AUDITING KANSAS DEPARTMENT OF TRANSPORTATION VEHICLE FLEET FUEL USE AND CARBON FOOTPRINT

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ABSTRACT

Transportation agencies have placed greater importance on reducing their energy use, both for sustainability reasons and to achieve financial savings from more efficient operations. An energy and greenhouse gases audit was conducted by the University of Kansas researchers to assess the building infrastructure and vehicle fleet owned and operated by the Kansas Department of Transportation (KDOT). The vehicle fleet assessment focused on the energy expended during the operation of KDOT’s transportation vehicles and heavy and light equipment. The audit was conducted using a database constructed for this project to track the use of non-renewable and renewable fuels. The database was also used to identify areas for reducing expenditures on energy. Carbon emissions from vehicle use averaged 36,000 tons per year over the study period of 2006-2011, with the vast majority of the emissions (~ 80%) resulting from diesel fuel consumption. Analysis of vehicle use records showed a decreasing trend in total miles traveled and fuel consumed over this period. The analysis also found that replacing older vehicle models with new models did not improve the fleet efficiency of the major vehicle types used by KDOT. However, measures are available to reduce KDOT fuel use and carbon emissions, including increased emphasis on the use of lighter duty and more fuel efficient vehicles where possible and the increased use of regionally available biofuel blends. The existing database tools developed for this work could be used to track future KDOT fuel consumption patterns and exhaust emissions of greenhouse gases and air pollutants.
INTRODUCTION

In recent years, transportation agencies have expressed increased interest in the social, economic, and environmental impacts of transportation activities and infrastructure. This attention has been driven by two major factors. The first is the emergence of sustainable transportation concepts focusing on meeting the needs of individuals and society for mobility while considering the broad impacts of transportation on human health, the environment, equity, economic productivity, and resource depletion (1, 2). Much of the emphasis has been on greenhouse gas (GHG) emissions, an area where transportation activity plays a central role. U.S. EPA estimates that transportation sources accounted for approximately 30% of all U.S. CO₂ emissions in 2010 through combustion of gasoline, diesel and aviation fuels (3). In response to this focus, a number of recent studies have attempted to quantify the GHG emissions from individual parts of the transportation sector (4-6).

The second factor fueling this attention is the sustained rises in energy costs over the past decade. These costs have caused state Departments of Transportation and other agencies to place a much greater emphasis on tracking energy use, maximizing operational efficiency and achieving cost savings wherever possible. As most GHG production is directly related to energy production, these sustainability and energy saving goals increasingly overlap (7). In addition, establishing an accounting and monitoring system for GHG emissions can help prepare agencies for any changes in regulatory requirements, including CO₂ reporting or carbon trading exchanges.

A common approach to addressing both factors is to establish an estimate for the extent of all GHG emissions produced by an agency’s infrastructure and activities, also known as the agency’s ‘carbon footprint’ (4). This carbon footprint will consist both of emissions directly produced by the agency, such as fuel consumption in agency-owned vehicles, and of indirect emissions caused elsewhere by the agency’s purchase of electricity or other utilities. In some cases, the carbon footprint assessment is based primarily on inventorying and reporting measurable emissions (7), using established guidelines for emission reporting (e.g. (8, 9)). In other cases, the assessment is conducted using more sophisticated tools to determine the full life-cycle emissions of materials and infrastructure as well (2). In either case, adapting existing agency data and reporting methods to utilize these tools can be a significant challenge.

This paper describes the results of a carbon footprint calculation of the Kansas Department of Transportation (KDOT) vehicle fleet. This carbon footprint calculation is part of a broader effort to conduct an energy and CO₂ audit of KDOT’s existing infrastructure and activities in three areas: 1.) building infrastructure 2.) utilities and 3.) the vehicle fleet. The impetus for this audit was twofold. At the time of the initial project proposal, there was a significant likelihood of changes to existing federal laws that would require the state of Kansas, and specifically KDOT, to report, account for, and propose solutions to reduce carbon emissions. To prepare for this possibility, KDOT wanted to acquire the necessary data to calculate a baseline level for KDOT CO₂ emissions and develop internal capabilities for carbon accounting. This would also allow KDOT to obtain credit for any reductions in emissions that could occur due to existing operational changes. Secondly, the collection and organization of agency-wide data provided an opportunity to conduct an assessment of existing activities and recommendation actions to lower KDOT’s direct energy and fuel costs.

