

# Greenhouse Gas Emissions Model (GEM) User Manual

Vehicle Simulation Tool for Compliance  
with the Proposed Greenhouse Gas  
Emissions Standards and Fuel Efficiency  
Standards for Medium and Heavy-Duty  
Engines and Vehicles: Phase 2

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## Vehicle Simulation Tool for Compliance with the Proposed Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium and Heavy-Duty Engines and Vehicles: Phase 2

Assessment and Standards Division  
Office of Transportation and Air Quality  
U.S. Environmental Protection Agency

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## Introduction

The Greenhouse gas Emissions Model (GEM) was first created by EPA as part of the “Heavy-Duty Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles: Phase 1” rulemaking finalized in 2011. The model was developed to serve as a means for determining compliance with EPA’s GHG emissions and NHTSA’s fuel consumption vehicle standards for Class 7 and 8 combination tractors and Class 2b-8 vocational vehicles. Since then, significant improvements have been made to the model for the Phase 2 proposed rulemaking.

This user guide contains the model documentation, including a summary of the upgrades from GEM version 2.0.1 (i.e., “Phase 1 GEM”), installation instructions, and instructions for running the model, including a description of the necessary input and resulting output files. A detailed description of the model architecture and updates can be found in Chapter 4 of the draft RIA.

## Installation

### Computer Requirements

EPA developed Phase 2 GEM to be a forward-looking Matlab/Simulink-based model for heavy-duty (Class 2b-8) vehicle compliance for the Phase 2 proposed rulemaking. The model is a free, desktop computer application provided as an executable to be operated on a single computer. Since it is provided as an executable, the user does not have to have access to the Matlab/Simulink software packages. However, the following minimum computer specifications are required for the model to run:

- Operating System: Windows 7 or newer
- CPU: 2 GHz processor
- Memory: 4 GB of RAM

### Installation Instructions

The downloadable installation file is available on EPA’s website (see Figure 1) at: <http://www.epa.gov/otaq/climate/gem.htm>.

A link to the most recent GEM version will be located at the top of the page. The GEM executable is bundled with the user guide and input file templates into a 600 MB file that can be downloaded in a single step. The user guide is also available on the website for convenience.

To request a CD of this software instead of downloading it, or to request assistance if you have trouble with accessibility of this software, please request through an email addressed to [OTAQPUBLICWEB@epa.gov](mailto:OTAQPUBLICWEB@epa.gov).

