Table of Contents

APPENDIX 6 - GREENHOUSE GAS EMISSIONS FROM NON-ENERGY and ENERGY SOURCES A6-1
I. Greenhouse Gases and Global Warming A6-1
II. Vermont's Greenhouse Gas Emissions A6-4
A. Methane Emissions from Landfills, Domestic Animals and Managed Wildlife, and Manure A6-4
B. Emissions from Nitrogen Fertilizers A6-6
C. Emissions from Land Use Change: New Forest Growth and Wetland Drainage A6-7
D. Modeled Policies with the Greatest Potential for Reducing Vermont's Greenhouse Gases A6-7

APPENDIX 6 - GREENHOUSE GAS EMISSIONS FROM NON-ENERGY and ENERGY SOURCES

I. Greenhouse Gases and Global Warming

Increased concentrations of certain gases in the atmosphere will increase the temperature on the earth's surface. These gases, which include water vapor, carbon dioxide, ground level ozone, chlorofluorocarbons (CFCs), methane, and nitrous oxide, are known as greenhouse gases because they trap heat in much the same way as the glass panels of a greenhouse. The greater the concentration of greenhouse gases in the atmosphere, the greater the greenhouse effect will be.

All greenhouse gases contribute to radiative forcing, which changes the radiative balance. Radiative balance is a state of equilibrium between incoming and outgoing radiation. The process is quite complex, but may be summarized as follows: greenhouse gases are virtually transparent to the visible part of sunlight, allowing it to pass through and heat the earth's surface. The surface absorbs sunlight and emits radiation (longer wavelength infrared radiation) back to the atmosphere. Greenhouse gases are not transparent to outgoing infrared radiation, which is absorbed by the atmosphere, raising its temperature. The atmosphere then re-emits the radiation, some to outer space and some back to the earth, increasing its surface temperature. At natural levels this process provides enough warmth to support life. Without the greenhouse effect, the earth would be about 60 degrees Fahrenheit colder than it is now (US EPA, 1992, iv). Changes in the atmospheric concentration of greenhouse gases change the earth's radiative balance and cause additional greenhouse warming. Increased concentrations of greenhouse gases might increase average global temperatures to a level that has critical effects on the habitats of many species that now inhabit the planet, as well as agriculture, public health, and natural resources.

Greenhouse gases are constantly being cycled through the environment and are temporarily stored in various components of the environment as they are cycled. Components of the environment that store greenhouse gases or their constituents, some in huge amounts, are known as reservoirs or sinks. The main carbon reservoirs are the biosphere, the oceans, and the atmosphere. Large amounts of carbon move through these reservoirs each year, and these movements are known as carbon fluxes. Carbon fluxes are a natural part of the carbon cycle, and they are necessary for life. These cycles tend to be in a steady state so that the amount of gas or constituent in the reservoirs tends to remain constant, even though large amounts of the material continuously cycle.

Another major reservoir or sink of carbon is the earth's fossil fuel supply. This carbon has been removed from the carbon cycle for millions of years. During the last 200 years, human activities such as burning fossil fuels (and many other activities such as deforestation and farming practices) have caused concentrations of greenhouse gases in the atmosphere to increase. By the year 2050, if major carbon sinks continue to be released, carbon dioxide levels are expected to be twice the level they were 200 years ago. Past increases in greenhouse gases coincide with an increase in global average temperatures of 0.6 degrees Celsius (1.4 degrees Fahrenheit) over the past century, leading many scientists to surmise that the two trends are linked. In fact, global climate records show that the 10 warmest years in the past century have all occurred since 1980. Since we are already facing the early effects of an altered climate, scientists are focusing on the need to better anticipate future climate patterns. A panel of U.N. scientists, the Intergovernmental Panel on Climate Change (IPCC), issued an assessment of climate change in 1995 that projects an additional rise of 0.8-3.5 degrees Celsius (1.4-6.3 degrees Fahrenheit) in the global average temperature by 2100. This projected increase covers a wide range, but even at the lower end it is faster than any experienced since human civilization began. For example, global average temperature has risen just 3-5 degrees Celsius since the last ice age, 10,000-12,000 years ago (IPCC, 1995, reported in Brown, 1996, 23).

