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Distillate Usage Patterns in Minnesota: Development of Data and Tools to Analyze Policies Affecting Biodiesel Usage

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Biodiesel is a renewable fuel derived from vegetable oils or animal fats that can substitute for diesel fuel in engines or fuel oil in furnaces. Biodiesel is produced by the process of transesterification, a simple chemical process that breaks individual triglyceride molecules into three molecules of methyl esters consisting of long chain fatty acids, similar to diesel derived from petroleum. Biodiesel has proven lubricity benefits at low blends, which will be important when sulfur levels are reduced in the U.S. supply of diesel in 2006. In addition, blends of biodiesel and its usage in a pure form reduce particulate matter (PM), volatile organic compounds (VOC), as well as other toxic gases and Greenhouse Gases (GHG). Reduced emissions from biodiesel blends result from its zero sulfur content and higher oxygen content versus petro-diesel.
Federal standards established by the U.S. Environmental Protection Agency (EPA) may force local authorities to implement a variety of policies to reduce VOC's, one of the precursors of ground level ozone formation, and other toxic emissions. There is also substantial concern among public health professionals concerning the formation of particulate matter (PM) from diesel engines, especially when originating from school buses, transit buses, and diesel-powered electrical generators.

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Distillate Usage Patterns in Minnesota: Development of Data and Tools to Analyze Policies Affecting Biodiesel Usage

Final Report

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Executive Summary

Biodiesel is a renewable fuel derived from vegetable oils or animal fats that can substitute for diesel fuel in engines or fuel oil in furnaces. Biodiesel is produced by the process of transesterification, a simple chemical process that breaks individual triglyceride molecules into three molecules of methyl esters consisting of long chain fatty acids, similar to diesel derived from petroleum. Biodiesel has proven lubricity benefits at low blends, which will be important when sulfur levels are reduced in the U.S. supply of diesel in 2006. In addition, blends of biodiesel and its usage in a pure form reduce particulate matter (PM), volatile organic compounds (VOC), as well as other toxic gases and Greenhouse Gases (GHG). Reduced emissions from biodiesel blends result from its zero sulfur content and higher oxygen content versus petro-diesel.

Federal standards established by the U.S. Environmental Protection Agency (EPA) may force local authorities to implement a variety of policies to reduce VOC's, one of the precursors of ground level ozone formation, and other toxic emissions. There is also substantial concern among public health professionals concerning the formation of particulate matter (PM) from diesel engines, especially when originating from school buses, transit buses, and diesel-powered electrical generators.

Minnesota statutes enacted during the 2002 Legislative Session mandate the inclusion of 2% biodiesel for use in a majority of diesel-powered vehicles in the state starting in 2005. The statute takes effect when 8 million gallons of annual biodiesel production capacity exist within the state and/or enactment of federal or state credits that reduce the cost of this fuel. In 2003 Governor Pawlenty appointed the Biodiesel Taskforce to study and suggest policies encouraging a smooth transition in production and use of this renewable fuel in Minnesota. The taskforce met eight times in 2003 and 2004.

Biodiesel typically costs more than diesel derived from petroleum because of the higher costs of vegetable oils, which have a vast number of competing uses. However, passage of federal legislation in 2004 will serve to make usage of this renewable fuel much cheaper due to the creation of a credit of $.01 for each percent blended in the case of vegetable oils, and $.005 for each percent blended in the case of animal fats and waste greases. The net effect of the credit will be to make biodiesel blends up to 20% (B20) nearly equal to the price of petro-diesel.

This study was undertaken to assist policy-makers who may suggest utilization of biodiesel blends as part of an overall strategy to reduce ground level ozone and also to reduce immediate harm from particulate matter due to diesel engine exhaust. Vehicles that may be prime targets for use of higher blends of biodiesel include school buses, transit buses, road equipment, diesel-powered electrical generators, and diesel "gensets" used for emergency and peak-shaving. In addition, the monthly patterns of fuel usage may be helpful to fuel distributors as they determine how to supply vehicles and machines that may utilize biodiesel of various blends across the state.

The number of diesel-powered vehicles is in constant flux and most are mobile, emitting in various localities of the state. This study attempts to establish diesel and fuel oil usage levels and patterns for 2002 in Minnesota. The patterns of diesel and distillate usage presented may suggest policy choices to environmental scientists who may be able to predict the amount of emissions originating from diesel and fuel oil usage.

A workbook model has been developed, which contains fuel usage data by class of machine, county in the state, and month of usage. A menu page in the workbook has been established to offer policymakers the opportunity to determine the amounts of 100% biodiesel (B100) needed to satisfy various blends in the machines emitting the greatest amounts of pollutants in closest proximity to people.

Using the workbook to pose policy questions produces the following annual biodiesel requirements in Minnesota:

Statewide Usage

17,058,105 gallons of B100 would be needed to satisfy the B2 mandate statewide with 78.1% of this amount used on-road.

3,178,934 gallons of B100 would be needed to fuel school buses with B20, statewide.

90,204 gallons of B100 would be needed statewide to fuel state tax-exempt vehicles with B5. **22,551** gallons of B100 would be needed to fuel state off-road equipment, statewide with B5.

270,613 gallons of B100 would be needed statewide to fuel county and city on-road vehicles statewide with B5. To provide the B5 blend for county and city off-road equipment would require **67,653** gallons of B100.

260,960 gallons of B100 would be needed to fuel both emergency and peak-shaving generators, statewide with B20, with 42.6 % used in the Metro area.

8,577,650 gallons of B100 would be needed to provide B5 blends for all fuel oil used statewide in the residential, commercial and industrial categories, of which 11.4% would arise from usage in the Metro area.

Metro Usage

11, 484 gallons of B100 would be needed to fuel state-owned tax-exempt vehicles based in Metro counties with B5. **2,871** gallons of B100 would be needed to provide B5 for the state-owned off-road equipment in the Metro area.

72,572 gallons of B100 would be needed to fuel county and city on-road vehicles in the Metropolitan area with B5 while **18,143** gallons of B100 would be needed to provide B5 blends for the off-road equipment in Metro counties.

2,264,000 gallons of B100 would be needed to fuel Metro-area transit buses with B20.

3,926,751 gallons of B100 would be needed to provide B20 blends for all fuel oil used in the Metro area with 55.8% used residentially, 20.7% used commercially, and 23.5% used industrially.

Readers of this report are welcome to pose scenarios of blend percentages applied to various classes of machines, whether on-road or off-road, whether metro or outstate, and whether private or public fleets of vehicles. The policy analysis tool developed for this project is available at the following website for investigation by any interested parties:

http://www.lrrb.org/pdf/MNBiodieselPolTool120904.xls

Chapter 1: Introduction

Diesel fuel and fuel oil are together called distillate fuels. These fuels, which are often identical in chemical composition and properties, are utilized in numerous activities in Minnesota throughout a typical year. This study was undertaken to gain a better understanding of the usage patterns of these fuels by activity, by month of the year, and by location within the state. Diesel fuel is used in pressure-ignition internal combustion engines, while fuel oil is burned for home heating or in industrial boiler applications. Suppliers of these two distillate fuels may introduce certain additives to each in order to improve performance and storage characteristics.

Diesel is often referred to as the “fuel of commerce” because so many heavy-duty machines use engines powered with this fuel, which typically consists of molecules fourteen carbon atoms long. Diesel engines are able to extract 40-50% more usable energy on a BTU basis for a given volume of fuel than gasoline engines (1). Diesel engines have a reputation for longer engine life and less required maintenance than gasoline engines as well. Diesel fuel has another advantage over gasoline in that less heat energy is expended in refining diesel fuel than gasoline because diesel fuel remains as longer chains of carbon atoms that don’t require as much cracking. The process of recovery, distillation, and transportation of diesel fuel yields .843 BTU of diesel for every BTU expended. For comparison, production of gasoline yields .805 BTU of fuel for each BTU of energy applied in the three steps (2).

Until the last few years, efforts to improve air quality mandated by the Federal Clean Air Act of 1990 focused on industrial emissions, power plant emissions, and automobile emissions. Much progress has been reported in these areas due to the efforts of the U.S. Environmental Protection Agency (EPA) as well as actions of state and local authorities. In recent years the EPA has turned its attention to diesel engines in efforts to further improve urban air quality by establishing new requirements in characteristics of diesel fuel and the heavy-duty engines that use the fuel.

Changes planned in diesel engine design and the requirements in fuel characteristics will combine to reduce emissions from diesel-powered machines and vehicles in the coming years. To reduce emissions of sulfur oxides and other emissions, the sulfur content of diesel fuel used in on-road use will be reduced from 500 ppm to 15 ppm by 2006. Reduction of sulfur to these levels will permit the introduction in 2007 of vastly cleaner burning diesel engines on trucks and cars equipped with catalytic converters and other after-treatment devices.

However, the sulfur currently contained in diesel fuel serves to lubricate the metal surfaces of moving engine parts. Government and industry research has proven that the proposed reduction in sulfur content in diesel fuel will result in greater engine wear, particularly in fuel injection pumps. The development and inclusion of additives to restore lubricity to diesel fuel containing drastically less sulfur has become important for engine manufacturers and fuel suppliers. Biodiesel is a fuel that can be derived from vegetable oils and animal fats and contains no sulfur. This alternative fuel has shown the ability to restore lubricity even when introduced at percentages as low as 1 to 2 percent when mixed in ultra-low sulfur diesel fuel (3).

Biodiesel: Origins and Attributes

Biodiesel can be made from vegetable oils, animal fats, and recycled cooking greases through the process of transesterification. This process uses alcohol and catalysts to break the branched molecular chains that characterize animal fats and vegetable oils. In Minnesota and other states, legislative efforts have been made to mandate the usage of biodiesel based on engine lubricity requirements, expected lower emissions, potential reduction in crude oil imports, and local economic development arguments.

Indeed, biodiesel offers certain advantages in terms of emissions. In particular, biodiesel results in reduced levels of particulate matter. Particulate matter (PM) has received increased attention as a human health issue due to the fact that these small particles are often drawn deep into one's lungs. In such a case, the host of chemicals adhering to particulates (such as aldehydes), have proven to have carcinogenic effects (4). Research and testing has occurred, seeking remedies to reduce PM in working environments. Bickel, et al, compared the particulate emissions resulting from mining machines using disposable filters and those using biodiesel (5). In this study, nearly identical reductions in particulates resulted from fuel consisting of 100% biodiesel (B100) and the use of disposable filters in machines using regular diesel fuel. Other studies have examined the emissions of particulates from heavy-duty diesel trucks and in diesel "gensets" (6).

Diesel Emissions Effects on Air Quality

A key environmental issue facing the Twin Cities Metropolitan Area and other regions of the country is that of ground level ozone, which forms from smog. Smog forms when volatile organic compounds (VOC) from vehicles and power plants combine with nitrogen oxides or NOx compounds. Persistence of smog and the activity of sunlight create ground level ozone. Ozone alerts have occurred at different times due to regional atmospheric conditions as well as emissions from a variety of sources, both local and regional. When ground level ozone levels rise, asthmatic individuals and others with poor pulmonary health are frequently seen in emergency rooms or are hospitalized. Federal laws and regulations may force local authorities to develop ozone mitigation plans in the Twin Cities if ozone levels are exceeded in a certain number of cases per year. Several studies have been conducted to determine possible economic effects of various strategies to improve air quality (7). The Milwaukee region was forced to develop ozone mitigation plans several years ago. Because ozone results when volatile organic compounds and NOx compounds mix to form a haze above a city, efforts to control ozone may include reductions of power generation from coal-fired plants, restrictions on time of day for fueling automobiles, and automobile usage.

