DELAWARE CLIMATE CHANGE ACTION PLAN

Prepared for the

Delaware Climate Change Consortium

by the

Center for Energy and Environmental Policy

University of Delaware

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and

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DISCLAIMER

The Delaware Climate Change Action Plan was developed as a consensus report of the Delaware Climate Change Consortium. The Action Plan includes the diverse ideas of the Consortium, but does not necessarily reflect those of any individual, organization, or corporation, which Consortium members represent.

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TABLE OF CONTENTS

CHAPTER 6
ELECTRIC UTILITY SECTOR CO_2 EMISSION REDUCTION STRATEGY

CHAPTER 7
WASTES AND FORESTS SECTORS

WASTES SECTOR EMISSION REDUCTION STRATEGY

CARBON SEQUESTRATION STRATEGIES FOR FOREST SINKS

CHAPTER 8
PUBLIC EDUCATION AND OUTREACH

CHAPTER 9

POLICY RECOMMENDATIONS

CHAPTER 10

CONCLUSION

LIST OF TABLES

LIST OF FIGURES

APPENDICES

ABBREVIATIONS

AFV	Alternative fuel vehicle
BAU	Business-as-usual
Btu	British thermal unit
CAFE	Corporate average fuel economy
CH_4	Methane
CNG	Compressed natural gas
CO_2	Carbon dioxide
CEEP	Center for Energy and Environmental Policy
DCCC	Delaware Climate Change Consortium
EV	Electric vehicle
FCCC	UN Framework Convention on Climate Change
GHG	Greenhouse gas
HOV	High occupancy vehicle lanes
IPCC	Intergovernmental Panel on Climate Change
NCCAP	National Climate Change Action Plan
kWh	Kilowatt hour
mpg	Miles per gallon
MWh	Megawatt hour (1,000 kWh)
GWh	Gigawatt hour (1,000 MWh)
PV	Photovoltaic
LDPV	Light duty passenger vehicle
LDT	Light duty truck
mt	metric tons
mmt	Million metric tons
$mtCO_2$	Metric tons of carbon dioxide
$mmtCO_2$	Million metric tons of carbon dioxide
$mmtCO_2(e)$	Million metric tons of carbon dioxide equivalent
TCM	Transportation control measure
ton	Metric ton (1,000 kilograms)
USDOE	U.S. Department of Energy
USEPA	U.S. Environmental Protection Agency
VMT	Vehicle miles traveled
%	Percent

EXECUTIVE SUMMARY

Background

The Delaware Climate Change Action Plan (DCCAP) was prepared with funding from the Delaware State Energy Office and the U.S. Environmental Protection Agency's State and Local Climate Change Program. The Center for Energy and Environmental Policy of the University of Delaware researched and wrote the Action Plan with the guidance and advice of the Delaware Climate Change Consortium (DCCC), comprised of representatives from government, business, labor, environment and community-based organizations. The Consortium includes individuals with knowledge about industry, transport, commerce, energy utilities, wastes and sinks, federal, state and local policy, and community concerns, awareness and goals. Throughout the two-year period of its development, the DCCAP was prepared as a consensus activity of the DCCC. The Action Plan includes the diverse ideas of the Consortium, but it does not necessarily reflect those of any individual, organization, or corporation which Consortium members represent.

The DCCC adopted a greenhouse emissions[1] reduction target for Delaware of 7% below the state's 1990 emissions by the year 2010. In this Action Plan, the DCCC has developed a set of policy options that can reduce Delaware's greenhouse gas emissions by 7% below the 1990 level. This amounts to a decrease of almost 25% in State emissions by 2010.

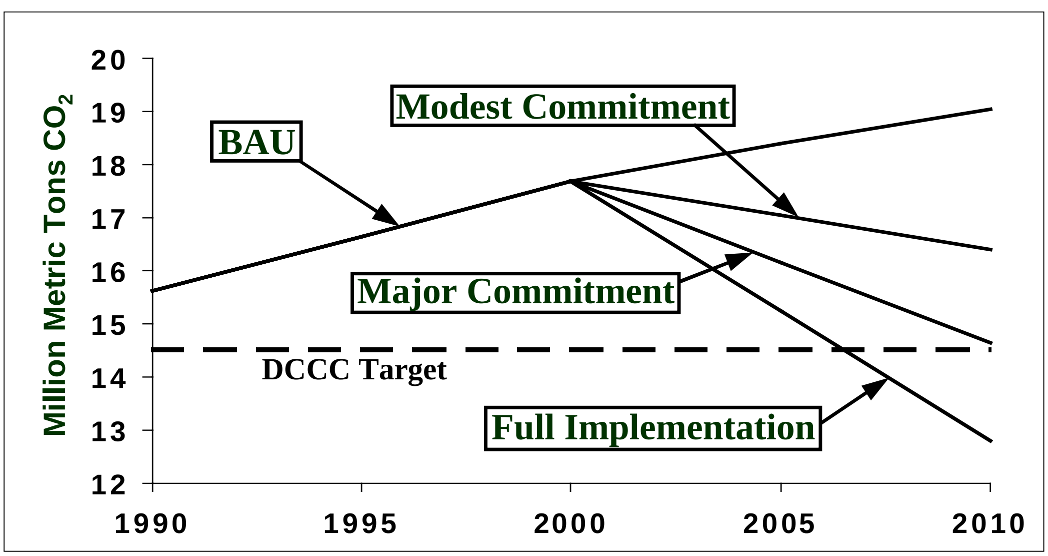
Three levels of implementation were devised: a *Full Implementation scenario* involving the adoption of all measures (i.e. 100%); a *Major Commitment scenario* which seeks to realize 65% of the reductions identified in the DCCAP through aggressive state policies and supporting federal strategies; and a *Modest Commitment scenario* with 35%

[1] The principal greenhouse gases (GHGs) are: carbon dioxide (CO_2), methane (CH_4), ozone (CO_3), nitrous oxide (N_20), sulfur dioxide (SO_2) and chlorofluorocarbons (CFCs). Carbon dioxide is the most important GHG from a policy standpoint. Scientific research (IPCC 1996) suggests that this gas accounts for 66% of the warming effect. Common human activities that lead to carbon dioxide emissions include: coal burned for electricity generation; gasoline consumed for automobile and truck travel; and oil used for home heating.

of the DCCAP's reductions targeted for state action and supporting federal initiatives. The three scenarios used in the DCCAP parallel a recent national study by the Interlaboratory Working Group (1997). The scenario approach provides insight into the relative emissions savings that can be expected from different levels of policy implementation.

Using the Delaware Econometric Model (which is maintained by the University of Delaware), an energy demand forecast was developed for the DCCAP. This forecast projects the state's greenhouse gas emissions to 2010 under "business-as-usual" (BAU) conditions. By 2010, the BAU estimate is for Delaware's emissions to increase to about 18.8 mmtCO_2. To meet the DCCC target for Delaware of 14.5 mmtCO_2, a 23% reduction from BAU levels will be required. The forecasted total increase in emissions divided on a sector basis is as follows: transport (29.6%), utility (29.6%), industrial (21.5%), residential (9.9%), and commercial (9.5%). The majority of emissions result from fossil fuel combustion to supply a wide range of energy services.

Figure ES-1
Policy Options for Reducing Delaware's
Future Greenhouse Gas Emissions



Findings

- The Delaware Climate Change Consortium finds that Delaware can reduce its greenhouse gas (GHG) emissions by 15-25% over the next 12 years by implementing the measures identified in this Action Plan. However, successful implementation of the Action Plan will require a **major policy commitment** by the State of Delaware to remove barriers to the adoption of cost-effective measures to improve energy efficiency throughout the State's economy (Overall results of the three implementation scenarios are shown in Figure ES-1).

- Two of the scenarios analyzed for the DCCAP - Full Implementation and Major Commitment (equal to 65% of the Full Implementation case) - would reverse the State's current trend of increasing emissions and satisfy DCCC's emission reduction target of 7% below 1990 emissions by the year 2010. But, implementing either scenario would require significant effort on the part of government and industry that has not been evident to date. Even implementation of the Modest Commitment scenario will need statewide efforts to overcome major barriers.

- Implementation of the Action Plan will require adoption of a policy agenda that encourages the state's government, industries, and citizen organizations to participate actively in a wide range of implementation activities. Such cooperation would involve legislative initiatives, community input and support, and education and outreach. Specific policy needs to support the Action Plan are described in detail in Chapter 9. The Policy Priorities identified by the DCCC appear at the conclusion of the Executive Summary.

- Achievement of the projected effects of any of the three implementation strategies analyzed for the DCCAP will be **difficult**. Still, the Consortium believes that it is worthwhile for Delawareans to undertake the challenges set forth in this Action Plan as part of the nationwide and international commitment to avert the prospect of climate change.

- Projected greenhouse gas emission savings for each sector of the Delaware economy are as follows:

  - ♦ Industrial Sector: Full implementation of the 170 identified efficiency measures in boiler and steam systems, heat recovery and containment, space conditioning, air compressors, motors, and lighting will lower emissions to 3.1 mmtCO_2 in 2010, compared to the BAU forecast of 4.2 mmtCO_2. Emissions under the Major Commitment scenario would be 3.5 mmtCO_2 and 3.8 mmtCO_2 under the Modest Commitment scenario.
  - ♦ Residential Sector: Full implementation of the identified efficiency measures (related to space and water heating, electric appliances, gas cooking, and lighting upgrades) will result in emissions of 1.4 mmtCO_2 in 2010; the BAU forecast is approximately 2.0 mmtCO_2 in 2010. For the Major Commitment scenario, emissions would be 1.6 mmtCO_2; and 1.8 mmtCO_2 for the Modest Commitment case.
  - ♦ Commercial Sector: Full implementation of efficiency measures in commercial lighting, refrigeration, space conditioning, fuel switching and building-integrated photovoltaics will lower this sector's greenhouse gas emissions to 1.4 mmtCO_2 in 2010. By comparison, the BAU projects this sector's 2010 emissions to be 1.9 mmtCO_2. Emissions under the Major Commitment scenario would be nearly 1.6 mmtCO_2; and over 1.7 mmtCO_2 under the Modest Commitment scenario.
  - ♦ Transportation Sector: Full implementation of measures to upgrade the energy efficiency of passenger and light-duty vehicles, to spur the use of alternative fuel vehicles, and to implement transportation conservation measures will reduce emissions to 3.1 mmtCO_2 in 2010. Under the BAU, emissions are projected to climb to 4.9 mmtCO_2 in 2010. For the Major Commitment scenario, emission would be 3.7 mmtCO_2; and nearly 4.4 mmtCO_2 for the Modest Commitment case.
  - ♦ Electric Utility Sector: Utilizing a renewable energy portfolio standard, switching fuels used for generation, and incorporating the savings identified

for the residential, commercial and industrial sectors, will lower emissions in 2010 to 4.4 mmtCO_2. The BAU forecast emissions from this sector to climb to 5.8 mmtCO_2 in 2010. Emissions under the Major Commitment scenario would be 4.9 mmtCO_2; and 5.3 mmtCO_2 under the Modest Commitment scenario.

- ♦ Wastes Sector: Through a full-potential recycling scenario, the sector's emissions from landfill operations are estimated to be approximately 0.18 mmtCO_2(e) in comparison with the BAU forecast of almost 0.25 mmtCO_2(e) at 2010 (see Chapter 7 for details of additional scenarios).
- ♦ Forests Sector: The BAU forecast for this sector indicates that the State is likely to lose nearly 260,000 mt of carbon storage as a result of land use changes. Pursuit of the full potential of the carbon sink restoration opportunities identified in the Action Plan would result in a loss of only 120,000 mt of carbon storage, less than half that of the BAU. The DCCC considers the strategies in the Action Plan to be a necessary near term response. It favors a long-term strategy to reverse the decline of the State's forest cover (see Chapter 7 for details of additional scenarios).

- A detailed emissions reduction policy strategy is included in the DCCAP (see Chapter 9) and is based on detailed analyses of a wide range of policy measures applicable to each sector of energy use. To ensure applicability to Delaware, the final selection of options was determined on the basis of cost-effectiveness. The Policy Strategy by sector emphasizes the following reforms:

  - ♦ Residential and Commercial – through the adoption of efficiency-based building codes, the use of market incentives to increase energy efficiency, and the development of programs to promote fuel switching to lower carbon fuels, Delaware can realize cost-effective reductions in GHG emissions from the state's buildings.
  - ♦ Transportation – through market incentives designed to increase consumer adoption of higher efficiency vehicles and alternatively fueled vehicles, and

through incentive programs to promote transportation conservation measures, such as ridesharing, vehicle miles traveled in Delaware can be cost-effectively reduced.

- Industrial – through the use of market incentives and greater participation in voluntary federal programs, more energy-efficient equipment and better operation and maintenance practices will be embraced by Delaware's manufacturers, increasing the State's economic competitiveness.
- Utility – through the adoption of a renewable portfolio standard and a fuel switching strategy to low-carbon fuels, overall greenhouse gas emissions can be lowered and the State can become an attractive location for the emerging "green" energy market.
- Waste Reduction – through a policy menu that includes volume-based fees, recycling/container deposit programs, and greater participation in voluntary federal programs, the volume of waste materials can be reduced along with the State's demand for raw materials. Greenhouse gas emissions from landfills would thereby decline.
- Sinks – through urban growth management, afforestation, and rural land and forest preservation policies, Delaware's carbon sink can be protected and enhanced, while offsetting a portion of Delaware's greenhouse gas emissions.

Sector analysis results for greenhouse gas emissions reduction are summarized in Table ES-1, ES-2 and ES-3. Estimations of the potential emissions reductions possible from the wastes sector and possible increases in the State's carbon sequestration capacity are summarized in Table ES-4, ES-5 and ES-6. After reporting Action Plan savings in physical units (Tables ES-1 and ES-4), these tables measure impacts from two benchmarks. Table ES-2 and ES-5 report DCCAP impacts from forecast emissions for 2010. This benchmark enables us to understand the likely level of future effort. However, since emissions in 2010 are forecasted (and, therefore, include estimation error), Action Plan impacts are also reported in terms of 1990 State levels. This benchmark has the advantage of communicating the level of effort needed against recent experience. Additionally, it points to the savings commitment needed to reverse trends in CO_2 emissions and, thereby, contribute to a climate-stable future.

Table ES-1
Summary of CO_2 Emission Reductions (mmt) for Energy Using Sectors by Policy Implementation Scenario

	1990 Baseline	BAU at 2010	Modest Commitment at 2010	Major Commitment at 2010	Full Implementation at 2010
Industry	3.2	4.2	3.8	3.5	3.1
Residential	1.8	2.0	1.8	1.6	1.4
Commercial	1.2	1.9	1.7	1.5	1.4
Transportation	4.0	4.9	4.4	3.7	3.1
Utilities	5.4	5.8	4.8	4.4	3.8
TOTAL	**15.6**	**18.8**	**16.5**	**14.7**	**12.8**

Table ES-2
Percent Reduction in CO_2 Emissions by Energy Using Sector Based on Forecast Emissions for 2010

DCCC Target Reduction for Delaware in 2010 = 23%

	Modest Commitment	Major Commitment	Full Implementation
Industry	9%	18%	27%
Residential	10%	18%	28%
Commercial	9%	18%	27%
Transportation	10%	24%	36%
Utilities	17%	24%	40%
TOTAL	**12%**	**22%**	**32%**

Table ES-3

Percent Change in CO_2 Emissions by Energy Using Sector Based on 1990 Levels

DCCC Target Reduction for Delaware Measured from 1990 Levels = 7%

	Modest Commitment	Major Commitment	Full Implementation
Industry	+18%	+9%	-3%
Residential	0%	-11%	-22%
Commercial	+41%	+25%	+16%
Transportation	+10%	-8%	-22%
Utilities	-11%	-19%	-30%
TOTAL	**+6%**	**-6%**	**-18%**

Table ES-4

Summary of CO_2 Emission Reductions (mt) for the Wastes Sector and Carbon Sequestration for the Forest Sector by Policy Implementation Scenario

	1995 Baseline	BAU at 2010	Modest Commitment at 2010	Major Commitment at 2010	Full Implementation at 2010
Wastes (CO_2 equivalent released)	156,720	249,840	234,570	210,159	181,362
Forests (CO_2 sequestered)	1,420,000	1,161,242	1,212,207	1,255,478	1,299,842

Table ES-5

Reduction in CO_2 Equivalent Releases for the Wastes Sector and Change in CO_2 Sequestered in the Forests Sector by Policy Implementation Scenario Based on Forecasts on 2010

No DCCC Target set for these Sectors

	Modest Commitment	Major Commitment	Full Potential
Wastes (CO_2 equivalent released)	6%	16%	27%
Forests (CO_2 sequestered)	4%	8%	12%

Table ES-6

Percent Change in CO_2 Emissions in the Wastes Sector and CO_2 Sequestered in the Forests Sector Based on 1995 Levels

No DCCC Target set for these Sectors

	Modest Commitment	**Major Commitment**	**Full Potential**
Wastes (CO_2 equivalent released)	+50%	+34%	+16%
Forests (CO_2 sequestered)	-15%	-11%	-8%

Policy Priorities

Policy priorities of the DCCAP are in two categories – programmatic and institutional – and are summarized below:

Policy Priorities

References

Intergovernmental Panel on Climate Change (IPCC). (1996). *Climate Change 1995: The Science of Climate Change*. Cambridge, UK: Cambridge University Press.

Interlaboratory Working Group on Energy-Efficient and Low Carbon Technologies (IWG). (1997). *Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy Efficient and Low-Carbon Technologies by 2010 and Beyond.* Washington, DC: National Technical Information Service.

INTRODUCTION

Goals of the Project

This project has the following goals:

- To identify those areas of opportunity for reducing the State's greenhouse gas emissions which use the best available information and are cost-effective for Delaware;
- To educate communities and raise their awareness of climate change and practical opportunities to reduce the State's greenhouse gas emissions;
- To establish a Delaware Climate Change Consortium representing a wide range of ideas and providing advice on the design and details of an Action Plan that serves Delaware's long-term economic, social and environmental interests; and
- To publish and disseminate an Action Plan that provides Delawareans with a practical, analytically-based strategy to contribute to regional, national and international efforts to reduce greenhouse gas emissions.

Structure of the Report

The Delaware Climate Change Project has followed a six-step process of development:

- Develop criteria via a consensus-building process among DCCC members for evaluating options, including greenhouse gas reduction potential, ecological sustainability needs, costs, and equity considerations;
- Conduct in-depth analyses of the potential greenhouse gas reduction options for each economic sector and analyze the potential for carbon sink preservation and waste minimization;
- Review, revise and refine sectoral options through workshops with Consortium members;
- Prepare an education and outreach strategy to complement GHG reduction, sink preservation, and waste minimization actions; and
- Produce a Delaware Climate Change Action incorporating the Consortium's results and findings.

The outcomes of this six-step process are captured in this report which includes an Executive Summary, an Introduction and 10 chapters. The Executive Summary highlights the major findings and recommendations of the Action Plan. The Introduction outlines the project's goal and aims, describes its background and rationale, provides a broad description of climate change science and impacts, including the potential impacts on Delaware, and outlines the link between national greenhouse gas emission reduction and that within Delaware. Chapter 1 describes the forecast model used to project economic activity, energy demand and GHG emissions under a business-as-usual scenario. The Economic, Energy and CO_2 ($EECO_2$) Forecast, developed for the Action Plan, utilizes the Delaware Econometric Model, maintained by the University of Delaware's College of Business and Economics, to develop an equation structure for projecting major economic, energy and environmental trends to 2010. Chapters 2 through 7 describe the databases and findings of in-depth analyses conducted for each sector examined for DCCAP. These sectors are: Industrial, Residential, Commercial, Transportation, Utility, and Wastes/Forests. Each of these chapters provides an overview of the greenhouse gas emission projections, the methodology used, an evaluation of the emission reduction options, and estimates of probable greenhouse gas emission effects of different state and federal policy strategies. Chapter 8 describes the education and outreach activities that would assist in emission reduction policy formulation and implementation. Chapter 9 provides the policy recommendations drawn from the sector analyses. In the final chapter, the report summarizes the major conclusions of DCCAP and suggests a course of action to refine and implement the Plan. A series of appendices provide summaries of data sources and methods used in an analysis conducted for the Plan.

Background to the Action Plan

Origins of the Delaware Climate Change Project

This project builds on policy analyses being conducted at the national level with support of the U.S. Environmental Protection Agency (USEPA), and parallel efforts at the state and local levels, including those supported by Delaware's State Energy Office (DSEO) in the Division of Facilities Management. This report comprises the second phase of climate change policy research jointly sponsored by the USEPA and DSEO, and was prepared by the Center for Energy and Environmental Policy (CEEP) at the University of Delaware in coordination with the Delaware Climate Change Consortium, a 36-member stakeholder group organized in the first phase of the project.

Under the first phase of the USEPA's State and Local Outreach Program, states compiled inventories of their greenhouse gas (GHG) emissions and sinks. These inventories mark the initial stage in building a strategic approach for a comprehensive and long-range State Action Plan to reduce emissions. Delaware's inventory, conducted by CEEP under this program, was completed in 1997 (see below).

In the second phase of the USEPA program, states formulate Action Plans for GHG emissions reduction. Funded by the USEPA and DSEO, this report is designed to assist policymakers, industry and citizen's organizations in Delaware to identify cost-effective options to mitigate GHG emissions identified in the 1997 state inventory.

This project has been conducted in a manner consistent with the USEPA's *State Guidance Document: Policy Planning to Reduce Greenhouse Gas Emissions* (USEPA 1998). Project assistance was provided by the State and Local Climate Change Program under the USEPA's Office of Policy, and by the DSEO. Several state agencies, local governments, industries and citizen's organizations throughout Delaware supported the project through the participation of their representatives over the 30 months it has taken to prepare the State's Greenhouse Gas Inventory and Climate Change Action Plan.

Delaware's Greenhouse Gas Inventory

In the first phase of the project, CEEP produced a report on Delaware's greenhouse gas sources and sinks for the Delaware State Energy Office entitled the *Delaware Greenhouse Gas Inventory* (CEEP 1995).

This analysis revealed the levels of major greenhouse gases produced by each economic sector within the state. Using a number of techniques, a set of estimates was produced by end-use sector. Inventory results established the benchmark for the modeling and analysis conducted in this study.

Rationale for the Project

Greenhouse gas emissions are associated with virtually every social and economic activity in contemporary society. As the *Delaware Greenhouse Gas Inventory* report indicates, all sectors of Delaware's economy and society are contributors to the State's emission stream. Thus, efforts to reduce greenhouse gas emissions require policy initiatives across a wide spectrum of the economy and involve communities, business and government in cooperative and innovative partnerships. Effective policy formulation to address this complex issue has significant information and analysis requirements and for policymakers to have the fullest array of options available for consideration, an extensive analytical effort is needed. In recognition of this fact, the USEPA and DSEO, have cooperated over the past two years to ensure that Delaware's citizens and organizations (private, public and non-profit) have the best information available to them on policy alternatives and their effectiveness.

Climate change represents a significant policy challenge not only because it would involve all sectors of society and would require substantial changes (especially in the way that energy and land use are used) but because decision makers must embrace long-term strategies of 20 years or more to contribute to a climate-stable future. Providing information appropriate to states facing these challenges is the primary goal of the USEPA's State and Local Outreach Program. Despite the obvious difficulties in formulating and operationalizing these policies, there are a number of inherent advantages for policy initiatives in this field.

A clear incentive for state action is to make timely decisions in the present that prevent the escalation of costs and difficulties in the future resulting from deferred decisions. Additionally, many emissions-reduction measures can be justified in their own right, such as the savings brought by increased energy efficiency and energy conservation. For example, as a result of increased efficiency and lowered costs, the competitiveness of Delaware's economy is strengthened, while other environmental and social advantages accrue, such as reducing other pollutants as well as carbon dioxide that benefit both human and ecological environmental health.

States can have the lead role in producing many policies to respond to the challenge of climate change, but effective long-term responses of state initiatives will depend on support and commitment of an informed and involved community. Energy production, transfer and consumption are the primary sources of greenhouse gas emissions. In addition, the reduction in forested land and growth in the volume of society's wastes contribute to the problem. Governments can only directly influence a proportion of the community's and industry's energy-, land-, and waste-related activities. For this reason, the scope of greenhouse gas reduction efforts needs to include all relevant sectors of Delaware's society and economy. Accordingly, this report has as its strategic focus the identification of those greenhouse gas reduction options offering the greatest potential from across the entire State—residential, commercial, industrial, transport, utilities, land use, forests and waste minimization. Because of the importance of involvement by all Delawareans in policy initiatives, this report includes an outreach and education agenda to attract actions by citizens, businesses and organizations throughout the State to meet the goals of the Action Plan.

Delaware Climate Change Consortium

In order that the diverse government, community, and business interests involved in climate change policy could be taken into account during this project, the Delaware Climate Change Consortium (DCCC) was established. In addition to workshops conducted for the full membership of the Consortium, a number of sector-specific working groups were established comprising Consortium members and CEEP project team specialists in these fields.

With the guidance and assistance of the Consortium, CEEP's project team was able to obtain access to information sources that would have been unavailable without the Consortium's assistance. Perspectives varied widely within the Consortium and this added to the scope of the issues addressed by the project. A great number of pragmatic concerns were addressed by the Consortium, in an effort to strengthen the Action Plan's relevance to policy-making and implementation.

Climate Change: Science and Impacts Issues

The Science of Global Warming and Climate Change

Evidence that weather patterns may be changing is provided by science. This century's 12 hottest years have all occurred since 1980. NOAA announced that 1998 was the hottest on record (kept for 119 years) surpassing 1997 - the next warmest year on record (NOAA 1999). Global temperatures have risen about 1.0^{o}F this century, mostly in the last 25 years.

Measurement of atmospheric gases and modeling of ocean-atmosphere systems in complex climate models have revealed that the rising global temperatures are the result of human activity. Direct atmospheric measurement, ice-core gas analysis, and tree-ring analysis have all provided the data on rising atmospheric gas concentrations. The United Nations-sponsored scientific advisory body, the Intergovernmental Panel on Climate Change (IPCC), concluded in its Second Assessment Report that the balance of evidence suggests that global warming and other changes in climate patterns are traceable to a discernible human influence on global climate (IPCC 1996a).

Coal, oil, and natural gas combustion have combined with land clearing practices and recent use of halogenated compounds to increase atmospheric concentrations of the so-called greenhouse gases of carbon dioxide, methane, nitrous oxide, ozone, chlorofluorocarbons (CFCs) and other trace gases. Changes in the gaseous composition of the atmosphere alter its radiative forcing capacity and these effects can be estimated with some precision. Rising atmospheric levels of greenhouse gases have intensified the greenhouse effect, increasing the amount of heat retained by the earth. Consequently, global temperatures have increased, leading to a change in global climate. Atmospheric carbon dioxide is now 30% greater than in pre-industrial times, methane has doubled, and nitrous oxide has risen by 15%.

Greenhouse gases released to the atmosphere have long residence times. For example, a molecule of carbon dioxide (CO_2) - the major greenhouse gas – can reside in the atmosphere for 100 – 200 years. As a result, achieving stabilization of the concentrations of these gases in the atmosphere requires a prolonged period of reduced emissions. Today's greenhouse gas releases will be influencing climate well into the next century. Some indication of the magnitude of the problem is shown by the IPCC calculation that stabilization of atmospheric carbon levels at twice the pre-industrial era level would require a 60% reduction in global emissions (IPCC 1996a). In this context, the popular goal of reducing carbon emissions to their 1990 levels is a modest, but important, step toward a much higher target.

Because industrialized nations are the source of most GHG emissions, current international negotiations have focused attention on reductions by these countries. In 1996, industrialized nations released almost 60% of the global CO_2 emissions (USDOE 1999). As population growth continues in developing nations, their greenhouse gas emissions are likely to increase in the future. IPCC has projected that by 2025 the developing nations will account for 45% of the forecast global emissions of 38.5 billion $mtCO_2$ (IPCC 1992). Their share will continue to increase, but industrialized nations will still account for the bulk of global emissions through mid-century. [1]

[1] Because developing countries currently contribute less than one-fifth of global emissions of greenhouse emissions at this time, and will be the source of only one-third of global emissions well into the next century, international negotiations to avert climate change have centered initially on activities to be undertaken by the industrialized countries of North America, Europe, Japan, Australia and New Zealand.

Modeling of climate change, using a range of greenhouse gas emission forecasts in general circulation models, suggests that global average surface temperature increases could be 1.8° to 6.3°F by the year 2100 if existing trends continue (IPCC 1996a). Such a rate of temperature increase exceeds that of at least the last 10,000 years. In comparison to daily temperature fluctuations, small changes in global average temperature can be mistakenly regarded as constituting only minor change, but the public should be aware that global changes of a few degrees have been associated with significant effects—the last Ice Age was only 5.0° to 10.0°F cooler than today.

Impacts of Climate Change

Aspects of human health and welfare, and the viability of a range of socio-economic and ecosystems, will be influenced by climate change. Agriculture, water resources, forestry and fisheries are considered vulnerable to climate change (IPCC 1996b). Climate change will pose additional stresses to ecosystems, such as tropical rainforests, that are already deleteriously influenced by human activity. Similarly, those nations and regions suffering from socioeconomic disadvantage will exhibit greater sensitivity to climate-induced disruptions. Certain ecological systems may suffer significant disruptions, with a corresponding increase in the rate of extinctions and loss of natural habitat for many terrestrial and coastal species.

Climate change is likely to bring greater precipitation extremes and induce extreme weather events, such as heat waves, floods, and droughts. Some researchers believe that these changes are already occurring. That recent increases in temperature and other associated climate changes, such as increased extreme weather events, are entirely due to natural climate fluctuations is now considered extremely unlikely.

Climate change effects on natural systems are potentially damaging, with high environmental costs forecast for coastal areas and islands. Sea-level rise is expected to be 15 to 94 cm. (6 to 37 inches) higher by 2100, with serious implications for flooding, inundation and storm surge. Shoreward erosion, saltwater intrusions, altered tidal ranges, nutrient transport disruption, and losses of coastal habitat exemplify potential coastal damage.

Agriculture may benefit from yields boosted by the atmospheric carbon fertilization effect, with regional changes in production patterns: however, changes in pests and diseases may counter these gains. Water supply may be affected by alterations to the availability and distribution of surface and ground waters. For example, flooding and drought frequency may alter water supplies and quality throughout coastal areas. Areas already vulnerable to quality or quantity problems in water supply systems are vulnerable to diminution of supplies.

Finally, human health is likely to be affected, although developing nations will suffer more extensively than the United States. Vector-borne diseases (such as malaria, dengue fever, and viral encephalitides) will probably have their ranges extended. Urban respiratory illness, heat stress, and allergenic disorders are likely to increase.

Delaware and Climate Change: Vulnerabilities and Potential Impacts

Delaware is vulnerable to climate change in several ways. A USEPA fact sheet entitled "Climate Change and Delaware" (USEPA 1997), together with IPCC reports and other research literature, can be used to develop a general profile of possible vulnerabilities and impacts of climate change on Delaware and the mid-Atlantic region. IPCC climate modeling of future temperature change for Delaware indicates that by 2100, temperatures in spring could be 3.0^{o}F higher and temperatures in other seasons could be 4.0^{o}F higher (USEPA 1997). Precipitation could increase by 15 to 40% in all seasons (USEPA 1997). There would be an increase in the number of high rain and snow days and the number of extremely hot days in summer would also likely increase.

Currently, ground-level ozone concentrations across Delaware exceed national standards for human health set by the USEPA. Wilmington and the northern region are classified as non-attainment areas, due to the frequent exceedance of USEPA ozone standards. An increase in air temperature associated with climate change would increase ozone in the region.

Climate change research has directed attention to potential impacts on human health. Insects that carry disease may respond to climate change with extended ranges and increased infectivity, spreading the incidence of malaria, dengue fever, and Lyme disease. Mosquitoes in the Delaware area can carry malaria and equine encephalitis, while Lyme disease already occurs in the state. In the marine environment where people are in contact with fresh and salt water bodies, primarily through recreation, there might also be climate-related health impacts. Warmer seas could create the conditions for an increase in the spread and duration of algal blooms; brown algal tides and toxic algal blooms are already a feature of the Atlantic waters.

Sea level rise is one of the major impacts of global warming and can be forecast with greater certainty than many other aspects of climate change. Obviously, it is a prospect of some concern to the State of Delaware. With some 381 miles of coastline, Delaware has a variety of inland bays, wetlands and estuaries, barrier beaches and islands, as well as marshlands. These resources provide considerable value through residential and commercial land uses, recreation and tourism, and resource-based activities, such as fishing. Many of these activities could be disrupted by climate change-induced increases in sea level. Inundation of low-elevation coastal areas, beach erosion, contamination of drinking water and damage to roads, causeways and bridges could occur as a result of sea level rise. During the last century, sea level rise has been measured at about 31 cm (12 inches) at Lewes, and could rise by a further 59 cm (23 inches) by the year 2100 (USEPA 1997). Delaware's inland bays are already eroding, and sea level rise would extend this process. Salinity levels in the Delaware River and Bay could be altered by these rises as well.

Water supplies for municipal and industrial purposes in Delaware draw heavily on groundwater sources. Increases in summer evaporation under climate change could reduce aquifer recharge, although such losses may be offset by any increases in winter precipitation. Increased migration of pollutants in groundwater as a result of altered infiltration may result from increased inflows into aquifers. Although agriculture is influenced by climatic conditions and water supply, a range of studies of U.S. agriculture suggest that while there may be regional shifts in production, it is likely that aggregate production levels would not fall as a result of climate change. Grain yields in Delaware could be improved by up to 24% or fall by up to 32%, depending upon the particular consequences of climate change in the region (USEPA 1997). Such variability in impact may adversely affect the economies of agriculture in Delaware.

Forecasts of future impacts of climate change on the State's forests indicate that the extent and density of forests could decline by up to 10 to 20% (USEPA 1997). Changes in species composition are likely; the northern hardwood-dominated forests would be replaced by mixed forests, with southern pines and oaks. Maritime forests are vulnerable to increased storm damage; estuarine environments are vulnerable to changes in hydrology that would be associated with changes to upland forest hydrology. Many of the State's rare species of flora and fauna are associated with wetland habitats, as well as many of its largest populations of shorebirds. These species are vulnerable to the potential coastal changes described above.

International and national policy responses

UN Framework Convention on Climate Change

Having been opened for signature at the 1992 Conference of the Parties in Rio de Janeiro (the so-called 'Earth Summit'), the UN Framework Convention on Climate Change (FCCC) entered into force in March 1994. There are now over 160 nations that have signed the FCCC, including the United States. It is the FCCC's objective to stabilize atmospheric greenhouse gas concentrations at levels that would prevent dangerous anthropogenic interference with the climate system. There were no binding requirements to reduce greenhouse gas emissions in the original Convention. Developed nations were asked to voluntarily limit emissions by formulating policies that would stabilize them by the year 2000 at 1990 levels. However, voluntary agreements have not succeeded in reducing emissions.

A protocol to the FCCC was subsequently developed at the Conference of the Parties meeting held in Kyoto, in December 1997. At this meeting, a set of binding targets and timetables were negotiated. Under the Kyoto Protocol, industrialized nations committed themselves to specific and binding reduction targets for six greenhouse gases. Developed countries under this agreement are required to reduce their collective emissions by an average of 5% below the 1990 baseline by 2008-2012. For the United States, the reduction target is 7% from the 1990 level averaged in the period of 2008-2012. This Protocol was opened for signatures in March 1998.

Under the Kyoto Protocol, countries are able to adopt a comprehensive approach by including all greenhouse gases in their national inventories and also make allowances for sink enhancement activities. Emission trading mechanisms are to be developed and may slow the burden on developed countries, including the United States, in meeting the Kyoto Protocol's targets. Approaches to the emissions trading and joint implementation (which involves project-specific partnerships among industrialized nations to mitigate GHG emissions) were further developed at the FCCC Conferences of the Parties in November 1998 in Buenos Aires and again in November 1999 in Bonn.

Senate opposition to the Kyoto Protocol in its present form has been expressed in a non-binding resolution. Since the U.S. Senate must ratify all treaties for the U.S. to officially be a party to them, the resolution has political significance. The Senate's objection is that large developing countries, such as China and India, are not expected to limit their GHG emissions during the 2008-2012 budget period. International efforts are underway to address this objection. It should be noted, though, that the average CO_2 emissions per U.S. citizen is over 19 tons per year (by molecular weight), while China is less than 2 tons per citizen, and India averages less than 1 ton per citizen (Byrne et al, 1998). Still, growth in per capita emissions is expected for these counties and high rates of per capita emissions from China and India are expected by the middle of next century.

Eventually, emissions from these countries will have to be addressed, if a climate-stable future is to be realized.

Implications for the United States and the National Policy Setting

There are considerable implications for the United States in the climate change issue. Although its proportion of the world's population is around 5%, its share of the total greenhouse gases emitted annually amounts to 25%. Calculated on a per capita basis, the United States emits twice was much as Japan and Germany, nine times that of China and about nineteen times that of India. Emissions categorized by U.S. economic sector show the problem to be distributed broadly; in 1998 CO_2 emissions for transport and industry accounted for about a third each, with the residential sector contributing a little under twenty per cent and the commercial sector, about 16% (EIA 1999).

National greenhouse emissions have increased since 1991, according to the Energy Information Administration (EIA), which considers the rise to be the consequence of strong national economic performance and the high cost of natural gas (which has discouraged the switch from coal); although 1998 was only slightly above the 1997 level (EIA 1999). At the time of the 1997 Kyoto Conference of Parties, it was estimated that the U.S. was 13% above the FCCC emission target of stabilization at 1990 emission levels. Earlier Presidential pledges to reach the target by the year 2000 had failed to be realized, indicative of the difficulty of achieving changes of this magnitude. However, emissions would have been greater than present levels if the National Climate Plan Action Plan had not been enacted in 1993.

Responding to the problems of climate change, the U.S. has launched an array of policy responses at the national, state and local government levels. National climate change policies have taken several forms, of which the most important is the 1993 National Climate Change Action Plan (NCCAP – see Office of the President, 1993). This overarching Plan contains 50 programs and 5,000 partners in buildings, energy, forestry, transport, utilities, and several industries.

In June 1997, President Clinton announced four additional climate change-related environment initiatives: the Million Solar Roofs Initiative; a Developing Country Climate Change Initiative; Overseas Private Investment Corporation's Environment Program; and the Technology Challenge. Considerable research and policy development is being devoted to climate change and related issues. Under the U.S. Global Change Research Program in fiscal 1997, total expenditure was $1.8 billion.

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CHAPTER 1
ECONOMIC, ENERGY, AND CO_2 EMISSION FORECASTS FOR DELAWARE

In this chapter, the method used to derive forecasts for Delaware's economic growth, energy demand, and CO_2 emissions to the year 2010 is described. These forecasts quantify the likely growth in the state's economy, energy consumption, and CO_2 emissions by 2010 under the assumption that no policy interventions to alter current patterns are adopted. The objective is to forecast emissions under business-as-usual assumptions in order to allow the measurement of possible effects of alternative emission reduction strategies.

The Delaware Econometric Model (DEM), maintained by the College of Business and Economics of the University of Delaware, was used as a reference framework and source for key variables. The DEM is a simulation model that treats the Delaware economy as consisting of 13 sectors and uses 47 variables to forecast state income growth. The DEM was used to project state economic growth and the projected growth was then used as an input to, in turn, forecast energy demand and associated CO_2 emissions.

Sector-specific regression equations predicting energy demand were devised for the residential, commercial, industrial, transport and utility sectors. These equations express the relationship between energy demand and key independent variables, including income, average energy price, and energy intensity. Estimates of the number of future households and population in Delaware were provided by the University of Delaware's Center for Applied Demography and Survey Research. The result is a forecast of state energy demand by sector, which was then converted to sector-specific CO_2 emission projections using established conversion factors.[1] This forecast is termed the Economic, Energy, and CO_2 (or $EECO_2$) forecast.

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[1] The forecast used for this report does not include greenhouse gas emissions from agricultural sources, e.g., bovine methane emissions.

Data for most economic variables derive from the DEM database and cover the period 1975-1995 (although in some cases a shorter span of records had to be used). An exponential smoothing technique was applied to regressions used for the $EECO_2$ forecast to project sector values through 2010.

Analysis of historical fuel mix trends for each sector was used as the basis to forecast future fuel mixes by sector. These fuel mix forecasts were, in turn, employed to project CO_2 emissions for the period 1996-2010 using standard conversion factors.[2] Summation across individual sectors produced the total forecast energy consumption and CO_2 emissions for the state.

Delaware Energy Demand Model

$$Y = {}_1 + {}_1X_1 + {}_2X_2 + {}_nX_n$$

Residential Sector

$$\ell nD = 2.43 - 0.11\ell nP + 0.17\ell nY + 5462I$$

(14.7) (-2.7) (32.7) (21.7)

$R^2 = .99$

Commercial Sector

$$\ell nD = 6.35 - 0.45\ell nP + 0.49\ell nY + 0.82\ell nI$$

(9.32) (-7.21) (10.79) (15.32)

$R^2 = .95$

Industrial Sector

$$\ell nD = 2.10 - 0.24\ell nP(-1) + 1.37\ell nN + 0.69\ell nI$$

(1.52) (-2.76) (9.31) (6.96)

$R^2 = .95$

Transportation Sector

$$\ell nD = 3.74 - 0.27\ell nP + 0.34\ell nI$$

(17.2) (-6.62) (-5.94)

$R^2 = .89$

Note: D = Energy demand, P = Energy price, I = Energy intensity,
Y = Delaware state income, and N = GDP of U.S.