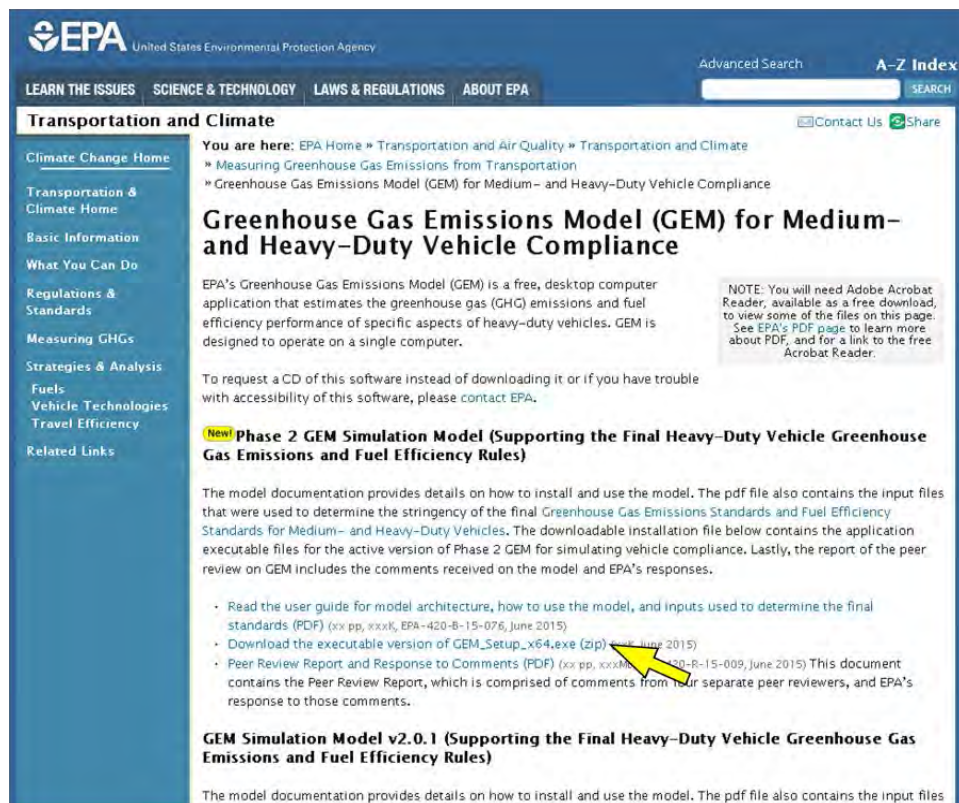


Figure 1: EPA Website to Obtain GEM Installation Package

Currently, GEM is only available to computers using 64-bit Windows operating systems (Windows 7 and newer). To check your computer's operating system, right click on "Computer" from a desktop icon or the Windows Start Menu to pull up the System Properties window. If your computer has a 64-bit operating system, it will be noted on the properties window, as is seen in Figure 2.

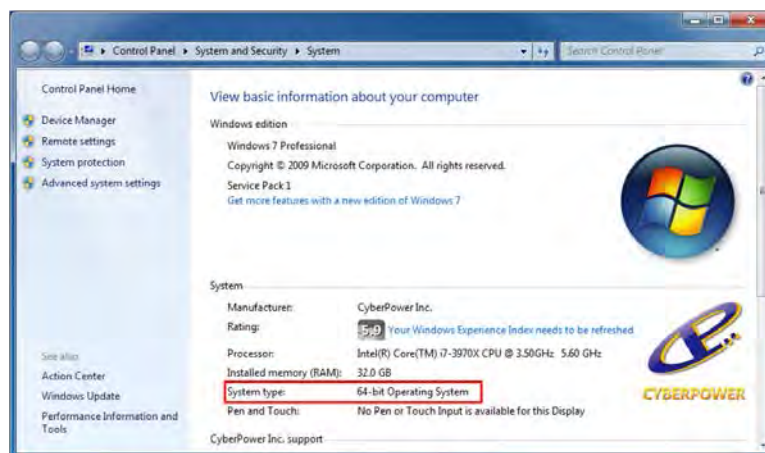
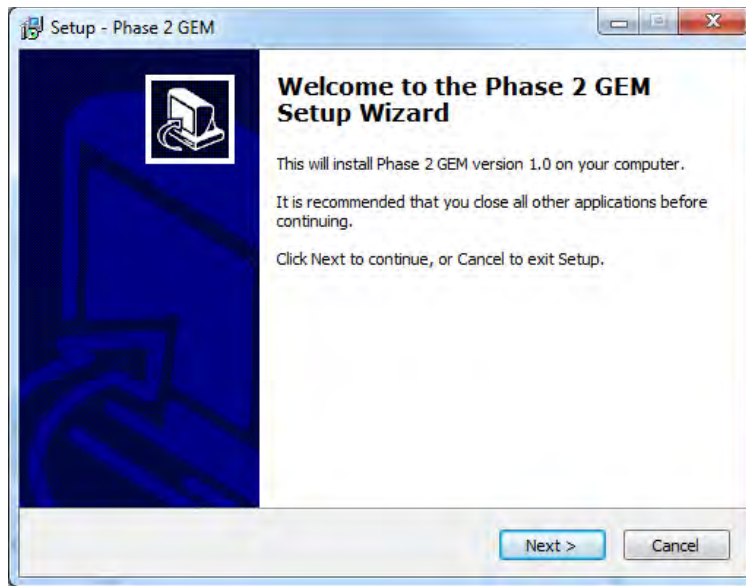