Unfortunately, high ozone conditions often occur during humid days of summer when winds are low and electrical demand to run air conditioning is high. In some instances the poor quality air and pollutants responsible for ground-level ozone formation may originate in other areas of the country. Biodiesel may have a role to play in helping to reduce the incidence of ozone alerts in the Twin Cities Metro Area if more of this fuel is used in diesel-powered vehicles, machines, and peaking generators.

Particulate matter (PM) is a troublesome emission issue associated with diesel engines. Particulate matter consists of microscopic particles of soot and can be harmful when drawn deep into one's lungs where adhering chemicals contribute to various types of lung disease and cancer. Children are more susceptible to this type of pollution because they breathe 50 percent more air per pound of body weight than adults. Major federal efforts have targeted particulate emissions from school buses because more than 24 million children are exposed to diesel exhaust every school day (8).

Chapter 2: Project Objectives

This study was conducted for several key reasons, including the following:

1) Biodiesel is scheduled to be included at a 2% blend in the diesel fuel of most diesel powered vehicles and machines in Minnesota in 2005 under current law (9). This statute is available in Appendix A.

2) Ground level ozone levels may trigger local responses in the Twin City Metropolitan Area due to federal air quality requirements. To prevent or reduce formation of ground-level ozone due to VOC's, biodiesel blend levels greater than 2% may be useful in certain classes of machines.

3) State and local authorities may require certain users of diesel fuel to reduce particulate emissions due to the potential harm to people in close proximity to engine operation, such as the case of electrical generation units, school buses, transit buses, and government vehicles. In these instances, blend levels higher than 2% may help reduce emissions of particulates and other emissions.

In the pages that follow, the process of building a workbook to aid analysis of strategies to utilize biodiesel for a variety of reasons will be described. The categories of machines that use distillate fuels will be described as well as a range of data sources utilized to allocate fuel usage to individual counties. The workbook will be demonstrated with some examples. Categories of machines that merit special consideration for biodiesel blends because of the locations of their operation are noted. Some possible scenarios will be identified, along with suggestions for further research, which may more directly determine the effect of fuel usage patterns on air quality.

Chapter 3: Research Approach and Methods

By collecting and studying data from various sources, usage patterns of various machines and fuel oil burners were identified in Minnesota. Efforts were made to parse out the amounts of fuel used by different classes of machines in each county of the state in each month of the year. Consumption patterns were estimated for 2002 based on published and derived data from a number of years. An Excel workbook was developed containing usage figures for each county of the state on a separate worksheet. An identically formatted "page" or sheet was determined for the state as a whole. A "menu" page was created to facilitate consideration of policy alternatives. For example, if policy-makers wanted all school buses in the state to run on 20% biodiesel blend (B20) to reduce particulate levels near school children, the necessary requirement for B100 needed in each county can be determined. If other counties were to follow the example of Hennepin County and the City of Brooklyn Park and use B5 blends in their road equipment, then the required amount of biodiesel can be determined in those counties. If the Metropolitan Transit Commission were to propose the use of B20 blends in the buses in its own fleet and the regulated opt-out carriers under MTC control, the amount of B100 needed to blend in those counties can be readily determined, especially for the months of the year when ozone alerts are most likely.

Assumptions and Conventions

To conduct a study of this nature, certain underlying assumptions or conventions were needed. As mentioned previously, 2002 was chosen as the baseline year. Data from 2002 was available during the research phase of this project and makes the study fairly current. Truck size and fuel usage figures were based on 1997 data compiled by the U.S. Department of Transportation (USDOT). Later in 2005 more up-to-date data on the characteristics of the trucks in 2002 should be released by USDOT. An important convention chosen was that of trying to determine the location where the distillate was placed in the tank of the machine or boiler using the fuel. This is especially important in the case of over-the-road trucks, railroad locomotives, and barges, all having tanks of large capacity that provide a long range of travel per tank. In the case of other machines, the fueling location conforms quite closely with the location where used, such as the case of fuel oil for home heating, diesel fuel used in farm operations, or diesel fuel used in school bus operations.

Development of the Workbook

An Excel workbook was developed in order to portray the variety of distillate users in the state as well as the composition of the distillate users in each county and their respective monthly usage figures. In the workbook, individual results pages are determined for each of the state's eighty-seven counties. A state summary page (**MnSum**) reports the statewide impacts based on biodiesel blend percentages posited on the **Menu** page. In the pages that follow, instructions will be given and examples portrayed using the workbook. As better data becomes available, the **Data** page can be updated. The established framework of the workbook will retain its usefulness in analyzing amounts of biodiesel required to blend diesel fuel and distillates used by particular classes of machines.

Chapter 4: Instructions for Using the Workbook

An electronic workbook is like an ordinary book, with numerous pages or worksheets containing data organized in columns and rows. In this case the workbook has been designed to organize the following components:

<u>**Description**</u>	<u>**Excel Tab Labels**</u>
conditions proposed for usage of biodiesel	**(Menu)**
usage data utilized	**(Data)**
monthly patterns of fuel usage	**(Patterns)**
individual county summaries	**(Aitkin-Yellow Medicine)**
statewide summary	**(MnSum)**

Starting from the **Menu** page **(Table 4.1)** , one can propose biodiesel blends to be used in various classes of machines, or in the case of fuel oil, in combustion units. One can set any reasonable percent of biodiesel in Column B adjacent to the class of machine or combustion unit that uses it. Column C is a (1,0) variable which signifies whether the rate in column B is to be applied in "Outstate" counties, with 1 equal to "yes, apply this blend rate in outstate counties." Column D is set up in a similar fashion with (1,0) variable with 1 meaning, "Yes, apply the stated biodiesel blend level for this class of machine in Metro Counties," or 0 ---- meaning, "No, do not apply this policy for this class of machine in Metro Counties." The Metro Counties characterized in the workbook and cited in this report are those currently in the Metropolitan Council, including Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington. Column F on the **Menu** page is the abbreviation for the pattern that will be applied for that class of distillate using machine.

The large worksheet in the workbook entitled **Data**, partially displayed in **Table 4.2,** contains numerous figures that represent county fuel usage for particular classes of machines. When the cells on this page are populated with data, the individual county pages are able to extract and use the correct figures for each individual county. **Appendix B** contains a subset of **Data** for all classes of distillate users for the Minnesota counties Aitkin - Clay. Counties from Clearwater through Yellow Medicine can be found on the Data sheet at the MnDOT website, which is the following:

http://www.lrrb.org/pdf/MNBiodieselPolTool120904.xls

Formulas on each county sheet called "VLookups" identify the correct cell from **Data** in order to calculate the diesel and fuel oil used in a particular county. Depending upon the conditions and blend levels proposed on the Menu sheet, various biodiesel blends are determined for particular classes of machines or vehicles in each county. The amount of B100 needed to achieve the proposed blend is calculated and recorded on each individual county sheet

Table 4.1 Menu

A	B	C	D	E	F
	Biodiesel Blend Proposed	Outstate Applic.	Metro Applic.		Pattern
	(Percent)	(1,0)	(1,0)		
ON-ROAD USAGE					
Pro-Rate Trucks MN origin	2	1	1		**TRD**
Pro-Rate Trucks Non-MN	2	1	1		**TRD**
Non-Pro-Rate Comm.Trucks					
0-6K	2	1	1		**TRD**
6K-10K	2	1	1		**TRD**
10K-14K	2	1	1		**TRD**
14K-16K	2	1	1		**TRD**
16K-19.5K	2	1	1		**TRD**
19.5K-26K	2	1	1		**TRD**
26K-33K	2	1	1		**TRD**
33K-56K	2	1	1		**TRD**
56K-113K	2	1	1		**TRD**
Farm Trucks					
0-6K	2	1	1		**TRD**
6K-10K	2	1	1		**TRD**
10K-14K	2	1	1		**TRD**
14K-16K	2	1	1		**TRD**
16K-19.5K	2	1	1		**TRD**
19.5K-26K	2	1	1		**TRD**
26K-33K	2	1	1		**TRD**
33K-56K	2	1	1		**TRD**
56K-113K	2	1	1		**TRD**
School Buses	20	1	1		**SCH**
Transit Buses	20	1	1		**EQL**
Other Buses	2	1	1		**EQL**
Tax-Exempt Vehicles					
State	5	1	1		**EQL**
Non-State	5	1	1		**EQL**
Military- On-Road	2	1	1		**FRM**
Automobiles	2	1	1		**TRG**
Pickups	2	1	1		**TRG**
Recreational Vehicles	2	1	1		**FRM**
Other On-Road	2	1	1		**EQL**
TOTAL ON-ROAD USAGE					
OFF ROAD USAGE---DIESEL					
Farm Off-Road	2	1	1		**FRM**
Military--Off Road	2	1	1		**FRM**
Utility Generation Equip.	2	0	1		**EQL**
Gensets-Interrupt. Peaking	20	1	1		**EPK**
Gensets-Emergency	20	1	1		**EQL**
Railroads	0	0	0		**EQL**
River Towboats	2	1	1		**BRG**
Great Lakes Vessels	2	1	1		**GLK**
Airlines	0	0	0		**EQL**
State Highway Off-Road	5	0	1		**EQL**
Local Highway Off-Road	5	0	1		**EQL**
Other---Off Road	2	1	1		**CON**
TOTAL OFF-ROAD DIESEL					
FUEL OIL USAGE					
Residential Heating	5	1	1	**HDD**	
Commercial Heating	5	1	1	**HDD**	
Indust. Heat & Processing	5	1	1	**EQL**	
TOTAL FUEL OIL USAGE					
TOTAL DISTILLATE USAGE					