In the residential sector, annual energy demand between 1996 and 2010 was forecast with an equation derived from historical trands among the combined variables of energy price, income, and energy intensity. Data from 1980 to 1995 were used to

[2] Specifically, conversion factors established by the Energy Information Administration of the U.S. DOE (see www.eia.doe.gov) were applied in the $EECO_2$ model

establish the historical relationships. For the commercial energy sector, energy demand was forecast by an equation using comparable variables to those for the residential sector forecast. Data for this sector were gathered for the period 1978-1995. In the industrial sector, energy demand was forecast by an equation involving the comparable variables of energy price, energy intensity, and state GDP that were applicable to this sector. Data from 1975-1995 were used to build the industrial sector forecast. For the transportation sector, energy demand was forecast by an equation with the independent variables of energy price and energy intensity. Data from 1975-1995 were used to anchor this sector's forecast.

Electric Utility Sector

Residential

$$\ell nD_{res} = \underset{(-4.67)}{-34.59} - \underset{(-1.77)}{0.34\ell nP_{res}} + \underset{(5.44)}{3.49\ell nH_{res}} + \underset{(4.55)}{0.38\ell nI_{res}}$$

$R^2 = .98$

Industrial

$$\ell nD_{ind} = \underset{(1.33)}{2.29} - \underset{(-4.14)}{0.31\ell nP_{ind}} + \underset{(3.69)}{0.39\ell nI_{ind}} + \underset{(3.32)}{0.6\ell nRGDP_{ind}} + \underset{(2.47)}{0.32\ell nD_{ind}(-1)}$$

$R^2 = .97$

Commercial

$$\ell nD_{com} = \underset{(0.58)}{3.57} - \underset{(-0.98)}{0.21\ell nP_{com}} + \underset{(2.35)}{0.05\ell nPI_{com}} + \underset{(2.55)}{0.24\ell nI_{com}} + \underset{(1.47)}{0.74\ell nD_{com}(-1)}$$

$R^2 = .98$

Total Electrical Consumption

$$Total_{elec} = D_{res} + D_{ind} + D_{com}$$

Electricity Losses

$$Loss_{elec} = Total_{fuel} - Total_{elec}$$

Note: H = number of households, D = electricity demand, P = electricity price, I = electricity intensity, Y = income, GDP = national GDP, RGDP = state GDP, and PI = Delaware Personal Income

Two special features must be taken into account when modeling the electricity sector: (1.) the existence of energy losses in the conversion of a fuel to end-use electricity; and (2.) the impact of end-use demand on the sector's energy losses. As to the first, the electric utility sector both consumes energy as fuel and produces energy as electricity. The difference between its fuel consumption and the generation, transmission, and distribution of electricity by the sector equals the losses within the system. Forecasts of energy consumption and energy supply by the electricity sector must account for these losses. With respect to the sector's second special feature, electricity savings made in other sectors impact total electricity demand, which, in turn affects energy losses by the sector. It is necessary for the methodology used to estimate CO_2 reductions to take account of this fact. The factors influencing end-use electricity demand are indicated by the regression equations above. The sum of the projected electricity demands of residential, industrial and commercial users provides the forecast of electricity demand in Delaware. Multiplying this forecast of state electricity demand by the loss rate associated with the electricity generation, transmission and distribution facilities in Delaware provides the net energy demand of the sector, which can then be used to forecast its CO_2 emissions (in conjunction with the forecasted fuel mix for the sector).

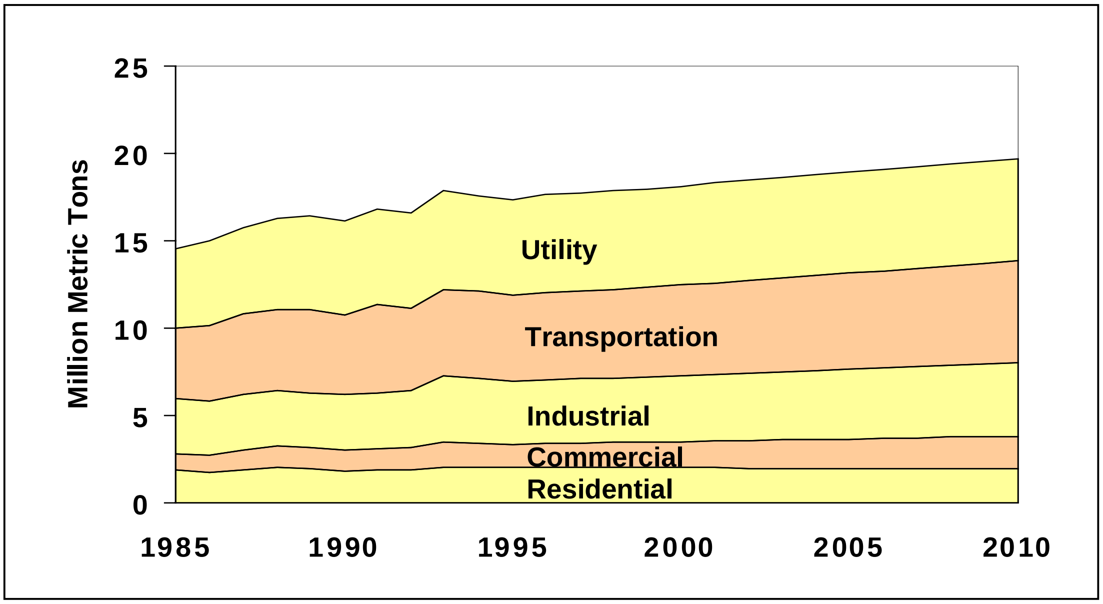
Electricity consumption to 2010 was estimated for each sector based on 1985-1995 data. Electricity losses were attributed to the electric utility sector based on sector demand. Because Delaware's expected generation capacity through 2010 is sufficient to meet forecast demand, no net electricity imports or exports are foreseen.[3] Energy consumption within the electric utility sector was converted to CO_2 emissions on the basis of the forecasted fuel mix for 2010 (obtained from the state's utility with generation facilities located in Delaware).

[3] There is a potential methodological problem associated with USEPA's approach to counting CO_2 emissions from this sector. USEPA limits each state to counting CO_2 emissions from generation within its borders. If a state is a net importer of electricity, this limit would be less than the emissions from electricity consumption in the state. Further, such a limit could affect the energy efficiency potential that could be investigated for electricity importers. CO_2 reductions from efficiency gains beyond an amount equal to the growth in CO_2 emissions from in-state generation would have to be disregarded under the USEPA's methodology. The reverse problem occurs with states that are electricity exporters. While USEPA's approach prevents double-counting between state and national estimates of CO_2 emissions, it could affect BAU forecasts and estimates of energy-efficiency potential in importing or exporting states. Fortunately, Delaware is projected to be self-sufficient in electricity supply through 2010.

Having obtained forecasts of non-electrical energy demand, electrical energy demand and losses in the electricity utility system, total energy demand to the year 2010 was calculated. These data formed the basis for the calculation of the forecast emissions for the state to the year 2010, as presented in Figure 1-1.

Figure 1-1

BAU Forecast of CO_2 Emissions in Delaware through 2010



Reducing Greenhouse Gas Emissions in Delaware: Goals

The Consortium has adopted a target for greenhouse gas emission reduction that is equivalent to that established for the U.S. under the Kyoto Protocol. As noted above (see the Introduction to this Action Plan), the U.S. target is to reduce emissions to 7% below those of 1990 during the target years of 2008-2012, although the United States has not ratified the Kyoto Protocol. Until the U.S. Senate has ratified the Kyoto Protocol, its target has no standing in U.S. national policy. However, the Kyoto Protocol target offers a reasonable basis for analysis at this time.

As is shown in Chapters 2-7, the Consortium was able to identify cost-effective CO_2 emission reduction strategies approaching the goal of a 7% reduction below 1990 levels. The target adopted by DCCC is a "soft target" for Delaware. That is, when cost-effective CO_2 emission reduction strategies were estimated to be available in a sector, the target could be met; when such savings were not found to be available, the target would not be met.

Examination of plans developed by other states' for USEPA's State and Local Climate Change Program reveals that the 1990 benchmark is commonly adopted especially for State reports produced or underway in the post-Kyoto period.

With a 1990 emissions baseline of 15.6 mmtCO_2, the DCCC's emissions goal translates to a reduction in State emissions to 14.5 mmtCO_2 in 2010. CEEP analyzed the likely trend of emissions in the absence of any intervening policy initiatives and arrived at a BAU forecast of state emissions reaching 18.8 mmtCO_2 by the year 2010 (Table 1-1). Accordingly, Delaware would need to reduce its greenhouse gas emissions by 23% below the BAU forecast for 2010 to meet the DCCC's target.

Table 1-1

BAU Energy and CO_2 Emission Distributions by Sector in 2010

	Energy (trillion Btus)	CO_2 Emissions (mmt)
Industrial	105.0	4.22
Residential	33.4	1.95
Commercial	28.9	1.86
Transportation	68.6	4.92
Utilities	85.0	5.81
TOTAL	**320.9**	**18.76**

CHAPTER 2
INDUSTRIAL SECTOR
CO_2 EMISSION REDUCTION STRATEGY

Key Findings

Figure 2-1

Industrial Sector CO_2 Emission Projections Through 2010

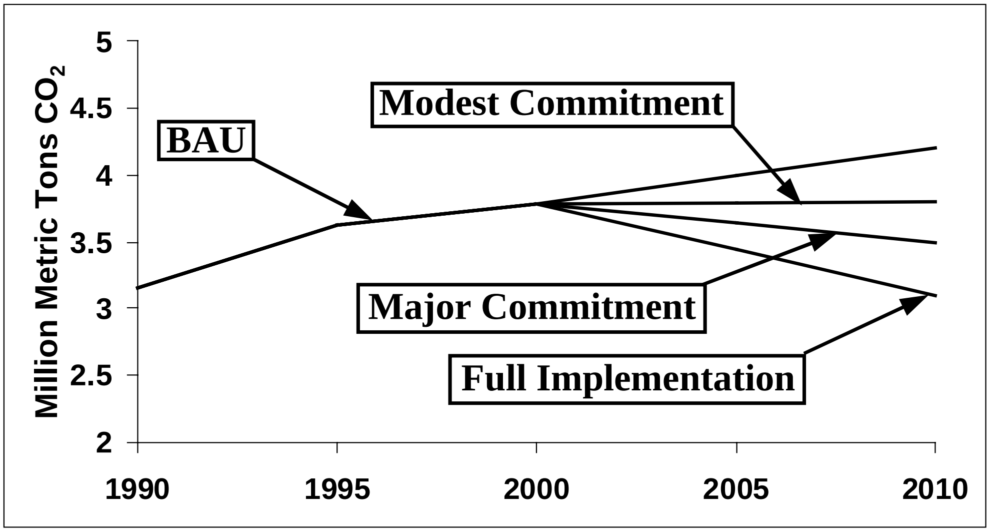


Table 2-1

Summary of Scenario Analyses to Reduce CO_2

in Delaware's Industrial Sector

	Energy Use (trillion Btus)	GHG emissions ($mmtCO_2$)*
1990	75.5	3.2
2010 BAU	105.0	4.2
Implementation Scenarios		
Modest Commitment (35%)	99.3	3.8 (9%)
Major Commitment (65%)	94.4	3.5 (18%)
Full Implementation (100%)	88.6	3.1 (27%)

* Percentage reductions from forecast emission level are indicated in parenthesis

Industrial sector energy use is forecast to grow by 40% between 1990 and 2010 under the BAU scenario, while CO_2 emissions are expected to increase by nearly 35%. This is to be contrasted with the DCCC's goal of a state-wide reduction in CO_2 emissions of 7% below 1990 levels by 2010. To consider alternatives to this growth, energy efficiency measures were evaluated that have a payback period of less than four years. This resulted in a list of 170 technology options (see below for details) with an average payback period of one year. Assuming that only 35% of these low-cost, fast payback emission reduction measures are implemented (Modest Commitment scenario),[1] it is estimated that the sector's emissions would be 9% lower by 2010 (Figure 2-1). Adopting policies consistent with the Major Commitment scenario[2] would yield 18% lower emissions by the target year. Full implementation of the identified measures would result in an emissions reduction of 27%, which exceeds the emission reduction target of 23%, adopted by the Consortium for all end-use sectors.

Background

Based on 1995 census information, Delaware's industrial sector (which includes construction) is comprised of more than 3,300 establishments, employing 20% of Delaware's working population. Of those establishments, almost 1,100 are manufacturers and employ almost 80% of Delaware's industrial employees (approximately 70,000 people), making them the largest source of State income and the third largest employer, following services and trade.

Industrial energy use is typically concentrated in four major manufacturing groups: petroleum and coal products; chemical and allied products; paper and allied products; and the primary metal industry (EIA 1997b: 5). The chemicals and petroleum industries alone account for over half of the energy consumed by US manufacturers (EIA 1997a: 2). Approximately 12% of Delaware's industrial employees are employed in these energy-intensive industries.

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[1] Each scenario is depicted in Figure 2-1. The Modest Commitment Scenario will require some state and federal policy support for its implementation, but less than its Major Commitment counterpart. See Chapter 9 for general outline of policy needs.

[2] Successful implementation of this scenario is expected to require significant state and federal policy support. See Chapter 9 for a general outline of policy needs.

Motor drives, boilers, and air compressors have been identified by a major national study as targets for cost-effective energy use reduction (IWG 1997). Several U.S. studies conclude that electric motors consume approximately two-thirds of electricity across all sectors, with the industrial sector accounting for between 26 and 30% of the total (STAPPA/ALAPCO 1998). The industrial sector also uses a substantial amount of steam. According to the Council of Industrial Boiler Owners, of the 16.55 quadrillion Btus consumed by U.S. manufacturers in 1995 for heat, power, and electricity generation, 9.34 quadrillion Btus of fuel were burned to produce steam, or approximately 56% of energy used by manufacturers (Jones and Jaber 1998). Each year U.S. industry releases over 700 mmtCO_2 while producing steam (EIA 1993).[3] These emissions represent over 40% of all U.S. industrial emissions of carbon dioxide and over 13% of total U.S. emissions. Demand for steam is projected to increase 20% in 5 major industries by 2015 (compared with 1990 levels), with demand in food processing and chemicals being even greater (Gas Research Institute 1996). If all U.S. manufacturers improved the efficiency of their steam systems by 30%, they would reduce CO_2 emissions by approximately 150 mmtCO_2 (EIA 1993). Many of the strategies investigated for reducing Delaware's industrial sector emissions are related to steam production and distribution.

Additionally, space conditioning and lighting are also seen as targets for significant energy savings. Through the development and application of more efficient lighting technologies and design, lighting energy use for industrial lighting could be reduced by over 50% by 2020, with equal or improved health, comfort, and productivity (IWG 1997). These technologies were therefore targeted, as well, in the scenario analyses of Delaware's industrial sector.

Sources and Trends of Emissions

Between 1986 and 1996, Delaware's industrial energy use has grown from 66 trillion Btus to 85 trillion Btus, an increase of 28%. Over the last decade, there is a trend

[3] EIA calculations of emissions were converted from units of carbon to units of CO_2.

of increasing energy use despite small annual fluctuations. Carbon dioxide emissions have also increased, although in recent years the emission benefits of switching to more efficient and cleaner fuels has become evident. Industrial sector CO_2 emissions grew by only 15% between 1986 and 1996. Electricity use has risen since 1986, extending a long running trend for the sector. There is a long-term trend of declining coal use, but in the period 1986-1996, there is considerable interannual variability. Annual natural gas use is in the range of 15-20 trillion Btus between 1986-1996 (see Appendix A).

Projections

It is projected that by 2010, under the BAU scenario, energy consumption in Delaware's industrial sector will increase from 75.5 trillion Btus in 1990 to 105 trillion Btus, a rise of 39%. This represents an annual average increase of 1.7% in energy consumption. Carbon dioxide emissions are projected to rise to 4.2 mmt by 2010 under the BAU scenario, which is an overall increase of 34%. The slightly slower increase in CO_2 emissions is due to the rising share of natural gas in the industrial sector's fuel mix (see Appendix A).

Based on EIA data, the industrial sector accounted for 31% of Delaware's energy consumption and emitted 20% of its CO_2 emissions in 1990. The BAU forecast for emissions and energy use in 2010 anticipates that the industrial sector will slightly increase to a 32% share of the state's energy use and increase its share of CO_2 emissions to 22%. For comparison, the national average for industrial sector contributions to total greenhouse gas emissions was 27% in 1995.

Methodology

The measures selected to achieve reductions in CO_2 emissions were based on recommendations from industrial assessments sponsored by the U.S. Department of Energy's Office of Industrial Technologies and the university-based Industrial Assessment Center program (IAC). The IAC coordinates assessments throughout the country using established engineering measurement methods as the basis for recommendations to facility managers. These recommendations focus on potential savings from energy efficiency improvements, waste minimization and pollution prevention, and productivity improvements (USDOE 1998).

In conjunction with its industrial assessment work, the IAC maintains a database of more than 8,000 manufacturing plants with almost 58,000 separate technology and maintenance recommendations. The database contains detailed data, available by Standard Industrial Classification (SIC), fuel type, base plant energy consumption, and recommended energy-efficiency improvements. Projected energy savings, cost savings, implementation cost, and simple payback are provided for each recommended measure (USDOE 1998).[4]

For our analysis, data matching the State's industrial profile were selected from the national database. Assessments were screened by state (Delaware, Maryland, Virginia, New Jersey, and Pennsylvania only) and two-digit SIC codes of major Delaware manufacturers (accounting for 58% of Delaware industrial employment) to identify the measures most applicable to Delaware. This initial screening effort resulted in a database containing 1,358 recommendations. These were further screened to include only energy efficiency measures. Within SIC codes, duplicate energy efficiency measures were eliminated by selecting the typical case. Measures with payback periods exceeding 4 years were eliminated because they were regarded as too expensive.

This second screening of the IAC database yielded 170 non-duplicate recommendations for 55 four-digit SIC categories of industrial establishments. This regional database represents plant facilities with 1,000 or fewer employees.[5] Potential

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[4] As the *Industrial Assessment Database* is derived from free audits of industrial enterprises, it does not represent a random sample of firms. However, the sample size is large and covers a wide range of technology upgrades. CEEP researchers, in consultation with the IAC, concluded that the database reasonably characterizes the range of technologies for upgrades of typically sized industrial plants, and provides a plausible basis for estimating the energy efficiency potential for Delaware's industrial sector. While audits in the database do not include plants with 1,000 or more employees, CEEP expects little bias in sector estimates since large-scale facilities have traditionally been more energy efficient than typical plants (due to there need to be more competitive in international markets).

[5] As noted above, large industrial plants are not assessed under the IAC guidelines.

measures, such as cogeneration and fuel switching, were not investigated. However, it is possible to subsequently consider these measures to satisfy the goals of the Action Plan. Detailed information on the methodology used to estimate savings for this sector is provided in Appendix B.

Analysis of Options

The 170 measures selected to achieve reductions in CO_2 emissions in Delaware's industrial sector include improvements in heat recovery and containment, space conditioning, boilers steam, air compressors, motors, and lighting. Table 2-2 lists the number of measures by type that were used in the industrial sector analysis. The energy and CO_2 impacts of selected examples of these measures and their economic payback periods are provided in Tables 2-3 through 2-8.

Table 2-2

Types of Measures to Save Energy and Reduce CO_2 Emissions in Delaware's Industrial Sector

Types of Measures	Number of Measures	Percentage (%)
Boilers and Steam Systems	50	29
Heat Recovery & Containment	39	23
Space Conditioning	35	20
Air Compressors	20	12
Motors	18	11
Lighting	9	5

Table 2-3

Space Conditioning Measures to Save Energy and Reduce CO_2 Emissions in Delaware's Industrial Sector

Examples of Space Conditioning Measures	Implement. Cost ($)	Energy Savings ($)	Payback Period (years)	Energy Saved (Btus)	mtCO_2 Mitigated
Improve Interior Circulation with Destratification Fans	5,220	5,303	0.98	11,752	618
Use Properly Designed and Sized HVAC Equipment	7,010	5,240	1.34	118,375	10,243
Use Computer Programs to Optimize HVAC Performance	12,000	20,807	0.58	26,026	2,290
Summary Data					
Average Measure	7,631	12,498	0.88	40,800	2,910
Subtotal	267,077	437,444	NA	1,427,993	101,834
Share Of Total	18.9%	21.8%	NA	36.4%	37.0%

Changes in space conditioning can be as inexpensive as insulating air conditioning ducts or as complex as redesigning heating, ventilation and air conditioning systems (HVAC), as indicated in the range of measures shown in Table 2-3. Annual energy savings from all measures in this category have the potential to reduce CO_2 emissions by an amount equal to 37% of the sector's target (See Chapter 1 for the method used to set sector targets). The database included 35 measures to improve energy efficiency. The average payback period for space conditioning is less than one year, even though some measures had high implementation costs.

Table 2-4

Boiler and Steam Systems Measures to Save Energy and Reduce CO_2 Emissions in Delaware's Industrial Sector

Examples of Boiler and Steam Measures	Implement. Cost ($)	Energy Savings ($)	Payback Period (years)	Energy Saved (Btus)	mtCO_2 Mitigated
Repair Leaks in Steam Lines and Valves	325	6,284	0.05	26,803	1,966
Analyze Flue Gas for Proper Air/Fuel Ratio	500	2,009	0.25	1,318	70
Insulate Steam Pipes	8,003	9,848	0.81	1,584	84
Preheat Boiler Intake Air Using Hot Flue Gas	11,600	4,636	2.50	2,240	119
Summary Data					
Average Measure	2,318	8,573	0.46	21,285	1,309
Subtotal	115,915	428,670	NA	1,064,269	65,441
Share Of Total	8.2%	21.3%	NA	27.1%	23.8%

The fifty measures examined in relation to boiler and steam systems account for almost 24% of the reduction in CO_2 emissions identified in the Action Plan for the industrial sector (Table 2-4). Annual energy savings in steam-related systems can have a large impact on CO_2 emission from this sector, as noted earlier. Many of these are comparatively low cost measures. This results in a high ratio of CO_2 mitigated to implementation cost (almost 4:1 - see Table 2-4) and short payback periods (on average, less than 0.5 years for the typical Delaware case).

Table 2-5

Heat Recovery and Containment Measures to Save Energy and Decrease CO_2 Emissions in Delaware's Industrial Sector

Examples of Heat Recovery and Containment Measures	Implement. Cost ($)	Energy Savings ($)	Payback Period (years)	Energy Saved (Btus)	mtCO_2 Mitigated
Use Insulated Doors on Furnace Openings to Reduce Heat Loss	522	6,458	0.08	404	21
Recover Boiler Room Waste Heat	1,360	11,475	0.12	15,920	847
Install Heat Exchangers	5,550	18,070	0.31	72,205	3,843
Insulate Rotating Kilns	16,700	21,127	0.79	1,040	55
Summary Data					
Average Measure	8,895	13,537	0.80	23,574	1,585
Subtotal	337,991	514,417	NA	895,805	60,215
Share of Total	23.9%	25.6%	NA	22.8%	21.9%

Preventing heat loss and improving energy-efficiency involving heat production and use is another important means to reduce industrial energy use and CO_2 emissions. Almost 22% of the reduction in CO_2 emissions identified in the Action Plan for the industrial sector are expected from the 38 measures in this category. While the implementation costs of some measures are high, the average payback period for this category remains attractive – less than one year (Table 2-5).

Table 2-6

Compressed Air System Measures to Save Energy and Reduce CO_2 Emissions in Delaware's Industrial Sector

Examples of Compressed Air Measures	Implement. Cost ($)	Energy Savings ($)	Payback Period (years)	Energy Saved (Btus)	$mtCO_2$ Mitigated
Repair Leaks in Compressed Air Lines	800	4,909	0.16	69	6
Replace Compressed-Air Wipers with Sponge Rollers	3,000	5,441	0.55	4,502	396
Install Higher Efficiency Compressors	36,000	38,326	0.94	14,822	1,304
Summary Data					
Average Measure	3,364	10,017	0.21	14,768	1,300
Subtotal	67,286	200,335	NA	295,366	25,992
Share Of Total	4.8%	10.0%	NA	7.5%	9.5%

Activities involving compressed air can be found in a vast array of enterprises and therefore comprise a varied number of measures. Twenty energy-saving strategies with an average payback period of less than one year were used in scenario analyses of the industrial sector. Although the total contribution to the industrial sector's overall energy savings is 10%, the relatively low average cost for implementation and average payback period (0.21 years – see Table 2-6) makes improvements in compressed air efficiency a sound investment.

Table 2-7

Motors System Measures to Save Energy and Reduce CO_2 Emissions in Delaware's Industrial Sector

Examples of Motor Measures	Implement. Cost ($)	Energy Savings ($)	Payback Period (years)	Energy Saved (Btus)	$mtCO_2$ Mitigated
Replace Standard V-Belts with Cogged V-Belts	955	5,663	0.17	12	1
Use Most Efficient Type Of Electric Motors	44,360	35,736	1.24	23,247	2,046
Install Variable Frequency Drives On Evaporative Condenser Fan	66,206	26,349	2.51	28,570	2,514
Summary Data					
Average Measure	17,293	15,105	1.12	9,714	855
Subtotal	293,977	256,792	NA	165,134	14,532
Share Of Total	20.8%	12.8%	NA	4.2%	5.3%

Just over 5% of the reduction in CO_2 emissions identified in the Action Plan for the industrial sector derive from the 17 motor-related measures. Results from our data indicate that improving the efficiency of motors is expensive, as shown by examples in Table 2-7. The Interlaboratory Working Group Study (IWG 1997) focused on motor systems because of the large energy efficiency gains that were possible with improvements. Motors have wide application within the industrial sector and improvements in efficiency would bring benefits to a large number of firms (USDOE 1996). Compared to the national average in the USDOE Industrial Assessment Center database, the energy savings from motor upgrades identified for Delaware are relatively low. Thus, the DCCAP's estimate may be conservative.

Table 2-8

Lighting Equipment Measures to Save Energy and Reduce CO_2 Emissions in Delaware's Industrial Sector

Examples of Lighting Measures	Implement. Cost ($)	Energy Savings ($)	Payback Period (years)	Energy Saved (Btus)	$mtCO_2$ Mitigated
Reduce Lighting Usage	6,120	7,021	0.87	851	75
Install High Efficiency Lighting	48,924	18,336	2.67	19,902	1,751
Install High Pressure Sodium Fixtures	26,726	26,996	0.99	12,846	1,130
Summary Data					
Average Measure	36,123	23,239	1.36	8,429	742
Subtotal	325,103	209,150	NA	75,862	6,676
Share Of Total	2.6%	1.2%	NA	0.2%	0.3%

Of the 170 selected measures used in the Action Plan analysis of the industrial sector, 9 were lighting-related. A relatively small percentage of annual energy conserved and CO_2 emissions mitigated by the Action Plan would derive from this category, but there is a short payback period (less than 1.5 years) justifying the investment. In the case of lighting, use of the screening criterion of including only those measures which decreased energy use for the particular category (in this case, lighting) by 5% or more, led to selection of large-scale upgrade projects with comparatively higher costs. Thus, it is possible that cheaper lighting upgrade options exist in Delaware, which are cost-effective but may require greater management initiative to pursue. Indeed, the 5% savings threshold was used on advice from industry representatives of the DCCC who indicated that smaller savings were unlikely to win management support. This is because few rewards would accrue to managers for achieving low-impact improvements, even though the upgrades are cost-effective.

Results

Table 2-9
Summary of Results: Full Implementation Scenario

Analysis by Measure Category	Energy Saved (%)	CO_2 Mitigated (%)
Space Conditioning	36	37
Boiler and Steam Systems	27	24
Heat Recovery and Containment	23	22
Compressed Air	8	9
Motors	4	5
Lighting	2	2
TOTAL	100	100
Average Payback (all measures)		0.7 years

Note: Average payback = (measure payback) * (CO_2 mitigated by a measure / CO_2 mitigated in the sector).

CO_2 reductions are spread unevenly among the categories of measures, with lighting offering the least reduction and space conditioning offering the greatest (see Table 2-9 above). However, achieving cost-effective energy savings and reductions in CO_2 emissions across the sector requires initiatives employing the full range of equipment upgrades examined for the Action Plan.

Of course, it would be difficult to achieve all savings identified by the Action Plan, even if each meets strict cost-effectiveness standards. For this reason, the Action Plan adopts the approach used in the recent Interlaboratory Working Group Study (IWG 1997) in which scenarios are built for 100%, 65% and 35% implementation rates. The same 170 measures are employed for all three cases. Full implementation would realize a 27% reduction (1,140,100 $mtCO_2$) from 2010 levels. The Major Commitment scenario (65% implementation rate) would achieve an 18% reduction (741,100 $mtCO_2$), while the Modest Commitment scenario (35% implementation rate) would achieve a 9% reduction (399,000 $mtCO_2$) in emissions (Table 2-1). A detailed description of the measures analyzed for the Action Plan is provided in Appendix C.

Conclusion

In 1990, the sector's emissions totaled 3.2 mmtCO_2 and are forecast to increase to 4.2 mmtCO_2 under the BAU scenario by 2010. Under the Major Commitment scenario, emissions would be 3.5 mmtCO_2. Using the Major Commitment scenario as the benchmark for action, emissions in the industrial sector can be reduced by 18% from the forecast level for 2010. This is equivalent to less than 10% above the 1990 level for this sector.

The potential exists to make significant, cost-effective reductions in the energy consumption and carbon dioxide emissions of the industrial sector in Delaware. Although industrial processes entail a myriad of individual energy-consuming activities, our analysis has shown that by concentrating mitigation policy in key areas it is possible to slow industrial sector greenhouse gas emissions at relatively low cost. Implementation of 65% the 170 measures in six categories (air compressors, motors, lighting, space conditioning, boiler/steam, and heat recovery) identified in the Plan would result in annual savings in energy expenditures that would make Delaware's industry more competitive in the future. Specific policy actions to support the adoption of the analyzed measures for CO_2 emission reduction in the industrial sector are identified in Chapter 9.

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CHAPTER 3
RESIDENTIAL SECTOR
CO_2 EMISSION REDUCTION STRATEGY

Key Findings

Figure 3-1

Residential Sector CO_2 Emission Projections Through 2010

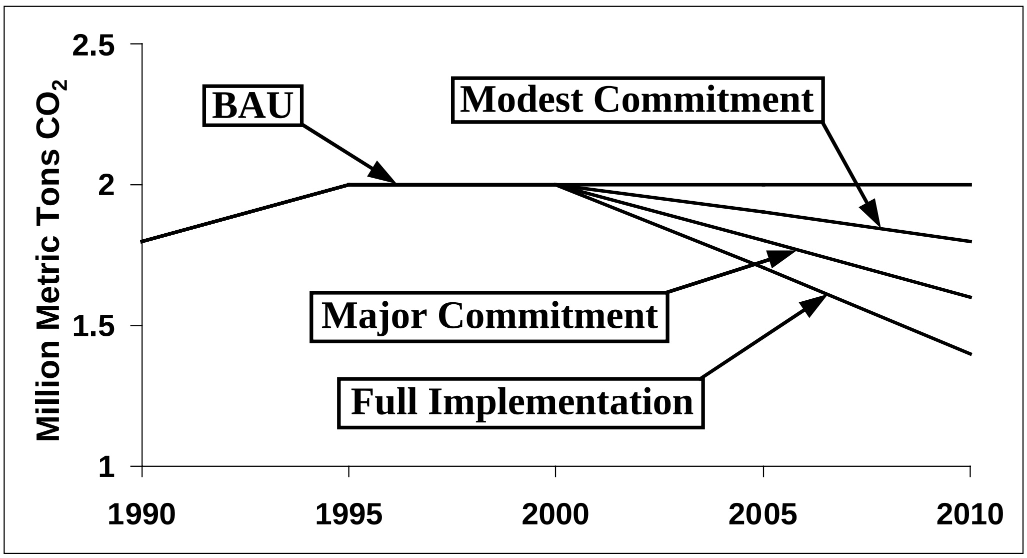

Table 3-1

Summary of Scenario Analyses to Reduce CO_2

in Delaware's Residential Sector

	Energy Use (trillion Btus)	GHG emissions ($mmtCO_2$)*
1990	26.7	1.8
2010 BAU	33.4	2.0
Implementation Scenarios		
Modest Commitment (35%)	31.5	1.8 (10%)
Major Commitment (65%)	30.0	1.6 (18%)
Full Implementation (100%)	28.1	1.4 (28%)

* Percentage reductions from forecast emission level are indicated in parenthesis

Under the BAU scenario, residential energy consumption increases slightly to approximately 2.0 mmtCO_2 in 2010 (Table 3-1). This represents an 11% increase during the forecast period. Implementation of all measures identified in the Action Plan (the Full Implementation Scenario) produces an emission total for the sector of 1.4 mmtCO_2 by 2010, which is a 22% reduction from 1990 levels. The Major Commitment scenario, involving significant state and federal policy support to capture 65% of the savings identified in the Action Plan, would result in an 11% reduction below 1990 emissions. The Modest Commitment scenario (which realizes 35% of identified savings in the Plan) returns this sector's emissions level to 1990 levels. Measured from the emission forecast for 2010 of 2.0 mmtCO_2, the Full Implementation, Major Commitment and Modest Commitment Scenarios would lead to a 28%, 18% and 10% reductions in emissions, respectively. Efficiency upgrades of space and water heating equipment, electric appliances and gas cookers, and lighting are the focus of the Action Plan for the residential sector. Figure 3-1 and Table 3-1 depicts the effects of the three scenarios analyzed for DCCAP.

Background

Delaware had 289,900 housing units in 1990, 45% of which were less than 21 years old (DHSC 1990). The occupancy level for these units was 85% (DHSC 1990). In 1990, total CO_2 emissions were 1.8 mmtCO_2, rising to 2.0 mmtCO_2 in 1996. The *Delaware Greenhouse Gas Inventory* indicates that emissions in this sector accounted for 7% of Delaware's total CO_2 emissions in 1990 (CEEP 1995). Emissions from Delaware's residential sector are proportionally less than the national contribution (the IWG reports in its 1997 study that about 20% of national greenhouse gas emissions originate in the residential sector), but are consistent with its climate.

Most of the state's residential sector emissions are associated with natural gas and electricity for space heating and air conditioning. Energy use in space heating and cooling correlates with the state's climate, which shapes total consumption and affects the seasonal distribution of energy use.

Sources and Trends of Emissions

The main sources of energy consumed in the residential sector are natural gas (about 30%) and the largest energy source, electricity (about 34% - annual consumption by fuel type is listed at Appendix D). Strong growth has characterized residential energy use in recent years. Increasing energy use correlates with growth in total residential buildings in the state and behavioral patterns and decisions that result in greater home energy use, including the trend of increasing numbers and usage of energy-consuming appliances in the home. In 1990 total fuel and end-use electricity consumption was 26.7 trillion Btus with a corresponding 1.8 mmtCO_2 of emissions (CEEP 1995). By 1998 these had increased by 19% and 13% respectively (see Table 3-2). Within this time period, the residential fuel mix changed, with overall declines in coal and kerosene, and increases in natural gas and electricity (both of which are less CO_2-intensive) (see Appendix D).

Table 3-2
Residential Sector Fuel And End-Use Electricity Consumption, 1990, 1998 and 2010

Year	**Btus Trillion**	**Million Metric Tons of CO_2**
1990 (actual)	26.7	1.8
1998 (forecast)	31.7	2.0
2010 (forecast)	33.4	2.0

Residential energy use is associated with a wide variety of energy-consuming services within the home, and the relatively broad mix of energy sources applied to these services. Mechanization, automation, and computerization of many domestic services has achieved high levels, and few tasks in the home are without the potential for demand on energy systems through the use of some type of appliance. Examples include televisions, computers, furnace fans, well pumps, spas and an array of kitchen equipment.

Delaware's residential energy use is dominated by its application to space heating, and to a lesser extent, water heating (see Table 3-3). Electricity supplies about 11% of the energy consumed in space heating and slightly less than a quarter of water heating energy (as shown in Table 3-3). Minor energy-consuming devices have a growing collective energy demand (see 'Miscellaneous (electric)' in Table 3-3.)

Table 3-3

Residential Energy Consumption By Major End-Uses, Emissions, 1996

Selected End Use	Percentage	mt of CO_2 Emissions
Space heating (all fuels)	43.0	757,335
Space heating (electric only)	(5.0)	(128,380)
Water heating (all fuels)	13.3	234,075
Water heating (electric only)	(3.2)	(83,795)
Miscellaneous (electric)	10.1	260,696
Space cooling (electric)	4.1	107,071
Refrigerators (electric)	3.7	95,433
Lighting (electric)	3.1	79,140
Clothes dryers (electric)	1.7	44,225
Cooking (gas)	1.7	30,050
Freezers (electric)	1.2	30,259
Miscellaneous (gas)	0.9	15,816

Note: Percentages and tons in parentheses are included in the "all fuels" category of an end use.
Source: Appendix E

<u>Projections</u>

A dominant factor in shaping total residential energy use is the number of households, and accordingly, increasing population size has historically resulted in increased residential energy demand. It is projected that by 2010 total housing units will increase to 311,400. Under the BAU scenario, overall energy consumption is projected to increase by 20% (rising to 33.4 trillion Btus) and emissions to increase by 8% over 1990 levels (see Table 3-1).

Much of the increase in emissions between 1990 and 2010 under the BAU scenario occurs in the first decade of the projection, while the sector's total energy use continues to grow throughout the period. This difference is due to the forecast fuel mix becoming less CO_2-intensive in the future, and as a result, CO_2 emissions become flat after 1995. Because of this factor, emissions fall slightly while energy use continues to increase.

Methodology

The *Delaware Greenhouse Gas Inventory* (CEEP 1995) supplied data on State energy use by fuel type and consumption levels and provided the 1990 baseline from which projections of future trends were made. Breakdowns of residential energy end-uses are not available for Delaware, so national residential statistics were used as the basis for establishing state conditions. Regional data were selected on the basis of Delaware's climatic classification developed on the associations between climate and energy use by the U.S. Department of Energy's Energy Information Administration (EIA 1997).

A recently completed study jointly prepared by five national energy research laboratories for the U.S. Department of Energy (IWG 1997) provided estimates of reduced energy use for major residential sector equipment. A cost-effectiveness test was applied to these potential measures: only those with a cost of conserved energy less than 4.0¢/kWh and whose payback period was less than five years were included in the Action Plan for Delaware. This is consistent with the criterion used by the Interlaboratory Working Group (IWG).

Scenarios were developed by applying measures that met the DCCC's cost-effectiveness criterion to the goal of CO_2 emissions reduction by assuming their introduction on a replacement basis (described below) and calculating the combined effect on emissions and energy use. Appliance introduction rates were taken from published measurements of product 'lives' of existing appliances (most of the appliances analyzed for the Action Plan are used for between 14 and 18 years). More efficient appliances were introduced into the forecasts at existing appliance replacement rates, which represent current residential decision-making.

Estimates of the costs of these upgrades were obtained from the IWG study (1997) and were used to calculate scenario costs. Energy use was calculated on the basis of the overall consumption level and specific type of energy consumed (results are shown in Appendix E). The effects of implementation of these measures are captured in the Full Implementation scenario, while the Modest and Major Commitment scenarios were developed by scaling down the results of the Full Implementation scenario to 35% and 65% of potential, respectively (results are shown in Appendix F). The scaling factors are identical to those used by the IWG and correspond to alternative policy environments: the 35% case is intended to correspond to a case where modest state and federal policy incentives are present and results are largely driven by the pace of market changes; the 65% case would reflect a circumstance where state and federal policy incentives are stronger (higher investment tax credits, for example) and society responds to these policy signals by aggressively pursuing its high-efficiency options.

Analysis of Options

The measures to reduce CO_2 emissions include high-efficiency models of home appliances, such as electric clothes dryers, refrigerators and freezers, gas cookers, electric and gas water heaters, lighting and space conditioning equipment improvements. These measures were grouped together in the scenario analyses for this sector. In addition, the effects of higher efficiency building design and materials, and the choice of fuel base for energy supply to the home were modeled.

Switching to appliances of greater energy efficiency offers a ready means to sectoral energy savings. For example, the average energy consumption for refrigerators was 944 kWh per year in 1997, the average of higher efficiency refrigerators is 647 kWh/year; and the highest efficiency model available on the market is estimated to use 437 kWh/year (IWG 1997). All appliances considered in the analysis are currently available on the market and meet a cost-effectiveness test of 4.0 ¢/kWh and paying back their incremental cost (compared to conventional models) in less than 5 years through reduced household energy bills.

In 1996, the energy consumed by refrigerators in Delaware's residential sector is estimated in the Action Plan to account for 95,433 mtCO_2, freezers for 30,259 mtCO_2, clothes dryers for 44,225 mtCO_2, and gas cookers for 30,050 mtCO_2, for a combined total of 199,967 mtCO_2. Analyses for the Action Plan show that, under the BAU scenario, the use of standard 1997 technologies for these appliances would reduce CO_2 emissions by some 34% to 132,101 mtCO_2 in 2010. Thus, the BAU assumes the upgrade to the typical 1997 appliance. The Modest and Major Commitment and the Full Implementation scenarios analyze efficiency upgrades that are greater than those embodied in the typical 1997 appliance. With full use of cost-effective, high-efficiency technologies (Full Implementation scenario), the emissions from these appliances could be reduced by a further 14,392 mtCO_2 or 11% below the projected 2010 levels in the BAU scenario. Details on the energy consumption and CO_2 emissions for specific measures are presented in Appendices E and F.

