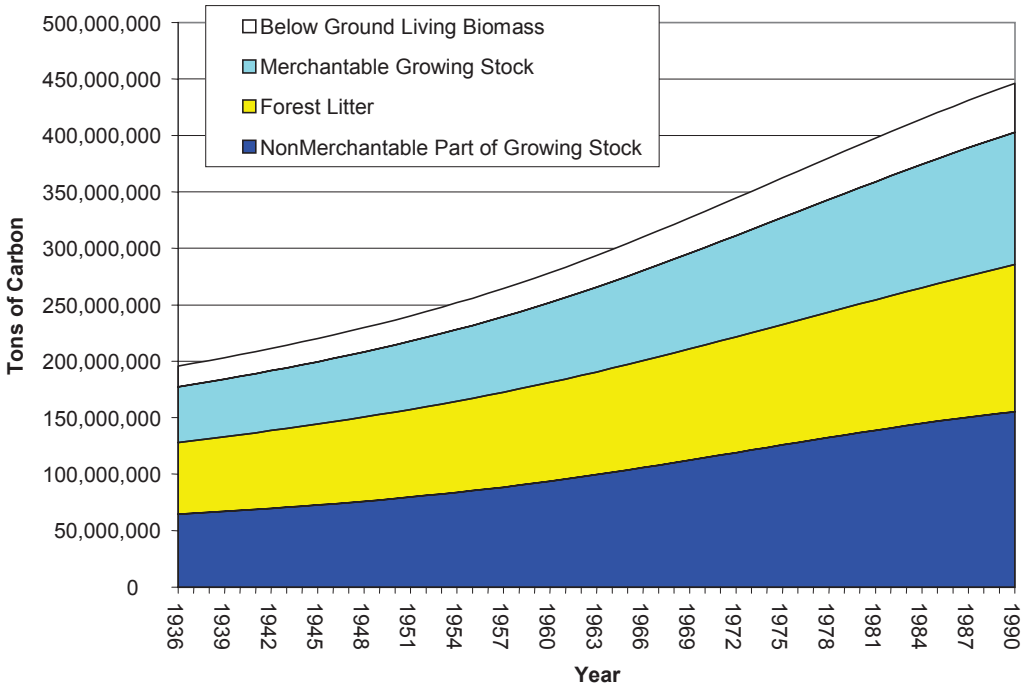


Figure 5.71 Carbon Storage on Minnesota Timberlands

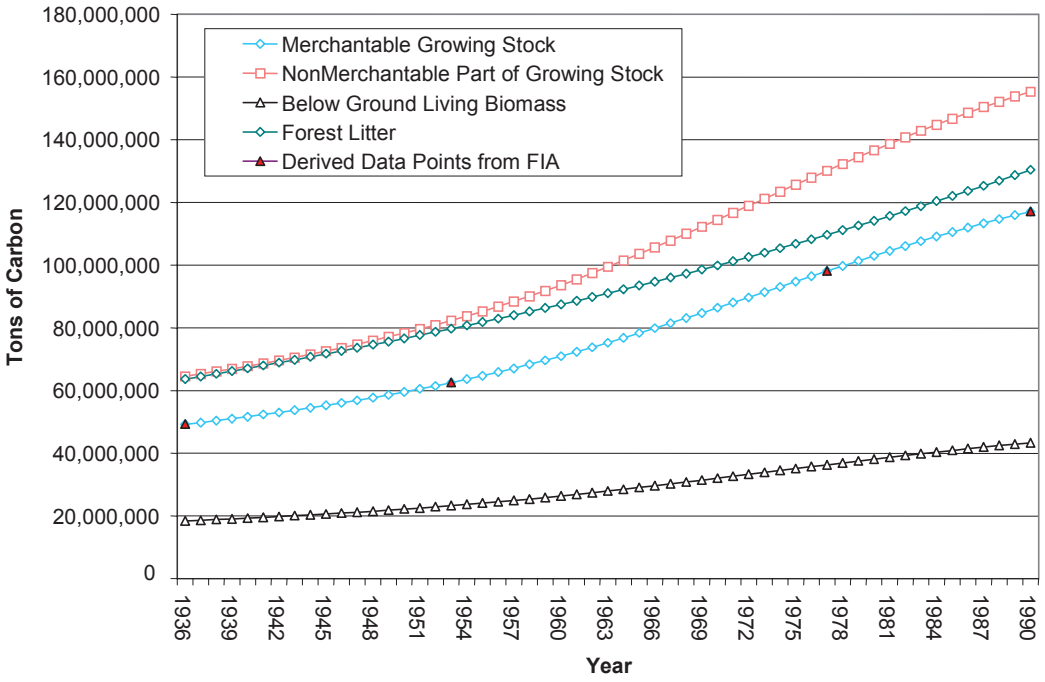
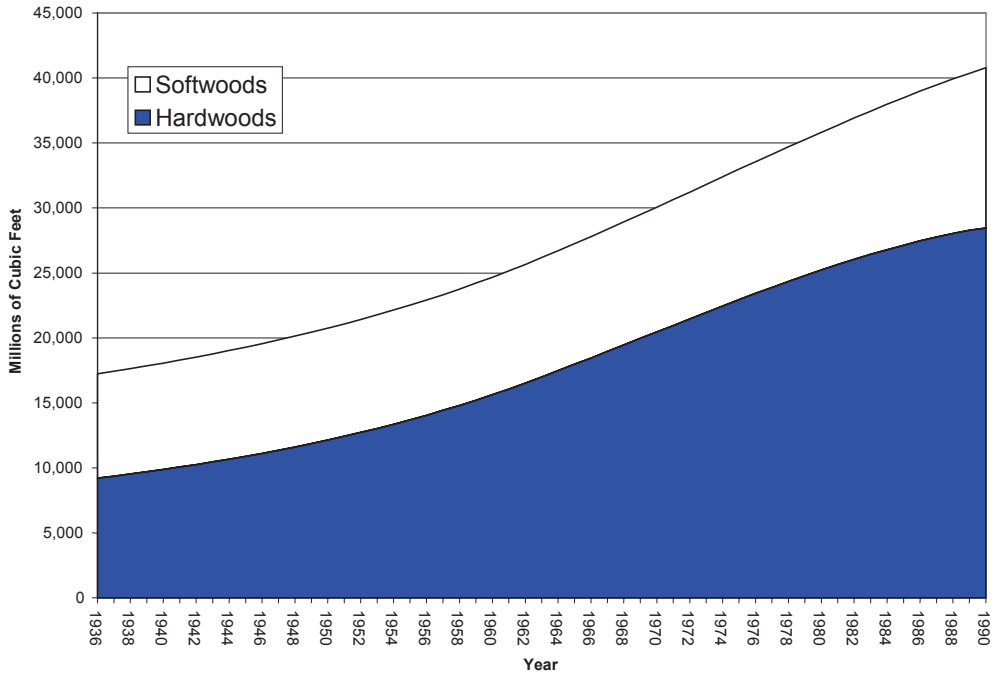


Figure 5.72 Volume of Above and Below Ground Living Biomass on Minnesota Timberlands



The methods used to produce the estimates of stored carbon given in Figures 5.70, and 5.71 were taken from USEPA (1995) and Birdsey (1992). Carbon storage in forest soils was not estimated. While it is possible to develop an estimate of present day carbon storage in forest soils, insufficient information exists to evaluate trends in forest soil carbon.

Likewise, no forecast was developed for future rates of carbon storage on Minnesota timberlands. Based on the apparent decline in the annual rate of carbon storage that is evident in the historic record (see Figure 5.70), a continued reduction in the annual rate of carbon sequestration seems plausible. However, with the ongoing amelioration in winter, spring and fall temperatures that is evident in the record of Minnesota temperatures, it is difficult to forecast future annual rates of carbon storage on timberlands. The next USFS forest inventory assessment is scheduled for 2004.

5.10 Summary of Minnesota Greenhouse Gas Emissions Trends and Forecasts

In aggregate, emissions of greenhouse gases from Minnesota sources have increased about 40 million CO_2-equivalent tons between 1970 and 2000, or about 40 percent. Most of this resulted from increased emissions from transportation and electric generation. Increased emissions from agriculture accounted for most of the remainder. Since 1990, greenhouse gas emissions have increased by about 21 million CO_2-equivalent tons, or by about 18 percent. Since 1990, greenhouse gas emissions have been increasing at a rate of 1.7 percent per year, doubling roughly every 40 years. The percentage distribution of emissions by gas has remained roughly constant since 1970.

The aggregate trend in Minnesota greenhouse gas emissions is shown in Figure 5.73 by emitting sector and in Figure 5.74 by gas.

Figure 5.73 Greenhouse Gas Emissions from Minnesota

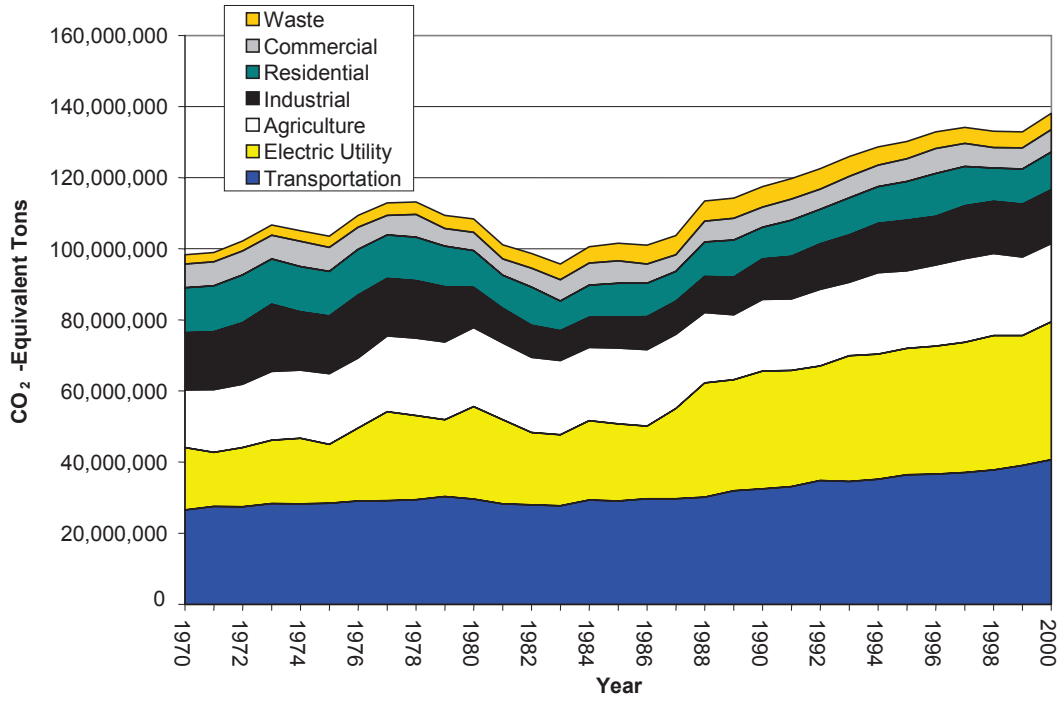
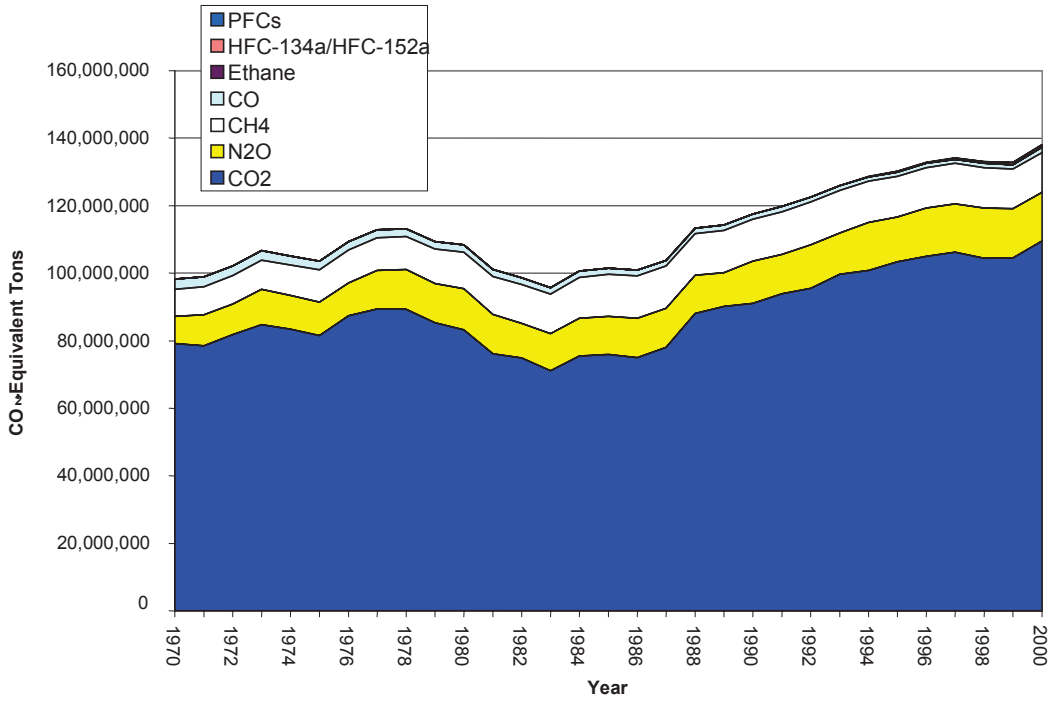


Figure 5.74 Greenhouse Gas Emissions from Minnesota, 1970-2000



The aggregate trend in stored carbon for the three carbon sinks that were evaluated—timberlands, landfills, and housing—is shown in Figure 5.75 for 1970 to 1990. Carbon storage is dominated by storage on timberlands. Landfills and housing contribute only marginally. The long-term trend in the amount of carbon stored on timberlands and in housing and landfills suggests an annual rate of storage of about 7 million tons of carbon, or 25 million CO_2-equivalent tons, offsetting about one-fifth of all Minnesota greenhouse gas emissions over the period.

Figure 5.76 shows forecasted trends in greenhouse gas emissions out to the year 2010. Emissions are expected to increase to about 160 million CO_2-equivalent tons by 2010, continuing past trends in emission. This will leave emissions roughly 35 percent higher than the targets laid out in 1992 in the U.N. Framework Convention on Climate Change. Due to the difficulty in projecting economic change in the industrial sector, emissions from industrial activity were left at 2000 levels. On this basis it is possible that the 2010 forecast level could be higher by several million tons or, given past volatility in emissions, lower by 5 to 10 million tons.

Figure 5.75 Carbon in Place on Timberland and in Landfills and Housing in Minnesota

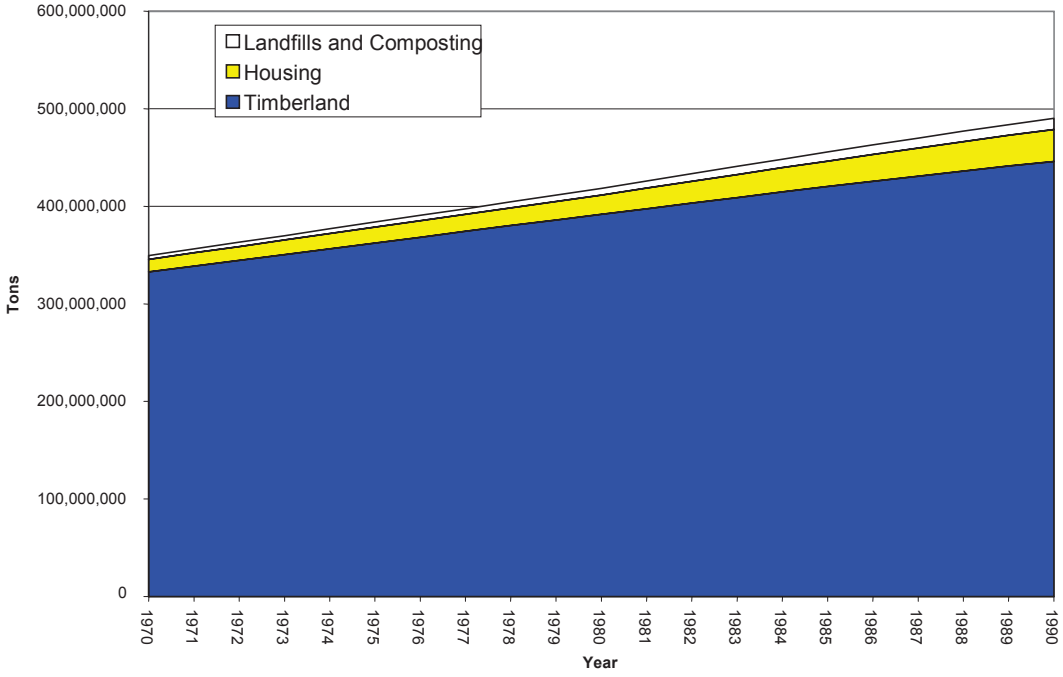
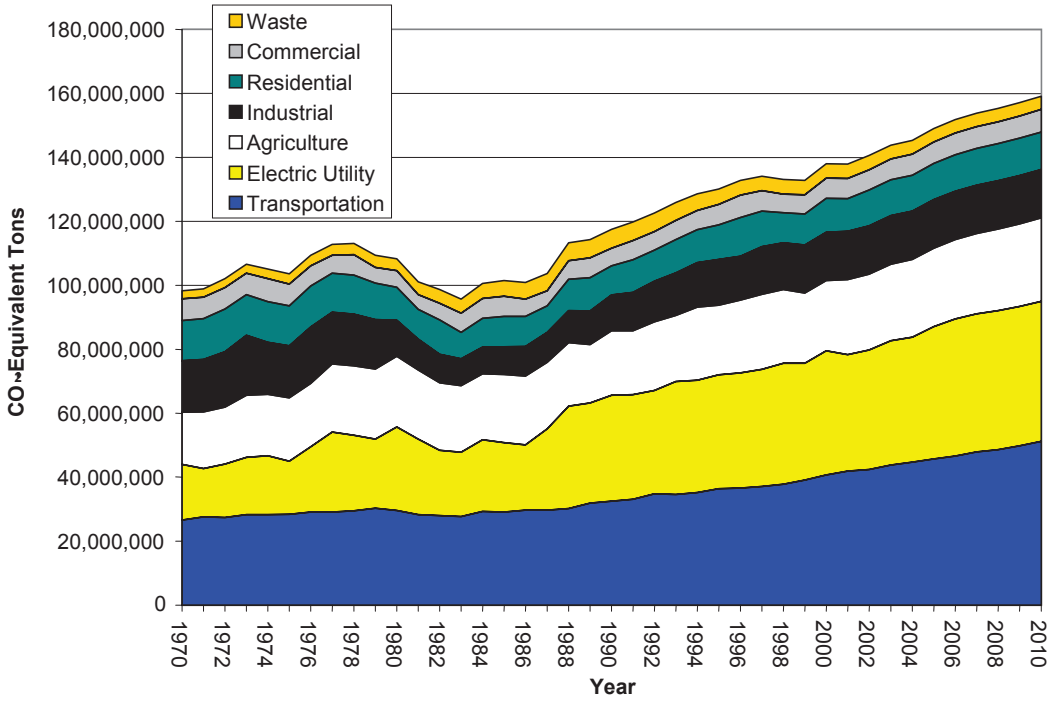


Figure 5.76 Historic and Forecasted Greenhouse Gas Emissions from Minnesota



Inventory References Cited

U.S. Environmental Protection Agency, State Workbook: Methodologies for Estimating Greenhouse Gas Emissions, second edition EPA 230-8-95-001 (Washington, D.C., 1995)

Intergovernmental Panel on Climate Change (IPCC), Greenhouse Gas Inventory Reference Manual: IPCC Guidelines for National Greenhouse Gas Inventories, 1996, http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm

U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1999, EPA 430-R-02-003 (Washington, D.C.: April 2001)

U.S. Environmental Protection Agency Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2000, EPA 430-R-02-003 (Washington, D.C.: April 2002)

U.S. Environmental Protection Agency, US Methane Emissions 1990-2020: Inventories, Projections and Opportunities for Reduction, EPA 430-R-99-03 (Washington, D.C., September 1999)

U.S. Environmental Protection Agency, Airdata, http://www.epa.gov/air/data/index.html

U.S. Environmental Protection Agency, Regulatory Impact Analysis: Protection of Stratospheric Ozone, Vol III, Part 3, (Washington, D.C., 1988)

R. Birdsey, Carbon Storage and Accumulation in the United State Forest Ecosystems, USFS General Technical Report WO-59 (Washington, D.C.: US Forest Service, 1992)

U.S. Forest Service, North Central Forest Experiment Station, Minnesota Forest Statistics 1990 (and earlier), NC-158 (St. Paul, Minnesota, 1938, 1955, 1979, 1992)

Minnesota Pollution Control Agency, Criteria Pollutant Emission Inventory System, 2001

P. Ciborowski, "Minnesota Greenhouse Gas Inventory 1990," Minnesota Pollution Control Agency, St. Paul, Minnesota, 1995.

R.W. Beck/Ecobalance, Municipal Solid Waste Management and Its Impact on Resource Conservation and Greenhouse Gas Emissions," report prepared for the Minnesota Office of Environmental Assistance, St. Paul, Minnesota, September 1999

U.S. Department of Energy, Emissions of Greenhouse Gases in the United States 1997, DOE/EIA-0573 (97) (Washington, D.C.: October 1998)

U.S. Department of Energy, Emissions of Greenhouse Gases in the United States 2000, DOE/EIA-0573 (2000) (Washington, D.C.: November 2001)

B. Ryan and D. Tiffany, "Minnesota Agricultural Energy Use and the Incidence of a Carbon Tax," prepared for the Institute for Local Self Reliance, University of Minnesota Department of Applied Economics, April 1998.

Radian Corp., "Methane Emissions from the Natural Gas Industry," vols. 1-15, prepared for the U.S. Environmental Protection Agency and the Gas Research Institute, EPA-600/R-96-080 (Austin, TX: Radian, 1996).

6.0 Stakeholder Climate Change Input

Addressing a complex issue such as climate change necessarily requires the involvement of many entities – multi-government agencies, local government, business, non-government organizations, and citizens. For a government entity to successfully address an issue such as climate change several conditions must be met:[85]

1. the political decision-makers must feel that the problem is a serious one; that, unless something is done, someone's quality of life may be significantly affected;
2. government intervention is appropriate and legitimate;
3. responsibility for addressing the problem suits the mission of the agency(s); and
4. the agency has the technical ability to solve the problem.

The MPCA and Office of Environmental Assistance (OEA) conducted three distinct surveys to obtain stakeholder input to help gauge the degree to which these conditions are met and obtained other information useful in developing a climate change plan. The purpose of the first survey in 2001was to seek broad stakeholder input on the benefits of developing a state greenhouse gas goal and on the appropriate entity to develop a goal. One of the key findings from this survey was a sharp division in opinions on the role of the state in climate change efforts. Industry, in particular, generally did not feel state government intervention was appropriate. In addition, most felt that a goal would be more effective if developed jointly by the MPCA and sister agencies, rather than by the MPCA alone. This led to the development of a strategy by the MPCA to engage sister agencies in the issue.

Stakeholder input in 2002 focused on sister agencies. Phone interviews of manager level staff at various agencies were held to better understand that agency's interest in climate change and learn what existing programs may be relevant to greenhouse gas control. In addition, an electronic survey was sent randomly to staff at eleven agencies to gauge knowledge of and attitudes towards climate change issues. This information can be used with other data gathered to inform outreach efforts with state government and others.

6.1 Stakeholder Input on Development of a State Greenhouse Gas Reduction Goal

More than twenty representatives of industry, environmental groups, sister agencies and the MPCA were informally interviewed by staff over a two week period in April 2001. Interviewees included eight industry-related organizations, four environmental organizations/citizen groups, and eight different government agencies. A summary of the responses is included below.

What do you see as the benefits or advantages of the state of Minnesota having a greenhouse gas reduction goal?

Overall, the interviewee's response was influenced by their concern (or support) for the actions implicit in a goal. Nearly all assumed the MPCA plans to take some sort of regulatory or program-oriented action.

- Industry generally saw little benefit to a Minnesota goal and said that goals are more appropriately set at the national level. "Minnesota is a small part of the problem and thus there is no basis for a goal."

[85] Institute for Participatory Management and Planning. Listed conditions adapted from Citizen Participation Handbook for Public Officials and Other Professionals Serving the Public. Montery, CA. Tenth Edition. 1997.

- Sister agencies, agency leaders and environmental groups said that a goal would help give focus and show leadership and commitment on this issue. Many expressed the view that state action was more important than ever to fill a leadership vacuum at the national level and to spur federal action.
- Goal supporters also believe a goal encourages a new look at feasibility of reduction actions and provides a new opportunity for education on this issue.

What do you see as the dangers or weaknesses of the state of Minnesota having a greenhouse gas reduction goal?

Again, the degree of support for actions that reduce greenhouse gas emissions appeared to influence the responses. Most agreed that an effective goal must be associated with a plan of action.

- Industry representatives said that a goal could have negative economic impacts and hurt Minnesota competitiveness if other states took less aggressive approaches. They also expressed concern about the uncertainty of economic and environmental consequences.
- Some environmental groups and government agencies expressed concern that a goal could backfire by galvanizing opposition. The MPCA could get a lot of "flak" over a goal. Problems could be lessened if sister agencies and others signed on as well.
- A number of interviewees said that risks vary depending on the aggressiveness of a goal – if it is too weak, it's meaningless; too strong, would bring economic hardship. Risk associated with a "hard number" that is announced too soon was another concern expressed.
- A danger that some expressed was that unless people are better educated, they may not see it as a Minnesota issue.

