IMPLICATIONS OF THE MOVES2010 MODEL ON MOBILE SOURCE EMISSION ESTIMATES

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EXTENDED ABSTRACT

Introduction

This article provides a variety of results obtained with the U.S. Environmental Protection Agency's (EPA) MOVES2010 model[1], employing the database originally released with the model (version 20091221). For several cases, comparisons are made with the U.S. EPA MOBILE6.2 model[2] (version 24-Sep-2003). Since the release of MOVES, a new default database (version 20100515) has been distributed along with an updated errata sheet providing solutions to known errors[3]. Earlier this month, MOVES2010a[4] was released as a minor update. The updates to the original release of MOVES2010 are not reflected in this article. The documented problems are expected to have a negligible effect on emission estimates for criteria pollutants and otherwise small effects for most additional pollutants and calendar years with some exceptions as noted by the U.S. EPA[3,4].

The analysis herein focuses on carbon monoxide (CO), nitrogen oxides (NOx), volatile organic compounds (VOC), particulate matter (PM) of size $\leq$ 2.5 micrometers (PM2.5), benzene, diesel PM (DPM), and carbon dioxide equivalent (CO2e) greenhouse gases. A nation-wide inventory of emissions by calendar year is presented, highlighting some differences between MOVES2010 and MOBILE6.2 forecasts. Since cleaner fuels and technology have become more effective in reducing overall emissions from vehicles, for some pollutants the significance of tailpipe emissions while vehicles are operating on highways has diminished relative to the proportion while vehicles are parked, when vehicles start, during extended idling, and from brake wear and tire wear. The contributions of the different emission processes are shown.

Also shown is the variability of emission factors as a function vehicle speed – arguably the most important traffic activity parameter. An alternative perspective is given for changes in emission factors versus the demand-to-capacity ratio, a measure of traffic congestion. A new function introduced in the MOVES2010 model is the ability to compute emissions for the project-scale. An example of how emissions differ while vehicles are cruising, decelerating, idling, and accelerating on different highway grades (a range of uphill and downhill plus level) is represented.

Methodologies and Data

The MOVES2010 and MOBILE6.2 models were run using a consistent set of meteorology and fuel specification parameters representing the national scale. As part of a model run, aggregated, activity-weighted temperature and humidity values are calculated and saved in an execution database. Similarly, aggregated, activity-weighted fuel supply tables reflecting market share fractions are calculated and saved.

There are, however, some differences in the models. The MOVES2010 and MOBILE6.2 models share the same basic concept – that is, emission factors are based on empirical measurements conducted for vehicles operated during prescribed drive cycles to simulate typical trips. MOBILE6.2 is based on numerous fixed driving cycles[5] to simulate vehicle travel on freeway and arterial roadway types for different levels of service (i.e., congestion categories), plus local streets and freeway ramps at fixed speeds. An advantage offered by MOVES2010 is its ability to compute emission factors for any locally-derived drive cycle; although the drive cycles used for this analysis are model defaults (i.e., rural and urban restricted and unrestricted access road types).

Since the measurements that form the basis of MOBILE6.2 are conducted primarily under laboratory conditions using established protocols, adjustment factors are employed to reflect in-use and local-specific conditions such as vehicle tampering, aggressive driving, air conditioning, temperature, speed, fuel, etc. MOVES2010, on the other hand, is largely based on actual second-by-second on-road emissions data, eliminating the need for speed adjustments. Other correction factors are still applied to the underlying data to facilitate consistent emissions measurements among diverse testing locales.

In addition, there are inevitable differences in the emission factor results produced by MOVES2010 and MOBILE6.2 solely because of the contrast in the default information inherent in the models. These include differences in vehicle classifications, population among the vehicle types, distributions of vehicle activity, and fuel and vehicle emission standards.

Emission reductions realized from inspection/maintenance programs are considered in the MOVES2010 model using built-in parameters. Because of the difficulty in defining a national-average inspection/maintenance program for input into MOBILE6.2, such emission reductions were not taken into account in the analysis and are assumed not have a significant effect on nation-scale emission factors.