Table 4.2 Data Sheet

Cty #	(codat)	3 ProRate Trucks--MN Origin	4 ProRate Trucks--Non MN	5 Non-ProRate Trucks; 0-6K	6 Non-ProRate Trucks; 6K-10K	7 Non-ProRate Trucks; 10K-14K
1	**Aitkin**	331,605	415,558	0	59,862	40,520
2	**Anoka**	2,657,444	3,330,238	0	651,637	441,087
3	**Becker**	1,740,925	2,181,681	0	67,171	45,468
4	**Beltrami**	884,279	1,108,156	0	92,430	62,565
5	**Benton**	736,899	923,463	0	130,735	88,493
6	**Big Stone**	607,942	761,857	0	9,622	6,513
7	**Blue Earth**	2,150,825	2,695,358	0	183,935	124,504
8	**Brown**	3,228,541	4,045,922	0	83,178	56,302
9	**Carlton**	792,167	992,723	0	83,918	56,803
10	**Carver**	704,660	883,062	0	184,120	124,629
11	**Cass**	244,098	305,897	0	84,658	57,304
12	**Chippewa**	1,128,377	1,414,053	0	38,489	26,053
13	**Chisago**	580,308	727,227	0	159,232	107,782
14	**Clay**	2,081,741	2,608,783	0	69,300	46,908
15	**Clearwater**	759,928	952,321	0	31,458	21,293
16	**Cook**	55,267	69,260	0	22,853	15,469
17	**Cottonwood**	792,167	992,723	0	28,960	19,602
18	**Crow Wing**	594,125	744,542	0	172,000	116,425
19	**Dakota**	7,392,023	9,263,488	0	696,511	471,461
20	**Dodge**	663,210	831,117	0	56,254	38,078
21	**Douglas**	907,307	1,137,014	0	102,978	69,705
22	**Faribault**	1,017,842	1,275,533	0	39,600	26,805
23	**Fillmore**	792,167	992,723	0	54,403	36,825
24	**Freeborn**	1,229,701	1,541,029	0	81,142	54,924
25	**Goodhue**	2,381,106	2,983,940	0	120,187	81,353
26	**Grant**	138,169	173,149	0	19,245	13,027
27	**Hennepin**	19,256,105	24,131,243	0	2,037,443	1,379,124
28	**Houston**	1,179,039	1,477,541	0	37,657	25,489
29	**Hubbar**	271,732	340,527	0	46,539	31,502
30	**Isanti**	303,971	380,928	0	115,561	78,222
31	**Itasca**	815,195	1,021,581	0	122,778	83,107
32	**Jackson**	750,716	940,778	0	24,148	16,346
33	**Kanabec**	193,436	242,409	0	56,809	38,453
34	**Kandiyohi**	1,773,164	2,222,083	0	133,140	90,121
35	**Kittson**	193,436	242,409	0	13,046	8,831
36	**Koochiching**	115,141	144,291	0	38,767	26,241
37	**Lac Qui Parle**	488,196	611,794	0	19,800	13,402
38	**Lake**	101,324	126,976	0	26,647	18,037
39	**Lake of the Woods**	96,718	121,205	0	11,380	7,703
40	**Le Sueur**	561,886	704,141	0	89,469	60,561
41	**Lincoln**	432,928	542,535	0	16,839	11,398
42	**Lyon**	2,219,910	2,781,932	0	83,178	56,302
43	**McLeod**	838,223	1,050,439	0	103,810	70,268
44	**Mahnomen**	188,830	236,637	0	8,327	5,636
45	**Marshall**	230,281	288,582	0	29,607	20,041
46	**Martin**	1,667,235	2,089,335	0	46,076	31,189
47	**Meeker**	589,520	738,770	0	66,431	44,967
48	**Mille Lacs**	428,323	536,763	0	88,637	59,997
49	**Morrison**	589,520	738,770	0	114,913	77,784
50	**Mower**	1,174,434	1,471,769	0	73,833	49,977
51	**Murray**	801,378	1,004,266	0	28,775	19,477

Usage patterns of diesel and fuel oil through the year were derived for various classes of fuel based on various sources of information. If one assumes an equal pattern of usage in each month, then 100%/12 = 8.33% is used in each month. **Table 4.3** contains the patterns of diesel usage assumed and ultimately applied to county and state usage figures. The data contained in **Table 4.3** is contained in the **Patterns** worksheet. Minnesota Department of Revenue data, Tax Revenue Data (TRD) on diesel fuel give a pattern that reflects the activity of prorate and non-prorate commercial trucks. Patterns of fuel sales witnessed by CHS, Inc. reflect the times of heavy usage on the farms. Patterns of fuel usage for school buses reflect the nine-month school year. Patterns of fuel usage by river barges and Great Lakes ships reflect the unique patterns of movement of water-borne freight. Heating Degree Days (HDD) offer information on the pattern of usage of fuel oil for home heating, commercial and industrial users. **Figure 4.1** graphically shows the patterns ascribed to the two distillate fuels; diesel and fuel oil.

Table 4.3 Patterns of Distillate Usage **Copyright, Douglas G. Tiffany, University of Minnesota**

	Abbrev.	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Tax Revenue Diesel	TRD	0.0767	0.0751	0.0684	0.0746	0.0757	0.0901	0.0830	0.0899	0.0913	0.0869	0.1007	0.0876
School Year	SCH	0.1111	0.1111	0.1111	0.1111	0.1111				0.1111	0.1111	0.1111	0.1111
Equal	EQL	0.0833	0.0833	0.0833	0.0833	0.0833	0.0833	0.0833	0.0833	0.0833	0.0833	0.0833	0.0833
Farm	FRM	0.0288	0.0262	0.0779	0.1214	0.0938	0.0754	0.0794	0.0958	0.1146	0.1686	0.0855	0.0326
Tax Revenue Gasoline	TRG	0.0821	0.0775	0.0714	0.0770	0.0770	0.0905	0.0866	0.0941	0.0925	0.0824	0.0870	0.0820
Electrical Peaking	EPK						0.3330	0.3340	0.3330				
River Towboats	RIV				0.1120	0.1280	0.1120	0.1520	0.1480	0.1200	0.1000	0.1280	
Great Lakes Shipping	GLK				0.1250	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250	
Construction	CON	0.0500	0.0500	0.0500	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.0500
Heating Degree Days	HDD	0.1976	0.1567	0.1288	0.0723	0.0323	0.0090	0.0022	0.0056	0.0287	0.0685	0.1222	0.1763

Figure 4.1 Distillate Usage Patterns of Key Usage Groups in Minnesota

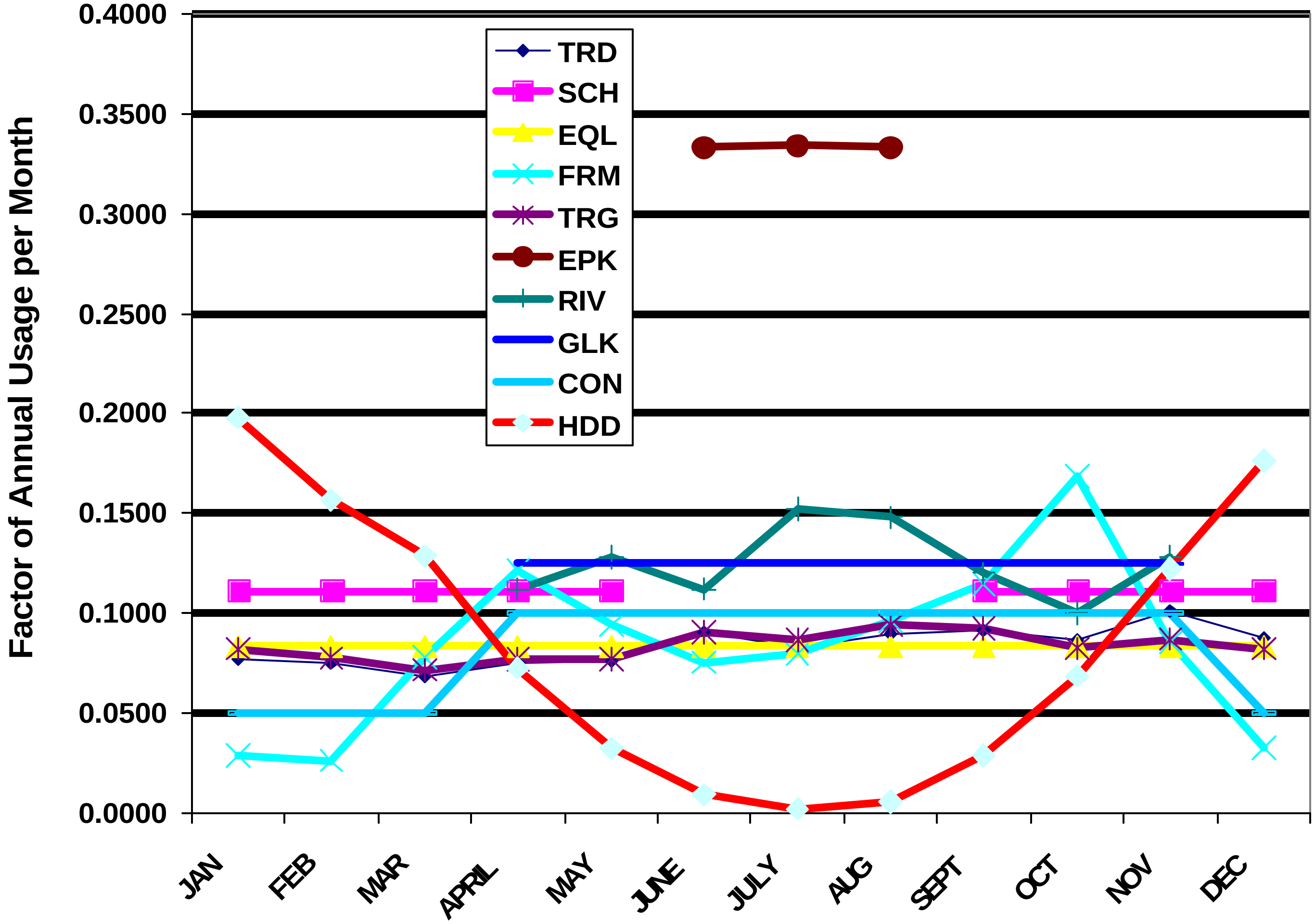


Figure 4.2 Gallons of Diesel Fuel Taxed Per Month on MN Highways 2002
(Source: Minnesota Department of Revenue)