In developing a greenhouse gas reduction goal, what factors/characteristics do you think are most important to consider?

As far as factors to consider in setting a goal, many believe the goal should be achievable, cost-effective, non-regulatory (focus on voluntary efforts and incentives -make it easier to take early action), and comprehensive in scope (all sectors, all gases, and all sinks) – at least for the short-term. It was suggested that the goal could be ratcheted down in the future as better information is developed that is supportive of a more stringent goal. Other considerations were to:

- emphasize the public education and information role;
- tie the goal to improving Minnesota's quality of life in other areas such as public health, economics, forestry, etc.; and
- emphasize multi-pollutant reduction benefits.

What advice do you have for the MPCA in setting a greenhouse gas goal?

The following input represents the more common advice given:

- Include a broad set of stakeholders for input. Global warming affects interests well beyond MPCA's traditional stakeholders. Learn from past stakeholder efforts.
- Pair a goal with actions.
- Pursue a "No regrets" strategy.

- Include many partners: Department of Natural Resources, Department of Commerce, Department of Agriculture, environmental groups. Get the Governor's support and legislative approval.
- Work with other states and know what they're doing as the MPCA proceeds
- Make the consequences real for Minnesota. For example, describe the effects of global warming on the Boundary Waters Canoe Area.
- Be flexible with the time horizon over which the goal is to be reached.
- Industry representatives say that a qualitative goal would be more effective, but environmentalists recommend a quantitative goal.

Is there anything else you would like to tell us?

A wide variety of responses were given to this question. Here is a sampling:
- Make this a multi-state effort.
- Formally request other agencies to participate.
- Industry representatives believe there will be federal action on global warming. They think a federal strategy will take different approach.
- Get the Department of Agriculture and Department of Natural Resources to support sequestration actions.
- Don't just start something and let it founder. Especially with staffing shortages, the MPCA can't be a leader in everything.

Would you be interested in continued participation with us in this effort*?*

All of those interviewed were interested in participating as this effort proceeds. The Department of Commerce suggested using the Electric Energy Legislative Task Force. A few suggested the Environmental Quality Board as a natural place to move this issue forward.

6.2 Sister Agency Input On The Role Of Their Agency In Climate Change

Seventeen individuals from fourteen sister agencies were interviewed by MPCA and OEA staff to better understand each individual agency's interest in climate change, what existing state programs are affecting greenhouse gas emissions, receive input on future activities to reduce greenhouse gas emissions, and learn what steps agencies may be taking to adapt to a changing climate. Sixteen of the individuals interviewed were in management and two were staff level.

The agencies listed below were selected because their activities have the potential to impact greenhouse gas emissions and/or a changing climate potentially will impact their activities/mission.

- Board of Water and Soil Resources
- Department of Natural Resources
- Department of Agriculture
- Department of Commerce
- Department of Health
- Department of Administration
- Department of Transportation
- Department of Trade and Economic Development
- Dept. of Children, Families, and Learning
- Environmental Quality Board
- Metropolitan Council
- Minnesota Planning
- Public Safety – Emergency Management
- Public Utility Commission

The questions posed to the agency representatives are listed below along with a brief summary of the responses received.

Is climate change important to your agency?

- Most interviewed said it is important, but it is not a primary concern or only saw their work affected indirectly. Those agencies whose mission was more connected to environmental issues or were more impacted saw a greater importance and role. However, overall it seemed low on the radar screen for most.

  "Our mission is to improve the quality and productivity of Minnesota government. We want to work with OEA/PCA and if climate change is important to OEA/PCA then it is important to us in travel management as well." Department of Administration

  "We promote weather-resistant marketing to the tourism industry. This means we encourage the tourism industry to promote activities that are not dependent on snow and ice (such as cultural features, sports, indoor amenities, etc.) in how they market themselves to make them more attractive." Office of Tourism

What programs/activities directly or indirectly lead to the reduction of greenhouse gases or the sequestration of carbon?

- Most agencies have programs/activities that appear to be relevant to greenhouse gas control – although greenhouse gas reduction was never the primary reason for undertaking the activity. These programs are detailed in Section 9 of this report.
- As an example of an activity directly related to greenhouse gases, the Public Utilities Commission requires utilities to provide detailed strategies for reducing greenhouse gas emissions under different scenarios in their integrated resource plans.

What do you see as barriers to your agency implementing activities that would further reduce greenhouse gas emissions?

Responses typically touched on some combination of the following factors:

- Climate change is not a priority in this Administration or in the Legislature.
  "The major barrier is a lack of legislative support and expectation that agencies should work on this issue. Not seen as a high priority and is not on governor's radar screen. Because the EQB is made up of government appointees, can't move the issue substantively until that support is there." Environmental Quality Board

- Lack of national direction or standards.
  "Without a standard for CO_2 emissions, we would not recognize greenhouse gas emissions in our environmental outreach with businesses." Department of Trade and Economic Development

- Lack of resources. (However, fewer agencies mentioned this as a barrier than the interviewers had expected.)
  "[We] need resources that will give people the opportunity to talk about it, such as regional forums, think tanks, sessions on the issue." Board of Water and Soil Resources

- Lack of understanding and awareness of the issue.
  "I think we really need information that we can use to clearly articulate cause and effect in regard to climate change." Office of Tourism

- Lack of research on [fossil fuel] alternatives and economics.
  "There needs to be more research and development. Until we have economic replacements for coal or a way to sequester CO_2, it will be difficult. Also there are infrastructure problems." Public Utility Commission

Are any agency programs/activities affected by a changing climate today?

- Many agencies had at least one example of how they were affected –some mentioned small effects such as using caution in building winter recreation facilities to more substantial effects such as the Endangered Species Program, where populations are small already and these species may not have corridors to move to suitable climate.

  "We are seeing the northward migration of certain plants and animal pests that couldn't previously survive in our climate, which includes pests that now exist or could become problems in the future." Department of Agriculture

Have you evaluated how a changing climate might affect your agency's ability to carry out its mission and programs in the future?

- Other than the Dept. Agriculture representative, no agency spokesperson was aware that this activity had been undertaken.

  "In general, with our strategic planning process we identify new value-added crops or new uses for existing crops and would take a look at how climate change would impact those plans and how external costs would effect that effort." Department of Agriculture

How could the OEA/MPCA best assist you?

- Overwhelmingly, sister agencies look to the MPCA/OEA to help them understand the data and its impacts in terms a lay person can understand. They look to the MPCA for assistance in understanding how climate change affects their agency and measuring their agency's contribution to greenhouse gas emissions and the sectors they deal with. They want a central source of data and information for agencies and the public.
  "MPCA/OEA could help us by providing information – the better the information about what is actually happening [with climate change], the sources, and what the effects are; it helps us to add to the list of reasons why to undertake the activities we do." Department of Commerce

- Also suggested was that the MPCA become even more involved in sister agency planning processes/decisions that ultimately affect greenhouse gas emissions.
  "*Best for PCA/OEA to work with Commerce and bring these issues/ideas to the PUC for decision."* "*PCA might help by participating in the evaluation of integrated resource plans, to the extent that resources allow. Also current involvement in Certificate of Need is good."* Public Utility Commission

- Coordination with sister agencies was another theme.
  "PCA/OEA could help by working with other environmental agencies to help tell the story. It is an issue of having livable communities the same way that good air quality is." Met Council

6.3 State Agency Survey Regarding Knowledge of and Opinions About Climate Change

The MPCA and OEA jointly conducted a survey in early June 2002 to learn whether staff in certain state government agencies view climate change as an issue of concern and their level of awareness about the causes and possible impacts. Information gained from the survey, along with other tools, could provide guidance for future outreach/educational efforts on climate change with individual state agencies. The survey results could also serve as a baseline measure to determine if future outreach efforts are successful.

The electronic survey was confidential and random. It was sent to 1,036 state agency employees via e-mail. Five hundred and sixty four (564) staff completed the survey. The margin of error due to sampling varies from agency to agency depending on their response rate and ranges from nine to 16 percentage points at the 95 percent confidence level. (Appendix A describes the methodology and margin of error for each agency.) Only certain divisions within some agencies were included, as the intent was to survey agencies whose work impacts greenhouse gas emissions and/or whose work may be impacted by a changing climate. The following state agencies were included in the survey.

- Department of Administration- Materials Management, Resource Recovery, Travel Management Divisions (Admin)
- Department of Agriculture (Ag)
- Board of Water and Soil Resources (BWSR)
- Department of Commerce – Energy Division (Comm)
- Department of Transportation (DOT)
- Department of Natural Resources (DNR)
- Department of Trade and Economic Development (DTED)
- Department of Health – Environmental Services Division (Health)
- Office of Environmental Assistance (OEA)
- Pollution Control Agency (PCA)
- Minnesota Planning (Plan)

6.3.1 Summary

Due to the level of debate about climate change over the past 20 years, it can be difficult to distinguish between knowledge and skepticism in evaluating the responses to the questions characterized as "knowledge" questions. Is the respondent that answers differently than the consensus of most experts simply ignorant, or do they have knowledge of the science but are skeptical? This survey was not designed such that we can distinguish between these two groups.

Outreach efforts on the science of climate change would be developed differently for those that are skeptical versus those that are ignorant. Listed below is a summary of the survey results.

- The majority of respondents at each of the eleven agencies responded to each of the five "climate change knowledge" questions in accordance with the best available scientific information.[86]
- In responding to the five knowledge survey questions, Commerce's Energy Division and the Office of Environmental Assistance most often answered in accordance with the majority of scientific experts (ranked in top three for all questions). The Department of Administration and Department of Agriculture ranked among the bottom three for each knowledge question.
- The majority of staff at most state agencies (eight of the 11 surveyed) believe that human-caused climate change is happening today.
- There was a significant difference among the agencies in the percent of respondents that were very concerned about impacts over the next ten years. OEA and Commerce exhibited significantly higher levels of concern about climate change impacts than the other agencies. Half or more at both agencies are very concerned about climate change impacts in the next ten years and this increased to 73 percent very concerned at each agency when asked about the next 50 years.
- The same agencies that most consistently responded in accordance with the scientific experts to the knowledge questions were the same agencies that had the highest levels of concern over impacts.
- When asked about concern about impacts over the next 50 years, a much greater percentage of respondents at all agencies said they were very concerned compared to the percentage that were very concerned over impacts over the next ten years.
- With regards to striking the right balance in addressing climate change at the state level, the greatest percentage at Commerce, OEA, PCA, Planning, and DNR answered that the state has not gone far enough. The greatest percentage at Administration, Agriculture, DOT, DTED and Health said that they did not know.
- A minority of staff at most agencies (OEA and Commerce being the exception) have thought about the connection between climate change and their work – both how a changing climate may impact their work and how their work may impact greenhouse gas emissions. Half or more did say they had considered the impact of their work on emissions at DNR and PCA, as well.

6.3.2 Outreach Opportunities

Based on the survey results, the agencies most motivated to work on addressing the issue of climate change appear to be OEA and Commerce's Energy Division. This is based on responses to questions regarding the level of concern about impacts and their belief in climate change happening today.

With less than half of respondents at most agencies making the connection between their work and climate change issues, there is an opportunity to find ways to connect the issue of climate

[86] The authors deemed information from Intergovernmental Panel on Climate Change which is jointly sponsored by the United Nations and the World Meteorological Association, the National Academy of Sciences, the U.S. Environmental Protection Agency, and Minnesota Pollution Agency greenhouse gas inventory to be the "best scientific information available" for the various questions.

change with the work that these agencies do. Again, these agencies were selected because of their potential impact of their work on greenhouse gas emissions or the impact that a changing climate may have on their work.

As a whole, PCA, Planning, DNR, and Health responses indicate staff at these agencies may be less motivated to address climate change issues than OEA and Commerce, but concerned about the issue especially in the long term. If outreach efforts were developed, the results of the survey suggest targeting this "middle" group of agencies first could help appropriate staff understand these connections and that connection may help motivate people to work on the issue. Agriculture might also be included in this middle group.

6.3.3 Characteristics of Respondents

The table below illustrates the size, gender, age, and education level of the agencies surveyed.

Table 6.1 Demographics of Agencies Surveyed

	Admin*	Ag	BWSR	Comm *	DNR	DOT	DTED	Health*	OEA	PCA	Plan
Total Employee Pool for Survey	70	511	88	49	2330	4465	232	337	69	728	86
% Male	37	56	69	68	65	66	40	44	61	60	64
% with 4-yr degree or more	36	71	78	86	81	45	67	75	88	80	91
% over 40 yrs	93	76	54	68	67	72	69	71	58	72	78

* Number does not represent entire agency but divisions included in the survey. See 6.3 for specific divisions included.

The agencies fall into roughly three size categories. DNR and DOT are comparatively large agencies. PCA, Agriculture, Health and DTED are middle-sized agencies. The remaining five, Administration, BWSR, Commerce, OEA and Planning are all under 100 employees (for the purposes of this survey).

The majority of overall respondents (64 percent) were male. The agencies, which were an exception to this, were Administration, DTED and Health. This demographic was included because surveys of the general public often find an "environmental gender gap" where women, for the most part, express more pro-environment sentiments than men.[87]

Seventy percent of the total respondents were over 40. BWSR respondents were the youngest with only 54 percent over 40 and Administration respondents were the oldest with 93 percent over the age of 40. Generally, pro-environment sentiment decreases, as people grow older.[88] An example cited in the 2000 National Environmental Education and Training Foundation

[87] National Environmental Education and Training Foundation; Roper Starch Worldwide. *Lessons From the Environment: Why 95% of Adult Americans Endorse Environmental Education.* May 2001.
[88] Ibid.

(NEETF)/Roper Report Card found the preference for environmental protection over economic development (if forced to choose) decreases from 75 percent of Americans age 18-34 to 72 percent of those age 35-44, and to 68 percent of those over the age of 45.

Respondents on the whole were a highly educated group with 73 percent completing four years or more of college (almost a third had advanced degrees). The level of education is important, because the 2000 NEETF/Roper Report Card found that the most significant factor in whether people have environmental knowledge appears to be their level of education.

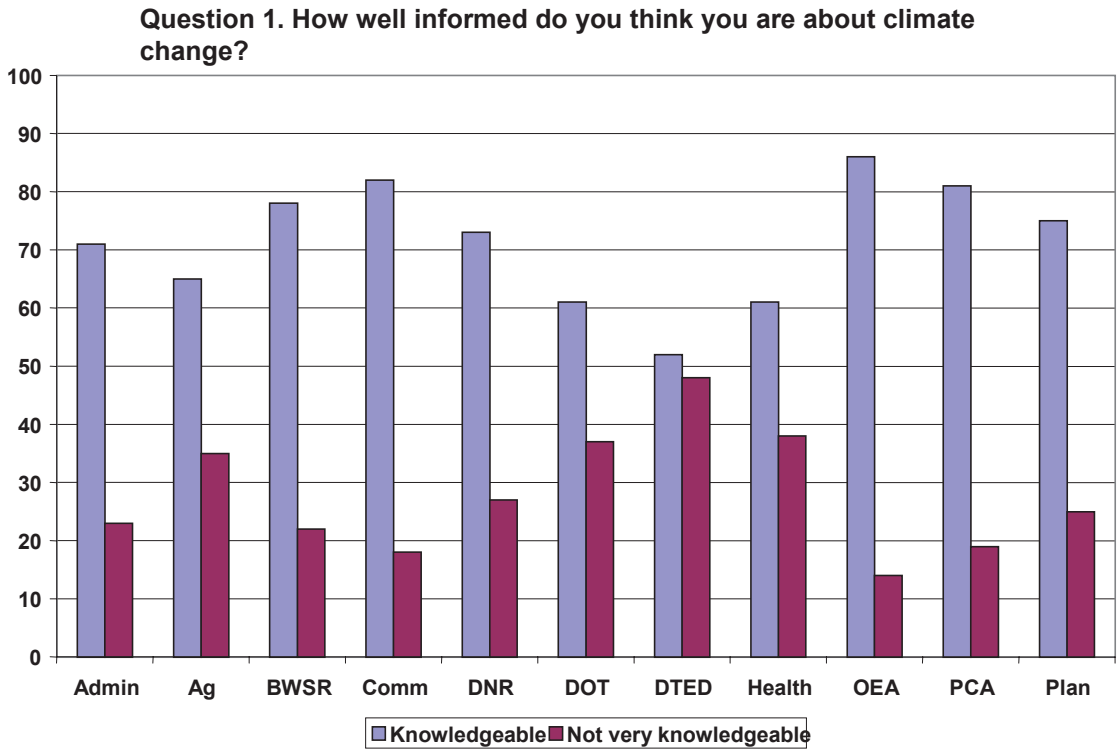
Respondents were asked what union represents them to better determine the type of work that they do. The majority of respondents belonged to the Minnesota Association of Professional Employees at each agency, except for DOT where the majority was part of the American Federation of State, County, and Municipal Employees. Managers representing all levels of management from supervisor to those on the commissioner's plan made up nine to 30 percent of the respondents at any given agency.

The survey also solicited information about the primary sources of climate change information used by the respondents and their preferred information sources. This information will be used when designing outreach strategies with specific agencies.

6.3.4 Knowledge About Climate Change

Most respondents believe themselves knowledgeable about climate change

Question 1: When asked how well informed they thought they were about climate change, 70 percent of respondents said they were somewhat knowledgeable (60 percent) or very knowledgeable (10 percent) about climate change. The "very knowledgeable" and "somewhat knowledgeable" responses were combined and called "knowledgeable" in the figure below. Thirty percent thought they were not very knowledgeable and one percent responded they "don't know". OEA, Commerce and PCA respondents rated themselves most highly in terms of knowledge. The three agencies rating themselves the lowest were DTED, Health and DOT.



Most respondents answered climate change knowledge questions in accordance with best scientific information

The survey included five multiple-choice questions to gauge the respondent's beliefs on various aspects related to climate change:

- The trend of the earth's average surface temperature over the past century
- The primary cause of the earth's temperature increase
- The trend in Minnesota's greenhouse gas emissions over the past decade
- The largest source of greenhouse gases in Minnesota
- The largest source of electricity generation in Minnesota

Overall, the majority of respondents at each agency responded in accordance with the best available scientific information[89] to the knowledge questions, however, there were significant differences among the agencies for some of the questions. In responding to the five knowledge survey questions, Commerce's Energy Division and the Office of Environmental Assistance most consistently answered in accordance with the best scientific information (ranked in the top three for all questions), followed by Planning (top three for three questions), and then Board of Water and Soil Resources (top three for two questions). The Department of Administration and Department of Agriculture most consistently had the lowest percentages that answered in accordance with the best scientific information (bottom three for three questions). DOT ranked among the bottom three in four of the five questions. BWSR was among the bottom three for

[89] The source for the "correct" answer is described under each question. Some respondents felt the survey biased and that there was still much debate and uncertainty regarding some of the issues.

one of the questions. Individual agency response to the knowledge questions (numbers 2 through 6) can be found in Appendix A of this report.

Some respondents responding differently than what the MPCA deems to be the best scientific information may not be ignorant of the information but, rather, have knowledge of the information but are skeptical of the scientific information. Thus, those agencies ranking lower in the knowledge questions are not necessarily less knowledgeable than those ranking higher. They may be aware of the science, but have a greater percentage that is skeptical of it.

6.3.5 Attitudes and Beliefs About Climate Change

The survey asked three questions related to the respondent's beliefs and attitudes regarding climate change:

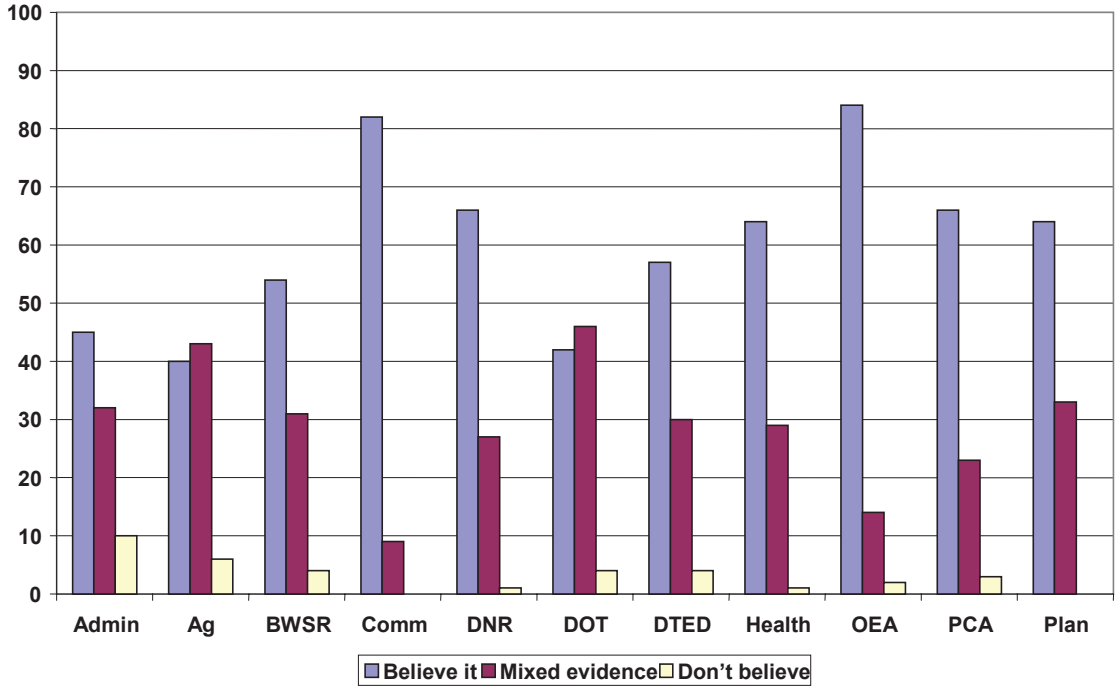
- Whether they believe human-caused climate change is happening today
- Their level of concern about impacts over the next ten years
- Their level of concern about impacts over the next fifty years

These questions are important in evaluating the degree of motivation to work on this issue and give a sense of the importance of this issue to each agency. While the previous questions were about climate change basics, these three questions are key in determining whether the respondents view climate change as a problem.

Majority at most agencies believe climate change is happening today

Question 7 A majority of staff at eight of the eleven agencies believes that human-caused climate change is happening today. Sixty percent of overall respondents said they believe human-caused climate change is happening today. Notably, the two agencies with the highest percentage (greater than 80 percent) of employees believing climate change is happening were the same two that answered in accordance with the best scientific information on the knowledge questions (Commerce and OEA).

Question 7. To what extent do you believe human-caused climate change is happening today?

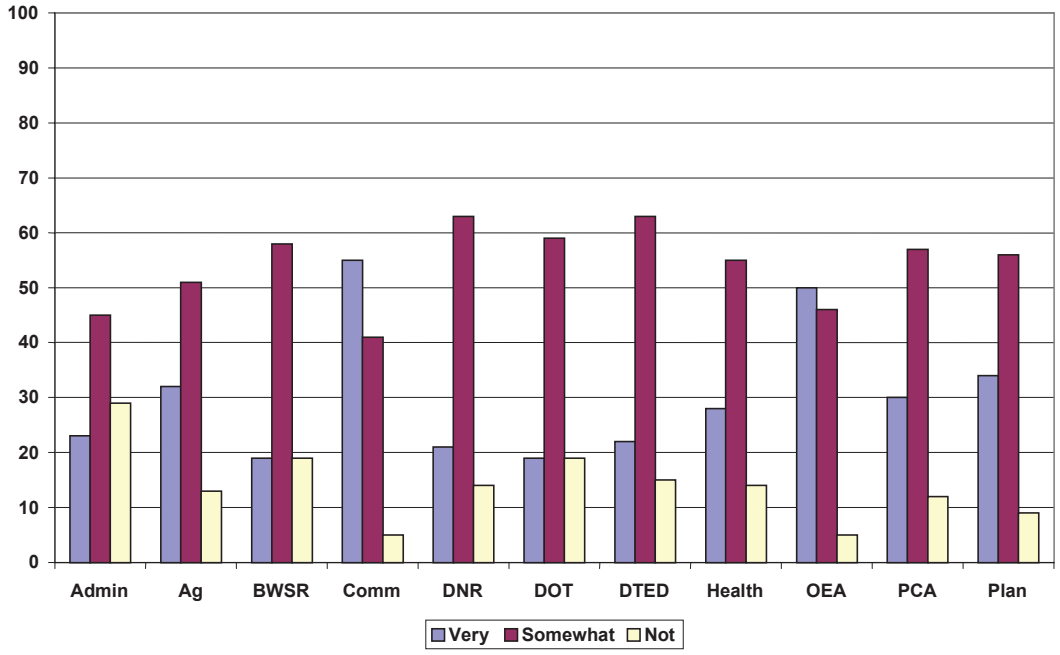


A minority of respondents at Administration, Agriculture, and DOT believe climate change is happening today. These were the same three agencies whose answers to the knowledge were least in accordance with what the MPCA deemed the best scientific information. Ten percent of Administration respondents didn't believe climate change is happening today – higher than the other agencies. Overall, eight percent of respondents chose "Don't know" as a response.