In 1996, energy consumption by electric water heaters in Delaware accounted for 3.2% of total residential energy consumption, while gas water heaters used 13.3%. Water heaters have an average lifetime of 10 years and consume considerable quantities of electricity on a unit basis: the U.S. annual average energy use in 1997 per electric unit was 4,924 kWh/year (IWG 1997). Current electric water heaters exhibit improved energy efficiency; 1997 models have an annual energy consumption of 3,899 kWh/year (IWG 1997).

Under the BAU scenario, it is estimated that 2010 CO_2 emissions attributable to electric water heaters would decrease from 83,795 mtCO_2 in 1996 to 70,819 mtCO_2, a decline of 15%. Emissions from gas heaters would only decrease from 234,075 mtCO_2 to 230,196 mtCO_2, down 1.6% from 1996 levels. This effect will be caused by an increasing proportion of gas heaters, which involves the combustion of natural gas, a more efficient means of heating water than its common alternative, electricity; and because natural gas combustion releases less CO_2 than the combustion of the coal-dominant fuel mix for electricity generation in Delaware, an increase in the proportion of gas water heaters will lower CO_2 emissions. By using cost-effective, high-efficiency models, it is estimated that, under Full Implementation, carbon dioxide emissions would decrease by 20% relative to forecast levels for Delaware.

Studies have shown that, in general, fluorescent lighting is more energy efficient and causes less carbon dioxide to be emitted than incandescent lighting. Conventional lighting has a short equipment lifetime (one year according to the IWG study) and this greatly influences the cost-effectiveness of introducing new technology. There are considerable opportunities to replace traditional incandescent lighting, which is associated with 90% of U.S. residential lighting, with more energy-efficient technologies, such as halogen and compact fluorescent lights.

In Delaware, electric lighting accounted for 3.1% of the energy consumed in the residential sector, and 79,140 mtCO_2 emissions in 1996. Under the BAU scenario these emissions are projected to decrease to 72,683 mtCO_2 in 2010, down by 8% from 1996. By using high-efficiency, cost-effective lighting technologies, however, it is possible under Full Implementation to reduce emissions in 2010 by 38,522 mtCO_2 or 53% below the BAU projections for 2010 (see Appendix F). These measures can be introduced for immediate cost savings, as discussed below.

Space heating and cooling is the largest consumer of energy and emitter of carbon dioxide in the residential sector in Delaware. Energy consumption is largely shaped by the number of days requiring heating and cooling (i.e. climatic conditions), building energy efficiency, and the efficiency of the heating/cooling systems. The cost of conserved energy tends to be lower for new buildings than for existing ones.

As with the case of water heating, gas- fueled space heating is more efficient than electric systems and produces lower emissions of greenhouse gases. Under the BAU scenario, CO_2 emissions from the current proportion of electric heaters will decrease from 128,380 $mtCO_2$ to 116,545 $mtCO_2$ in 2010, or by 9% over 1996 levels. By contrast, emissions from the current proportion of gas fueled space heating will decrease from 757,335 $mtCO_2$ to 671,473 $mtCO_2$ in 2010, down by 11% from 1996 levels. By switching more Delaware households to natural gas, greater CO_2 emissions savings can be realized than from the continued use of electricity for this end use (see Appendix E). By using cost-effective, high-efficiency models for both electric and gas heating/cooling systems, it is estimated that, under Full Implementation, carbon dioxide emissions would decrease by 14% relative to forecast levels for Delaware.

Results

Switching residential technology to those of maximum end-use efficiency (while still meeting the cost-effectiveness tests of 4.0 ¢/kWh and payback periods less than or equal to 5 years) at the rates determined by existing appliance/equipment life, makes considerable energy savings possible by 2010. No additional technological improvements over the best available technologies in the present market are needed to achieve residential energy services at lower CO_2 emissions. The Action Plan's residential sector strategy concentrates on those end uses with a high proportion of sectoral energy use and where applicable technologies offer considerable energy and emissions benefits.

Under the Full Implementation scenario (i.e., all cost-effective measures are implemented), there would be an estimated 28% reduction or 552,729 $mtCO_2$ below BAU at 2010. The Modest Commitment scenario (35% of cost-effective measures implemented) would achieve a 10% reduction and the Major Commitment scenario (65% implementation) would achieve an 18% reduction in emissions from forecast levels for 2010.

Conclusion

Under the BAU scenario, the sector's emissions are forecast to rise from their 1990 level of 1.8 $mmtCO_2$ to 2.0 $mmtCO_2$ by 2010. Emissions under the Modest Commitment scenario are 1.8 $mmtCO_2$ and 1.6 $mmtCO_2$ under the Major Commitment scenario by the target year. Adoption of the Full Implementation scenario will result in emissions of 1.4 mmtCO_2 by 2010. Using the Major Commitment scenario as the benchmark for action, emissions in the residential sector can be reduced by 18% from the forecast level for 2010. This is equivalent to an 11% reduction from the 1990 level for this sector.

Analyses prepared for the Action Plan show that the application of existing high-efficiency, cost-effective measures, can yield substantial reductions in emissions for the sector. These measures are spread across a wide array of residential energy services. Overall, the cost of conserved energy for these measures is low, but the policy challenge is to interest residential consumers in making these upgrades when they replace older equipment. Policy actions to support the adoption of the analyzed measures for CO_2 emission reduction in the residential sector are identified in Chapter 9.

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CHAPTER 4
THE COMMERCIAL SECTOR
CO_2 EMISSION REDUCTION STRATEGY

Key Findings

Figure 4

Commercial Sector CO_2 Emission Projections Through 2010

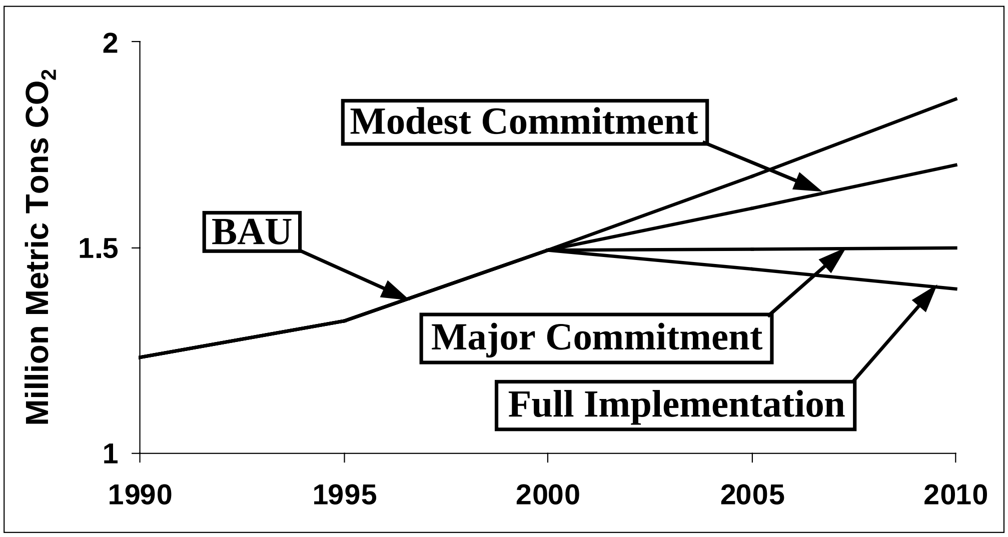

Table 4-1

Summary of Scenario Analyses to Reduce CO_2

in Delaware's Commercial Sector

	Energy Use (trillion Btus)	GHG emissions ($mmtCO_2$)*
1990	16.3	1.2
2010 BAU	28.9	1.9
Implementation Scenarios		
Modest Commitment (35%)	27.0	1.7 (9%)
Major Commitment (65%)	25.3	1.5 (18%)
Full Implementation (100%)	23.4	1.4 (27%)

* Percentage reductions from forecast emission level are indicated in parenthesis

Energy use in the commercial sector has grown rapidly in the recent past and is expected to continue to do so. This sector's energy consumption is forecast to increase by more than 75% between 1990 and 2000 – faster than any other sector in Delaware. Such growth is due to the transition of the Delaware (and U.S.) economy from manufacturing to services. Carbon dioxide emissions grew less quickly (over 50%), due to the reliance of this sector on natural gas – a low-carbon fuel – and technology improvements expected for the sector.

Under the Full Implementation scenario, greenhouse gas emissions in the commercial sector can be reduced significantly, from the 2010 forecast of 1.9 mmtCO_2 to 1.4 mmtCO_2 – a 27% decline (see Table 4-1). However, even the Full Implementation scenario is insufficient to return the sector to the emission levels of 1990. Under the Major Commitment scenario, a decrease from forecast emissions for 2010 of 18% is anticipated; while the Modest Commitment scenario is projected to realize a 9% decrease from the 2010 forecast. Lighting measures are especially attractive in this sector, offering near term net savings. The use of building-integrated photovoltaics (PV) represents a long-term investment in CO_2 mitigation that the DCCC believes is appropriate, given Delaware's leadership in PV research and manufacturing.

Background

The pattern of the sector's energy consumption and CO_2 emissions in Delaware is consistent with national trends. National consumption is about 14 quadrillion Btu of energy (EIA 1997), a modest level in comparison to other sectors. The electricity sector accounts for more than 50% of energy used in the sector and lighting is the largest end use. Delaware's commercial sector reflects these national patterns. The commercial sector contributes the smallest share of the state's CO_2 emissions, and most of the energy consumed is electricity (with natural gas as the second most common source).

Sources and Trends of Emissions

CO_2 emissions in the commercial sector are produced primarily by the consumption of electricity, which accounted for 58% of the total from this sector in 1996, and natural gas, which accounted for 23%. The remaining emissions derive from distillate, residual fuels, and coal. The CO_2 contributions by fuel type are presented in Appendix G. According to the Action Plan's projections, the fuel mix is expected to change slightly through the year 2010, with electricity contributing 57% of total CO_2 emissions in that year, and natural gas increasing its share to 27% (see Appendix G).

Projections

Total CO_2 emissions from the commercial sector in 1990 were 1.2 mmtCO_2, rising to 1.4 mmt in 1996. The 1990 emissions accounted for 3% of total State CO_2 emissions for that year (CEEP 1995), 2% less than the national average for the commercial sector. By 2010, commercial sector emissions are forecast to reach 1.9 mmtCO_2 under the BAU, over a 50% increase from 1990 levels. Improvements in energy efficiency are broadly available and inexpensive to implement. Generally, strategies identified in the Action Plan produce near-term financial benefits to commercial enterprises in the form of lower energy bills.

Methodology

Modeling of cost-effective CO_2 mitigation is quite similar for the residential and commercial sectors, since energy use in both is largely concerned with buildings-related technologies and management strategies. Just as the residential sector strategy used the IWG study (1997) to model residential energy efficiency improvement, analysis for this sector applied commercial measures researched by the IWG to Delaware. A cost-effectiveness screen of 4.0¢/kWh and payback period of less than 5 years was used. National data were used, with regional adjustment for climate, due to the absence of detailed state-level data on energy use by activity (heating, lighting, etc.).

Analysis of Options

The emission reduction measures selected for analysis include: high efficiency lighting, space conditioning, refrigeration, building-integrated PV,[1] and fuel switching. The estimated CO_2 emissions-reduction potential from these measures under three implementation scenarios is illustrated in Figure 4-1.

In this sector, space conditioning (including heating, ventilation and air conditioning) uses both gas and electricity. Space conditioning is influenced by many factors, but principally by building characteristics, climate, type of heating and cooling equipment, and thermal gains from equipment.

Action Plan projections show that, under the BAU scenario, emissions from electric space conditioning and ventilation will increase from 179,468 $mtCO_2$ in 1996 to 203,349 $mtCO_2$ in 2010, a gain of 13%. Emissions from gas-powered space conditioning will rise from 241,630 $mtCO_2$ in 1996 to 315,780 $mtCO_2$ in 2010, an increase of 31%. An even greater increase in the use of natural gas – a low-carbon fuel – with a decrease in the use of electricity could lead to an overall reduction in CO_2 emissions in 2010. As shown in Appendix I, with fuel switch beginning in the year 2000, CO_2 emissions could decrease to 127,359 $mtCO_2$ for electricity and to 250,525 $mtCO_2$ for natural gas in 2010, a savings of 37% and 21% of emissions, respectively. Fuel switching would involve high initial cost, but can return economic benefits to commercial users relatively quickly. Due to its high capital cost, only a modest level of fuel switching is anticipated in the Action Plan.

At present, lighting in the commercial sector accounts for 245,509 $mtCO_2$ of emissions. If the technological status quo is maintained, it is projected that in 2010

[1] This measure did not meet the cost-effectiveness criteria set by DCCC for other measures. However, special benefits accrue to Delaware since it is home to a leading PV manufacturer and the University of Delaware has been designated by the U.S. Department of Energy as one of only two "Centers of Excellence" in the country for development of advanced PV technology and market and policy requirements for its diffusion. DCCC expects rapid technical and economic improvements in this technology and believes that Delaware can be a leader in its market development.

emissions will rise to 285,273 $mtCO_2$, an increase of 16%. At present, fluorescent lighting accounts for 70% of the energy used for lighting in the sector, with incandescents accounting for 18% (IWG 1997).

The Full Implementation scenario would include the widespread use of halogen and compact fluorescent technologies. With these technologies, CO_2 emissions in 2010 are projected to be 225,841 mt. This would translate to 21% lower emissions in 2010 than the BAU forecast (see Appendix I). There is a net saving for investing in high-efficiency lighting in this sector. The IWG report (1997) indicates that this benefit includes savings in maintenance costs because halogen and compact fluorescent lighting have longer lifetimes and need to be replaced less frequently.

Refrigeration constitutes a modest component of the energy consumed in the commercial sector. But analyses conducted for the Action Plan show that the potential exists to cost-effectively reduce the level of CO_2 emissions by introducing higher efficiency models of this technology. Commercial refrigeration covers a wide array of devices, such as ice-makers, walk-in centralized systems, vending machines, and reach-in freezers. The largest energy savings derive from supermarket upgrades. The cost of conserved energy is low across the wide array of refrigeration units examined, ranging from $0.003 kWh (for centralized systems in small groceries) to $0.022 kWh (for vending machines).

As shown in Appendix H, under the BAU scenario, CO_2 emissions from refrigeration will increase by 23% from 29,888 $mtCO_2$ in 1996 to 36,809 $mtCO_2$ in 2010. With the use of more efficient technologies (especially technologies with an energy use index (EIU) of 2.0 kBtu/sf), emissions from refrigeration could fall to 29,202 $mtCO_2$, 21% below the BAU (see Appendix I).

Recently enacted state policies to deregulate electricity markets in the mid-Atlantic region anticipate from 3% (Pennsylvania) to 6.5% (New Jersey) of electricity to be provided by renewable energy by 2010-2012. One important opportunity for reducing energy use and greenhouse gas emissions in this regard is the application of photovoltaic (PV) technology to buildings to reduce electricity demand. The National Renewable Energy Laboratory has sponsored research on the CO_2 effects of a national strategy to provide 2% of national buildings-related electricity consumption from photovoltaic systems (Byrne et al 1999). PV systems can be installed on rooftops or other suitable locations and incorporated into commercial building energy systems, and thereafter operated as a peak management technology. This application has proved to be cost-effective at current technology prices (e.g. Byrne et al, 1997 and 1998). The Action Plan's analysis is based on existing PV systems that are commercially available and in operation around the country. It identifies emission reductions of 75,650 $mtCO_2$ by 2010 through a PV measure that anticipates the use of the technology for peak-shaving and emergency power purposes (see Appendix I).

Results

The Full Implementation Strategy would realize a 27% reduction in emissions by the year 2010; the Major Commitment Strategy (65% of full implementation) would result in an 18% reduction, and the Modest Commitment Strategy (35% of full implementation) would realize a 9% reduction below forecast levels. Results for all measures are presented in Appendix I.

Conclusions

Under the BAU scenario, emissions from the sector will increase by more than 50%, from 1.2 $mmtCO_2$ in 1990 to 1.9 $mmtCO_2$ in 2010. Reductions under the Modest Commitment scenario result in emissions of 1.7 $mmtCO_2$, while the Major Commitment scenario results in 1.5 $mmtCO_2$ by 2010. Forecast emissions under the Full Implementation scenario are 1.4 $mmtCO_2$ by the target year. Using the Major Commitment scenario as the benchmark for action, emissions in the commercial sector can be reduced by 18% from the forecast level for 2010. Still, this is equivalent to 24% above the 1990 level for this sector. The increase in emissions above 1990 levels, even after an aggressive savings program is implemented can be explained by the rapid economic growth forecast for the sector as part of a state and national trend toward a service-based economy.

Many opportunities are available to arrest the forecast trend of increasing energy use in the commercial sector. Implementation can be achieved with reasonable cost-effectiveness. Improving energy efficiency will benefit commercial activities by lowering the expenditure on energy; in the case of improved lighting, the financial and greenhouse benefits are immediate. For the sector to achieve an emissions reduction of Strategy. Policy actions to support the adoption of the analyzed measures for CO_2 emission reduction in the sector are identified in Chapter 9.

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CHAPTER 5
TRANSPORTATION SECTOR
CO_2 EMISSION REDUCTION STRATEGY

Key Findings

Figure 5-1

Transportation Sector CO_2 Emission Projections Through 2010

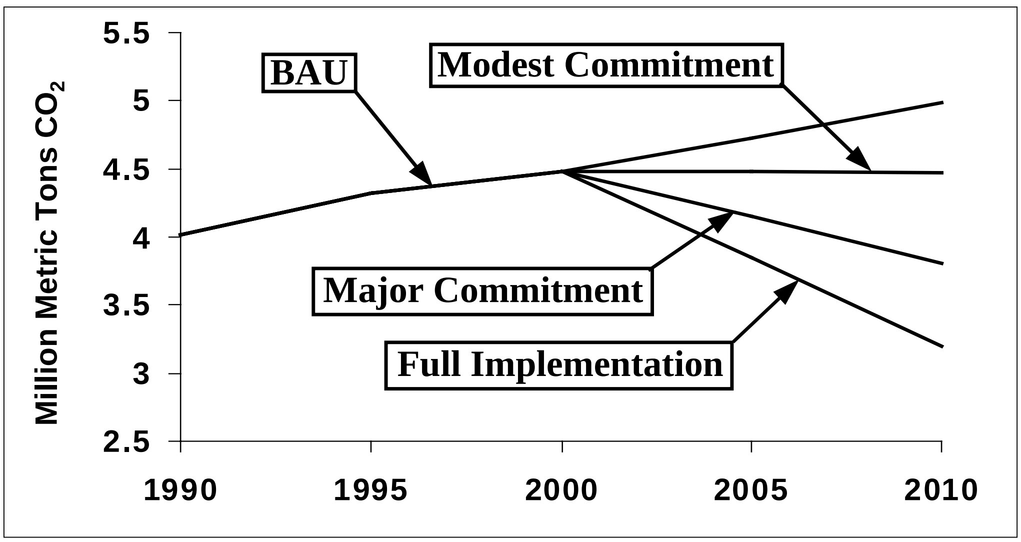

Table 5-1

Summary of Scenario Analyses to Reduce CO_2

in Delaware's Transportation Sector

	Energy Use (trillion BTUs)	GHG emissions ($mmtCO_2$)*
1990	55.59	4.0
2010 BAU	68.61	4.9
Implementation Scenarios		
Modest Commitment (35%)	-	4.4 (10%)
Major Commitment (65%)	-	3.7 (24%)
Full Implementation (100%)	-	3.1 (36%)

* Percentage reductions from forecast emission level are indicated in parenthesis

Carbon dioxide emissions from the transportation sector have accounted for approximately 26 to 30% of Delaware's total CO_2 emissions on a yearly basis since 1985

(EIA, 1997). The existing trend of rising emissions is forecast to continue to 2010 under the BAU scenario. The $EECO_2$ forecast for the Action Plan (see Chapter 1) anticipates more than 20% growth over 1990 levels in energy use and CO_2 emissions for this sector. Three levels of CO_2 mitigation scenarios were developed: the Modest Commitment scenarios, which involves modest technology upgrades and low-cost conservation measures; the Major Commitment scenarios which anticipates higher efficiency technologies penetrating the market, an increase in the pace of diffusion of alternative fuel vehicles (AFVs), and greater use of low-cost conservation measures; and the Full Implementation scenarios, which accelerates market penetration of high-efficiency technology, aggressively markets AFVs and extensively employs low-cost conservation measures. For all three implementation scenarios, it is expected that the State of Delaware will pursue an aggressive program of managed growth strategies that are discussed below. While the Consortium was unable to calculate specific, measurable CO_2 impacts for growth management, it believes that such a program is an essential tool that will be needed to meet the objectives of the Action Plan.

The Modest Commitment scenarios achieve a 10% reduction in CO_2 emissions measured from the BAU benchmark. The Major Commitment scenarios doubles the reduction to 24%, while the Full Implementation scenarios results in a 36% reduction in CO_2 emissions.

Background

In 1995, the transportation sector accounted for 28% of Delaware's total CO_2 emissions, second only to the utility sector (EIA 1997). Almost all greenhouse gas emissions from Delaware's transportation sector are in the form of CO_2. Consequently, CEEP chose to focus on ways to reduce CO_2 emissions from this sector.

Impacting transportation emissions is complex because many different modes of travel spanning a wide range of activities must be considered. Fuels consumed by highway vehicles, boats, airplanes, jets, railroads, and pipelines all contribute to emissions from the sector. However, jet and aviation fuels were excluded from this Action Plan based on a recommendation by USEPA that bunkered fuels should not be included in state emission figures.[1] Of the remaining emission sources, highway vehicles burning motor gasoline and distillate (diesel) fuel account for roughly 85% of CO_2 emissions from the transportation sector on a yearly basis.[2] Highway vehicles include light-duty cars and trucks, heavy-duty vehicles, and motorcycles. This Action Plan focuses specifically on ways to reduce gasoline and diesel fuel consumption, and hence CO_2 emissions, from cars and light-duty trucks (known collectively as light-duty vehicles or LDVs). By themselves, LDVs accounted for 72% of the total CO_2 emissions from the transportation sector in 1990.[3]

Three different tools for reducing CO_2 emissions from highway vehicles are considered in this report – improvements in LDV fuel economy, introduction of compressed natural gas (CNG) vehicles and electric vehicles (EVs), and the use of transportation control measures (TCMs) to reduce vehicle miles traveled (VMTs). Consistent with the modeling approach for other sectors, three implementation scenarios were evaluated: Full Implementation, which results in a 36% reduction in CO_2 emissions from the BAU forecast of 4.9 mmt; the Major Commitment case, which results in a 24% reduction; and the Modest Commitment case which would realize a 10% cut in CO_2 emissions. Although implementing any of these strategies will be challenging, each shows significant potential for reducing CO_2 emissions cost-effectively from the transportation sector. A cost-effectiveness screen of a five-year payback period was used to evaluate CO2 mitigation options for this sector.

Sources and Trends of Emissions

The majority of CO_2 emissions from the transportation sector result from the burning of fossil fuels. The primary fossil fuels burned are motor gasoline, distillate fuel,

[1] A discussion of bunkered fuels can be found in CEEP's *Delaware Greenhouse Gas Inven*tory (CEEP 1995).
[2] This figure is based on CEEP's calculations of fuel consumption for Delaware vehicles – see Appendix I.
[3] This figure is based on CEEP's calculations of fuel consumption for Delaware vehicles – see Appendix I.

and residual fuel (EIA 1997). The remaining CO_2 emissions derive from the breakdown of lubricants. A small amount of CO_2 is also produced by burning compressed natural gas, liquid petroleum gas and some other alternative fuels, but their portion of total CO_2 emissions is too small to be considered.[4] The relative contributions of the CO_2 sources in 1990 and 1995 are shown in Table 5-2.

Table 5-2

Delaware CO_2 Emissions by Fuel Type from the Transportation Sector

Fuel Type	CO_2 Emissions (metric tons of CO_2)			
	1990		1995	
Distillate	586,663	14.64%	746,135	15.25%
Residual	450,264	11.23%	582,926	12.00%
Motor Gasoline	2,953,805	73.76%	3,518,012	72.40%
Lubricants	14,880	0.37%	16637	0.35%
Total	**4,010,000**	**100%**	**4,860,000**	**100%**

Highway vehicles produce the majority of CO_2 emissions in the transportation sector. In 1990, highway vehicles accounted for 85% of the 4.0 mmtCO_2 emitted by the entire sector. Highway vehicles also accounted for 95% of emissions from gasoline and diesel fuel consumption. In 1996, highway vehicles accounted for 79% of total transportation sector emissions and 90% of gasoline and diesel fuel consumption.[5]

Projections

In 1990, the transportation sector emitted 4.0 million metric tons of carbon dioxide. The BAU forecast for CO_2 emissions in 2010 is 4.9 mmt, an increase of 0.9 mmt (or 22%) from 1990 levels. A 7% reduction from 1990 levels, as per the DCCC emissions reduction goal, yields a target for this sector of 3.7 mmtCO_2. Therefore, a reduction of 1.2 mmt from forecasted 2010 levels (a 24% decline) is required to meet the DCCC goal.

[4] LPG and CNG each count for less than one-tenth of a percent of Delaware's total CO_2 emissions – see the *Delaware Greenhouse Gas Inventory* (CEEP 1995)
[5] The basis for these calculations is described in the methodology section of this chapter.

Increases in Delaware's vehicle miles traveled (VMTs) are fueling the growth in emissions from the transportation sector. VMTs are increasing at a rate much faster than Delaware's population. VMTs increased by 55% during the 1980s, while population increased by only 11% during the same period (DelDOT 1998). Between 1990 and 2010, VMTs are expected to increase by another 43% (DelDOT 1998). Although the rate of VMT increase is expected to slow between now and 2010, the rate of increase is still rapid and will continue to outstrip population growth by a large margin. The rapid growth rate in VMTs reflects two important trends in Delaware; higher proportions of Delawareans are becoming licensed drivers, and those drivers are, on the whole, driving more miles. Sometime after the year 2010, the proportion of licensed drivers in Delaware will stabilize at an upper limit, but VMTs per driver may still increase, if current trends continue.

Increases in the average fuel economy of cars and light-duty trucks during the 1980s and early 1990s partially offset increasing VMTs during the same period. Increasing fuel economy translates into less fuel burned per mile and, hence, less CO_2 emissions per mile traveled. However, the average fuel economy of both cars and trucks stabilized during the 1990s, while VMTs continued to increase (USDOE 1998).[6] Average fuel economy is expected to increase little or not at all in the near future, as corporate average fuel economy (CAFE) standards have leveled off at 27.5 and 20.7 mpg for cars and light-duty trucks, respectively (USDOE 1998). A comparison of CAFE standards with fuel economy for cars and light-duty trucks over the past 15 years is shown in Table 5-3.

[6] Fuel economy rates and the figures for new vehicles sold in Delaware were not obtainable. Therefore, national average fuel economy rates and sales figures were used in lieu of Delaware-specific data. This information was obtained from the U.S. Department of Energy's *Transportation Energy Data Book: Edition 18* (USDOE 1998).

Table 5-3

Average Fuel Economy and CAFE Standards for Cars and Light-Duty Trucks, 1984-1998

	Cars		Light-Duty Trucks	
Model Year	CAFE Standards	Fuel Economy (miles per gallon)	CAFE Standards	Fuel Economy (miles per gallon)
1984	27.0	17.4	20.0	14.0
1985	27.5	17.4	19.5	14.3
1986	26.0	17.4	20.0	14.6
1987	26.0	18.0	20.5	14.9
1988	26.0	18.7	20.5	15.4
1989	26.5	19.0	20.5	16.1
1990	27.5	20.2	20.0	16.1
1991	27.5	21.1	20.2	17.0
1992	27.5	21.0	20.2	17.3
1993	27.5	20.5	20.4	17.4
1994	27.5	20.7	20.5	17.3
1995	27.5	21.1	20.6	17.3
1996	27.5	21.3	20.7	17.3
1997	27.5	N/A	20.7	N/A
1998	27.5	N/A	20.7	N/A

Source: U.S. Department of Energy. (1998) *Transportation Energy Data Book: Edition 18*.

The plateau reached in fuel efficiency, may remain, or even fall, due to the increasing prevalence of sport utility vehicles (SUVs). SUVs are subject to the lower CAFE standard of 20.7 mpg for light-duty trucks. Accordingly, as more SUVs are sold, overall fuel economy for LDVs worsens. Forecasts indicate that light-duty trucks will account for 62% of all light-duty vehicles sold in the U.S. by 2010 (STAPPA/ALAPCO 1998). This is a 105% increase over the proportion of light-duty trucks sold in 1990. An increase in sales of new light-duty trucks by this amount would produce an additional 210,220 mt of CO_2 in 2010 over a comparable baseline that held the proportion of new light-duty trucks sold at 1996 levels. CEEP included an increasing portion of light-duty trucks in its BAU analysis.

Methodology

Three strategies for reducing CO_2 emissions were developed: improvements in fuel economy of cars and light-duty trucks; increased use of alternative fueled vehicles (AFVs); and State and local adoption of menus of transportation control measures, or TCMs, to reduce VMTs. The measures and policies put forth in the Action Plan to reduce CO_2 emissions target only highway vehicles, and specifically, cars and light-duty trucks (both gasoline and diesel powered). Heavy-duty vehicles, such as delivery trucks and tractor-trailers, are not targeted for emission reductions in this Plan, due to data limitations.

In 1996, fuel efficiency for Delaware's automobile fleet was 21.3 mpg, while the light-duty truck fleet averaged 17.3 mpg (USDOE 1998). These figures are based on the most recent national averages published in USDOE's *Transportation Energy Data Book.* As no projections were available for BAU scenario changes in fuel efficiency, a consistent fleet fuel efficiency is assumed throughout the study period. Recent trends in fuel efficiency of new cars and trucks support this assumption.

Two types of AFVs are assessed in the Action Plan analysis: compressed natural gas vehicles (CNGs) and electric vehicles (EVs). CNG vehicles were chosen because of their current and potential market penetration, technological robustness and low CO_2 emissions. A car burning natural gas produces 25% fewer CO_2 emissions per gallon of gasoline equivalent than a conventional car. Furthermore, a variety of natural gas vehicles are currently sold by several domestic manufacturers, and have performance characteristics (e.g. power, acceleration, range, safety features) similar to conventional vehicles.

EVs produce no tailpipe emissions of CO_2. However, lifecycle emissions – those associated with fuel use, production, and distribution – from EVs vary widely. For example, if the electricity for an EV comes from a coal burning power plant, the CO_2 emissions associated with an EV would be higher than those of a car powered by conventional gasoline.[7] However, an EV using renewable energy as its source of electricity would produce a fraction of the lifecycle CO_2 emissions associated with a gasoline powered car. For the purposes of this study, CEEP assumes the electricity used to power EVs would be generated by renewable energy sources such as solar and wind power.

Three AFV scenarios are examined and the target AFV penetrations in each scenario are based on the Energy Policy Act (EPAct) of 1992 mandate for AFVs among fleet vehicles. These scenarios demonstrate potential CO_2 reductions associated with different levels of AFV penetration.

The TCMs chosen for this study will reduce VMTs by considerable amounts, although variations occur in implementation due to local conditions, degree of program implementation, and public behavior. Several studies of the costs and benefits of multiple TCMs have been performed by Harvey and Deakin (1991), Apogee Research (1991), Barton-Aschman (1981), Loudon and Dagang (1992), Cameron (1991), and others. Estimates of energy consumption impacts of TCMs from these studies were generated by investigation and by analytical projections. TCM projections based on these studies are generic, but in practice the response to TCMs may vary from community to community, influenced by economic conditions, existing land uses, and the availability of transportation alternatives.

The studies used by CEEP generally considered each TCM individually, rather than in combination with other TCMs. In reality, the effects of multiple TCMs may be additive, synergistic, redundant, or antagonistic. TCM pricing measures that make driving more costly, for example, tend to increase transit use, carpooling, bicycling, and walking. However, a method for quantitatively valuing these effects was not available for this Action Plan. In lieu of an established methodology, TCM effects were treated as additive. Selecting TCMs whose effects are not redundant strengthened the validity of this assumption.

[7] A list of lifecycle emissions by fuel type is given in STAPPA/ALAPCO (1998).

All TCMs chosen for this study aim at reducing single occupancy vehicle (SOV) travel and reducing the total amount of VMTs for the State of Delaware. The percent reductions for all VMTs were taken from the available literature. The TCMs selected in the Action Plan reduce VMTs in several ways. Some TCMs encourage carpooling or ridesharing, thereby reducing the amount of SOV travel and VMTs. Other measures encourage the use of alternative modes of travel, such as transit, bicycling, and walking, by either making these measures more attractive or by making automobile travel more expensive. Lastly, some TCMs encourage individuals to reduce their total amount of travel, either through the consolidation of trips or the decision not to make a given trip in the first place.

CEEP used projections of VMTs for all highway vehicles and breakdowns of VMTs by vehicle type to determine the impact of each strategy on gasoline and diesel fuel consumption. CEEP then calculated the corresponding change in CO_2 emissions relative to the entire transportation sector.

Analysis of Options

Three implementation scenarios were investigated: Full Implementation, which seeks to realize 100% of the cost-effective options identified in the Action Plan; the Major Commitment scenario, which endeavors to realize 35% of the cost-effective energy savings identified in the Energy Plan; and the Major Commitment scenario, whose goal is to capture 65% of the full savings potential. Each scenario developed for the transportation the sector uses three basic tools: fuel efficiency improvements, alternative fuel vehicle technology development, and diffusion of transportation control measures. The impact of each scenario is described below.

1. Fuel Efficiency Improvements

Table 5-4

Reductions of CO_2 from Fuel Efficiency Improvements in the Delaware Transportation Sector

Strategies	CO_2 Reduction from 2010 Baseline (metric tons)	Percent Reduction from 2010 Transportation Sector Forecast
Modest Commitment	325,650	6.5%
Major Commitment	769,750	19.5%
Full Implementation	1,101,700	22.4%

Technologies currently exist which could increase the fuel efficiency of cars and light-duty trucks without sacrificing size, features, or performance. However, low gasoline prices and stagnant CAFE standards (set by federal legislation) have created a market where automakers concentrate on increasing performance and amenities, not fuel economy. The introduction of feebate programs (in which consumers receive rebates on the purchase price of vehicles whose MPG ratings are above a specified level above an average rating and pay a fee for those with below average ratings) could create a market-based incentive for automakers to improve the fuel economy of new and existing models. Without feebates or increases in CAFE standards, it is doubtful that automakers will utilize existing technologies to increase fuel economy.

CEEP analyzed three different levels of fuel economy improvements for reducing CO_2 emissions from the transportation sector. The first fuel efficiency improvement strategy, the Modest Commitment case, features a 2-mpg improvement for light-duty cars and trucks by 2010. This strategy would reduce CO_2 emissions in 2010 by 325,650 metric tons, or 6.5% for the entire transportation sector. The second fuel efficiency improvement scenario, the Major Commitment strategy, uses a forecast prepared by the State and Territorial Air Pollution Program Administrators (STAPPA) Association of Local Air Pollution Control Officials (1998). This strategy anticipates a possible fuel efficiency increase among new cars and trucks of 1% per year beginning in the year 2000 (STAPPA/ALAPCO 1998). Using a vehicle turnover rate of 7% for cars and 10% for new trucks,[8] this improvement in new car fuel efficiency yields an increase of 5.9 mpg for Delaware's entire automobile fleet by 2010, and an increase of 3.4 mpg for the light-duty truck fleet. As a result, the Major Commitment strategy for fuel efficiency improvements reduces CO_2 emissions in 2010 by 769,747 metric tons or 19.5%.

The third fuel efficiency improvement case, the Full Implementation strategy, predicts fuel efficiency increases among light-duty vehicles of 1% beginning in the year 2000 and increasing to 3% per year in the year 2005 (STAPPA/ALAPCO 1998). Using the same vehicle turnover rates as in the Major Commitment strategy, fuel efficiency for Delaware's existing car fleet increases 7.7 mpg by 2010, while efficiency for the light-duty truck fleet increases by 6.5 mpg. This strategy reduces CO_2 emissions in 2010 by 1,101,700 mt or 22.4% (as shown above in Table 5-4). This strategy incorporates the high-efficiency case developed by the Interlaboratory Working Group (IWG 1997).

2. Alternative Fuel Vehicle Development

Table 5-5

Reductions of CO_2 from CNG & Electric Vehicle Fleet Penetration in the Delaware Transportation Sector

Strategies	CO_2 Reduction from 2010 Baseline (metric tons)	Percent Reduction from 2010 Transportation Sector Forecast
Modest Commitment	11,760	0.4%
Major Commitment	20,570	0.7%
Full Implementation	102,820	2.1%

The AFV strategies analyzed for the Action Plan involve the introduction of compressed natural gas (CNG) and electric vehicles (EV) into Delaware's fleet of cars and light-duty trucks. For the Modest Commitment strategy for AFVs, a 1.2% level of

[8] This turnover rate was obtained by analyzing yearly new car and light-duty truck purchase figures and comparing those to the total number of registered cars and light-duty trucks in the US. These figures were obtained from the *Transportation Energy Data Book, Edition 18*, (USDOE 1998).

CNG vehicle usage resulted in a CO_2 emissions reduction of 11,760 mtCO_2 from 2010 levels. The Major Commitment strategy for AFVs increases the proportion of CNG vehicle VMTs from 1.2% to 2.1%. This higher level of CNG vehicle usage reduces CO_2 emissions by 20,570 mt from 2010 levels. In the Full Implementation strategy, the CNG VMT proportion increases to 3.5%, and EVs are introduced into Delaware's vehicle mix. EVs account for 1.75% of Delaware's VMTs in the Full Implementation scenario. This scenario reduces CO_2 emissions by 102,870 mtCO_2 from 2010 levels (as shown in Table 5-5). The AFV proposals in the Modest and Major Commitment strategies are modeled on STAPPA/ALAPCO projections, while the AFV strategy in the Full Implementation strategy follows the most aggressive projection of the Interlaboratory Working Group Study (IWG 1997).

3. Diffusion of TCM measures

Table 5-6
Summary of TCM Packages for Scenario Analyses of the Delaware Transportation Sector

Strategies	Percent Reduction In VMTs	Percent Reduction from 2010 Transportation Sector Forecast
Modest Commitment	2.9%	6.5%
Major Commitment	15.9%	13.2%
Full Implementation	20.4%	22.7%

Transportation control measures (TCMs) represent a broad range of policy tools including pricing, ridesharing, alterations to work patterns, and transit improvements. The packages vary in the Action Plan by implementation scenario. Itemized TCM packages with their respective VMT reductions are listed in Table 5-7.

Under the Modest Commitment strategy for TCMs, five measures – ridesharing, transit improvements, creation of restricted high-occupancy vehicle (HOV) lanes, the use of compressed work weeks as an option for some organizations and telecommuting (where practicable) - produce a VMT reduction of just under 3%.[9] This amounts to a transportation sector emissions reduction of almost 7% by 2010. By adding parking pricing, congestion pricing, non-work parking pricing and pay-as-you-drive insurance measures, the TCM package for the Major Commitment strategy produces approximately a 13% reduction in CO_2 emissions from the BAU scenario of 2010. By increasing the participation in telecommuting and the intensity of parking and congestion pricing, the Full Implementation strategy produces approximately a 23% reduction in CO_2 emissions from the BAU scenario of 2010 (as shown above in Table 5-6).

The TCM packages were developed from discussions of the transportation sector committee of the Delaware Climate Change Consortium. The strategies represent a spectrum of policy options available to Delaware. A review of other states' Action Plans indicates the alternatives analyzed for Delaware are within the range of what is being considered in U.S. state transportation conservation policy.

[9] A major study regarding the impact of telecommuting on VMTs was conducted by the Wisconsin Department of Natural Resources, *Wisconsin Greenhouse Gas Emissions Reduction Cost Study* (1998).

Table 5-7

Transportation Control Measures (TCM) Scenarios

Modest Commitment		Major Commitment		Full Implementation	
TCM	**VMT % Reduction**	**TCM**	**VMT % Reduction**	**TCM**	**VMT % Reduction**
Area-Wide Ridesharing	0.5	Area-Wide Ridesharing	1.0	Area-Wide Ridesharing	1.0
Transit Improvements	0.5	Transit Improvements	1.0	Transit Improvements	1.0
HOV Lanes	0.3	HOV Lanes	0.3	HOV Lanes	0.3
Compressed Work Week	0.6	Compressed Work Week	0.6	Compressed Work Week	0.6
Telecommuting	1.0	Telecommuting	3.0	Telecommuting	5.0
		Parking Pricing (work)	1.5	Parking Pricing (work)	3.0
		Parking Pricing (non-work)	3.5	Parking Pricing (non-work)	3.5
		Congestion Pricing	3.0	Congestion Pricing	4.0
		Pay-as-You-Drive Insurance	2.0	Pay-as-You-Drive Insurance	2.0
TOTAL	**2.9**	**TOTAL**	**15.9**	**TOTAL**	**20.4**

Results

Results for the transportation sector CO_2 reductions are derived by combining the fuel economy, AFV, and TCM tools into implementation scenarios. Improvements in fuel economy of light-duty vehicles contribute the most to CO_2 mitigation, while also being the most cost-effective. TCMs have almost the same potential, while AFVs emerge as a relatively expensive measure. The various combinations of policy tools, which form the Action Plan's three implementation scenarios, are depicted in Table 5-8.