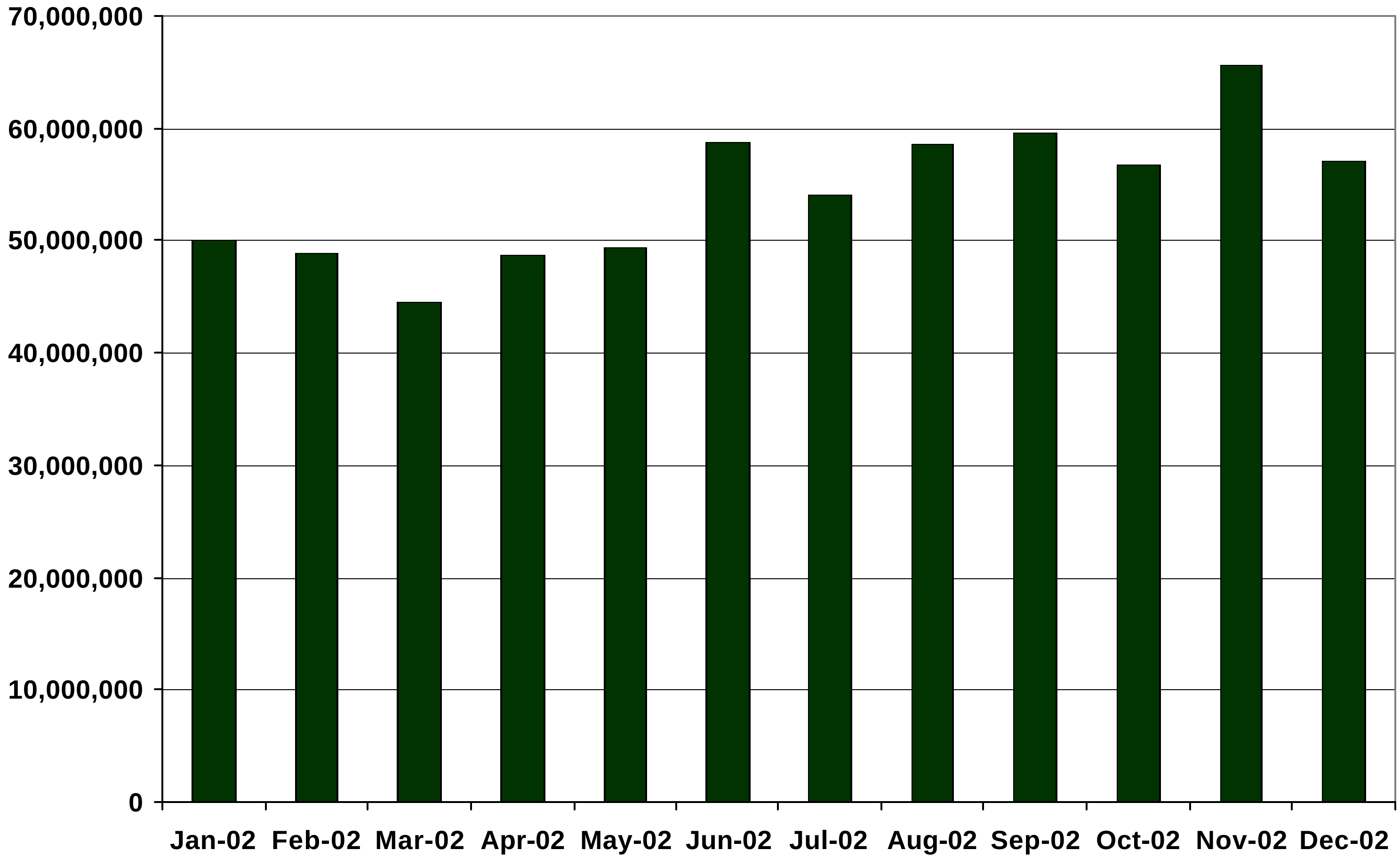
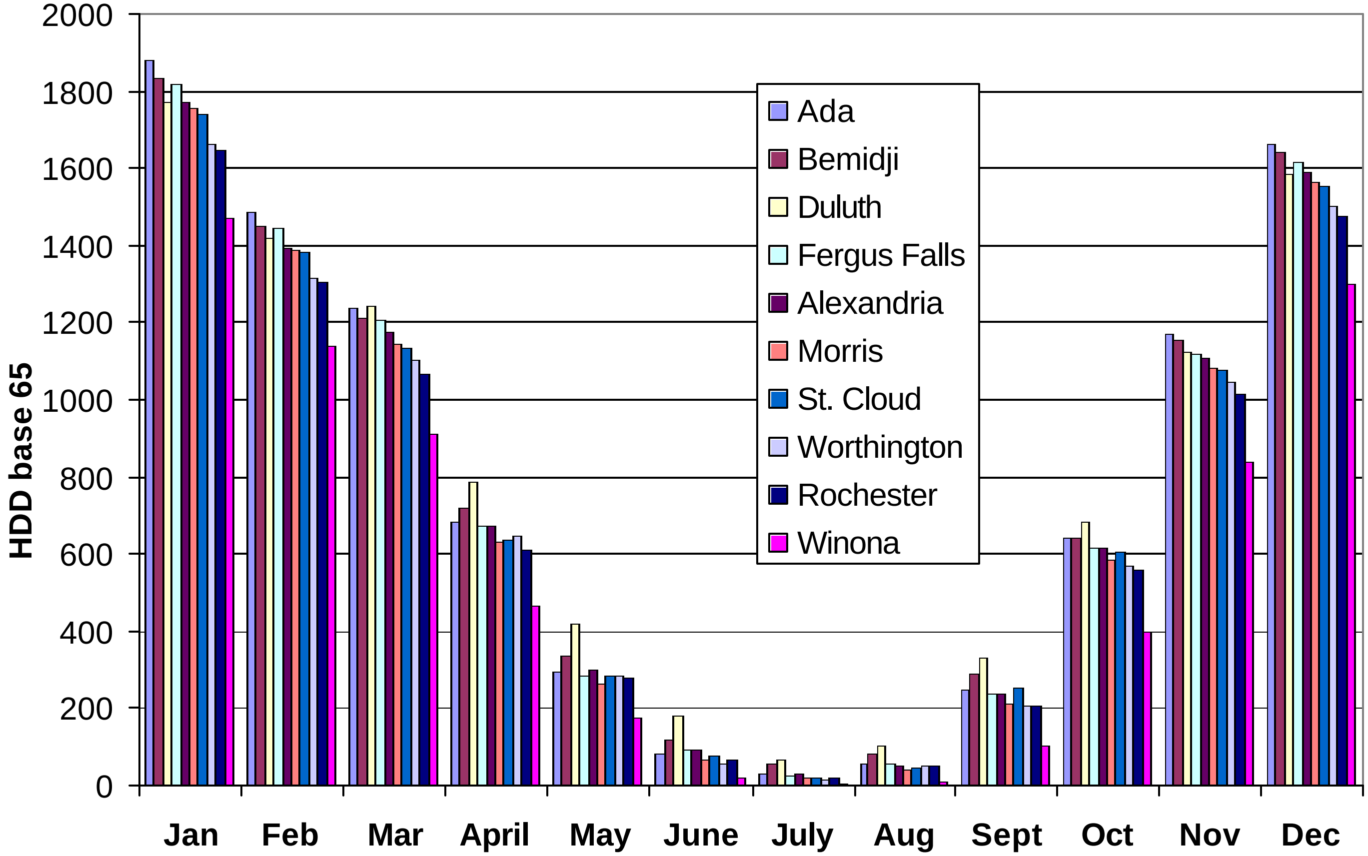


Figure 4.3 Heating Degree Days by Month at Minnesota Locations
(Midwestern Regional Climate Center, Historical Climate Summaries 1971-2000)



Individual pages for each Minnesota County are organized identically with the categories of machines placed on the corresponding lines in Column A as shown in **Table 4.4** of Becker County. In Cell B2 of each county's sheet is either 1 or 0, indicating 1= Metro County or 0 = Outstate County. Column C is purposely left blank. Column D contains the calculated annual county usage figures of diesel or fuel oil based upon the data pulled from the Data sheet. Column E contains the annual amount of B100 needed to supply the blends for each classification of machine. Column F contains a three letter abbreviation that reflects the monthly pattern of fuel usage by that class of machine. Columns G through Column R contain embedded formulas that apply factors to produce the monthly usage of B100, or pure biodiesel needed in each county for each class of machine.

The next key page of the workbook to study is entitled **MnSum**, standing for Minnesota Summary, as shown in **Table 4.5** The categories of machines to use diesel fuel and fuel oil are identical to those on the individual county pages and the menu page, with categories in the same rows. Column D on **MnSum** contains the estimate of statewide usage of diesel or fuel oil by each category of machine. The figures in Column D are calculated by formulas which add the corresponding figures for each individual County Sheet. The figures recorded in Column E represent the summation of B100, or pure biodiesel, needed to satisfy the requirements for B100 established in the **Menu** page for each of the categories of machines in all of the counties of the state.

Finding and Developing Data

Data for this study were collected from numerous sources. In many cases, statewide usage figures were available from the Energy Information Agency (EIA) of the U.S. Department of Energy. Then efforts were needed to allocate state usage numbers for a class of machines to each county of the state and to conform to monthly usage patterns throughout the year. The pie-chart that follows in **Figure 4.4** shows the annual usage pattern of distillate fuel in Minnesota as compiled by EIA.

The U.S. Census of 2000 was used to allocate fuel oil usage patterns because census questionnaires noted principal fuel used in residences. U.S. Census data in conjunction with Minnesota Department of Education figures of fuel usage by school districts were used to allocate by county the amount of diesel fuel used in the school buses throughout the state. Minnesota Department of Commerce data and Minnesota Pollution Control data were used to allocate the diesel used to produce power in baseload, interruptible, and emergency generators. With respect to vessel bunkering, industry sources strongly suggested that EIA figures were too low. By developing further detail in certain categories of distillate users, a greater number of total gallons of usage were identified than by EIA. However, in considering total distillate usage within Minnesota, this study identified only 2.6% more gallons than those estimated by EIA. This amount of difference is negligible in terms of the usage of a commodity that can vary greatly from year to year due to the severity of the winter or the size of the crops needing to be hauled.

Table 4.4
Becker

A	B	C	D	E	F	G	H	I
			County Usage Gallons	Annual B100 Gallons Needed	Pattern	JAN	FEB	MAR
Metro =1, Outstate =0	0							
On-Road Usage								
Pro-Rate Trucks-- MN origin			1,740,925	34,819	TRD	2,670	2,614	2,381
Pro-Rate Trucks Non-MN			2,181,681	43,634	TRD	3,345	3,276	2,984
Non-Pro-Rate Comm. Trucks				-		0	0	0
0-6K			-	-	TRD	0	0	0
6K-10K			67,171	1,343	TRD	103	101	92
10K-14K			45,468	909	TRD	70	68	62
14K-16K			61,723	1,234	TRD	95	93	84
16K-19.5K			8,694	174	TRD	13	13	12
19.5K-26K			99,231	1,985	TRD	152	149	136
26K-33K			190,112	3,802	TRD	292	285	260
33K-56K			383,296	7,666	TRD	588	575	524
56K-113K			499,615	9,992	TRD	766	750	683
Farm Trucks				-		0	0	0
0-6K			-	-	TRD	0	0	0
6K-10K			3,143	63	TRD	5	5	4
10K-14K			14,361	287	TRD	22	22	20
14K-16K			14,108	282	TRD	22	21	19
16K-19.5K			3,602	72	TRD	6	5	5
19.5K-26K			71,143	1,423	TRD	109	107	97
26K-33K			137,556	2,751	TRD	211	207	188
33K-56K			462,062	9,241	TRD	709	694	632
56K-113K			621,372	12,427	TRD	953	933	850
School Buses			114,801	2,296	SCH	255	255	255
Transit Buses			-	-	EQL	0	0	0
Other Buses			-	-	EQL	0	0	0
Tax-Exempt Vehicles				-				
State			22,607	452	EQL	38	38	38
Non-State			70,765	1,415	EQL	118	118	118
Military- On-Road			657	-	FRM	0	0	0
Automobiles			23,299	466	TRG	38	36	33
Pickups			124,968	2,499	TRG	205	194	178
Recreational Vehicles			12,293	246	FRM	7	6	19
Other On-Road			-	-	EQL	0	0	0
Total On-Road Usage			6,974,652	139,480		10,790	10,564	9,675
				-				
OFF ROAD USAGE---DIESEL				-				
Farm Off-Road			1,339,663	26,793	FRM	772	703	2,086
Military--Off Road			-	-	FRM	0	0	0
Utility Generation Equip.			3,908	-	EQL	0	0	0
Gensets-Interrupt. Peaking			278	-	EPK	0	0	0
Gensets--Emergency			3,397	-	EQL	0	0	0
Railroads			-	-	EQL	0	0	0
River Towboats			-	-	BRG	0	0	0
Great Lakes Vessels			-	-	GLK	0	0	0
Airlines			-	-	EQL	0	0	0
State Highway Off-Road			5,652	113	EQL	9	9	9
Local Highway Off-Road			17,691	354	EQL	29	29	29
Other---Off Road			344,658	6,893	CON	345	345	345
TOTAL OFF-ROAD DIESEL			1,715,247	34,153				
FUEL OIL USAGE								
Residential Heating			1,264,639	-	HDD	0	0	0
Commercial Heating			468,499	-	HDD	0	0	0
Indust. Heat & Processing			533,491	-	EQL	0	0	0
Total Fuel Oil Usage			2,266,629	-				
TOTAL DISTILLATE USAGE			10,956,528	173,633				
						JAN	FEB	MAR