Level of concern increased with longer time-frame

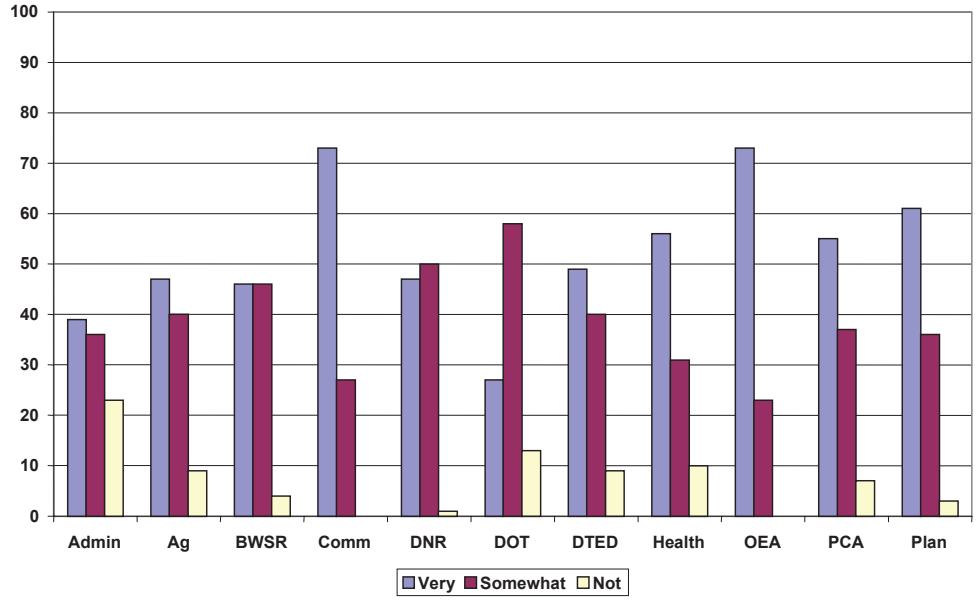
Question 8 When asked about their degree of concern about climate change impacts over the next ten years, the agencies with the greatest concern were Commerce and OEA with half or more responding they were very concerned about impacts over the next ten years. Agencies with lower levels of concern about short-term impacts included DOT, Administration, BWSR, DNR, and DTED. Interestingly, Agriculture respondents fell more in the middle as far as concern about short-term impacts.

Question 8. Concern about impacts over next ten years

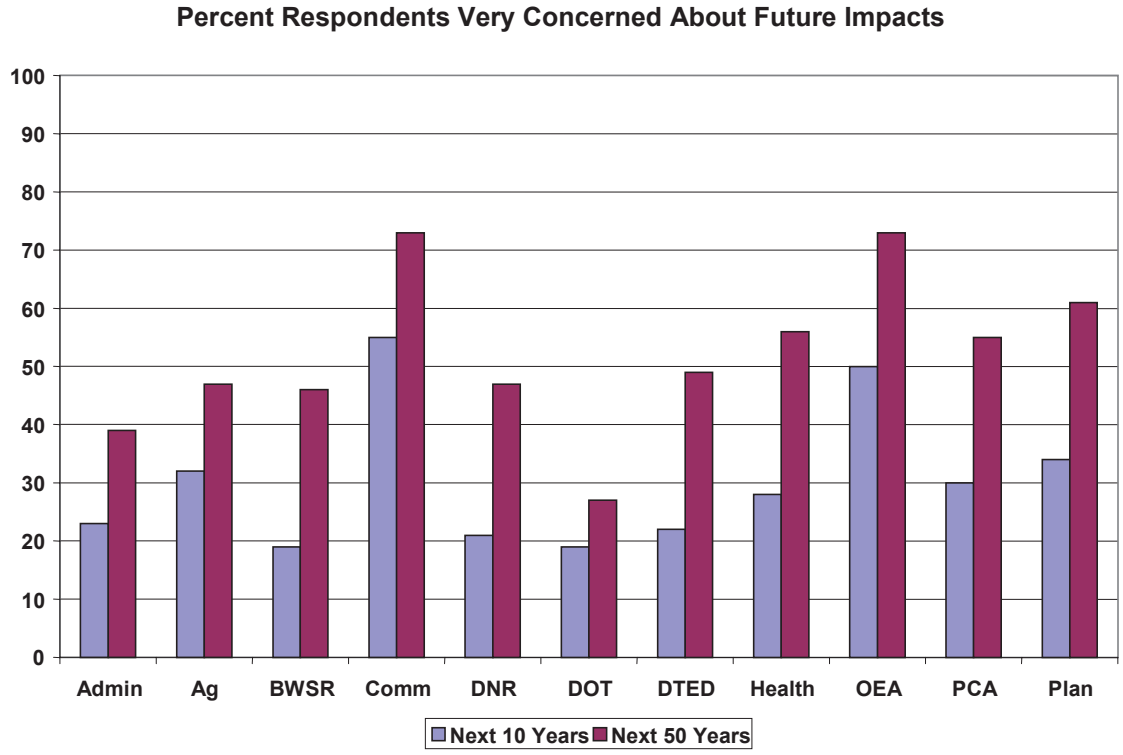


Question 9 Concern about impacts increased with a longer timeframe. When asked about concern about impacts over the next 50 years, a much greater percentage of respondents at all agencies said they were very concerned. Again, the pattern was similar with OEA and Commerce expressing the highest level of concern (73 percent at each agency). A majority of staff at PCA, Health, and Planning also are very concerned about long-term impacts. The question did not specify impacts in Minnesota vs. global impacts, so respondents could have had the local or the global picture in mind when responding.

Question 9. Concern about impacts over next 50 years



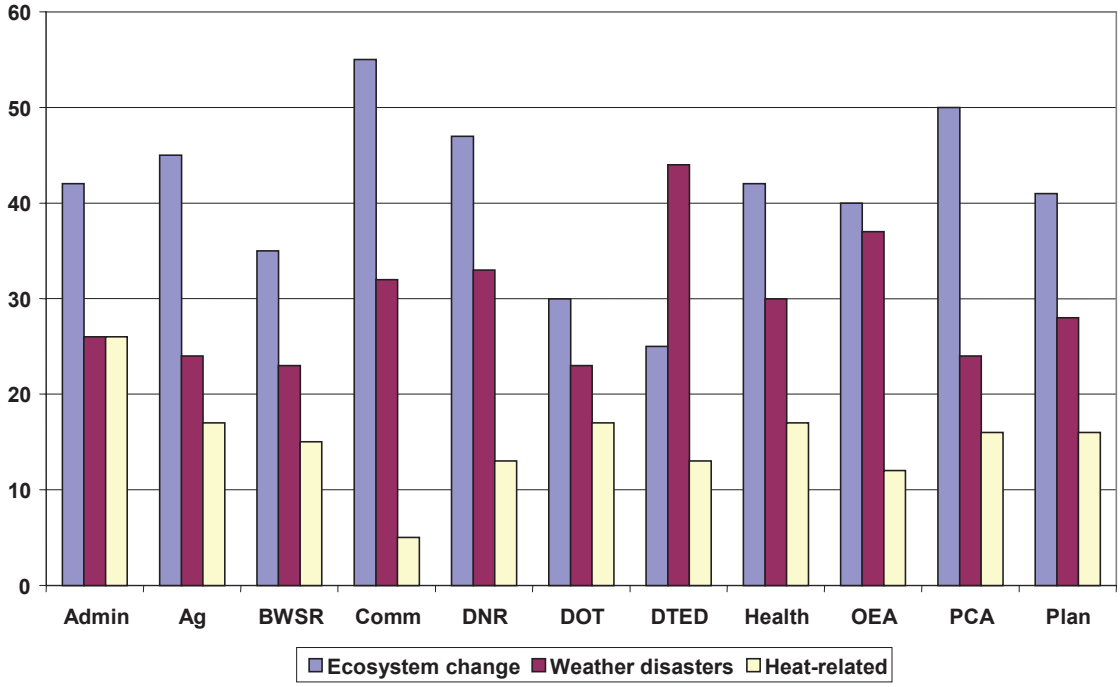
The next figure compares how the percentage of respondents that are very concerned shifts when thinking about ten-year impacts vs. fifty-year impacts. DOT stands out as having a significantly lower percentage (27 percent) of respondents very concerned about long-term impacts. It is important to know the level of concern and belief in a problem because unless stakeholders believe a problem exists, it is difficult to work on actions to address an issue.



Ecosystem changes rank as biggest concern

Question 10 Respondents were asked which climate change-related potential impact they would be most concerned about in Minnesota. This question was asked to learn if there was a particular issue of interest within an agency. This type of information would be useful to make educational information relevant. Respondents were given five responses to choose from and the greatest percentage of respondents from all agencies, with the exception of DTED, chose "ecosystem changes that result in the loss of Minnesota plants and animals and an increase in non-native species" as the impact they would be most concerned about. The greatest percentage of DTED employees (44 percent) chose "increase in frequency of floods, tornadoes, and other unpredictable weather patterns" compared to 29 percent of overall respondents. Other choices for respondents included: "Increase in heat-related illnesses and some diseases borne by insects" (15 percent overall), "Decrease in winter recreation opportunities" (two percent), "Something else" (eight percent), and "Don't know" (four percent). There was no one theme to those responding "Something else". A sampling of responses included some stating a combination of impacts was of most concern, others stating they didn't believe it was happening, while others citing a concern for actions that may be taken.

Question 10. Potential Minnesota Impact Respondents Most Concerned About

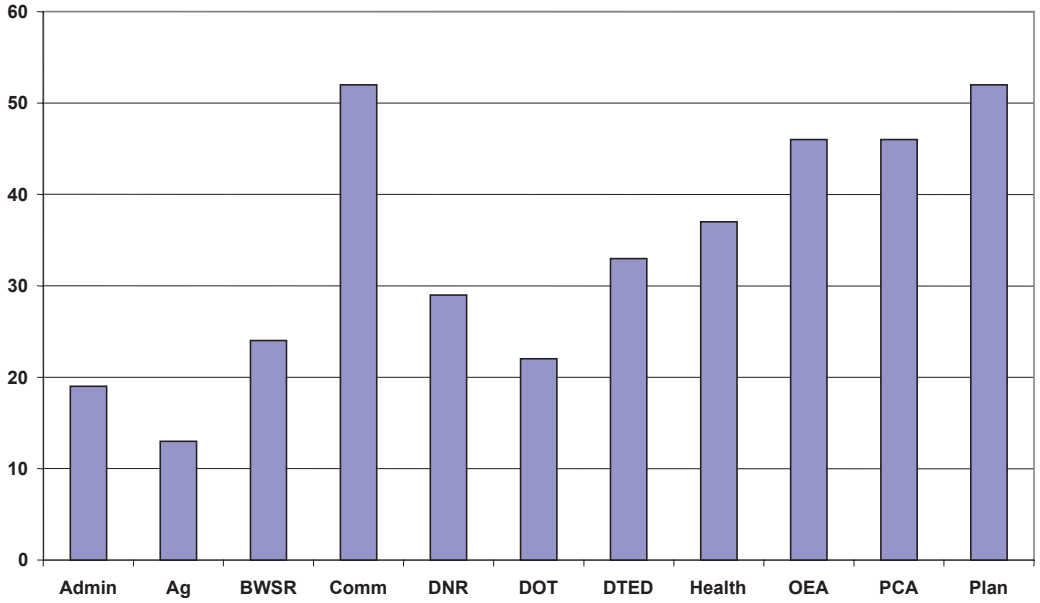


Barriers to state climate change initiatives

Question 11 In order to identify what barriers state agencies might see to state action, respondents were given a number of barriers commonly named when actions to reduce greenhouse gases are discussed, and asked to choose the one of biggest concern or choose "not concerned [about state initiatives]". Interestingly, more than half the respondents at Commerce and Planning were not concerned about economic threats, increased taxes or fees or limiting freedom of choice. The overall breakdown of responses is shown in the table below. The ranking of barriers at each agency was similar to the overall ranking as no one barrier stood out for any agency. Those providing responses to "Other" expressed concerns that not enough will be done, poor planning, execution of initiatives by state government will not accomplish anything, and numerous other concerns.

Choice	Percent of Total Respondents
Not concerned	34
Increases taxes or fees	21
Other	17
Limits individual's freedom of choice	16
Slows economic growth	9
Decreases jobs	3

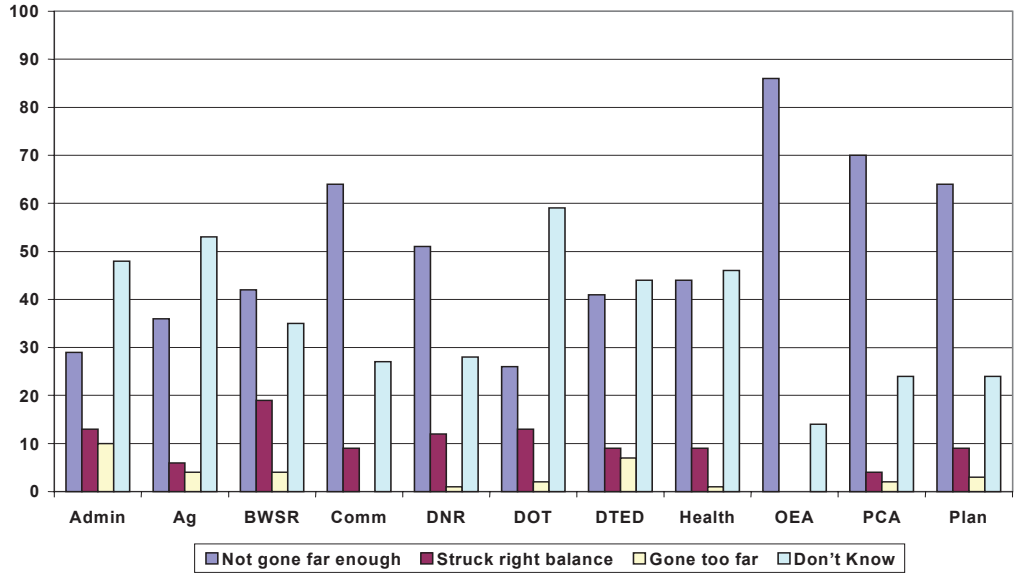
Question 11. Percent Respondents Not Concerned About Negative Impacts from Implementing State GHG Initiatives Over Next Ten Years



Has state climate change action gone far enough?

Question 12 It is difficult to draw any overall conclusions from responses to the question "with regard to striking the right balance in addressing climate change, the state of Minnesota has". Thirty-eight percent of overall respondents answered "don't know". However, at each agency a greater percentage responded the state hadn't gone far enough compared with the combined percentages that chose "struck the right balance" and "gone too far". A majority at Commerce, OEA, DNR, PCA and Planning all felt that the state has not gone far enough in addressing climate change. At Administration, Agriculture, DOT, DTED and Health the greatest percentage said that they didn't know.

Question 12. With regard to striking right balance in addressing climate change, the state of MN has

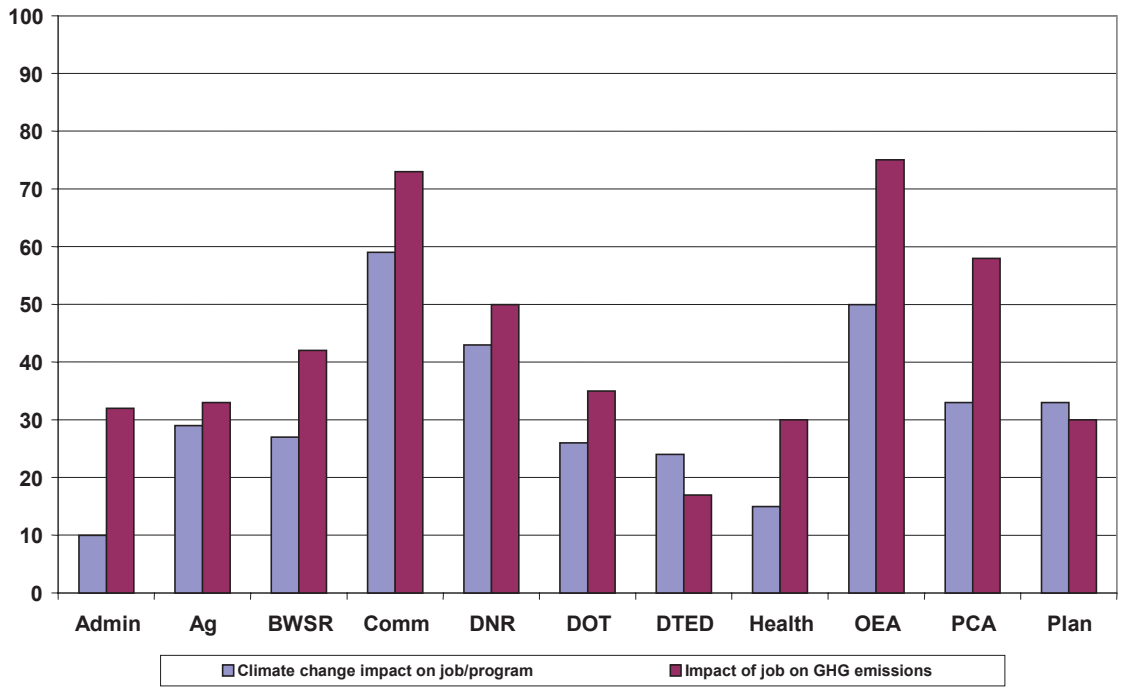


Minority of staff at most agencies have thought about the connection between climate change and their work

Questions 13,14 Two questions were asked of respondents to learn whether they have considered climate change issues in the context of their work. The first asked whether the respondent or their department had thought about how a change in Minnesota's climate would affect their job or program. For example, would increased frequency of flooding impact the work you do for the state? Only 31 percent of overall respondents said they had thought about the impacts of a changing climate, with more than half from OEA and Commerce responding affirmatively. The second question asked was whether the respondent had thought about the impact their job has on greenhouse gas emissions. Again a minority (43 percent) of overall respondents had thought about how the work they do may reduce (or increase) greenhouse gas emissions. Half or more did say they had considered the impact of their work on emissions at OEA, Commerce, DNR, and PCA.

The responses to both of these questions points to the need for providing information to help agency workers make the connection between climate change and the work that they do. The agencies included in the survey were selected because either their work/mission would be impacted by a changing climate or the work they do may be relevant to greenhouse gas control.

Questions #13,14 Percent of Respondents That Have Thought About Relationship Between Their Job or Program and Aspects of Climate Change



7.0 Considerations in the Design of State-Level Strategies for Global Warming

The global warming problem places a state in an inherently difficult position. Emissions leading to warming are local, but effects are global, and effective action to limit emissions can take place only at the global level. Minnesota is a relatively small contributor to greenhouse gas emissions, but there is reason to believe that it could be one of the more intensely impacted parts of the U.S. If a state chooses to take a leadership role, depending on how aggressive the state is, its actions to slow the rate of greenhouse gas emissions could result in substantial costs to the economy, but also potential longer-term economic benefits.

7.1 Broad Considerations in Determining Climate Change Policy

An exhaustive literature has been building for two decades on the best approach of society to the global warming problem. What this literature reveals more than anything else is the complexity of the policy calculus that goes into the design of global warming policies. The global warming problem is a mix of different elements, for instance, long time-frames, scientific uncertainty, intense ecological effects, and global commons problems. Some of the elements or characteristics argue for immediate action, some for delay. Some characteristics of the problem argue for no action whatever over any period of time. Some argue for an incremental learn and 'feel-your-way' approach, some for adaptation to impacts. This jumble of characteristics pushes in different directions. Because of this, most policymaking necessarily has tended to reduce to a subjective balancing of competing pressures or demands, some pushing forward toward action, some repelling.

It is this subjective balancing of these considerations that, at a practical level, is at the heart of policy making on global warming. How are the risks to the global ecological system balanced with the costs of a rapid conversion of the commercial energy sector from fossil fuels to nonfossil fuels? How should the need for better scientific information be balanced with the limits to what is knowable about global change?

A quick survey of the policy analysis literature on global warming suggests the following characteristics or components of the problem as critically important in the policy calculus that feeds into the design of global warming policies.

Physical Dimensions of the Problem: There is relatively little uncertainty that the planet will warm as a result of atmospherically accumulating greenhouse gases. Even the most vociferous skeptics concede that mean global temperature will rise at least 1 degree Celsius in the next century.[90] There is, however, a wide range of possible effects, extending from a smaller planetary warming of about 1.5 degrees Celsius above the present condition to a warming, averaged over all points on the surface of the earth, of as much as 6 degrees Celsius in 100 years, 8 degrees Celsius in 150 years. At this point, it is scientifically impossible to distinguish these outcomes from each other, or from more middle-of-the-road predictions of warming (2.5 to 3 degrees Celsius), in terms of their likelihood of occurrence.

[90] R. Lindzen, Testimony to the Senate Environment and Public Works Committee, 2001

This is a problem in that the more extreme parts of the range of possible warming involve very radical departures from present conditions. A warming of 3 to 4 degrees Celsius would be about of the same intensity of warming as the earth underwent between 20,000 and 10,000 years ago when the last ice age gave way to warm interglacial conditions globally. A warming of 6 degrees Celsius would return the earth to conditions unknown since the Eocene 50 million years ago. As with change in all large physical systems, the further that the change is from initial conditions, the more unpredictable the outcomes become. Scientists simply do not know what will happen under the conditions of a 100-year 4 or 6 degrees Celsius warming worldwide.

The most worrisome aspect of this is the potential for large, particularly abrupt or discontinuous changes in climate, both at the global and regional scale, as the planet warms. The general sense in the scientific community is that there is a chance that global climatic change could manifest itself as a series of such discontinuous 'step-changes', rather than as a gradual, linear, predictable change, and that the chances of abrupt discontinuous climatic changes increase as the rate of warming accelerates.[91] Is this more or less likely than a more gradual, continuous change in climate? Scientists simply cannot say.

Thus, because of the physical dimensions of the problem, there is at least some potential later in this century for climatic changes that are highly disruptive and inherently unpredictable. It is this potential for highly disruptive, unpredictable climatic change that gives rise to much of our concern about an intensifying greenhouse effect. For instance, it is the basis for much in the 1992 United Nations Framework Convention on Climate Change and the 1997 Kyoto Protocol to that convention. The underlying reasoning of both of these agreements is precautionary. There is risk of highly disruptive climatic change later in this century. This risk increases with the rapidity of our 'forcing' of the climate. Until it can be demonstrated that patently unacceptable impacts will not occur as a result of an intensifying greenhouse effect, society is best advised to adopt a go-slow policy on greenhouse gas emissions.

A precautionary strategy would argue for a gradual backing away from a business-as-usual emissions trajectory, as well as intensive scientific research to resolve uncertainties. The policy is incremental in nature, subject to change as scientists learn more. Implemented at a state level, the policy might call for a gradual reduction in emissions, and a continuing effort on the science.

Ecological Effects: It appears that, as global surface temperature rises, natural species are moving geographically in pursuit of migrating climates, shifting 50 to 100 miles south to north for every degree Celsius of increase in mean global surface temperature. This pattern of response, which is also the dominant pattern of ecological response in periods of warming in the geological past, suggests a future world in which natural species could be displaced from present ranges by one hundred to hundreds of miles, where established communities are disrupted, and where landscapes are at least partially transformed. The results of this are highly uncertain, but the possibility of severely negative effects cannot be discounted.[92] As in the case of the scale arguments given above, this condition seems to argue for a slow-down in emissions to limit the

[91] National Academy of Sciences, *Abrupt Climatic Change: Inevitable Surprises*, Washington, D.C., 2002.
[92] In Minnesota, the loss of the existing spruce-fir and aspen-birch forests of the north and north central parts of the state seems possible.

stress on the ecological system, at least until it can be demonstrated that outcomes that are manifestly unacceptable will not result.

Irreversibility: Once set into motion, global climate change is probably irreversible. At present, there are no technical means by which to remove emitted greenhouse gases from the atmosphere in substantial quantities. It is possible that some means of future removal might be developed, but the sheer amount of carbon that would have to be removed from the atmosphere—many hundreds of billions of tons—probably limits prospects for a quick reversible process.[93] Ecological processes certainly will not be reversible; once set into motion, these processes will not return regional ecology to its initial condition even in the event of a return to prior climatic conditions.

If the scale of possible climatic changes and their ecological effects give one reason to slow the rate of emissions, the irreversibility of these changes makes this doubly so. This presents an additional reason for a slow-down in the rate of greenhouse gas build-up.

Persistence: The persistence of greenhouse gases in the atmosphere is long. Once emitted to the atmosphere, the more important of the greenhouse gases can be expected to remain there for tens-to-hundreds of years. Once concentrations of carbon dioxide, the most important greenhouse gas, reach a doubling or more of preindustrial levels, which will occur in the next century under business-as-usual conditions, they can be expected to remain at those levels for many hundreds of years. This means that the decisions made by this and the next generation will have consequences that reach far into the future, affecting the lives and livelihood of generations of humans in the 22nd century, the 23rd century, perhaps the 26th century. The individuals of those generations that will be impacted by the decisions today's society makes have no voice in those decisions. They cannot tell today's decisionmakers what they want. This raises the difficult problem of somehow representing the desires and the welfare of future generations in today's decisions.

This changes the nature of today's decisions. The problem becomes a problem in the exercise of democracy. How are the interests of many tens to hundreds of billions of future residents of the planet satisfactorily represented? How are today's decisions weighted to adequately represent their interests? As importantly, how, if at all, are today's decisions weighted to avoid the potential mistakes in representing their interests? How can today's society avoid wrongly interpreting the unknowable interests and desires of as many as twenty-five distant future generations?