KDOT is a cabinet-level state agency that coordinates the planning, development, and operation of transportation within the state of Kansas. As of FY 2012, KDOT had an annual budget of $1.6 billion, of which $287 million was devoted to operating costs, $1.2 billion to
routine maintenance, $6.6 billion to the State Highway Program for construction and maintenance operations, and the remainder to local transportation programs and debt service (10). KDOT is directly responsible for operation and regular maintenance of the 10,400 miles of state highways (representing just under 24,000 lane miles), including snow/ice removal, minor roadway repair, and roadside mowing and upkeep. Most construction activities, however, are contracted to private companies. To perform its management, operational and maintenance activities, KDOT maintains a vehicle fleet consisting of on and off-road vehicles as well as portable and stationary equipment (construction tools, mowers, generators, etc.) with internal combustion engines. An inventory assessment of all KDOT direct CO2 emissions resulting from use of the vehicle fleet was conducted using existing data on fuel purchases and vehicle use and maintenance logs. This assessment was carried out through the development of a database that added electronic search and retrieval capability to KDOT’s existing vehicle records system. Following the initial assessment of the vehicle fleet’s overall carbon footprint, the database was re-analyzed to determine patterns of fuel use and identify approaches that could be implemented to provide reductions in fuel consumption and/or greenhouse gas emissions.

EXPERIMENTAL PROCEDURE

The primary source of data for the carbon footprint calculation was the KDOT vehicle use inventory. Each vehicle or stationary equipment item registered in the inventory is assigned a unique identification number upon purchase by KDOT, which it retains throughout its lifetime with the agency. The item is also assigned to an equipment classification and, in most cases, a sub-classification depending on item type and primary function. Every month an entry for each item is added detailing the item’s miles traveled and/or hours of operation and gallons of fuel added. The inventory also identifies the type of fuel used by each piece of equipment. Vehicle inventory data were obtained from KDOT for fiscal years 2006-2011. As the KDOT fiscal year runs from July to June, these data included all inventory entries from July 2006 to June 2011. Major construction activities were not included in the scope of this CO2 audit because vehicle use records were not available from the private companies contracted for those projects.

The initial data file consisted of a set of Excel spreadsheets that were imported into a Microsoft Access database developed for this project, the Fuel Use Database. Within this database, basic tables were used to organize data based on broad categories, such as entry year or fuel type. These tables were used to obtain numbers for total consumption of each fuel type on a yearly basis and to establish the overall carbon footprint, as described below. For the analysis of fuel consumption patterns, queries were then used to extract information based on specific identifiers (e.g. vehicle classification) and to perform additional analysis and calculations from the raw data, such as fuel mileage calculations. To streamline this work, vehicles whose total fuel usage over the five year period was less than 100 gallons (~ 1400 items) were removed from the fuel consumption analysis.

The queries were also used to add information on equipment fuel efficiency trends into the database. The primary equipment efficiency values calculated from the basic vehicle inventory data were miles per gallon (MPG) and gallons per hour (GPH). MPG shows how much output, in terms of vehicle miles, was obtained for a certain volume of fuel. This field was calculated for all vehicles and all three major fuel types (diesel fuels, gasoline fuels and E85) represented in the database. However, MPG has limitations as an appropriate assessment of efficiency for some items in KDOT’s inventory. Vehicles and equipment which are often stationary during operation will appear to have a much lower efficiency based on MPG than may
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The GPH measurement was therefore also used to estimate the efficiency of certain types of equipment. GPH was calculated by dividing the total monthly fuel purchased by the hours of use recorded for that piece of equipment within the same month. This approach was used both for stationary equipment items (generators, mowers, etc.) and for vehicles with significant stationary operations, such as backhoes. For both MPG and GPH calculations, we assumed that fuel purchases in a given month corresponded to the mileage traveled or hours of operation within that month. While this may not be accurate for each individual record (i.e. a vehicle filled up on the 28th of a given month will use most of that fuel in the next month), over a six year period these differences will generally even out.