Table 5-8

CO_2 Reduction Scenarios for the Delaware Transportation Sector

Scenario	Fuel Economy Strategy	AFV Strategy	TCM Strategy
Modest Commitment	2 mpg increase for LDVs	1.2% CNG vehicles	2.9% VMT reduction
Major Commitment	5.9 mpg increase for light-duty cars, 3.4 mpg increase for light-duty trucks	2.1% CNG vehicles	15.9% VMT reduction
Full Implementation	7.7 mpg increase for light-duty cars, 6.6 mpg increase for light-duty trucks	3.5% CNG & 1.75% EVs	20.4% VMT reduction

The Action Plan analyzes each scenario for its impact on fuel consumption and CO_2 emissions in 2010. The Modest Commitment scenario achieves a 10% reduction below BAU; the Major Commitment scenario produces a 24% reduction, and the Full Implementation scenario results in a 36% reduction. The reductions achieved by each scenario are presented in Table 5-9.

Table 5-9

CO_2 Reduction Scenario Results for the Delaware Transportation Sector

Scenario	CO_2 Reduction from 2010 Forecast (metric tons)	Percent Reduction from 2010 Transportation Sector Forecast
Modest Commitment	508,970	10%
Major Commitment	1,166,970	24%
Full Implementation	1,778,360	36%

Conclusion

Emissions from the sector were 4.0 mmtCO_2 in 1990 and are forecast to increase by more than 20% to 4.9 mmtCO_2 by 2010 under the BAU scenario. Emissions reductions under the Modest Commitment scenario result in 4.4 mmtCO_2 by the target year. While under the more effective Major Commitment scenario, the emissions are 3.7 mmtCO_2 by 2010. The Full Implementation scenario would further reduce emissions to 3.1 mmtCO_2. Using the Major Commitment scenario as the benchmark for action, emissions in the transportation sector can be reduced by 24% from the forecast level for 2010. This is equivalent to an 8% reduction from 1990 levels for this sector.

Effective measures to reduce emissions are strongly influenced by cost-effectiveness, available technology, and the relatively short time between the present and the target year of 2010 for achieving change. Improving fuel economy emerges as a cost-effective means to reduce emissions. However, its achievement depends heavily upon federal action. TCMs have been shown to have high potential, but involve considerable behavioral change. The State can play a major role in formulating policies to realize the TCM strategies described in the Action Plan, especially if it adapts the recommended Major Commitment package as part of land use planning reforms to curb sprawl in the State. The proposed AFV penetration into Delaware's vehicle fleet is relatively small and therefore has a lesser impact on CO_2 emissions. However, a larger number of AFVs in the vehicle fleet could greatly lower emissions. Market expectations of the automobile industry, technology development, and federal and state policy will all affect early rates of market penetration of this promising option.

As noted in the introduction of this chapter, the policy tools identified in the Action Plan for the transportation sector will need a general planning framework to inform their development. For this reason, the Consortium believes that all levels of Delaware government will need to cooperate in reforming land use planning so that the State's development is informed by principles of growth management (see CEEP 1996).

Specific policy actions to support the adoption of the analyzed measures for CO_2 emission reduction in the sector are identified in Chapter 9.

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CHAPTER 6
ELECTRIC UTILITY SECTOR
CO_2 EMISSION REDUCTION STRATEGY

Key Findings

Figure 6

Utility Sector CO_2 Emission Projections Through 2010

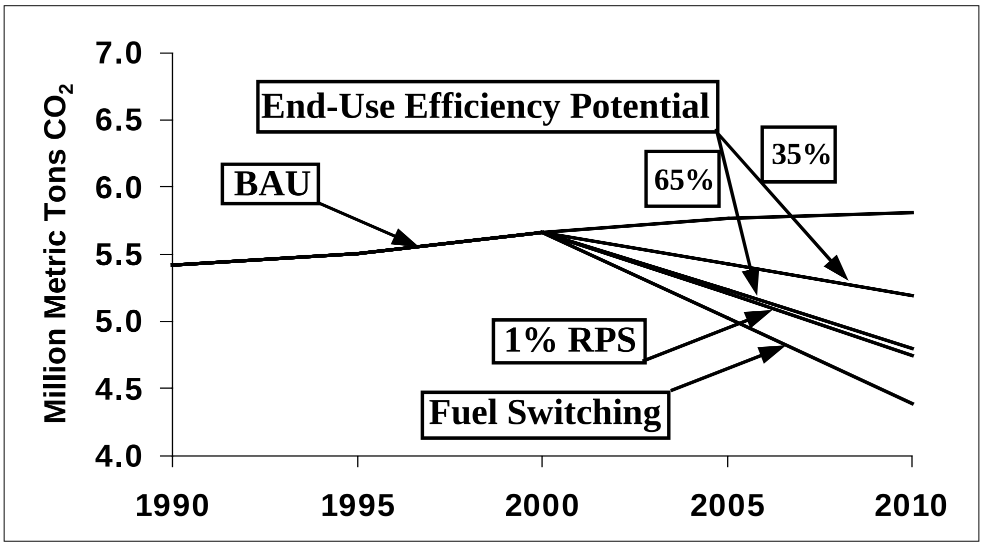

Table 6-1

Summary of Scenario Analyses to Reduce CO_2

in Delaware's Utility Sector

	Energy Use (trillion Btus)	GHG emissions ($mmtCO_2$)
1990	61.7	5.4
2010 BAU	85.0	5.8
Implementation Scenarios		
1% RPS	84.3	5.75
Fuel Switching	81.3	5.5
Avoided Electricity Losses – 35% / 65% Potential	78.5 / 72.9	5.2 / 4.8
Combined Implementation (with 65% End-Use Efficiency Potential)	68.6	4.4

Note: The summary data in Table 6-1 are sectoral emissions in 2010 resulting from the implementation of each measure and end-use scenario, whereas Figure 6-1 projections (shown above) indicate the cumulative emission reductions.

For the electric utility sector, three emission mitigation tools were analyzed: a 1% renewable portfolio standard (RPS), fuel switching, and the reduction of electricity losses associated with a 35% and 65% implementation of residential, commercial, and industrial electricity-related emission mitigation measures. Implementation of a 1% RPS scenario achieves a 1% reduction in forecasted 2010 emissions. Fuel switching of a coal-fired facility (due for repowering during the forecast period) results in a 6% reduction of emissions. Avoided electricity losses from energy efficiency actions in the end-use sectors (see Chapters 2-4) reduce emissions by 18% using the 65% (Major Commitment) scenario, and nearly 10% for the 35% (Modest Commitment) scenario. If all three mitigation tools are implemented together, the result will be a 19% reduction from the 2010 BAU (assuming a 65% implementation rate in the end-use sectors – see Figure 6-1 and Table 6-1).

Background

Improving the electricity sector's overall energy efficiency is essential for achieving Delaware's greenhouse gas emission reduction goal. Overall, the electric utility sector accounted for 46% of the state's total CO_2 emissions in 1995 (which substantially exceeded the national utility sector average of 35%). The sector represents the largest single source of CO_2 emissions in the State. Under the BAU scenario, Delaware's greenhouse gas emissions from this sector will increase by more than 7% to 5.8 mmtCO_2, between 1990 and 2010.

The electric utility sector in Delaware includes 30 generation units with a nameplate capacity of 2,287 MW. The bulk of electric generation and CO_2 emissions, however, is attributable to 11 generation units, 10 of which are owned and operated by Conectiv, the state's primary electric utility.

The electric utility industry is one of the largest consumers of fossil fuels in the U.S. (28% of national fossil fuel consumption and 88% of coal consumption) and collectively is the largest source of CO_2 emissions, accounting for 35% of total U.S.

emissions in 1996 (USEPA 1999). In 1996, U.S. CO_2 emissions from the utility sector totaled 516.8 mmtCO_2, an 8% increase over the 1990 total of 476.8 mmt. Electricity generation from coal is the primary source of national CO_2 emissions from the utility sector, and has been increasing (USEPA 1999). In 1996 coal was used to produce 57% of electricity nationally and coal-fired power plants accounted for 89% of utility sector CO_2 emissions. During 1990-1996, CO_2 emissions from coal-based generation increased 13%, accounting for 56% of the overall national increase in CO_2 emissions from fossil fuel combustion (USEPA 1999).

Reductions in electrical demand from other sectors – residential, industrial, and commercial – as a result of end-use efficiency improvements projected by the Action Plan, reduce the utility sector's energy consumption and therefore lower greenhouse gas emissions. Emission reductions in the other sectors result in a reduced demand for electricity generation and these savings are counted as reduced end-use demand in each sector. Since each kWh saved at a consumer site avoids the equivalent of 2 kWh of energy used to generate, transmit and distribute a kWh of electricity to consumers, the utility sector experiences 2-to-1 energy savings at its own facilities per customer-conserved kWh. These savings (known as "avoided electricity losses" because energy that would be consumed to generate and deliver a kWh of electricity is avoided) translate as avoided CO_2 emissions from power plants. Analysis of this sector takes into account the avoided CO_2 emissions by power plants associated with potential reductions in electricity demand within Delaware when forecasting future electricity use.

Nationally, electricity utilities are going through a period of restructuring in which both retail and wholesale transactions of the market are subject to generation deregulation. The Federal Energy Regulatory Commission has already established competition in wholesale electricity markets. Delaware and several of its neighboring states that are connected to the PJM Interconnection (the largest power pool in the U.S.) have all passed deregulation laws and are implementing retail competition initiatives. The PJM power pool has now become an independent system operator in anticipation of regional deregulation.

Sources and Trends of Utility Sector Emissions

Greenhouse gas emissions released by the electric utility sector are traceable to fossil fuel combustion in power plants, which accounts for the largest volume of fuel consumed among all sectors in Delaware. The main fuels consumed are bituminous coal, fuel oil (No. 6 and No. 2), and natural gas. In 1997, coal accounted for 63% of generation in the State, natural gas for 20% and fuel oil for 18%. The combustion of coal was the source of approximately 75% of the sector's CO_2 emissions. Combustion of fuel oil accounted for nearly 16% of sectoral CO_2 emissions, while natural gas combustion was responsible for only 10% of the sectoral total.

The fuel mix of the sector will shape future emission patterns. Delaware is part of a national trend to replace coal with natural gas as a combustion fuel for electrical generation. This trend has implications for greenhouse gas emission rates, other pollutant outputs, and the energy efficiency and cost-effectiveness of the sector.

Emission factors vary widely by fuel and plant. In 1997 Conectiv's average CO_2 emission rate for its system (this includes all plants throughout its three-state jurisdiction) was 0.89 $mtCO_2$ per MWh. The 1997 average emission factor fuel for coal was 1.06 $mtCO_2$ per MW hour, while the emission factor fuel oil was 0.77 $mtCO_2$ per MWh, and under 0.46 $mtCO_2$ per MWh for natural gas. By comparison, Conectiv reported to the USEPA in 1995 that CO_2 emission rates for its system varied between 0.96-0.84 $mtCO_2$ per MWh during 1990-1994.

This disparity is due to the differing emission factors of the various fuels, as well as the difference in the age and efficiency of Conectiv's installed generation capacity. The oldest generation unit in Delaware (Edgemoor #3) began operation in 1954, while the state's most recently built plant (Hay Road #1-4) brought its final unit on-line in 1993. Not surprisingly, the Hay Road facility is the state's most efficient and cleanest, with a heat rate of 8,230 Btu/kWh, and an estimated 1997 CO_2 emission factor of 0.315

short tons of CO_2 per MWh. Conversely, Edgemoor #3, with a heat rate of 10,550 Btu/kWh, and a 1997 emission rate of 1.43 short tons of CO_2 per MWh of generation, has the highest CO_2 emission rate in the state. However, Edgemoor #3 is approximately 0.3 cents per kWh cheaper to operate, [1] (due primarily to the price disparity between coal and natural gas) and is operated at a higher capacity factor than the Hay Road plants. Thus, the intersection of fuel and plant economics plays a key role in determining CO_2 emissions connected to the generation of electricity in Delaware.

Projections

Conectiv's 1995 and 1996 Integrated Resource Plans (IRP) predict the retirement of 262 MW of coal-fired generating capacity between 2009-2011, and the addition of 910 MW of natural gas-fired generating capacity between 2005-2011.[2] The BAU scenario assumes that all potential additional generation capacity installed between now and 2010 will consist of technologies utilizing natural gas.[3] Conectiv's installed capacity is assumed to reach 2,821 MW in 2010, comprising the following mix of fuel sources: 1,421 MW from natural gas, 759 MW from coal, and 641 MW from fuel oil.

Emission factors for coal and oil-fired plants are assumed to remain the same as present over the forecast period to 2010. Improvements in natural gas generation technologies are expected to lower emissions for natural gas-fired plants (assuming combined cycle operation) to 0.24 metric tons of CO_2 per MWh (California Energy Commission 1998).

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[1] Of course, if the environmental costs of coal plants were included in the economic evaluation, a very different picture of operating costs would result. See, for example Hohmeyer (1992).

[2] Currently, Delaware imports approximately 20% of its electricity supply. Using the 1995 and 1996 IRPs as a guide to future utility decision making, it is expected that plants in the State will generate electricity at a level equal to the BAU forecast by 2010. Because of deregulation, this power may be marketed to other states and Delaware may receive power from plants in other states. USEPA guidelines for Action Plan development call for states to account for only the CO_2 released from in-state plants. Since Delaware will likely be neither a net exporter nor importer of electricity by 2010, this accounting guideline raises no problems for this analysis. However, if Delaware were to remain a net importer, it would be penalized by this procedure since it would not receive credit for avoided CO_2 from electricity losses that would be avoided by end-use efficiency improvements greater than the in-state generation rate.

[3] There are no plans by Delaware's municipal utilities or its electric cooperative to build new power plants in the State. For this reason, the analysis in the Action Plan focuses on the plants under the jurisdiction of the State's investor-owned utility.

Using Delaware's Econometric Model to build equations to forecast electricity consumption in the state, a BAU electricity demand of 13,185,000 MWh is expected by 2010. Given the anticipated installed capacity and plant utilization rates based on current practice, the majority of electricity generated is predicted to come from natural gas units (62%), followed by coal (33%), and fuel oil (6%). Under this 2010 projection, the utility sector is expected to emit 5.8 mmtCO_2 with a system-wide emission rate of 0.4 mt of CO_2/MWh.

Despite the forecasted increase in generation using natural gas, the majority source of sectoral CO_2 emissions will continue to be from coal combustion. Under the BAU scenario, coal-fired plants will provide 33% of total generation but cause 65% of the sector's CO_2 emissions. Natural gas combustion, while accounting for nearly two-thirds of generation, will only be responsible for 26% of CO_2 emissions. Fuel oil will account for 6% of the total generation and 9% of CO_2 emissions.

Methodology

A unit-by-unit analysis of all major electric generation units in Delaware was conducted. Data concerning annual generation, emissions, and marginal cost of generation were collected from the USEPA, EIA and Conectiv. Primary sources included: *Continuous Emission Monitoring Database* (USEPA 1999); *Electric Generator Data 1997* (EIA 1999a)*; Inventory of Power Plants* (EIA 1999b); *1999 Fuel Use Forecast* (Conectiv 1998); *1996 Integrated Resource Plan* (Delmarva Power 1996)*; Greenhouse Gas Emissions Reduction Strategies for California, Volume 1* (California Energy Commission 1998). Other background information utilized: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1996* (USEPA 1998), *Wisconsin Climate Change Action Plan* (Wisconsin Department of Natural Resources 1998).

Data from these sources were utilized to determine or calculate gross generation, emission factors, capacity factors and other pertinent operational data for each major generation unit in the State, using 1997 as the reference year. Recent historical data were consulted in order to assure that data from the reference year did not contain significant operational anomalies. The unit-specific data were then used to determine the operational and environmental characteristics of Delaware's generation portfolio, enabling the Action Plan to construct least-cost options for supply-side CO_2 mitigation. The unit-specific analysis focused on fuel switching and environmental dispatch options, which could be employed utilizing current generation capacity. The operational profile also allowed the Action Plan to generate a percent reduction in CO_2 emissions from the implementation of a renewable portfolio standard and the implementation of electricity efficiency measures within other sectors.

As a part of normal operating procedure, the electricity utilities in Delaware and the neighboring states of Pennsylvania, Maryland and New Jersey operate within an interconnected pool system that crosses state boundaries and dispatches units under complex rules and procedures. The PJM Interconnection determines the dispatch order for power plants operating in these states. At this time, no individual state can determine the dispatch order for plants within their borders. For this reason, the Action Plan reviews the possibility of an environmentally-based dispatch policy but did not include it as a CO_2 mitigation tool.

For the calculations regarding Delaware, CO_2 emissions regarding electrical generation in Delaware equal the projected emissions of plants expected to be operating within the State. This follows USEPA's guidelines.

Analysis of Options

Four GHG mitigation options were examined: avoided CO_2 emissions at power plants associated with a 35% and 65% implementation of end-use efficiency measures identified by the Action Plan for electricity-using equipment in the residential, commercial, and residential sectors (see Chapters 2-4 for details); fuel switching; and implementation of a renewable portfolio standard. An investigation of environmental dispatch operational procedures is also described. This could be a useful tool in the event that the projected development of natural gas-fired units does not fully materialize. This option does not figure into the Action Plan scenarios to reduce CO_2 emissions from this sector for the reason stated above.

End-use efficiency measures in other sectors involve a wide range of technologies that serve to reduce electricity demand (commonly referred to as 'load'). Reductions in electricity demand in the industrial, residential, and commercial sectors must be factored into the future demands on the electricity utility sector. Reduced load results in a reduction in power plant output and CO_2 emissions from the utility sector.

If 65% of the electricity savings identified in Chapter2-4 is realized, a load reduction of 3 million MWh is projected for 2010. The attendant CO_2 emission reductions due to avoided electric losses would total 1.1 mmtCO_2, given the projected utility sector fuel mix. Under a 35% implementation scenario for electricity efficiency, the reduced load falls to 1.6 million MWh and avoided CO_2 emissions are reduced to 0.6 mmtCO_2.

Changing the fuel used within an existing generating plant, which can be achieved by altering or replacing existing equipment, is known as 'fuel switching.' A generation unit was identified in a technical report by Conectiv (See its Integrated Resource Plan Report in 1996 under its prior corporate name of Delmarva Power) as a primary candidate for fuel switching because repowering from coal to natural gas would involve only relatively minor alterations. As a result, this unit was chosen as the least-cost option with which to investigate the fuel-switching scenario. According to the Action Plan analysis, switching the plant identified by Conectiv to natural gas would result in a CO_2 emission offset of 0.3 mmtCO_2 by the year 2010. This analysis applied 1997 generation data and emission factors, and assumed that fuel switching to natural gas would produce an emission factor of 0.5 short tons of CO_2 per MWh.

It is indicative of the scale of energy use within the electricity utility sector that switching one plant from coal to natural gas would result in a saving of 6% in the CO_2 emissions forecast for this sector under the BAU scenario for 2010.

The renewable portfolio standard (RPS) measure in the Action Plan assumes implementation, either through regulatory or legislative mandate, of a policy requiring that 1% of all electricity generated in Delaware must use renewable sources of energy. Technologies which could be utilized to meet this standard include: photovoltaics, solar thermal technologies, wind power, fuel cells utilizing hydrogen produced from renewable sources, or sustainable biomass. Implementation of the RPS would result in a 1% reduction in the sector's CO_2 emissions, totaling 0.06 mmtCO_2 based on the anticipated 2010 fuel mix.

Utilities and their power pools employ a process called 'least-cost dispatch' to determine which generation plants will run, and in what order, in response to prevailing system requirements. In effect, the allocation of electrical supply from the individual plants in a generating system is determined by a hierarchy whose order is determined by specific characteristics. This involves assessing system reliability to determine which plants must be available to meet loads, while maintaining the necessary voltage and frequency standards. Electricity is then dispatched from specific plants on a marginal cost basis to meet demand

An alternative approach is the environmental dispatch model. This approach incorporates the relative fuel efficiency and emission factor characteristics of various generation plants into the dispatch equation. Under an environmental dispatch scenario, plant dispatch would be determined primarily by system reliability requirements, followed by environmental performance, and then cost. The dispatch of plants would attempt to maximize environmental benefits in relation to additional marginal cost. Therefore, plants with equivalent environmental characteristics would be dispatched on a strictly marginal cost basis, while plants with marginally beneficial environmental characteristics and substantially higher generation costs would not move up in the dispatch hierarchy.

Environmental dispatch can offer substantial CO_2 offsets at low cost. An analysis for this Action Plan of an environmental dispatch scenario, utilizing individual plant data, determined that important CO_2 offsets could be achieved at low cost. The environmental dispatch scenario used the Hay Road natural gas plant and the Edgemoor #5 fuel oil/natural gas unit as baseload (65% capacity factor), rather than intermediate load plants (1997 capacity factor was utilized as a reference to determine available excess generation capacity). The shift in generation for these units was modeled for 1999, utilizing Conectiv's 1999 fuel use projection report to determine the marginal cost of CO_2 displacement. A preliminary analysis by CEEP suggested that a CO_2 emission offset of 0.95 mmtCO_2 could be achieved at modest cost. To implement this option, the PJM Interconnection, to which Conectiv belongs, would have to agree to the dispatch formula used in this analysis.

The results of this analysis are not included in the Action Plan at this time because the Action Plan can be achieved through measures that depend on State action only. However, the strategy is reported here for future consideration in the event that PJM or the federal government embraces environmental dispatch as a policy tool.

Results

Carbon dioxide emission reduction in the electric utility sector is derived in this Action Plan by combining a 1% renewable portfolio standard, fuel switching, and avoided power plant emissions associated with end-use efficiency improvements. A 65% implementation scenario (corresponding to the Major Commitment scenario discussed in Chapters 2-4) for end-use efficiency upgrades in the residential, commercial and industrial sectors achieves emission reductions of 1.1 mmtCO_2, given the projected utility sector fuel mix. For a 35% implementation scenario involving end-use electricity efficiency gains detailed in the Modest Commitment scenario (see Chapter 2-4), 0.6

$mmtCO_2$ are avoided at power plants. Fuel switching would result in a CO_2 emission offset of 0.3 $mmtCO_2$ by the year 2010. Implementation of a 1% RPS would result in a 1% reduction in the sector's CO_2 emissions, totaling 0.06 $mmtCO_2$ based on the anticipated 2010 fuel mix. Thus, 1.0-1.5 $mmtCO_2$ emissions can be avoided in the utility sector by following the Action Plan's recommended measures for this sector.

Conclusions

In 1990, the utility sector produced emissions of 5.4 $mmtCO_2$ and these are forecast to increase by 20% to 5.8 $mmtCO_2$ by 2010 under the BAU scenario. Under the Combined Implementation scenario (with implementation of 65% of end-use electricity efficiency upgrades identified by DCCAP), emissions are reduced to 4.4 $mmtCO_2$, which is a 24% reduction from the forecast level for 2010. This is equivalent to a 19% reduction from the 1990 level for this sector.

Measures utilized in this sector would have notable synergistic benefits by substantially reducing the point source emissions of criteria pollutants such as SO_2, NO_x, and PM_{10} particulates within the State, in addition to lowering CO_2 emissions. Implementation of these measures would improve air quality within Delaware and aid the State in meeting its obligations under the Clean Air Act. At the same time, Delawareans would be benefited by a more competitive State economy using efficient, environmentally sound technology. In this respect, implementation of DCCAP's utility sector strategy may be justified on the "no regrets" criterion of providing net economic benefits, even without consideration of its CO_2 effects. Specific policy actions to support the adoption of the analyzed measures for CO_2 emission reduction in the sector are identified in Chapter 9.

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CHAPTER 7
WASTES AND FORESTS SECTORS

Introduction

Efforts to reduce GHG emissions through waste reduction and efforts to increase the carbon sequestration rates of forest sinks are cross-sectoral in nature, encompassing the activities of all sectors of the society (i.e., residential, commercial, transportation, and industrial). A comprehensive response to climate change must include initiatives to reduce greenhouse gas emissions through better waste management and to sequester CO_2 by expanding forest sinks.

Waste reduction and sink improvements are discussed below in separate sections. For each section, an overview is first presented, followed by a description of the sources and trends of emissions/carbon sequestration and the current status of policy in Delaware. In the final section of the chapter, the results of the Action Plan concerning this sector are summarized.

WASTES SECTOR
EMISSION REDUCTION STRATEGY

Key Findings

Figure 7-1

Wastes Sector CO_2 Emission Projections Through 2010

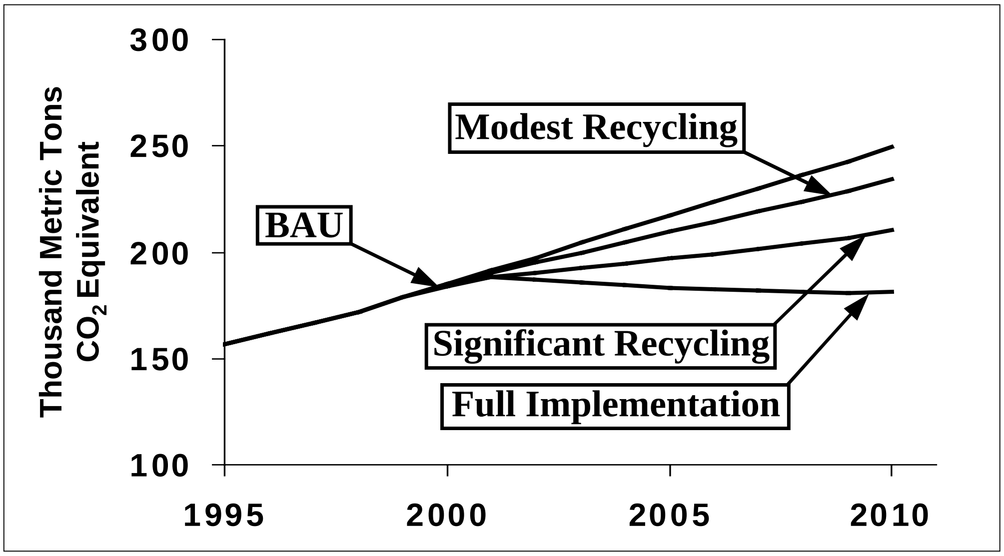

Table 7-1

Results from Projected Waste Reduction Scenarios

Scenarios	GHG Emissions ($mtCO_2$ equivalent)	Percent Reduction in Emissions
1995	156,720	NA
2010 (BAU) Scenario	249,840	NA
Modest Recycling Scenario	234,570	6.11%
Significant Recycling Scenario	210,159	15.88%
Full Potential Waste Reduction Scenario	181,362	27.41%

The CO_2 equivalent emissions from municipal waste are projected in the business-as-usual (BAU) scenario to increase steadily through 2010. Three alternative recycling scenarios are considered to reduce the waste stream. Each of these scenarios allows a reduction in CO_2 equivalent emissions in 2010 compared to the BAU projection. These results are reported in Table 7-1 and are illustrated in Figure 7-1.

Background

The two primary greenhouse gases emitted from municipal waste are methane (CH_4) and carbon dioxide (CO_2). Both CH_4 and CO_2 are produced by the decomposition of organic wastes in the anaerobic environment of landfills.[1]

The Solid Waste Management Branch of the Division of Air & Waste Management in Delaware's Department of Natural Resources and Environmental Control (DNREC) regulates the management of solid waste in Delaware. This branch also oversees the solid waste reduction, reuse, and recycling programs in the State. Title 7, Chapter 64 of the Delaware Code, in 1975, designated the Delaware Solid Waste Authority (DSWA) the sole entity with responsibility for planning and implementing solid waste management throughout Delaware. DSWA receives 100% of the solid waste generated from state, county and municipal facilities, and residential communities. Major industries in Delaware must have their own private waste disposal facilities.[2]

There are currently three DSWA landfills active in Delaware — Cherry Island Landfill (CIL), the Central Solid Waste Management Center (CSWMC), and the Southern Solid Waste Management Center (SSWMC). The Pigeon Point Landfill (PPLF) was closed in 1985, but still emits both CH_4 and CO_2. These four landfills contain only municipal solid waste (MSW) taken from the residential and commercial sectors.

Data used to analyze MSW in Delaware were provided by DSWA. The U.S. Environmental Protection Agency (USEPA) Landfill Gas Emissions Model Version 2.01

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[1] The organic materials responsible for CH_4 emissions include yard waste, household garbage, food waste, and paper. When deposited in landfills, these organic materials decompose aerobically (in the presence of oxygen), and are then attacked by anaerobic bacteria and converted into substances such as cellulose, amino acids, and sugars. These substances are further broken, through a series of processes, into stabilized organic materials and a biogas (50% CO_2 and 50% CH_4 by volume — see USEPA, http://www.epa.gov/globalwarming/inventory).

[2] There are seven industrial landfills in Delaware. Delaware Recyclable Products, Inc. operates one site holding its waste. Conectiv, the state's largest electric utility, manages two sites holding its ash waste. The DuPont Company manages two sites holding its sludge and ash wastes. Star Enterprises also manages two sites that contain its sludge and ash wastes (DNREC, http://www.dnrec.state.de.us).

was used to calculate the CO_2 equivalent emissions for both the BAU and the three alternative scenarios (discussed below).

Sources and Trends of Emissions

In 1990, 266 million metric tons of municipal solid waste (MSW) were generated in the U.S. (USEPA 1998), 71% of which were disposed in landfills (*Biocycle* 1997). Landfills account for approximately 36% of the total CH_4 emissions in the country, making them the largest anthropogenic source (USEPA 1999). In the U.S., MSW landfills account for about 93% of the total landfill emissions, while industrial landfills account for the remaining 7% (USEPA 1999). Of the more than 6,000 landfills throughout the country, the 1,300 largest sites receive over 50% of the waste and generate most of the landfill-attributed emissions (USEPA 1999).

Delaware's CO_2 equivalent emissions (these include CH_4 releases calculated in CO_2 equivalent units), since 1966, have generally increased. The annual additions of waste at each of the four landfills have increased emissions, while recent CH_4 flaring has decreased CH_4 emissions.[3] Therefore, for a brief period in the late 1980s and early 1990s, emissions decreased due to the CH_4 flaring by DSWA. Delaware currently landfills 63.7% of the total solid waste generated in the State, while 33.7% is incinerated and 2.5% is recycled (Drew Sammons, DSWA).

Projections

The BAU scenario was developed in order to project CO_2 equivalent emissions in the event that no additional efforts were made to reduce the amount of waste entering landfills. This scenario assumes that 2.5% of the total MSW stream will continue to be recycled until 2010 through DSWA's Recycle Delaware program. The percentage of material landfilled and incinerated was also assumed to remain the same under the BAU

[3] PPLL opened in 1966 and began flaring in 1988; CSWMC opened in 1982 and began flaring in 1990; CIL opened in 1986 and began flaring in 1990; and SSWMC opened in 1986 and began flaring in 1994.

scenario, while the total amount of MSW is assumed to steadily increase in proportion to the growth in Delaware's population.

In 1995, 156,718 mtCO_2(e) were emitted from the CIL, CSWMC, SSWMC, and PPLF landfills. Under the BAU scenario, these four landfills are projected to emit 249,840 mtCO_2(e)[4] in 2010.

Current Status of Policy in Delaware

The State of Delaware has enacted three separate policies to address waste management issues (DSWA 1994):

- Bi-County Recycling Project (1988), which directed DSWA to implement a Material and Energy Recovery Program for Kent and Sussex Counties;
- Program for Infectious Waste (1989), a project which directed DSWA to implement a statewide infectious waste management program; and
- Recycling and Waste Reduction Project (1990), which directed DSWA to implement a statewide recycling and waste reduction program.

There is currently no incineration in the State of Delaware. The 33.7% of MSW generated in Delaware that is incinerated is contracted out to Chester, Pennsylvania.

Recycle Delaware operated by DSWA as a result of the 1990 law, provides Delawareans with voluntary drop-off points for recyclable materials across the state. Delaware does not have a mandatory recycling laws. In 1995, New Jersey recycled approximately 60% of its total solid waste generated, in part due to a mandatory recycling law. New Jersey has established a goal of recycling 65% of its solid waste by December 31, 2000 (New Jersey Bureau of Recycling and Planning 1999).

[4] The CO_2 equivalent measurement includes the CH_4 and the CO_2 emitted from the four landfills, as well as the CO_2 emitted as a by-product of CH_4 flaring.

There has been an effort in Delaware to implement market-based policies that reduce the amount of waste received by landfills. For example, the Delaware Economic Development Office (DEDO) and the Department of Natural Resources and Environmental Control (DNREC) have embarked upon a Green Industries Initiative to promote the use of recycled materials and increased recycling of waste generated within Delaware's manufacturing sector through corporate tax credits and reductions in the gross receipts tax for source reduction and recycling activities.

Methodology

The Action Plan utilized the USEPA Landfill Gas Emissions Model Version 2.01 to calculate both the CH_4 and the CO_2 emissions from the four active landfills in Delaware (CIL, CSWMC, SSWMC, and PPLF) for the BAU and the three alternative scenarios. In order to estimate annual CH_4 and CO_2 landfill emissions, the amount of refuse in place for each of the four active landfills was entered into the model. Actual data were used through 1998. Projections were made to 2010 based upon Delaware population projections. In a second step, CO_2 emissions from DSWA's CH_4 flaring process were estimated. Flaring reduces the amount of CH_4 that enters the atmosphere, while at the same time emits additional amounts of CO_2. The final step is to sum the amount of CH_4 emitted from the landfills after flaring, the amount of CH_4 emitted from the landfills, and the amount of CO_2 released during the flaring process. See Appendix O for a detailed account of the methodology used.

Analysis of Options

Recycling was the primary measure evaluated in the Action Plan to promote waste reduction. Three scenarios were explored, each of which projected the results of additional recycling efforts in the MSW management program in Delaware. These three scenarios are further described in Appendix P.

Modest Recycling Scenario

The Modest Recycling scenario assumes that the percentage of the MSW stream recycled through DSWA's Recycle Delaware program will gradually increase to 15% in 2001 (5% in 1999, 10% in 2000) and remain at 15% until 2010. An increase in the percent recycled will be accompanied by a corresponding decrease in the amount of material landfilled, while the incineration rate is assumed to remain the same. This scenario anticipates that DSWA achieves less than half of its goal of recycling 35% of Delaware's waste stream by 2001.

Significant Recycling Scenario

The Significant Recycling scenario reflects DSWA's goal of recycling 35% of the MSW stream through its Recycle Delaware program in 2001 (seen as a gradual increase from 10% in 1999 to 20% in 2000 and 35% in 2001 — see DSWA, 1994).

Full Potential Waste Reduction Scenario

The Full Implementation scenario also reflects DSWA's goal of recycling 35% of the total MSW stream through Recycle Delaware (i.e., 25% residential and 10% nonresidential). However, this scenario anticipates an additional 25% recycling rate in 2001 due to the implementation of a Pay-As-You-Throw (PAYT)[5] program in Delaware (USEPA 1997). Thus, in 2001, 60% of the MSW stream is expected to be recycled and consequently diverted from the State's four landfills. This rate of recycling would put Delaware roughly at parity with New Jersey.

Results

Each of the three scenarios leads to reductions in CO_2 equivalent emissions from the BAU projections. Under the Modest Recycling scenario, the four landfills are projected to emit 234,570 mtCO_2(e) in 2010. This represents a 6% (15,270 mt) reduction from CO_2 equivalent emissions projected under the BAU for 2010. Under the Significant

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[5] Instead of paying for trash collection and disposal indirectly, the PAYT program prices each unit of trash separately. This gives an incentive for individuals and communities to reduce the amount of waste sent to landfills and to incineration (USEPA 1997).

Recycling scenario, these same four landfills are projected to emit 210,159 $mtCO_2(e)$ in 2010. This represents a 16% (39,681 mt) reduction from the BAU projection for 2010. Under the Full Implementation scenario, the four landfills are projected to emit 181,362 $mtCO_2(e)$ in 2010. This represents a 27% (68,478 mt) reduction from the BAU projection for 2010.

Given the current recycling situation in Delaware (2.6% of the MSW stream is recycled), the three alternative scenarios represent major shifts from the BAU. Obviously, new policies will be needed to realize such targets. Specific policy recommendations are identified in the final chapter of the Action Plan.

FORESTS SECTOR
CARBON SEQUESTRATION STRATEGIES

<u>Key Findings</u>

Figure 7-2

CO_2 Sequestration Capacity Through 2010 for Delaware's Forest Sinks

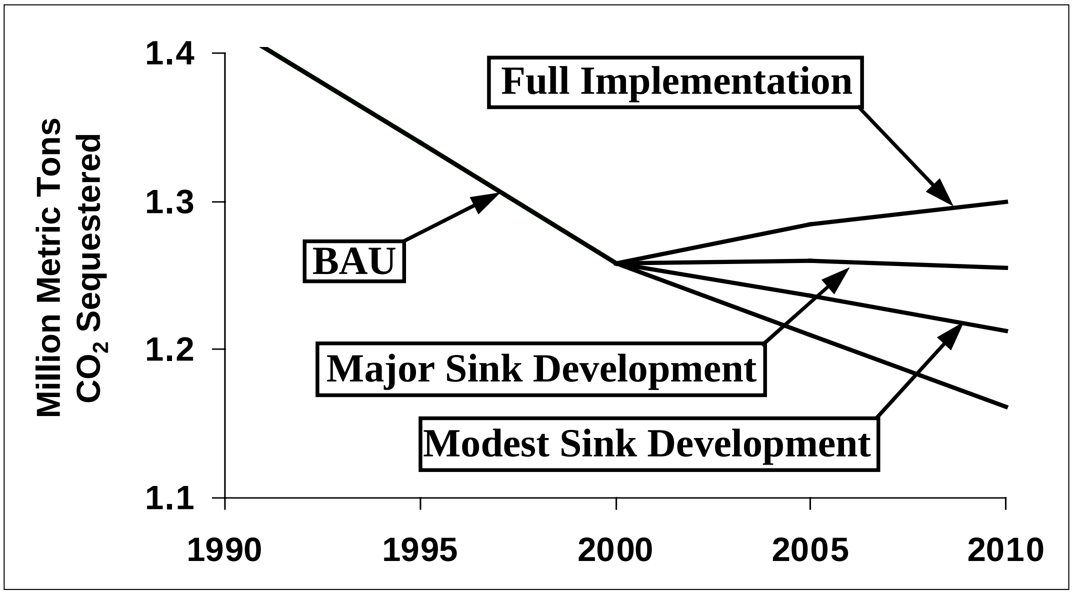

Table 7-2

Results from Projected Carbon Sequestration Strategies

for Delaware's Forest Sinks

Scenarios	**CO_2 Sequestered in 2010(mt)**	**Increase from BAU in 2010**
1990	1,420,000	NA
2010 BAU	1,161,242	NA
Modest Sink Development	1,212,207	4.4%
Advanced Sink Development	1,255,478	8.1%
Full Implementation	1,299,842	11.9%

Carbon sequestration is projected in the BAU case to decrease steadily from 1990 to 2010. Three alternative forest sink development scenarios are evaluated. Each of these scenarios shows an increase of CO_2 sequestered in 2010 compared to the BAU projection. These results are reported in Table 7-2 and are illustrated in Figure 7-2.

Background

Carbon sinks such as forestlands, wetlands, croplands, pasturelands and bodies of water[6] play a critical role in the reduction of GHG emissions. USEPA estimates that the annual net CO_2 flux in U.S forests offset about 14 % of the 1996 CO_2 emissions from fossil fuel combustion (USEPA 1998). In the State of Delaware, forests and wetlands are the primary carbon sinks.

Sources and Trends of Carbon Sequestration

Table 7-3 reports the aggregate land use and land cover changes of the state of Delaware in 1984 and in 1992. The preliminary estimates of Mackenzie and McCullough (1998) indicate a 9% decrease in forest acreage in Delaware between 1984 and 1992. Except for wetlands, the acreage of other potential sinks of Delaware also reduced. The USDA Forest Service inventory in 1992 indicates that 95.89 % of Delaware's forestlands were owned privately (See Table 7-4).[7] From 1992 to 1998, Delaware lost forestlands at a rate of 5,667 acres per year.[8]

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[6] The global carbon cycle is made up of large carbon flows and reservoirs. Billions of tons of carbon in the form of CO_2 are absorbed by the oceans or terrestrial sinks (forests and agricultural systems) or are emitted to the atmosphere annually through natural processes (USEPA 1998). As carbon reservoirs, terrestrial sinks store carbon mostly in soils. For instance, in forests ecosystems, 61% of stored carbon is found in forest soils, 29% in trees, and the remaining 10% in woody litter, debris and humus on the forest floor as well as understory vegetation (STAPPA/ALAPCO 1998). In agricultural systems such as croplands (soil sinks), CO_2 is stored as soil organic carbon (SOC). Wetlands also produce high rates of organic carbon accumulation, ten times as much organic soil carbon (OSC) as their more well-drained counterparts (Rabenhorst 1995).