Sheer numbers suggest that substantial weight be given to their interests in the decisions of today's society. As far as substance, that current generations do nothing to irretrievably compromise either the global ecological system or the economic system is probably the best guidance that could be offered.[94] This preserves a studied neutrality on what is after all matter of

[93] The current annual emission resulting from all global energy production is about 6.5 billion tons of carbon.

[94] Based on current trends, distant generations will likely be much more affluent than present generations of humans. As very affluent populations, they are likely to place a much higher value on a stable healthy global ecosystem than do current generations, and relatively less value than now on the next marginal unit of income. In general, the demand for environmental protection increases with the level of affluence, while the utility of the next unit of income declines at high incomes.

speculation—what future generations would want today's humans to do—in thought and action. For some, this suggests a risk adverse strategy on the ecological side of things, perhaps involving a present-day go-slower strategy on emissions, but with substantial attention to the health of the economic system.

Irreducible Need for Adaptation: Regardless of what actions are taken globally to reduce greenhouse gas emissions, some surface warming is now inevitable. About one degree Celsius of warming to as much as two or three degrees Celsius of warming over the next century is now probably unavoidable. Whatever else we do, we will need to adapt to these unavoidable changes in climate. This consideration argues for a focus not on emissions or scientific research, but on adaptation as the principal mode of response by society to climatic change, essentially because humans will need to adapt anyway.

Uncertain Benefits: Due to the uncertainties in how much it will warm in the future and how the climate will change, the impacts of climate change are poorly defined, both at the global and at a country level, and have yet to be narrowly placed in time. Because of this, it is impossible to narrowly calculate the benefits of greenhouse gas control at any single level. Scientists cannot say what the benefits of, say, 30 percent control on greenhouse gas emissions will be on conditions in Minnesota or the U.S. for any decade or set of decades this century, or if there even will be demonstrable benefits to controls. Until this information can be developed, it will be impossible to rigorously evaluate the effectiveness of policies at different levels of stringency of control, which by itself (and accepting the usefulness of a stringent test) for some would argue for continued scientific study of the question.

Capital Turnover Time: A very large amount of energy-using or energy-producing equipment is in use throughout the economy. Not all of it, or even a large part of it, is at the end of its economic lifetime. Because of this, retirement of that equipment now would be premature and involve economic costs to society. This suggests that whatever changes are required in the energy system be slow enough to accommodate the natural rate of turn-over of capital in the economy[95]. As many have noted, this argues for a go-slow approach, one that targets only those older facilities or structures that are near the end of their economically useful lifetime. It would also argue that, if intervention to control long-term greenhouse gas emissions is the goal, special attention be paid to new investments in long-lived plant, equipment and buildings, involving perhaps enhanced energy efficiency requirements beyond current requirements for *new* long-lived equipment and facilities.

The central idea here is to limit costs by limiting any program to facilities that would be retired anyway as a natural course of things. Some of the same goals could be achieved on the cost side of things through a delay in the implementation of all emission control requirements for a decade or more for existing facilities.

[95] The rapidity of the required capital turnover in the economy under the Kyoto Protocol is the principal source of the high estimated cost of U.S. participation in the agreement.

Technology Development: According to some, including officials in the Bush Administration, the problem of greenhouse gas control is fundamentally a technology problem. Present day alternatives to fossil fuel–based energy production technology are costly. End-of-the-pipe greenhouse gas control equipment is either nonexistent or prohibitively expensive to operate. Over a period of a decade or so, technology innovation might rectify this situation. Examples of technologies that are under investigation include CO_2 stack scrubbing with disposal beneath surface bedrock and hydrogen fuel cells. Using these technologies, one day it might be possible to economically combust fossil fuels without greenhouse gas emissions or to dispense with fossil fuels altogether. At a minimum, energy technology research and development should lower the costs of either greenhouse gas control equipment or of alternatives to fossil fuels, reducing the costs to society of emission reductions.

If present-day research and development lowers the total future costs of greenhouse gas control substantially, society might be best advised to wait a decade or so before initiating aggressive greenhouse gas control programs. For many, this argues for a wait-and-invest strategy.

Time Needed to Change the Energy System: On the other hand, historically, the energy system has changed slowly. Typically it has taken between 50 and 100 years for the energy system to change from one dominant fuel to another, for instance, from wood to coal or from coal to oil. This has been true both globally and in the United States. This means that, regardless of when society wants to act, if society decides that the risks of unsustainable impacts warrant preventive action, it may have to act soon, if only to assure that if stringent limits on emissions do become necessary, success in achieving those limits is not foreclosed by the slowness of change in the energy system and present-day inaction. Like concerns for persistence and irreversibility, this places a premium on an active precautionary response.

Induced R&D and Learning by Doing: It has been argued that technology development can be accelerated through the proper pricing of goods and services. By taxing or setting emission caps, prices can be made to reflect the environmental costs of different activities, thereby providing economic incentives for the development of new technology. A substantial lowering of the costs of pollution control also can result from learning by doing. From EPA's experiences in controlling acid rain, they learned that there are a wide variety of measures that are generally available for pollution control that do not involve new technology that firms, given flexibility, can and will adopt at low costs to meet regulatory obligations. These often reveal themselves only after regulations are imposed and firms are forced to innovate to find the lowest cost solutions.

With an acceleration of the rate of technological innovation, it might be possible to skip the waiting period for the development of new technology, making more feasible near-term regulatory actions.

Competitive Advantage: In acting alone to limit emissions of greenhouse gases, a state may be placing its businesses in a competitive disadvantage in relation to their competitors in surrounding states. This consideration argues that a state, should it decide to act to limit emissions of greenhouse gases, act in concert with surrounding states.

Limited Effects of State Action: Acting on its own, Minnesota can have little effect on the rate of global surface warming. Minnesota's emissions of greenhouse gases comprise less than half of a percent of all global greenhouse gas emissions. If these emissions were completely eliminated, the effect on surface temperatures, even over a period as long as fifty years, would be tiny, a few hundredths of a degree Celsius. This argues, as others have noted, that whatever else is done, Minnesota act within a larger framework of a national or international program of action.

Setting an Example: While it is true that, acting on its own, no one state can influence the buildup of greenhouse gases in the atmosphere, it is also true that a state, acting on its own, can exercise a leadership role in the issue. With its adoption of automobile exhaust standards for greenhouse gases, California has seized the mantle of leadership. New York is following California's lead in supporting tailpipe emission standards. By taking a stand in this issue, individual states have demonstrated the seriousness of their concern about global warming, and have, as a matter of the historical record, prompted other states to act similarly. This suggests that the effect of unilateral action by any single state need not be limited to what happens within its borders, and that by setting an example, a state, even a small state, can make a difference.

Risk of Future Regulatory Action: The global climate change problem is fundamentally different from others with which we have dealt over the years. It involves the energy system, one of the main underpinnings of the economy. It lacks an easy, inexpensive technical fix, like stack scrubbers, which means that, after the easy things are done, emissions reductions will fall on the energy sector and require major changes in energy production. It is the subject of international conventions to which the U.S. is a party, and is now a point of contention between the U.S. and its major trade partners (and principal strategic allies) around the world. It has been recognized as a serious environmental problem by both major U.S. political parties, which disagree only over the timing and nature of actions to begin to limit emissions—whether they should be taken immediately or should be delayed for a decade to allow for the development of next generation of energy production technology, and what they should be.

It is current policy for the U.S. not to participate in the Kyoto Protocol, nor to institute mandatory emission controls. This, however, is only the current condition, and there is no guarantee that that policy will even outlive this Administration, much less reach to the end of this decade or into the next decade.

In this situation, there is risk to Minnesota of future federal regulatory actions stemming from sudden change in the political landscape or sudden change inside the political parties as to how

the question is perceived.[96] For instance, in the event of a decision to join the nations adhering to the Kyoto Protocol in that Protocol, the state of Minnesota could be required to shed 15 to 20% of its greenhouse gas emissions, in a period of perhaps a few years. The cost of this would be substantial, if only because those more costless things like improved energy efficiency proceed at a slow rate and typically realize large gains to the economy over decades. To deal with this contingency, the state of Minnesota may want to limit the exposure of the economy by limiting, at least to some degree, the *rate of growth* in emission levels less than what would otherwise naturally occur.

Underinvestment of Minnesota in Energy Efficiency: Engineering cost studies of commercially available energy end-use technology have confirmed that, across nearly all sectors of the economy, the US is underinvested in energy efficiency. These studies, which stretch back 25 years in a sequence of analyses, have demonstrated that consumers—and the economy more generally—systematically undervalue energy end-use efficiency in their purchases of products, structures, vehicles, and services. Technological innovation acts to continuously improve the end-use efficiency of energy-using equipment and buildings on the market. For many such improvements, operating costs savings due to lower energy use acts to offset higher initial costs of such improvements over periods of a few years. Using fairly conventional financial analysis, these cost savings have been shown often to be large enough to justify the purchase of this equipment and buildings purely on economic grounds.

Because of the underinvestment in energy efficiency, the average end-use efficiency of newly purchased equipment and buildings is consistently worse than what might be expected based on economic grounds. In the case of the existing stock of equipment and buildings in the economy, the situation is compounded by the generally lower efficiency of older vintages of equipment and buildings. Thus if in new purchases of equipment and buildings the society is underinvesting in energy end-use efficiency, the situation is much worse when one considers the existing stock of equipment and buildings in the economy. This contributes to relatively high greenhouse gas emissions. The inefficient use of energy and materials also contributes to higher production costs for goods and services and a less competitive economy.

There is a good deal of debate about how large the gap is between the economic potential for end-use energy efficiency and actual energy end-use efficiency. It seems undeniable, however, that the economy of the U.S. and the state is underinvested to some degree in energy efficiency.[97] This suggests the possibility that, through energy efficiency improvements, Minnesota might be

[96] To forestall the introduction of mandatory controls on greenhouse gas emissions by the Congress, the Bush Administration is pressuring the largest U.S. corporations to commit to specific voluntary reductions in their greenhouse gas emissions. This is an indicator of the pressures on the Administration to reverse its position on greenhouse gas emissions control. It is also a measure of the potential for quick reversal of current U.S. global warming policy as we go forward. To a degree, the actions of US corporations reflect this uncertainty about the staying power of current policy. For instance, since 1994, claims for roughly 1.5 billion CO_2-equivalent tons of early greenhouse gas reductions have been filed by U.S. corporations with the US Department of Energy under its 1605b program, an early reductions registry. They have been made on the understanding that the participating firms will be able to apply these early reductions against any future obligations incurred under a Federal greenhouse gas regulatory program. Section 2 of this report describes additional actions of states, businesses and local entities. What all of this activity points to is the very fluid state of policy in the U.S. on global warming.

[97] See, for instance, M. Bernstein, et al., "The Public Benefit of Energy Efficiency to the State of Minnesota," Rand Science and Technology, Santa Monica, CA, 2002.

able to pursue greenhouse gas reductions while benefiting the larger economy. In terms of strategy, this argues for the pursuit of energy efficiency improvements for their own sake irrespective of the complexities introduced by other more impacts-related dimensions of the global warming problem.

Risk to Early Actors: Finally, in the future, as national regulatory programs become established, early actors may or may not be credited with emission reductions made prior to the implementation of mandatory controls. It depends in part on the design of the programs. There is no way of knowing in advance what types of reductions might qualify under future regulations and which might not. This places early actors at risk. This argues that, in absence of better information on what types of early actions might be credited under future regulatory programs, the state of Minnesota avoid any state requirements that go beyond business-as-usual requirements.

7.2 A Climate Change Strategy Framework For Minnesota

Formal analytical frameworks for evaluating policy have been of limited use in the global warming problem. The problem characteristics diverge widely in the degree to which they are amenable to quantitative description. This has made the easy quantification of trade-offs impossible. Because of this, it has proven very difficult to apply the standard cost/benefit framework of analysis to the problem. The same is true of the more ambitious optimization frameworks proposed by some economists for determining the schedule of economically optimal level of emissions for the next century—there are simply too many of the problem's critical components that are not resolvable within that type of objective framework of analysis. Thus it has proven very difficult to incorporate the issues of irreversibility or persistence into these frameworks, not to mention problems associated with the physical dimensions of the problem or the lack of certain impacts information.

The issue here is an inability to resolve these problem characteristics into a common currency that makes them somehow comparable and enables the analysis of trade-offs under different decisions. Lacking this, decision-making tends to reduce to a subjective balancing of the different demands of the problem discussed above.

One way that society historically has sought to deal with this problem is to leave the pursuit for the objectively right answer for policy on climate change in favor of the answers to a more narrow set of questions: do we have to act now or have we a window of time for more study and consideration of our options? What is the minimum we have to do in the long-run to meet the irreducible demands of the climate problem, at least as we now understand them, and when? Are there cost-free options that are available to us? The answers to these questions allow decision-makers to address the minimum of what needs to be decided now, and leave for the future what can be postponed to the future.

On the question of whether time exists for further study, Minnesota probably has a window of time of a decade or so before the real decisions on global warming must be taken. This is not to say that no actions need to be taken over the next decade, just that the hard decisions on whether emissions are to be reduced substantially and how are probably a decade off. If Minnesota is sensitive to the risks of federal regulatory action that comes sooner, the time-frame might shorten

somewhat, but the point that there is a window of time for study and consideration of long-term options holds.

As far as the minimum Minnesota might have to do now to meet the long-term irreducible demands of the climate problem, this is more difficult. Given uncertainties, the question is really one of the minimum necessary to do now to lessen the risks that present-day inaction may render longer-term efforts to address the long-term demands of the problem difficult or impossible. If there is a likelihood of a federal regulatory program coming out of Congress sometime in this decade, what is the minimum the state needs to do now to cushion the economic blow in Minnesota of the implementation of such a program? Or again, if in the very long-term greenhouse gas emissions must decline substantially from present levels out of regard for sheer physical dimensions of the problem, ecological effects, issues of irreversibility or whatever, what must the state do now to make technically and economically feasible such a long-term emissions decline in Minnesota?

The issue here is one of the minimum that might be done now to keep open the state's long-term options. In fact, we do not know what in fact the long-term demands of the problem will be; our understanding of how the politics and science will evolve is limited to what we know from the present state of the science and political developments to date. But the costs of being wrong and foreclosing options are probably substantial, particularly if in the event of the institution of a Federal regulatory program the state is caught flat-footed. This argues that, as insurance against this eventuality, some minimal effort be made to prepare the state for possible long-term greenhouse gas emission reductions, as well as adaptation to unavoidable climatic change.

What might this entail? At a minimum, the state probably ought to begin to plan for how it will, over a period of decades, stabilize and then reduce greenhouse gas emissions. This may require major changes in the energy system, including changes to the existing infrastructure and the development of new energy infrastructure. How will these changes proceed, at what pace, driven by what motive-force, and guided by what plan? Should carbon sequestration on land become an important component of a national and international greenhouse gas mitigation strategy, a long-term strategy to stabilize and then reduce greenhouse gas emissions also may require changes in the agricultural and forestry sectors. Again, the state may want to begin to plan for such an eventuality.

In terms of actions, to preserve the state's long-term options it probably will be necessary to institute actual measures to slowly wean the economy from its dependence on fossil fuels and their associated greenhouse gas emissions. These need not involve dramatic reductions in emissions, but just begin the longer-term process of decoupling economic growth from emissions--of slowing the rate of emissions increase and slowly deflecting the trajectory of greenhouse gas emissions from business-as-usual kinds of growth.

The place of cost-free emission reductions in the policy calculus was discussed earlier in relation to energy efficiency improvements. Because of the economic benefits of many energy efficiency improvements to the economy, such improvements offer a no-regrets means to reduce CO_2 emissions (or the rate of growth in emissions) at no net cost or even a benefit to society. Where

beneficial in themselves on economic grounds, these can and should be pursued for their own sake.

The advantage of this type of framework is that it allows for the changing nature of the science and politics. It is incrementalist by design—delay the decisions that can be delayed, take a longer view of what will needed into the next century and only slowly act on it. Only in the case where the economics of action are fairly clear cut, and are justified in themselves, as in the case of energy efficiency improvements, are aggressive policies pursued and fairly firmly established for the foreseeable future.

It also reconciles, to the degree that this is possible, the seemingly antagonistic demands of the problem. It recognizes the changeable nature of the science and the need for more research, while also acknowledging how the physical dimensions of the problem impel one to action. It addresses cost concerns, while identifying costless options or relatively inexpensive options for reducing greenhouse gas emissions. It acknowledges the need to begin to act on this problem, while stressing that whatever measures that are contemplated that go beyond improved energy efficiency are instituted only slowly and cautiously.

We think that this reasoning argues for a two-track strategy: a 'no-regrets' short-term strategy centering on improved efficiency of the state's economy in the use of energy and materials, and a longer-term effort to slowly wean the economy from its dependence on fossil fuels and their associated greenhouse gas emissions. By aggressively pursuing opportunities to improve overall energy and materials-use efficiency in the state, it should be possible in the short-term to simultaneously grow the economy and limit the growth in emissions of greenhouse gases. By slowly going beyond energy efficiency improvements to eventually de-couple economic growth from greenhouse gas emissions, it should be possible to minimize the economic costs of long-term emission reductions, while, at the same time, respond to a serious environmental problem. It has the additional virtue in that is acts to minimize the risk to the economy of long-term federal regulatory action, while affording the state ample opportunity to adjust policy to the evolving science of the climate change.

Some specific governmental actions that would be consistent with this framework might include:

- continuation of annual greenhouse gas inventory (tracking aggregate trends in state emissions) with annual reporting;
- development of a firm-level greenhouse gas inventory with ranking and public disclosure;
- continuation of emissions disclosure in the electric utility sector;
- development of an early emission reduction credit registry;
- promotion in the state of the Chicago Climate Exchange early reductions markets;
- provision of technical assistance to small businesses and farmers desiring to participate in early credits markets like the Chicago Climate Exchange;
- development of a prototype contract for use by small businesses and farmers in the sale of early reduction credits in developing markets;
- development of a detailed state-level carbon sink inventory;
- promotion of energy efficiency in MPCA loans to public facilities for pollution control or through requirements in Supplemental Environmental Projects;

- integration of energy efficiency as a consideration in MPCA facility permitting, loan, and grant processes;
- participation in state energy planning processes like the Integrated Resources Planning process and Conservation Improvement Program.

Beyond these measures, another important role for state government is in the development of information on climate change impacts. Is the climate changing in Minnesota, and if so, with what effects on the state's natural resources and economy? What are the possible impacts of climatic change in the future in Minnesota and what are the vulnerabilities? How might policies be designed to help to Minnesotans adapt to a changing climate? The state is the home of a large land-grant university with expertise in climate change impacts. State government can act as a focus for those research activities, assembling the information from disparate sources and synthesizing it and disseminating it.

State government also can and probably should continue to integrate global warming as a consideration in its outreach/educational efforts. There is also an important role for state government in increasing awareness of the environmental benefits of energy efficiency improvements.

Common to many of these efforts is the understanding that informed decision-making depends on access to good information. This is true for both public and private decisions. Markets work best when buyers and sellers of goods and services have as complete information as possible about the effects of the goods and services being purchased, including environmental effects. Sound public decision-making requires sound, reliable information. On global warming, this includes information on the underlying climate science, emission sources and trends, regulatory developments, mitigation technology, opportunities for early reductions.

Beyond this, the state has a compelling interest in the development of the energy technology and fuel sources that will be central to virtually any national global warming mitigation strategy. The use of biomass-based fuels like ethanol and biodiesel in place of petroleum-based liquid fuels acts to constrain the rate of growth of greenhouse gas emissions from the state. Roughly 10 million tons of CO_2 have been avoided in Minnesota since 1990 through the use of ethanol blends in transportation fuels. To encourage a growing agricultural processing industry, the state already encourages the production and use of ethanol through an oxygenate requirement for transportation fuels and production subsidies. The state may wish to explore other opportunities for Minnesota to become a leader in the development of new nonfossil fuel energy supplies. In the event of regulatory action to limit the emission of greenhouse gases, particularly CO_2, to the atmosphere, the economic gainers will be states that have positioned themselves as suppliers of alternative energy and alternative energy technology.

Biofuels development is the rough equivalent on the fuel supply side of energy efficiency improvement on the demand side—due to the economic benefits, it is best pursued for its own sake, but also contributes to a solution to the global warming problem.

In the long-term, it will be necessary for the state to develop a plan of how it is going to gradually deflect emissions of greenhouse gases from their business-as-usual trajectory toward a

more sustainable path. This may require substantial changes to the energy system in Minnesota, as well as changes in land-use practices. A substantial amount of advance planning will be required to insure that whatever changes are made are made in an orderly fashion, are lowest cost, and are effective with respect to environmental and other goals. The state may want to slowly build-up its capacity to perform this type of analysis over a period of time. Technology assessment will be critical in this effort. What are the technologies of the future that can get us there? When will they be available? What types of public infrastructure changes will be necessary to accommodate them? What should the state be doing now to ease the way for these future technologies? In the meanwhile, the state will want to maintain and strengthen its existing capability to analyze the current-day effects of different policy measures on emissions and its greenhouse gas emission inventory and forecasting capability.

There are hints from officials in the Bush Administration that more minor sources of greenhouse warming, like methane, hydrofluorocarbons and perfluorocarbons, and carbon black may be targeted for control in the next few years. Control of emissions from these sources is often an order of magnitude cheaper than control of emissions of CO_2 from fossil fuel combustion. In Minnesota, most emissions from these sources derive from landfills, natural gas transmission, and manure storage—sources which are already regulated for other purposes. It is possible that the state of Minnesota may wish to investigate the opportunities for encouraging voluntary control of these more minor sources in anticipation of federal action and participation in existing national partnership programs targeting these gases.[98]

7.3 Possible Emission Reduction Goals for Minnesota

Emission reduction goals are commonly treated in presentations at the state and local level of policy frameworks for greenhouse gases. Consistent with the above discussion, the following types of goals might recommend themselves for the state of Minnesota:

- an energy efficiency goal measured as a minimum rate of annual improvement;
- a greenhouse gas emissions goal measured as a rate of emissions per unit of gross state product;
- a 10-year state greenhouse gas target measured in net tons of emissions and developed with a mind to slowly move the trajectory of emissions from a business-as-usual type of trajectory toward one that is more sustainable in the longer-term.

The average rate of improvement in the efficiency of energy use in the Minnesota economy between 1980 and 2000 was about 1 percent per year. This suggests that something in the 1.5 to 2 percent per year range sustained over several decades might constitute a useful goal. The large apparent pool of efficiency improvements that is economically justifiable using conventional financial analysis suggests that the historic rate of improvements could be increased by at least half.

The Bush Administration has established as national goal that greenhouse gas emissions per unit of gross domestic product decline by 18 percent by 2010. The state might consider a goal that matches or exceeds that.

[98] Information about existing national programs targeting these gases may be found at: www.epa.gov/methane , www.epc.gov/cppd , and www.epa.gov/ghginfo/topics/topic7.htm

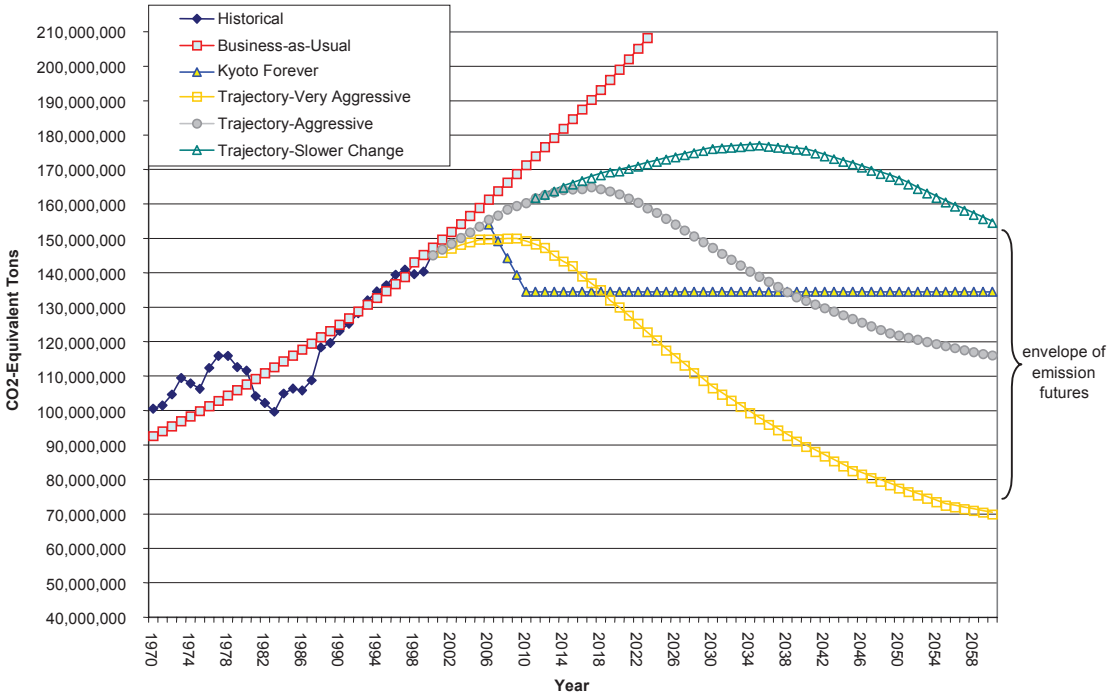
Given existing trends in emissions, a ten-year target developed with a mind to slowly deflecting the trajectory of emissions toward more sustainable paths would probably fall somewhere in the 155,000 to 160,000 ton range. This would still represent a substantial increase in emissions from the present (10 to 15 percent), but gets the state started along a road toward eventually leading to no further emissions growth and then decline.