The vehicle inventory records that were the foundation of the Fuel Use Database identified only total diesel and gasoline fuel use. (No distinction is made between on and off-road diesel.) Existing statutes requires KDOT to purchase 10% ethanol blends and at least 2% biodiesel blends whenever the price premium for these fuels is no more than ten cents (11). As a result, two distinct diesel fuels, #2 diesel and B5 (a 5% biodiesel blend in #2 diesel) were used throughout the KDOT system, depending on local biodiesel availability and purchase price. Similarly, both unleaded gasoline and E10 (a 10% blend of ethanol with gasoline) were available for gasoline-powered vehicles. The extent of actual biofuel blending was estimated using monthly purchase orders that provided total purchased volumes of all fuels for each fiscal year. Records from FY 2006-2010 were available for the four different types of fuel purchased by KDOT in significant quantities: unleaded gasoline, standard (#2) diesel, E10, and B5. While there may be some carryover between one fiscal year to another, as fuel purchased in May or June may not be used immediately, this will even out over longer time periods. We therefore assumed for this study that all fuel purchased in a given fiscal year was used in that same year. This assumption allowed us to estimate the amount of total fuel use that was attributable to biofuel blends, even without knowing specifically which vehicles used those fuels. For FY 2011, only the aggregated totals of all gasoline and all diesel fuels were obtained. E10 and B5 purchases for that year were assumed to be the same percentage of total unleaded and diesel purchases as in FY 2010, the most recent year for which data were available.

Direct emissions of greenhouse gases were calculated from KDOT gasoline and diesel fuel use data using emission factors based on the carbon content of the fuel on a volumetric basis. These emission factors report emissions as total mass of CO2 produced. The value of the emission factors for petroleum fuels are calculated based on standard carbon contents of 2.40 kg carbon per gallon of gasoline, and 2.77 kg carbon per gallon of diesel fuel (12). Based on fuel energy content, carbon factors for pure ethanol and biodiesel are estimated to be 1.52 kg C/gallon and 2.58 kg C/ gallon, respectively (13). Carbon factors for gasoline-ethanol and biodiesel-diesel blends are then calculated as weighted averages of their respective end members. The final CO2 emission factors are then determined by multiplying these carbon content factors by the molar weight ratio of carbon dioxide to carbon (44/12). This approach assumes that all carbon in the fuel is converted completely to CO2 (an oxidized fraction of 100%) as recommended by IPCC guidelines for mobile emissions (14). This method produced the fuel emission factors shown in Table 1, which were used in this study.
**Table 1 Direct CO₂ Emission Factors for KDOT Fuels**

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Carbon Factor (kg C/ gal)</th>
<th>CO₂ Emissions Factor (lb CO₂/gallon)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unleaded Gasoline</td>
<td>2.40</td>
<td>19.4</td>
</tr>
<tr>
<td>E10</td>
<td>2.31</td>
<td>18.7</td>
</tr>
<tr>
<td>Standard Diesel</td>
<td>2.77</td>
<td>22.4</td>
</tr>
<tr>
<td>B5</td>
<td>2.76</td>
<td>22.3</td>
</tr>
<tr>
<td>E85</td>
<td>1.65</td>
<td>13.3</td>
</tr>
</tbody>
</table>

**RESULTS AND DISCUSSION**

*Carbon Footprint Calculation*

The KDOT vehicle inventory database for FY 2006-2011 consisted of 261,212 discrete entries. 61% of the total entries were for diesel-powered vehicles or equipment, while 25% were for gasoline-powered vehicles or equipment. In terms of total fuel volume, however, these entries accounted for 99.5% of the total recorded amount of fuel used during the study period. KDOT also has a small number of flex-fueled vehicles capable of running either E85 (85% ethanol) or standard gasoline fuels. In our calculations, these entries are all assumed to be E85 fuel. The total amount of fuel used by these vehicles, about 2,200 gallons annually, is small enough that this assumption will have minimal effect on the calculated results. The remaining entries consisted of vehicles and equipment for which no fuel type was listed (12.5% of total entries, primarily shop equipment and mowers), or other specialty fuel types (0.5% of total entries). Despite their relatively large contribution to the database, the entries with no fuel type listed accounted for less than 0.5% of total fuel volume over the study period, so they were excluded from the carbon footprint calculations. This resulted in an underreporting of the vehicle emissions database of less than 1%, which was determined to be acceptable.