The mainstream scientific community is now in agreement that there is no alternative to reducing carbon emissions. Evidence that atmospheric CO_2 levels are rising is clear-cut. So too is the greenhouse effect of these gases in the atmosphere. What is debatable is the rate at which global temperatures will rise and what the precise local effects will be.

If global warming proceeds at its current rate, it will have devastating effects on local temperature ranges, precipitation patterns, and sea levels. It could harm agriculture, forests, wildlife, coastal communities, urban infrastructures, and other aspects of society. The risk to natural ecosystems is great because many species may not be able to adapt to a rapidly changing climate. Heavy costs would be incurred by future generations if they are forced to cope with an increasingly warmer climate.

There is considerable uncertainty about the timing and magnitude of the effects that greenhouse gases may have on global temperature. The global climate system is very complex, and our understanding of feedback mechanisms, such as clouds and the oceans, on the earth's climate is limited. Therefore it is very difficult to predict the climate impacts of greenhouse gas emissions.

Progress toward reducing greenhouse gas emissions and building an environmentally sustainable global economy is slow and complicated by numerous obstacles, but some basic steps have been taken and constructive efforts are being made. Some of these positive trends that provide a glimpse of a sustainable future are highlighted below. The policies discussed in Chapter 4 of this Plan and those considered in the composite policy case will also promote progress toward an environmentally sustainable future.

- Support for reducing our dependence on fossil fuels is starting to build as public understanding of the costs associated with global warming increases and evidence of the effects of higher temperatures accumulates. Environmental groups have been joined by island nations, insurance industry representatives, and farmers in many areas of the world in support of their common interest to not alter the global climate.

- Alternatives to fossil fuels that do not alter the climate are starting to become competitive, or nearly so, with support by national governments, and these new technologies are gaining an increasing share in energy markets. Solar and biomass based energy sources and wind power are advancing in technological sophistication, with a resultant decline in cost.

- Major gains in slowing greenhouse gas emissions are coming from reforms such as incorporating hidden costs and externalities into the price of fossil fuels and cutting public subsidies now in place for fossil fuel use, giving consumers greater access to and information about the energy marketplace. Efforts are underway to make energy prices reflect the full cost to society of burning fossil fuels, the cost of pollution, acid rain, and global warming. A carbon tax is one way to adjust the market price of energy so that societal costs are fully reflected, and the principle "the polluter pays" is upheld.

- Human mobility needs can be accommodated in a manner that is consistent with an environmentally sustainable global economy by investing in alternative types of transportation, and by making automobiles cleaner and more efficient. It is in the interest of societies everywhere to promote the use of public transportation and bicycles, and to follow least cost planning principles for transportation that draw on a broad inventory of options.

Table A6.1 Vermont's Greenhouse Gas Emissions Estimates for 1990

GHG Emissions Source Category[a]	GHG	GWP	CO_2 Equivalent Tons	Percent
Fossil fuels and biomass[b]	CO_2	1	6,939,000	90.8%
	CH_4	11[c]	6,930	0.1%
	N_2O	270	175,500	2.3%
Landfills	CH_4	11	174,735	2.3%
Domestic animals & managed wildlife	CH_4	11	297,011	3.9%
Animal manure	CH_4	11	5,423	0.0%
Nitrogen fertilizer use	N_2O	270	111,667	1.5%
Land use changes: New forest growth	CO_2	1	-71,341	-0.9%
Wetland	CO_2	1	4	0.0%
drainage	CH_4	11	-37	0.0%
Totals			7,638,892	100.0%

Notes:
[a]Figures for fossil fuels and biomass are updated numbers that were developed in the modeling for this Plan. Figures for fossil fuels and biomass include emissions from Vermont's ownload electricity supply, which includes all fossil fuels and biomass used to generate electricity consumed in Vermont, and some of this generation took place out-of-state. Figures for other GHG source categories were developed in the DPS Technical Report No. 31, *Vermont Greenhouse Gas Emissions Estimates for 1990*, 1994, 7.

[b]Biomass, specifically wood, accounts for a very small portion of these GHG emissions because when wood resources are managed sustainably, as is usually the case in Vermont, CO_2 emissions are zero.