Mode Results

National inventories of on-road mobile source emissions produced by the MOVES2010 and MOBILE6.2 models are presented in Figure 1. The hourly distributions of vehicle emissions for the different emission processes considered by the MOVES2010 model are shown in Figure 2 for selected pollutants. Resulting emission factors generated by the MOVES2010 and MOBILE6.2 models are provided in a series of charts for morning peak-hour CO, daily average VOC and NOx, plus annual average PM2.5, DPM, and CO2e (see to Figure 3).

Another series of charts were prepared (see Figure 4) to reveal the changes in NOx, PM2.5, DPM, and CO2e emission factors produced by MOVES2010 for different levels of traffic congestion as represented by the demand volume divided by roadway capacity. Figure 4 is based on a procedure recommended by the Texas Transportation Institute[6] for area-wide planning applications to forecast vehicle speeds considering demand and capacity. Figure 5 displays modal emission factors of NOx, PM2.5, benzene, and CO2e computed with the MOVES2010 model for a range of positive (uphill), negative (downhill), plus zero (level) highway grades. The modes of vehicle operation depicted include steady-state cruise at 35 mph, decelerate from 35 mph at a typical rate of 7.6 mph/s, idle, and accelerate to 35 mph at a typical rate of 4 mph/s.

Similar, but Different, Results

MOVES2010 and MOBILE6.2 provide obviously different results in many respects. The models generate comparable national-scale emission inventories (Figure 1). In contrast to MOBILE6.2, MOVES2010 provides lower estimates of CO; higher estimates of NOx, PM2.5, and DPM; but remarkably similar estimates of CO2e. National-scale VOC inventories created with MOVES2010 are equivalent to MOBILE6.2 for near-term years, but generally lower for future years.

There are many emission components associated with motor vehicles (Figure 2). These include engine starts of largely uncontrolled emissions before pollution controls attain optimum efficiency; evaporative emissions from vehicles while parked and on highways; emissions due to brake and tire wear; and emissions during extended periods of engine idling for delivery and freight trucks. Start emissions are a predominant component of wintertime CO, summertime VOC (and by inference, benzene), and wintertime benzene (and by inference, VOC). NOx, PM2.5, and DPM emissions consists largely of running exhaust and running crankcase emissions. Evaporative emissions are an important component of VOC/benzene emissions during the summertime. Cooler temperatures during the wintertime help minimize evaporative VOC/benzene emissions. Brake and tire wear are consequential components of PM2.5 emissions. The practice of extended idling contributes to NOx emissions.

MOVES2010 estimates of CO2e emissions are sensitive to changes in vehicle speeds – higher rates associated with lower speeds and lower rates associated with higher speeds (Figure 3). Similar outcomes are observed for PM2.5 and DPM emissions. In addition to variations with speed, PM emission rates in MOVES2010 are sensitive to changes in ambient temperature and vehicle deterioration in contrast to MOBILE6.2. For the cases studied, MOVES2010 produces lower emissions for CO and VOC and generally higher emissions for NOx compared with MOBILE6.2. The distinctions in pollutant emissions among the roadway types in MOVES2010 are largely due to variations in the default vehicle fleet mixes for restricted (i.e., freeways, expressways) and unrestricted (arterials, collectors, locals) highways in urban and rural areas. Emission factors for freeways and arterials in MOBILE6.2 are generally indistinguishable.

Since MOVES2010 predicts much higher emissions of CO2e, CO, NOx, VOC, PM2.5, and DPM for very slow traffic speeds, mitigating congestion can lower emissions (Figure 4). But the gains can be offset by attracting higher traffic volumes on the less congested highway. A classic measure of traffic congestion is the demand volume weigh against the highway capacity. Intuitively, as conditions become more congested (demand approaches capacity), traffic slows down.

The MOVES2010 model offers the capability of predicting emissions at the project scale (Figure 5). With this new tool, emissions may be differentiated accounting for the modal operation of vehicles. Emissions tend to be higher for idling vehicles and vehicles accelerating on uphill (positive) highway grades.