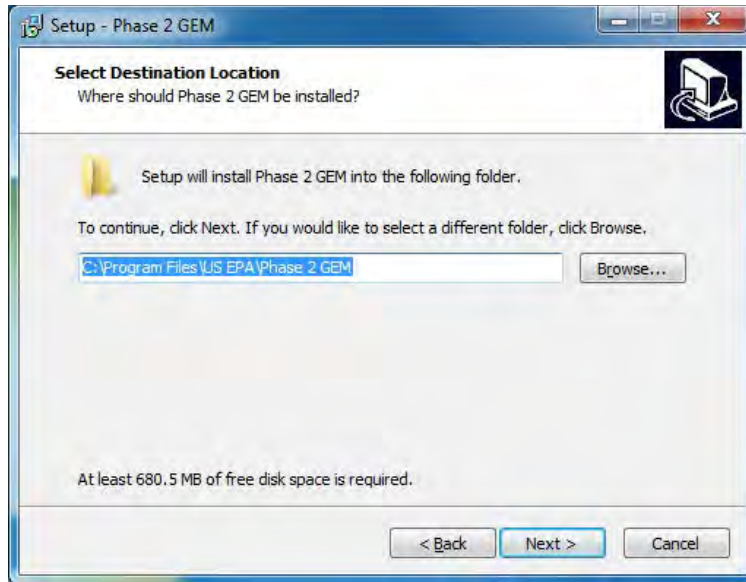
Figure 2: System Properties for a 64-bit Operating System (Newer than Windows XP)

To install GEM, download the installation file from EPA's website. Once downloaded, double-click the "GEM\_P2v1.0\_Setup\_x64" executable to start the setup wizard that will walk you through the steps of installation.

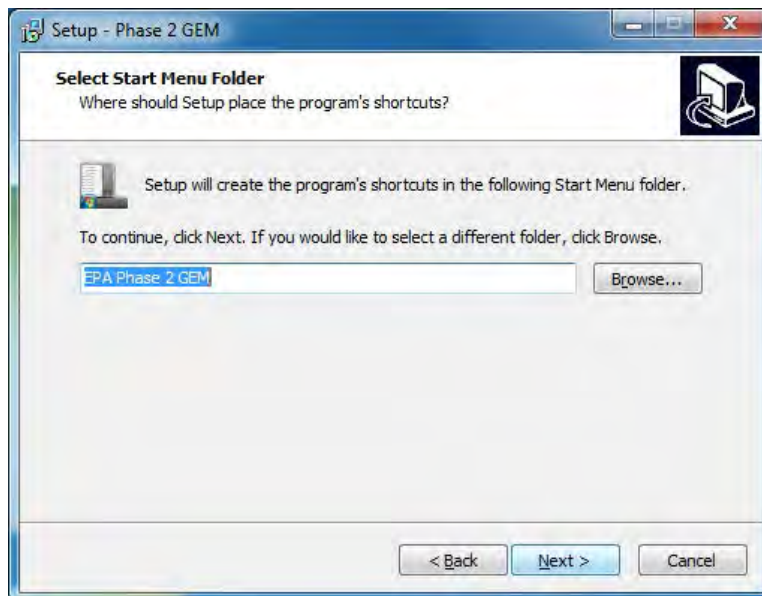


**Figure 3: Welcome Window for the Setup Wizard for Phase 2 GEM**

Users have the option of choosing a separate location for their Phase 2 GEM installation, but we recommend the default folders and shortcuts, as seen in Figure 4 and Figure 5. The instructions throughout this user guide assume the user installed Phase 2 GEM in the default locations with its default folder names.



**Figure 4: Destination for Phase 2 GEM Download; the Agencies Recommend the Default Location**



**Figure 5: Start Menu Folder for Phase 2 GEM Download; the Agencies Recommend the Default Folder Name**

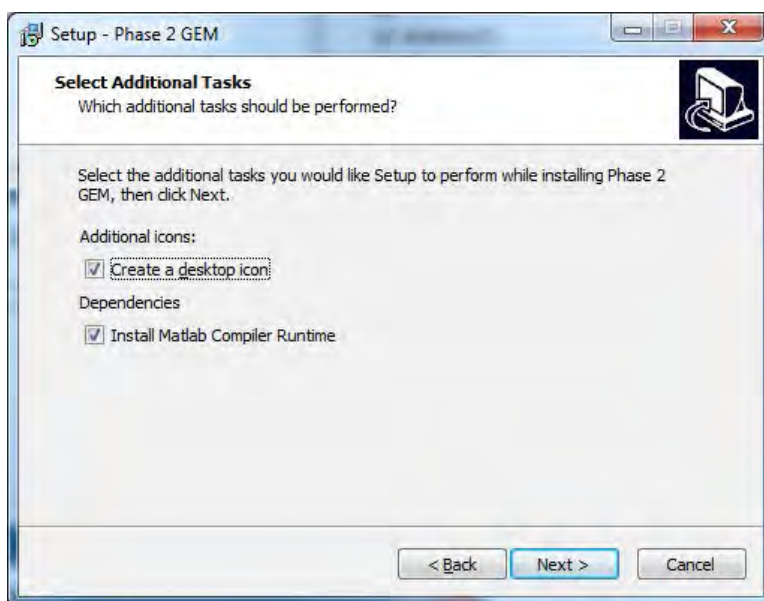
The next screen gives users an option to create a shortcut to Phase 2 GEM on their desktop. Users that choose to install a desktop icon will see a “Phase 2 GEM” shortcut, similar to the one shown in Figure 6, on their desktop. Users can uncheck the box next to the “Create a desktop icon” if they do not wish to have a desktop shortcut.





