CFIRE

Evaluation of Green House Gas Emissions Models

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16. Abstract The objective of the project is to evaluate the GHG emissions models used by transportation agencies and industry leaders. Factors in the vehicle operating environment that may affect modal emissions, such as, external conditions, vehicle fleet characteristics, vehicle activities, vehicle gasoline specifications, inspection and maintenance programs and anti-tampering programs, etc. are considered. EPA's newly released MOVES2010 is recommended.			
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Evaluation of Green House Gas Emissions Models

Abstract

The objective of the project is to evaluate the GHG emissions models used by transportation agencies and industry leaders. Factors in the vehicle operating environment that may affect modal emissions, such as, external conditions, vehicle fleet characteristics, vehicle activities, vehicle gasoline specifications, inspection and maintenance programs and anti-tampering programs, etc. are considered. EPA's newly released MOVES2010 is recommended.

1. Review of GHG Emissions Models

The most significant GHG emitted by vehicle is Carbon dioxide (CO_2), which is emitted in direct proportion to fuel consumption. As a result, estimating the GHG implications of vehicle involves estimating the amount of fuel used by the vehicle. Vehicle fuel consumption depends on a variety of factors, including vehicle type, model year, fuel type, vehicle operating characteristics, such as speeds, and other factors such as vehicle maintenance and tire wear. To examine the impacts of routing optimization on GHG emissions, two basic steps are involved: 1) determining the impacts on vehicle travel, fuel economy, or fuel type used; 2) calculating the GHG impacts based on the change in these factors (ICF Consulting, 2006).

A range of models are available that can be used to calculate GHG emissions from the log trucks. These models require the user to provide transportation activity levels (e.g., VMT or fuel consumption) and vehicle fleet inputs (e.g., vehicle fleet mix, age) in order to calculate GHG emissions. One category of GHG calculation models are called Direct GHG Emission Calculation models, which focus solely on transportation sources, and are designed to develop emission factors or emission estimates for gases emitted during vehicle use. The most commonly used of these models include EPA's MOBILE6, NONROAD, National Mobile Inventory Model (NMIM), Climate Leadership in Parks (CLIP), the California Air Resources Board's (CARB) EMFAC, and Draft New York State DOT Guidance on Transportation GHG Analysis. Another category of models are called Life-Cycle GHG Emission Calculation models, including Argonne National Laboratory's Greenhouse Gases, Regulated Emissions, and Energy use in Transportation (GREET) Model, University of California, Davis' Lifecycle Emissions Model (LEM), EPA's Motor Vehicle Emissions Simulator (MOVES). Table 1 summarizes eight models that can be used to calculate the GHG implications from the transportation sector.

2. Selection of GHG Emissions Models

To select a well-suited model for our study, we considered the following issues: 1) What level of detail is needed? 2) What type of vehicles will be addressed? 3) What data are available? Data availability will influence what types of assumptions must be developed. For instance, if limited data are available on vehicle characteristics, assumptions will need to be made about the types of vehicles or the types of vehicle trips that are reduced as a result of optimization.

The current study requires a model which is able to calculate GHG emissions from heavy-duty trucks operating on routes at the county/regional level before and after routing optimization. These nine models summarized in Table 1 have different capabilities and reflect

different levels of data input. Many of the models, however, have significant limitations for conducting the types of analyses that are needed by our study. For example, CLIP and LEM are not appropriate for regional transportation analysis or local level analysis. GREET cannot be applied on Heavy-Duty vehicle which are predominantly used in log industries. EMFAC is the approved emissions model used in the State of California only. As a result of these eliminating processes, EPA's MOBILE6 and MOVES are the finalists for our study.

*Table 1: Applicability of Models for Calculating GHG Emissions

	Geographic Level of Analysis				Vehicle Types	
Model	**State**	**Region**	**Local**	**Project**	**Light-duty Vehicles**	**Heavy-duty Trucks**
MOBILE6	■	■	■	■	■	■
NONROAD	■	■	■	-	■ off-road only	-
NMIM	■	■	■	-	■	■
CLIP	-	-	■	-	■	■
MOVES	■	■	■	■	■	■
GREET	■	■	■	■	-	-
LEM	□	-	-	-	■	■
EMFAC	■	■	■	■	■	■

Key: ■ Designed for this type of analysis; □ Not designed for this type of analysis but could potentially be applied; - Not applicable; *Adapted from ICF Consulting, 2006

MOBILE was initially developed in the late 1970s and has gone a number of significant updates over time. MOBILE6.0 was released in draft form in 2002 and finalized as MOBILE6.2 in 2004. MOBILE6 Model is the EPA-approved model that generates on-road motor vehicle emission factors for use in transportation analysis at the state, region, or project level.

MOBILE6 is based on emissions testing data and accounts for the impacts of factors such as vehicle emission standards, vehicle type, vehicle operating characteristics, and local conditions such as temperature, humidity and fuel quality on criteria pollutant emission factors. The model's output is in grams of pollutant per vehicle mile, which when combined with vehicle miles traveled (VMT) data produces emissions estimates. In addition to criteria pollutants, the model generates CO_2 emission factors, which can be combined with VMT data to estimate CO_2 emissions.

However, the CO_2 emission factors only account for vehicle type and model year; the emission factors do not account for impacts of vehicle operating conditions (e.g., travel speeds) on CO_2, thus, not able to adequately address the impacts of routing optimization. Another limitation of MOBILE6 is the model uses average fuel economy for the entire national fleet for each vehicle category and model year, and assumes future fuel economy stays constant as model years progress for heavy-duty trucks. Consequently, projections of CO_2 in future years do not account for future changes in fuel economy.