Table 4.5 MNSUM

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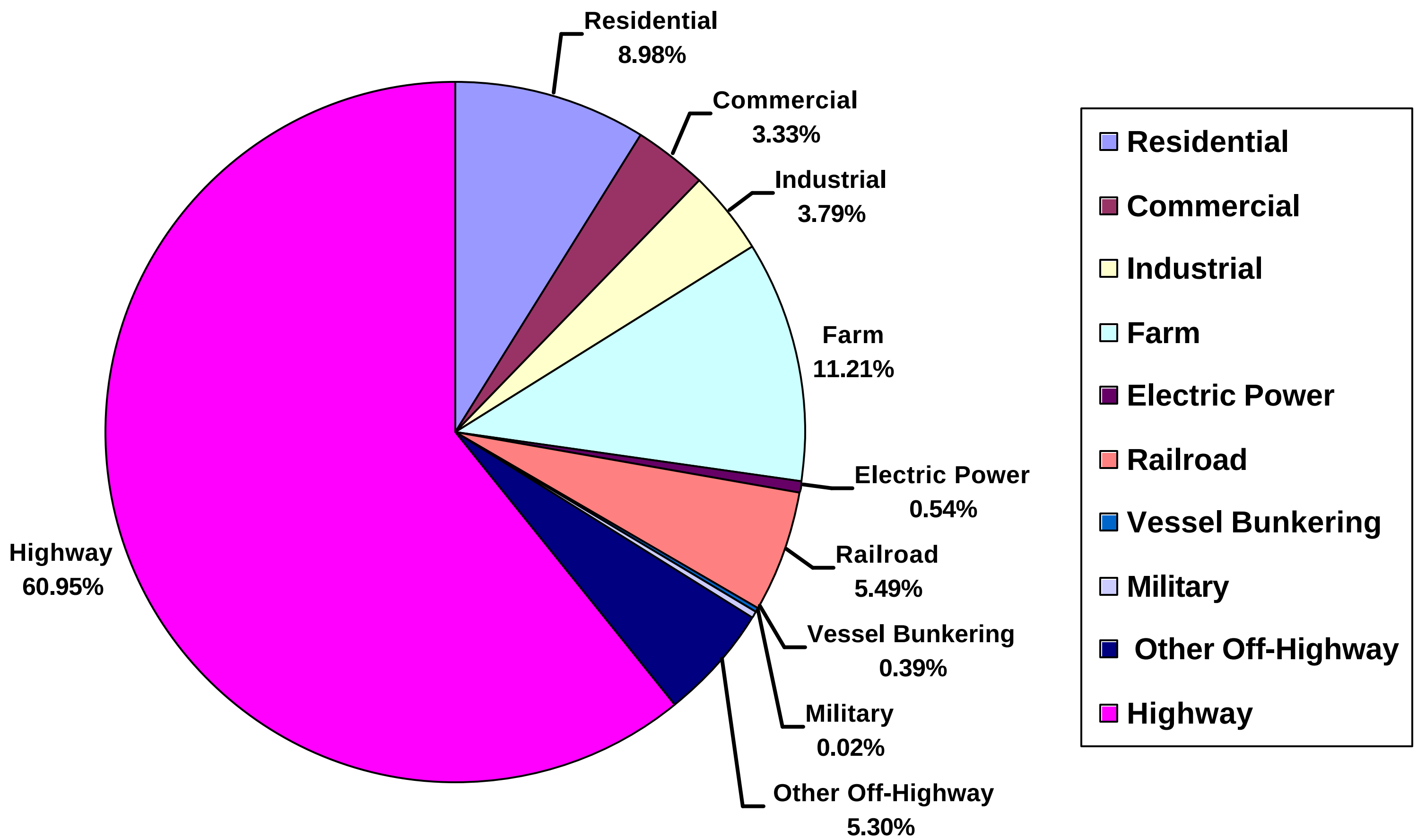
A	B	C	D	E	F	G	H	I
	# of MN Vehicles		Estimated Diesel Gal.	Annual B100 Needed	Pattern	JAN	FEB	MAR
On-Road Usage								
Pro-Rate Trucks-- MN origin	32,833		123,099,058	2,461,981	TRD	188,766	184,821	168,349
Pro-Rate Trucks Non-MN			154,264,496	3,085,290	TRD	236,556	231,613	210,971
Non-Pro-Rate Comm. Trucks	129,647							
0-6K			0	0	TRD	0	0	0
6K-10K			11,309,144	226,183	TRD	17,342	16,980	15,466
10K-14K			7,655,045	153,101	TRD	11,739	11,493	10,469
14K-16K			10,391,882	207,838	TRD	15,935	15,602	14,212
16K-19.5K			1,463,728	29,275	TRD	2,245	2,198	2,002
19.5K-26K			16,706,700	334,134	TRD	25,619	25,083	22,848
26K-33K			32,007,725	640,154	TRD	49,082	48,056	43,774
33K-56K			64,532,513	1,290,650	TRD	98,957	96,889	88,254
56K-113K			84,116,260	1,682,325	TRD	128,988	126,292	115,037
Farm Trucks	32,066							
0-6K			0	0	TRD	0	0	0
6K-10K			250,370	5,007	TRD	384	376	342
10K-14K			1,143,809	22,876	TRD	1,754	1,717	1,564
14K-16K			1,123,655	22,473	TRD	1,723	1,687	1,537
16K-19.5K			286,899	5,738	TRD	440	431	392
19.5K-26K			5,666,384	113,328	TRD	8,689	8,508	7,749
26K-33K			10,956,123	219,122	TRD	16,801	16,450	14,984
33K-56K			36,802,428	736,049	TRD	56,435	55,255	50,331
56K-113K			49,491,195	989,824	TRD	75,892	74,306	67,684
School Buses	5938		15,894,668	317,893	SCH	35,318	35,318	35,318
Transit Buses	4843		12,282,200	245,644	EQL	20,462	20,462	20,462
Other Buses	0		0	0	EQL	0	0	0
Tax-Exempt Vehicles								
State	12,603		1,804,086	36,082	EQL	3,006	3,006	3,006
Non-State	28,668		5,412,259	108,245	EQL	9,017	9,017	9,017
Military- On-Road			107,692	0	FRM	0	0	0
Automobiles	3,156,906		3,951,614	79,032	TRG	6,486	6,122	5,643
Pickups	890,648		13,700,624	274,012	TRG	22,488	21,226	19,564
Recreational Vehicles	39,584		1,502,291	30,046	FRM	866	789	2,339
Other On-Road			0		EQL	0	0	0
Total On-Road Usage			665,922,848	13,316,303		1,034,989	1,013,695	931,314
OFF ROAD USAGE---DIESEL								
Farm Off-Road			119,518,000	2,390,360	FRM	68,904	62,735	186,101
Military--Off Road			430,768	0	FRM	0	0	0
Utility Generation Equip.			9,159,813	0	EQL	0	0	0
Gensets--Interrupt. Peaking			652,401	0	EPK	0	0	0
Gensets--Emergency			652,401	0	EQL	0	0	0
Railroads			58,524,000	0	EQL	0	0	0
River Towboats			3,900,000	78,000	RIV	0	0	0
Great Lakes Vessels			5,350,000	107,000	GLK	0	0	0
Airlines			0	0	EQL	0	0	0
State Highway Off-Road			451,022	9,020	EQL			
Local Highway Off-Road			1,353,065	27,061	EQL			
Other---Off Road			56,518,000	1,130,360	CON	751	751	751
TOTAL OFF-ROAD DIESEL			256,509,470	3,741,802		2,254	2,254	2,254
FUEL OIL USAGE								
Residential Heating			95,716,000	547,721	HDD	0	0	0
Commercial Heating			35,459,000	202,909	HDD	0	0	0
Indust. Heat & Processing			40,378,000	231,057	EQL	108,239	85,809	70,523
Totals Assoc. w/ Fuel Oil			171,553,000	981,688		40,098	31,789	26,126
Total Distillate Usage			1,093,985,318	18,039,793		1,077,342	1,047,738	959,694
						JAN	FEB	MAR

Figure 4.4 Usage of Diesel and Fuel Oil In Minnesota, 2002
Source: Energy Information Agency, Table 4



Chapter 5: Discussion of Data

The listing below identifies twenty-five classes of machines capable of using distillate fuels. The lists are divided between on-road and off-road users. Bunker oils used to propel large ships were not included in this analysis because little research has been completed on utilization of biodiesel blends in such heavy oil. Bunker oils are certainly burned in diesel engines of ships, but they require processing on board to heat, strain, and remove water before burning.

On-Road Users of Diesel Fuel

1) Prorate Commercial Trucks (based in MN or other states & provinces)
2) Non-Prorate Commercial Trucks (sorted by Gross Vehicle Weight)
3) Farm Trucks (sorted by Gross Vehicle Weight)
4) School Buses
5) Transit Buses
6) Tax-Exempt State Vehicles
7) Tax-Exempt Non-State Vehicles
8) Military On-Road Vehicles
9) Automobiles
10) Pickups
11) Recreational Vehicles (Motor homes)
12) Other On-Road Vehicles

Off-Road Users of Diesel Fuel

13) Farm Off-Road Machinery
14) Military Off-Road Equipment
15) Utility Generation Equipment—Baseload or Intermediate
16) Utility Generation Equipment—Emergency and Peak-Shavers
17) Railroads
18) River Barges
19) Great Lakes Shipping and Recreation
20) State Highway Off-Road Equipment
21) Local Highway Off-Road Equipment
22) Other Off Road Usage

Fuel Oil Usage

23) Residential Fuel Oil Usage
24) Commercial Fuel Oil Usage
25) Industrial Fuel Oil Usage

Discussion of Categories

A few comments are in order about the categories chosen, although some may seem self-explanatory.

Prorate Trucks are typically the large semi's that haul cargo in interstate commerce. It is possible to distinguish between the amount of fuel used by Minnesota-based trucks and those from other states that pass through the state. The data on fuel usage by the prorate trucks are collected by a consortium that allocates among the states the amount of state fuel tax collected by diesel purchases in accordance with the number of miles driven in a particular state. This system ensures that irrespective of the state where diesel fuel is purchased, pro-rate truckers pay the appropriate rate for the gallons considered used in each particular state. In order to ensure compliance, pro-rate truckers are responsible for maintaining log-books that contain figures verifying the miles recorded on wheel-mounted odometers. Prorate truckers must also submit monthly reports indicating the number of highway miles driven in each state. Minnesota Department of Revenue data of fuel tax collections by month were used to determine usage patterns throughout the year as shown previously in **Figure 4.2**.

Non- Prorate Trucks are the Commercial Class Trucks ("Y" class) that are registered in Minnesota and classified by their home county by the Minnesota Department of Public Safety. These trucks make all kinds of deliveries, but conduct almost all of their travel within the state borders (intrastate commerce). Gross vehicle weights were used to stratify the Non-Prorate Trucks because a smaller proportion of the small trucks are likely to use diesel fuel. National data were applied to determine the percentage of fuel used by each of the size categories as shown in **Figure 4.5** (10). Minnesota Department of Revenue data of fuel tax collections by month for 2002 were used to determine usage patterns throughout the year as shown previously in **Figure 4.2** .