**Figure 6: Desktop Icon Shortcut to Phase 2 GEM**

Phase 2 GEM requires the use of Matlab Runtime Compiler and Microsoft Visual C++ 2005 or 2008 Redistributable (x64). The setup wizard will install Matlab Runtime Compiler R2014a (version 8.3) if the box, shown in Figure 7, is checked. For computers that already have the runtime compiler (R2014a or newer) installed, users can uncheck this box to avoid reinstallation.

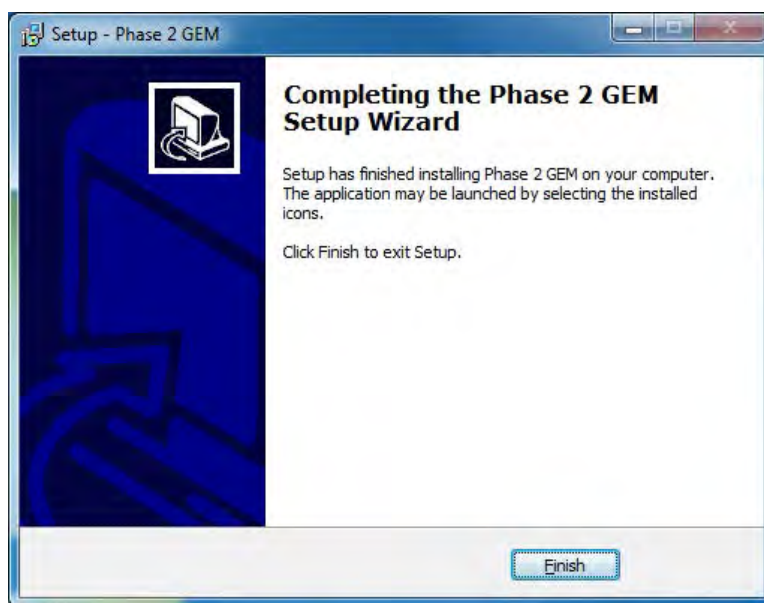


**Figure 7: Additional Installation Options for Phase 2 GEM; Matlab Runtime Compiler R2014a or Newer is Required for GEM Use**

The following windows allow users to review the installation settings and install Phase 2 GEM. The installer will warn users if their computers do not have Microsoft Visual C++ 2005 or 2008 Redistributable (x64) installed. A pop-up window will initiate installation of this software and will remain displayed until installation is complete.

A final screen (Figure 8) will show up when Phase 2 GEM has completed installing. The installation process for Matlab Runtime Compiler (if selected) will initiate shortly after this completion screen appears. The Matlab setup wizard for the runtime compiler is not described in this user guide.