Figure 1 shows the total amounts of diesel and gasoline fuels used on a yearly basis by KDOT as determined by the Fuel Use Database. Average annual diesel and gasoline fuel use rates during the study period were 2,647,000 and 685,000 gallons per year, respectively. Diesel fuel consumption increased from FY 2006 through FY 2008, reaching a peak of just under 3 million gallons, and then decreased by 23% in FY 2009. While diesel fuel consumption in FY 2010 and 2011 was slightly above 2009 levels, yearly volumes remained well below FY 2006. The change from FY 2008 to FY 2009 likely represents a combination of increasing efforts to minimize costs (including fuel use) throughout the agency and a reduction in activities due to budget constraints. Total gasoline fuel use, by contrast, declined consistently throughout the study period, with an average year-to-year decrease of 5.5%. For both gasoline and diesel, total travel miles per year followed the same patterns as fuel use, indicating no significant variation in overall fleet fuel efficiency during this period.
Figure 1: Yearly diesel and gasoline fuel use (in thousands of gallons) based on KDOT vehicle inventory records.

Table 2 shows the changes in sources of gasoline and diesel fuels over the study period, as determined from KDOT purchasing records. B5 purchases declined as a percent of total diesel, particularly after 2008, most likely due to increased differences in fuel price compared to regular diesel. E10 purchases, by contrast, increased throughout the study, reaching 80% of all gasoline purchases by FY 2010. Values for yearly diesel fuel consumption from the Fuel Use Database (Figure 1) show good agreement with the aggregated total of #2 diesel and B5 purchased each fiscal year, ranging between 95% and 97% of the volume purchased. The amount of total gasoline fuel consumption, however, was only 55-70% of the volume of unleaded and E10 fuels that KDOT purchased over the same time frame. This is because fuel purchased by KDOT is also resold to other state agencies. For FY 2011, we obtained actual use records showing consumption of diesel and gasoline fuels for KDOT vs. other state agencies. For both fuels, KDOT-specific fuel consumption was within 1% of the calculated value from the Fuel Use Database. Based on these results, the vehicle inventory database is effectively recording all fuel use by KDOT vehicles and equipment.

Table 2 Sources of KDOT Diesel and Gasoline Fuels (in gallons)

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>#2 Diesel</th>
<th>B5</th>
<th>% B5</th>
<th>Unleaded</th>
<th>E10</th>
<th>E10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>964,297</td>
<td>1,802,344</td>
<td>65%</td>
<td>455,532</td>
<td>710,601</td>
<td>61%</td>
</tr>
<tr>
<td>2007</td>
<td>1,045,357</td>
<td>1,944,916</td>
<td>65%</td>
<td>363,365</td>
<td>759,659</td>
<td>68%</td>
</tr>
<tr>
<td>2008</td>
<td>1,641,915</td>
<td>1,455,029</td>
<td>47%</td>
<td>287,001</td>
<td>764,716</td>
<td>73%</td>
</tr>
<tr>
<td>2009</td>
<td>1,432,265</td>
<td>979,646</td>
<td>41%</td>
<td>289,107</td>
<td>875,970</td>
<td>75%</td>
</tr>
<tr>
<td>2010</td>
<td>1,817,772</td>
<td>809,867</td>
<td>31%</td>
<td>191,427</td>
<td>818,767</td>
<td>81%</td>
</tr>
<tr>
<td>2011</td>
<td>2,561,918a</td>
<td>1,109,054a</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. Only aggregated data for total diesel and total gasoline purchases are available for FY 2011
Figure 2: Direct and Adjusted Carbon Emissions from Fuel Combustion by Year

Figure 2 shows calculated values for direct CO₂ emissions from the vehicle fleet over the study period, based on the emission factors from Table 1. Since the vehicle inventory does not distinguish between unleaded and E10, or between #2 diesel and B5, we assumed that E10 and B5 fuels were used by KDOT in proportion to the amounts of each fuel purchased that year. (That is, if E10 made up 61% of KDOT purchases, it also made up 61% of the fuel used specifically by KDOT.) For diesel fuels, this assumption has little impact, since interagency sales are less than 5% of purchased fuel volumes, so the vast majority of fuel purchased by KDOT is also used by their vehicle fleet. For gasoline fuels, simulations showed that actual carbon emissions could be up to 1% higher or lower than the calculated value, depending on the relative proportion of unleaded and E10 fuels actually used by KDOT vehicles. Since gasoline fuels are a minor contribution to total carbon emissions, the effect on the final emissions level would be even lower, around 0.2-0.3%.