[7] Mackenzie & McCullough's estimate (1998) is slightly lower than that of the USDA Forest Service. The discrepancy might be attributed to the fact that Mackenzie & McCullough did not include some wetlands which were forested (Austin Short, Delaware Department of Agriculture, personal communication).

[8] Using USDA Forest Service estimates of Delaware's forestlands in 1992 (389,000 acres) and the estimated acreage of Delaware's forestlands in 1998 (355,000 acres), the State lost forest areas at a rate of 5,667 acres per year or about 1.5 % annually between 1992 and 1998.

Table 7-3

Delaware Land-Use/Land Cover Changes, 1984 & 1992

	1984 Area (Acres)	Percent	1992 Area (Acres)	Percent
Residential	80,996	6.3%	120,808	9.4%
Commercial/Industrial	37,044	2.9%	59,356	4.6%
Recreation	8,045	0.6%	8,811	0.7%
Agriculture	599,109	46.7%	560,479	43.7%
Brushland	43,870	3.4%	22,957	1.8%
Forest *	380,684	29.7%	345,778	27.0%
Water	31,363	2.5%	46,275	3.6%
Wetland	96,077	7.5%	101,284	7.9%
Beach/Barren	3,684	0.3%	17,141	1.3%
Total	1,280,872	100.0%	1,282,887	100.0%

*Includes deciduous, coniferous, and mixed forests.
Source: Mackenzie, J. and McCullough (1998).

Table 7-4

Forest Land Area in Delaware and the U.S. by Ownership, 1992

	Delaware (1000 acres)	Percent	Total U.S. (1000 acres)	Percent
Public Forest				
Forest Service			139,944	19.0%
Other Federal *	2	0.5%	109,187	14.8%
Other Public	14	3.6%	64,747	8.8%
Total Public Lands	16	4.1%	313,878	42.6%
Private Forests				
Forest Industry	31	8.0%	71,209	9.7%
Other Private	342	87.9%	352,546	47.8%
Total Private Forests	373	95.9%	423,755	57.5%
Total Forest Lands	**389**	**100.0%**	**737,633**	**100.0%**

*Includes Bureau of Land Management, U.S. Park Service, U.S. Department of Defense and all other Federal ownership.
Source: USDOA Forest Service (1992).

Current Status of Policy in Delaware

The existing mix of economic incentives, regulation, and non-economic and voluntary programs of the State regarding carbon sinks (See Appendix Q) aim to achieve three interrelated goals:

(1) decrease the rate of loss of existing Delaware forest sinks (e.g., Delaware's Open Space Program);
(2) expand the storage base of Delaware forest sinks (e.g., Delaware Seed Tree Law and Delaware Forestry Practices Erosion and Sediment Law);
(3) support a reduction in energy demand through urban landscaping (e.g., Urban and Community Tree Planting Grants).

Delaware's Open Space Program[9] has helped to preserve 13,000 acres of land, and the Northern Delaware Rehabilitation Program restored nearly 10,000 acres of wetlands along the Christiana and Delaware Rivers in New Castle County. It is also estimated that 2,100 acres are reforested annually and another 1,700 acres are regenerated naturally (Abbott-Donnelly and Short, Delaware Department of Agriculture, personal communications). In 1998, considering reforestation and natural regeneration in the accounting of net acreage of standing forest, the total net loss of forest lands is 2,725 acres.[10]

In 1991, $530,000 in urban forestry grants was awarded to communities for tree planting and tree maintenance projects. The average cost for planting trees was $140-240

[9] The signing into law of the Land Protection Act (July 13, 1990) and Subchapter II of the Realty Transfer Tax Act created the Delaware Open Space Program. The Division of Parks and Recreation in the Department of Natural Resources and Environmental Control (DNREC) administers the program. Program funds support land preservation activities of DNREC's Division of Parks and Recreation and Fish and Wildlife, the Department of Agriculture's Division of Resource Management and the Department of State's Division of Historical and Cultural Affairs.

[10] The net acreage of standing forest is computed as the sum of the following: acres of existing rural/community/urban forest (355,000 acres) + acres of natural regeneration in open spaces and harvested rural forests (1,700 acres) + acres of artificial regeneration in open spaces and harvested rural forests (2,100 acres) – acres lost due to harvesting of rural forests (5,325 acres) – acres lost due to community/urban development (1,000 acres) – acres lost due to agricultural land conversion (200 acres) (Abbot-Donnelly, personal communication).

per acre.[11] In addition to State programs, the New Castle Conservation District has an urban forest cost-share program that promotes tree planting.

The State programs allow landowners with forested land to claim tax deductions or offer other economic incentives, such as the Commercial Forest Plantation Act and the Farmland Assessment Program. These programs encourage the retention of certain forms of forest cover. A mix of federal and states initiatives include economic incentives for forest protection through the Steward Incentive Program, Forest Incentive Program, Conservation Reserve Program, and Conservation Reserve Enhancement Program. The Delaware Center for Horticulture sponsors tree-planting and conservation easement programs, as well.

Methodology

Delaware's forest and urban tree CO_2 sequestration potential were evaluated. Other sinks were not analyzed due to insufficient data. The total CO_2 sequestered by forests and urban trees is the sum of the CO_2 sequestered by existing and growing forested communities coupled with the CO_2 sequestered by natural and artificial plantings (See Appendix R).

The basic structure of the BAU and the three alternative scenarios are described in Appendix S. There are three measures that are evaluated in each scenario: (1) urban trees planting, (2) harvesting of rural forests, and (3) urban conversion. It is assumed that natural regeneration of forests, artificial regeneration of forests, and annual loss of forests due to agriculture conversion remains constant until 2010.

[11] Austin Short of the Delaware Department of Agriculture has estimated that the cost to plant pine trees per acre is around $140. However, there are sites which needs additional work, and this could add an additional $100 per acre. This estimate does not include an allotment for personnel expenses.

BAU Case

It is assumed that there will be an annual net loss of forest acreage of 2,725 acres through 2010. This loss is projected even while it is assumed that 10,000 trees are planted annually through 2010.

Modest and Major Sink Development Scenarios

These scenarios would increase urban tree planting and slow down rural forest harvesting and urban conversion.

Full Implementation

This scenario would require a halt in urban land conversion through 2010, substantial urban tree planting and a substantial reduction in rural forest harvesting.

Analysis of Options

Table 7-5 shows the amount of CO_2 sequestered by Delaware's forest and urban trees for each scenario from 1990 to 2010. As shown in Figure 7-2, the forecasted decline in Delaware's forest and urban tree CO_2 sequestration capacity is slowed under the Modest Sink Development scenario. The Major Sink Development scenario has the potential to stabilize the declining carbon sequestration capacity between the range of 1.2 to 1.3 mmt. The Full Potential Sink Development scenario, on the other hand, reverses the decline in CO_2 sequestration capacity (See Figure 7-2).

Table 7-5

CO_2 Sequestered in Each Scenario

	Business-as-Usual (mt)	Modest Sink Development (mt)	Major Sink Development (mt)	Full Implementation (mt)
1990	1,420,020	1,420,020	1,420,020	1,420,020
1992	1,400,400	1,400,400	1,400,400	1,400,400
1998	1,278,036	1,278,000	1,278,000	1,278,000
1999	1,268,226	1,271,439	1,274,671	1,277,902
2000	1,258,460	1,265,081	1,271,611	1,278,157
2001	1,248,701	1,258,924	1,268,821	1,278,766
2002	1,238,950	1,252,966	1,266,299	1,279,728
2003	1,229,207	1,247,205	1,264,042	1,281,041
2004	1,219,474	1,241,640	1,262,050	1,282,703
2005	1,209,748	1,236,267	1,260,318	1,284,711
2006	1,200,031	1,231,083	1,258,843	1,287,060
2007	1,190,322	1,226,088	1,257,625	1,289,752
2008	1,180,620	1,2,21,278	1,256,659	1,292,780
2009	1,170,927	1,216,652	1,255,944	1,296,144
2010	1,161,242	1,212,207	1,255,478	1,299,842

Source: Appendix T

Conclusion

Emissions from the wastes sector totaled 156,720 $mtCO_2$ in 1995 and are forecast to rise to 249,840 $mtCO_2$ by 2010 under the BAU scenario. Adopting the Modest Recycling scenario results in emissions of 234,570 $mtCO_2$ in 2010, which can be further lowered using the Significant Recycling scenario to 210,159 $mtCO_2$. Under the Full Implementation scenario for waste reduction, emissions would be 181,362 $mtCO_2$ by 2010. Using the Major Commitment scenario as the benchmark for action, emissions in the wastes sector can be reduced by 16% from the forecast level for 2010.

Sequestration in carbon sinks was 1,420,000 $mtCO_2$ in 1990 and increases to 1,161,242 $mtCO_2$ in 2010 under the BAU scenario. Under the Modest Sink Development scenario, carbon sequestration increases to 1,212,207 $mtCO_2$ at 2010, and increases to 1,255,478 $mtCO_2$ by 2010 using the Major Sink Development scenario. Sequestration can improve to 1,299,842 $mtCO_2$ at 2010 under the Full Implementation scenario. Using the Major Sink Development scenario as the benchmark for action, emissions in the forest sinks sector can be reduced by 22% from the forecast level for 2010.

The wastes and forest sinks sectors complete the analysis of CO_2 emissions and storage attributable to human activities in Delaware. Whereas the other sectors analyzed for the Action Plan release CO_2 through production or consumption, this sector examines ways to reduce CO_2 releases across the other sectors and to enhance CO_2 absorption.

In terms of waste reduction, measures that cost-effectively reduce or eliminate waste at the source (i.e., source reduction/ resource reduction) are highlighted in the Plan. Measures analyzed to enhance Delaware's forest sink capacity include efforts to curb the amount of land converted for development purposes and increased tree planting. The success of the measures proposed for the wastes and forest sinks sectors will depend upon cooperation among the other sectors (residential, commercial, industrial, utility, and transportation) in meeting the targets identified by the Action Plan.

Waste reduction and forest sinks development offer many benefits in addition to CO_2 reduction/absorption, including improved air quality, enhanced biodiversity, and an overall increase in the quality of life of Delawareans. Specific policy actions to support the adoption of the analyzed measures for CO_2 emission reduction or sequestration are identified in Chapter 9.

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CHAPTER 8
PUBLIC EDUCATION AND OUTREACH

Introduction

Implementation of the Delaware Climate Change Action Plan (DCCAP) will require the participation, collaboration and cooperation of a broad spectrum of agencies, organizations and officials. In fact, it will require the participation of Delawareans in general. In order to be effective and to be sustained over time, such participation will have to be cultivated. A well-conceived public education and outreach program will be critical to efforts to implement the Climate Change Action Plan. This chapter describes a program for stimulating the interest of the wider public to take concrete actions as contained in the DCCAP.

Goal

The goal of the Education and Outreach Program for the DCCAP is to increase awareness among Delawareans about climate change, its potential environmental, social, economic and political impacts on the State of Delaware, and the need to reduce the emissions of the greenhouse gases which lead to climate change.

In seeking to realize this goal, efforts will be made to articulate and discuss the current state of knowledge of climate change and its impacts, as well as the uncertainties in climate science. It is considered important that these issues are brought to the fore so as to address public misgivings about climate change, as well as to elaborate the need to take action even in the face of uncertainty.

Target Audience

While it is important to reach out to all Delawareans to achieve the stated goal of this program, there are certain groups in the population who, by their daily activities, can make specific contributions in the area of greenhouse gas emissions reduction, and in developing an ethic of mitigation in the State. Within the context of this State-wide program, therefore, some activities will be specifically shaped to the needs and potential of particular groups of the population, along with those activities that focus on Delawareans as a whole. These target audiences include:

- Policy makers and administrators
- State agencies
- Developers and the construction industry
- Manufacturing, commercial, industrial, agricultural transportation and residential sectors
- Students (all levels)
- NGOs and community organizations
- Financial institutions
- The media
- Delawareans in general

The activities that will be developed for these target audiences are included in the statement of objectives below, and are elaborated as each objective is further developed in the respective components of this program.

Objectives

The specific objectives of the Education and Outreach Program are as follows:

1. To develop and publish a directory of sources of information on climate change, including an inventory of groups and agencies engaged in activities related to climate change;

2. To develop and disseminate educational materials on climate change in keeping with the goals of this program, and to promote the Delaware Climate Change Action Plan throughout the state;

3. To develop a website on the Climate Change Action Plan for the State of Delaware;

4. To convene a series of educational and information exchange forums (seminars, discussions, workshops, etc.) for target audiences and for specialized sectors addressed in the DCCAP;

5. To promote the diffusion of information on climate change in curricula of Delaware's schools; and

6. To develop activities specifically aimed at utilizing the mass media (TV, radio, and press) to help achieve the goals and objectives of this Education and Outreach Program.

A summary of these objectives and details on the activities and methods for achieving them are outlined in the attached Activity Matrix.

Program Details

Objective 1: Directory of Information Sources

Rationale:

An inventory of information sources and materials is one of the first steps to successfully implementing climate change education and outreach goals. Such an inventory allows individuals to locate existing information with relative ease.

This program component aims to create and publish an information directory which would serve as an inventory of existing sources for target audiences as they implement measures and policies to mitigate climate change in Delaware. The directory will also be used as an outreach tool to further educate individuals on climate change. Such a directory will include website addresses, current publications on climate change, and sources of contact for organizations, which address global climate change. All audiences are targeted.

Activities and Timeframe:

The project activities are divided into four phases: [1] Preparation, [2] Compilation and Publication, [3] Website Publication, and [4] Distribution. The first phase involves the preparation of an inventory of information sources, as well as briefs on various organizations, which provide information on climate change. The second phase is the compilation and publication of the information directory. The third phase works jointly with the website objective. The final phase involves the distribution of the information directory to all target audiences.

Monitoring and Evaluation:

The published information directory will be monitored through a structured questionnaire. The number of hits and feedback from users will serve to monitor the usability of the information directory published on the website.

Objective 2: Materials Production

Rationale:

The Delaware Climate Change Action Plan proposes many sector-specific strategies, which could be undertaken in order to mitigate global climate change in the State of Delaware. Given the strategies proposed in the Action Plan, all sectors will need practical information indicating *how* proposed measures and policies could actually be implemented. Thus, specialized information must be provided to target audiences to further implementation efforts.

This program component aims to develop and disseminate educational materials on climate change, which can be of use to each of the target groups during the implementation stage of the Climate Change Action Plan. The materials will be compiled from two sources: (1) already existing information, and (2) newly developed material. The outputs will include fact sheets, technical papers, reports, and other materials. All audiences are targeted.

Activities and Timeframe:

The project activities are divided into four phases: (1) identification, (2) compilation, (3) production, and (4) distribution. The first phase involves the identification of the types of materials needed by each of the target audiences in order to implement the measures and/or policies proposed in the Delaware Climate Change Action Plan. During the second phase, existing sources for material will be consulted in order to avoid duplication of information. Existing material will be compiled and organized in a way to serve the needs of the different target audiences. The third phase involves the production of new materials to complement the existing information. The final phase is the distribution of the materials to appropriate audiences.

Monitoring and Evaluation:

Structured surveys and evaluation forms will be distributed to target audiences to ascertain the progress of the materials production project.

Objective 3: Website

Rationale:

Up-to-date information is an integral component in sustaining citizen's involvement in a sustained initiative such as that described in the Action Plan. In today's information age, information accessible electronically plays a key role in disseminating relevant, timely facts to address problems.

This project aims to develop a website on the Climate Change Action Program of the State of Delaware, with the goal of making pertinent information regarding the issue of climate change accessible electronically to the public. This information will include: (1) the science of climate change; (2) actions being taken to address the problem globally, nationally and locally; (3) an inventory of resources and linkages; (4) kits for citizens participation; and (5) a children's section. There are two general target groups: (1) the general public and (2) children (K-12).

Activities and Timeframe:

The project activities are divided into three phases: [1] pre-construction, [2] construction, and [3] maintenance. The pre-construction phase involves the collection of relevant materials for the website. These materials include: (a) the science of climate change; (b) actions being taken at the international, national, and local levels; (c) an inventory of resources and linkages; and (d) educational kits for children. The construction phase involves the actual design and construction of the website. The last phase is the maintenance, monitoring and evaluation of the project.

Monitoring and Evaluation Scheme:

The number of hits and feedback from users will serve to monitor the usability of the website. A structured survey will also be administered among targeted groups for evaluation purposes.

Objective 4: Education for Specialized Audiences

Rationale:

This component of the education and outreach program aims to present pertinent information regarding the issue of climate change to specialized audiences through a seminar or workshop format. The rationale is that professional, technical and other groups that may be directly involved in the implementation of the DCCAP, would benefit from educational activities designed to address their particular fields of work. Focused seminar/workshop/consultative sessions will help to meet these requirements.

Two types of audiences are targeted: (1) high-impact specialized groups and (2) the general public. High impact specialized groups include policy makers, developers, industry, community organizations, the media and personnel from the sectors addressed in the DCCAP.

Activities and Timeframe:

The development and implementation of the workshop/seminar activities will occur in three phases: pre-construction, construction and presentation. Pre-construction will involve the collection of relevant materials for the preparation of handouts for workshops. The construction phase will involve the design and organization of materials into a coherent presentation. Presentation will entail delivering this program to the target audiences in the forums that facilitate implementation of the DCCAP.

Monitoring and Evaluation:

Feedback from questionnaires distributed at the conclusion of workshops will provide information for evaluation purposes.

Objective 5: Climate Change Education in Delaware's Schools

Rationale:

The schools constitute a pre-existing, formal structure for the gathering of young minds curious to learn about the world in which we live. These young people of today will be the decision-makers of tomorrow and it is therefore important that they are equipped with the necessary tools to act responsibly as adults and as leaders. This component of the education and outreach program is to harness the natural curiosity and enthusiasm of young people by raising their level of awareness and understanding of climate change so that they can act individually and collectively in their schools and communities to help reduce the emission of greenhouse gases.

Objectives:

The aim of this component of the program is to develop information on climate change that can be incorporated into the curricula of Delaware's schools. School children (K-12), teachers and school administrators are targeted.

Activities and Timeframe:

Activities are divided into five phases, some of which may run concurrently. These are: (1) consultations with teachers and education officials to build support for the program and gain the cooperation and assistance of school officials; (2) inventory of courses/curricula to which climate change is relevant; (3) organization of seminars/workshops for teachers; (4) development of teaching materials for use in schools; (5) creation of school-based activities for children (e.g., competitions). The expected outputs are teaching materials, workshop materials, an inventory of classes/courses, and school-based activities.

Monitoring and Evaluation:

Questionnaires to teachers on the suitability and effectiveness of materials and usefulness of workshops and seminars will be used. Each school-based activity will need a specific evaluation mechanism, with participation used as a measure where relevant.

Objective 6: Education via the Mass Media

Rationale:

The mass media – television, radio, press, billboards – is a powerful tool for transmitting information to large numbers of people simultaneously. Materials specifically designed for these media are useful in educating the general public with little effort required on the part of the recipients. The aim of this component of the program is to design and deliver education/ information to Delaware's media for dissemination to the general public.

Activities and Timeframe:

A mass media program requires specialized skills and may entail the services of public relations personnel, graphics artists, scriptwriters, or others with expertise in the preparation of media-usable information on climate change. For example, effective materials for use on television may range from documentaries to discussions focusing on specific aspects of the subject to selected interviews that cover a range of perspectives (science, policy, and community action).

The activities for this component will involve the following stages: (1) consultation with Delaware's media to obtain their cooperation; (2) preparation of general and scientific information of climate change and on the DCCAP (materials from components 1, 2 and 3); (3) preparation of information in formats suitable to the mass media (TV and/or documentaries, newspaper articles, graphic arts, etc.); and, (4) broadcast and/or publication of the programs/materials.

Monitoring and Evaluation:

Publications and broadcasts should be accompanied by telephone numbers and the website address, to which viewers/listeners/readers should be invited to send their comments and questions. Some programs might also reserve time for telephone calls to be taken "on air." These will provide feedback from which to assess the effectiveness of the activities.

CHAPTER 9
POLICY RECOMMENDATIONS

Introduction

Two sets of policy recommendations are provided in this Chapter. In Part I are those policy initiatives required to facilitate the range of measures to reduce greenhouse gas emissions and/ or enhance sink capacity applied in the sector-by-sector analysis conducted for this Action Plan. It is intended that these policies are sufficient to deliver the individual measures identified in the Action Plan. These policies are necessarily general in scope and are appropriate for the range and scale of responsibility to be experienced by state government agencies, industries and non-government organizations. In some cases, existing Delaware policies are identified as providing a basis for emissions reduction/sink enhancement, but needing strengthening in a specific manner to ensure their efficacy. Policies identified in Part I are designed to ensure that the measurable benefits of sectoral measures are achieved within the Action Plan's timeframe.[1]

Part II provides a set of policies considered to be important by the DCCC in achieving emission reductions/sink enhancement, but are not necessarily linked to specific quantifiable steps to reduce or store CO_2 or other GHGs. These policies have not been systematically assessed against the cost-effectiveness criteria applied to the measures in the Action Plan. Further, these policies may not necessarily deliver the anticipated benefits in the timeframe applied to the policies in Part I, i.e. some or all of these policies may only be capable of delivering medium or long-term benefits.

[1] In accordance with the goals and scope of this Action Plan, as described in the Introduction, there are no recommendations regarding the implementation of these policies. Implementation issues are to be addressed in Phase III of the U.S. EPA Climate Change Action Plan Initiative.

Part I. Policies to Achieve Action Plan Goals and to Implement Action Plan Measures.

Industrial Sector

1. Provide incentive programs for industrial efficiency upgrades.

There are a variety of state and federal policy measures, which have proved to be effective in promoting high-efficiency technology choices in the industrial sector. Two policies are recommended for action in Delaware.

Tax incentives for high-efficiency industrial lighting

Delaware (as well as the federal government) can support the introduction of high efficiency lighting by providing limited tax credits to offset the higher purchase price of more efficient lighting. Rebate programs in partnership with electricity providers and lighting service companies can also be promoted through state programs modeled after USEPA and USDOE initiatives (described below).

Accelerated depreciation of capital investments in specific technologies

State tax policy should be reviewed for the purpose of incorporating provisions for accelerated depreciation of capital investments in specific high-efficiency technologies for energy-intensive industries. Key technologies would include cogeneration, motor systems, HVAC equipment, compressed air technologies and boiler and steam systems. Targeted tax credits would have the effect of accelerating market penetration of energy efficient equipment that improves the productivity of Delaware's industries.

2. Promote auditing and benchmarking, especially for small- and medium-scale industries

The U.S. Department of Energy has supported an energy assessment service for several years that targets small- and medium-scale industrial facilities. Through a partnership with universities, the USDOE program has identified a wide range of highly cost-effective operations and maintenance procedures and technology upgrades to improve energy efficiency in industrial facilities. Implementing such efficiency strategies has environmental benefits while also improving the competitiveness of area industries. Delaware should participate actively in this program. Analyses performed for the Action Plan indicate that significant reductions in CO_2 emissions are possible with an approach that focuses on cost-effective measures for Delaware's small- and medium-scale industries.

3. Increase Delaware's participation in existing voluntary programs.

Several USEPA- and USDOE-sponsored voluntary programs to promote industrial sector efficiency in energy and materials use deserve active support of Delaware's state and local governments. Five are highlighted below.

Climate Wise (USEPA)

The Climate Wise program provides information and assistance on a range of emission reduction opportunities at industrial facilities. Companies are encouraged to reduce emissions by measures such as altering production processes, switching to lower carbon content fuels and renewable energy, implementing employee mass transit, and auditing systems to identify efficiency improvements. Currently, Delaware is only modestly active in this program.

Industrial Assessment Centers (USDOE)

The university-based Industrial Assessment Center (IAC) program conducts assessments throughout the country using established engineering measurement methods as the basis for recommendations for facility improvements. These recommendations focus on potential savings from energy efficiency improvements, waste minimization, pollution prevention, and productivity improvements for small- and medium-scale industrial facilities. At this time, Delaware is not actively participating in this program.

Steam Challenge (USDOE)

The U.S. Department of Energy's Steam Challenge develops public-private initiatives to promote the comprehensive upgrade of industrial steam systems wherever profitable. By communicating with industry to identify useful tools and information on more efficient steam use, the program aims to lower energy costs, reduce pollution, and improve competitiveness through technology upgrades and better facility management. Delaware is moderately active in this program.

Motor Challenge (USDOE)

USDOE's Motor Challenge promotes energy efficient electric motor systems; motor systems account for 75% of the electricity used in industry. The aims of the program are to increase the use of efficient motors and drive systems, improve industrial competitiveness and productivity, save energy, and decrease industrial waste and pollution. Delaware is active in this program, but it could expand participation to include the development of an annual inventory of industrial motors in the state (by type and size).

Compressed Air Challenge (USDOE)

The USDOE Compressed Air Challenge is a voluntary program designed to improve the energy efficiency of compressed air systems and promote the installation of energy efficient compressors systems. Delaware is not actively participating in this program.

Residential Sector

1. Raise energy-efficiency standards for buildings and appliances

By raising energy-efficiency standards to a higher level, existing energy demand can be reduced, resulting in economic savings to Delawareans and reduced greenhouse gas emissions. These include standards for building design, insulation, construction materials, and major residential appliance energy use (e.g., refrigerators, air conditioners, and water heaters). Research indicates that higher efficiency standards are one of the most effective policy tools for encouraging economical energy use in the residential sector.

2. Promote wide participation in Federal programs for residential energy conservation and greenhouse gas emissions mitigation.

Examples of existing federal programs that promote residential energy conservation and efficiency include: the Energy Star Program (U.S. Environmental Protection Agency); Energy Improvement Mortgages (through the Federal Housing Administration); and the Home Energy Rating System and the Energy Efficiency Financing Consortium (U.S. Department of Energy). Such programs bring together public and private sector organizations to develop information and marketing strategies to increase market penetration of high-efficiency technology into the residential sector (as well as to other energy users).

3. Provide incentives to switch from electric to natural gas space and water heating where possible, or switch to higher efficiency electrical appliances.

Space and domestic hot water heating are major sources of energy use in most Delaware homes. Electric systems generate more greenhouse gas emissions than comparable natural gas units. Switching from electricity to natural gas for water heating lowers overall emissions attributable to the sector. Where electricity customers have no access to natural gas, higher-efficiency electrical appliances should provide these services. A variety of economic incentives, such as rebates, can assist consumers by reducing the effective purchase price of higher efficiency gas or electric water heaters. State and federal tax policy can include rebates to consumers and vendors for equipment purchased/sold above a designated efficiency standard. In the electricity sector, distribution charges can be adjusted to take into account the energy efficiency of users. As similar approach can be taken in the case of the natural gas sector.

4. Improve product information so that consumers can choose energy-efficient appliances.

Assisting consumers in making decisions to save energy and reduce greenhouse gas emissions in their energy-related purchases can be achieved in several ways. These include: energy labeling, customer information supplied by retailers and utilities, advertising and other communication strategies. When energy-inefficient equipment needs to be replaced, appropriate advice and labeling can help consumers identify those higher efficiency models with low operating costs. Switching from electric stoves to those using gas, when possible, typically is also an economically and environmentally sensible choice.

5. Promote the use of cost-effective, energy-efficient lighting.

A range of high energy-efficiency lighting is available, but market penetration remains relatively low, partially due to higher initial prices compared to traditional products. Considerable potential exists for increasing market penetration by encouraging consumers to replace lighting fixtures with high-efficiency options (e.g., compact fluorescent lighting). Delaware and federal tax policy can support the introduction of high efficiency lighting by providing limited rebates to mitigate the purchase price of more efficient lighting.

Commercial Sector

1. Encourage the use of cost-effective and energy-efficient lighting through commercial sector lighting standards.

Lighting is a principal energy user in the commercial sector. Establishing higher energy-efficiency standards for commercial lighting is a cost-effective means of lowering CO_2 emissions. The added benefit of increasing lighting efficiency standards is that it would promote rapid development and diffusion of new technology including high-efficiency fluorescent lamps, ballasts, lighting fixtures, and lighting control switches.

2. Promote wider use of natural gas for heating, ventilation, and air conditioning systems (HVAC).

Because electricity is typically a greater source of CO_2 emissions than natural gas, using this energy source (when available) can result in significant reductions in CO_2 emissions for this sector. A variety of policy instruments can be employed, but standards and market incentives (especially tax credits and rebates) are typically most effective.

3. Encourage the use of more efficient refrigeration technologies.

Considerable potential exists for upgrading refrigeration technology in Delaware's commercial sector with more energy efficient models at the time of equipment replacement or retirement. With the use of more efficient technologies, specifically those technologies with an energy use index (EUI) of 2.0 kBtu/f^2 or greater, emissions from refrigeration in the sector could be much lower. Incentives, such as tax credits and rebates, can be used to spur market development of this key technology.

4. Encourage building-integrated photovoltaics.

One important opportunity for reducing energy use and greenhouse gas emissions is the application of photovoltaic (PV) technology to buildings to reduce electricity demand. The National Renewable Energy Laboratory has sponsored research at CEEP on the CO_2 effects of a national strategy to provide 2% of national buildings-related electricity consumption from photovoltaic systems. This work is in anticipation of national electricity restructuring legislation, which could include a so-called renewable energy portfolio requiring electricity providers to generate a specified percentage of their electricity from renewables. PV systems can be installed on rooftops or other suitable locations and incorporated into commercial building energy systems, and thereafter operated as a peak management technology. This application has proved to be cost-effective if it is combined with emergency power applications to permit orderly shutdown of computers and other equipment in commercial buildings.

A building-integrated PV program can also be encouraged through the Environmental Incentive Fund. This Fund was recently established in Delaware as part of legislation to promote retail competition in the electricity sector.

5. Promote wide participation in Federal programs for commercial sector energy conservation, renewable energy use and other actions to reduce greenhouse gas emissions.

Apart from the specific policies recommended above, there a several federally sponsored programs available to the commercial sector to assist in the development of its use of energy conservation and renewable energy and other initiatives that can lower CO_2 emissions. Examples include the USEPA's Energy Star Buildings and Green Lights programs, Energy Star Small Business Program and Energy Star Product Labeling, and the USDOE's Rebuild America Program. Both agencies have found that considerable energy and cost savings and CO_2 emissions reduction can be realized in the commercial sector from these voluntary partnerships between private and public sector organizations.

Transportation Sector

1. Increase CAFE standards for vehicles.

The use of more fuel-efficient vehicles will reduce CO_2 emissions per vehicle mile traveled. Some of the policies aimed at increasing fleet fuel-efficiency in Delaware will require federal leadership. For example, corporate average fuel economy (CAFE) standards must be implemented on a federal level. CAFE standards determine the average minimum fuel efficiency for all new cars sold in the U.S. CAFE standards have not been raised for light duty cars or light duty truck since 1989 and 1995 respectively.

As a consequence, U.S. new vehicle fuel efficiency has begun to plateau. Federal action to increase CAFE standards will promote fuel efficiency and encourage the rapid introduction of new technology.

2. Provide incentives for the purchase/sale of fuel-efficient vehicles.

Feebates are market-based incentives designed to increase energy-efficiency and which can also reduce CO_2 emissions. The basic concept is to award a rebate to consumers buying fuel-efficient vehicles, and to charge a fee to consumers buying fuel-inefficient vehicles. Such an incentive would result in higher sales of fuel-efficient vehicles, leading manufacturers to produce more fuel-efficient vehicles in subsequent years. Feebates may be implemented on a statewide basis, although their effectiveness would improve if they were implemented on a national scale. Another method for improving fuel efficiency would be state-sponsored buy-backs of older vehicles. In this program, Delaware would purchase inefficient, highly polluting vehicles with the assumption that they would be replaced by cleaner, more fuel-efficient vehicles.

3. Use statewide mandates and market mechanisms to encourage the adoption rapid penetration of Alternative Fuel Vehicles.

The adoption of AFVs will be dependent on the use of market-based incentives and statewide mandates for the purchase of AFVs. California's current AFV program is a good example of a statewide mandate. This program requires 10% of all new vehicles purchased in the state to be zero emission vehicles (ZEVs) by 2004. Delaware could adopt a similar plan and join the northeastern states and Washington D.C. in the National Low Emission Vehicle (NLEV) program.

Market-based incentives can be used to make AFVs more cost-competitive. The costs to the consumer of purchasing an AFV could be defrayed directly by rebates or indirectly by tax incentives. Such incentives will stimulate the market for AFVs, thereby increasing sales and leading to further economies of scale in their manufacture. A doubling of the market for AFVs could lead to a 15% reduction in their price. Delaware could also subsidize part of the construction costs of AFV infrastructure, such as CNG refueling stations and battery recharge facilities.

While the Electricity Policy Act (1992) promotes alternative fuel vehicles in public and private fleets, it has yet to influence private fleet fuel use, making the full implementation of the Act a candidate for future policy activity.

Delaware should support the adoption of a wide array of AFV technologies. For example, support of electric vehicles (EVs) should extend to battery-powered EVs, hybrid EVs, and fuel cell EVs.

4. Reduce vehicle miles traveled (VMTs) by adopting policies to implement transportation control measures.

Reducing VMTs by using transportation control measures (TCMs) presents the widest array of options to Delaware policy makers. TCMs can be effective on a local or statewide basis. Although most TCMs can be implemented by individual employers on a local scale, statewide policy implementation or funding is usually needed to initiate their widespread adoption. For example, a state partnership with employers to reduce single occupant vehicle (SOV) employee travel by a specified percentage will spur the creation of area-wide ridesharing programs. Although all TCMs are dependent on policy formation, they can be divided into three basic categories: employer-based initiatives, facility improvements, and market mechanisms. Employer-based initiatives include the promotion of telecommuting, compressed workweek, and area-wide ridesharing. Facility improvements include High Occupancy Vehicle (HOV) lanes and public transit improvements. Market mechanisms include parking pricing, congestion pricing, gas taxes, and pay-as-you-drive-insurance. All of these TCMs will require a commitment to new policies in Delaware and at the national level if they are to produce substantial reductions in CO_2 emissions.

5. Develop policies aimed at changing land use patterns.

Land use changes will not have a large impact on transportation systems or CO_2 emissions within the short term. However, over longer time spans, land use changes aimed at creating denser, mixed-use settlements may offer important opportunities to reduce transport energy intensity and CO_2 emissions.

Land use and travel behavior are integrally linked. The typical suburban development that characterizes northern Delaware increases the demand for new roads and highways. This process of development, often referred to as sprawl, intensifies automobile use and discourages the use of less polluting alternatives such as public transit, bicycling, or walking.

Policies that promote coordination of land use and transportation to reduce energy use and CO_2 emissions from the transportation sector include tax measures, impact fees and new zoning ordinances, and statewide growth management planning. Growth management enhances the effectiveness of different means of transportation by shaping land use patterns to foster fewer trips, shorter trip distances, and alternatives to automobile use (CEEP 1994 and 1996). Higher density, greater functional diversity, and pedestrian/bicycle friendly design have, in combination, the potential to reduce automobile dependency, lower VMT per capita, and reduce CO_2 emissions. Thus, appropriate land-use changes are integral to vehicular CO_2 emission reductions over the next several decades.

Electric Utility Sector

1. Undertake fuel switching from high to low carbon fuels.

Changing the fuel used within an existing generating plant can be achieved by altering or replacing existing equipment. One specific generation unit was identified as a primary candidate for fuel switching because repowering from coal to natural gas would involve only relatively minor alterations. National cost estimates indicate a relatively low level of expenditures required (Department of Natural Resources 1994). Fuel switching at this single plant will produce significant carbon reductions from this sector because of the amount of fuel involved. The State of Delaware should work with Conectiv to plan the conversion of the power planet already identified by the utility for fuel switching.

2. Develop and implement a renewable portfolio standard.

Delaware should, through legislation or regulatory action, implement a renewable portfolio standard, mandating that a minimum 1% of the electricity in the State must be generated from a portfolio of renewable sources as listed in this section. Technologies which could be utilized to meet this standard include: photovoltaics, solar thermal technologies, wind power, fuel cells utilizing hydrogen produced from renewable sources, or sustainable biomass. Coupled with the recently established Environmental Incentive Fund, this policy can help Delaware to be competitive in attracting so-called “green” energy marketers to the State. Since New Jersey has moved aggressively to develop its green energy market, policy action in this direction would be a timely step to promote Delaware as a competitive location for this fast-growing market.

3. Investigate a regional environmental dispatch policy.

It is recommended that relevant Delaware agencies in consultation with Conectiv initiate a regional consultative process for the investigation of environmental dispatch criteria and procedures to be followed by the PJM Independent System Operator. Implementation of environmental dispatch criteria would provide long-term CO_2 emission reductions, as well as regional air quality benefits. The state public utility commissions of both New Jersey and Maryland have expressed concerns that differential emission standards across the Mid-Atlantic region may threaten air quality as electric generation markets are deregulated. The implementation of environmental dispatch operational criteria is one way in which these concerns might be addressed in a restructured, competitive market, while also substantially aiding Delaware in meeting the CO_2 reduction target of this Action Plan.

4. Investigate state emission standards for electricity generation facilities.

Delaware should investigate the adoption of an emission standard for the State's portfolio of electric generation units. This standard could be implemented utilizing the "bubble model," whereby electric generation within the state would be limited to a certain system emission factor. This would entail a cap on the overall emissions of CO_2 per unit of electricity generated within the State. Such a standard would be relatively simple to implement as the vast majority of installed capacity is owned and operated by a single investor-owned electric utility. The implementation of a system-wide average emission factor would encourage the implementation of the fuel switching and environmental dispatch options contained within this Action Plan, while also providing the operating utility with a substantial degree of flexibility in implementing the mandate through the pursuit of least-cost strategies.

Wastes Sector

1. Implement Pay-As-You-Throw (PAYT) or Volume-Based Fees Programs.

A PAYT program, or the establishment of volume-based fees, would enable each citizen to understand the environmental and economic costs of the volume of waste they send to a landfill. If Delawareans are charged per bag or per amount of waste produced, it is likely that the amount they dispatch individually to a landfill would decline. There are several different methods by which a PAYT program can be initiated and enacted. For example, a PAYT or volume-based fees policy may be enacted either state-wide or within individual communities. An alternative policy approach that sets permit fees according to the volume of greenhouse gas emissions attributable to a waste type could achieve a similar incentive for waste reduction.

2. Implement a mandatory curbside recycling program.

In order to meet the State target for recycling, it would appear that mandating recycling is needed. Such a policy would make it easier and more convenient for Delawareans to participate in the recycling of wastes.

Currently, Delaware Solid Waste Authority's *Recycle Delaware* Program offers a strictly voluntary approach to recycling, which has resulted in a lower recycle rate than neighboring states. A curbside recycling program, such as the one enacted in New York, would provide Delawareans with the means to separate their recyclables from the remainder of their garbage for weekly pick-up.

3. Improve the bottle refund system.

Currently, Delaware has a refund system through which citizens can return their bottles to different stores across the state in exchange for a portion of the deposit money paid. A two-fold improvement can be made on this refund system. First, more locations can be established at which this exchange can take place. Second, the bottle refund system can be better advertised so as to promote the scheme and increase participation of Delawareans.

4. Increase participation in voluntary federal programs.

There are several federal government programs that Delaware can take advantage of in order to reduce GHG emissions from the wastes sector. For example, through USEPA's Wa$teWi$e Program, local municipalities, larger corporations, or non-profit organizations can partner with the USEPA to reduce costly municipal solid waste that would otherwise end up in landfills. Greater participation in federal programs should be encouraged.

Forest Sinks Sector

1. Strengthen afforestation/ reforestation and urban tree planting programs.

Tree planting is a primary means of enhancing Delaware's total carbon sink capacity. Programs supporting and/or encouraging tree planting can be affective in both rural and urban settings. Existing programs have typically sought a range of goals, such as habitat conservation, scenic values, and wildlife corridors. Afforestation and urban tree planting are no-regret options that provide benefits beyond emission reductions. Expansion of the State's existing afforestation and urban tree planting programs can yield low-cost carbon sequestration.

2. Develop growth management strategies that include afforestation/ reforestation goals.

Low-density urban expansion continues to characterize new development in Delaware. Allowing urban development to spread out upon rural, undeveloped land accelerates the already rapid rate of loss of existing forests. However, strategies exist to support development that does not contribute to sprawl. Growth management policies provide a compromise between the need for growth and the need to control sprawl by encouraging compact growth that preserves existing forestlands. Development is directed to areas where infrastructure exists or can be adequately and efficiently provided. Such policies typically require state and local governments to adopt comprehensive, coordinated land use plans that include consideration of natural resources, farmland, and forest impacts of development.

3. Strengthen forest management legislation to encourage conservation

A Rural and Forest Preservation Act is needed in Delaware. State funds would be earmarked to better preserve forestlands and rural areas vulnerable to development. Such legislation has been recommended in earlier studies conducted by the Center for Energy and Environmental Policy in 1994 (*Clean Air Act Compliance Options: Policies to Address Land Use, Transportation, and Air Quality in Delaware*) and in 1996 (*Growth Management in Delaware: Planning for Delaware's Future*).

Part II. Additional Policy Initiatives with the Potential to Reduce GHG Emissions and/ or Enhance Forest Sink Capacity

Policies can be identified which will provide medium to longer-term support for efforts to reduce GHG emissions and/or enhance sink development. Additionally there are a range of concepts that are not policies in the strict sense which nonetheless offer a means to achieve similar results. In both cases, the quantity of reductions and/or enhancement cannot be readily estimated, but such initiatives are nonetheless deemed essential by the DCCC to the overall success of the Action Plan.