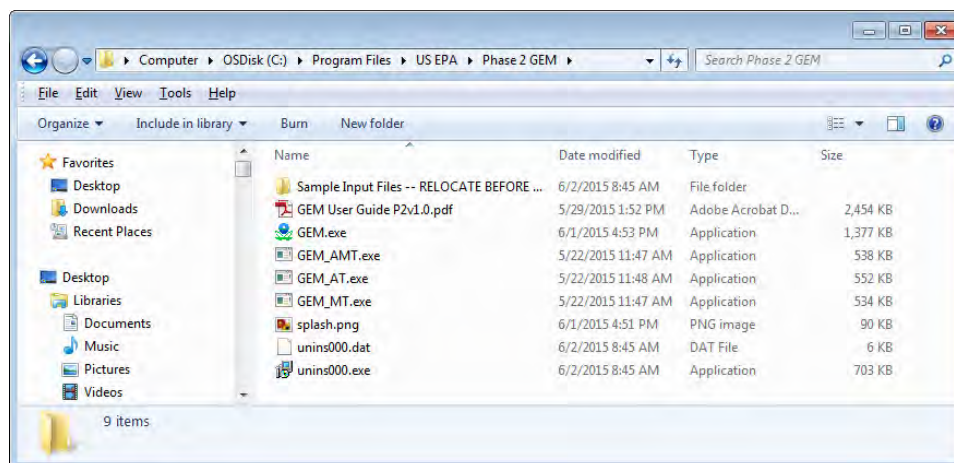




**Figure 8: Installation Complete Window for Phase 2 GEM**

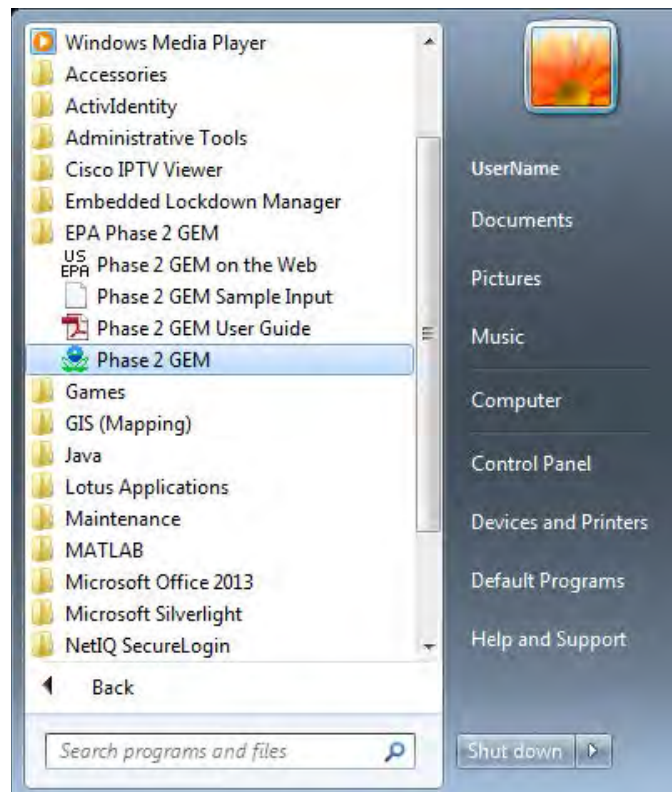
## Contents of Installation Package

Once installed, several files are stored in the installation location selected (i.e., C:\Program Files\US EPA\Phase 2 GEM\ by default). Figure 9 shows the contents of the default installation folder. Users can access the GEM User Guide, the GEM executables, and sample files from this directory. They can also uninstall GEM and remove all of its contents by clicking on the “unins000.exe” executable.



**Figure 9: Contents of Installation Folder for Phase 2 GEM**

GEM is also available from the Start Menu, under the folder named “EPA Phase 2 GEM”, as seen in Figure 10. Within the Start Menu folder, users have access to the executable, as well as a copy of this User Guide, a link to the EPA website, and sample input files that can be used as templates for running GEM.



**Figure 10: Start Menu Location of GEM**

## Sample Input Files

Sample input files are stored with the Phase 2 GEM executable. Within the “Sample Input Files – RELOCATE BEFORE USE” folder, the agencies provide sample files for each of the three vehicle regulatory subcategories that use GEM: Tractor, Trailer, and Vocational vehicles. The following documents will be available in three folders:

- Tractor sample files folder
  - Sample engine input file: *EPA\_Sample\_350hp.csv*
  - Sample engine input file: *EPA\_Sample\_455hp.csv*
  - Sample transmission input file: *EPA\_Sample\_AMT.csv*
  - Sample transmission input file: *EPA\_Sample\_MT.csv*
  - Sample vehicle input file: *GEM\_TRACTOR.csv*
  - Sample vehicle Excel macro file: *GEM\_TRACTOR.xlsm*
- Trailer sample files folder
  - Sample vehicle input file: *GEM\_TRAILER.csv*
  - Sample vehicle Excel macro file: *GEM\_TRAILER.xlsm*
- Vocational sample files folder
  - Sample engine input file: *EPA\_Sample\_200hp.csv*
  - Sample engine input file: *EPA\_Sample\_270hp.csv*
  - Sample engine input file: *EPA\_Sample\_345hp.csv*