The overall trend in emissions strongly follows the trend of diesel fuel use from Figure 1, with peak carbon emissions of 39,200 tons of CO₂ in 2008 and a significant drop in emissions in FY 2009. Due to the higher carbon content of diesel fuels, the percent of total emissions resulting from diesel combustion is around 2% higher than the diesel share of the total fuel volume. Total carbon emissions were 9% lower in FY 2011 than in FY 2006. The major source of this drop was the reduced diesel fuel consumption beginning in FY 2009. Carbon emissions from gasoline-powered vehicles and equipment decreased slightly more than total gasoline fuel volume over the study period (25.4% decline for gasoline emissions vs. a 24.8% drop in fuel volume) due to the increased use of E10 fuels, which have a lower CO₂ emission factor. Since the emission factors for B5 and #2 diesel are very similar, the relative proportion of B5 in the diesel volume had no significant effect on diesel carbon emissions.

From a greenhouse gas perspective, total carbon emissions only describe a portion of the story. Both ethanol and biodiesel are produced from biomass, a renewable source of carbon. From a greenhouse gas emission standpoint, therefore, CO₂ released from biomass fuels has little
net impact on atmospheric CO₂ levels. This distinction in biomass vs. anthropogenic carbon is often reflected in emission factor calculations. In the Energy Information Administration’s formula for voluntary reporting of greenhouse gases, for example, 100% ethanol and biodiesel fuels are assigned emission factors of 0 g carbon/gallon, reflecting their net rather than direct contribution to atmospheric GHG (9). Using this approach, the biofuel adjusted KDOT vehicle carbon emissions would be approximately 2-3% lower than the total emission level, varying with the extent of E10 and B5 use in a given year. This is represented as the adjusted CO₂ emissions in Figure 2. While the adjusted value complies with the voluntary reporting formula, it represents a best-case estimate for the impact of biofuel use on CO₂ emissions. Biofuels are not truly carbon neutral fuels, because the refining and combustion processes are not 100% efficient, and therefore waste some of the energy stored in the biomass. Determining the actual reduction in CO₂ emissions for a given biofuel requires a full life cycle analysis (LCA) for the fuel, and ongoing debates about the proper inputs and calculations required for this LCA make reported values highly variable (15). The EPA currently requires that a renewable fuel must reduce net CO₂ emissions by 50% compared to a baseline 2005 petroleum diesel using a specified LCA methodology. Using this criteria, some biodiesel fuels, including soy-based biodiesels, are currently classified as renewable fuels (16).

While the specific value may be debatable, the use of biofuels will result in some level of reduction in the net CO₂ released from fuel combustion by the KDOT vehicle fleet. The values listed in Figure 2 for total and adjusted CO₂ emissions can therefore be seen as an upper and lower limit on the reportable carbon footprint from KDOT’s fuel consumption. Over the six year study period, the average annual carbon footprint was 36,000 (total) or 35,000 (biofuel adjusted) tons of CO₂ per year. If future regulations were to use higher emission factors for CO₂ from biofuel combustion to reflect actual net CO₂ reductions, the adjustment seen here of ~1,000 tons per year could decrease substantially. Based on data collected from utility providers in another facet of this project, total KDOT utility carbon production in 2009 are in the range of 15,000-20,000 tons of CO₂ (17), compared to 32,00 total tons CO₂ from the vehicle fleet in the same year. Vehicle fleet emissions thus likely represent the single greatest source of operational CO₂ emissions for KDOT.

Table 3 Top Five Equipment Classes for Fuel Use from Database Records

<table>
<thead>
<tr>
<th></th>
<th>Diesel</th>
<th></th>
<th>Gasoline</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>Fuel (gallons)</td>
<td>% of Total</td>
<td>Class</td>
<td>Fuel (gallons)</td>
</tr>
<tr>
<td>Trucks</td>
<td>10188628</td>
<td>73.8%</td>
<td>Trucks</td>
<td>2700659</td>
</tr>
<tr>
<td>Tractors</td>
<td>1203558</td>
<td>8.7%</td>
<td>Autos</td>
<td>494155</td>
</tr>
<tr>
<td>Loaders</td>
<td>875530</td>
<td>6.3%</td>
<td>Van</td>
<td>324311</td>
</tr>
<tr>
<td>Motor graders</td>
<td>596635</td>
<td>4.3%</td>
<td>Sweeper</td>
<td>22072</td>
</tr>
<tr>
<td>Asphalt</td>
<td>244513</td>
<td>1.8%</td>
<td>General</td>
<td>20506</td>
</tr>
<tr>
<td>Distributor</td>
<td></td>
<td></td>
<td>Equipment</td>
<td></td>
</tr>
</tbody>
</table>