[c]GWP factor for methane used here and throughout this Plan is 11, based on the EPA *States Workbook* (1992). However, in 1995, EPA reported that the GWP of one ton of methane is 24.5 times that of one ton of carbon dioxide (U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1994*, 1995, ES-2). A GWP of 21 for methane is used by the U.S. Congress, Office of Technology Assessment, 1991, 55.

Source: Vt. DPS

II. Vermont's Greenhouse Gas Emissions

Table A6.1 is a summary of Vermont's 1990 Greenhouse Gas (GHG) Emissions Estimates, showing the global warming potential factor (GWP) and CO_2 equivalent tons that provide a basis for comparing different GHG gases.[i] Estimates for Vermont's 1990 GHG emissions total approximately 7.6 million tons (CO_2 equivalent). Fossil fuels combustion accounts for about 93.2% of these emissions, with a very small portion attributable to biomass or wood resources. (See Chapter 3, Section III, E. Baseline Projections - Air Emissions among Fuels.) The balance, 6.8% of Vermont's greenhouse gas emissions or about 519 thousand CO_2 equivalent tons, comes from non-energy sources.

The major portion of this Plan focuses on Vermont's energy use, which is primarily fossil fuels and biomass, analyzing current consumption, future trends and issues, and proposing an inventory of policies as well as a composite policy case for meeting state and federal goals related to energy use and environmental quality. (See Table A6.2.) Since about 7.7% of Vermont's greenhouse gas emissions comes from non-energy sources, it is important to address these non-energy emissions source categories that pertain to Vermont. They are:

- Methane emissions from landfills;
- Methane emissions from domestic animals and managed wildlife;
- Methane emissions from animal manure (volatile solids);
- Nitrous oxide emissions from fertilizer use; and
- Methane and carbon dioxide from land use changes--new forest growth and wetland drainage.

A. Methane Emissions from Landfills, Domestic Animals and Managed Wildlife, and Manure

Methane's greenhouse warming potential factor (GWP) of 11 indicates that it has a relatively strong impact compared to a ton of CO_2, which has a GWP of 1. Methane emissions from landfills, domestic animals and managed wildlife (particularly those with ruminant digestive systems) and animal manure (volatile solids) can be a very significant non-energy source of GHG emissions. Fortunately, the actual volume of methane emissions released into the air in Vermont by these sources is very small; 6.2% of Vermont's total 1990 GHG emissions, in CO_2 equivalent tons.

Specifically, landfills account for 2.3% of Vermont's 1990 GHG emissions. See Chapter 3, Section II.F.10 Electricity from Landfill Gas for more information about landfill emissions, Vermont landfills, flaring, and capturing landfill methane for direct use or to sell to a nearby facility.

Domestic animals and managed wildlife produce enough methane to account for 3.9% of Vermont's 1990 greenhouse gas emissions in CO_2 equivalent terms, and emissions from animal manure are an insignificant percentage of the 1990 estimates. The section of Chapter 3 referenced above contains information about capturing gas from other sources and describes a farm that uses cow manure to produce electricity rather than leaving the gas to enter the atmosphere.

Chapter 4 of this Plan, Section I on Energy Sources and Supply, includes Strategy D - Support Appropriate Uses of Hydro Power and Methane Sources. This strategy focuses on the opportunities to use methane sources such as landfills and farm manure digesters as local, renewable energy sources. Two policies are proposed, and the impacts resulting from modeling these policies individually are reported in the referenced section of Chapter 4. The first policy presented in this Plan that will reduce greenhouse gas emissions from methane is:

> Increase Appropriate Use of Landfill Methane Energy
> *The Agency of Natural Resources should work with the Department of Public Service and solid waste planners to require the recovery of landfill methane from solid waste sites throughout the state, wherever economically feasible, for use in producing electricity or for direct heating.*

To model the potential generation capacity from landfills, it was assumed that in addition to the Windham County Landfill in Brattleboro (operating in 1990) and the Burlington Landfill (located in the Intervale and operating since 1992), four more large landfills with recovery systems for generating electricity could operate in the state. Since these facilities are required to trap and flare the gases, the fuel is essentially free, making the cost of the electricity about 4.29 cents/kWh (real levelized cost in 1997$). The most significant costs are those associated with capital costs associated with generators and the connection to the electric grid.