- Sample engine input file: *EPA\_Sample\_455hp.csv*
- Sample transmission input file: *EPA\_Sample\_AT\_5\_HHD.csv*
- Sample transmission input file: *EPA\_Sample\_AT\_5\_MLHD.csv*
- Sample transmission input file: *EPA\_Sample\_MT\_10\_HHD.csv*
- Sample vehicle input file: *GEM\_VOCATIONAL.csv*
- Sample vehicle Excel macro file: *GEM\_VOCATIONAL.xlsm*

A description of each of these input files and instructions for running the model are provided in later sections.

If users select the default installation folder, C:\Program Files\US EPA\Phase 2 GEM\, it is recommended that they copy the folder “Sample Input Files – RELOCATE BEFORE USE” from this default folder to a local folder. By doing so, users can easily run GEM and write output results into the selected local folder and avoid potential administrative rights issues, since not all organizations allow users to write files to C:\Program Files folders. Users can copy the sample files folder to any convenient local folder and can rename it as needed once it is copied to its new destination.

### **GEM Executable**

The agencies propose to require that vehicle manufacturers use the Phase 2 GEM executable, which does not require the use of Matlab or Simulink software, for demonstrating compliance with the proposed CO<sub>2</sub> and fuel consumption standards. Phase 2 GEM does not offer a graphical user interface (GUI) for users to provide their vehicle parameters. Instead, inputs are provided in a .csv file. However, the agencies do provide a simple Microsoft Excel file with a macro built in, allowing individual users or manufacturers to generate the necessary input file and run GEM with one button-click. Results are available in a generated report that can be viewed using either a text editor or spreadsheet. The following sections will describe the model, its input files, and its output files in more detail.

## **Model Description**

Phase 1 GEM was updated in order to meet proposed Phase 2 rulemaking requirements. Phase 2 GEM improves the fidelity of the Phase 1 model to better match the function of the simulated vehicles and accurately reflect changes in technology for compliance purposes. Many of the modifications were the result of numerous constructive comments from both public comments and GEM peer reviews<sup>1</sup>. The following sections describe the model with an emphasis on the additional vehicle parameters available in the Phase 2 upgrade of the model. Users are directed to Chapter 4 of the draft RIA for more detailed information regarding the model architecture and validation.

### **GEM Architecture and Summary of Upgrades**

The GEM architecture is comprised of four systems: Ambient, Driver, Powertrain, and Vehicle as seen in Figure 11. The Powertrain and Vehicle systems consist of one or more subcomponent models and a description of the subcomponent models is available in Chapter 4 of the draft RIA.