Finally, it is common to include in discussions of policy frameworks some more numerical consideration of what the long-term future holds for emissions. Regarding what the future will hold for greenhouse gas emissions from Minnesota—what will be allowed under the terms of national regulatory programs and international agreements—by definition, this is a hazardous undertaking. What we seem to understand is as follows:

- actions to slow the rate of increase in greenhouse gas emissions nationally already are being taken as part of the strategy of the Bush Administration; if successful, these will bring about a departure in the near-term from business-as-usual trends;
- in the long-term, mandatory domestic greenhouse controls on some sort are a virtual certainty;
- again, in the long-term, whatever regulatory controls are imposed on greenhouse gas emissions are likely to closely mirror requirements made of other advanced industrial countries;
- in absence of some major upset to the science, it seems reasonable to expect that reduction requirements in advanced industrial economies will range from a minimalist no reduction (or only a slight increase) from 2000 levels to on the order of 50 percent reduction from 2000 levels;
- whatever controls are implemented will take effect only gradually.

The range of possible greenhouse gas emissions futures that would seem to fit what we understand about the evolving politics and science of global warming is shown in Figure 7.1. It is our judgment that the actual long-term trajectory of greenhouse gas emissions will fall somewhere within the envelope of trajectories shown. In the extreme low emissions case, where very aggressive actions are required, emissions peak in 2008, return to 2000 levels by about 2015, and then decline to 50 percent of current levels by 2060. In the least aggressive scenario, emissions peak in about 2035 at a level that is about 25 percent higher than current levels (but still well below what they might be under business-as-usual conditions), then decline to a level that remains about 5 to 10 percent higher than current levels by 2060. We think that this captures the range of possible long-term emissions trajectories within which long-term planning in the state of Minnesota will need to proceed.

Figure 7.1 Range of Possible Minnesota Greenhouse Gas Emission Trajectories



8.0 Monitoring Efforts in Minnesota

If fairly systematic changes are occurring in Minnesota's climate, and if substantial impacts can be expected from large changes in climate, scientists and other observers of natural systems should be seeing the impacts, or at least the initial indications of effects. However, while a well-developed greenhouse emission inventory exists for Minnesota, relatively little is known about how the observed and ongoing changes in climate are effecting Minnesota's natural and built environment, human and ecosystem health, and economy. This may well be due to the lack of an adequate monitoring system for heretofore slow, broadly based changes in the natural and built environment that might be expected to have been associated with observed climatic change in Minnesota.

Listed below are state agency efforts to monitor changes in Minnesota's environment and stressors on the environment. Other non-state government agency efforts, such as those conducted by the University of Minnesota or the federal government, may exist but are not included. Most of these efforts listed below have been developed for other purposes, without climate change in mind, and so can offer only very limited information, if any, on current-day impacts. It is likely that a system of monitoring dedicated solely to climatic change will be necessary.

Monitoring of Natural Resources

Ecological Classification System **Dept. of Natural Resources (DNR)**
This system is part of nationwide mapping initiative developed to improve Minnesota's ability to manage all natural resources on a sustainable basis. This is done by integrating climatic, geologic, hydrologic and topographic, soil and vegetation data.

Minnesota Heritage Program/Minnesota County Biological Survey **DNR**
This program began in 1987 as a systematic survey of rare biological features. The goal of the Survey is to identify significant natural areas and to collect and interpret data on the distribution and ecology of rare plants, rare animals, and native plant communities. Forty-one counties are complete, and 23 are underway.

Forest Resource Assessment and Inventory **DNR**
Program develops and maintains statewide forest inventory systems.

Biomass Resource **Survey Dept. of Commerce**
Commerce has nearly completed a survey of the state's biomass resources and has already completed surveys of the state's wind and solar resources.

Water Monitoring **MPCA**
MPCA recently added ice cover period on lakes and thermocline depth to the list of information collected from citizens. In addition, information on water quality, depth, temperature, etc. is also available but long periods of record for any given lake are rare.

Environmental Indicators **MPCA**
MPCA develops and tracks various environmental indicators to determine the current conditions of Minnesota's environment.

Plant Pest Survey Unit **Minnesota Dept. of Agriculture**
Unit provides real-time information on the distribution, abundance and management of crop pests.

State Climatology Office **DNR**
The Minnesota Climatology Working Group exists to study and describe the climate of Minnesota.

Monitoring of Greenhouse Gas Emissions/ Carbon Storage

Greenhouse Gas Emission Inventory **MPCA**
MCPA develops an annual inventory of greenhouse gases for area, point and mobile sources. Included in the inventory are carbon storage estimates. The U.S. EPA also conducts a national greenhouse gas emission inventory annually.

Environmental Indicators for Transportation **Dept. of Transportation**
As part of its most recent transportation plan draft, DOT is proposing to track greenhouse gas emissions from on-road sources as an environmental and community indicator.[99]

Monitoring of Stressors on System

Minnesota Milestones **Minnesota Planning**
The 2002 report uses 70 progress indicators to determine whether the state is achieving 19 publicly determined goals. Report began in 1991. Indicators that relate to greenhouse gases or carbon sequestration include: renewable energy resources, energy use per person, vehicle miles, solid waste and recycling, timber harvest, energy efficiency of the economy, water quality in lakes and rivers, erosion of cropland, wildlife habitat, changes in land use, parkland and open space.

[99] Elizabeth Swift in the Environmental and Community Indicators group at the Department of Transportation is the primary contact. MPCA will provide calculations for the indicator.

9.0 State Agency Programs of Potential Relevance to Greenhouse Gas Control

This section describes state agency efforts underway that may be relevant to greenhouse gas control – by potentially contributing to reduced greenhouse gas emissions or increased carbon sequestration. However, the degree to which any program reduces greenhouse gases is not known as few programs quantify emissions. Further, this report does not attempt to identify state programs or policies that may lead to increases in greenhouse gas emissions.

The list was compiled through interviews with management at the various agencies and program information contained on agency websites. With only a few exceptions, the programs listed in this section were created for purposes other than to address climate change, such as achieving greater energy efficiency, promoting water conservation, fostering smart growth, increasing transportation efficiency, reducing waste, using natural resources more wisely, promoting sustainable agriculture practices, or preserving forests or farmland. Only a few programs directly have the reduction of greenhouse gases or sequestration stated as a primary purpose. For some agencies, the connection between their program activities and greenhouse gas reductions was not something they had considered. Many interviewed were interested in knowing more specifics about how their program activities may be relevant to greenhouse gas reductions.

More than 100 state agency programs were identified as being of potential relevance to greenhouse gas control. Of these, more than a quarter are geared to preservation of agricultural and forest lands. While this report lists many of the major types of programs that may help address climate change, other programs and activities could potentially be included as well. The kinds of activities that go towards addressing climate change are so diverse and numerous, it is impossible to identify all activities. This report does not quantify each program's impact on greenhouse emissions and it is possible, under certain circumstances, some programs could actually increase greenhouse gas emissions. In addition, the programs listed should be viewed as a snapshot because factors such as budget and changing priorities can cause the elimination or reduced effectiveness of any given program.

This section is broken out into seven sectors: Transportation, Electricity, Agricultural, Buildings, Waste, Industrial, and Forestry/ Land Use. For each of the sectors, a brief description is given of the kinds of activities within the sector that may contribute to greenhouse gas reduction (over business as usual) and a listing of programs named by the agencies as helping to address climate change. In addition agencies were asked for their suggestions to further reductions of greenhouse gas emissions or carbon sequestration. Agencies generally wanted to strengthen those activities that fit most closely with other goals they are charged with achieving. The benefit of greenhouse gas reduction was yet another reason to carry out the activity they are already performing.

Some of the programs the state implements are federal programs. A listing of federal programs that potentially reduce greenhouse gases can be found in the U.S. Climate Action Report 2002.[100]

[100] U.S. Department of State, U.S. Climate Action Report 2002, Appendix B: Policies and Measures, Washington, D.C., May 2002.

An attempt was made to describe how the programs primarily achieve their goals. This could be done in many different ways and further breakdowns are possible. For the purpose of this report, a simple means with as few categories as possible is desirable. The programs/activities are characterized as falling into one or more of the following five primary functions:

Assistance /Information: Educational materials, conferences, workshops, training, technical assistance, research or demonstration projects, phone assistance, and web links characterize the ways in which assistance and information is provided by these programs.

Incentive: This program is characterized by some financial incentive to encourage others to participate in a particular behavior or activity. The program uses grants, loans, tax benefits, or user fee as the incentive (although this last was uncommon). Often the incentives are combined with information and assistance activities.

Rule-Based: The program/activity is primarily based on a regulation and there is often an enforcement component to the program.

Operations: The program/activity is carried out by the agency itself, not through others, and potentially results in direct greenhouse gas reductions/carbon sequestration.

Policy/planning: The activity involves policy guidelines, planning documents, development of priorities, program guidance and, overarching principals that serve to guide and shape programs, agency activities and decision-making. These are sometimes one-time reports or policy decisions but their influence can be broad.

A rough breakdown of the programs is characterized in the Table 9.1. Where more than one function characterized a program, a decision was made to choose a primary one. Thus, each program/activity is listed just once. Most programs use information/assistance and/or incentives to achieve their goals.

Table 9.1 Number and Type of State Programs of Potential Relevance to Greenhouse Gas Control (Based on survey information gathered in spring of 2002)

Sector	Information/ assistance	Rules Based	Operations	Incentives	Policy/ planning	Total
Buildings	4	3	2	4	1	14
Transportation	6	1	4	3	2	16
Industry	2	3	--	2	--	7
Electricity	4	5	--	4	3	16
Landuse/Forestry	4	3	5	11	8	31
Agricultural	5	1	--	5	3	14
Waste	7	1	5	1	--	14
Total	32	17	16	30	17	112

9.1 Transportation Sector

9.1.1 Description

Burning of petroleum products (gasoline, diesel, jet fuel, etc.) by the transportation sector releases carbon dioxide, a greenhouse gas, and other greenhouse gases and are responsible for about a third of Minnesota's greenhouse gas emissions. Sources included in this sector include: on-road passenger vehicles, natural gas pipelines, on-road freight, off-road vehicles/equipment, barge, rail, air travel, and recreational sources such as boats, snowmobiles, and ATVs.

For on-road passenger vehicles, programs that do the following may lead to a reduction in greenhouse gas emissions:

- Reduce vehicle miles traveled
- Reduce congestion
- Improve fleet fuel efficiency
- Encourage use and market penetration of alternative renewable fuels
- Improve the efficiency of transportation through mass transit
- Increase vehicle occupancy
- Increase the density of land-use leading to transportation efficiencies

For freight transport, programs that do the following may reduce greenhouse gas emissions:

- Encourage energy efficiency in freight movements
- Improve intermodal transport
- Encourage use of alternative renewable fuels.

Methane is given off during natural gas transmission through pipelines and energy is needed to transport natural gas through pipelines. Emissions can be reduced by:

- Reducing natural gas leaks from distribution and transmission compressors, compressor stations, pipeline interconnections, city gate connections, and the pipelines and services themselves; and
- Improving energy efficiency in gas transmission.

Traditionally state agency programs have had less focus on recreational sources and off-road vehicles and equipment. However, the principle ways that emissions can be reduced from these sources, besides conservation, include improved fuel efficiency and use of alternative fuels and technologies.

9.1.2 State Agency Programs of Potential Relevance to Greenhouse Gas Control in the Transportation Sector

Assistance/Information Focused Programs

Oxy-Fuel/Ethanol Info; Biomass Energy Development **Agriculture**
This program promotes the development of ethanol production and use as well as biodiesel and growth of Generation Farmer Coop organizations.

Clean Cities Coalition **Commerce**
The Twin Cities participates in this nationally directed program. The chief purpose is to advance use of clean motor fuels. The Department of Commerce is the coordinator of many partners (for example, the American Lung Association) for this effort. The Coalition is working on alternative energy sources, fuel efficiency, and many other things.

Sustainable Transportation Initiatives **MnDOT**
The mission of this group within DOT is to help manage traffic growth by integrating bicycling, walking, and telework with all other modes such that they become safe, realistic, alternatives to driving. They do this through research, advocacy, community planning and program development. They help communities plan their transportation system through the Transportation Action Model.

Metro Commuter Services **Met Council**
Promotes alternative transportation to commuters in the Twin Cities. Offers information on telecommute, walk, bike, bus, vanpool and rideshare to work or school. Offers direct assistance to individuals, employers, schools, government planning agencies and transportation management organizations. Through partnering, Metro Services has promoted high occupancy vehicle lanes, free or discounted parking, and ramp meter bypasses.

Mobile Source Outreach Program **MPCA**
The MPCA promotes fuel-efficient vehicles, increased transit, and alternative fuels through work with partner organizations, information, participation in events like Auto Show, involvement in the Clean Cities Coalition, and others.

Voluntary Investigation and Cleanup Program/Voluntary Petroleum Investigation and Cleanup Program **MPCA**
Companies voluntarily undertake an investigation of a potentially contaminated site and, if necessary, cleanup action approved by the MPCA through the program. This process allows property transactions to move forward quickly, but it also helps promote redevelopment of contaminated property, mitigate health or environmental risks posed by wastes on these properties, and benefits communities by bringing new development, jobs, and tax base to old industrial zones. This work may result in transportation efficiencies.

Incentive-based Programs

Redevelopment Grant Program **Trade and Economic Development**
This program's goal is to revitalize urban core infrastructure and areas in greater Minnesota. Grants pay up to 50 percent of redevelopment costs for a qualifying site. Only for sites where a past use and the need to "recycle" the land for a more productive use exist. Program may lead to transportation efficiencies.

Transit Operations **Met Council**
Met Council promotes increase in transit ridership through tax benefit incentive programs like TransitWorks, Commuter Check and MetroPass. Goal is to double transit riders by 2020. Program also offers bike lockers and Park and Ride lots.

Rules – Based Programs

Metro Division Environmental Planning Unit **MnDOT**
This unit reviews laws and regulations. They develop appropriate MnDOT policies and procedures to implement these regulations and develop quality assurance and quality control measures to ensure that these policies and procedures function properly. Provides project review, monitoring, consultation and recommendations of future noise and air quality impacts along our roadways.

Operations of State Agencies

Travel Management Division **Administration**
This division promotes the use of E85 in flexible fuel fleet vehicles and provides information about E85. Administration has an E85 fueling station at its maintenance office.

Transit **MnDOT**
The mission of this group is to help people and communities meet their mobility needs by supporting safe, responsive, efficient, and environmentally sound transportation systems. Programs include greater Minnesota transit plan, rural transportation assistance program, Rideshare, and other transit programs.

MPCA Operations **MPCA**
One strategy of the MPCA is to "model the way" by implementing practices in the area of transportation that result in lower emissions. The agency has two hybrid vehicles in its fleet, two electric bicycles, and promotes and monitors the use of E85 in its fleet flex-fuel vehicles. The MPCA also promotes MetroPass and provides bike lockers for employees.

9.2 Electricity Generation Sector

9.2.1 Description

Electricity production accounts for about a quarter of Minnesota's total greenhouse gas emissions and about 38 percent of its carbon dioxide emissions. When electricity from other states is included, 75 percent of the electricity used by Minnesotans comes from power plants fired with coal according to the Minnesota Department of Commerce. The table below shows a breakdown of fuels used from Minnesota generators only – it does not include generation from out-of-state sources.

Table 9.2 Fuels Used to Generate Electricity in Minnesota

Coal	62.2%	Natural Gas	2.1%
Nuclear	27.4%	Petroleum-based	2.2%
Hydropower	2.4%	Other (wind, RDF, solar)	3.8%

Source: U.S. Department of Energy, 1999 data from Energy Information Administration.
http://www.eia.doe.gov/cneaf/electricity/st_profiles/minnesota/mn.html

Carbon dioxide is the principal greenhouse gas produced by electricity generation. Coal-fired power plants produce more than two times as much carbon dioxide to produce a unit of electricity compared to natural gas. Nuclear, wind, and solar produce no greenhouse gases other than incidental emissions from manufacturing processes and operations. Decay of organic

matter in shallow lakes created by hydroelectric projects results in production of small amounts of greenhouse gases.

Activities that move Minnesota's electricity sources towards renewable resources, more efficient technologies (on both the production and demand sides) and cleaner technologies will result in reduced greenhouse gas emissions.

9.2.2 State Agency Programs of Potential Relevance to Greenhouse Gas Control in the Electricity Sector

Assistance/Information Focused Programs

Environmental Disclosure **Commerce/ Public Utilities Comm./MPCA**
In September 2002, the PUC ordered regulated utilities to inform their customers where their electricity comes from, the emissions, the effects, and the cost trade-offs. CO_2 emissions are included. Commerce and the MPCA have a role as well.

Renewable Energy Technologies **Commerce**
Commerce promotes uses of renewable resources and technologies. In addition, Commerce monitors Minnesota's wind energy resource at sites around the state. Also monitors and evaluates solar energy potential.

Renewable Energy Tax Incentives **Commerce**
Federal and state incentives exist for energy production from hydro, wind, solar, biomass, and ethanol. Incentives in the areas of rebates, less property tax, depreciation, tax credits, net energy billing. Commerce provides information on these programs.

Incentive-based Programs

Green Pricing **Commerce/ Public Utilities Comm.**
Utilities must give customers the option of paying extra on their monthly bill for renewable energy. Additional funds go towards development of renewable technologies such as wind. Commerce provides comment on plans filed by utilities. The PUC approves the plans filed by utilities. All regulated utilities will have a green pricing program in place by spring 2003.

Environmental Emissions Rate Reduction Rider **Commerce/ Public Utilities Comm.**
2001 legislation allow utilities to recover costs from ratepayers for emissions reduction projects outside of the normal rate making process. Xcel Energy has proposed projects at three metro area plants. Two of the plant projects would reduce greenhouse gas emissions. Commerce and the MPCA have a role in reviewing proposals; the PUC gives approval.

Renewable Energy Transmission Rate Rider **Commerce/ Public Utilities Comm.**
2001 legislation allows cost recovery outside of the normal rate-making process for transmissions line projects that are needed to bring renewable energy to customers. Xcel Energy has a proposal in under this for bringing wind power from Buffalo Ridge.

Conservation Improvement Program **Commerce/Public Utilities Comm.**
Commerce oversees utility expenditure of funds collected to go towards conservation. Xcel Energy's energy assets program is an example how funds are used. The energy assets program provides professional energy resources to architects and engineers, financial incentives for professional energy resources to architects and engineers, and financial incentives for businesses that implement the recommended energy-saving strategies. PUC approves spending and plans.

Solar Electric Rebate Program **Commerce**
State Energy Office is administering a Solar Electric Rebate Program, funded by Xcel Energy, for grid-connected solar electric energy installations. This new program will rebate between $2,000-$8,000 per participant at a rate of $2,000 per kilowatt.

Rules – based Programs

Certificate of Need/Environmental Review Commerce/PUC/Environmental Quality Board
Commerce has a role in review of both new power plants and transmission lines. The PUC now has a role in approving the size, type and timing of large power plant projects. The EQB has always had a role in power plant siting and energy facility planning and siting. In the 2001 legislative session, legislators identified energy as an area for EQB to take a more active role, particularly in Certificate of Need decisions by PUC. The Environmental Review process currently does not require that CO_2 be addressed as a pollutant but the process does address other pollutants that indirectly can have an effect on greenhouse gas emissions.

Fuel contracting/ purchasing **Public Utilities Comm.**
The PUC approves Requests for Proposal for power purchase agreements

Environmental Externalities Costs **Public Utilities Comm.**
Utilities are mandated under statute to estimate externality costs in resource acquisition plans for new sources. There is a value for CO_2.

Policy/Planning Related Activities

Renewable Energy Objectives /Mandates **Commerce/ Public Utilities Comm.**
Commerce works with the PUC to develop renewable energy goals. The 2001 Minnesota Energy Security and Reliability Act states that 10 percent of electricity should be derived from renewable resources by 2015. Commerce works with PUC to develop renewable energy objectives for utility energy portfolios.

Integrated Resource Planning **Commerce/ Public Utilities Comm.**
The PUC approves integrated resource plans that are filed by utilities every two years. These plans provide information about each utility's plans for policies, fuel sources, etc., for the next 14 years. Commerce does technical review and analysis of the plans, plus public advocacy and numeric values on emissions.

As part of integrated resource planning, each utility is required to file a greenhouse gas mitigation plan. This part of the plan must include total CO_2 emissions, effects of various

mitigation strategies on rate programs, and the effects of international or national CO_2 policies on utility systems and ratepayer costs. This was a requirement that came out of the merger of Northern States Power and New Century Energy to form Xcel Energy, but all utilities must do it.

NARUC member **Public Utilities Comm.**
As a member of the National Association of Regulatory Utility Commissioners (NARUC) Environmental and Energy Commission, the PUC influences positions on environmental issues nationally.

9.3 *Agricultural Sector*

9.3.1 Description

Agriculture is the original foundation of Minnesota's economy. In 2000, Minnesota had 79,000 farms covering 28.6 million acres or more than half of Minnesota's total land area. Ranking seventh in the nation, Minnesota's farm income in 2000 totaled over 7 ½ billion dollars, almost equally divided between livestock and crops.[101]

Since agriculture plays such a large role in Minnesota, greenhouse gas emissions related to this sector accounts for almost 20 percent of Minnesota's total greenhouse gas emissions. [See Section 5.0]

Biomass
Marketing activities by the agricultural sector to develop biomass fuels for transportation, electricity or industrial sectors ultimately can result in reduced greenhouse gas emissions. [See also Section 9.2, Transportation] However, the production of many biomass fuels is still in the development stage and greater efficiencies in energy and nitrogen inputs are still to be realized. Biomass fuels include ethanol, soybean oil, switch grass, agricultural waste, hybrid poplar, and wood waste. (Switch grass and hybrid poplars have yet to be commercialized.) Because of the much shorter carbon cycle of these fuels compared to fossil fuels, replacement of fossil fuels with biomass can result in net reductions of greenhouse gases.

Land Conservation
Conversion of lands from less intensive to more intensive uses results in the release of carbon. Efforts to retire vulnerable lands to less intensive uses can reduce greenhouse gases. Examples of land or water types that may be conserved through agriculturally-based programs include: wetland, river bottoms (riparian land), agricultural, prairie/grasslands, timberland, and urban greenspace.

Sustainable Land Practices
Nitrogen-based fertilizer usage is responsible for about a fifth of the greenhouse gas emissions from the agricultural sector. Nitrogen over-applications are estimated to range from 30 to 50 percent. In addition, soil erosion is shown to increase release of carbon, although quantification has been difficult. Best management practices for fertilizer inputs, tillage, and

[101] Minnesota Department of Agriculture, "Minnesota's Ag Profile" Brochure, Dec. 2001. http://www.mda.state.mn.us/newsroom.htm

pesticide/herbicide may lead to reduced greenhouse gas emissions. Minimizing agricultural equipment fuel usage is another area where greenhouse gas emissions can be reduced.

Manure Management
Proper management of manure can reduce methane releases. Practices related to control of odor/air emissions, nutrient conservation and manure used for energy production all can lead to reduced greenhouse gas emissions.

Water Quality
Programs directed at improving water quality through reduced nitrogen application, tillage practices, streamside land retirement, and post-field erosion control also may reduce greenhouse gas releases.

9.3.2 State Agency Programs of Potential Relevance to Greenhouse Gas Control in the Agricultural Sector

Assistance/Information Focused Programs

Post-Conservation Reserve Program Land Management Fact Sheet Series **Agriculture**
Programs provide a wide array of publications for Minnesota landowners interested in soil, water, and wildlife conservation and agricultural land protection.

Energy and Sustainable Agriculture Soil Quality Initiatives **Agriculture**
Initiatives assist farmers, University staff, experiment stations, and state agency staff with on-site research, design, and implementation in area of soil quality. Agriculture staff assesses management effects of simulated rainfall on soil and water quality.

Agricultural Environmental Outreach **Agriculture**
Program identifies and assesses agricultural non-point source pollution issues; provides customer input into state, local and federal programs; conducts customer and policy research; assesses technology and information needs of producers, and links customers to programs/resources.

Agricultural Development and Land Use Technical Assistance Program **Agriculture**
Program provides practical assistance to local governmental units in addressing land-use-related issues to agriculture and animal agriculture. Program maintains a voice in preserving agricultural land.

Agricultural Nutrient Best Management Practices **Agriculture**
Nitrogen best management practices have been assembled by Agriculture and the University of Minnesota. Best management practices are defined in Stat. 103H.005, subd. 4 as: “Practicable voluntary practices that are capable of preventing and minimizing degradation of groundwater, considering economic factors, availability, technical feasibility, implementability, effectiveness, and environmental effects.” Nitrogen is an essential plant nutrient that is applied to Minnesota crops in greater quantity than any other fertilizer.

Incentive-based Programs

Sustainable Agriculture Grants **Agriculture**
Grants are provided to farmers, educators, and non-profit organizations for on-farm demonstrations of increased energy efficiency, and reduced chemical usage.

Sustainable Agriculture Loans **Agriculture**
Low interest loans are provided to farmers for equipment that is more environmentally sound and profitable.

Agricultural Best Management Practices Loan Program **Agriculture**
Program provides no interest loans to local governmental units who provide low interest loans to individuals for agricultural best management practices. This program is geared to non-point sources.

Manure Methane Digesters Loans **Agriculture**
Program provides zero interest loans for anaerobic manure digesters. Haubenschild Farm was the first project.