Conclusions

Inferences into how emission estimates may differ when transitioning to the new MOVES2010 model from MOBILE6.2 are provided based on national default data. The association of high emission levels with slow traffic speeds is more pronounced in MOVES2010 than MOBILE6.2 for some pollutants. Applying MOVES2010 to a highly congested highway network is likely to produce higher emission estimates, but indicate higher benefits by mitigating traffic congestion. Estimates of CO2e, NOx, PM2.5, and DPM emissions are generally higher with MOVES2010 versus MOBILE6.2, while estimates of CO and VOC are generally lower. When formulating mobile source control strategies, emission components other than engine exhaust may be more important to consider.

DISCLAIMER

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KEY WORDS

MOVES2010 model
MOBILE6.2 model
Mobile source emission modeling

Figure 1. National trends in mobile source emissions and vehicle-miles traveled.

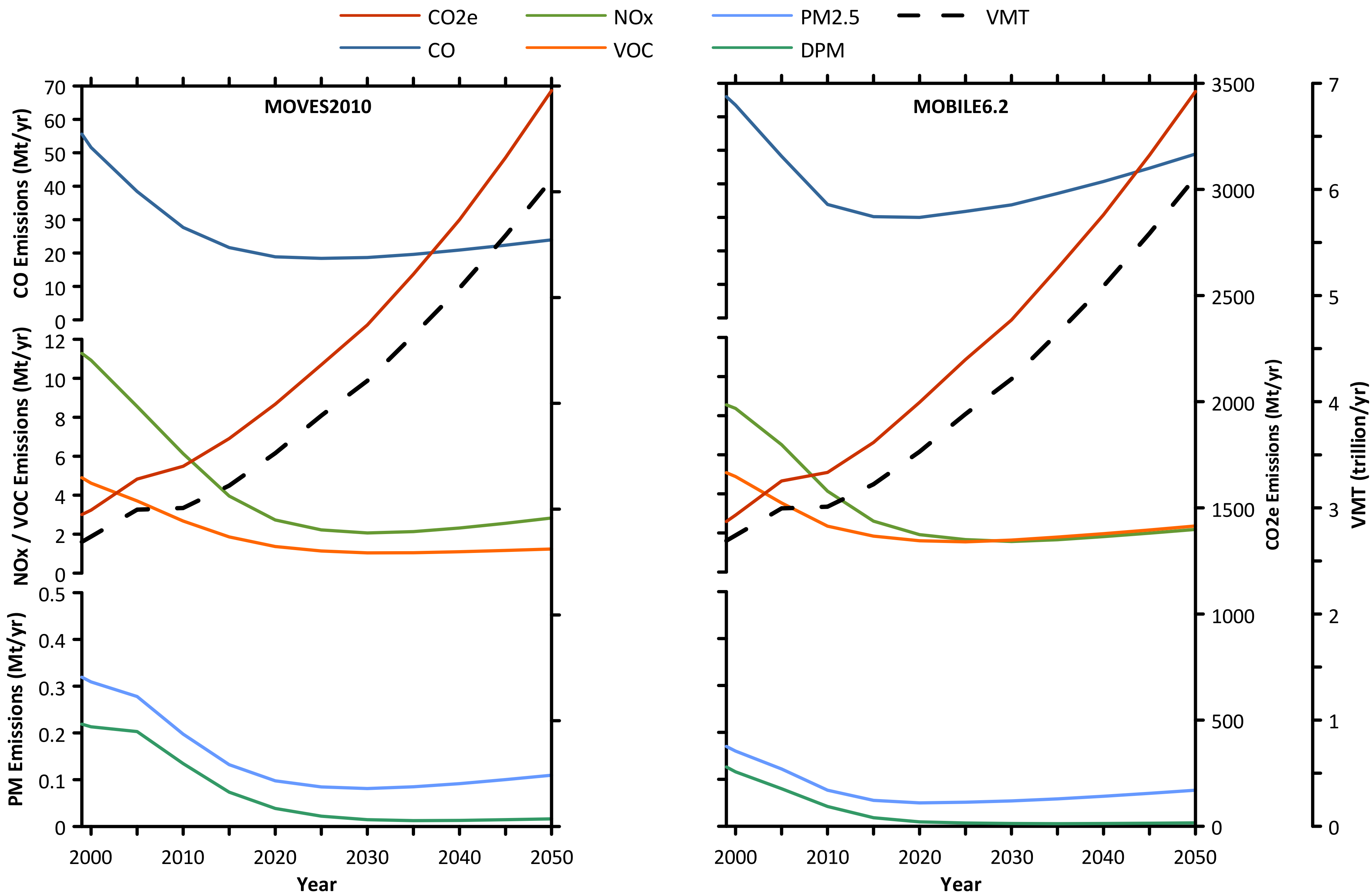

Figure 2. Amounts attributable to individual emission processes.