1. Reform Delaware's land use planning.

A number of professionals and experts dealing with air quality issues in the region have focused their attention on the need for major revisions to the State's overall policy approach to transport and land planning activities, and the relationship between the two. Reducing greenhouse gas emissions in the longer term necessitates fundamental revisions to the manner in which development is planned and transport services are provided. Accordingly, a long term policy approach of growth management is recommended by the DCCC which emphasizes changes to the structure, settlement density, and social organization of urban centers on the one hand, and to providing a variety of means of providing transport services characterized by minimal environmental impact, on the other.

2. Expand Delaware's mass transit options and opportunities.

A variety of specific measures have been identified that link energy, climate change, planning and other policy agendas. Further extending the state's mass transit infrastructure and its widespread promotion would provide the opportunity and the necessary awareness for increased utilization of this transport mode. Linking mass transit to commercial and residential development increases the population of potential users. Portland, Oregon exemplifies such integrated land use and public transport planning. Policy initiatives include alternative fuels that exploit biologically-derived fuels (such as wood ethanol and organic-based biodiesel).

3. Investigate a broader-based renewable energy policy initiative.

If promised technological improvements materialize, it will be possible to implement a renewable portfolio standard greater than the 1% recommended in the Action Plan. If such improvements occur over the lifetime of the Action Plan's implementation, then an appropriate policy response would be technically feasible. A greatly increased role for low-carbon fuels and renewable fuels for generating electricity offers the principal means to significantly reduce the utility sector's greenhouse gas emissions. Principal proven renewable energy technologies include photovoltaic cells, solar water heating, wind energy, geothermal energy, and hydro, all of which have found commercial applications. Achieving large-scale market penetration of alternative energy still appears to be several years away, despite rapid growth in applications around the country in recent years. In the longer-term, other technologies might achieve sufficient development to become commercially viable, such as fuel cells, tidal energy and advanced wood gasification. Capture of greenhouse gas emissions from landfills can reduce overall state emissions (especially of methane and CO_2); it also provides a potential fuel source for electricity generation. Local, community and domestic scale energy systems may develop the potential to replace centralized grid power.

CHAPTER 10
CONCLUSION

Emissions

Without policy intervention, existing greenhouse gas emissions trends in Delaware are forecast to continue rising between 1996 and 2010. The principal source of these increasing emissions is the combustion of fossil fuels for energy use. Under a business-as-usual scenario, the State's emissions will reach approximately 20 mmtCO_2 by 2010. The emission target for the DCCC is a reduction to 7% below Delaware's 1990 level during 2010-2012, which will require a 23% reduction from the forecast BAU total by 2010.

Sector analyses conducted for this Action Plan reveal that greenhouse gas contribution by 2010 will likely have the following distribution: Industry (22%), Residential (11%), Commercial (10%), Transportation (26%), and Utility (31%). Reducing statewide emissions requires a strategy that achieves energy savings in each sector. This Action Plan also investigates contributions from wastes and the decrease in Delaware's carbon sinks (principally, its forests).

The recommended steps in this Action Plan would enable Delaware to contribute to a national strategy to cost-effectively lower CO_2 emissions. In addition to satisfying the emission reduction goals set by the Delaware Climate Change Consortium, there are a range of other environmental and social benefits that result from reducing energy use and emissions from transport, industry and other sources, and protecting carbon sinks in our ecosystems. These include cleaner air, reduced congestion, improved water quality, a more competitive state economy, healthier ecosystems and greater biodiversity in the State.

Action Plan

The Delaware Climate Change Action Plan represents a consensus-building effort to identify, with the aid of analysis, a wide range of measures applicable to each sector. Appropriateness of specific measures was determined qualitatively by assessment of their applicability to the State's economic and geographic circumstances, and quantitatively through an assessment of their cost-effectiveness, impact on energy efficiency, and environmental benefit.

A wide variety of sources were used for the assessment. Nearly all the policy options involve either proven or existing technology and established and documented practices. The Action Plan is designed to provide guidelines for the selection of emission reduction measures and policies for each sector that meet the cost-effectiveness and efficiency criteria adopted by the Consortium. Policy options were identified through reviews of other state action plans and the policy research literature, and at the suggestion of members of the Consortium. Final selection of policy options reflected those that represented the least cost and highest energy savings for Delaware, which in combination could achieve the Consortium's emission reduction target by the year 2010.

Three policy scenarios are developed for each sector: Full Implementation (100%) of all measures; a Major Commitment scenario in which approximately two-thirds of the identified cost-effective energy savings are realized; and the Modest Commitment scenario in which State actions are able to encourage Delawareans to realize approximately on-third of the cost-effective energy savings identified in the Action Plan. This method was adopted for a national assessment conducted by the Interlaboratory Working Group entitled *Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy-Efficient and Low-carbon Technologies by 2010 and Beyond (1997).* The Consortium found this approach a reasonable one given the political and economic uncertainties in current discussions in the U.S. and Delaware concerning the need to act on the climate change problem.

Full implementation would result in emission savings that exceed the DCCC reduction target of 23% for 2010, realizing a 32% decrease in CO_2 emissions. Under the Major Commitment scenario, Delaware would realize a 22% reduction in CO_2 emissions, while a Modest Commitment scenario would yield a 12% decline from the 2010 forecasts.

It should be observed that, while the Action Plan can identify strategies to meet its target for Delaware under certain scenarios, any reasonable plan must ultimately rely on national and regional, as well as state and local action. Actions by other states may impinge on Delaware and its Climate Change Action Plan, adding emphasis to the need for effective regional coordination. Thus, the Delaware Action Plan, in any of its scenario formats, may be found to make significant contributions to a national effort which, ultimately, must coordinate initiatives throughout the society to fully realize reductions in CO_2 emissions.

Sector Results

Industrial Sector: After screening nearly 2,000 energy-saving measures, it was possible to select 170 individual measures for application to Delaware. Measures included upgrades to boiler and steam systems, heat recovery and containment, space conditioning, air compressors, motors, and lighting. A feature of the identified measures is their high cost-effectiveness: an average payback period of less than one year. This scenario would lead to an 18% decline from this sector's forecast emissions for 2010.

Residential Sector: Through a combination of replacing existing household equipment with more energy efficient appliances and by changing the energy source of selected household devices, it was possible to devise a set of policy options that achieve a cost-effectiveness of less than 5.0¢/kWh of energy saved. This is below the price paid by most Delaware households for electricity service. The focus in this sector was on refrigeration, water heating, cooking, space conditioning, freezers, clothes dryers, lighting and building shell measures. This scenario would lead to an 18% decline from this sector's forecast emissions for 2010.

Commercial Sector: Equipment replacement and fuel-switching produced the target energy savings at a reasonable cost for this sector. Higher-efficiency lighting, refrigeration, space conditioning and other equipment, together with some fuel switching and the use of building-integrated photovoltaics led to energy savings with overall costs of less than 4.0¢/kWh. Again, this is below the price paid by commercial customers for electricity service. This scenario would yield an 18% decrease from this sector's forecast prepared for DCCAP.

Transportation Sector: A combination of measures affecting fuel efficiency of cars and light trucks, the diffusion of alternative fuel vehicles into Delaware corporate and government fleets and the adoption of a comprehensive array of transportation control measures to reduce vehicle miles traveled in the State are found to produce sizable energy savings in the forecast period. Measures recommended in this study are cost-effective with payback periods of less than 5 years for most measures. A 24% reduction in the CO_2 releases from forecast levels for 2010 is expected under this scenario. In addition, the Action Plan recommends a long-term land use planning strategy that can reduce transportation needs and encourage greater use of public transit, bicycling, and walking.

Utility Sector: Emissions reductions are possible in the forecast period by fuel switching from coal to natural gas at appropriate generating facilities and by instituting a renewable portfolio standard. The cost of these actions taken together would be modest. If the Major Commitment scenario, with a 1% renewable portfolio standard and fuel switching, is adopted, this would mean a 24% reduction in CO_2 emissions for the sector (compared to forecast emissions). In addition to these actions, investigation of a regional environmental dispatch policy and a state emission standard for electricity generation is encouraged as a means of securing long-term benefits from the Action Plan.

Wastes and Forest Sinks Sectors: Waste reduction through recycling can produce significant emission reductions by preventing biodegradable materials reaching landfills, and by lowering resource consumption and processing. Three recycling strategies – pay-as-you-throw, curbside recycling and improvements in the Delaware bottle refund program – are recommended for implementation over the forecast period. Carbon sink enhancement can be used to offset greenhouse gas emissions. Several measures are proposed, including urban tree planing and reducing the extent of forest clearance for urban land use.

Education and Outreach: Increasing awareness of climate change and its environmental, social, economic, and political impacts among Delawareans will aid the implementation of DCCAP's emission reduction measures. DCCAP proposes reaching out to targeted audiences (government, industry, students, interest groups, and the media) as well as the general public by holding workshops, distributing educational materials, and developing a website.

Summary of Policy Options Linked to the Action Plan

- Industrial Sector – Through market incentives and greater participation in voluntary federal programs, more energy efficient equipment and better operations and maintenance will increase energy efficiency, produce lower costs, and reduce CO_2 emissions from this sector.
- Residential and Commercial Sectors – Through improved building standards, market incentives, and participation in voluntary partnerships, the Action Plan would increase energy efficiency and lead to use of lower carbon fuels in these sectors.
- Transportation Sector – Through standards, market incentives, and land use policy, vehicle fuel efficiency and the penetration of alternatively fueled vehicles can be increased, while vehicle miles traveled are reduced, under the Action Plan.
- Utility Sector – Through the adoption of a renewable portfolio standard, fuel switching, pursuit of a regional environmental dispatch policy, and state emission

standards for electricity generation, overall greenhouse gas emissions can be lowered, under the Action Plan.

- Wastes Sector – Through volume-based fees, recycling/container deposit programs, and greater participation in voluntary federal programs, the volume of waste can be reduced along with total demand for materials. Greenhouse gas emissions from landfills and industrial processing are thereby reduced, under the Action Plan.
- Forest Sinks Sector – Through urban growth management, afforestation, and rural land and forest conservation, Delaware's carbon sinks can be protected and enhanced, thereby offsetting a portion of the State's greenhouse gas emissions.

The Next Stage

Reaching the required emission reduction targets necessitates policy responses in each sector throughout the forecast period. These can be achieved at relatively low cost and comprise proven and practical measures.

Having broadly identified the necessary policy options to satisfy the greenhouse gas emission goals of the Delaware Action Plan, there remains the considerable task of policy formulation and implementation, which involves a wide range of activity. The Consortium considers public education and outreach a key tool for overall success of the Action Plan. An initiative is needed which engages Delawareans of all ages and walks of life, as well as government, industry and citizen groups in addressing the legal, regulatory and economic barriers and impediments to the implementation of emissions reduction policy as identified by the Consortium. The time to act is now if Delaware is to be effective, environmentally and economically, in its response to the international call for steps to reduce greenhouse gas emissions.

APPENDIX A:
INDUSTRIAL SECTOR: FUEL AND END-USE ELECTRICITY CONSUMPTION

	Coal			Natural Gas			Asphalt & Road Oil			Distillate Fuel			Kerosene	
Year	Trillion BTUs	Metric Tons CO_2	Year	Trillion BTUs	Metric Tons CO_2 (7% sequest.)	Year	Trillion BTUs	Metric Tons CO_2 (100% sequest.)	Year	Trillion BTUs	Metric Tons CO_2	Year	Trillion BTUs	Metric Tons CO_2
1985	5.388	512537	1985	22.051	1E+06	1985	5.4877	0	1985	2.4944	182633	1985	0	0
1986	5.1	485145	1986	21.2	1E+06	1986	4	0	1986	2.4	175720	1986	0	0
1987	5.4873	521990	1987	18.158	898695	1987	3.7912	0	1987	2.4942	182619	1987	0.0998	7220.6
1988	6.1139	581590	1988	15.134	749041	1988	2.7061	0	1988	2.6059	190796	1988	0.1002	7253.7
1989	5.1942	494110	1989	15.383	761348	1989	3.4961	0	1989	2.5971	190152	1989	0	0
1990	5.2947	503666	1990	17.283	855371	1990	3.5964	0	1990	2.4975	182858	1990	0	0
1991	5.2	494657	1991	16.5	816633	1991	0.9	0	1991	2.6	190363	1991	0	0
1992	3.5965	342118	1992	18.682	924606	1992	0.4995	0	1992	1.998	146289	1992	0	0
1993	4.4041	418943	1993	20.119	995727	1993	0.7006	0	1993	2.1019	153897	1993	0.2002	14488
1994	4.8044	457024	1994	17.816	881779	1994	1.101	0	1994	2.0018	146567	1994	0.8007	57951
1995	4.9	466119	1995	20.1	994807	1995	1.2	0	1995	1.9	139111	1995	0	0
1996	4.3322	412108	1996	17.646	873370	1996	1.184	0	1996	1.9284	141192	1996	0.2852	20643
1997	4.1788	397518	1997	17.37	859698	1997	1.1711	0	1997	1.8454	135116	1997	0.3114	22538
1998	4.0591	386132	1998	17.229	852704	1998	1.1673	0	1998	1.7775	130145	1998	0.3396	24577
1999	3.9414	374935	1999	17.094	846016	1999	1.1639	0	1999	1.7106	125244	1999	0.3677	26611
2000	3.8256	363913	2000	16.964	839620	2000	1.1609	0	2000	1.6446	120409	2000	0.3957	28641
2001	3.7114	353052	2001	16.841	833499	2001	1.1582	0	2001	1.5793	115632	2001	0.4238	30670
2002	3.5988	342337	2002	16.722	827641	2002	1.1558	0	2002	1.5148	110909	2002	0.4518	32699
2003	3.4875	331757	2003	16.609	822033	2003	1.1538	0	2003	1.451	106234	2003	0.4799	34729
2004	3.3776	321300	2004	16.501	816661	2004	1.1521	0	2004	1.3877	101603	2004	0.508	36762
2005	3.2689	310955	2005	16.397	811516	2005	1.1506	0	2005	1.325	97010	2005	0.5361	38798
2006	3.1612	300710	2006	16.297	806585	2006	1.1495	0	2006	1.2627	92452	2006	0.5643	40840
2007	3.0544	290556	2007	16.202	801860	2007	1.1487	0	2007	1.2009	87925	2007	0.5926	42889
2008	2.9485	280484	2008	16.11	797330	2008	1.1481	0	2008	1.1394	83423	2008	0.621	44945
2009	2.8434	270484	2009	16.022	792987	2009	1.1478	0	2009	1.0782	78945	2009	0.6496	47010
2010	2.739	260547	2010	15.938	788823	2010	1.1478	0	2010	1.0173	74485	2010	0.6782	49084
2011		0	2011		0	2011		0	2011		0	2011		0
2012		0	2012		0	2012		0	2012		0	2012		0

	LPG			*Motor Gas*			*Residual*			*Other*			*Lubricants*	
Year	Trillion BTUs	Metric Tons CO_2 (80% sequest.)	Year	Trillion BTUs	Metric Tons CO_2	Year	Trillion BTUs	Metric Tons CO_2	Year	Trillion BTUs	Metric Tons CO_2 (80% sequest.)	Year	Trillion BTUs	Metric Tons CO_2 (50% sequest.)
1985	1.0975	13687	1985	0.2993	21323	1985	4.0909	322639	1985	17.461	164672	1985	0.3991	14823
1986	1.3	16212	1986	0.3	21370	1986	4.4	347021	1986	17.3	163154	1986	0.4	14856
1987	1.5963	19907	1987	0.2993	21321	1987	5.8864	464251	1987	18.058	170305	1987	0.4988	18527
1988	1.303	16249	1988	0.3007	21419	1988	7.0159	553333	1988	20.747	195663	1988	0.4009	14890
1989	1.0988	13703	1989	0.2997	21347	1989	6.0933	480564	1989	20.677	195003	1989	0.4994	18550
1990	1.2987	16196	1990	0.2997	21349	1990	4.6953	370310	1990	21.479	202561	1990	0.4995	18552
1991	1.3	16212	1991	0.3	21370	1991	6	473210	1991	22.3	210308	1991	0.4	14856
1992	0.6993	8720.9	1992	0.2997	21349	1992	7.7923	614567	1992	25.375	239308	1992	0.3996	14842
1993	0.8007	9985.7	1993	0.3003	21390	1993	11.01	868353	1993	24.523	231270	1993	0.4004	14870
1994	1.6015	19971	1994	0.3003	21390	1994	11.41	899920	1994	25.323	238819	1994	0.5005	18587
1995	1.3	16212	1995	0.3	21370	1995	10	788683	1995	24.4	230113	1995	0.4	14856
1996	1.1373	14183	1996	0.296	21085	1996	11.031	869961	1996	26.524	250147	1996	0.4305	15990
1997	1.1144	13897	1997	0.2928	20856	1997	11.57	912532	1997	27.095	255530	1997	0.4259	15817
1998	1.1001	13719	1998	0.2918	20789	1998	12.19	961389	1998	27.862	262764	1998	0.4245	15766
1999	1.0863	13547	1999	0.291	20728	1999	12.809	1E+06	1999	28.633	270036	1999	0.4232	15719
2000	1.0729	13380	2000	0.2902	20673	2000	13.429	1E+06	2000	29.409	277348	2000	0.4221	15678
2001	1.0599	13218	2001	0.2895	20625	2001	14.05	1E+06	2001	30.189	284705	2001	0.4212	15642
2002	1.0472	13060	2002	0.289	20583	2002	14.672	1E+06	2002	30.974	292111	2002	0.4203	15610
2003	1.0349	12906	2003	0.2884	20547	2003	15.295	1E+06	2003	31.765	299568	2003	0.4196	15582
2004	1.0229	12756	2004	0.288	20517	2004	15.921	1E+06	2004	32.561	307081	2004	0.4189	15559
2005	1.0112	12610	2005	0.2877	20491	2005	16.549	1E+06	2005	33.364	314653	2005	0.4184	15540
2006	0.9997	12467	2006	0.2874	20471	2006	17.18	1E+06	2006	34.174	322288	2006	0.418	15525
2007	0.9886	12328	2007	0.2872	20456	2007	17.814	1E+06	2007	34.99	329988	2007	0.4177	15514
2008	0.9776	12192	2008	0.287	20446	2008	18.451	1E+06	2008	35.814	337756	2008	0.4175	15506
2009	0.9669	12058	2009	0.2869	20441	2009	19.093	2E+06	2009	36.645	345597	2009	0.4174	15502
2010	0.9565	11928	2010	0.2869	20440	2010	19.738	2E+06	2010	37.485	353512	2010	0.4174	15501
2011		0	2011		0	2011		0	2011		0	2011		0
2012		0	2012		0	2012		0	2012		0	2012		0

	Biofuels				***Electricity***				***Total***		
Year	Trillion BTUs	Metric Tons CO_2 (No Net Emissions)		Year	Trillion BTUs	Metric Tons CO_2		Year	Trillion BTUs	Million Metric Tons CO_2	
1985	0	0		1985	9.1795	815435		1985	67.948	3.1391	
1986	0	0		1986	9.7	873977		1986	66.1	3.1467	
1987	0	0		1987	9.1788	813166		1987	65.549	3.118	
1988	0	0		1988	9.722	867118		1988	66.15	3.1974	
1989	0	0		1989	10.788	935722		1989	66.127	3.1105	
1990	7.3926	0		1990	11.189	982447		1990	75.524	3.1533	
1991	7.1	0		1991	11.10	950961		1991	73.7	3.1886	
1992	7.2928	0		1992	11.089	973986		1992	77.723	3.2858	
1993	7.4068	0		1993	11.711	1E+06		1993	83.677	3.7464	
1994	7.5069	0		1994	11.811	982515		1994	84.978	3.7245	
1995	7.8	0		1995	12	953721		1995	84.3	3.625	
1996	7.6431	0		1996	12.315	1E+06		1996	84.753	3.6215	
1997	7.6524	0		1997	12.474	1E+06		1997	85.502	3.6462	
1998	7.7192	0		1998	12.726	1E+06		1998	86.886	3.69	
1999	7.7881	0		1999	12.979	1E+06		1999	88.288	3.734	
2000	7.8589	0		2000	13.236	1E+06		2000	89.709	3.7781	
2001	7.9316	0		2001	13.494	1E+06		2001	91.148	3.8224	
2002	8.0063	0		2002	13.756	1E+06		2002	92.608	3.8667	
2003	8.0828	0		2003	14.02	1E+06		2003	94.087	3.9112	
2004	8.1613	0		2004	14.287	1E+06		2004	95.587	3.9556	
2005	8.2417	0		2005	14.557	1E+06		2005	97.107	4.0002	
2006	8.3239	0		2006	14.83	1E+06		2006	98.648	4.0447	
2007	8.4081	0		2007	15.107	1E+06		2007	100.21	4.0893	
2008	8.4941	0		2008	15.386	1E+06		2008	101.79	4.1338	
2009	8.5821	0		2009	15.669	1E+06		2009	103.4	4.1782	
2010	8.6719	0		2010	15.955	1E+06		2010	105.03	4.2226	
2011		0		2011				2011	0	0	
2012		0		2012				2012	0	0	

APPENDIX B:
INDUSTRIAL SECTOR: METHODOLOGY AND DATA SELECTION

SOURCES EXAMINED

- Motor and Steam Challenge Program Material
- Interlaboratory Working Group Study (1997)
- USDOE Industrial Assessment Database (IAD)
- ACEEE 1997 Energy Efficiency and Economic Development in NY, NJ, and PA
- Delaware Census Data

DATA SELECTION PROCESS

- Downloaded IAD, including Assessments Table and Recommendation Table
  - Assessment Table included 8,193 entries on industries surveyed
  - Recommendation Table included 57,769 entries on industrial productivity and energy efficiency enhancements
- Limited size of IAD so that Access query was manageable
  - Assessment Table Limited by:
    - Two-digit SIC codes represented in Delaware.
      - Selected two-digit SICs with 1,000 or more employees in Delaware (Except for Petroleum Refining and Stone, Glass and Clay, both of which were included — even though number of employees is < 1,000 — due to high energy consumption per worker. Both of these SICs are targeted by Interlaboratory study.)
- Recommendation Table limited to energy efficiency measures
  - Combustion Systems
    - Furnaces, Ovens, and directly fired operations; Boilers; and Fuel Switching
  - Thermal Systems
    - Steam; Heat Recovery; Heat Containment; and Cooling
  - Electrical Power
    - Demand Management and Co-generation
  - Motor Systems
    - Motors; Air Compressors; and Other Equipment
  - Buildings and Grounds
    - Lighting and Space Conditioning
- Selected energy efficiency measures for SIC codes within selected states
  - Query Criteria
    - ID/SUPER ID
    - SIC Code – limited to manufacturing codes that are represented in Delaware
    - STATE (PA, DE, MD, VA, and NJ)
    - ARC (Assessment Recommendation Code)
    - Description of Recommendation
    - Implementation Cost for Recommendation

- Energy Cost Total
- Energy Usage by Fuel Type
    - Electricity, Natural Gas, LPG, Fuel Oil #1, Fuel Oil #2, Fuel Oil #4, Fuel Oil #6, Coal, Wood, Paper, Other Gas, Other (to calculate Total Energy Usage by establishment)
- Energy Savings by Primary Resource
    - Fuel Type
    - Energy Conserved
    - Dollar Value Saved
- Energy Savings by Secondary Resource
    - Fuel Type
    - Energy Conserved
    - Dollar Value Saved

- Notable Data Excluded:
    - Tertiary Resource
        - (Source, Energy Conserved, Dollar Value Saved)
    - Quaternary Resource
        - (Source, Energy Conserved, Dollar Value Saved)
- Query resulted in 1,358 entries

❑ Selection of Non-Duplicate Measures by Size of Energy Savings (to eliminate duplicate cases of the same measure; and to eliminate measures with small savings which typically result in high overhead requirements)
- SIC codes often had duplicate measures. A typical case was picked based on energy savings and payback period.
- Energy savings were ranked regardless of SIC and top 75th percentile were selected (eliminating small savings cases)
- 1,358 entries reduced to 171 entries

❑ Used national energy-employment ratio (energy consumption per worker) to determine energy consumption by SIC in Delaware
- Extracted energy-employment ratios by two-digit SICs relevant to Delaware from ACE^3 database
- Using Delaware Census data, determined the number of employees for selected Delaware four-digit SICs
- Multiplied number of employees for each Delaware four-digit SIC by national energy-employment ratio for corresponding two-digit SIC
    - In effect, assumed that each chemical industry SIC used the same amount of energy on average per employee
- Provides energy consumption for selected four-digit SICs in Delaware

❑ Calculated the energy savings in Delaware for each efficiency measure
- Calculated the percentage of primary and secondary energy conserved for each efficiency measure by dividing the sum of primary and secondary energy savings by the particular facility's energy consumption
- The energy consumption totals by four-digit SIC for Delaware were multiplied by the energy savings percentages for each measure (calculated as described above) to determine energy savings by efficiency measure by four-digit SIC

- Calculated the CO_2 emission reductions for Delaware
  - To scale the emission reductions derived from the database, a scaling factor was used. The energy consumption in the database was divided by the projected industrial energy consumption in 2010. This yielded a factor of 27%.
  - Next, each measure's primary and secondary energy savings (in BTUs) were multiplied by a conversion factor based on fuel type to determine metric tons of reduced CO_2 emissions
    - <u>Conversion factors</u>

- Electricity	0.088*		
- Natural Gas	117.080	x	2200**
- Fuel Oil #2	161.386	x	2200**
- Fuel Oil #4	161.386	x	2200**

* electricity conversion factor was based on a 1990-1995 average fuel mix coefficient from the EIA's *State Energy Data Report*

** natural gas and fuel oil conversion factors were based on EIA's *Voluntary Reporting of Greenhouse Gases: Appendix B. Fuel and Energy Source Codes and Emission coefficients* (1997)

  - The estimate of CO_2 emission reduction derived in this manner was divided by the scaling factor of 27% to derive an estimate of CO_2 emission reduction for the Delaware industrial sector in 2010.
  - To determine the percent reduction, the above estimate of sectoral emission reductions was divided by the total projected sectoral emissions in 2010.
- Alternative scenarios were developed by multiplying the potential emission reduction by 65% and 35%
  - These alternative scenarios were based on implementation levels suggested in the Interlaboratory Working Group Study (1997).

APPENDIX C:
INDUSTRIAL SECTOR: ENERGY EFFICIENCY MEASURES

	STATE	SIC	ARC	DESCRIPTION	Implementation Cost per Establishment	Energy Usage by SIC	% Conserved Energy	Payback Period (years)	Annual Energy Savings by Establishment
1	DE	2015	2436	Install Desuperheater Water Heat Exchanger on Ice Maker System	$26,618	3,360,352	2.71%	2.1	$12,618
2	DE	2015	2626	Install Demand Defrost Controls on Freezer Coils	$33,000	3,360,352	0.95%	1.1	$29,378
3	DE	2015	4111	Replace V-Belts with Energy Efficient Belts	$2,803	3,360,352	0.17%	0.5	$5,159
4	DE	2015	4133	Install High Efficiency Motors	$45,837	3,360,352	1.24%	1.2	$38,274
5	DE	2015	4141	Install Variable Frequency Drives on Evaporative Condensor Fan	$66,206	3,360,352	0.85%	2.5	$26,349
6	DE	2015	7142	Install High Efficiency Lighting	$48,924	3,360,352	0.59%	2.7	$18,336
7	VA	2653	1212	Adjust Boiler Air-Fuel Ratio	$1,495	626,140	1.22%	1.0	$1,495
8	PA	2653	1213	Duct warm air to boiler air intake	$2,090	626,140	5.67%	0.3	$6,565
9	PA	2653	1233	Analyze Flue Gas for Proper Air/Fuel Ratio	$500	626,140	5.08%	0.1	$3,797
10	NJ	2653	1233	Analyze Flue Gas for Proper Air/Fuel Ratio	$0	626,140	2.18%	0.0	$2,812
11	PA	2653	2131	Insulate pipes	$317	626,140	0.98%	0.3	$1,201
12	NJ	2653	2133	Repair Leaks in Steam Lines and Valves	$1,455	626,140	12.35%	0.1	$11,639
13	PA	2653	2411	Use Waste Heat from Hot Flue Gases to Preheat Combustion Air	$6,800	626,140	13.03%	0.7	$9,848
14	PA	2653	7222	Air Condition Only Space in Use	$6,100	626,140	4.60%	1.8	$3,475
15	DE	2653	7243	Improve Interior Circulation with Destratification Fans, etc.	$4,320	626,140	2.11%	1.3	$3,434
16	NJ	2655	7233	Use Properly Designed and Sized HVAC Equipment	$7,010	626,140	18.91%	1.3	$5,240
17	NJ	2656	1233	Analyze Flue Gas for Proper Air/Fuel Ratio	$537	1,341,728	0.99%	0.2	$2,651
18	NJ	2656	7226	Use Computer Programs to Optimize HVAC Performance	$20,000	1,341,728	13.65%	0.1	$139,451
19	DE	2657	1233	Analyze Flue Gas for Proper Air/Fuel Ratio	$500	626,140	2.23%	0.1	$3,536
20	NJ	2657	2131	Insulate steam pipes	$2,420	626,140	3.11%	0.5	$4,874
21	NJ	2657	2411	Install heat exchangers	$5,550	626,140	11.53%	0.3	$18,070
22	DE	2657	4236	Eliminate Leaks in Inert Gas and Compressed Air Lines	$0	626,140	2.21%	0.0	$11,757
23	DE	2657	7243	Improve Interior Circulation with Destratification Fans, etc.	$4,140	626,140	2.37%	1.2	$3,548
24	DE	2657	7261	Install Timers and/or Thermostats	$2,151	626,140	2.34%	0.6	$3,707
25	VA	2671	1233	Adjust Steam Boiler Air-Fuel Ratio	$400	1,341,728	0.47%	0.2	$1,807
26	DE	2671	2428	Use Hot Flue Gases in Radiant Heaters for Space Heating, Etc.	$66,700	1,341,728	12.87%	0.8	$80,513
27	DE	2671	4115	Recover and Reuse Cooling Water	$0	1,341,728	0.92%	0.0	$18,842
28	DE	2671	4231	Reduce the Pressure of Compressed Air to Minimum	$3,200	1,341,728	0.40%	0.4	$8,150
29	VA	2671	7143	Install Energy-Efficient Lighting	$25,510	1,341,728	1.21%	1.8	$14,327

Primary Source Code	Primary % Conserved	Primary Energy Saved	Cost of Energy	Primary CO_2 saved [t]	Second. Source Code	Secondary % Conserved	Secondary Energy Saved	Cost of Energy	Secondary CO_2 Saved [t]	
# 2 Fuel Oil	2.71%	91,107	$4.91	6,683.34						1
Electricity	0.95%	31,861	$13.82	2,803.75						2
Electricity	0.17%	5,590	$13.82	491.94						3
Electricity	1.24%	41,520	$13.82	3,653.75						4
Electricity	0.85%	28,570	$13.82	2,514.19						5
Electricity	0.59%	19,902	$13.82	1,751.37						6
Natural Gas	1.22%	7,609	$2.84	404.92						7
Natural Gas	5.67%	35,500	$2.84	1,889.25						8
Natural Gas	5.08%	31,793	$2.84	1,691.97						9
# 4 Fuel Oil	2.18%	13,638	$4.91	1,000.45						10
Natural Gas	0.98%	6,157	$2.84	327.65						11
Natural Gas	9.81%	61,440	$2.84	3,269.74	# 2 Fuel Oil	2.54%	15,888	$4.91	1,165.49	12
Natural Gas	13.03%	81,591	$2.84	4,342.11						13
Natural Gas	4.60%	28,797	$2.84	1,532.51						14
Natural Gas	2.15%	13,444	$2.84	715.46	Electricity	-0.04%	(254)	$13.82	(22.35)	15
# 2 Fuel Oil	31.27%	195,797	$4.91	14,363.14	Natural Gas	-12.36%	(77,422)	$2.84	(4,120.25)	16
Natural Gas	0.99%	13,347	$2.84	710.32						17
Electricity	10.88%	145,915	$13.82	12,840.51	Natural Gas	2.78%	37,297	$2.84	1,984.85	18
Natural Gas	2.23%	13,986	$2.84	744.32						19
Natural Gas	3.11%	19,464	$2.84	1,035.85						20
Natural Gas	11.53%	72,205	$2.84	3,842.61						21
Electricity	2.21%	13,863	$13.82	1,219.93						22
Natural Gas	2.42%	15,149	$2.84	806.19	Electricity	-0.05%	(335)	$13.82	(29.45)	23
Natural Gas	2.34%	14,673	$2.84	780.88						24
Natural Gas	0.47%	6,367	$2.84	338.83						25
# 2 Fuel Oil	12.87%	172,695	$4.91	12,668.45						26
Electricity	0.92%	12,288	$13.82	1,081.31						27
Electricity	0.40%	5,318	$13.82	467.95						28
Electricity	1.21%	16,264	$13.82	1,431.26						29

	STATE	SIC	ARC	DESCRIPTION	Implementation Cost per Establishment	Energy Usage by SIC	% Conserved Energy	Payback Period (years)	Annual Energy Savings by Establishment
30	DE	2671	7243	Improve Interior Circulation with Destratification Fans, etc.	$5,220	1,341,728	0.88%	1.0	$5,303
31	DE	2672	1233	Analyze Flue Gas for Proper Air/Fuel Ratio	$2,000	626,140	9.42%	0.1	$19,516
32	DE	2672	4111	Utilize Energy Efficient Belts and Other Improved Mechanisms	$0	626,140	0.75%	0.0	$7,753
33	NJ	2672	7243	Improve Interior Circulation with Destratification Fans, etc.	$6,660	626,140	9.20%	1.5	$4,528
34	NJ	2741	4236	Eliminate Leaks in Inert Gas and Compressed Air Lines	$56	7,644	3.46%	0.0	$7,750
35	NJ	2752	2432	Recover Heat from Oven Exhaust/Kilns	$23,000	42,626	4.08%	4.0	$5,783
36	NJ	2752	2441	Preheat Boiler Makeup Water with Waste Process Heat	$9,500	42,626	5.79%	1.1	$8,856
37	VA	2752	2442	Install Combustion Pre-Heater	$5,634	42,626	18.46%	0.5	$11,625
38	MD	2752	4132	Install High Efficiency Motors	$21,621	42,626	3.73%	1.4	$15,720
39	MD	2752	7143	Install High Efficiency Lighting	$14,284	42,626	5.80%	0.6	$23,794
40	NJ	2819	1233	Analyze Flue Gas for Proper Air/Fuel Ratio	$500	2,051,483	6.96%	0.2	$3,169
41	VA	2819	2131	Insulate presently uninsulated steam mains and condensate line	$2,700	2,051,483	1.19%	0.5	$5,639
42	NJ	2819	2411	Use Waste Heat from Hot Flue Gases to Preheat Combustion Air	$6,800	2,051,483	8.16%	1.8	$3,748
43	NJ	2819	2443	Reuse/Recycle Hot or Cold Process Exhaust Air	$11,000	2,051,483	6.70%	4.1	$2,714
44	VA	2819	2511	Insulate exterior surface of heat exchangers	$790	2,051,483	0.79%	0.2	$3,753
45	VA	2819	4115	Recover and Reuse Cooling Water	$10,940	2,051,483	0.61%	0.3	$37,721
46	VA	2819	4133	Install High Efficiency Motors	$6,838	2,051,483	0.07%	1.5	$4,599
47	VA	2819	4236	Repair Leaks in Compressed Air Lines	$1,600	2,051,483	11.46%	0.2	$8,052
48	PA	2821	1213	Preheat boiler intake air using hot flue gas	$11,600	700,712	0.32%	2.5	$4,636
49	NJ	2821	1233	Analyze Flue Gas for Proper Air/Fuel Ratio	$750	700,712	7.35%	0.0	$48,442
50	NJ	2821	2113	Repair or Replace Steam Traps	$30,000	700,712	14.69%	0.3	$94,269
51	NJ	2821	2411	Use Waste Heat from Hot Flue Gases to Preheat Combustion Air	$7,500	700,712	0.58%	1.1	$6,895
52	NJ	2833	2411	Install stack heatexchanger to preheat combustion air	$11,610	168,846	9.50%	1.1	$10,486
53	NJ	2833	7142	Install high efficiency lighting	$81,329	168,846	4.59%	2.3	$34,962
54	NJ	2834	1233	Analyze Flue Gas for Proper Air/Fuel Ratio	$537	1,055,290	3.41%	0.0	$11,719
55	NJ	2834	2133	Repair Leaks in Steam Lines and Valves	$500	1,055,290	9.06%	0.0	$31,090
56	NJ	2834	7226	Use Computer Programs to Optimize HVAC Performance	$12,000	1,055,290	2.47%	0.6	$20,807
57	NJ	2844	1232	Clean/Adjust boiler	$220	1,055,290	3.24%	0.0	$5,227
58	NJ	2865	2131	Insulate Steam/Hot Water Lines	$8,786	2,110,580	1.21%	2.0	$4,470
59	NJ	2865	2133	Repair Leaks in Steam Lines and Valves	$160	2,110,580	6.47%	0.0	$23,820
60	NJ	2869	1233	Analyze Flue Gas for Proper Air/Fuel Ratio	$537	492,469	2.79%	0.2	$2,411
61	NJ	2891	1233	Analyze Flue Gas for Proper Air/Fuel Ratio	$500	28,141	3.56%	0.3	$1,646
62	VA	2951	2511	Insulate the Rotating Kiln	$5,655	715,227	2.87%	0.8	$7,287
63	VA	2951	4131	Install High Efficiency Motors	$45,026	715,227	0.63%	3.6	$12,439

Primary Source Code	Primary % Conserved	Primary Energy Saved	Cost of Energy	Primary CO_2 saved [t]	Second. Source Code	Secondary % Conserved	Secondary Energy Saved	Cost of Energy	Secondary CO_2 Saved [t]	
Natural Gas	0.89%	11,962	$2.84	636.62	Electricity	-0.02%	(211)	$13.82	(18.56)	30
Natural Gas	9.42%	58,955	$2.84	3,137.47						31
Electricity	0.75%	4,682	$13.82	411.99						32
Natural Gas	9.47%	59,275	$2.84	3,154.53	Electricity	-0.27%	(1,667)	$13.82	(146.71)	33
Electricity	3.46%	264	$13.82	23.26						34
Natural Gas	4.08%	1,741	$2.84	92.64						35
Natural Gas	5.79%	2,468	$2.84	131.35						36
Natural Gas	18.46%	7,870	$2.84	418.85						37
Elect. Consumpt.	3.73%	1,590	$13.82	139.93	Elect. Demand	0.00%	0	$0.00	-	38
Electr. Consump.	5.80%	2,474	$13.82	217.74	Electr. Demand	0.00%	0	$0.00	-	39
# 2 Fuel Oil	6.96%	142,704	$4.91	10,468.41						40
# 2 Fuel Oil	1.19%	24,327	$4.91	1,784.57						41
# 2 Fuel Oil	8.16%	167,338	$4.91	12,275.46						42
# 2 Fuel Oil	6.70%	137,355	$4.91	10,076.01						43
# 2 Fuel Oil	0.79%	16,191	$4.91	1,187.73						44
Electr. Consump.	0.61%	12,578	$13.82	1,106.85	Electr. Demand	0.00%	0	$0.00	-	45
Elect. Consumpt.	0.07%	1,534	$13.82	134.97	Elect. Demand	0.00%	0	$0.00	-	46
Elect. Consump.	11.46%	235,189	$13.82	20,696.60	Elect. Demand	0.00%	0	$0.00	-	47
Natural Gas	0.32%	2,240	$2.84	119.22						48
Natural Gas	7.21%	50,509	$2.84	2,688.01	# 6 Fuel Oil	0.15%	1,016	$2.62	80.35	49
Natural Gas	12.31%	86,262	$2.84	4,590.70	# 6 Fuel Oil	2.38%	16,678	$2.62	1,318.33	50
Natural Gas	0.58%	4,048	$2.84	215.45						51
Natural Gas	9.50%	16,043	$2.84	853.76						52
Electr. Consump.	4.59%	7,756	$13.82	682.56	Electr. Demand	0.00%	0	$0.00	-	53
# 4 Fuel Oil	3.41%	36,012	$4.91	2,641.71						54
# 4 Fuel Oil	9.06%	95,570	$4.91	7,010.75						55
Electricity	2.47%	26,026	$13.82	2,290.27						56
Natural Gas	3.24%	34,229	$2.84	1,821.63						57
Natural Gas	1.06%	22,391	$2.84	1,191.63	# 4 Fuel Oil	0.15%	3,232	$4.91	237.12	58
Natural Gas	5.65%	119,333	$2.84	6,350.68	# 4 Fuel Oil	0.82%	17,220	$4.91	1,263.19	59
Natural Gas	2.79%	13,736	$2.84	731.03						60
Natural Gas	3.56%	1,001	$2.84	53.25						61
Natural Gas	2.87%	20,492	$2.84	1,090.54						62
Electricity	0.63%	4,478	$13.82	394.04						63