Rules – based Programs

Feedlot Program **MPCA**
The MPCA regulates and controls pollution emitted from animal production facilities. Although not directed at control of greenhouse gases, some of the required controls and practices also result in the reduction of methane.

Policy/Planning Related Activities

Sustainable Agriculture Program: Whole Farm Planning Program **Agriculture**
Program assists local groups in identifying management options that integrate environment, economic, landscape, and farmer goals into long-term site-specific farm planning.

Animal Agriculture GEIS **Environmental Quality Board**
The Generic Environmental Impact Statement (GEIS) is a statewide study funded by the 1998 Minnesota Legislature. The Environmental Quality Board was directed to "…examine the long-term effects of the livestock industry as it exists and as it is changing on the economy, environment, and way of life of Minnesota and its citizens". The final report was released Sept., 2002. The greenhouse gas contribution by methane was qualitatively addressed in the report. Policy recommendations such as those calling for mandatory best management practices for nutrient management may also be relevant to greenhouse gas control.

Agricultural Lands Preservation **Met Council**
Met Council articulated a policy for agricultural lands preservation in Blueprint 2030, but have yet to take steps to turn into a program.

9.4 Buildings Sector (Commercial and Residential)

9.4.1 Description

The buildings sector includes actions, interventions, and technical changes related to buildings in both the commercial and residential sectors. Activities related to buildings that may reduce greenhouse gas emissions mainly involve improved energy end-use efficiency in the areas of space heating, water heating, lighting, appliances, and other activities as shown in Figure 9.1. In addition activities such as water conservation can indirectly lead to a reduction in greenhouse gases because if less water is used than less water needs to be heated.

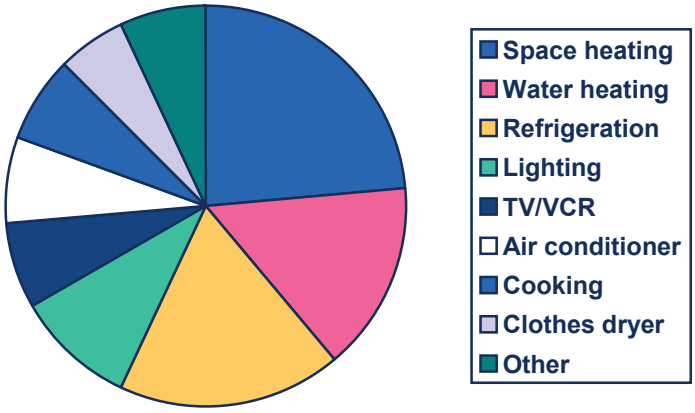


Figure 9.1 CO_2 Emissions for an Average Minnesotan Household
Average household emits 75 tons annually from these sources. Transportation CO_2 emissions of 27 tons not included. Source: MPCA data

Sources of greenhouse gas emissions in commercial buildings include space heating, water heating, lighting, electronic devices such as computers, and others.

Chemical usage by these sectors also results in the release of greenhouse gases to the atmosphere. Chemical usage can include solvent uses in the commercial sector, plus home fertilizer and yard chemical uses, as well as the use of aerosols or liquids like detergents.

In addition, commercial and residential structures can contribute to carbon sequestration. Stored carbon can by calculated by knowing their number, size, wood density per square foot of floor space, and their average lifetime.

The following actions related to buildings can have an impact on greenhouse gas emissions:

- Increased use of energy efficient appliances/equipment.
- Enhanced conservation – using less through behavior change
- Energy efficient buildings by design
- Increased use of renewable fuels for heating and in generation of electricity
- Whole-building cleaning and maintenance issues including chemical use

- Improved water efficiency
- Expanded use of recycling programs
- Exterior maintenance programs

A flourishing energy efficiency and renewable energy industry exists in Minnesota. A 2001 study revealed 336 energy efficiency and renewable energy companies in Minnesota with $2.2 billion in revenues providing about 12,000 jobs.[102]

9.4.2 State Agency Programs of Potential Relevance to Greenhouse Gas Control in the Buildings Sector

Assistance/Information Focused Programs

Contractor Training **Commerce**
Commerce provides training on energy for contractors to both build and manage energy efficient buildings. Training is also provided for school building managers.

Renewable Energy Tax Incentives **Commerce**
Federal and state incentives exist for energy production from hydro, wind, solar, biomass, and ethanol. Incentives in the areas of rebates, less property tax, depreciation, tax credits, net energy billing. Commerce provides information on these programs.

Energy Information Center **Commerce**
A staff of energy experts answers general energy questions and give specific advice on improving the energy efficiency of homes and businesses. In addition to consumer information, they are providing K-post secondary curriculum on energy to schools.

Commerce also provides information on EPA's Energy Star® program, which now includes businesses; schools, local government, hospitals, and non-governmental organizations. Participating non-business entities include: Barnesville Public schools, Byron Public Schools ISD #531, City of Jackson, District Energy St. Paul, Fairview Southdale Hospital, Minneapolis Public Schools and Spec Dist #1, Monticello Public Schools, Moose Lake Public Schools, Nevis Public Schools, Norman County West Public Schools, North Memorial Health Care, Grand Marais School District, Pine Island Public Schools, Ridgeview Medical Center, Truman Public Schools, University of Minnesota-Twin Cities, White Bear Lake Area Public Schools, and Yellow Medicine East Public Schools.[103]

Green Building Program **Office of Environmental Assistance**
This program strives to help communities find creative environmental solutions that are economically viable and meet social needs. Current focus is to provide technical assistance for

[102] Minnesota Environmental Initiative, "Minnesota's Energy Efficiency and Renewable Energy Industry: An Economic Analysis". Energy Alley Program of MEI. Minneapolis, MN. January 2002. http://www.mn-ei.org/eapage.html
[103] U.S. Environmental Protection Agency's and Department of Energy's Energy Star home web site www.energystar.gov. Site accessed September, 2002.

state and local public institutions to restructure their standard building procedures by integrating sustainable design.

Incentive-based Programs

State Energy Program Grants **Commerce**
U.S. Department of Energy funded program of small loans for energy projects.

Low interest loans to schools **Commerce**
Program would provide low interest loans for energy efficiency projects, but is not funded yet.

Performance Contracts with Schools **Dept. of Children Families, and Learning**
Energy efficiency contracts are authorized under Stat. 123(b) 65. The statute sets up conditions under which a school district may enter into a guaranteed energy savings contract with a qualified provider to significantly reduce energy or operating costs. Projects are not subject to competitive bid. Contract approved if cost of energy conservation measures recommended not likely to exceed the amount to be saved in energy and operation costs over 15 years. A district annually may transfer from the general fund to the reserve for operating capital account an amount up to the amount saved in energy and operation costs as a result of guaranteed energy savings contracts. Dept. of Children, Families and Learning oversees the process.

Sales Tax Exemption **Revenue**
A sales tax exemption for energy-efficient products was implemented in fall 2001. Products included are compact fluorescent light bulbs, and highly efficient electric heat pump water heaters (HPWHs), natural gas water heaters, and natural gas furnaces.

Rules – Based Programs

Building Codes and Standards Division **Administration**
This division develops and enforces building codes that include standards for energy efficiency. Minnesota has been a national leader in the area of energy efficiency and balancing of energy efficiency with indoor air quality needs.

Sustainable Design Guidelines for State Buildings **Commerce/Admin.**
(One-time report)
The Energy Security and Reliability Act of 2001 requires the Dept. of Administration and Commerce, with assistance from other agencies, to develop sustainable building guidelines for all new state buildings by January 15, 2003. Focus is on energy efficiency and use. For example, guidelines must exceed existing energy code by at least 30 percent. Guidelines are mandatory for all new buildings receiving funding from bond proceeds after January 1, 2004.

Operations of State Agencies

Energy Management Services Office **Administration**
This Office promotes energy efficiency in state-owned and wholly leased buildings throughout the state. The EMS office was initially created by the 1976 state legislature to monitor and

control the increasing energy use in state-owned buildings and to help conserve the nation's limited energy resources. Today, the EMS office primarily focuses on overall energy planning and management of energy programs for state-owned buildings. State agencies participate in EMS programs because they get facility improvements without capital expenditure (programs are financed through third party vendors or through utility companies). The state agencies repay the loans from their energy cost savings. Once the loan is paid off, the state agencies keep the savings. EMS monitors energy consumption in selected leased spaces. For existing buildings, the Dept. of Administration must report preliminary energy conservation goals to the legislature by January 15, 2002. By January 15, 2003, Administration must develop a plan to maximize energy efficiency in existing buildings, including quantification of energy savings and projected implementation costs.

Renewable Energy in State Parks **DNR**
The DNR partnered with the Center for Energy and Environment to implement 12 renewable energy projects at various state parks and created a guidebook called "Using Renewable Energy in Parks: A Guidebook for Park Managers", 1999.

Policy/Planning Related Activities

Return on Investment - High Performance Buildings **Planning**
(One-time report)
Minnesota Planning released a report in January 2002 with recommendations for more efficient state buildings. A law was passed in the 2002 legislative session that requires Commerce and Administration to develop sustainable building guidelines by January 2003 that would apply to any state-bonded building.

9.5 Waste Sector

9.5.1 Description

The waste sector includes both waste management and waste reduction activities. Overall, the waste management sector contributes about 3 percent of Minnesota's greenhouse gas emissions annually. Sources of greenhouse gases related to waste management activities include landfills (open and closed), waste incineration (all types), open-burning of solid waste, sludge combustion, wastewater treatment, soil roasting, and septic systems. Municipal solid waste landfills also act as a carbon sink for biogenic waste (such as paper products and food waste). (See Section 5 for emissions and description of how these activities contribute to greenhouse gas emissions.)

About 5.6 million tons of municipal solid waste were produced in Minnesota in 2000, an increase of 3.3 percent over 1999 and 33 percent more than in 1993[104]. The three principle ways that waste is handled in Minnesota are:

- Recycling: 40.3%
- Landfills: 33.9%
- Waste Processing /Resource Recovery: 21.8% (incinerators to produce energy/composting)

[104] Minnesota Office of Environmental Assistance, "Report on 2000 SCORE Programs", April, 2002.

The remainder is divided between on-site disposal and problem materials that are not recycled. The above percentages are by weight.

Waste reduction activities (reduction, reuse, and recycling) contribute to reduced greenhouse gas emissions. The Minnesota Office of Environmental Assistance (OEA) commissioned a study on the impact of municipal solid waste management on greenhouse gas emissions in 1999. Resource conservation efforts reduce greenhouse gas emissions primarily through avoided resource use and emissions as a result of reducing the drain on natural resources, making products using less energy, and emitting fewer pollutants. The report estimated that in 1996 Minnesota's integrated Municipal Solid Waste(MSW) management systems avoided the emission of 900,000 tons of carbon dioxide. This estimate is not the emissions avoided in 1996 but total emissions avoided over a substantially longer time period. The methods used by OEA for emissions estimates differs from that used by the MPCA in the greenhouse gas emissions inventory. Essentially, OEA traces the effect of one ton of municipal solid waste and estimates the emissions avoided for decades out (depending on the waste management method scenario).

The analysis found that, "historically, the two largest factors in reducing global warming potential through waste management activities in Minnesota have been recycling and waste-to-energy incineration. In contrast, landfilling contributes the largest amount of gases that influence the warming potential, most notably through the release of methane. Waste reduction has significant benefits on a per ton basis, but its overall impact has been small due to its relatively small prominence relative to other management strategies." [105]

The OEA study also looked at how potential changes in waste management as a result of policy or program initiatives would influence greenhouse gases emission reductions from 2000 to 2020. Each of the four scenarios modeled focused on a different type of waste management for the additional waste generated: landfilling, resource recovery, waste reduction, and recycling. The study predicted additional annual reductions in greenhouse gas emissions of about 250,000 (under the landfill scenario) to almost 4 million (under the recycling scenario) metric-tons carbon equivalent per year by 2020 depending on the scenario.

These are the findings from the OEA study:

- "An integrated solid waste management system, incorporating source reduction and recycling in addition to energy recovery through MSW processing and landfilling, can be a significant method of reducing greenhouse gas generation when compared with systems that do not incorporate source reduction, use only virgin materials as feedstocks, or do not recover energy from wastes.

- Source reduction, because it avoids the energy and materials needed for extraction, transportation, and production, is the most effective way to reduce greenhouse gases on a per ton basis.

[105] Minnesota Office of Environmental Assistance, Summary of "Assessment of the Effect of MSW Management on Resource Conservation and Greenhouse Gas Emissions" prepared for OEA by R.W. Beck, Inc. and Ecobalance, 1999.

- Manufacturing with recycled feedstock is the next most effective way to lower greenhouse gas emissions on a per ton basis; it often has lower overall materials and energy requirements than processes involving extraction or transportation of, and production using, virgin materials.

- Generation of electricity using MSW processing can also result in lower greenhouse gas emissions in comparison with systems that use virgin materials as a source of fuel.

- In comparison with landfills that do not recover landfill gas, those that do recover landfill gas provide a significant reduction in total metric ton of carbon equivalent."

9.5.2 State Agency Programs of Potential Relevance to Greenhouse Gas Control in the Waste Sector

These are the activities named by the agencies as potentially contributing to greenhouse gas reductions. They are broken into the areas of waste reduction and waste management.

9.5.2.1 Waste Reduction Activities

Assistance/Information Focused Programs

Cooperative Purchasing Venture **Administration**
Program provides leadership and service to government entities in the acquisition of products and services in a socially and environmentally responsible manner. It is part of the Resource Recovery Program administered through the Material Management Division. Clients include state agencies, local governmental units, and acquisition professionals from other states.

Environmentally Preferable Purchasing **Office of Environmental Assistance**
To reduce the quantity and toxicity of waste in Minnesota, state law requires state agencies and other public entities to purchase recycled, repairable, and durable goods. Attributes of goods include reduced toxicity, the use of recycled materials, and increased energy efficiency. OEA assists in developing a guidebook for agencies that includes suggestions for vehicles and buildings.

Recycling Market Development **Office of Environmental Assistance**
Program goal is to create recycling manufacturing jobs and recycled-content products. Recyclables collected from residents and businesses are sold to companies that use them as raw materials to make products sold to consumers. OEA staff provide information, research assistance, and referrals.

Environmental Education **Office of Environmental Assistance**
OEA's educational efforts make the connection between behavior and consumer choices, waste reduction, and energy conservation. OEA works to integrate environment into formal education, however, these efforts are not specific to climate change.

Waste Prevention - Pollution Prevention **Office of Environmental Assistance**
OEA helped produce a guide for companies to comply with the toxics pollution prevention act. OEA also submits a biennial report to the legislature on pollution prevention. New in the 2002 report is the addition of greenhouse gas pollution prevention strategies.

Waste Prevention - Source Reduction **Office of Environmental Assistance**
OEA provides solid waste reduction assistance and information towards the goals of less waste to manage and thus less greenhouse gases.

Operations of State Agencies
Resource Recovery Program **Administration**
Provides recycling/waste reduction services for most state agencies.

Empty Pesticide Container Collection and Recycling Program **Agriculture**
Program has been in place since 1990. It provides growers with an opportunity to recycle pesticide containers. 100-110 tons recycled annually.

9.5.2.2 Waste Management Activities

Assistance/Information Focused Programs

Environmental Services **Met Council**
Main activities include working with users of the wastewater treatment system and the Council's own facilities to minimize adverse impact on the wastewater system and the environment; conducting river, lake, ground water and air quality monitoring, modeling and analysis to document the region's environmental quality, fulfill permit requirements, develop environmental management strategies and assess future needs; provide technical expertise to regional water management policy; identify, analyze and develop options for the improved operation and cost effectiveness of the wastewater treatment system; and promote non-point source pollution abatement across the region.

Incentive-based Programs

Capital Assistance Program **Office of Environmental Assistance**
Program funds upgrades to solid waste facilities that increase emission controls and reduce greenhouse gases.

Rules – Based Programs

Closed Landfill Program **MPCA**
Program provides MPCA authority and funding to clean up and manage the state's old landfills. MPCA evaluates closed landfills that exceed one million cubic yards for active gas collection. Currently, the program captures methane from five landfills and generate electricity. Legislature authorized Minnesota Landfill Cleanup Act in 1994 and provided broad-based funding for activities.

9.6 Industrial Sector

9.6.1 Description

Minnesota's economy is one of the most diverse in the nation with most of the major U.S. industries represented in the state.[106] Energy usage is the predominant way in which the industrial sector contributes to greenhouse gas emissions. However, certain processes, such as industrial limestone consumption and solvent usage, by specific sectors contribute to greenhouse gas emissions as well. Minnesota's industrial sector consumes about 29 percent of all natural gas, almost 20 percent of petroleum products, and 53 percent of all electricity in the state.[107] Industrial electric consumption has grown at a greater rate during the past 30 years than the residential and commercial sectors.[108]

Programs aimed at industry that result in any of the following may lead to reductions in greenhouse gas emissions as well.

- Enhanced efficiency of electricity usage
- Use of less carbon intensive fuels, for instance switching from coal to natural gas
- Increased use of renewable energy
- Environmentally preferential procurement practices
- Increased buildings efficiency
- Improved process efficiency
- Water conservation
- Waste reduction
- Recycling
- Pollution controls

Some nationally-based businesses with operations in Minnesota have established greenhouse gas reduction targets and taken action to reduce greenhouse gas emissions. Some state programs do exist, such as the Rebuild Minnesota program described below, to provide incentives to businesses to increase energy efficiency and their use of renewable energy. In addition, the market is growing for carbon credits trading and carbon is a tradable commodity now internationally. Some businesses with operations in Minnesota, such as Alliant Energy and Navitas Energy, are participating in the design of the Chicago Climate Exchange℠.[109]

EPA's Climate Wise efforts are now being redirected into the Energy Star® for Business program, which includes both the industrial and commercial sectors. Minnesota businesses participating in Energy Star® include: 3M Company, Americraft Carton Inc., Aveda Corporation, DiaSorin, John B. Goodman Limited Partnership, Mercury Technologies of Minnesota, Inc., North Star Steel, SuperValu Stores, Inc., Target Corporation, and Tilsner Carton Co.

[106] MN Department of Trade and Economic Development website, http://www.dted.state.mn.us/00x02f-faq.asp
[107] Minnesota Department of Commerce, 2001 Energy Planning Report, www.commerce.state.mn.us
[108] Minnesota Department of Commerce, 2001 Energy Planning Report, www.commerce.state.mn.us
[109] See www.chicagoclimatex.com/ for additional information.

9.6.2 State Agency Programs of Potential Relevance to Greenhouse Gas Control in the Industrial Sector

Assistance/Information Focused Programs

Pollution Prevention Program **MPCA**
The MPCA incorporates pollution prevention and other strategies for enhanced environmental outcomes, including sustainability, into the agency's permitting, inspections, enforcement, rules development, remediation, assistance and other functions. Greenhouse gas emissions are typically not targeted for reduction, but may result in efforts to prevent emissions of other pollutants.

Toxics Release Inventory **Public Safety**
Certain industries are required to report their toxic releases under the TRI program. Voluntary reductions are encouraged through pollution prevention plans the companies submit. Some toxic reductions that result may also reduce greenhouse gases if the pollutant is a greenhouse gas or influences greenhouse gas concentrations.

Incentive-based Programs

Rebuild Minnesota **Commerce**
Rebuild Minnesota is a U.S. Department of Energy program administered by Commerce working with many private partners. Result is a number of energy efficiency/renewable projects – focussed more on institutions and industry, not residences at this time. Projects include fuel cell applications, high efficiency gas turbines, conservation audits, efficiency projects and renewables.

Industries of the Future **Commerce**
Industries of the Future is a new joint project between Commerce and the Iron Range Resource and Rehabilitation Board funded by U.S. Department of Energy. It focuses on the mining and forest products industries in Minnesota. The project will work to implement energy efficiency projects.

Rules – based Programs

Environmental Review Program **EQB/Health/MPCA**
Minnesota Planning's Environmental Quality Board writes the rules for conducting environmental reviews. The rules are currently undergoing changes. The actual reviews are usually conducted by governing bodies such as a county board, city council or the MPCA. An environmental review is a study of how a major development project, such as housing, a new road or a commercial or industrial site, will affect its surroundings. The goal is to ensure that such projects leave the environment as intact as possible. The Department of Health reviews proposals, projects and policies for their potential impact on the environment. The department's review focuses on environmental impacts that may affect human health. Significant areas include: protecting ground water through proper well management; protecting the public water supply; minimizing exposure to radiation; minimizing exposure to lead from any source; and properly disposing of hazardous substances. [The review process currently does not include

greenhouse gas emissions, but it was mentioned as a potential future vehicle by several interviewees and some co-benefits of greenhouse gas control may result from the existing program. See also Electricity Sector and Landuse /Forestry sectors]

9.7 Land use/Forestry Sector

9.7.1 Description

Land use is included with the forestry sector as the two are often linked. How land is used can result in reduced greenhouse gas emissions or increased carbon sequestration. Urban development of land may lead to increased greenhouse gas emissions through the disturbance of the land itself which releases greenhouse gases and through the more indirect effects of increased transportation, etc. Preservation and restoration of natural lands tends to lead to a decrease in emissions and increased carbon storage. However, the emissions change depends largely on the previous use of the land.

With 86,943 square miles, Minnesota is the 12th largest state in the nation. Land usage in Minnesota breaks down into the following categories: [110]

Cultivated land	42%
Forested land	26.7 %
Bog/marsh/fen	10.6%
Hay/pasture/grassland	9.2 %
Water	5.9 %
Urban and rural development	2.7 %
Brushland	2.5 %
Mining	0.3 %

The last complete inventory of Minnesota's forests took place in 1990. A summary of Minnesota forest statistics can be found in a 2001 compilation of U.S. forest statistics.[111] Here are some statistics that describe Minnesota's forestry sector taken from the summary:

- Forest land in Minnesota covers about 16.8 million acres. The area of forest land has increased slightly in recent decades.
- Of all the forest land, 14.8 million acres are classified as timberland. Two forest types dominate aspen-birch (41 percent) and spruce-fir (27 percent).
- About half of the forest land is publicly owned. Most of the publicly owned land is held by state, county and municipal governments.
- Net annual growth exceeds removals.

Carbon dioxide is removed from the atmosphere through photosynthesis and plant growth. Over the lifetime of a large, long-lived plant like a tree, substantial amounts of carbon can be removed from the atmosphere and be incorporated into above- and below-ground plant biomass or into the forest floor. After harvest, part of this goes into semi-permanent storage as the structural components of housing or into landfills for paper uses of forest products. Therefore, activities

[110] Data from Minnesota's *1990's Census of the Land* available on Minnesota Planning's website. http://www.mnplan.state.mn.us/datanetweb/landuse.html

[111] Smith, W. Brad et al. 2001. Forest Resources of the United States, 1997. Tables available at http://srsfia.usfs.msstate.edu/rpa/inv/

such as those listed below that increase plant growth, acreage devoted to plants especially plants capable of storing greater amounts of carbon, and maintaining plant litter on the forest floor help increase the amount of carbon stored.

- Preservation of old growth forest
- Increase the productivity of existing forests
- Increase timberland acreage
- Increase woodlots acreage
- Increase use of natural windbreaks along highways
- Leave carbon litter on the forest floor (vs. burning)
- Promote other sustainable practices during harvest.

Not all natural systems act as sinks for greenhouse gases. Natural wetlands are sources of methane. Drainage of wetlands reduces methane emissions but increases the oxidation rate of carbon in wetlands sediments, and thus CO_2 production.

Water quality management activities tend to focus on three areas: agricultural practices, industrial and wastewater releases, and stormwater runoff. Some of the measures used to improve water quality can also have the effect of mitigating greenhouse gases. For example, converting or preserving lands adjacent to lakes, rivers, and streams to less intensive uses (increased carbon sequestration). Minimizing the amount of impervious surface in a watershed can mean less nitrogen runoff into waters and therefore less nitrous oxide emissions from the water body. Minimizing stormwater runoff that is high in organic matter and nitrogen compounds from entering water bodies also reduces the amount of nitrous oxide and methane emitted from the water body. Agricultural practices that are beneficial to water quality, i.e., proper crop fertilization, minimal soil erosion, no pasturing by rivers, etc., also can lead to reduced greenhouse gas emissions.

9.7.2 State Agency Programs of Potential Relevance to Greenhouse Gas Control in the Landuse/Forestry Sector

Assistance/Information Focused Programs

Neighborhood Wilds Program **DNR**
DNR provides forester and Wilds resource experts to work with neighborhoods to restore and bring "nature" back to neighborhood, through plantings, lakescaping, etc. Operates at the grassroots level.

Private Land Forest Stewardship Program **DNR**
This is a cooperative effort of federal, state, and local governments, and industry to have private landowners develop a Forest Stewardship Plan with assistance of forester. Once a plan (includes inventory) is registered then owner receives information on ongoing basis. Goal is statewide to have 50 percent of landowners with more than 20 acres develop plans by 2005. Current project focus is on Aitkin County.

Natural Resource Use/Preservation **Dept. of Trade and Economic Development**
DTED assists businesses that use natural resources and relies on DNR to advise and use resources at sustainable levels. The Tourism Office is interested in preserving natural resources where a tourism activity depends on the resource.

Sustainable Communities **Office of Environmental Assistance**
Program promotes sustainable activities to communities through information, education, financial and technical assistance, consultation, program design, conferences, and workshops and referrals.