The strengths of MOBILE6 are its inputs and assumptions are generally available to transportation agencies. It is a standard emissions model used by transportation agencies for

criteria pollutant analysis; as a result, GHG analysis assumptions would be consistent with criteria pollutant analysis assumptions.

Motor Vehicle Emissions Simulator (MOVES), released in draft in January 2005 and developed in stages by the EPA, is eventually ready to replace MOBILE6, NONROAD, and NMIM. EPA launched MOVES 2010 in January 2010 and requires it to be used in official SIP submissions and in new regional emissions analyses for transportation conformity determinations after a two-year grace period. MOVES can estimate emissions on a range of scales from national emissions impacts down to the impacts of individual transportation projects.

The MOVES model estimates energy consumption (for use in calculating CO_2), N_2O, and CH_4 from on-road vehicles from 1999 to 2050 and accounts for the impacts of vehicle speeds, age, and stock on emissions. The strengths of MOVES are that it uses a physical emissions rate estimator (PERE) model to calculate energy consumption for all travel modes, accounting for the effects of vehicle speed, operating mode, and vehicle type. It also combines GREET well-to-pump estimates for numerous fuel production and distribution pathways with capability to estimate energy consumption and emission totals over multiple calendar years and multiple advanced vehicle market penetration scenarios.

The limitation of MOVES is that the vast amount of data contained in the model make it complex to use for certain types of simple project analyses and if the user wants to replace default values. Moreover, there is currently limited documentation on how to use the tool to generate emission factors for project-level analyses.

We further evaluated MOBILE6 and MOVES across four attributes: data input availability, ease of application, technical robustness, and policy sensitivity using a rating system of low, medium, and high. Table 2 summarizes the strengths and limitations, and ratings of MOBILE6 and MOVES.

Table 2 shows the MOVES wins over MOBILE6 in the categories of ease of application, technical robustness, and policy sensitivity: 1) The MOVES model provides a new user-friendly graphical user interface (GUI) and a great deal of default values that simplifies analysis at different levels of geography (e.g., nation, state, county) and time spans. It has a database-centered design that allows users much greater flexibility in organizing input and output data; 2) As a result of using data collected from millions of vehicle since MOBILE6.2 was released in 2004, MOVES2010 provides increased accuracy in emissions inventory results; 3) MOVES also relies on inputs from the transportation planning process, such as VMT and speeds, rather than inputs of fuel consumption. These inputs are generally available to transportation practitioners; 4) MOVES contains much more complex relationships between travel activity and GHG emissions than MOBILE6, and can be used to analyze the implications of changes in vehicle operating characteristics on GHG emissions. MOBILE6 is not sensitive to important factors like vehicle speeds in calculating carbon dioxide (CO_2) emissions; 5) Another improvement is the ability to express output as either total mass (in tons, pounds, kilograms, or grams) or as emissions factors (grams-per-mile, and in some cases, grams-per-vehicle); 6) MOVES is designed to be used in coordination with other models (e.g., travel models, dispersion models).

Furthermore, MOVES2010 estimates $PM_{2.5}$ and PM_{10} to account for speed and

temperature variations, and models emissions at high resolution, which allows users to incorporate a much wider array of activity data and to model emissions at the link and project level. MOVES2010 includes the capability to estimate vehicle exhaust and evaporative emissions as well as brake wear and tire wear emissions for criteria pollutants and precursors (EPA, 2010, MOVES2010 Policy Guidance).

*Table 2: Evaluation of Models for Transportation GHG Analysis

Model	Data Input Availability	Ease of Application	Technical Robustness	Policy Sensitivity
MOBILE6	★★★ • Inputs (VMT, VMT mix) are generally available to transportation agencies • However, requires some data processing (e.g., converting HPMS VMT estimates into EPA vehicle categories)	★ Relatively complex to run	★★ • Can account for impacts of local vehicle mix and age, but not speeds; • Does not take into account future changes in fuel economy	★★ • Does not take into account impacts of vehicle speed and operating conditions on CO_2. • Does not account for feedback effects (prices, distances, operating costs) impacting fuel economy.
MOVES	★★★ • Default data tables can be used or adjusted to reflect local conditions • To take advantage of full capabilities requires substantial local data	★★★ • Relatively easy to run using the provided GUI and reporting functions • Includes the GREET model pathways analysis	★★★ • Uses second-by-second CO_2 emissions data for all source types • Uncertainty analysis by EPA show relatively close results to fuel-based calculation methods	★★★ Sensitive to VMT, vehicle operating characteristics, and vehicle characteristics

Key: ★ Low ★★ Medium ★★★ High *Adapted from ICF Consulting, 2006

MOVES2010 is a significant improvement over MOBILE6.2 and previous versions of MOVES for GHG estimation. It is currently the best tool for estimating GHG emissions from the transportation sector. Consequently, MOVES2010 was recommended as a preferred modeling approach for our study.

Bibliography

1. U.S. EPA, 2009. SmartWay Transport Web Resources
2. U.S. EPA, 2003. MOBILE6 User Guide, EPA420-R-03-010
3. U.S. EPA, 2005. National Mobile Inventory Model, A Consolidated Emissions Modeling System for MOBILE6 and NONROAD, EPA420-R-05-024
4. ICF Consulting, 2006. Greenhouse Gas Analysis Techniques, NCHRP 25-25(17)

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