	STATE	SIC	ARC	DESCRIPTION	Implementation Cost per Establishment	Energy Usage by SIC	% Conserved Energy	Payback Period (years)	Annual Energy Savings by Establishment
64	PA	2952	2411	Install recuperators on asphalt heaters	$8,140	1,129,306	3.63%	0.3	$23,449
65	PA	2952	4221	Use outside air for compressor intakes	$400	1,129,306	0.23%	0.1	$5,530
66	PA	2952	7111	Reduce light level in warehouse	$500	1,129,306	0.77%	0.0	$18,420
67	PA	2952	7143	Install high pressure sodium fixtures	$26,726	1,129,306	1.14%	1.0	$26,996
68	VA	3052	4231	Reduce Compresspor Air Pressure	$100	16,428	2.69%	0.0	$3,644
69	VA	3052	7111	Reduce Lighting Usage	$6,120	16,428	5.18%	0.9	$7,021
70	VA	3052	7241	Add Economizers on Air Handling Units	$6,985	16,428	7.14%	0.7	$9,680
71	NJ	3061	1233	Analyze Flue Gas for Proper Air/Fuel Ratio	$500	102,677	7.50%	0.0	$10,885
72	PA	3069	1222	Install turbulators in boiler tubes	$1,040	55,857	0.37%	0.8	$1,291
73	NJ	3069	1233	Analyze Flue Gas for Proper Air/Fuel Ratio	$537	55,857	6.68%	0.0	$15,337
74	PA	3069	2131	Insulate Steam Pipes	$8,003	55,857	2.84%	0.8	$9,848
75	NJ	3069	2133	Repair Leaks in Steam Lines and Valves	$100	55,857	3.34%	0.0	$7,660
76	NJ	3069	2411	Use Waste Heat from Hot Flue Gases to Preheat Combustion Air	$7,500	55,857	9.96%	0.6	$11,747
77	NJ	3069	2412	Use Flue Gas to Preheat Boiler Feedwater	$3,000	55,857	3.58%	0.4	$8,211
78	PA	3069	2511	Insulate Hot Sufaces of the Presses	$6,986	55,857	2.52%	0.8	$8,274
79	NJ	3069	4231	Reduce the Pressure of Compressed Air to Minimum	$0	55,857	0.75%	0.0	$9,625
80	PA	3069	7243	Install Destratification Fans	$7,200	55,857	2.79%	1.7	$4,267
81	NJ	3069	7261	Install Timers and/or Thermostats	$675	55,857	5.18%	0.1	$11,903
82	NJ	3081	1233	Analyze Flue Gas for Proper Air/Fuel Ratio	$2,500	167,843	1.06%	0.9	$2,825
83	PA	3081	2133	Repair Leaks in Steam Lines and Valves	$430	167,843	0.29%	0.2	$1,725
84	NJ	3081	2411	Use Waste Heat from Hot Flue Gases to Preheat Combustion Air	$25,000	167,843	13.17%	0.7	$35,120
85	NJ	3087	4221	Install Compressor Intakes in Coolest Locations	$700	101,856	2.38%	0.0	$14,131
86	PA	3089	1213	Duct Warm air to Boiler Air intakes	$2,330	248,890	14.01%	0.2	$12,196
87	NJ	3089	1233	Analyze Flue Gas for Proper Air/Fuel Ratio	$500	248,890	5.44%	0.2	$3,179
88	NJ	3089	1233	Analyze Flue Gas for Proper Air/Fuel Ratio	$269	248,890	2.83%	0.0	$5,698
89	NJ	3089	2133	Repair Leaks in Steam Lines and Valves	$325	248,890	10.77%	0.1	$6,284
90	VA	3089	2163	Use Minimum Steam Operating Pressure	$0	248,890	2.40%	0.0	$2,783
91	VA	3089	2437	Install Heat Reovery System on Extruder	$5,691	248,890	2.47%	0.5	$12,028
92	PA	3089	2492	Recover boiler room waste heat	$1,360	248,890	6.40%	0.1	$11,475
93	NJ	3089	2614	Use Cooling Tower/Economizer Cooling to Replace Chiller	$11,500	248,890	2.76%	0.7	$16,605
94	PA	3089	3291	Install energy managers	$5,000	248,890	1.39%	0.2	$23,639
95	MD	3089	4111	Replace Drive Belts with HTD Belts	$6,600	248,890	5.62%	1.6	$4,204
96	VA	3089	4133	Install High Efficiency Motors	$8,261	248,890	1.59%	1.7	$4,776
97	MD	3089	4231	Reduce Compressor Air Pressure	$15	248,890	0.28%	0.0	$2,247

Primary Source Code	Primary % Conserved	Primary Energy Saved	Cost of Energy	Primary CO_2 saved [t]	Second. Source Code	Secondary % Conserved	Secondary Energy Saved	Cost of Energy	Secondary CO_2 Saved [t]	
Natural Gas	3.63%	40,987	$2.84	2,181.27						64
Elect. Consump.	0.23%	2,627	$13.82	231.20	Elect. Demand	0.00%	0	$0.00	-	65
Electr. Consump.	0.77%	8,752	$13.82	770.17	Electr. Demand	0.00%	0	$0.00	-	66
Electr. Consump.	1.14%	12,846	$13.82	1,130.48	Electr. Demand	0.00%	0	$0.00	-	67
Electricity	2.69%	442	$13.82	38.86						68
Electricity	5.18%	851	$13.82	74.90						69
Electricity	7.14%	1,173	$13.82	103.18						70
# 2 Fuel Oil	7.50%	7,701	$4.91	564.92						71
Natural Gas	0.37%	208	$2.84	11.05						72
# 2 Fuel Oil	6.68%	3,730	$4.91	273.65						73
Natural Gas	2.84%	1,584	$2.84	84.30						74
# 2 Fuel Oil	3.34%	1,866	$4.91	136.88						75
Natural Gas	8.77%	4,899	$2.84	260.71	# 2 Fuel Oil	1.19%	663	$4.91	48.65	76
# 2 Fuel Oil	3.58%	1,997	$4.91	146.51						77
Electricity	2.52%	1,406	$13.82	123.72						78
Electricity	0.75%	421	$13.82	37.03						79
Natural Gas	2.79%	1,558	$2.84	82.89						80
# 2 Fuel Oil	5.18%	2,895	$4.91	212.37						81
# 2 Fuel Oil	1.06%	1,779	$4.91	130.51						82
Natural Gas	0.29%	483	$2.84	25.72						83
# 2 Fuel Oil	13.17%	22,103	$4.91	1,621.44						84
Electricity	2.38%	2,424	$13.82	213.29						85
Natural Gas	14.01%	34,882	$2.84	1,856.35						86
# 4 Fuel Oil	5.44%	13,549	$4.91	993.89						87
# 2 Fuel Oil	2.83%	7,044	$4.91	516.71						88
# 4 Fuel Oil	10.77%	26,803	$4.91	1,966.22						89
Natural Gas	2.40%	5,983	$2.84	318.41						90
Electr. Consump.	2.47%	6,142	$13.82	540.52	Electr. Demand	0.00%	0	$0.00	-	91
Natural Gas	6.40%	15,920	$2.84	847.26						92
Electricity	2.76%	6,865	$13.82	604.09						93
Electr. Consump.	1.39%	3,452	$13.82	303.80						94
Electricity	5.62%	13,984	$13.82	1,230.63						95
Electricity	1.59%	3,957	$13.82	348.21						96
Electricity	0.28%	704	$13.82	61.94						97

	STATE	SIC	ARC	DESCRIPTION	Implementation Cost per Establishment	Energy Usage by SIC	% Conserved Energy	Payback Period (years)	Annual Energy Savings by Establishment
98	VA	3089	4233	Replace Compressed-Air Wipers with Sponge Rollers	$3,000	248,890	1.81%	0.6	$5,441
99	VA	3089	4237	Replace Compressed Air Cooling with Water or Air Cooling	$13,460	248,890	5.33%	0.5	$24,816
100	MD	3089	7111	Reduce Lighting	$9,819	248,890	2.73%	0.5	$21,730
101	NJ	3089	7221	Maintain Lower Temp. in Winter & Higher in Summer	$0	248,890	43.88%	0.0	$8,044
102	MD	3089	7224	Set Back Space Heaters During Heating Season	$900	248,890	3.13%	0.1	$8,812
103	PA	3089	7226	Use Computer Programs to Optimize HVAC Performance	$0	248,890	7.30%	0.0	$31,161
104	PA	3089	7261	Install Timers and/or Thermostats	$2,800	248,890	11.97%	0.5	$5,664
105	PA	3229	2131	Insulate Steam Pipes	$2,745	33,442	0.61%	0.4	$6,143
106	PA	3229	2422	Preheat Lehr Intake Air using the surface heat near burners	$677	33,442	0.76%	0.2	$3,479
107	PA	3229	2437	Recover furnace waste heat	$3,690	33,442	1.48%	0.2	$14,990
108	PA	3229	2443	Install a Stack Heat Exchanger	$3,500	33,442	2.37%	0.5	$6,502
109	PA	3229	2511	Insulation of Day tanks	$910	33,442	1.21%	0.2	$5,488
110	PA	3229	2514	Use Doors on 16 pot furnace openings to reduce heat loss	$522	33,442	1.21%	0.1	$6,458
111	PA	3229	4231	Reduce compressor air pressure	$35	33,442	0.17%	0.0	$4,577
112	PA	3295	1213	Preheat Intake air using hot surface	$4,500	87,240	0.52%	3.3	$1,367
113	PA	3296	2411	Preheat Boiler Intake air using hot fuel gas	$3,700	254,451	0.78%	0.4	$9,068
114	PA	3296	2437	Use Process heat to preheat water	$7,710	254,451	0.54%	1.2	$6,325
115	PA	3296	2511	Insulate Intake pipe to waste heat boiler	$288	254,451	0.36%	0.1	$4,143
116	VA	3297	2511	Insulate the Rotating Kiln	$16,700	14,540	7.16%	0.8	$21,127
117	VA	3297	4236	Repair Leaks in Compressed Air Lines	$1,200	14,540	1.04%	0.2	$6,452
118	PA	3312	4226	Install Small Compressor	$36,000	1,185,121	1.25%	0.9	$38,326
119	PA	3312	7291	Eliminate Heaters in the Compressor Room	$19	1,185,121	0.47%	0.0	$4,127
120	NJ	3315	1233	Analyze Flue Gas for Proper Air/Fuel Ratio	$537	553,057	0.49%	0.3	$1,936
121	MD	3315	4111	Utilize Energy Efficient Belts and Other Improved Mechanisms	$21,400	553,057	1.98%	1.3	$16,798
122	MD	3315	4133	Use Most Efficient Type of Electric Motors	$44,360	553,057	4.20%	1.2	$35,736
123	PA	3321	7233	Use Properly Designed and Sized HVAC Equipment	$8,240	1,185,121	4.58%	1.8	$4,470
124	NJ	3429	7243	Improve Interior Circulation with Destratification Fans, etc.	$5,040	13,392	1.91%	1.3	$3,847
125	NJ	3442	1233	Analyze Flue Gas for Proper Air/Fuel Ratio	$500	39,059	3.37%	0.2	$2,009
126	NJ	3442	2437	Recover Waste Heat from Equipment	$500	39,059	2.96%	0.1	$4,934
127	NJ	3442	4236	Eliminate Leaks in Inert Gas and Compressed Air Lines	$200	39,059	2.77%	0.0	$20,305
128	NJ	3442	7231	Install Infrared heaters	$6,000	39,059	5.85%	0.9	$6,903
129	PA	3442	7243	Install destratification fans	$10,400	39,059	5.72%	3.8	$2,763
130	NJ	3442	7261	Install secure thermostats	$5,000	39,059	9.46%	0.4	$11,162
131	PA	3444	7221	Maintain Lower Temp. in Winter & Higher in Summer	$0	134,587	30.48%	0.0	$4,207

Primary Source Code	Primary % Conserved	Primary Energy Saved	Cost of Energy	Primary CO_2 saved [t]	Second. Source Code	Secondary % Conserved	Secondary Energy Saved	Cost of Energy	Secondary CO_2 Saved [t]	
Electricity	1.81%	4,502	$13.82	396.17						98
Electricity	5.33%	13,276	$13.82	1,168.25						99
Electricity	2.73%	6,807	$13.82	598.98						100
Natural Gas	43.88%	109,219	$2.84	5,812.42						101
Natural Gas	3.13%	7,791	$2.84	414.60						102
Electricity	7.30%	18,181	$13.82	1,599.89						103
Natural Gas	11.97%	29,791	$2.84	1,585.40						104
Natural Gas	0.61%	202	$2.84	10.77						105
Natural Gas	0.76%	256	$2.84	13.61						106
Natural Gas	1.48%	494	$2.84	26.29						107
Natural Gas	2.37%	793	$2.84	42.18						108
Natural Gas	1.21%	403	$2.84	21.45						109
Natural Gas	1.21%	404	$2.84	21.49						110
Electricity	0.17%	58	$13.82	5.10						111
Natural Gas	0.52%	454	$2.84	24.15						112
Natural Gas	0.78%	1,978	$2.84	105.25						113
Natural Gas	0.54%	1,379	$2.84	73.39						114
Natural Gas	0.36%	903	$2.84	48.08						115
Natural Gas	7.16%	1,040	$2.84	55.37						116
Elect. Consumpt.	1.04%	151	$13.82	13.32						117
Electricity	1.25%	14,822	$13.82	1,304.31						118
Natural Gas	0.47%	5,578	$2.84	296.84						119
# 4 Fuel Oil	0.49%	2,722	$4.91	199.70						120
Electricity	1.98%	10,930	$13.82	961.81						121
Electricity	4.20%	23,247	$13.82	2,045.75						122
# 2 Fuel Oil	4.58%	54,236	$4.91	3,978.57						123
Natural Gas	1.97%	264	$2.84	14.03	Electricity	-0.06%	(7)	$13.82	(0.66)	124
Natural Gas	3.37%	1,318	$2.84	70.13						125
Natural Gas	2.96%	1,156	$2.84	61.54						126
Electricity	2.77%	1,081	$13.82	95.11						127
Natural Gas	5.85%	2,286	$2.84	121.68						128
Natural Gas	5.79%	2,260	$2.84	120.30	Electr. Consump.	-0.06%	(24)	$13.82	(2.15)	129
Natural Gas	9.46%	3,696	$2.84	196.69						130
Natural Gas	30.48%	41,022	$2.84	2,183.10						131

	STATE	SIC	ARC	DESCRIPTION	Implementation Cost per Establishment	Energy Usage by SIC	% Conserved Energy	Payback Period (years)	Annual Energy Savings by Establishment
132	VA	3471	1233	Adjust Boiler Air-Fuel Ratio	$1,495	13,392	3.03%	0.3	$4,337
133	PA	3471	2133	Repair Leaks in Steam Lines and Valves	$0	13,392	1.42%	0.0	$6,034
134	PA	3479	1213	Use Hot Flue Gas to Preheat Intake Combustion Air	$7,445	2,232	6.04%	1.7	$4,294
135	PA	3479	1233	Adjust Boiler/Oven Air-Fuel Ratio	$5,000	2,232	14.19%	0.5	$10,127
136	NJ	3479	2153	Close Off Unneeded Steam Lines	$1,880	2,232	1.65%	1.1	$1,773
137	PA	3479	2422	Use Waste heat from Hot Flue Gases to Generate Steam	$15,000	2,232	18.00%	0.3	$52,380
138	PA	3491	7241	Add economizers on air conditioning units	$11,628	2,232	8.90%	1.1	$11,051
139	NJ	3496	2422	Use Waste heat from Hot Flue Gases to Generate Steam	$11,500	2,232	5.02%	1.2	$9,901
140	DE	3496	2532	Use Only Amount of Air Necessary to Drive Off Combustible Solv	$10,000	2,232	8.03%	1.7	$5,773
141	NJ	3498	7224	Reduce/Eliminate Space Heating/Cooling During Non-Working Hour	$0	41,068	1.31%	0.0	$4,210
142	MD	3499	1233	Analyze Flue Gas for Proper Air/Fuel Ratio	$500	13,392	0.89%	0.2	$2,376
143	NJ	3499	2131	Insulate Steam/Hot Water Lines	$2,290	13,392	4.20%	1.1	$2,107
144	VA	3546	2525	Create an Indoor Recirc. Loop for Heat Treat Oil	$3,677	6,911	2.39%	0.2	$20,090
145	VA	3546	4141	Instal VSD on Cooling Tower Fans	$5,698	6,911	0.58%	1.2	$4,595
146	PA	3561	1233	Analyze Flue Gas for Proper Air/Fuel Ratio	$0	1,152	5.07%	0.0	$1,830
147	VA	3561	4236	Repair Leaks in Compressed Air Lines	$400	1,152	1.99%	0.2	$1,834
148	PA	3564	4236	Eliminate Leaks in Inert Gas and Compressed Air Lines	$0	6,911	1.60%	0.0	$9,599
149	MD	3585	1233	Adjust furnace air fuel ratio	$2,000	43,197	3.00%	0.7	$2,667
150	PA	3589	7261	Install Timers and/or Thermostats	$239	1,152	13.49%	0.1	$4,071
151	NJ	3613	7231	Use Radiant Heater for Spot Heating	$10,500	7,303	33.26%	1.2	$8,910
152	VA	3679	2411	Install a Heat Reclaim System in Ovens	$7,873	7,303	3.77%	0.9	$9,088
153	VA	3679	2612	Free Cooling from Chilled Water Heat Rejection Loop	$66,950	7,303	1.76%	2.7	$24,554
154	VA	3679	4131	Reduce Air Handler Air Flow	$1,296	7,303	1.19%	0.1	$8,786
155	VA	3679	4141	Install VFD on Cooling Tower Motor	$6,136	7,303	0.66%	0.7	$9,378
156	NJ	3679	7261	Install Timers and/or Thermostats	$2,800	7,303	10.66%	0.4	$6,567
157	PA	3711	7231	Change oil heaters to radiant heaters	$9,600	1,316,241	48.35%	3.0	$3,205
158	VA	3713	7261	Install Timers and/or Thermostats	$0	1,755	13.06%	0.0	$5,046
159	VA	3714	4111	Replace standard V-belts with cogged V-belts	$955	1,755	0.66%	0.2	$5,663
160	VA	3714	4221	Move compressor air intakes outdoors	$1,120	1,755	0.62%	0.2	$6,310
161	VA	3714	4236	Repair compressed air leaks	$5,000	1,755	0.68%	0.7	$6,880
162	PA	3823	2131	Insulate Pipes of the Boiler	$490	1,003	2.54%	0.4	$1,191
163	PA	3823	7224	Reduce/Eliminate Space Heating/Cooling During Non-Working Hour	$0	1,003	7.77%	0.0	$8,820
164	NJ	3842	2411	Install Stack Heat Exchanger	$1,110	6,021	5.73%	0.1	$16,870
165	PA	3842	2443	Use inside air for air makeup systems	$0	6,021	3.26%	0.0	$8,932
166	NJ	3842	7142	Install high efficiency lighting	$111,891	6,021	3.47%	2.6	$43,564

Primary Source Code	Primary % Conserved	Primary Energy Saved	Cost of Energy	Primary CO_2 saved [t]	Second. Source Code	Secondary % Conserved	Secondary Energy Saved	Cost of Energy	Secondary CO_2 Saved [t]	
Natural Gas	3.03%	406	$2.84	21.62						132
Natural Gas	1.42%	190	$2.84	10.13						133
Natural Gas	6.04%	135	$2.84	7.18						134
Natural Gas	14.19%	317	$2.84	16.85						135
Natural Gas	1.65%	37	$2.84	1.96						136
Natural Gas	18.00%	402	$2.84	21.38						137
Electr. Consump.	8.90%	199	$13.82	17.48						138
Natural Gas	5.02%	112	$2.84	5.97						139
Natural Gas	8.03%	179	$2.84	9.54						140
Natural Gas	1.31%	538	$2.84	28.62						141
Natural Gas	0.89%	119	$2.84	6.33						142
# 2 Fuel Oil	4.20%	562	$4.91	41.23						143
Electricity	2.39%	165	$13.82	14.51						144
Electricity	0.58%	40	$13.82	3.53						145
# 2 Fuel Oil	5.07%	58	$4.91	4.28						146
Elect. Consumpt.	1.99%	23	$13.82	2.02						147
Electricity	1.60%	111	$13.82	9.76						148
Natural Gas	3.00%	1,295	$2.84	68.93						149
Natural Gas	13.49%	155	$2.84	8.27						150
Natural Gas	33.26%	2,429	$2.84	129.27						151
Natural Gas	3.77%	275	$2.84	14.65						152
Electr. Consump.	1.76%	129	$13.82	11.31						153
Elect. Consumpt.	1.19%	87	$13.82	7.64	Elect. Demand	0.00%	0	$0.00	-	154
Elect. Consumpt.	0.66%	48	$13.82	4.26						155
Natural Gas	10.66%	778	$2.84	41.42						156
# 2 Fuel Oil	48.35%	636,339	$4.91	46,680.07						157
# 2 Fuel Oil	12.64%	222	$4.91	16.27	Electricity	0.42%	7	$13.82	0.65	158
Electricity	0.66%	12	$13.82	1.03						159
Elect. Consumpt.	0.62%	11	$13.82	0.95	Elect. Demand	0.00%	0	$0.00	-	160
Elect. Consumpt.	0.68%	12	$13.82	1.05	Elect. Demand	0.00%	0	$0.00	-	161
Natural Gas	2.54%	26	$2.84	1.36						162
Natural Gas	7.77%	78	$2.84	4.15						163
Natural Gas	5.73%	345	$2.84	18.36						164
Natural Gas	3.26%	196	$2.84	10.45						165
Electr. Consump.	3.47%	209	$13.82	18.41	Electr. Demand	0.00%	0	$0.00	-	166

	STATE	SIC	ARC	DESCRIPTION	Implementation Cost per Establishment	Energy Usage by SIC	% Conserved Energy	Payback Period (years)	Annual Energy Savings by Establishment
167	VA	3949	1233	Adjust Boiler Air-Fuel Ratio	$1,495	4,128	5.09%	0.3	$4,337
168	VA	3949	4236	Repair Leaks In Compressed Air Lines	$800	4,128	1.67%	0.2	$4,909
169	VA	3999	2411	Install Combustion Air Preheater	$5,800	688	9.06%	0.4	$16,369
170	VA	3999	7221	Reduce Setpoints on Unit Heaters in Warehouse B and C	$0	688	4.71%	0.0	$8,524

Primary Source Code	Primary % Conserved	Primary Energy Saved	Cost of Energy	Primary CO_2 saved [t]	Second. Source Code	Secondary % Conserved	Secondary Energy Saved	Cost of Energy	Secondary CO_2 Saved [t]	
Natural Gas	5.09%	210	$2.84	11.19						167
Elect. Consumpt.	1.67%	69	$13.82	6.07						168
Natural Gas	9.06%	62	$2.84	3.32						169
Natural Gas	4.71%	32	$2.84	1.72						170

	Energy usage (TBtu)	
Projected energy consumption in 2010	105.03	
Energy consumption in data set	25.12	
	CO_2 emissions	
2010 projected emissions	4,222,594	4,222,594
Datasheet's emission reductions	274,994	1,149,794
Emissions Reduction		27%
	Emission Reductions	
100% Scenario CO_2 Reduction (t)	1,140,100	27%
Remaining Emissions (t)	3,082,493	
65% Scenario CO_2 Reduction (t)	741,065	18%
Remaining Emissions (t)	3,481,528	
35% Scenario CO_2 Reduction (t)	399,035	9%
Remaining Emissions (t)	3,823,558	
Average Payback Period (yr)		0.68

APPENDIX D:
RESIDENTIAL SECTOR: FUEL AND END-USE ELECTRICITY CONSUMPTION

	Coal			*Natural Gas*			*Distillate Fuel*			*Kerosene*	
Year	Trillion BTUs	Metric Tons CO_2	Year	Trillion BTUs	Metric Tons CO_2	Year	Trillion BTUs	Metric Tons CO_2	Year	Trillion BTUs	Metric Tons CO_2
1985	0	0	1985	6.315	336075	1985	7.8186	572452	1985	3.7088	268417
1986	0.1	9512.6	1986	7	372527	1986	6.2	453942	1986	1.8	130270
1987	0.3007	28601	1987	7.1158	378689	1987	7.8173	572358	1987	1.9042	137813
1988	0.1004	9552.5	1988	7.7323	411498	1988	8.134	595540	1988	1.7071	123549
1989	0.2	19025	1989	7.7	409780	1989	7.7	563767	1989	1.5	108559
1990	0.2	19025	1990	7.4	393815	1990	5.6	410012	1990	0.8	57898
1991	0.2	19025	1991	7.4	393815	1991	5.9	431977	1991	0.9	65135
1992	0	0	1992	8.5	452355	1992	6.1	446621	1992	0.8	57898
1993	0.4008	38123	1993	8.6163	458543	1993	6.6125	484144	1993	0.6011	43506
1994	0.2004	19061	1994	8.9166	474525	1994	6.9129	506136	1994	0.5009	36254
1995	0	0	1995	8.8	468320	1995	6.3	461264	1995	0.7	50661
1996	0.1766	16801	1996	8.9142	474395	1996	5.8762	430238	1996	0.68	49213
1997	0.1776	16891	1997	8.9674	477230	1997	5.6413	413040	1997	0.6669	48269
1998	0.1782	16950	1998	9.0042	479188	1998	5.4066	395853	1998	0.6533	47284
1999	0.1788	17009	1999	9.0409	481140	1999	5.182	379410	1999	0.6404	46345
2000	0.1798	17099	2000	9.0939	483962	2000	4.9759	364320	2000	0.6291	45532
2001	0.181	17221	2001	9.1634	487660	2001	4.7865	350449	2001	0.6195	44837
2002	0.1823	17343	2002	9.2329	491361	2002	4.6038	337074	2002	0.6104	44173
2003	0.1836	17465	2003	9.3026	495066	2003	4.4275	324163	2003	0.6016	43538
2004	0.1849	17588	2004	9.3723	498777	2004	4.2571	311687	2004	0.5932	42930
2005	0.1862	17711	2005	9.4422	502495	2005	4.0922	299620	2005	0.5851	42349
2006	0.1875	17835	2006	9.5122	506221	2006	3.9327	287936	2006	0.5775	41791
2007	0.1888	17959	2007	9.5824	509956	2007	3.778	276613	2007	0.5701	41257
2008	0.1901	18084	2008	9.6527	513700	2008	3.628	265629	2008	0.563	40745
2009	0.1914	18209	2009	9.7233	517454	2009	3.4823	254965	2009	0.5562	40253
2010	0.1927	18335	2010	9.794	521220	2010	3.3408	244603	2010	0.5497	39781

	LPG				***Bio-Fuel***				***Electricity***				***Total***	
Year	Trillion BTUs	Metric Tons CO_2		Year	Trillion BTUs	Metric Tons CO_2 (No Net Emissions)		Year	Trillion BTUs	Metric Tons CO_2		Year	Trillion BTUs	Million Metric Tons CO_2
1985	2.105	131254		1985	0	0		1985	6.6158	587692		1985	26.563	1.8959
1986	1.5	93530		1986	0	0		1986	7.2	648725		1986	23.8	1.7085
1987	1.804	112485		1987	0	0		1987	7.9176	701430		1987	26.86	1.9314
1988	2.0084	125229		1988	0	0		1988	8.6361	770258		1988	28.318	2.0356
1989	2	124707		1989	0	0		1989	8.9	771959		1989	28	1.9978
1990	2.1	130942		1990	1.6	0		1990	9	790257		1990	26.7	1.8019
1991	2.3	143413		1991	1.7	0		1991	9.6	822452		1991	28	1.8758
1992	2.2	137177		1992	1.8	0		1992	9.5	834414		1992	28.9	1.9285
1993	2.4045	149931		1993	1.9036	0		1993	10.42	905319		1993	30.959	2.0796
1994	2.5047	156174		1994	1.9035	0		1994	10.62	883437		1994	31.559	2.0756
1995	3.1	193295		1995	2.1	0		1995	10.8	858349		1995	31.8	2.0319
1996	2.7288	170151		1996	2.0918	0		1996	11.115	901707		1996	31.583	2.0425
1997	2.7761	173097		1997	2.1388	0		1997	11.288	907972		1997	31.656	2.0365
1998	2.817	175649		1998	2.1805	0		1998	11.436	913432		1998	31.676	2.0284
1999	2.8567	178126		1999	2.2208	0		1999	11.58	918103		1999	31.7	2.0201
2000	2.9006	180861		2000	2.264	0		2000	11.741	922001		2000	31.785	2.0138
2001	2.9488	183867		2001	2.3104	0		2001	11.921	925135		2001	31.93	2.0092
2002	2.9963	186827		2002	2.3559	0		2002	12.098	927514		2002	32.079	2.0043
2003	3.043	189744		2003	2.4006	0		2003	12.272	929146		2003	32.231	1.9991
2004	3.0892	192621		2004	2.4446	0		2004	12.445	930031		2004	32.386	1.9936
2005	3.1347	195460		2005	2.4879	0		2005	12.615	930173		2005	32.543	1.9878
2006	3.1797	198266		2006	2.5306	0		2006	12.783	929570		2006	32.703	1.9816
2007	3.2242	201041		2007	2.5727	0		2007	12.95	928218		2007	32.866	1.975
2008	3.2683	203787		2008	2.6143	0		2008	13.115	926113		2008	33.032	1.9681
2009	3.3119	206506		2009	2.6553	0		2009	13.279	923248		2009	33.2	1.9606
2010	3.3551	209201		2010	2.696	0		2010	13.442	919612		2010	33.37	1.9528

APPENDIX E:

RESIDENTIAL SECTOR: PROJECTED ENERGY CONSUMPTION AND CO_2 EMISSIONS BY SELECTED END-USES

		BAU scenario								
		1996	1996		2000	2000		2010	2010	
Selected end use	Life time	% of total EU	EU Trillion Btus	CO_2 emission Metric Tons	% of total	EU Trillion Btus	CO_2 emission Metric Tons	% of total	EU Trillion Btus	CO_2 emission Metric Tons
Refrigerators (Elec.)	19	3.7%	1.16	95433	3.2%	1.01	79097	2.3%	0.76	52183
Freezers (Elec.)	19	1.2%	0.37	30259	1.0%	0.31	24168	0.7%	0.22	14909
Water Heating (Elec.)	10	3.2%	1.02	83795	3.2%	1.01	79097	3.1%	1.04	70819
Water Heating (All Fuel)	13.9	13.3%	4.20	234075	13.2%	4.20	228608	13.3%	4.44	230196
Clothes Dryers (Elec.)	17	1.7%	0.54	44225	1.8%	0.56	43943	1.8%	0.60	41001
Cooking (Gas)	19	1.7%	0.54	30050	1.8%	0.56	30481	1.4%	0.46	24008
Lighting (Elec.)	1	3.1%	0.96	79140	3.1%	0.98	76900	3.2%	1.06	72683
Space Heating (Elec.)	18	5.0%	1.57	128380	4.6%	1.46	114399	5.1%	1.70	116545
Space Heating (All Fuel)	20	43.0%	13.59	757335	41.7%	13.26	722299	38.8%	12.95	671473
Space Cooling (Elec.)	13	4.1%	1.31	107071	4.2%	1.34	105462	4.4%	1.47	100638
Miscellaneous (Elec.)	12	10.1%	3.18	260696	12.8%	4.06	318584	16.2%	5.39	369007
Miscellaneous (Gas)	12	0.9%	0.28	15816	0.9%	0.28	15241	0.9%	0.30	15535
Electricity		32.0%			33.7%			36.7%		
Other Fuel		58.9%			57.6%			54.4%		
Subtotal		90.9%	28.72	1866275	91.3%	29.01	1838279	91.1%	30.40	1778997
Total		100%	31.58	2042505	100%	31.78	2013775	100%	33.37	1952752
	Life time	**Total shells in 1996**	**Total shells in 2000**	**Total shells in 2010**	**Old shells in 2010**	**New shells in 2010**				
Household Envelope	50	270615	279364	311385	194843	116542				
					63%	37%				

	Fuel Switching			**Savings Scenario**							
	2010	**2010**		**1996-2010**		**1996-2010**		**2000-2010**		**2000-2010**	
Selected end use	**% of total**	**EU Trillion Btus**	CO_2 **Metric Tons**	**EU Trillion BTUs**	CO_2 **emission Metric Tons**	**Energy Savings Trillion Btus**	CO_2 **reduction Metric Tons**	**EU Trillion BTUs**	CO_2 **emission Metric Tons**	**Energy Savings Trillion Btus**	CO_2 **reduction Metric Tons**
Refrigerators (Elec.)	2.3%	0.76	52183	0.58	39703	0.18	12480	0.63	43268	0.13	8914
Freezers (Elec.)	0.7%	0.22	14909	0.17	11843	0.04	3066	0.19	12719	0.03	2190
Water Heating (Elec.)	1.4%	0.47	32009	0.34	23167	0.70	47652	0.34	23167	0.70	47652
Water Heating (All Fuel)	15.0%	5.01	259606	3.88	201042	0.56	29154	4.19	217473	0.25	12723
Clothes Dryers (Elec.)	1.8%	0.60	41001	0.59	40330	0.01	671	0.59	40521	0.01	479
Cooking (Gas)	1.4%	0.46	24008	0.39	20077	0.08	3931	0.41	21200	0.05	2808
Lighting (Elec.)	3.2%	1.06	72683	0.50	34161	0.56	38522	0.50	34161	0.56	38522
Space Heating (Elec.)	3.4%	1.14	77734	0.81	55126	0.90	61420	0.82	56315	0.88	60231
Space Heating (All Fuel)	40.5%	13.52	700883	11.86	614633	1.10	56840	11.97	620773	0.98	50700
Space Cooling (Elec.)	4.4%	1.47	100638	1.20	82276	0.27	18362	1.32	90267	0.15	10371
Miscellaneous (Elec.)	16.2%	5.39	369007	3.61	247234	1.78	121772	3.91	267530	1.48	101477
Miscellaneous (Gas)	0.9%	0.30	15535	0.27	13981	0.03	1553	0.27	14240	0.02	1295
Electricity				*Fuel Switch*	*-215367*		215367	*Fuel Switch*	*-215367*		215367
Other Fuel											
Subtotal	91.1%	30.40	1760195	24.19	1168205	6.21	610792	25.15	1226268	5.25	552729
Total	100%	33.37	1933950	27.16	1341960			28.12	1400023		
		100% case		81.4%	68.7%	18.6%	31.3%	84.3%	71.7%	15.7%	28.3%
		35% case				6.5%	10.9%			5.5%	9.9%
		65% case				12.1%	20.3%			10.2%	18.4%

APPENDIX F:
RESIDENTIAL SECTOR: IMPLEMENTATION SCENARIOS

	100% Implementation					65% Implementation		35% Implementation	
	EU Trillion BTUs	CO_2 emission Metric Tons	Energy Savings Trillion Btus	CO_2 reduction Metric Tons	Total Cost ($)	Energy Savings MMBtus	CO_2 reduction Metric Tons	Energy Savings MMBtus	CO_2 reduction Metric Tons
Refrigerators (Elec.)	0.632	43268	0.130	8914	1289960	84694	5794	45605	3120
Freezers (Elec.)	0.186	12719	0.032	2190	422595	20810	1424	11205	767
Water Heating (Elec.)	0.339	23167	0.697	47652	6554321	452743	30974	243785	16678
Water Heating (All Fuel)	4.195	217473	0.245	12723	527625	159515	8270	85892	4453
Clothes Dryers (Elec.)	0.592	40521	0.007	479	77790	4555	312	2453	168
Cooking (Gas)	0.409	21200	0.054	2808	129992	35206	1825	18957	983
Lighting (Elec.)	0.499	34161	0.563	38522	4673478	365995	25039	197074	13483
Space Heating (Elec.)	0.823	56315	0.880	60231	9411252	572246	39150	308133	21081
Space Heating (Gas)	11.974	620773	0.978	50700	5212483	635669	32955	342283	17745
Space Cooling (Elec.)	1.319	90267	0.152	10371	807995	98536	6741	53058	3630
Miscellaneous (Elec.)	3.910	267530	1.483	101477	14402530	964124	65960	519144	35517
Miscellaneous (Gas)	0.275	14240	0.025	1295	149825	16231	841	8740	453
Fuel Switching		-215367		215367			139989		75379
Subtotal	25.154	1226268	5.247	552729	43659846	3410324	359274	1836328	193455
% Savings			15.7%	28.3%		10.2%	18.4%	5.5%	9.9%

APPENDIX G:
COMMERCIAL SECTOR: FUEL AND END-USE ELECTRICITY CONSUMPTION

	Coal			Natural Gas			Distillate Fuel			Kerosene			LPG	
Year	Trillion BTUs	Metric Tons CO_2	Year	Trillion BTUs	Metric Tons CO_2	Year	Trillion BTUs	Metric Tons CO_2	Year	Trillion BTUs	Metric Tons CO_2	Year	Trillion BTUs	Metric Tons CO_2
1985	0.1	9512.6	1985	3.5	186264	1985	1.9	139111	1985	0.3	21712	1985	0.4	24941
1986	0.1	9512.6	1986	3.6	191585	1986	1.4	102503	1986	0.1	7237.2	1986	0.3	18706
1987	0.6	57076	1987	3.8	202229	1987	2.1	153755	1987	0.1	7237.2	1987	0.3	18706
1988	0.2991	28450	1988	4.0874	217525	1988	2.2929	167881	1988	0.1994	14430	1988	0.3988	24865
1989	0.3	28538	1989	4.2	223516	1989	1.7	124468	1989	0	0	1989	0.4	24941
1990	0.2991	28454	1990	4.0879	217551	1990	1.9941	146001	1990	0.0997	7215.9	1990	0.3988	24868
1991	0.3	28538	1991	4.4	234160	1991	2.6	190363	1991	0.1	7237.2	1991	0.4	24941
1992	0	0	1992	5.1	271413	1992	2	146433	1992	0	0	1992	0.4	24941
1993	0.8	76101	1993	5.4	287378	1993	1.9	139111	1993	0	0	1993	0.4	24941
1994	0.4021	38251	1994	5.7301	304944	1994	1.5079	110404	1994	0	0	1994	0.4021	25073
1995	0	0	1995	5.93	315585	1995	1.6081	117743	1995	0	0	1995	0.5025	31335
1996	0.3217	30603	1996	5.8868	313284	1996	1.7916	131177	1996	0	0	1996	0.4461	27818
1997	0.3247	30888	1997	6.07	323037	1997	1.7617	128986	1997	0	0	1997	0.4523	28203
1998	0.326	31007	1998	6.2174	330881	1998	1.7234	126182	1998	0	0	1998	0.456	28433
1999	0.3291	31310	1999	6.3989	340538	1999	1.6964	124205	1999	0	0	1999	0.4623	28829
2000	0.3357	31938	2000	6.646	353687	2000	1.6873	123540	2000	0	0	2000	0.4735	29523
2001	0.3426	32593	2001	6.8992	367163	2001	1.6795	122966	2001	0	0	2001	0.485	30243
2002	0.3498	33276	2002	7.1589	380982	2002	1.6728	122478	2002	0	0	2002	0.497	30990
2003	0.3573	33986	2003	7.4253	395159	2003	1.6672	122070	2003	0	0	2003	0.5094	31762
2004	0.365	34723	2004	7.6987	409710	2004	1.6627	121736	2004	0	0	2004	0.5222	32562
2005	0.3731	35489	2005	7.9794	424650	2005	1.6591	121473	2005	0	0	2005	0.5355	33388
2006	0.3814	36284	2006	8.2678	439997	2006	1.6564	121275	2006	0	0	2006	0.5492	34243
2007	0.3901	37107	2007	8.5641	455765	2007	1.6545	121139	2007	0	0	2007	0.5634	35127
2008	0.3991	37960	2008	8.8686	471970	2008	1.6535	121061	2008	0	0	2008	0.578	36040
2009	0.4083	38843	2009	9.1816	488630	2009	1.6532	121039	2009	0	0	2009	0.5931	36983
2010	0.4179	39757	2010	9.5035	505761	2010	1.6536	121069	2010	0	0	2010	0.6087	37957