Farm Trucks are licensed to haul agricultural commodities and are assumed to generally confine their travel within the state's borders. They are classified according to the gross vehicle weights and assigned to their home counties based on Minnesota Department of Public Safety records. The fleet of farm trucks tends to be older than the commercial trucks, and higher proportions are thought to be gasoline-powered. Many are used only seasonally with relatively low mileage and fuel usage figures. Federal fuel usage patterns were applied based on the gross vehicle weight of the trucks as shown in **Figure 4.5 .**

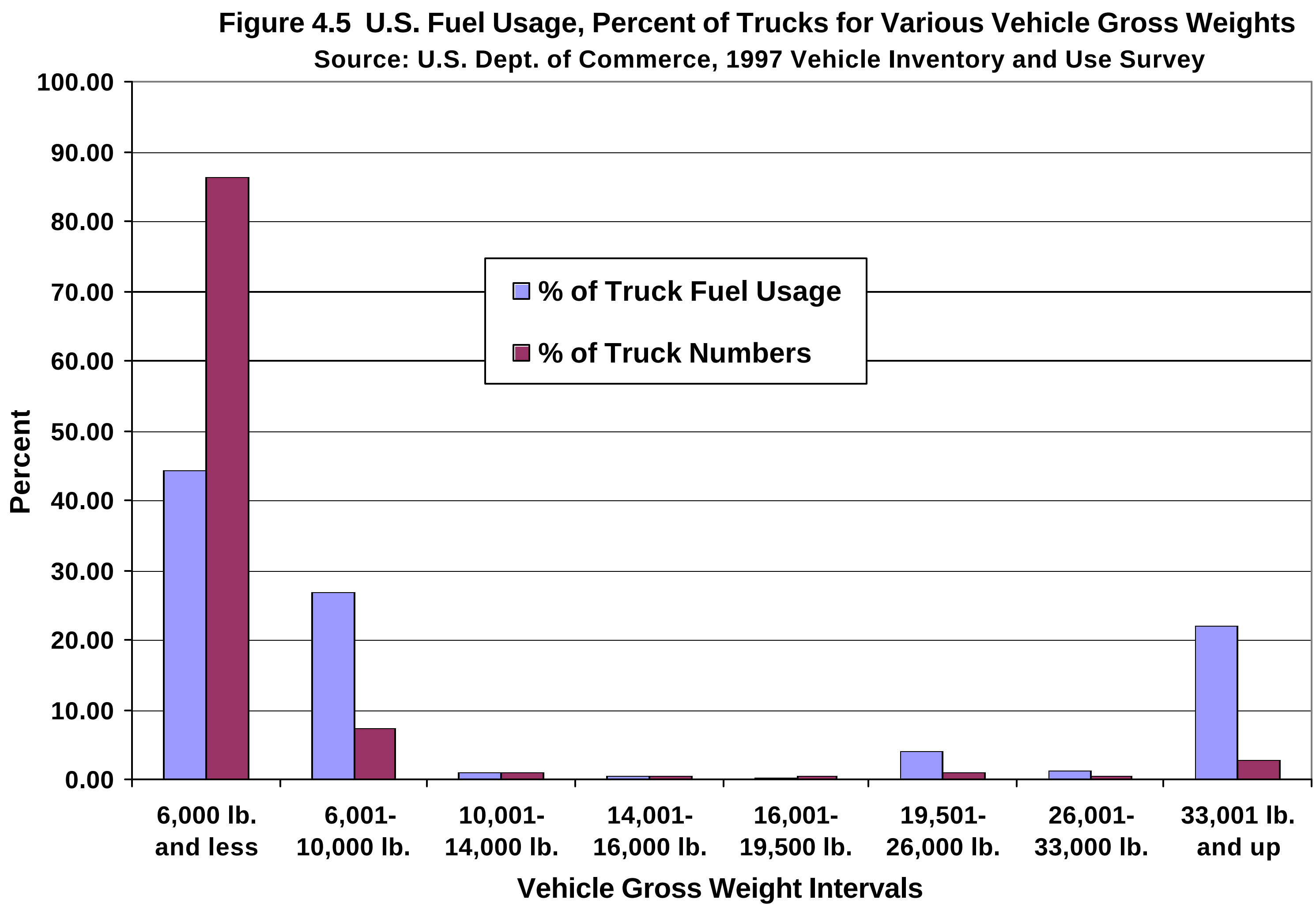


Figure 4.5 U.S. Fuel Usage, Percent of Trucks for Various Vehicle Gross Weights
Source: U.S. Dept. of Commerce, 1997 Vehicle Inventory and Use Survey
Percent
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
% of Truck Fuel Usage
% of Truck Numbers
6,000 lb. and less
6,001-10,000 lb.
10,001-14,000 lb.
14,001-16,000 lb.
16,001-19,500 lb.
19,501-26,000 lb.
26,001-33,000 lb.
33,001 lb. and up
Vehicle Gross Weight Intervals

School Buses are noted in the Minnesota Department of Public Safety records. The most complete and recent data of diesel usage by school buses in Minnesota was compiled by the Minnesota Department of Education in 1996-1997. At that time there was reporting of fuel used in buses owned by school districts and also buses contracted by school districts to verify state transportation aid to school districts. U.S. Census data on the school age population was used to derive gallons of diesel per pupil in the counties based on the various levels of student density. (L. Schroeder, Minnesota Department of Education, 2004, print-out of electronic data)

Transit Buses are a separate class of buses, primarily used by the Metropolitan Transit Commission and their opt-out carriers. MTC staff estimated fuel usage in each county in their service area based on passenger-mile data collected. (D.Christianson, Metropolitan Transmit Commission, 2004, personal communication)

Tax-Exempt Vehicles; State Owned Minnesota Department of Public Safety data was used to allocate the number of state-owned tax-exempt vehicles in each county of the state. Most of the diesel-using vehicles were assumed to be Minnesota Department of Transportation vehicles.

Tax-Exempt Vehicles; Non-State Owned Minnesota Department of Public Safety data was used to allocate the number of vehicles in this classification in each county of the state. Most of the diesel- consuming vehicles were assumed to be in the street and highway departments of counties and cities.

Military Vehicles—On-Road These are vehicles used by the Minnesota National Guard. The fuels manager for the Minnesota National Guard indicated that 20% of the usage of diesel occurs on-road in the home counties of the various formations, while 80% of the fuel used for ground vehicles and equipment occurs at Camp Ripley in Morrison County. (D.Gafke, Minnesota National Guard, 2004, personal communication)

Automobiles that use diesel fuel are not very common in Minnesota. There are a few older Mercedes Benz models (the company hasn't sold any diesels in the U.S. for several years) and Volkswagens that have the TDI engine in either Jettas, Golfs, or Beetles. Volkswagen was unable to precisely tell how many diesels are on the road in Minnesota, but anecdotal evidence from one metropolitan dealership indicated that a third of the three models mentioned are sold with diesel engines. National data on car sales were examined and used to allocate diesel cars in proportion to state share of the national car fleet and each county's share of the state's car fleet (11).

Pickups have increased in popularity in recent years overall, with more and more of the heavy ones powered by diesel engines. In particular, owners of pickups doing significant towing are attracted to diesels due to higher torque, better fuel economy, and longer engine life than similar trucks with equivalent gasoline engines. Ford, General Motors, and Dodge market diesel- powered trucks in their 3/4 Ton and 1.0 Ton sizes. It is typical for diesel-powered pickups to initially cost $4500 more than a comparably equipped gasoline model.

Recreational Vehicles are an interesting class of vehicle. Based on a survey of recreational vehicle (RV) owners, it was assumed that 100% of the models 36 feet or longer in length are powered with diesel engines (12) Minnesota Department of Public Safety records were sorted to find the larger vehicles, which were allocated according to the proportion recreational vehicles found in each county. Diesel usage per RV was based on 10,000 miles of annual driving averaging 7.5 miles per gallon (12) (13).

Farm Off-Road diesel usage is represented by tractors and combines that perform cropping operations as well as livestock activities (14). The seasonal usage pattern for farm machines was provided by CHS Inc. (D. Hunhoff, CHS, Inc. Spreadsheet of Petroleum Sales by Month, 2004). Individual county allocations of diesel usage were made on their proportion of state farm sales (15).

Military Off-Road diesel usage represents the equipment used in training in the state. The federal government is using biodiesel at some of the U.S. Army's training facilities in the case of equipment that is determined to be non-deployable. The fuels manager for the Minnesota National Guard indicated that 80% of the total diesel fuel use by state units occurs at Camp Ripley in Morrison County during field exercises. (D.Gafke, Minnesota National Guard. August, 2004, personal communication)

Utility Generation Equipment (baseload and intermediate) Data on diesel usage in this category were available from reports filed by the Minnesota Department of Commerce, which listed the amount of fuel used by each facility in 2000. These were sorted by county and summarized. In some cases electric generation occurs with combustion turbines fueled with diesel fuel and in other instances, large internal combustion engines are used to generate baseload power (16).

"Gensets" for Emergency and Peak-Shaving are smaller diesel-powered generators that serve offices, hospitals, laboratories, and other facilities that cannot afford power interruptions. Power from emergency generators is typically not fed into the grid. Peak-shavers are privately-owned generators with which the power companies have contracted for on-call generation capacity at times when power loads are high. Peak-shavers may feed power into the grid for 70 hours in a typical year, based on Minnesota Pollution Control Agency studies. MPCA staff estimated that interruptible and emergency generators each used 652,401 gallons of diesel fuel in 2002 and contributed 1.6% of statewide diesel emissions; however that figure can be much higher on peak load days of summer. Other electric generating plants in the state used 9,159,813 gallons of diesel fuel in 2002. (B. Timerson, Minnesota Pollution Control Agency, Fact Sheet "Diesel Generator Emissions," 2004)

Railroads consume a great deal of diesel fuel in the state because they have substantial freight to haul throughout the year. EIA reported that railroads in Minnesota used 58,524,000 gallons in 2002. Grain movements tend to be heaviest during the autumn harvest and at other times when the Mississippi River and the Great Lakes are open for navigation. Minnesota legislation that mandated the inclusion of biodiesel in the state's diesel fuel supply specifically excluded this requirement for railroads, copper and iron mining operations, and nuclear powered electricity generation plants. However, federal regulations released by the Environmental Protection Agency in May 2004 will require the use of ultra low sulfur diesel (ULSD) fuel in nonroad diesel engines. Smaller off-road new engines will be required to use low-sulfur diesel fuel starting in 2008. By 2015 diesel engines larger than 750 horsepower such as locomotives will be required to use low sulfur fuel (17). In order to restore lubricity in ultra low sulfur diesel, some of the railroads may be attracted to use of biodiesel due to its lubricity enhancing qualities even at low blends of 1-2%. One railroad in the state, the Prairie Line, is currently using 2% biodiesel with consideration of using 5% blends in the future (18).