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Analyzing KDOT Fuel Consumption

An analysis of KDOT fuel consumption patterns was conducted to investigate strategies for reducing overall KDOT fuel requirements and carbon emissions. For both diesel and gasoline fuels, overall fuel use was dominated by a relatively small number of vehicle classes. Table 3 shows the top three equipment classes with the largest shares of total diesel and gasoline fuel use based on records in the Fuel Use Database. These top five categories account for 95% and 97% of total diesel and gasoline use, respectively. For both fuels, trucks are responsible for approximately three-quarters of all consumption. The dominant role played by trucks in both diesel and gasoline consumption makes them the best subjects for further study of ways to minimize fuel use and carbon emissions. There are, however, differences in the nature of truck use patterns between gasoline and diesel vehicles in KDOT fleet.

The diesel truck category was composed of light trucks used primarily for transportation (pickups and SUVs), utility and maintenance vehicles, and heavy construction/repair vehicles. Fuel use in this category, however, was dominated by dump trucks, which by themselves accounted for a majority (55%) of total diesel fuel use. A total of 805 distinct dump trucks, ranging in model year from 1984 to 2009, were present in the database. Vehicles in this sub-class cover a range of heavy-duty truck roles in road repair and maintenance operations. The average fuel economy of these trucks is 5.6 MPG, within the typical range of larger heavy-duty trucks (18). Given the age of the vehicle inventory, we examined fuel economy as a function of model year to determine whether accelerated replacement of older vehicles might help to improve overall fuel economy. As shown in Figure 3, however, average fuel economy actually showed a significant decrease in newer vehicles. There are several possible explanations for this trend. One is that the same model of truck may have undergone an increase in engine size and power (at the expense of fuel economy) in recent years. Another possibility is that the newer vehicles are being disproportionately used for stationary (or non-driving) operations. This should be addressed by the gallons per hour of work metric described above, which was a useful parameter for stationary equipment in the vehicle inventory. However, the hours of work reported for dump trucks appear inconsistent and bear little relationship to recorded fuel use, and contain a large number of records with very low reported hours. (Unlike mileage, which can be recorded by odometer settings after the fact, hours worked must be recorded independently and are therefore harder to track.) The resulting GPH values for this vehicle category did not allow for identification of any patterns in stationary operations for dump trucks by model year.

Given their large impact on overall fuel consumption levels, any substantial decrease in the amount of fuel used by dump trucks would have a significant impact on overall KDOT fuel use and carbon emissions. The analysis above indicates that accelerated replacement will not provide an improvement in dump truck fuel economy, and may in fact increase fuel consumption rates. Some reduction could probably be achieved by changes in operator behavior, such as reducing vehicle idling time and warm-up. This is complicated, however, by the wide range of vehicle types even within this category and the variations in environmental conditions under which work must be performed. These variations make global guidelines for fuel reduction difficult to write or implement. Making operators aware of fuel efficiency issues and the potential for increased cost savings may be a more reasonable goal. A more systematic and reliable measure that could be implemented would be attempting to match work activities to the most fuel efficient vehicle capable of performing the specified job. As similar model vehicles become larger and more powerful, it may be possible to substitute some of the work typically done by these units with smaller, more fuel-efficient vehicles. One particular areas of focus could
be to limit the use of dump trucks where possible, or explore purchasing lighter, more fuel-efficient vehicles to replace some of the current work load.

For gasoline vehicles, the truck category consists primarily of light-duty pickups, which can be used both for transporting light equipment loads and for general travel. In fact, the top three equipment classes for gasoline use (trucks, autos and vans) are all personal transportation vehicles. There are, however substantial differences in fuel economy (mpg) between these different classes. The average fuel economy for a gasoline-powered truck during the study period was 14.4 MPG, compared with 25.3 MPG for an automobile. These values remain relatively consistent across all model years from 1992-2009 for trucks and 1997-2009 for autos. Diesel pickups have a similar average fuel economy to unleaded pickups (14.5 MPG), although the average does decrease slightly (to 12.8 MPG) for vehicles purchased since 2007.