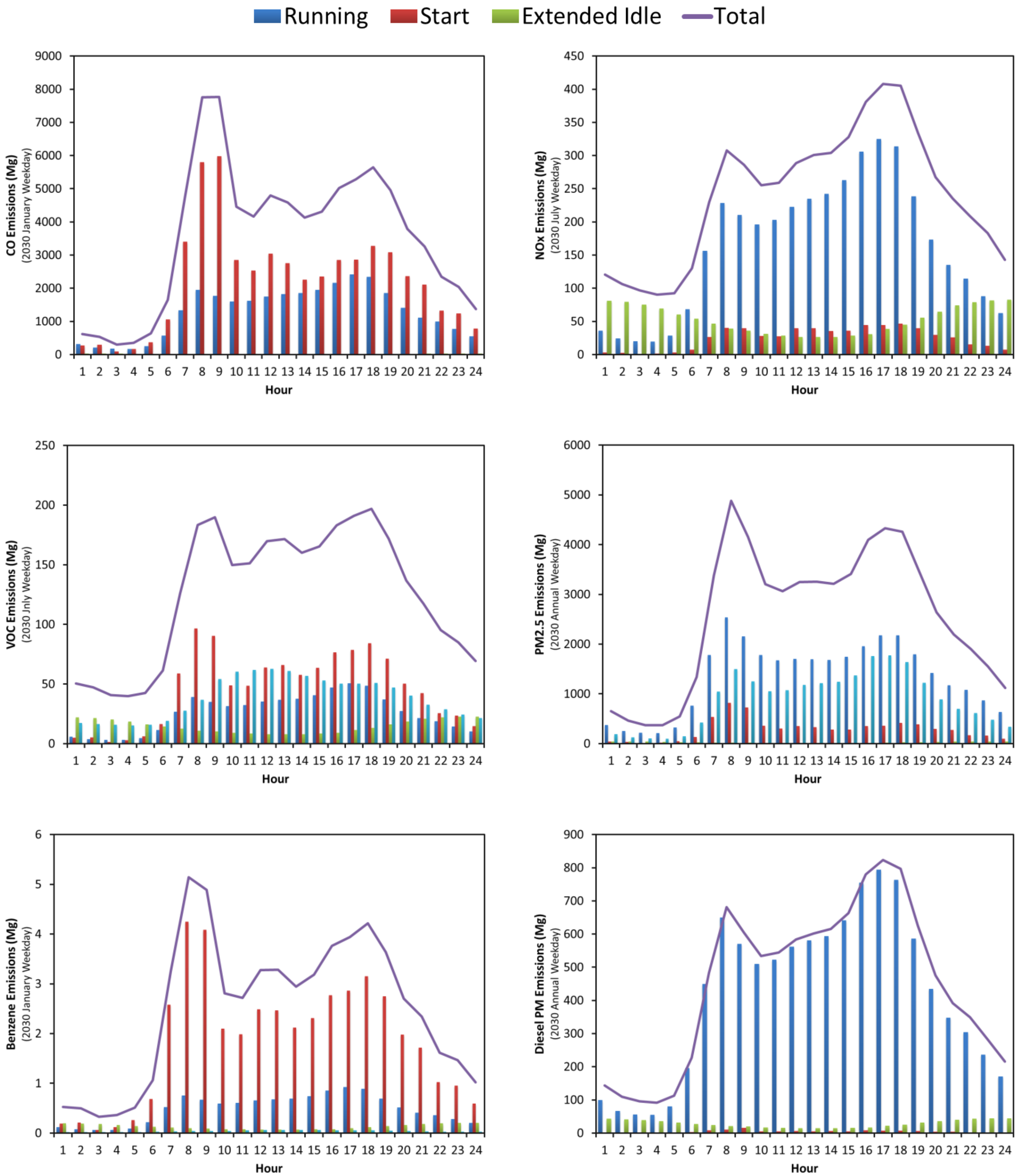

Figure 3. Running components emission factors versus vehicle speed for calendar year 2030.