River Towboats are responsible for moving considerable volumes of grain from Minnesota to other markets. Their operating season is typically April through early December. There is typically a slack time of barge movement in July and August each year. Because river barges have large tanks and because Minnesota ports are at the terminus, fueling activities are inordinately high for Ramsey County. The next port downstream with significant fuelling activity for barges is St. Louis, Missouri. (R. Lambert, Minnesota Department of Transportation, personal communication, June 2004) The Tennessee Valley Authority prepares a detailed study of diesel fuel usage by towboats based on freight movement patterns on the nation's waterways in order to allocate tax revenues to sections of the system in for lock maintenance. The pattern of towboat usage of fuel was derived from the monthly pattern of grain movements through Lock 27 at Granite City, Illinois, with reallocation for the months of December, January, February and March when the Mississippi River is not open for barges in Minnesota (19).

Great Lakes Vessels coming in to the ports of Duluth, Two Harbors, and Silver Bay utilize #2 diesel for their on-board generators, which power many ship functions except propulsion. For propulsion, large freighters generally use the heavier bunker grades of fuel. Bunker fuel requires additional processing on-board before it can be used. It is typically heated, centrifuged, strained, and has water removed before it can be burned. (J. Cuzio, Murphy Oil Company, June 2004, personal communication) EIA data on diesel used as ships and barges was considered to be underreported based on interviews with diesel fuel merchants, so the author revised published data upward (14).

Airlines are listed as a category, but were not analyzed.

State Highway Off-Road Equipment is a category that includes payloaders, road graders, tractors and mowers that support roadway services, primarily.

Local Highway Off-Road Equipment includes payloaders, road graders, tractors and mowers that support roadways in counties and cities for the most part. Certain addition equipment may be used to support other public utilities, especially in cities.

Fuel Oil--Residential Heating The EIA of the U.S. Department of Energy publishes data by state for this category of fuel oil use (14). U.S Census Data from 2000 estimates that 6.4% of Minnesota homes use either fuel oil or kerosene. This body of data was extracted and analyzed to determine the number of homes in each Minnesota County that heat with fuel oil (20). Because the prevalence of house heating with kerosene is so low, all respondents were assumed to be using fuel oil. Published data of heating degree days (HDD) were examined for various state locations to determine the pattern of annual usage in homes as portrayed in **Figure 4.3** (21). The pattern of HDD for St. Cloud was considered representative of statewide patterns. St. Louis County leads the state in the number of homes using fuel oil for home heating.

Fuel Oil—Commercial Heating The EIA publishes an overall figure for this category of fuel oil usage. Usage of fuel oil in commercial facilities is more common in older buildings and in areas of the state without access to natural gas. Therefore, the pattern of usage was assumed to conform to the same proportions as the residential heating oil usage pattern (14).

Fuel Oil—Industrial Heat & Processing The EIA publishes an overall figure for this category of fuel oil usage. Industrial users have shown movement away from fuel oil to natural gas in the last three decades due to generally cheap natural gas and broader availability. Usage of fuel oil in industrial facilities is more common in older plants and in areas of the state without access to natural gas. Because this fuel is used in industrial processing, the pattern of usage was applied equally in each month (14).

Chapter 6: Key Classes of Distillate Users for Policy-Makers

After considering the categories of diesel and fuel oil users and the opportunities to reduce harmful emissions such as particulates and poly-aromatic hydrocarbons, certain situations seem likely to receive high consideration for higher blends of biodiesel. The following categories seem to be likely candidates for utilization of higher biodiesel blends:

School buses
Transit Buses
Diesel Gensets (Emergency & Peak-Shaving)
Diesel Generators (Base Load)
State Tax Exempt Vehicles
State Off-Road Equipment
Non-State Tax Exempt Vehicles
Non-State Off-Road Equipment
Fuel Oil in Residential, Commercial, and Industrial Uses

School buses are likely candidates for using blends of biodiesel because of published studies that identify air quality on and around diesel school buses as the worst air encountered by young children during a school day (22). School buses are centrally fueled, so higher blends of biodiesel could more easily be used in these vehicles than those of the general public. Transit buses are likely candidates because they operate in congested urban settings that could benefit from reduced emissions. Transit buses are also fueled at central locations. Because diesel "gensets" for emergency and peak-shaving operate near ground level and in many cases by hospitals, factories, schools, and critical installations, they are prime candidates. The larger generators that serve as intermediate and baseload capacity may be candidates as well, especially when located in close proximity to substantial populations. The tax exempt vehicles owned by state government, as well as those owned by counties and cities, are often centrally fueled and include snowplows and other street maintenance equipment. Many of these vehicles operate in urban settings with air quality issues. The tax exempt fleets also include a substantial amount of diesel equipment that can operate off-road. Fuel oil usage in residential, commercial, and industrial settings represents an additional opportunity for usage of biodiesel, particularly in urban settings with air quality issues.

Chapter 7: Using the Workbook to Analyze Key Policy Scenarios

The following scenarios were established and solved using the "Biodiesel Policy Analysis Workbook":

Statewide Scenario-----B2 Biodiesel Mandate in Engines except excluded classes
Statewide Scenario---- B20 in School Buses
Statewide Scenario---- B20 in Gensets (Peak-Shavers and Emergency)
Statewide Scenario---- B5 in State Tax-Exempt Vehicles and Equipment
Statewide Scenario---- B5 in County and City Tax-Exempt Vehicles
Statewide Scenario---- B5 in Fuel Oil in Residential, Commercial, and Industrial classes

Metro Scenario---------B5 in State Tax-Exempt Vehicles and Equipment
Metro Scenario---------B5 in County and City Tax-Exempt Vehicles and Equipment
Metro Scenario---------B20 Transit Buses
Metro Scenario---------B20 Fuel Oil in Residential, Commercial, and Industrial classes
Metro Scenario---------B5 in Fuel Oil in Residential, Commercial, and Industrial classes

B2 Biodiesel Mandate in Engines Except Excluded Classes, Statewide. In this instance the total amount of B100 necessary to achieve 2% blends (B2) in the state of Minnesota for the diesel utilized in engines with the exception of electrical generation, railroads, and military vehicles and equipment. The calculated figure is 17,058,105 gallons of B100, which consists of 13,316,303 gallons on-road and 3,741,802 gallons off-road.

B20 in School Buses, Statewide. The scenario using B20 in all state school buses would require 3,178,934 gallons of B100, statewide, with 1,538,289 needed in the Metro Counties.

B20 in Gensets (Peak-Shavers and Emergency), Statewide. This statewide scenario would require 260,960 gallons of B100, with much of this usage occurring during the summer months when weather conditions may favor the use of biodiesel to reduce the formation of ground-level ozone and particulates.

B5 in State Tax-Exempt Vehicles and Equipment, Statewide. In this scenario it is estimated that **90,204** gallons of B100 would be necessary to achieve B5 in the current fleet of MnDOT vehicles on the road. An additional 22,551 gallons of B100 would be needed for the off-road MnDOT machines, statewide.

B5 in County and City Tax-Exempt Vehicles and Equipment, Statewide. In this scenario it is estimated that 270,613 gallons of B100 would be necessary to achieve B5 in the fleet of county and city vehicles on the road. An additional 67,653 gallons B100 would be needed for off-road equipment, statewide.

B5 in all Fuel Oil, Statewide. In this scenario it is estimated that 8,577,650 gallons of B100 would be needed, statewide, with 55.8% used residentially, 20.7% used commercially, and 23.5% used industrially.
In the Twin Cities Metropolitan area, the following scenarios are presented:

B5 in State Tax-Exempt Vehicles and Equipment in the Metro-area. This scenario would require 11,484 gallons of B100 in vehicles and 2,871 gallons needed for off-road equipment in the metropolitan area.

B5 in County and City Vehicles and Equipment in the Metro-area. Counties would require 72,572 gallons of B100 for on-road vehicles and an estimated 18,143 gallons for the off-road, unlicensed machines of the counties and cities of this area with key air quality issues.

B20 Transit Buses in the Metro-area. If the transit buses of the Twin Cities Metropolitan area were to use B20 in a move to reduce emissions affecting denser populations, 2,264,000 gallons of B100 would be needed with only 192,440 more gallons needed in outstate transit buses.

B20 Fuel Oil in Residential, Commercial, and Industrial Classes in the Metro-area. In the event that efforts were made to try to reduce emissions from fuel oil usage in the Metro area, a total of 3,926,751 gallons of B100 would be required. The largest class of fuel oil users would be residential users requiring **2,190,885** gallons per year.

B5 Fuel Oil in Residential, Commercial, and Industrial Classes in the Metro-area. Using a less aggressive approach of B5 in fuel oil would require 981,688 gallons of B100. Residential, commercial and industrial classes would require 55.8%, 20.7%, and 23.5%, respectively in the three classes.

Chapter 8: Conclusions

Diesel fuel and fuel oil usage patterns in Minnesota reflect the fact that diesel fuel is the "fuel of commerce." The usage patterns for diesel fuel and fuel oil provide an interesting frame of reference to observe all sorts of economic activity in the state. In order to comply with more stringent air quality standards and respond to air quality issues emerging due to greater congestion in the Minneapolis-St. Paul Metropolitan area, the usage patterns of diesel and fuel oil may suggest target categories of machines for various blends of biodiesel. Research with biodiesel reveals that in addition to restoring lubricity in ultra-low sulfur diesel fuel, emissions of particulates, poly-aromatic hydrocarbons, and VOC's will be reduced by usage of higher blends of biodiesel. The accompanying workbook was constructed in order to support analysis of policy choices that establish biodiesel blends for various categories of machines. The workbook can help policymakers focus on the categories of machines using distillate fuels and determine how much biodiesel would be required to provide blends for particular categories. As time goes by, the data populating the **Data** worksheet will become out of date. When this occurs it will be possible to update the figures and use the workbook framework to estimate costs and the potential for emissions reductions possible by use of this renewable fuel.

Readers of this report are welcome to pose various scenarios of blend rates applied to various classes of machines whether on-road or off-road, whether metro or outstate, whether private or part of publicly owned fleets of vehicles. The policy analysis tool represented by this workbook is available at the following website for investigation by any interested parties:

http://www.lrrb.org/pdf/MNBiodieselPolTool120904.xls

Recommendations for Implementation
After consultation with contracting authorities in the Research Services Division of the Minnesota Department of Transportation and the Center for Transportation Studies (CTS) at the University of Minnesota, the following dissemination opportunities were pursued:

1) Presentation of research at the CTS Environmental Seminar, February 24, 2004.
2) Presentation of research findings at the CTS Annual Research Conference, May 4, 2004.
3) Demonstration of workbook and presentation of research findings at Minnesota Pollution Control Agency (MPCA) with MPCA and MnDOT staff, August 12, 2004.
4) Poster presentation planned for National Biodiesel Conference & Expo at Fort Lauderdale, FL on January 30- February 2, 2005.
5) Posting of this research report and the policy tool on MnDOT website by January 31, 2005.

Further Research Suggestions

Data on fuel usage patterns by certain categories of machines were difficult to obtain. More information could be gathered on the inventory and size of diesel-powered machines owned by minor civil divisions (MCD's), counties and units of state government. A better understanding of the diesel usage by state tax-exempt and non-state tax-exempt fleets would permit more accurate estimates in this category of users.