Both the scope and impacts of this policy are quite modest compared to other policies in the Plan. Computer modeling shows that the landfills would generate 15 GWh of electricity per year. Over the life of the forecast (which extends to 2020), the cumulative impacts on energy use, efficiency, cost, and the economy are negligible. There are proportionately much larger impacts on the sustainability, affordability, and environmental indicators. The percent of energy from renewables climbs 0.19%, and the cost of air emissions declines 0.16% or $30 million between now and 2020 compared to the base case. Greenhouse gases show the greatest change, declining approximately one million tons (CO_2 equivalent) cumulatively through 2020 (a 0.42% decline). Overall, the policy results in a modest but valuable decline in air emissions with no negative economic impacts to Vermont. (See the full discussion of the policy on landfill methane energy in Chapter 4, Section I.) This policy is also selected for the composite policy case which is discussed in Chapter 5.

The second policy in this Plan that reduces greenhouse gas emissions from methane is:

> Increase Appropriate Use of Farm Methane Energy
> *Encourage the recovery of methane for electricity generation from farm manure.*

Currently there is only one active farm methane digester in Vermont. Foster Brothers Farm, a 500 cow dairy farm in Middlebury, produces electricity from its methane digester mostly for the farm's electrical needs. A by-product of this process is a high quality soil additive that can be spread on their fields or sold as a commercial potting soil additive or bagged cow manure.

The Vermont Department of Agriculture is also exploring the possibility of siting a community manure pit for gathering manure from 1,000 or more cows. This type of community manure pit can make farm methane projects feasible for small dairy farms. With manure management guidelines becoming more strict to protect water quality, community manure pits have good potential.

In local, regional, and statewide permitting processes, producing energy from methane should be promoted as a desirable practice. In addition, research and development into the capture and use of methane should be encouraged and promoted. For example, development of small-scale equipment could increase the feasibility of small farms using this technology. Including community wastes, food processing wastes, and other agricultural wastes with animal wastes for methane digestion could also expand the potential of small farms to use this technology.

There are a few large dairy farms in the state that are roughly equivalent to Foster Brothers Farm, which has about 500 milking cows. For modeling purposes it was assumed that the estimated 2,950 milk cows on these large dairy farms had a generation potential of 2.2 GWh per year, a conservative estimate. Modeling the farm methane policy was identical to that of the landfill methane policy, except that a total of 2.2 GWh of electricity was assumed to be generated per year. As in the case of the landfill methane policy, the only detectable effects occurred in the indicators related to sustainability (0.03% increase in renewable fuel use through 2020 compared to the base case), affordability (0.02% cumulative decrease in the cost of air emissions), and environmental soundness (0.06% cumulative decrease in greenhouse gases). Both the landfill methane and farm methane generation policies result in modest decreases in greenhouse gases with no negative impacts on the state's economic vitality in terms of employment opportunities and per capita disposable income. (See the full discussion of the policy on farm methane energy in Chapter 4, Section I.) This policy is also selected for the composite policy case which is discussed in Chapter 5.

B. Emissions from Nitrogen Fertilizers

With its GWP of 270, indicating that 1 ton of nitrous oxide has an impact 270 times greater than that of CO_2 when measured over 100 years, nitrous oxide is a very potent greenhouse gas.

Some nitrous oxide (N_2O) is naturally produced in soils by microbial processes. Commercial nitrogen fertilizers provide an additional nitrogen source and increase nitrous oxide emissions from the soil. Fertilizer nitrogen generally produces nitrous oxides from two fundamental forms, ammonium (NH_4) and nitrate (NO_3). Nitrous oxide is produced as an intermediate when nitrate (NO_3) is reduced to nitrogen gas (N_2) in a multi-step reaction under aerobic conditions yielding nitrous oxides as a byproduct.

1990 estimates of nitrous oxide emissions from fertilizer use account for about 1.5% of Vermont's greenhouse gas emissions. No policies have been proposed in this Plan for reducing emissions from nitrogen fertilizers. However, the policy for Increasing Appropriate Use of Farm Methane Energy will have positive effects, along with the state's efforts to promote better manure management. Any improvements in manure management will reduce runoff and promote better use of fertilizers where they are applied. Reduced use of natural gas derived chemical fertilizers will also have positive effects in reducing these emissions.