	Motor Gas			Residual			Electricity			Total	
Year	Trillion BTUs	Metric Tons CO_2	Year	Trillion BTUs	Metric Tons CO_2	Year	Trillion BTUs	Metric Tons CO_2	Year	Trillion BTUs	Million Metric Tons CO_2
1985	0.2	14247	1985	0.4	31547	1985	5.8	515227	1985	12.6	0.9426
1986	0.2	14247	1986	1	78868	1986	6.4	576645	1986	13.1	0.9993
1987	0.2	14247	1987	1	78868	1987	6.8	602424	1987	14.9	1.1345
1988	0.1994	14203	1988	1.0966	86489	1988	7.3773	657988	1988	15.951	1.2118
1989	0.2	14247	1989	1.5	118302	1989	7.8	676548	1989	16.1	1.2106
1990	0.1994	14205	1990	1.0968	86499	1990	8.0761	709133	1990	16.252	1.2339
1991	0.2	14247	1991	0.3	23660	1991	8.4	719646	1991	16.7	1.2428
1992	0.2	14247	1992	0.6	47321	1992	8.5	746581	1992	16.8	1.2509
1993	0	0	1993	1.4	110416	1993	9.1	790656	1993	19	1.4286
1994	0	0	1994	1.0053	79284	1994	9.4496	786093	1994	18.497	1.3441
1995	0	0	1995	0.8041	63416	1995	9.9504	790824	1995	18.795	1.3189
1996	0	0	1996	0.9598	75698	1996	10.035	795871	1996	19.441	1.3745
1997	0	0	1997	0.9592	75648	1997	10.308	816374	1997	19.876	1.4031
1998	0	0	1998	0.9536	75208	1998	10.521	836818	1998	20.197	1.4285
1999	0	0	1999	0.9539	75233	1999	10.792	857190	1999	20.633	1.4573
2000	0	0	2000	0.9642	76043	2000	11.174	877474	2000	21.281	1.4922
2001	0	0	2001	0.9752	76916	2001	11.567	897649	2001	21.948	1.5275
2002	0	0	2002	0.9871	77849	2002	11.97	917693	2002	22.635	1.5633
2003	0	0	2003	0.9997	78841	2003	12.384	937576	2003	23.342	1.5994
2004	0	0	2004	1.013	79892	2004	12.809	957269	2004	24.071	1.6359
2005	0	0	2005	1.0271	81002	2005	13.246	976736	2005	24.82	1.6727
2006	0	0	2006	1.0419	82170	2006	13.696	995936	2006	25.593	1.7099
2007	0	0	2007	1.0574	83396	2007	14.159	1014826	2007	26.388	1.7474
2008	0	0	2008	1.0737	84679	2008	14.634	1033358	2008	27.207	1.7851
2009	0	0	2009	1.0907	86021	2009	15.124	1051478	2009	28.051	1.823
2010	0	0	2010	1.1084	87421	2010	15.627	1069127	2010	28.919	1.8611

APPENDIX H

COMMERCIAL SECOR: PROJECTED ENERGY CONSUMPTION AND CO_2 EMISSIONS BY SELECTED END-USES

		BAU								
Year/Study period		**1996**	**1996**		**2000**	**2000**		**2010**	**2010**	
	Life time	% of total EU	EU Trillion Btus	CO_2 Metric Tons	% of total EU	EU Trillion Btus	CO_2 Metric Tons	% of total EU	EU Trillion Btus	CO_2 Metric Tons
Space Conditioning & Vent (Elec.)	18	11.3%	2.188	179468	11.1%	2.359	185223	10.3%	2.972	203349
Space Conditioning & Vent (Fuel)	18	20.2%	3.928	241630	19.3%	4.107	249829	18.3%	5.300	315779
Lighting (Elec.)	12	15.4%	2.993	245509	15.4%	3.274	257096	14.4%	4.170	285273
Refrigeration (Elec.)	15	1.9%	0.364	29888	1.9%	0.409	32137	1.9%	0.538	36809
Miscellaneous (Elec.)	12	14.5%	2.811	230565	15.8%	3.356	263523	19.2%	5.548	379597
Miscellaneous (Gas)	12	20.1%	3.904	240133	20.6%	4.393	267176	20.6%	5.952	354628
PV	25									
Elec. Use		43.0%			44.2%			45.7%		
Other Fuel Use		40.3%			39.9%			38.9%		
Subtotal		83.3%	16.188	1167194	84.1%	17.898	1254983	84.7%	24.481	1575435
Total		100%	19.441	1374452	100%	21.281	1492205	100%	28.919	1861091

	Fuel Switching + PV			Savings							
Year/Study period	**2010**			**1996-2010**		**1996-2010**		**2000-2010**		**2000-2010**	
	% of total EU	EU Trillion Btus	CO_2 Metric Tons	EU Trillion BTUs	CO_2 Emission Metric Tons	Energy Savings Trillion Btus	CO_2 Reduction Metric Tons	EU Trillion BTUs	CO_2 Emission Metric Tons	Energy Savings Trillion Btus	CO_2 Reduction Metric Tons
Space Conditioning & Vent (Elec.)	8.8%	2.539	173671	1.591	108834	1.382	94515	1.862	127359	1.111	75990
Space Conditioning & Vent (Fuel)	19.8%	5.734	341625	3.593	214085	1.707	101694	4.205	250525	1.095	65254
Lighting (Elec.)	14.4%	4.170	285273	3.127	213955	1.042	71318	3.301	225841	0.869	59432
Refrigeration (Elec.)	1.9%	0.538	36809	0.382	26159	0.156	10650	0.427	29202	0.111	7607
Miscellaneous (Elec.)	19.2%	5.548	379597	3.717	254330	1.831	125267	4.023	275208	1.526	104389
Miscellaneous (Gas)	20.6%	5.952	354628	5.357	319165	0.595	35463	5.456	325075	0.496	29552
PV	-1.0%	-0.289	-19785	-0.289	-75650	0.289	75650	-0.289	-75650	0.289	75650
Elec. Use				Fuel Switch loss emission	-85416		85416		-85416		85416
Other Fuel Use											
Subtotal			1571603	17.479	975462	7.002	599973	18.984	1072144	5.497	503291
Total		28.919		21.918	1261117			23.423	1357800		
			100% case	75.8%	67.8%	24.2%	32.2%	81.0%	73.0%	19.0%	27.0%
			35% case			8.5%	11.3%			6.7%	9.5%
			65% case			15.7%	21.0%			12.4%	17.6%

APPENDIX I

COMMERCIAL SECOR: IMPLEMENTATION SCENARIOS

	100% Implementation					65% Implementation		35% Implementation	
	EU Trillion Btus	CO_2 Emission Metric Tons	Energy Savings Trillion Btus	CO_2 Reduction Metric Tons	Total Cost ($)	Energy Savings mmBtus	CO_2 Reduction Metric Tons	Energy Savings mmBtus	CO_2 Reduction Metric Tons
Space Conditioning & Vent (Elec.)	1.862	127359	1.111	75990	4565099	721974	49393	388755	26596
Space Conditioning & Vent (Fuel)		250525	1.095	65254	4501348	711892	42415	383326	22839
Lighting (Elec.)	3.301	225841	0.869	59432	-8860783	564658	38631	304046	20801
Refrigeration (Elec.)	0.427	29202	0.111	7607	518165	72276	4945	38918	2663
Miscellaneous (Elec.)	4.023	275208	1.526	104389	15563536	991794	67853	534043	36536
Miscellaneous (Gas)	5.456	325075	0.496	29552	2976012	322401	19209	173601	10343
PV	-0.289	-75650	0.289	75650	6420116	187976	49172	101218	26477
Fuel Switching		-85416		85416			55521		29896
Subtotal (w/o PV)	15.068	1147794	5.208	427641	19263378	3384996	277967	1822690	149674
Subtotal (with PV)	14.779	1072144	5.497	503291	25683494	3572972	327139	1923908	176152
BAU	28.919	1861091							
% Savings (w/o PV)			18.0%	23.0%		11.7%	14.9%	6.3%	8.0%
% Savings (with PV)			19.0%	27.0%		12.4%	17.6%	6.7%	9.5%

APPENDIX J:
TRANSPORTATION SECTOR: FUEL AND END-USE ELECTRICITY CONSUMPTION

Aviation Fuel*			***Distillate***			***Jet Fuel****			***LPG***		
Year	Trillion BTUs	Metric Tons CO_2	Year	Trillion BTUs	Metric Tons CO_2	Year	Trillion BTUs	Metric Tons CO_2	Year	Trillion BTUs	Million Metric Tons CO_2
1985	0.100	6925	1985	7.200	527159	1985	8.400	598063	1985	0	0
1986	0.100	6937	1986	8.614	630710	1986	7.212	513479	1986	0.200	12491
1987	0.100	6925	1987	9.100	666270	1987	6.900	491266	1987	0	0
1988	0.100	6936	1988	8.413	615977	1988	7.311	520555	1988	0	0
1989	0.100	6915	1989	10.884	796852	1989	6.790	483414	1989	0	0
1990	0.401	27745	1990	8.013	586663	1990	7.011	499178	1990	0	0
1991	0.100	6915	1991	8.188	599522	1991	12.882	917150	1991	0	0
1992	0.100	6925	1992	8.000	585732	1992	7.800	555344	1992	0	0
1993	0.300	20745	1993	9.486	694540	1993	7.689	547423	1993	0	0
1994	0.322	22269	1994	9.647	706310	1994	3.216	228946	1994	0	0
1995	0.336	23266	1995	10.191	746135	1995	0.448	31893	1995	0	0
1996	0.303	20999	1996	8.927	653622	1996	8.967	638437	1996	0	0
1997	0.322	22324	1997	8.949	655207	1997	9.083	646706	1997	0	0
1998	0.343	23739	1998	9.011	659722	1998	9.239	657815	1998	0	0
1999	0.363	25154	1999	9.073	664329	1999	9.396	668994	1999	0	0
2000	0.384	26568	2000	9.138	669027	2000	9.554	680245	2000	0	0
2001	0.404	27983	2001	9.203	673815	2001	9.713	691572	2001	0	0
2002	0.425	29399	2002	9.270	678693	2002	9.874	702976	2002	0	0
2003	0.445	30816	2003	9.338	683662	2003	10.035	714461	2003	0	0
2004	0.465	32235	2004	9.407	688720	2004	10.197	726029	2004	0	0
2005	0.486	33657	2005	9.477	693868	2005	10.361	737682	2005	0	0
2006	0.507	35081	2006	9.548	699106	2006	10.526	749423	2006	0	0
2007	0.527	36509	2007	9.621	704433	2007	10.692	761255	2007	0	0
2008	0.548	37942	2008	9.695	709849	2008	10.860	773180	2008	0	0
2009	0.569	39378	2009	9.770	715355	2009	11.028	785200	2009	0	0
2010	0.589	40819	2010	9.847	720950	2010	11.199	797317	2010	0	0

*=not included in consumption or emissions total

Motor Gas			***Residual***			***Lubricants***			***Total***		
Year	Trillion BTUs	Metric Tons CO_2	Year	Trillion BTUs	Metric Tons CO_2	Year	Trillion BTUs	Metric Tons CO_2	Year	Trillion BTUs	Million Metric Tons CO_2
1985	39.200	2792400	1985	1.500	118302	1985	0.400	14856	1985	48.300	3.453
1986	40.067	2854129	1986	3.706	292298	1986	0.300	11161	1986	52.888	3.801
1987	40.800	2906376	1987	7.600	599399	1987	0.400	14856	1987	57.900	4.187
1988	42.566	3032190	1988	5.509	434451	1988	0.401	14879	1988	56.888	4.097
1989	42.236	3008669	1989	5.592	440994	1989	0.399	14834	1989	59.110	4.261
1990	41.466	2953805	1990	5.709	450264	1990	0.401	14880	1990	55.588	4.006
1991	40.442	2880907	1991	8.288	653677	1991	0.399	14835	1991	57.318	4.149
1992	42.400	3020351	1992	6.500	512644	1992	0.400	14856	1992	57.300	4.134
1993	43.237	3079953	1993	7.189	567022	1993	0.399	14834	1993	60.312	4.356
1994	46.412	3306158	1994	8.575	676296	1994	0.429	15924	1994	65.063	4.705
1995	49.386	3518012	1995	7.391	582926	1995	0.448	16637	1995	67.416	4.864
1996	42.813	3049803	1996	7.653	603601	1996	0.400	14863	1996	59.794	4.322
1997	42.926	3057817	1997	7.855	619518	1997	0.401	14900	1997	60.131	4.347
1998	43.230	3079506	1998	8.091	638093	1998	0.404	15005	1998	60.736	4.392
1999	43.541	3101619	1999	8.327	656711	1999	0.407	15111	1999	61.348	4.438
2000	43.857	3124156	2000	8.563	675377	2000	0.410	15220	2000	61.968	4.484
2001	44.180	3147113	2001	8.801	694098	2001	0.413	15331	2001	62.596	4.530
2002	44.508	3170491	2002	9.039	712880	2002	0.416	15443	2002	63.232	4.578
2003	44.842	3194289	2003	9.278	731729	2003	0.419	15558	2003	63.876	4.625
2004	45.182	3218504	2004	9.518	750652	2004	0.422	15675	2004	64.528	4.674
2005	45.527	3243138	2005	9.759	769652	2005	0.425	15794	2005	65.188	4.722
2006	45.879	3268189	2006	10.001	788737	2006	0.429	15915	2006	65.857	4.772
2007	46.237	3293657	2007	10.244	807911	2007	0.432	16038	2007	66.534	4.822
2008	46.600	3319543	2008	10.488	827180	2008	0.435	16163	2008	67.219	4.873
2009	46.969	3345848	2009	10.734	846548	2009	0.439	16290	2009	67.912	4.924
2010	47.344	3372570	2010	10.981	866021	2010	0.442	16419	2010	68.614	4.976

APPENDIX K

TRANSPORTATION SECTOR: FUEL EFFICIENCY MEASURES

Baseline CO_2 Emissions for Highway Vehicles in 2010					
Vehicle Type	*Percentage of VMT*	*Total VMT (millions)*	*Avg. Vehicle Fuel Efficiency (mpg)*	*Gas Consumption (gallons)*	*CO_2 (metric tons)*
LDGV	47.50	4441.25	21.3	208509389.7	1861515.0
LDGT	45.70	4272.95	17.3	246991329.5	2205071.2
HDGV	3.60	336.60	6.3	53428571.4	476995.7
LDDV	0.25	23.38	21.3	1097417.8	11165.7
LDDT	0.15	14.03	17.3	810693.6	8248.4
HDDV	1.00	93.50	6.3	14841269.8	151003.2
MC	1.80	168.30	35.0	4808571.4	42929.6
LDV Subtotal		8919.90		462217402.1	4128930.0
HDV Subtotal		430.10		68269841.3	627998.9
TOTALS		**9350.00**		**530487243.3**	**4756928.9**

Modest Commitment Strategy -- Projected Delaware Roadway CO2 Emissions in 2010					
Vehicle Type	*Percentage of VMT*	*Total VMT (millions)*	*Avg. Vehicle Fuel Efficiency (mpg)*	*Gas Consumption (gallons)*	*CO_2 (metric tons)*
LDGV	47.50	4441.25	23.3	190611588.0	1701728.3
LDGT	45.70	4272.95	19.3	221396373.1	1976566.4
HDGV	3.60	336.60	6.3	53428571.4	543611.4
LDDV	0.25	23.38	23.3	1003218.9	8956.5
LDDT	0.15	14.03	19.3	726683.9	6487.6
HDDV	1.00	93.50	6.3	14841269.8	151003.2
MC	1.80	168.30	35.0	4808571.4	42929.6
LDV Subtotal		8919.90		418546435.3	3736668.4
HDV Subtotal		430.10		68269841.3	694614.6
TOTALS		**9350.00**		**486816276.6**	**4431283.0**
Total CO_2 **Reduction from 2010 Baseline (Increased Trucks) in Metric Tons**					**325645.8**

Major Commitment Strategy -- Projected Delaware Roadway CO_2 Emissions in 2010					
Vehicle Type	*Percentage of VMT*	*Total VMT (millions)*	*Avg. Vehicle Fuel Efficiency (mpg)*	*Gas Consumption (gallons)*	*CO_2 (metric tons)*
LDGV	47.50	4441.25	27.2	163281250.0	1457730.5
LDGT	45.70	4272.95	23.2	184178879.3	1644298.8
HDGV	3.60	336.60	6.3	53428571.4	476995.7
LDDV	0.25	23.38	27.2	859375.0	8743.8
LDDT	0.15	14.03	23.2	604525.9	6150.8
HDDV	1.00	93.50	6.3	14841269.8	151003.2
MC	1.80	168.30	35.0	4808571.4	42929.6
LDV Subtotal		8919.90		353732601.6	3159853.4
HDV Subtotal		430.10		68269841.3	627998.9
TOTALS		**9350.00**		**422002442.9**	**3787852.302**
Total CO_2 **Reduction from 2010 Baseline (Increased Trucks) in Metric Tons**					**969076.6**

Full Implementation Strategy Projected -- Delaware Roadway CO_2 Emissions in 2010					
Vehicle Type	*Percentage of VMT*	*Total VMT (millions)*	*Avg. Vehicle Fuel Efficiency (mpg)*	*Gas Consumption (gallons)*	*CO_2 (metric tons)*
LDGV	47.50	4441.25	29.0	153146551.7	1367250.6
LDGT	45.70	4272.95	25.0	170918000.0	1525909.3
HDGV	3.60	336.60	6.3	53428571.4	543611.4
LDDV	0.25	23.38	25.0	935000.0	8347.4
LDDT	0.15	14.03	29.0	483620.7	4317.6
HDDV	1.00	93.50	6.3	14841269.8	151003.2
MC	1.80	168.30	35.0	4808571.4	42929.6
LDV Subtotal		8919.90		330291743.8	2948754.6
HDV Subtotal		430.10		68269841.3	694614.6
TOTALS		**9350.00**		**398561585.1**	**3643369.2**
Total CO_2 **Reduction from 2010 Baseline (Increased Trucks) in Metric Tons**					**1113559.7**

APPENDIX L
TRANSPORTATION SECTOR: ALTERNATIVE FUEL VEHICLES

Modest Commitment Scenario -- CO_2 Emissions for Highway Vehicles in 2010 with 1.2% CNG fleet penetration					
Vehicle Type	*Percentage of VMT*	*Total VMT (millions)*	*Avg. Vehicle Fuel Efficiency (mpg)*	*Gas Consumption (gallons)*	*CO_2 (metric tons)*
LDGV	46.30	4329.05	21.3	203241784.0	1814487.2
LDGT	45.70	4272.95	17.3	246991329.5	2205071.2
HDGV	3.60	336.60	6.3	53428571.4	476995.7
LDDV	0.25	23.38	21.3	1097417.8	11165.7
LDDT	0.15	14.03	17.3	810693.6	8248.4
HDDV	1.00	93.50	6.3	14841269.8	151003.2
MC	1.80	168.30	35.0	4808571.4	42929.6
LDCNGV	1.20	112.20	21.3	n/a	35271.4
LDV Subtotal		8919.90		456949796.4	4081902.2
HDV Subtotal		430.10		68269841.3	627998.9
TOTALS		**9350.00**		**525219637.7**	**4745172.5**
TOTAL CO_2 **REDUCTION FROM 2010 BASELINE**					**11756.3**

Major Commitment Scenario -- CO_2 Emissions for Highway Vehicles in 2010 with 2.1% CNG fleet penetration					
Vehicle Type	*Percentage of VMT*	*Total VMT (millions)*	*Avg. Vehicle Fuel Efficiency (mpg)*	*Gas Consumption (gallons)*	*CO_2 (metric tons)*
LDGV	45.40	4244.90	21.3	199291079.8	1779216.4
LDGT	45.70	4272.95	17.3	246991329.5	2205071.2
HDGV	3.60	336.60	6.3	53428571.4	476995.7
LDDV	0.25	23.38	21.3	1097417.8	11165.7
LDDT	0.15	14.03	17.3	810693.6	8248.4
HDDV	1.00	93.50	6.3	14841269.8	151003.2
MC	1.80	168.30	35.0	4808571.4	42929.6
LDCNGV	2.10	196.35	21.3	n/a	61725.0
LDV Subtotal		8919.90		452999092.2	4046631.4
HDV Subtotal		430.10		68269841.3	627998.9
TOTALS		**9350.00**		**521268933.5**	**4736355.3**
TOTAL CO_2 **REDUCTION FROM 2010 BASELINE**					**20573.6**

Full Implementation Scenario -- CO_2 Emissions for Highway Vehicles in 2010 with 3.5% CNG and 1.75% Electric fleet penetration					
Vehicle Type	*Percentage of VMT*	*Total VMT (millions)*	*Avg. Vehicle Fuel Efficiency (mpg)*	*Gas Consumption (gallons)*	*CO_2 (metric tons)*
LDGV	42.25	3950.38	21.3	185463615.0	1655768.6
LDGT	45.70	4272.95	17.3	246991329.5	2205071.2
HDGV	3.60	336.60	6.3	53428571.4	476995.7
LDDV	0.25	23.38	21.3	1097417.8	11165.7
LDDT	0.15	14.03	17.3	810693.6	8248.4
HDDV	1.00	93.50	6.3	14841269.8	151003.2
MC	1.80	168.30	35.0	4808571.4	42929.6
LDCNGV	3.50	327.25	21.3	n/a	102874.9
LDHV	1.75	163.63	21.3	n/a	0.0
LDV Subtotal		8919.90		439171627.4	3923183.6
HDV Subtotal		430.10		68269841.3	627998.9
TOTALS		**9350.00**		**507441468.7**	**4654057.4**
TOTAL CO_2 **REDUCTION FROM 2010 BASELINE**					**102871.4**

APPENDIX M

TRANSPORTATION SECTOR: TRANSPORTATION CONTROL MEASURES (TCM'S)

Modest Commitment Scenario

TCM	VMT Reduction
Area-Wide Ridesharing	0.50%
Transit Improvements	0.50%
HOV lanes	0.30%
Compressed Work Week	0.60%
Telecommuting	1.00%
TOTAL	**2.90%**

Major Commitment Scenario

TCM	VMT Reduction
Area-Wide Ridesharing	1.00%
Transit Improvements	1.00%
HOV lanes	0.30%
Compressed Work Week	0.60%
Telecommuting	3.00%
Parking Pricing (work)	1.50%
Parking Pricing (non-work)	3.50%
Congestion Pricing	3.00%
Pay-as-you-drive Insurance	2.00%
TOTAL	**15.90%**

Full Implementation Scenario

TCM	VMT Reduction
Area-Wide Ridesharing	1.00%
Transit Improvements	1.00%
HOV lanes	0.30%
Compressed Work Week	0.60%
Telecommuting	5.00%
Parking Pricing (work)	3.00%
Parking Pricing (non-work)	3.50%
Congestion Pricing	4.00%
Pay-as-you-drive Insurance	2.00%
TOTAL	**20.40%**

Summary of TCM Scenarios

Scenario	Percentage Reduction	Reduction in LDV VMT's	CO_2 Reduction (metric tons)
Moderate	2.90%	258.6	323,824.7
Major	15.90%	1016.9	656,953.2
Full Implementation	20.40%	2087.3	1,127,198.4

Modest Commitment Scenario -- CO_2 Emissions for Highway Vehicles in 2010					
Vehicle Type	*Percentage of VMT*	*Total VMT (millions)*	*Avg. Vehicle Fuel Efficiency (mpg)*	*Gas Consumption (gallons)*	*CO_2 (metric tons)*
LDGV	70.60	6418.8	21.3	301352112.7	2690389.5
LDGT	22.47	2042.8	17.3	118080924.9	1054194.3
HDGV	3.70	336.6	6.3	53428571.4	476995.7
LDDV	0.25	22.7	21.3	1065727.7	10843.3
LDDT	0.15	13.6	17.3	786127.2	7998.5
HDDV	1.03	93.5	6.3	14841269.8	151003.2
MC	1.80	163.4	35.0	4668571.4	41679.7
LDV Subtotal	100.00	8661.3		425953463.8	3805105.3
HDV Subtotal		430.1		68269841.3	627998.9
TOTALS		**9091.4**		**494223305.1**	**4433104.2**

Major Commitment Scenario -- CO_2 Emissions for Highway Vehicles in 2010					
Vehicle Type	*Percentage of VMT*	*Total VMT (millions)*	*Avg. Vehicle Fuel Efficiency (mpg)*	*Gas Consumption (gallons)*	*CO_2 (metric tons)*
LDGV	70.28	5856.9	21.3	274969892.0	2454856.2
LDGT	22.37	1863.9	17.3	107741185.0	961883.9
HDGV	4.04	336.6	6.3	53428571.4	476995.7
LDDV	0.25	20.7	21.3	972314.6	9892.9
LDDT	0.15	12.4	17.3	718277.5	7308.1
HDDV	1.12	93.5	6.3	14841269.8	151003.2
MC	1.79	149.1	35.0	4260394.3	38035.6
LDV Subtotal		7903.0		388662063.3	3471976.8
HDV Subtotal		430.1		68269841.3	627998.9
TOTALS	**100.00**	**8333.1**		**456931904.6**	**4099975.7**

Full Implementation Scenario -- CO_2 Emissions for Highway Vehicles in 2010					
Vehicle Type	*Percentage of VMT*	*Total VMT (millions)*	*Avg. Vehicle Fuel Efficiency (mpg)*	*Gas Consumption (gallons)*	*CO_2 (metric tons)*
LDGV	69.72	5063.6	21.3	237727920.2	2122370.0
LDGT	22.19	1611.5	17.3	93148699.4	831606.2
HDGV	4.63	336.6	6.3	53428571.4	476995.7
LDDV	0.25	17.9	21.3	840624.4	8553.0
LDDT	0.15	10.7	17.3	620994.2	6318.3
HDDV	1.29	93.5	6.3	14841269.8	151003.2
MC	1.78	128.9	35.0	3683365.7	32884.1
LDV Subtotal		6832.6		336021604.0	3001731.6
HDV Subtotal		430.1		68269841.3	627998.9
TOTALS	**100.00**	**7262.7**		**404291445.2**	**3629730.5**

APPENDIX N

TRANSPORTATION SECTOR: COMBINED EMISSION REDUCTION SCENARIOS

Modest Commitment Strategy -- Modest Commitment Fuel Efficiency, AFV and TCM Scenarios Combined					
Vehicle Type	*Percentage of VMT*	*Total VMT (millions)*	*Avg.Vehicle Fuel Efficiency (mpg)*	*Gas Consumption (gallons)*	*CO_2 (metric tons)*
LDGV	46.30	4203.51	23.3	180408049.4	1610633.9
LDGT	45.70	4149.03	19.3	214975878.2	1919246.0
HDGV	3.60	336.60	6.3	53428571.4	476995.7
LDDV	0.25	22.70	23.3	974125.5	9911.3
LDDT	0.15	13.62	19.3	705610.1	7179.3
HDDV	1.00	93.50	6.3	14841269.8	151003.2
MC	1.80	163.42	35.0	4669122.9	41684.7
LDCNGV	1.20	108.95	23.3	N/A	31308.7
LDV Subtotal		8661.22		401732786.1	3619963.8
HDV Subtotal		430.10		68269841.3	627998.9
TOTALS		**9091.32**		**470002627.4**	**4247962.7**
Total CO_2 **Reduction from 2010 Baseline (Increased Trucks) in Metric Tons**					**508966.1**

Major Commitment Strategy -- Major Commitment Fuel Efficiency, AFV and TCM Scenarios Combined					
Vehicle Type	*Percentage of VMT*	*Total VMT (millions)*	*Avg.Vehicle Fuel Efficiency (mpg)*	*Gas Consumption (gallons)*	*CO_2 (metric tons)*
LDGV	45.40	3760.98	27.2	138271375.0	1234449.1
LDGT	45.70	3785.83	20.7	182890516.9	1632796.7
HDGV	3.60	336.60	6.3	53428571.4	476995.7
LDDV	0.25	20.71	27.2	761406.3	7747.1
LDDT	0.15	12.43	20.7	600297.1	6107.8
HDDV	1.00	93.50	6.3	14841269.8	151003.2
MC	1.80	149.11	35.0	4260394.3	38035.6
LDCNGV	2.10	173.97	27.2	N/A	42825.8
LDV Subtotal		7903.03		326783989.5	2961962.0
HDV Subtotal		430.10		68269841.3	627998.9
TOTALS		**8333.13**		**395053830.8**	**3589960.9**
Total CO_2 **Reduction from 2010 Baseline (Increased Trucks) in Metric Tons**					**1166968.0**

Full Implementation Strategy -- Full Implementation Fuel Efficiency, AFV and TCM Scenarios Combined					
Vehicle Type	*Percentage of VMT*	*Total VMT (millions)*	*Avg.Vehicle Fuel Efficiency (mpg)*	*Gas Consumption (gallons)*	*CO_2 (metric tons)*
LDGV	42.25	3144.50	29.0	108430982.8	968042.2
LDGT	45.70	3401.27	23.8	142910428.6	1275865.3
HDGV	3.60	336.60	6.3	53428571.4	476995.7
LDDV	0.25	18.61	25.0	744260.0	7572.6
LDDT	0.15	11.16	23.8	469071.4	4772.6
HDDV	1.00	93.50	6.3	14841269.8	151003.2
MC	1.80	133.97	35.0	3827622.9	34172.0
LDCNGV	3.50	260.49	29.0	N/A	60145.7
LDEV	1.75	130.25	29	N/A	0
LDV Subtotal		7100.24		256382365.6	2350570.4
HDV Subtotal		430.10		68269841.3	627998.9
TOTALS		**7530.34**		**324652206.9**	**2978569.3**
Total CO_2 **Reduction from 2010 Baseline (Increased Trucks) in Metric Tons**					**1778359.6**

APPENDIX O

WASTES SECTOR: METHODOLOGY FOR CALCULATING CO_2 EQUIVALENT EMISSIONS

Step 1: USEPA Landfill Gas Emissions Model Version 2.01:

This model was used to calculate both the CH_4 and CO_2 emissions from the four active landfills in Delaware (CIL, CSWMC, SSWMC, and PPLF) for the BAU and three alternative scenarios. The model calculated the historical CH_4 and CO_2 emissions for each of the landfills, beginning with the operation of each landfill. The model also projected future emissions until each landfill reached its capacity. Data provided by DSWA was utilized to generate emission rates. DSWA provided actual "refuse in place" data for each of the four landfills through 1998. In order to generate emission rates for the BAU scenario, the landfill refuse in place was projected into the future based upon projected growth in Delaware's population. This projection was then manipulated for the three alternative scenarios.

Step 2: Calculation for Flared Methane:

DSWA currently flares 98% of the methane emitted from each of the four landfills (Drew Sammons, DSWA)[1]. The following procedure was used to calculate the total CO_2 equivalent emissions (unflared CH_4 from landfill + CO_2 from landfill + CO_2 from flared methane) per year for each of the four landfills:

1. [amount of CH_4 in tons] x [.02] = amount of CH_4 unflared
2. [amount of CH_4 unflared] x [22] = amount of CH_4 unflared in CO_2 equivalent
3. [amount of CH_4 in tons] x [.98] = amount of CH_4 flared
4. [amount of CH_4 flared] x [2.75] = amount of CO_2 emitted from flared CH_4 process
5. [amount of CO_2 emitted from flared CH_4 process] + [amount of CO_2 from landfill] = total CO_2 emissions
6. [total CO_2 emissions] + [amount of CH_4 unflared in CO_2 equivalent] = total CO_2 equivalent emissions from that particular landfill
7. Add total CO_2 equivalent emissions per year for each of the four landfills to get the total emissions from landfills in the State of Delaware per year

[1] Methane flaring began at PPLF in 1988, at CSWMC in 1990, at SSWMC in 1994, and at CIL in 1990.

APPENDIX P
WASTES SECTOR: THREE SCENARIOS AND MEASURES

Scenarios	Measures	Assumptions
BAU	Recycling	2.5% recycling[1]
Modest Recycling	Recycling	15% recycling by 2001[2]
Major Recycling	Recycling	35% recycling by 2001[3]
Full Implementation	Recycling; Pay-As-You-Throw Program	60% recycling by 2001[4]

[1] The BAU scenario assumes that 2.5% of the total municipal solid waste stream will continue to be recycled up until 2010 through DSWA's Recycle Delaware program.

[2] The Modest Recycling Scenario assumes that the percentage of total municipal solid waste recycled through DSWA's Recycle Delaware program will gradually increase to 15% in 2001 (5% in 1999, 10% in 2000) and remain at 15% until 2010.

[3] The Significant Recycling Scenario reflects DSWA's goal of recycling 35% of the total municipal solid waste stream through the Recycle Delaware program in 2001 (seen as a gradual increase from 10% in 1999 to 20% in 2000, and 35% in 2001) (DSWA, 1997). This rate is assumed to remain at 35% until 2010.

[4] The Full Potential Waste Reduction Scenario also reflects DSWA's goal of recycling 35% of the total municipal solid waste stream through the Recycle Delaware program in 2001 (maintained through 2010). The second component of this scenario is the implementation of a Pay-As-You-Throw program in Delaware, which would result in recycling an additional 25% of the municipal solid waste stream (USEPA, 1997). Thus, in 2001, 60% of the municipal solid waste stream would be recycled.

APPENDIX Q
SINKS SECTOR: DELAWARE'S POLICIES AND PROGRAMS

Types of Policy	Policy Intent and Programs
Economic Incentives	1. **Commercial Forest Plantation Act**: A property tax program providing a 30 year tax exemption for the production of merchantable timber on ten and more acres of forest land. 2. **Cost- Share Incentive Programs**: a. USDA Farm Bill Provisions : Stewardship Incentive Program (SIP) Forest Incentive Program (FIP) Conservation Reserve Program (CRP) Conservation Reserve Enhancement (CREP) Environmental Quality Incentive (EQIP) b. New Castle Conservation Program Urban Forestry 3. **Delaware Center for Horticulture** : Urban tree planting and rural reforestation) 4**. Urban and Community Grants**: Administered through the Delaware Department of Agriculture, to encourage planting and maintaining urban trees and to reduce "urban heat island effect." 5**. Federal Biomass Tax Credit- IRS Section 45 Tax Credit give** % of investment cost that can be taken as a credit.
Regulatory	1. **Unified Development Code for New Castle County** 2. **Riparian Buffer Management** 3. **Forestry Practices Erosion & Sediment Law** 4. **Delaware Seed Tree Law** (replenishes the forest base after harvesting) 5. **Major Subdivision Reviews for Urban Forestry Interests** (New Castle County)
Others	1. **Forestry Educational Program**: Arbor Day Activities Delaware ENVIROTHON Project Learning Tree 2. **Bioenergy Fuelwood Plantations Demonstration Sites** 3. **Delaware Biomass Program Work Group** (network of interested parties that provides biomass information throughout the state between agencies and private interest groups)

Source: Abbot-Donnelly, D. 1998. *Delaware Greenhouse Gas Mitigation Action Plan Forestry Sector Report.*

APPENDIX R

FOREST SINKS SECTOR: METHODOLOGY FOR CALCULATING CO_2 SEQUESTRATION IN FORESTS AND URBAN TREES

General Equation:

Total CO_2 Sequestered = CO_2 Sequestered by Forest + CO_2 Sequestered by Urban Trees

Step 1: Computation of CO_2 Sequestered by Forestlands:

CO_2 Sequestered by Forest = Net Acreage of Standing Forest x CO_2 Sequestration Factor

Net Acreage of Standing Forests = [$X_1+X_2+X_3+X_4+X_5+X_6-X_7-X_8-X_9$];

Where:

X_1 - acres of existing rural forests
X_2 - acres of existing community/urban forests
X_3 - acres of natural regeneration in converting open spaces
X_4 - acres of natural regeneration in harvested rural forests
X_5 - acres of artificial regeneration (plantings) in converted open spaces
X_6 - acres of artificial regeneration (plantings) in harvested rural forests
X_7 - acres lost due to harvesting of rural forests
X_8 - acres lost due to community/urban development
X_9 - acres lost due to agricultural land conversion

For CO_2 forest sequestration factor, the American Forest estimate is used. An average fully stocked forest will remove about 3.6 metric tons of CO_2 per acre per year.[1]

Thus: CO_2 Sequestered by Forest = 3.6 [$X_1+X_2+X_3+X_4+X_5+X_6-X_7-X_8-X_9$]

Step 2: Computation of CO_2 Sequestered due to Urban Tree Planting:

The suggested method for calculating carbon sequestration by trees in urban and suburban setting by the Voluntary Reporting of Greenhouse Gases Program of the U.S. Department of Energy is used. For this computation, we used the following assumptions: [1] moderate survival factors by growth rate, [2] hardwood species, and [3] a moderate annual sequestration by tree type and growth rate.

CO_2 Sequestered by Urban Trees = [Number of Trees Planted] x [Survival Factors by Growth Rate] x [Annual Sequestration Rates by Growth Rate]

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[1] There has been a good deal of debate regarding the use of carbon sequestration factors for different kinds of carbon sinks. For computation purposes, the estimates by American Forest (1999) of 3.6 tons per acre per year is used to illustrate the trend of carbon sequestration capacity of Delaware's forests and urban trees. Moreover, it is assumed that newly rehabilitated and reforested forests have the same carbon sink capacity as the existing forest stand.

APPENDIX S
FOREST SINKS SECTOR: THREE SEQUESTRATION SCENARIOS AND MEASURES

Scenario	Measures Explored	Other Assumptions [1]
BUSINESS-AS-USUAL SCENARIO	M_1- 10,000 trees planted per year M_2 – 1.5 % of existing forest M_3 – 1,000 acres per year	M_4-1,700 acres annually M_5- 2,100 acres annually M_6 – 200 acres annually
MODEST SINK DEVELOPMENT	M_1- 15,000 trees per year M_2- 1.25 % of existing forest M_3- 33.3 % decrease	M_4-1,700 acres annually M_5- 2,100 acres annually M_6 – 200 acres annually
MAJOR SINK DEVELOPMENT SCENARIO	M_1- 25,000 trees per year M_2 – 1.0% of existing forest M_3 - 66.7% decrease	M_4-1,700 acres annually M_5- 2,100 acres annually M_6 – 200 acres annually
FULL IMPLEMENTATION SCENARIO	M_1- 35,000 trees per year M_2- .75 % of existing forest M_3- 100% decrease in 2010	M_4-1,700 acres annually M_5- 2,100 acres annually M_6 – 200 acres annually

Legend: M1 – number of trees planted in urban areas [2]
M2 – acres lost due to harvesting of rural forests [3]
M3 – acres lost due to community/urban development [4]
M4 – acres of natural regeneration [open spaces and harvested rural areas]
M5 – acres of artificial regeneration [open spaces and harvested rural areas]
M6 – acres lost due to agricultural land conversion.

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[1] Due to insufficient data, it assumed that there will be an annual natural regeneration of both open spaces and harvested rural forests of 1,700 acres until 2010; annual artificial regeneration of open spaces and harvested rural areas of 2,100 acres until 2010; and annual loss due to agricultural land conversion of 200 acres until 2010.

[2] The average number of trees planted in urban centers from 1991 to 1994 is 10,000 trees. For the Business-as-Usual scenario, it is assumed that the same number of trees will be planted annually in the urban centers until 2010. The projected numbers of urban trees planted for the rest of the scenarios are based on Delaware's Department of Agriculture projections in 1994. The number of trees planted, however, does not include plantings by developers, homeowners and Delaware Department of Transportation (DelDOT). The numbers represent only the seedlings and trees planted through the Department of Agriculture's urban forestry programs.

[3] The 1998 *Delaware Forest Annual Report* indicates that 1.5 % of Delaware's existing forest has been harvested or removed. It is assumed that there will be a decrease of deforestation: 1.25 % for the Modest Sink Development Scenario, 1.0 % for the Major Sink Development Scenario, and .75 % for the Full Implementation Scenario.

[4] In 1998, the number of acres lost due to community/urban development is 1,000 acres. It is assumed that in the next ten years this number will decrease: 33.3 % decrease in 2010 for the Modest Sink Development Scenario, 66.7 % decrease in 2010 for the Major Sink Development Scenario, and 100 % decrease in 2010 for the Full Implementation Scenario. This assumption, however, does not reflect the possibility that the number of acres lost will increase due to development pressures on Delaware's private forests.

APPENDIX T

FOREST SINKS SECTORS: CO_2 SEQUESTRATION PROJECTIONS

Business-as Usual Scenario				Modest Sink Development Scenario			
YEAR	Forest	(urban-trees	Total	YEAR	Forest	(urban-trees	Total
	MT/year	MT/year	MT/yr		MT/year	MT/year	MT/yr
1990	1420020		1420020	1990	1420020		1420020
1992	1400400		1400400	1992	1400400		1400400
1998	1278000		1278036	1998	1278000		1278000
1999	1268190	36	1268226	1999	1271385	54	1271439
2000	1258380	80	1258460	2000	1264962	119	1265081
2001	1248570	131	1248701	2001	1258728	196	1258924
2002	1238760	190	1238950	2002	1252681	285	1252966
2003	1228950	257	1229207	2003	1246819	386	1247205
2004	1219140	334	1219474	2004	1241139	501	1241640
2005	1209330	418	1209748	2005	1235639	627	1236267
2006	1199520	511	1200031	2006	1230317	766	1231083
2007	1189710	612	1190322	2007	1225171	917	1226088
2008	1179900	720	1180620	2008	1220198	1080	1221278
2009	1170090	837	1170927	2009	1215396	1255	1216652
2010	1160280	962	1161242	2010	1210764	1443	1212207

Major Sink Development Scenario				Full Implementation Scenario			
YEAR	Forest	(urban-trees	Total	YEAR	Forest	(urban-trees	Total
	MT/year	MT/year	MT/yr		MT/year	MT/year	MT/yr
1990	1420020		1420020	1990	1420020		1420020
1992	1400400		1400400	1992	1400400		1400400
1998	1278000		1278000	1998	1278000		1278000
1999	1274580	91	1274671	1999	1277775	127	1277902
2000	1271412	199	1271611	2000	1277879	278	1278157
2001	1268495	327	1268821	2001	1278309	457	1278766
2002	1265824	475	1266299	2002	1279064	665	1279728
2003	1263398	644	1264042	2003	1280140	901	1281041
2004	1261215	834	1262050	2004	1281535	1168	1282703
2005	1259272	1046	1260318	2005	1283247	1464	1284711
2006	1257567	1277	1258843	2006	1285273	1787	1287060
2007	1256096	1529	1257625	2007	1287611	2141	1289752
2008	1254859	1800	1256659	2008	1290260	2520	1292780
2009	1253852	2092	1255944	2009	1293215	2929	1296144
2010	1253073	2405	1255478	2010	1296476	3367	1299842