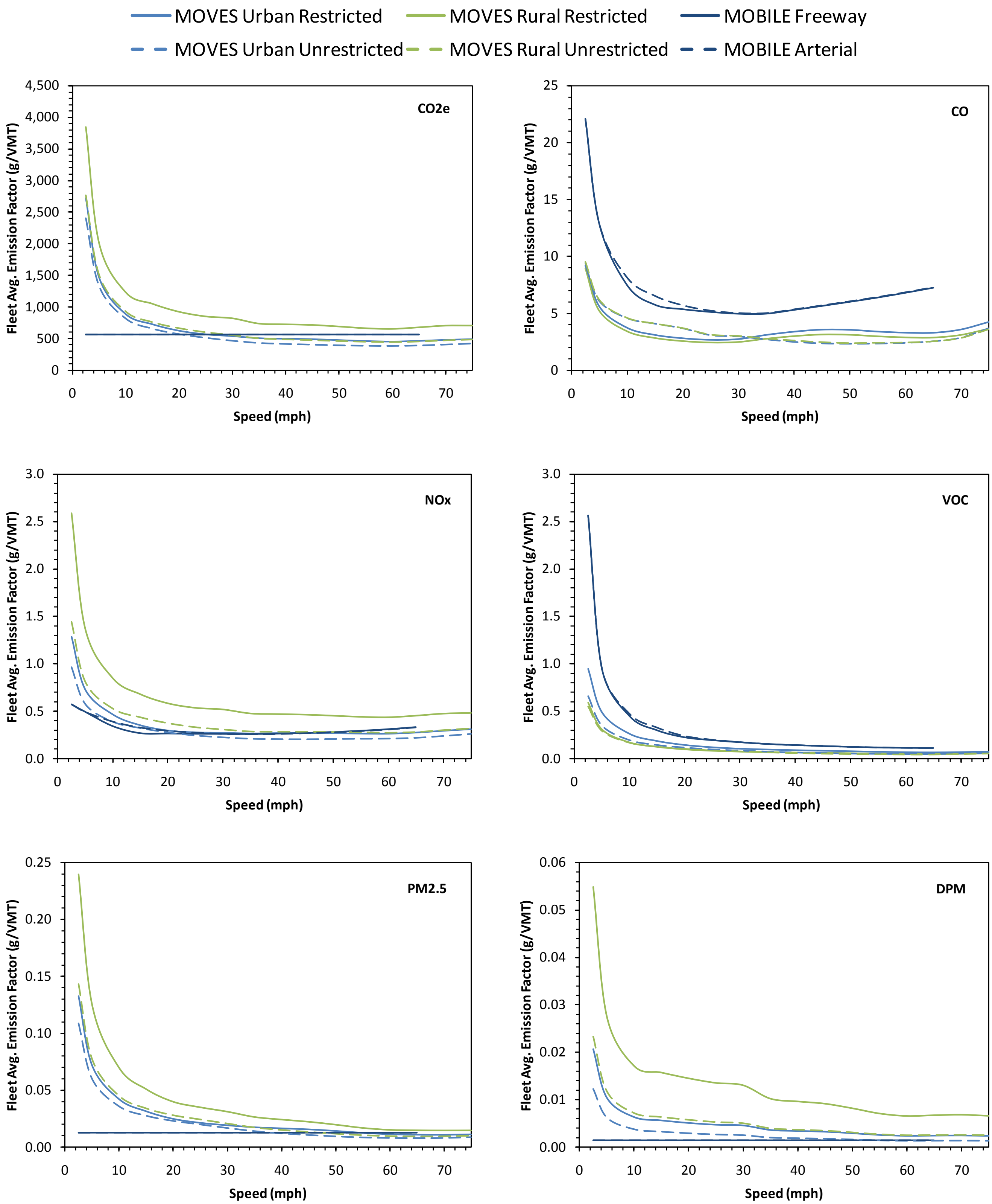

Figure 4. Running components emission factors versus demand/capacity for calendar year 2010.