C. Emissions from Land Use Change: New Forest Growth and Wetland Drainage

Among EPA's GHG emissions source categories related to land use changes, two subcategories pertain to Vermont: new forest growth and wetland drainage. Their combined impacts in 1990 actually reduced Vermont's total GHG emissions by about 0.9%.

Specifically, new forest growth served as a take up for CO_2 emissions, reducing estimates of total emissions by about 0.9%. Very little wetland drainage occurred in Vermont in 1990. As a result, there was an insignificantly small production of CO_2 and a reduction in the natural production of methane by an insignificantly small percentage. No policies have been proposed in this Plan for reducing emissions from new forest growth and wetland drainage.

Land use change can also refer to land development policies and planning and settlement patterns, which are addressed extensively in this Plan. There is a discussion of the state's role in land use and development planning in Chapter 3, as established in Act 200 and Act 250 (which are summarized in Appendix 2). Chapter 4, Section II, Strategy C - Reduce Vehicle Miles Traveled, includes the policy Encourage High-Density, Mixed-Use Land Use Planning. This policy ranks highest among the individual policies that have the potential to reduce Vermont's greenhouse gas emissions. (See Table A6.2)

D. Modeled Policies with the Greatest Potential for Reducing Vermont's Greenhouse Gases

Table A6.2 lists the energy and non-energy related policies modeled in this edition of the Plan, sorted so that the policies having the greatest potential to reduce greenhouse gas emissions (expressed in tons of CO_2 equivalent) cumulatively over the life of the forecast are at the top of the list. Each of these policies was designed to meet one or more of the Plan's goals, and for some of the policies listed, reducing greenhouse gas emissions was not the primary goal. Each policy that reduces greenhouse gas emissions also has other beneficial impacts on increasing energy efficiency, economic benefits, and meeting other environmental goal; impacts on meeting two other environmental goals are also shown in Table A6.2. Note also that the composite policy case, a set of 19 policies, has the potential of reducing greenhouse gas emissions by 21.37% cumulatively through 2020. The remainder of Table A6.2 relates to individual policies. In Chapter 4, there is a discussion of each of these policies and its impacts. The composite policy case is discussed in Chapter 5.

ENDNOTE:

Table A6.2 Policies with the Greatest Potential for Reducing Vermont's Greenhouse Gas Emissions

Cumulative Percent Change in Emissions, Compared to the Base Case, for the Forecast Period 1997-2020

Reference: Chapter, Section, Strategy	Policy Number and Title	GHG Emissions	Acid Rain Precursors	Ground Level Ozone Precursors
Chapter 5	Combined Impacts of Composite Policy Case (Selected package of 19 policies)	-21.37%	-24.16%	-29.87%
4.II.C Reduce VMT	Policy 5. Encourage High-Density, Mixed-Use Land Use Planning	-5.67%	-5.50%	-7.35%
4.II.B Increase Vehicle Efficiency	Policy 1. Increase Federal CAFE Standards	-5.19%	-4.62%	-7.94%
4.I.H Energy Taxation	Carbon Tax at $100/Ton with Revenue Returned to Taxpayers	-4.63%	-4.75%	-4.04%
4.II.E Transportation Energy Taxation	Policy 1. Internalize Hidden Costs: Combined results of 3 policies - Shift Construction/ Maintenance Funding & Police/Fire Transportation Funding to Motor Fuels Tax; and Remove Sales Tax Exemptions on Motor Fuels	-4.39%	-4.29%	-6.02%
4.II.E Transportation Energy Taxation	Policy 2. Shift Fees to Motor Fuels Taxes	-3.29%	-3.24%	-4.50%
4.II.E Transportation Energy Taxation	Shift Road Construction/Maintenance Funding from Property Tax to Motor Fuels Tax	-3.02%	-2.99%	-4.13%
4.I.A Energy Sources & Supply	Policy 4. Replace Vt. Yankee Power with Wood Gasification and Wind Power[a]	-2.40%	-1.78%	-1.14%
4.I.A Energy Sources & Supply	Policy 3. Replace Vt. Yankee Power with Two-Thirds Wood Gasification[a]	-1.50%	-0.84%	-0.37%
4.II.B Increase Vehicle Efficiency	Policy 2. Adopt 55 MPH Interstate Speed Limit	-1.50%	-1.54%	-1.94%
4.II.C Reduce Vehicle Miles Traveled	Policy 6. Pay-at-the-Pump Auto Liability Insurance	-1.45%	-1.36%	-2.04%
4.III.C Efficiency in Commercial Bldgs	Combined Impacts of Commercial New Construction and Retrofit Policies	-1.12%	-0.92%	-0.78%
4.II.E Transportation Energy Taxation	Policy 3. Support Commuter Buses with Motor Fuels Tax	-1.05%	-1.06%	-1.73%
4.II.E Transportation Energy Taxation	Remove Sales Tax Exemptions on Motor Fuels	-1.01%	-0.95%	-1.38%
4.III.A Efficiency in New Homes	Combined Impacts of Residential New Construction Policies	-0.87%	-0.74%	-1.05%