Incentive-based Programs

State Resource Cost Share Program **Board of Water and Soil Resources**
Program provides funds to soil and water conservation districts for conservation projects that protect and improve water quality by controlling soil erosion and reducing sedimentation (best management practices).

Reinvest in Minnesota/Conservation Reserve Enhancement Program **Board of Water and Soil Resources**
Program uses financial and technical assistance to keep certain marginal agricultural land out of crop production to protect soil and water quality and support fish and wildlife habitat. Goal of this state-federal-local partnership is to retire up to 100,000 acres of sensitive land in the Minnesota River Valley.

Reinvest in Minnesota/Critical Habitat Match Program **DNR**
Program encourages private citizens and organizations to help fund the acquisition and development of critical fish and wildlife habitat by having their donations of land or cash matched from a special state fund.

Metro Greenways Planning Grants Program **DNR**
Program provides grants to support local government units, water districts, etc., in carrying out comprehensive natural resource inventories and local greenway plans in order to create a regional network of protected, restored, and connected lands.

Community Environmental Partnerships Grant Program **DNR**
Provide grants for environmental service projects, such as clean-up of streams, lakes, and wetlands and other natural areas; and environmental education, such as preparation and production of environmental education materials.

Minnesota ReLeaf **DNR**
Program provides grants to foster long-term urban and rural forest health. It assists Minnesota communities with planting and caring for their trees, to increase energy conservation, to reduce atmospheric carbon dioxide, and to achieve other environmental benefits. Focus since 1992 has been on community forestry projects, which achieve energy conservation.

Cooperative Trail Development **DNR**
Four grant programs support development of trails. Cooperative Trail Linkage grants promote relatively short trail connections between where people live and desirable destinations; Regional Trail Initiative grants promote development of regionally significant trails with local or federal funding; National Recreation Trail grants encourage development and maintenance of motorized, nonmotorized and diversified trails; and the Minnesota Trail Assistance grants provide support for the maintenance and development of recreational trails for use by a range of users.

Landscape Partnerships **MNDOT**
This program fosters roadside, community and environmental enhancements along eligible state highway rights-of-way by providing communities with technical delivery, financial and training assistance to install and maintain landscape plantings. Typically, MnDOT covers the cost of landscape materials and community volunteers install and maintain the plantings in accordance with a cooperative agreement.

Metro Environment Partnership Targeted Grants **Met Council**
The purpose of the grants is to improve water quality are in four areas: Smart Growth opportunity site enhancements, Regional Natural Resources Inventory, Local Environmental Planning Assistance, and Local Implementation of Alternative Stormwater Management techniques. Grants are available through a 5-year 7.5 million dollar program.

Clean Water Partnership Program **MPCA**
Grants or loans are provided by the MPCA to address pollution associated with agriculture or urban runoff. First phase is to identify pollution problems; second phase is to implement, often with best management practices.

Sustainable Forest Incentive Act **Revenue**
New program that allows payments to property owners of more than 20 acres as incentive to keep property undeveloped for eight years. Property owners had to apply by Sept. 30, 2002 for payment in 2003. Land must have an active forest management plan. The program hopes to enroll 10,000 landowners by 2010.

Rules – based Programs

Wetland Conservation Act **Board of Water and Soil Resources/DNR**
The goal of the Act is to not drain or fill wetlands unless the drain or fill activity is exempt or they are replaced by restoring or creating wetland areas of at least equal public value. A local government unit (LGU) usually administers program. BWSR is the LGU for a project that involves that state agency or activity on state land. DNR enforces the Act.

Waters Permit Program **DNR**
This permitting program provides monitoring information allowing DNR's Waters Division to continually assess levels of use and returns to the aquifer, thereby providing a regulatory basis that enables the DNR to sustain water quality and quantity for all Minnesotans.

Wild and Scenic Rivers Program **DNR**
Program goal is to preserve and protect rivers that have outstanding scenic, recreational, natural, historical and scientific value. Local units of government adopt zoning controls that specify allowable land uses, regulate subdivisions and require permits for alterations of the natural landscape.

Operations of State Agencies

Land Acquisition **DNR**
Various DNR programs, such as State Parks, Trails and Waterways, etc., acquire land to meet their mission. Land acquired for such programs is typically preserved in its natural state.

Living Snow Fence Program **MNDOT**
MNDOT plants or maintain crops, trees, shrubs along roadways to keep snow from drifting on roads in coordination with other agencies.

Prairie Passageway Program **MNDOT**
Through multi-agency and local community cooperation, MNDOT is seeking to integrate the natural, historical and cultural rediscovery of prairie and wildflowers through roadways education, protection, planting of wildflowers and grasses, and economic development. Started in 1993, the Federal Highway Administration responded to a proposal for a national prairie landscape. Iowa, Oklahoma, Missouri and Texas are also involved. MNDOT has helped secure funds from other sources for specific projects.

Smart Growth Bonding Criteria **Revenue**
Eleven agencies developed criteria that promote smart growth principals to use in evaluating individual bonding projects. Some of the criteria may influence greenhouse gases. To the extent that individual projects adhere to the smart growth principals, they have a better probability for inclusion in the governor's recommendations.

Policy/Planning Related Activities

Local Water Resource Planning and Management Program **Board of Water and Soil Resources**
BWSR conducts water planning with counties and other local government units. It works with five year implementation plans and develops 10-15 year plans as well. A comprehensive water plan is designed to: (1) identify existing and potential problems and opportunities for the protection, management and development of water and related land resources; and (2) to develop objectives and carry out a plan of action to promote sound hydrologic management of water and related land resources, effective environmental protection and efficient management. BWSR is looking at how their programs impact carbon sequestration.

Sustainable Grassland Landscape Project **DNR**
This program helps landowners, communities and institutions to build integrated strategies for the use and conservation of grass and forage lands in the Lake Agissiz Beach Ridges landscape area in northwest Minnesota. Five Oak Savannah landscape projects are underway as well as others.

Integrated Roadside Vegetation Management **MNDOT**
MNDOT fosters the development of local IRVM programs and written annual plans at the local (district or maintenance area) level within MN/DOT. IRVM is a decision-making and quality management process for maintaining roadside vegetation that results in many benefits including: safety, economic, flexibility, environmental, appearance, and public relations.

Sustainable Development Initiative **Environmental Quality Board**
The Minnesota Sustainable Development Initiative is a collaboration of business, government and civic interests to promote policies, institutions and actions that ensure Minnesota's long-term environmental, economic and social well-being. It is administered by Minnesota Planning and the EQB.

Community Development: Growth Policies and Planning **Met Council**
Met Council advocates smart growth development. Met Council does long range (20-30 year) planning for the 7 county region. Pertinent Blueprint 2030 goals include preserving and protecting natural resources, preserving agricultural lands, providing greater transportation choices, and focusing growth in urban centers. Planning is implemented by others.

Mississippi River Initiative **Met Council**
Initiative's goal is to integrate existing community planning efforts into an action framework for revitalization, development and preservation of the Mississippi Riverfront corridor. Funded by the McKnight Foundation and coordinated by Met Council, the kickoff was in fall 2001 with plan implementation to begin fall 2002.

Basin Management **MPCA**
This geographically-based approach, which focuses on the state's major river basins, will 1) help better identify water quality problems, 2) work with communities to establish shared goals and priorities, and 3) develop effective pollutant-reduction strategies. Goal is to develop with partners a water quality plan for each of 10 basins. MPCA coordinates plan development.

9.8 Programs That May Be Promising In Limiting The Rise In Emissions

Based on MPCA greenhouse gas inventory development work, the following programs appear to be among the more promising in limiting the rise in emissions from Minnesota:

- SCORE program (solid waste recycling)
- MPCA closed landfill program (methane capture at landfills)
- Conservation Improvement Program (demand-side management for investor-owned utilities)
- transportation fuel formulation mandate (ethanol)
- Xcel Energy wind power mandate (wind power replacement for coal-fired generation)
- Conservation Reserve Enhancement Program (agricultural land retirement)
- Minnesota Residential Building Code (residential energy efficiency)

Solid waste recycling has moved upwards of 40% of the waste that otherwise would have been disposed on in landfills, where it would have generated methane for 30-plus years, or been combusted in incinerators, leading to the emission of CO_2. Methane capture at landfills annually

results in the reduction of about 800,000 CO_2-equivalent tons of greenhouse gases emissions annually in Minnesota. In the residential energy use sector, greenhouse gases emissions have been nearly constant since the late 1970s, despite the addition of about 1 billion square feet of residential floor space. This has been partly due to improving efficiency of energy use in space heating in Minnesota residences. In terms of energy use per square foot of floor space, the average residence in Minnesota is now about 25% more efficient now than in 1978. At least some of this improvement has resulted from the development and enforcement of the Minnesota Energy Building Code.

Annually, the Conservation Improvement Program produces electricity savings equal to about 5 percent of total in-state electrical generation. This acts to reduce greenhouse gas emissions by about 2 million CO_2-equivalent tons annually. Currently, about half a million CO_2-equivalent tons of greenhouse gas emissions are avoided each year as a result of the development of wind energy. Finally, the emission of roughly 10 million tons of CO_2 has been avoided since 1990 through the use of ethanol blends in transportation fuels.

In addition, all of the above programs/activities were mentioned in the agency interviews when the interviewee was asked to which programs could be could be strengthened or if they had ideas for new programs. Agencies generally wanted to strengthen those activities that fit most closely with other goals they are charged with achieving. The benefit of greenhouse gas reduction was yet another reason to carry out the activity they are already performing.

Given the demonstrated past successes of these programs, it seems reasonable to expect their continued effectiveness in the future.

10.0 Recommendations

10.1 Summary of Basis for Recommendations

The global climate change problem is one with very long time-frames. It has taken many decades to induce the planetary warming that is now evident in the environment. It will take many decades to develop a truly effective response to the problem. It could certainly take many decades to direct the commercial energy sector away from fossil fuel use or, in absence of that, toward capture and sequestration of co-produced greenhouse gases. The development of a robust and effective international regulatory system will take many years.

The Bush Administration has taken the first steps toward the development of a national policy on global climate change. It recognizes the soundness of much of the underlying science and the serious nature of the issue. It establishes a voluntary greenhouse gas reduction goal of reducing the greenhouse gas intensity of the U.S. economy by 18 percent in the next ten years. (This is a 10-year target for the U.S. to realize an 18 percent reduction in total greenhouse gas emissions per every real dollar of U.S. gross domestic product.) Having based its principal objection to participation in the Kyoto Protocol on the present cost of greenhouse gas control, the U.S. is also developing a research and development program that concentrates on next generation energy pollution control technology. To narrow the scientific uncertainties, it is investing in a substantial global warming research effort.

What we think we understand about the dimensions of this problem:

- that international effort to control greenhouse gas emissions is going forward on the part of the U.S.'s major trading partners, and that trade pressures probably make it inevitable that at some point in the future the U.S. will be drawn into an international regulatory program;
- that the increasing body of biological and physical indicators (such as sea level rise, coral reef bleaching, and changing plant and animal ranges) of the apparent effect of greenhouse gas emissions will act as a continuing pressure for regulatory action, both nationally and in the state;
- that, despite this, the state probably has ample time to develop and implement greenhouse gas control measures—3 to 10 years;
- that unilateral action now on the part of the state of Minnesota to reduce greenhouse gas emissions, particularly if aggressive, may place Minnesota businesses at a competitive disadvantage in the regional and national economy, and may play Minnesota industry at a disadvantage in any future negotiations leading to a national regulatory system for greenhouse gas emissions;
- that the state also needs to be mindful that it not let emissions get so out of hand that, upon the implementation of regulations at some future date, the economy of the state is unduly harmed—that there is substantial long-term risk to the economy from this source;
- that the economy of Minnesota is probably far from optimally invested in energy and materials-use efficiency;
- that this under-investment in efficiency may make it possible, through a strategy designed to increase the efficiency of energy and materials use in the economy, to simultaneously reduce emissions of greenhouse gases (or at lease the rate of increase in emissions) and grow the economy;

- that present-day efforts to develop the energy technology that will be required nationally in future years to address the problem of global warming may yield long-term economic benefits to the state;
- and, that markets for greenhouse gas emission reductions are developing in anticipation of future regulatory action at the national level, and this may provide a present-day locus for voluntary actions to reduce greenhouse gas emissions that are undertaken in Minnesota.

Further, it is also clear that that scientists do not have a good grasp on the range of likely (or possible) impacts of global climatic change on Minnesota, its resources, landscape or people. This is an area that is very poorly understood. The state does not have a monitoring system in place to trace effects and provide the underlying information needed to build understanding of the effects of warming and whatever else global climatic change brings. The state also has made little headway in bringing to the citizenry the many complexities of this issue of global climate change.

All of this argues for a strategy for Minnesota consisting of:
1) a 'no-regrets' short-term strategy centered on improved efficiency of the state's economy in the use of energy and materials, and
2) a longer-term effort to slowly wean the economy from its dependence on fossil fuels and their associated greenhouse gas emissions.

By aggressively pursuing opportunities to improve overall energy and materials-use efficiency in the state, it should be possible in the short-term to simultaneously grow the economy and limit the growth in emissions of greenhouse gases. By slowly going beyond energy efficiency improvements to de-couple greenhouse gas emissions from economic growth, it should be possible to minimize the economic costs of long-term emission reductions, while, at the same time, respond to a serious environmental problem. This strategy has the additional virtue in that it acts to minimize the risk to the Minnesota economy of long-term federal regulatory action.

Thus a two-track approach has the virtue of reconciling shorter- and medium-term concerns for sustained economic growth with longer-term environmental considerations. Among other things, this would allow Minnesota's public leaders a window of time to become conversant in the question, to understand the long-term issues involved, and to bring the citizenry and the political parties in the state to a common understanding of what needs to be done.

10.2 Recommendations for 'No-Regrets' Short-term Actions

There are a number of ongoing efforts in the areas of pollution prevention and energy conservation. Many of these were described in Section 9.0. Based on the MPCA's greenhouse gas inventory development work, some of the more promising programs appear to be:
- SCORE program (solid waste recycling)
- MPCA closed landfill program (methane capture at landfills)
- Conservation Improvement Program (demand-side management for investor-owned utilities)
- transportation fuel formulation mandate (ethanol)
- Xcel Energy wind power mandate (wind power replacement for coal-fired generation)
- Conservation Reserve Enhancement Program (agricultural land retirement)
- Minnesota Residential Building Code (residential energy efficiency)

It is possible that these could form the initial basis for a shorter-term 'no-regrets' efficiency strategy. A substantial amount of program evaluation might be required to determine whether these programs have been effective or whether some other, different type of approach might be warranted.

An efficient economy would use energy at rates substantially lower than is realized under business-as-usual conditions. The average rate of improvement in the efficiency of energy use in the Minnesota economy between 1980 and 2000 was about 1 percent per year. This suggests that something in the 1.5 to 2 percent per year range sustained over several decades might constitute a useful goal. The large apparent pool of efficiency improvements that is economically justifiable using conventional financial analysis suggests that the historic rate of improvements could be increased by at least half.[112]

Innovation in the way that the state permits industrial facilities and large commercial buildings might be one pathway to induce or encourage a higher rate of energy efficiency improvement in the economy. It may be possible that some industrial firms could be induced to more optimally invest in energy efficiency improvements in exchange for the relaxation of certain existing regulatory burdens, like reporting, monitoring, and record-keeping. The state might wish to systematically explore the potential for such regulatory reform as a means to promote increased efficiency of energy and materials use in industry.

An example of an alternative permit process would be some of the pilots undertaken in the MPCA's permitting program. In exchange for regulatory flexibility, some of the more innovative pilots have committed to a program of continuous improvement in their production processes per unit of production. This model could be adapted to encourage energy and materials-use efficiency improvements in the Minnesota industrial sector.

10.3 Recommendations for Longer-Term Actions

The kinds of things that recommend themselves for the long-term component of a dual-track strategy include:

- research and monitoring
- technical assistance for farmers and small landowners
- information disclosure and education
- investigation of voluntary efforts to control methane and HFCs
- alternative energy development
- long-term planning

Research and Monitoring: Research into and monitoring of the effects of climate warming on Minnesota landscapes, ecological systems, lakes and streams, agriculture and forestry is essential if we are to understand what long-term climatic change means for Minnesota. Lacking this, it is almost impossible to discern where Minnesota's long-term interests lie in the question.

[112] All other things held constant, after 20 years energy use under conditions of a 1.5% per year rate of energy efficiency improvement would be approximately 13% less than energy use where end-use efficiency increased the historic 1% per year.

Technical Assistance For Farmers And Small Landowners: Some farmers and small landowners have expressed an interest in participating in the developing markets for carbon emission reductions. It is technically possible to remove from the atmosphere and store substantial amounts of carbon in the living biomass of trees or the roots of grasses and in soils or in forest litter. This acts to offset CO_2 emissions from fossil fuel combustion. The credits for carbon storage can be sold in developing markets for carbon emission reductions. One obvious role for the state would be to facilitate the participation of these small actors in these markets, and to encourage other larger entities to participate.

Information Disclosure And Education: Markets work best when buyers and sellers of goods and services have as complete information as possible about the effects of the goods and services being purchased, including environmental effects. An obvious role for the state would be in providing the information needed for the efficient operation of markets. In surveys conducted for this report, we learned that other agencies and external parties look to the MPCA for information on this issue.

Investigation Of Voluntary Efforts To Control Methane And HFCs: There are hints from officials in the Bush Administration that more minor sources of greenhouse warming, like methane, hydrofluorocarbons and perfluorocarbons, and carbon black may be targeted for control in the next few years. Control of emissions from these sources is often an order of magnitude cheaper than control of emissions of CO_2 from fossil fuel combustion. In Minnesota, most emissions from these sources derive from landfills, natural gas transmission, and manure storage—sources, which are already regulated for other purposes. It is possible that the state of Minnesota may wish to investigate the opportunities for encouraging voluntary control of these more minor sources in anticipation of federal action and participation in existing national partnership programs targeting these gases.[113]

Alternative Energy Development: The use of biomass-based fuels like ethanol and biodiesel in place of petroleum-based liquid fuels acts to constrain the rate of growth of greenhouse gas emissions from the state. Roughly 10 million tons of CO_2 emissions have been avoided since 1990 through the use of ethanol blends in transportation fuels. To encourage a growing agricultural processing industry, the state already encourages the production and use of ethanol through an oxygenate requirement for transportation fuels and production subsidies. The state may wish to explore other opportunities for Minnesota to become a leader in the development of new nonfossil fuel energy supplies. In the event of regulatory action to limit the emission of greenhouse gases, particularly CO_2, to the atmosphere, the gainers will be states that have positioned themselves as suppliers of alternative energy and alternative energy technology.

Long-Term Planning: In the long-term, it will be necessary for the state to develop a plan of how it is going to gradually deflect emissions of greenhouse gases from their business-as-usual trajectory toward a more sustainable path. This may require substantial changes to the energy system in Minnesota, as well as changes in land-use practices. A substantial amount of advance planning will be required to insure that whatever changes are made are made in an orderly fashion, are lowest cost, and are effective with respect to environmental and other goals. The

[113] Information about existing national programs targeting these gases may be found at: www.epa.gov/methane , www.epc.gov/cppd , and www.epa.gov/ghginfo/topics/topic7.htm

state may want to slowly build-up its capacity to perform this type of analysis over a period of time. Technology assessment will be critical in this effort. What are the technologies of the future that can get us there? When will they be available? What types of public infrastructure changes will be necessary to accommodate them? What should the state be doing now to ease the way for these future technologies? In the meanwhile, the state will want to maintain and strengthen its existing capability to analyze the current-day effects of different policy measures on emissions and its greenhouse gas emission inventory and forecasting capability. The development of a carbon sink inventory would help in any effort to promote the participation of Minnesota farmers and landowners in emerging markets for carbon emission reductions. Development of a 'direction setting' state greenhouse gas emission reduction goal along with a carbon sequestration target may help to focus long-term planning efforts.

10.4 Conclusion

The challenges involved in responding to the problem of human-induced global climate change are numerous. However, with all the pitfalls and perils, there also are substantial opportunities for Minnesota. If the state acts with due deliberation, responding incrementally to developments in nature as the effects of climatic change reveal themselves, as well as to developments in Washington and abroad, it should be possible to exploit these opportunities economically while at the same time profiting environmentally. A high efficiency economy with respect to the use of energy and materials is a competitive, growing economy. An exporter of renewable fuels and electricity generated from renewable energy sources is a state that benefits economically as well as environmentally.

The trick is in doing what is needed now when pursuing a no-regrets efficiency strategy, and later a more technology-based response that begins the shift of the economy from reliance on fossil fuels toward low-emitting sources of energy. There are risks in acting too soon, as well as risks in delaying too long. The sensible path is the no-regrets efficiency strategy, to which no risks attach, now, in conjunction with a slowly building effort to purposefully move the trajectory of Minnesota's greenhouse gas emissions from a business-as-usual path. The state probably has a window of three to ten years before any dramatic changes are required. During this period, it can put the rudiments of such a strategy into place and begin to develop answers to the questions that in the long run will need to addressed. Ultimately, it will be those answers that, in the long-term, will determine how successfully the state responds to the challenge of global climate change.

Appendix A

2002 State Agency Climate Change Survey Methodology and Questionnaire

Description of the Sample

The MPCA and OEA[114] sent surveys via e-mail to 1,036 state government employees at eleven different agencies to learn whether agency staff view climate change as a problem and their level of awareness about the causes and possible impacts. Five hundred and sixty four (564) responses were received. The intent was to survey agencies whose work impacts greenhouse gas emissions and/or whose work may be impacted by a changing climate. At some agencies, these criteria applied to only certain divisions within the agency and in those cases only the relevant divisions were included in the survey. The following are the state agencies that were included in the survey.

- Department of Administration- Materials Management, Resource Recovery, Travel Management Divisions (Admin)
- Department of Agriculture (Ag)
- Board of Water and Soil Resources (BWSR)
- Department of Commerce – Energy Division (Comm)
- Department of Transportation (DOT)
- Department of Natural Resources (DNR)
- Department of Trade and Economic Development (DTED)
- Department of Health – Environmental Services Division (Health)
- Office of Environmental Assistance (OEA)
- Pollution Control Agency (PCA)
- Minnesota Planning (Plan)

The survey was primarily designed to allow comparison between agencies. However, through the appropriate weighing of the responses, results could be projected to the total population of government employees at the agencies surveyed.

The margin of error due to sampling varies from agency to agency, depending on their response rate, in the range of plus or minus 9-16 percentage points at the 95 percent confidence level.

The survey response rate varied from 38 to 73 percent. Most response rates were lower than expected, but are still high enough to be potentially useful. The table below shows the response rate for each agency.

[114] OEA staff: Jeff Ledermann, Tom Miller and Ahndi Fridell. MPCA staff: Sherryl Livingston and Mary Jean Fenske.

	Admin	Ag	BWSR	Comm	DNR	DOT	DTED	Health	OEA	PCA	Plan	Total
Total Employee Pool	70	511	88	49	2330	4465	232	337	69	728	86	8965
No. sent for 10%	62	114	71	38	140	141	104	110	62	128	71	1041
No. responses	31	48	27	22	77	56	46	71	44	93	33	564
Response rate	50%	42%	38%	58%	55%	40%	44%	65%	71%	73%	47%	54%
Error Term	+/- 13%	+/- 13%	+/- 16%	+/- 16%	+/- 11%	+/- 13%	+/- 13%	+/- 10%	+/- 9%	+/- 9%	+/- 13%	

Sampling Method

A team of PCA and OEA staff members first selected which agencies (and in some cases, particular divisions within those agencies) were the proper targets for this survey. Next, a list of all e-mail addresses in those agencies was selected. Almost all employees had e-mail addresses in every agency but one, the Department of Agriculture, where 23 percent of employees did not have e-mail, primarily in the inspection divisions. Potential bias resulting from the omission of these employees should therefore be taken into consideration when looking at results from the Department of Agriculture. This is not a concern for other agencies.

After the list of e-mail addresses was compiled, a random sample of employees was selected from each agency. The number of employees chosen was designed to hold sampling error constant at 10 percent, with an anticipated 67 percent response rate. The PCA and OEA team members decided that this error rate would be acceptable for the purposes of the survey.

The survey was sent electronically the morning of May 29 2002, with responses due back by June 11. A reminder e-mail was sent the morning of June 6 to the entire sample. In order to maintain confidentiality of the responses, there was no tracking of individual responders, with a trade-off that there was no safeguard to prevent somebody from filling out the survey again. The PCA and OEA team members deemed this trade-off acceptable.

The response rate for the survey was lower than anticipated for most agencies, resulting in a higher error term in these agencies than the expected 10 percentage points. The approximate error terms, by agency, are contained in the table above.