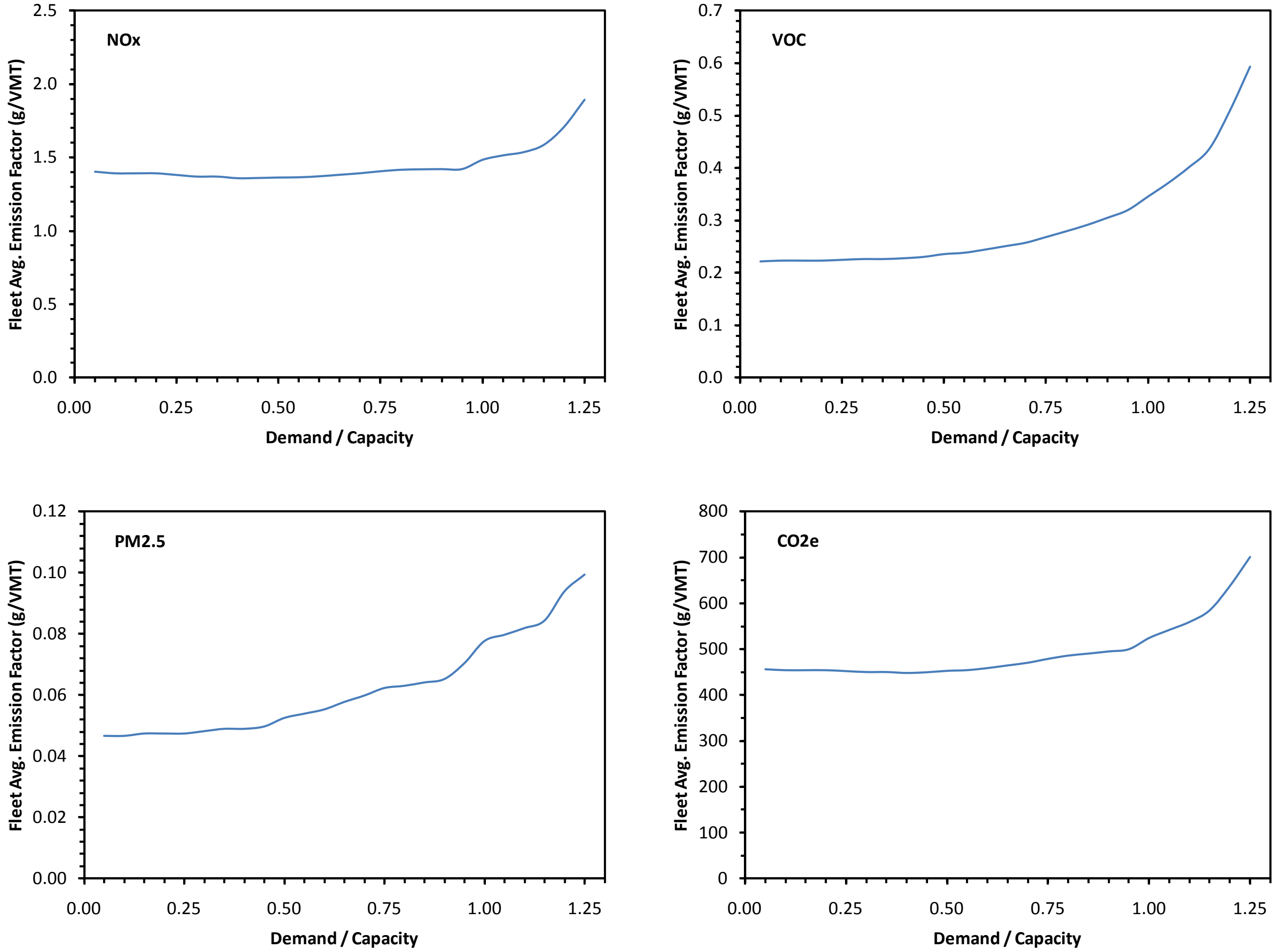

Figure 5. Project-scale modal emission factors for calendar year 2010.