4.I.B Promote Wind Generation	Policy 2. Renewable Portfolio Standard with Wind Power	-0.85%	-1.40%	-0.60%

Table A6.2 Policies with the Greatest Potential for Reducing Vermont's Greenhouse Gas Emissions (continued)

Cumulative Percent Change in Emissions, Compared to the Base Case, for the Forecast Period 1997-2020

Reference: Chapter, Section, Strategy	Policy Number and Title	GHG Emissions	Acid Rain Precursors	Ground Level Ozone Precursors
4.I.A Energy Sources & Supply	Policy 6. Renewable Portfolio Standard with Wood Gasification & Wind Power	-0.82%	-1.09%	-0.37%
4.IA Energy Sources & Supply	Policy 5. Renewable Portfolio Standard with Wood Gasification	-0.78%	-0.77%	-0.14%
4.I.B Promote Wind Generation	Policy 1. Replace Vt. Yankee Power with One-Third Wind Power[a]	-0.78%	-1.00%	-0.62%
4.II.E Transportation Energy Taxation	Shift Police/Fire Transportation Funding from Property Tax to Motor Fuels Tax	-0.68%	-0.64%	-0.93%
4.I.D Hydro power & Methane Sources	Policy 2. Increase Appropriate Use of Landfill Methane Energy	-0.42%	-0.08%	-0.03%
4.II.D Reduce Transportation Emissions	Policy 1. Implement a Vehicle Emissions Check Program	-0.18%	-0.18%	-0.24%
4.II.B Increase Vehicle Efficiency	Policy 3. Enforce Highway Speed Limits	-0.18%	-12.31%	-20.21%
4.II.C Reduce Vehicle Miles Traveled	Policy 4. Encourage Telecommuting	-0.15%	-0.15%	-0.24%
4.II.C Reduce Vehicle Miles Traveled	Policy 3. Encourage Non-Motorized Transportation	-0.13%	-0.12%	-0.20%
4.I.H Energy Taxation	Gross Fuel Receipts Tax with Revenue to Weatherization	-0.11%	-0.10%	-0.17%
4.I.D Hydro power & Methane Sources	Policy 3. Increase Appropriate Use of Farm Methane Energy	-0.06%	-0.02%	-0.01%
4.II.D Reduce Transportation Emissions	Policy 2. Use Vapor Recovery at Gas Stations	-0.06%	-0.06%	-3.34%

Note:

[a]Policies that replace Vermont Yankee power with wind power, wood power, or both, were not implemented in the modeling until late in the forecast period. Therefore their impacts would be much greater if considered

over a longer time frame.

---

i. The global warming potential (GWP) indicates the relative impact of each greenhouse gas on global warming over a 100 year time frame. Since the various greenhouse gases have very different lifetimes in the atmosphere, it is necessary to choose a particular averaging time. For example, 1 ton of CO_2 has a GWP of 1, since CO_2 is the reference gas, while 1 ton of nitrous oxide has a GWP of 270, since its impact is 270 times greater than that of CO_2 when measured over 100 years.