The difference in fuel economy between trucks and autos suggest that some savings in fuel use and CO\textsubscript{2} emissions could be achieved if a greater portion of KDOT travel was carried out using automobiles. For both work-related and logistical reasons, it is neither possible nor desirable to replace all pickup truck travel with automobile travel. A partial shift in vehicle miles traveled from unleaded pickups to autos, however, could result in noticeable reductions. Total unleaded pickup travel during the study period was 39 million miles. If 10\% of these miles (3.9 million) were transferred from an average pickup to an average automobile, the fuel savings would be 116,000 gallons, corresponding to a CO\textsubscript{2} emissions reduction of 1,100 tons. At a price of $3.35 per gallon for unleaded gasoline (the cost in Lawrence KS at the time of this calculation), this works out to a savings of $398,000. Figure 4, below, shows the effects of substituting 5-30\% of the total unleaded pickup miles during the six-year study period with

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**Figure 3:** Fuel efficiency (in mpg) for dump trucks by vehicle model year. Error bars represent 95\% confidence intervals.
automobile travel. A similar analysis was performed to examine the effect of substituting diesel pickup miles with automobile travel. Factoring in the difference in energy content and carbon emission, as well as the typically higher cost of diesel fuel (in our calculation, a value of $3.60 per gallon was used), this substitution produced around 15% greater cost savings and reductions in carbon emissions compared to the analysis shown above. In either case, while the cost savings here would provide some beneficial results from the switch, the total CO2 reductions represent only 1.6% of the total CO2 emissions over that time period (182,000 tons).

![Figure 4: Impact of Transferring Miles from Unleaded Trucks to Automobiles on Cost Savings and Carbon Emissions.](image)

**CONCLUSIONS**

During the six year study period (July 2005 to June 2011) the operation of KDOT vehicles and equipment consumed an average of 2,647,000 gallons of diesel fuels (#2 diesel and B5 blends) and 685,000 gallons, of gasoline fuels (unleaded and E10 blends) per year, resulting in the release of 36,000 tons of CO2 per year. Carbon emissions in the last year of the study period were 10% lower than those at the beginning, due primarily to a reduction in vehicle miles traveled. The Fuel Use Database constructed for this project provides an effective means of assessing KDOT fuel consumption and vehicle fleet carbon footprint. In addition the database allowed for better organization of existing fuel use information and assessment of patterns of fuel consumption across different vehicle classes. Continued use and updating of this Fuel Use Database after the end of the current study provides an opportunity for KDOT to stay current with changing fuel use and carbon emissions levels. The tools in the database will allow them to follow trends and make educated decisions about the most optimal paths to minimize fuel costs.

One additional area of analysis made possible by this database would be the impacts of reduced KDOT fuel use (or increased biofuel substitution) on other vehicle exhaust pollutants, such as NOx, total hydrocarbons, and particulate matter. EPA publishes emission factors for most
other regulated pollutants similar to the ones used for CO\textsubscript{2} in this study. Simple calculations from total fuel use numbers generated by the database could produce estimates for reduction in total emissions of these pollutants due to changes in fuel consumption patterns. Since these pollutants can produce adverse health effects, reducing fuel consumption can improve ambient air quality and promote respiratory health, particularly in urban environments or where KDOT activities are prevalent.

Reducing KDOT fuel use and CO\textsubscript{2} emissions is a complex task. Given the many requirements on KDOT and the size of the state of Kansas, future operations will require extensive use of gasoline and diesel fuels. To minimize the use of excess fuel, continued focus should be placed on the equipment types that contribute most to fuel consumption, particularly heavy duty trucks and transportation vehicles. Efforts to use the most fuel efficient equipment capable of completing the specific task could result in increased overall vehicle fleet fuel economy. KDOT should also keep aware of advances in technology that have the potential to improve vehicle fuel efficiency or GHG emissions. For example, KDOT currently utilizes a small number of flex-fuel vehicles that can run on E85 as well as standard gasoline fuels to provide flexibility with respect to fuel costs. These vehicles should be studied on a pilot basis to assess their potential impact on fuel efficiency, carbon footprint, and air quality. Another potential avenue for reducing the net carbon footprint of the KDOT vehicle fleet would be to increase the use of biodiesel blends beyond the current 5% level. While there can be concerns related to cold weather handling and storage of higher biodiesel blends, a number of state DOTs, including New York, Missouri and Kentuck, already have mandates for B10 or B20 blends (19), and procedures should be available for dealing with these issues.

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REFERENCES