Survey Analysis

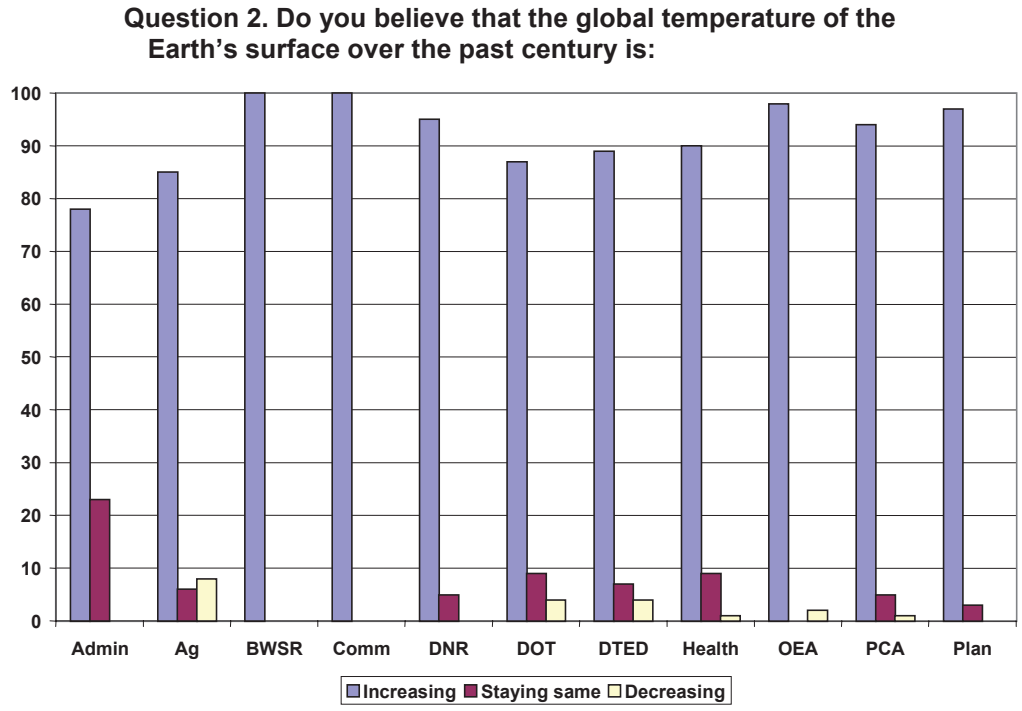
Responses to the survey were tabulated using the Perseus Survey Solutions and SPSS software packages.

Percentages Not Totaling 100 Percent

Responses were rounded off to the nearest whole percentage. As a result, percentages in certain charts and tables may sometimes total slightly more or less than 100 percent. Also, in certain charts and analyses, the results of those who said “don’t know” or chose not to answer may have been omitted.

Response to Knowledge Questions (# 2-6)

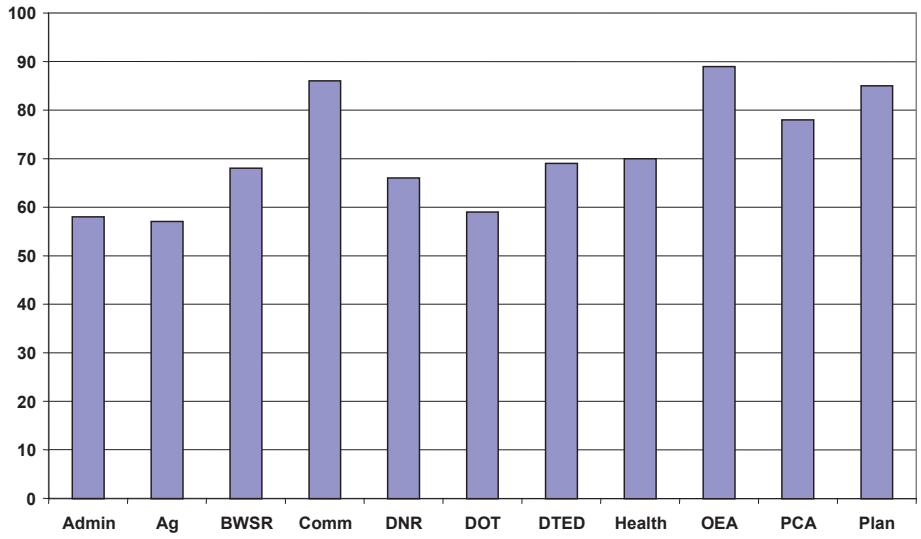
Question 2 The majority of respondents at all agencies surveyed believed that the average temperature of the earth has increased over the past century. The variation in responses among agencies is not significant given the margin of error in the survey. According to the National Academy of Sciences, the global average surface temperature measured over land surfaces has increased by about one degree Fahrenheit over the past century, with accelerated warming during the past two decades. The "increase" percent in the table above combines the responses of two choices offered to respondents in the survey: "increasing a little" and "increasing at an unprecedented rate." The responses were combined in the figure above and no further analysis can be justified because, as some respondents correctly pointed out, there was no time frame against which to reference the rate of increase over the past century.



Question 3 When asked what they thought the primary cause of the temperature increase was over the past century, majorities at each agency thought human activities were the primary cause. However, there was more variation in the responses among the agencies compared with the previous question. Although scientists are not 100 percent certain that human activities are the primary cause of the warming, human activities are the most likely cause according to prominent scientific organizations. The Bush administration in its recently-released 2002 Climate Action Report to United Nations states "Greenhouse gases are accumulating in the Earth's atmosphere as a result of human activities, causing global mean surface air temperature and subsurface ocean temperature to rise. While the changes over the last several decades are likely due mostly to human activities, we cannot rule out that some significant part is also a reflection of natural

variability."[115] The Intergovernmental Panel on Climate Change in its 2001 Third Assessment Report found "in the light of new evidence and taking into account the remaining uncertainties, most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas emissions."[116] Of the total responses received, 15 percent named natural variations in climate or some other natural phenomenon as the primary cause for the increase. Ten percent of total respondents chose "Other" and many provided answers that named a combination of factors as the primary cause. Four percent of total respondents did not agree that the earth's temperature has increased.

Question 3. Percent Respondents Naming Human Activities as Primary Cause of Temperature Increase Over Past Century



Question 4 When asked whether greenhouse gas emissions in Minnesota have been increasing, decreasing, or staying the same, most said that they were increasing. In fact, greenhouse gas emissions in Minnesota have increased about 18 percent from 1990 through 1999 or about an average of 1.5 percent a year.[117] This compares to a national rate of increase of 15.6 percent over the same time period.[118] The results did not vary greatly by agency; however, Commerce, Planning, and OEA were highest rate of those responding correctly.

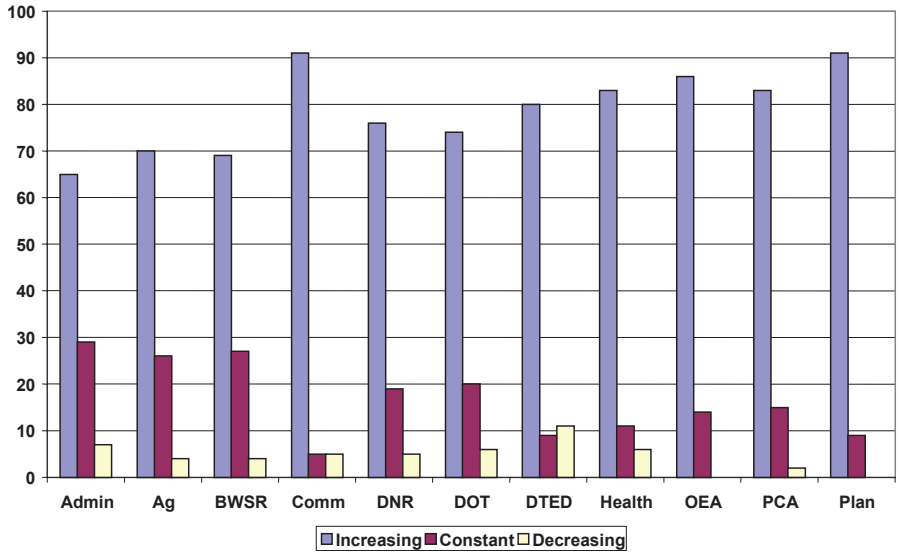
[115] U.S. Department of State, U.S. Climate Action Report 2002, Washington D.C., May 2002.

[116] Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis. Third Assessment Report.* Cambridge Press. U.S.A. 2001.

[117] Minnesota Pollution Control Agency, Minnesota greenhouse gas emission inventory data compiled by Peter Ciborowski. July, 2002.

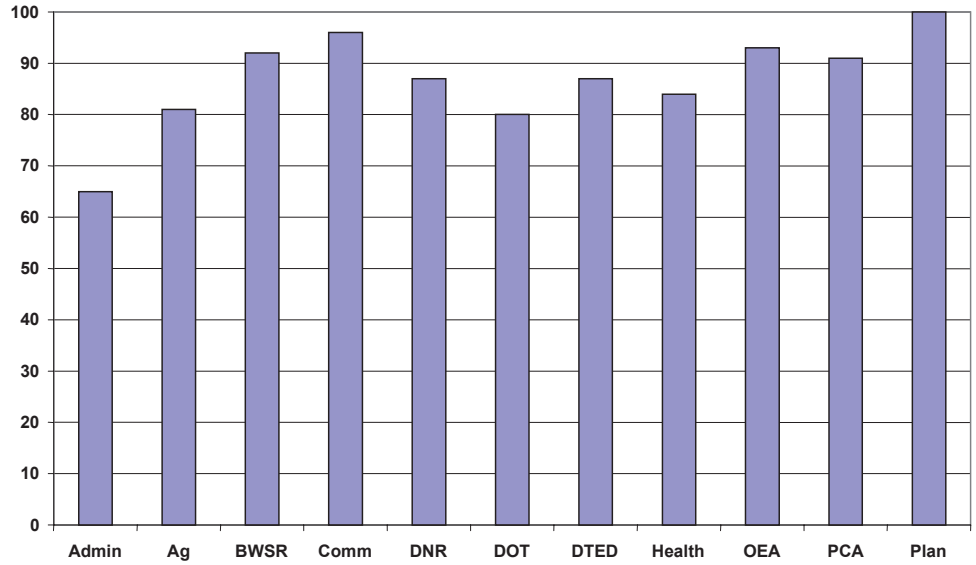
[118] U.S. Department of State, U.S. Climate Action Report 2002, Washington D.C., May 2002.

Question 4. Do you believe Minnesota greenhouse gas emissions since 1990 have been:

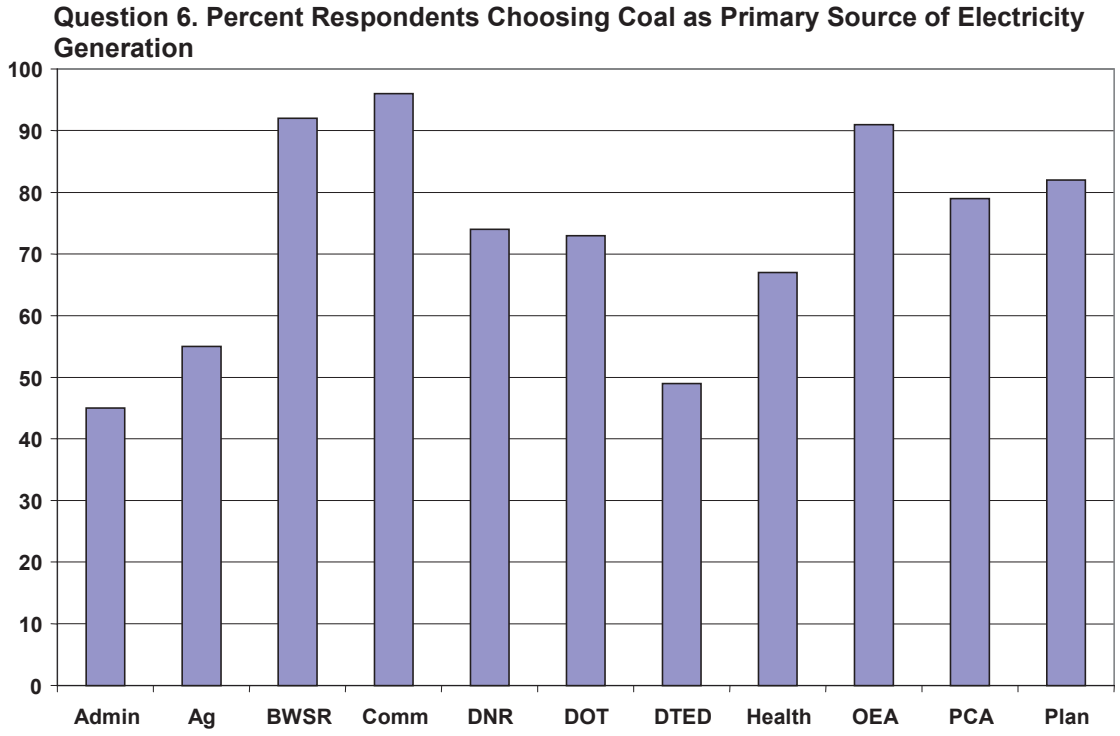


Question 5 Another area of knowledge tested was the primary source of human-caused greenhouse gas emissions in Minnesota. According to the PCA greenhouse gas emissions inventory, more than ¾ of human-caused greenhouse gas emissions in Minnesota come from the burning of fossil fuels such as gasoline, oil, natural gas and coal. Eighty-six percent of overall respondents correctly chose burning fossil fuels as the largest contributor from the choices given. Other choices offered included: Agricultural operations – manure storage, livestock digestion (five percent overall chose this), Agricultural Operations- crop fertilization (one percent), leakage from AC/refrigeration systems (four percent) and four percent chose "other" with a variety of responses from don't know to a combination of factors. Commerce, OEA and Planning had the highest percentages of respondents answering correctly.

Question 5. Percent Respondents Choosing Fossil Fuel Combustion as Largest Greenhouse Gas Contributor in Minnesota



Question 6 The last knowledge question regarding the primary source of electricity generation in Minnesota is indirectly related to climate change. Coal-fired power plants are responsible for 58.5 percent of the electric generation capacity in Minnesota[119] and supply about ¾ of the electricity used by Minnesotans.[120] This question was also included in the 2001 Minnesota State Survey conducted by the University of Minnesota of the general public. Forty-three percent of the general public knew the primary source of electricity while 71 percent of the respondents in this survey answered this correctly. The higher level of education among the government staff compared to the general public may contribute to this difference. As expected, the Energy Division of Commerce had the greatest percentage of respondents answer correctly. However, the variation among the agencies was significant as shown in the figure above. Those who did not select coal as the primary source most often chose nuclear energy. Sixteen percent overall selected nuclear power plants as the largest provider of electricity. Of the overall respondents, 4 percent chose hydropower and 8 percent didn't know.



OEA/MPCA 2002 Climate Change Survey

The survey was sent out in the following e-mail. A written version of the survey was included as an option for people to provide responses should the electronic version not be operable for them. Written responses received were hand entered by MPCA staff.

[119] U.S. Department of Energy statistics. http://www.eia.doe.gov/cneaf/electricity/st_profiles/minnesota/mn.html#t7
[120] Minnesota Department of Commerce, *2001 Energy Planning Report*, February 2002.

From: sherryl.livingston@pca.state.mn.us[SMTP:sherryl.livingston@pca.state.mn.us]
Sent: Wednesday, May 29, 2002 11:26 AM
To: sherryl.livingston@pca.state.mn.us
Subject: Climate Change Survey

Hello,
You have been randomly selected to complete a short survey of state agency staff regarding your attitudes and knowledge about climate change and greenhouse gas emissions. The Office of Environmental Assistance and Minnesota Pollution Control Agency are conducting this survey as part of a larger effort to develop state greenhouse gas goals and strategies.

Greenhouse gases, emitted from both natural sources and human activities, trap heat in the earth's atmosphere. Climate change is the term used to describe the changes that global warming could cause in the world's climate.

We believe that working with sister agencies on this issue is an important step. From this survey we hope to learn whether agency staff view climate change as a problem and their level of awareness about the causes and possible impacts. Your participation in the survey is critical to our efforts to design outreach/educational efforts on climate change with your agency. The survey results will also serve as a baseline measure to determine if educational efforts are successful.

The attached survey is primarily multiple choice and will take around 5 - 10 minutes to complete. Your answers to the survey are confidential. Results of the survey will be sent to you at a later date.

Thanks in advance for your cooperation and assistance. Please respond to the survey by June 11, 2002.

Survey Instructions

1. Please click on the attached "Climatechangesurvey.htm" file to open the survey. After you have finished completing the survey, click on the Submit Survey button to send the results back.
2. In case you have difficulty opening the "Climate Change Survey" file or submitting the survey, a copy of the survey questions is attached to the bottom of this e-mail message. To use this option, hit the "reply" button, and then fill out the questions below and e-mail the survey back to me. Your results will then be transferred into the database with other project responses.
3. If you have any other problems with the survey, please respond to this e-mail or call Sherryl Livingston at (651) 647-7832. If you have questions regarding the survey results, please contact Mary Jean Fenske at (651) 297-5472 or Jeff Lederman at (651) 215-0236.

****

Written version of the survey

Q. 1
How informed do you think you are about climate change?

(Type an X between the brackets preceding your choice. Select only one choice.)

[ ] 1. Very knowledgeable
[ ] 2. Somewhat knowledgeable
[ ] 3. Not very knowledgeable
[ ] 4. Don't know

Q. 2
Do you believe that the global average temperature of the Earth's surface over the past century is...

(Type an X between the brackets preceding your choice. Select only one choice.)

[ ] 1. Decreasing at an unprecedented rate
[ ] 2. Decreasing a little
[ ] 3. Staying the same
[ ] 4. Increasing a little
[ ] 5. Increasing at an unprecedented rate

Q. 3
If you agree with the statement that the Earth's average global surface temperature has increased over the past century, what do you think is the primary cause?

(Type an X between the brackets preceding your choice. Select only one choice.)
[ ] 1. Increased solar activity
[ ] 2. Natural variations in climate
[ ] 3. Increased concentrations of greenhouse gases due to human activities
[ ] 4. Increased activity from volcanoes worldwide
[ ] 5. Other
[ ] 6. Don't agree

Q. 3Specified

(Type your answer to question # 3 "Other" selection between the brackets. Don't worry about extra spaces at the end of your response.)

Other: [ ]

Q. 4
Greenhouse gases hold heat in the atmosphere. They are emitted by both natural sources and human activities. Do you believe that human-caused greenhouse gas emissions in Minnesota since 1990 have been...

(Type an X between the brackets preceding your choice. Select only one choice.)

[ ] 1. Decreasing at an unprecedented rate
[ ] 2. Decreasing a little
[ ] 3. Relatively constant
[ ] 4. Increasing a little
[ ] 5. Increasing at an unprecedented rate

Q. 5
All of the activities listed below are contributors of human-caused greenhouse gases in Minnesota. Which of the following do you believe is

the largest contributor to greenhouse gas emissions in Minnesota?

(Type an X between the brackets preceding your choice. Select only one choice.)

[ ] 1. Agricultural operations - manure storage, livestock digestion
[ ] 2. Leakage from vehicle air conditioning/other refrigeration systems
[ ] 3. Burning fossil fuels - coal, oil, gasoline, diesel and natural gas
[ ] 4. Agricultural operations - fertilization of crops
[ ] 5. Other

Q. 5Specified

(Type your answer to question #5 "Other" selection between the brackets. Don't worry about extra spaces at the end of your response.)

Other: [ ]

Q. 6
How do you think most of the electricity generated in Minnesota is produced?

(Type an X between the brackets preceding your choice. Select only one choice.)

[ ] 1. Burning coal
[ ] 2. Nuclear power
[ ] 3. Wind power
[ ] 4. Hydropower
[ ] 5. Other
[ ] 6. Don't know

Q. 6Specified

(Type your answer to question # 6 "Other" selection between the brackets. Don't worry about extra spaces at the end of your response.)

Other: [ ]

Q. 7
To what extent do you believe human-caused climate change is happening today?

(Type an X between the brackets preceding your choice. Select only one choice.)

[ ] 1. Don't know
[ ] 2. Don't believe it is happening
[ ] 3. I believe the evidence is mixed
[ ] 4. I believe it is happening

Q. 8
How concerned are you about the impacts of climate change over the next 10 years?

(Type an X between the brackets preceding your choice. Select only one choice.)

[ ] 1. Not concerned at all
[ ] 2. Somewhat concerned
[ ] 3. Very concerned
[ ] 4. Don't know

Q. 9
How concerned are you about the impacts of climate change over the next 50 years?

(Type an X between the brackets preceding your choice. Select only one choice.)

[ ] 1. Not concerned at all
[ ] 2. Somewhat concerned
[ ] 3. Very concerned
[ ] 4. Don't know

Q. 10
Scientists who study the climate have identified some possible effects of global warming in Minnesota. Which of the following effects would you be MOST concerned about?

(Type an X between the brackets preceding your choice. Select only one choice.)

[ ] 1. Ecosystem changes that result in loss of Minnesota plants and animals and an increase in non-native species
[ ] 2. Increase in heat related illnesses and some diseases borne by insects (i.e. malaria and yellow fever)
[ ] 3. Increase in frequency of floods, tornadoes and other unpredictable weather patterns
[ ] 4. Decrease in winter recreation opportunities
[ ] 5. Something else
[ ] 6. Don't know

Q. 10Specified

(Type your answer to question # 10 "Other" selection between the brackets. Don't worry about extra spaces at the end of your response.)

Something else: [ ]

Q. 11
What is your biggest concern regarding possible implementation of State initiatives over the next 10 years to reduce greenhouse gas emissions?

(Type an X between the brackets preceding your choice. Select only one choice.)

[ ] 1. Decreases jobs
[ ] 2. Slows economic growth
[ ] 3. Increases taxes or fees
[ ] 4. Limits individual's freedom of choice (e.g. housing, transportation)
[ ] 5. Other
[ ] 6. Not concerned

Q. 11Specified

(Type your answer to question # 11 "Other" selection between the brackets. Don't worry about extra spaces at the end of your response.)

Other: [ ]

Q. 12
In your opinion, with regard to striking the right balance in addressing the issue of climate change, has the State of Minnesota?

(Type an X between the brackets preceding your choice. Select only one choice.)

[ ] 1. Gone too far
[ ] 2. Not far enough
[ ] 3. Struck the right balance
[ ] 4. Don't know

Q. 13
Have you or your department thought about how a change in Minnesota's climate would effect your job or program?

(Type an X between the brackets preceding your choice. Select only one choice.)

[ ] 1. Yes
[ ] 2. No

Q. 14
Have you thought about the impact your job has on the emissions of greenhouse gases?

(Type an X between the brackets preceding your choice. Select only one choice.)

[ ] 1. Yes
[ ] 2. No

Q. 15
What is your primary source of information about climate change?

(Type an X between the brackets preceding your choice. Select only one choice.)

[ ] 1. Television/radio
[ ] 2. Internet
[ ] 3. Newspaper
[ ] 4. Magazines
[ ] 5. Friends

[ ] 6. Other

Q. 15 Specified

(Type your answer to question # 15 "Other" selection between the brackets. Don't worry about extra spaces at the end of your response.)

Other: [ ]

Q. 16
If you would like to receive more information about climate change, please provide the information below...

(Type your answer between the brackets. Don't worry about extra spaces at the end of your response.)

Name:
[ ]
Job Title:
[ ]
E-mail address:
[ ]
Phone number:
[ ]

Q. 17
What are your preferred ways for receiving information regarding climate change?

(Type an X between the brackets preceding each choice you wish to select. Select as many choices as appropriate.)

[ ] E-mail
[ ] Presentation
[ ] Presentation by peer
[ ] Informal meetings - Q&A
[ ] Seminar
[ ] Written materials
[ ] Other

Q. 17Specified

(Type your answer to question # 17 "Other" selection between the brackets. Don't worry about extra spaces at the end of your response.)

Other: [ ]

Q. 18
Please share any other comments or concerns you might have regarding climate change.

(Type your answer between the brackets, using as much space as necessary. Don't worry about extra spaces at the end of your response.)

[ ]

Q. 19
What is the name of your agency?

(Type an X between the brackets preceding your choice. Select only one choice.)

[ ] 1. Board of Water and Soil Resources
[ ] 2. Department of Administration
[ ] 3. Department of Agriculture
[ ] 4. Department of Commerce
[ ] 5. Department of Health
[ ] 6. Department of Natural Resources
[ ] 7. Department of Transportation
[ ] 8. Department of Trade and Economic Development
[ ] 9. Minnesota Office of Environmental Assistance
[ ] 10. Minnesota Planning
[ ] 11. Minnesota Pollution Control Agency

Q. 20
What is the name of your division, if applicable?

(Type your answer between the brackets, using as much space as necessary. Don't worry about extra spaces at the end of your response.)

[ ]

Q. 21
To help us understand the type of work you do, if you are represented by a union or pay plan, please select the correct one below.

(Type an X between the brackets preceding your choice. Select only one choice.)

[ ] 1. AFSCME
[ ] 2. Commissioner's Plan
[ ] 3. International Union of Operating Engineers
[ ] 4. Manager's Plan
[ ] 5. MAPE
[ ] 6. Middle Management Association
[ ] 7. Minnesota Conservation Officer Supervisor's Association
[ ] 8. Minnesota Conservation Officer's Association
[ ] 9. Minnesota Government Engineers Council
[ ] 10. Other
[ ] 11. None

Q. 21Specified

(Type your answer between the brackets. Don't worry about extra spaces at the end of your response.)

Other: [ ]

Q. 22
What is your gender?

(Type an X between the brackets preceding your choice. Select only

one choice.)

[ ] 1. Male
[ ] 2. Female

Q. 23
What is your age?

(Type an X between the brackets preceding your choice. Select only one choice.)

[ ] 1. 18-30
[ ] 2. 31-40
[ ] 3. 41-50
[ ] 4. 51-60
[ ] 5. 61 and other

Q. 24
What is the highest level of education you have completed?

(Type an X between the brackets preceding your choice. Select only one choice.)

[ ] 1. High school or less
[ ] 2. Some college
[ ] 3. 2-year college/technical school
[ ] 4. 4-year college
[ ] 5. Graduate school/doctorate degree