Fuel oil usage in Minnesota has declined drastically from the 1960's and 1970's as natural gas has increased in availability, even in rural areas. Usage of fuel oil is certainly more dominant in the New England states where substantial research has been conducted using biodiesel blends. Fuel oil suppliers in Massachusetts, Pennsylvania, New York, and Maine are marketing biodiesel blended with low-sulfur No. 2 fuel oil as "bioheat" to customers. Research conducted by the Massachusetts Oilheat Council (MOC) and the National Oilheat Research Alliance found that B20 reduced sulfur oxide emissions by 80 percent or more and nitrogen oxide emissions by 20 percent (23). The staff of the Minnesota Pollution Control Agency may have the capability to utilize air quality models to determine if biodiesel blended with fuel oil would provide substantial improvements to emissions, especially in the Twin Cities Metropolitan area.

Among the classes of diesel powered on-the-road vehicles, pick-up trucks and sports utility vehicles seem to show the most promise of growth in the next decade due to attractive towing, torque, fuel economy, and engine life available from these more expensive engines. Efforts should be made to quantify geographically the growing proportion of pick-ups using diesel fuel. Because U.S. consumers have demonstrated much more reluctant to seek diesel-powered automobiles than European consumers, diesel will remain the "fuel of commerce."

Continuing efforts of the Minnesota Pollution Control and the Environmental Protection Agency can be expected to further document the emissions risks posed by diesel fuel and fuel oil. Work by these agencies may further refine the selection of distillate users possessing the greatest need for reductions in targeted emissions.

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Appendix A

239.77 Biodiesel content mandate.

Subdivision 1. Biodiesel fuel. "Biodiesel fuel" means a renewable, biodegradable, mono alkyl ester combustible liquid fuel derived from agricultural plant oils or animal fats and that meets American Society for Testing and Materials Specification D6751-02 for Biodiesel Fuel (B100) Blend Stock for Distillate Fuels.

Subd. 2. Minimum content; effective date. (a) Except as otherwise provided in this section, all diesel fuel sold or offered for sale in Minnesota for use in internal combustion engines must contain at least 2.0 percent biodiesel fuel oil by volume.

(b) The mandate in paragraph (a) is effective on and after the date that the conditions in clauses (1) and (2), or in clauses (1) and (3), have been met:

(1) thirty or more days have passed since the commissioner of agriculture publishes notice in the State Register that annual capacity in Minnesota for the production of biodiesel fuel oil exceeds 8,000,000 gallons;

(2) eighteen months have passed since the commissioner of agriculture publishes notice in the State Register that a federal action on taxes imposed, tax credits, or otherwise, creates a reduction in the price of two cents or more per gallon on taxable fuel that contains at least two percent biodiesel fuel oil and is sold in this state;

(3) the date June 30, 2005, has passed.

Subd. 3. Exceptions. (a) The minimum content requirement of subdivision 2 does not apply to fuel used in the following equipment:

(1) motors located at an electric generating plant regulated by the Nuclear Regulatory Commission;

(2) railroad locomotives; and

(3) off-road taconite and copper mining equipment and machinery.

(b) The exemption in paragraph (a), clause (1), expires 30 days after the Nuclear Regulatory Commission has approved the use of biodiesel fuel in motors at electric generating plants under its regulation.

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Appendix B

Data Sheet **(1/19/05)**

(codat)	3	4	5	6	7	8	9	10	11	12	13
	ProRate Trucks MN Origin	ProRate Trucks Non-MN	Non-ProRate Trucks; 0-6K	Non-ProRate Trucks; 6K-10K	Non-ProRate Trucks; 10K-14K	Non-ProRate Trucks; 14K-16K	Non-ProRate Trucks; 16K-19.5K	Non-ProRate Trucks; 19.5K-26K	Non- ProRate Trucks; 26K-33K	Non-ProRate Trucks; 33K-56K	Non-ProRate Trucks; 56K-113K
Aitkin	331,605	415,558	0	59,862	40,520	55,007	7,748	88,433	169,425	341,587	445,249
Anoka	2,657,444	3,330,238	0	651,637	441,087	598,784	84,341	962,647	1,844,298	3,718,390	4,846,813
Becker	1,740,925	2,181,681	0	67,171	45,468	61,723	8,694	99,231	190,112	383,296	499,615
Beltrami	884,279	1,108,156	0	92,430	62,565	84,933	11,963	136,545	261,601	527,427	687,486
Benton	736,899	923,463	0	130,735	88,493	120,131	16,921	193,131	370,012	746,001	972,391
Big Stone	607,942	761,857	0	9,622	6,513	8,842	1,245	14,215	27,234	54,907	71,570
Blue Earth	2,150,825	2,695,358	0	183,935	124,504	169,017	23,806	271,723	520,583	1,049,575	1,368,091
Brown	3,228,541	4,045,922	0	83,178	56,302	76,432	10,766	122,877	235,414	474,632	618,669
Carlton	792,167	992,723	0	83,918	56,803	77,112	10,861	123,970	237,509	478,856	624,174
Carver	704,660	883,062	0	184,120	124,629	169,187	23,830	271,996	521,107	1,050,631	1,369,467
Cass	244,098	305,897	0	84,658	57,304	77,792	10,957	125,063	239,604	483,079	629,680
Chippewa	1,128,377	1,414,053	0	38,489	26,053	35,368	4,982	56,859	108,935	219,629	286,281
Chisago	580,308	727,227	0	159,232	107,782	146,317	20,609	235,229	450,665	908,611	1,184,348
Clay	2,081,741	2,608,783	0	69,300	46,908	63,679	8,969	102,374	196,135	395,439	515,443

		14	15	16	17	18	19	20	21	22	23	24	X 25
Cty #		Farm Trucks; 0-6K	Farm Trucks; 6K-10K	Farm Trucks; 10K-14K	Farm Trucks; 14K-16K	Farm Trucks; 16K-19.5K	Farm Trucks; 19.5K-26K	Farm Trucks; 26K-33K	Farm Trucks; 33K-56K	Farm Trucks; 56K-113K	School Buses	Transit Buses	Other Buses
1	**Aitkin**	0	1,588	7,253	7,125	1,819	35,929	69,469	233,353	313,809	57,669		
2	**Anoka**	0	2,006	9,165	9,003	2,299	45,403	87,787	294,884	396,554	691,789	566,000	
3	**Becker**	0	3,143	14,361	14,108	3,602	71,143	137,556	462,062	621,372	114,801		
4	**Beltrami**	0	2,559	11,691	11,485	2,932	57,915	111,981	376,151	505,841	249,611		
5	**Benton**	0	1,208	5,521	5,423	1,385	27,349	52,880	177,627	238,869	127,785		
6	**Big Stone**	0	2,788	12,737	12,513	3,195	63,099	122,004	409,819	551,116	26,781		
7	**Blue Earth**	0	6,042	27,603	27,117	6,924	136,744	264,399	888,134	1,194,346	127,015		
8	**Brown**	0	3,815	17,428	17,121	4,371	86,336	166,934	560,744	754,077	137,328		
9	**Carlton**	0	1,666	7,613	7,479	1,910	37,716	72,926	244,963	329,421	95,178		
10	**Carver**	0	2,188	9,995	9,819	2,507	49,514	95,736	321,586	432,462	265,217	113,200	
11	**Cass**	0	1,722	7,866	7,727	1,973	38,968	75,345	253,089	340,350	129,215		
12	**Chippewa**	0	3,136	14,325	14,072	3,593	70,964	137,211	460,901	619,811	48,062		
13	**Chisago**	0	1,358	6,206	6,097	1,557	30,745	59,446	199,685	268,533	171,493		
14	**Clay**	0	4,834	22,082	21,693	5,539	109,395	211,519	710,507	955,477	138,734	56,600	

				X				X					
		26	27	28	29	30	31	32	33	34	35	36	37
Cty #		State Tax Exempt	Non-State Tax Exempt	Military On-Road	Autos	Pickups	Rec. Vehicles	Other On-Road	Farm Off-Road	Military Off-Road	Utility Generation Equip.	Gensets---Interruptible, Peaking	Gensets---Emergency
1	**Aitkin**	32,751	24,670	335	12,503	81,600	10,466		170,170		3,356	239	1,809
2	**Anoka**	24,148	200,875	6,525	241,527	812,487	101,921		307,854		0	0	24,318
3	**Becker**	22,607	70,765	657	23,299	124,968	12,293		1,339,663		3,908	278	3,397
4	**Beltrami**	31,520	61,460	868	25,155	141,765	12,902		273,595		0	0	5,198
5	**Benton**	14,035	54,163	749	25,347	118,060	14,729		1,136,083		0	0	8,437
6	**Big Stone**	13,780	21,881	127	4,312	27,023	2,550		836,760		0	0	669
7	**Blue Earth**	25,118	71,798	1,225	41,237	167,934	19,676		3,081,313		12,489	890	7,899
8	**Brown**	13,041	43,088	589	22,143	107,318	9,172		2,821,218		91,274	6,501	3,238
9	**Carlton**	22,265	48,353	693	24,629	128,028	20,780		122,984		802	57	5,448
10	**Carver**	14,060	51,392	1,537	55,622	176,051	14,957		964,465		498,078	35,475	7,865
11	**Cass**	33,571	52,515	594	19,542	120,427	15,985		267,163		0	0	4,514
12	**Chippewa**	16,789	28,781	287	10,193	54,126	3,349		1,468,504		192	14	1,457
13	**Chisago**	14,874	40,401	900	38,813	176,711	24,738		408,932		17,973	1,280	3,456
14	**Clay**	29,475	53,002	1,121	36,981	143,617	12,331		2,081,527		4,576	326	5,689

		X			X								
		38	39	40	41	42	43	44	45	46	47		
Cty #		Railroads	River Towboats	Great Lakes Vessels	Airlines	State Highway Off-Road	Local Highway Off-Road	Other Off-Road Equipment	Fuel Oil Residential	Fuel Oil Commercial	Fuel Oil Industrial	Cty #	
1	**Aitkin**					8,188	6,168	175,787	721,412	267,255	304,329	**1**	**Aitkin**
2	**Anoka**					6,037	50,219	3,424,572	1,444,401	535,094	609,324	**2**	**Anoka**
3	**Becker**					5,652	17,691	344,658	1,264,639	468,499	533,491	**3**	**Becker**
4	**Beltrami**					7,880	15,365	455,524	1,177,124	436,078	496,572	**4**	**Beltrami**
5	**Benton**					3,509	13,541	393,209	824,696	305,517	347,900	**5**	**Benton**
6	**Big Stone**					3,445	5,470	66,864	343,755	127,348	145,014	**6**	**Big Stone**
7	**Blue Earth**					6,279	17,949	642,685	689,086	255,279	290,693	**7**	**Blue Earth**
8	**Brown**					3,260	10,772	309,170	688,298	254,987	290,360	**8**	**Brown**
9	**Carlton**					5,566	12,088	363,856	2,366,074	876,537	998,133	**9**	**Carlton**
10	**Carver**					3,515	12,848	806,558	918,519	340,275	387,479	**10**	**Carver**
11	**Cass**					8,393	13,129	311,916	1,103,011	408,622	465,308	**11**	**Cass**
12	**Chippewa**					4,197	7,195	150,363	842,830	312,235	355,550	**12**	**Chippewa**
13	**Chisago**					3,719	10,100	472,194	631,531	233,957	266,413	**13**	**Chisago**
14	**Clay**					7,369	13,250	588,550	2,416,533	895,230	1,019,420	**14**	**Clay**