## REVS\_VM Vehicle Model

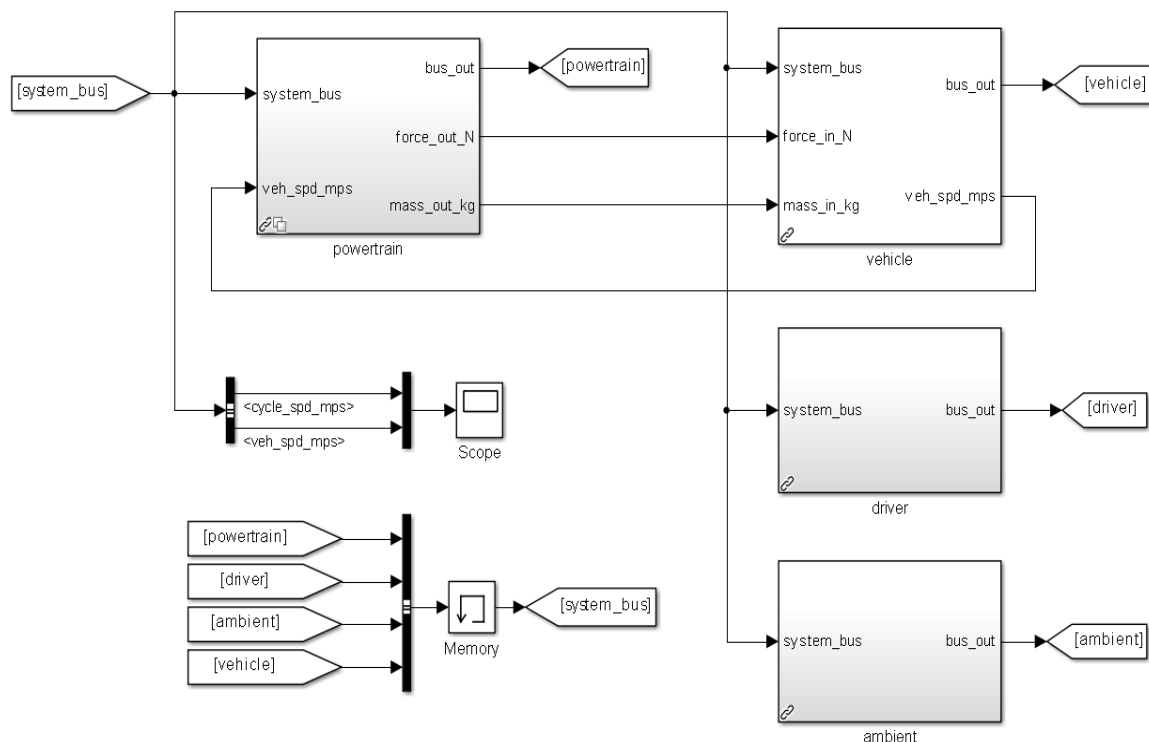


Figure 11: GEM model structure

The agencies are proposing additional regulatory subcategories to better represent the heavy-duty vehicles and these subcategories are reflected in the model with additional vehicle models. Phase 2 GEM also incorporates the proposed improvements to the duty cycles, including the addition of an idle cycle for vocational vehicles, and modified cruise cycles that account for changes in road grade. Specifically, the agencies are proposing to implement the following key technical features into Phase 2 GEM:

- An upgraded engine controller, which includes engine fuel cut-off during braking and deceleration
- An upgraded transmission model, which includes an upgraded manual transmission, along with newly developed automatic and automated manual transmissions
- An upgraded driver model with a distance-compensated driver that will drive the certification drive trace over a prescribed distance regardless of increased drive time due to vehicle under-performance, for example

With these upgrades, the model is capable of recognizing most technologies that could be evaluated in both engine and chassis dynamometers and is better able to reflect changes in technologies for compliance purposes. See Chapter 4 of the draft RIA for more information about these upgrades.

## **Vehicle Parameters for Each Regulatory Subcategory**

GEM is a flexible simulation platform that can model a wide variety of vehicles with conventional powertrains from Class 2b to Class 8. The key to this flexibility is the component description files that can be modified or adjusted to accommodate vehicle-specific information. Phase 2 GEM includes four main vehicle types, and several variations of each vehicle, to match the regulatory subcategories in the proposed Phase 2 rulemaking. Each regulatory subcategory is associated with specific vehicle parameters and technology options.

The agencies predefined many key parameters, since those parameters are either hard to quantify due to lack of certified testing procedures or difficult to obtain due to proprietary barriers. Examples of these parameters include transmission shifting strategies, transmission gear mechanical efficiency, and transmission spin and pumping losses. The values selected for these parameters are a result of substantial testing by EPA, as well as confidential discussions with engine, chassis and component manufacturers.

Each vehicle subcategory has a set of user-defined parameters. These parameters include vehicle technologies or component attributes that impact CO<sub>2</sub> emissions and fuel consumption, but have the potential to vary across manufacturers. Parameters such as aerodynamic performance, vehicle weight, engine fuel map, transmission gear ratios, tire radius, or axle ratio can all be changed as inputs by the user.

The sections to follow outline the regulatory vehicle subcategories that would use GEM for compliance and summarizes the user-defined and predefined model parameters applicable to each subcategory.

## **Drive Cycles and Transient Correction Factor**

The proposed rulemaking also predefines three drive cycles including a transient cycle and two cruise speed cycles. The transient mode is defined by California Air Resources Board (CARB) in their Highway Heavy-Duty Diesel Transient (HHDDT) cycle. The cruise speed cycles are represented by two constant speed 65 mph and 55 mph cycles, each with varying road grade. A stationary “idle cycle” is also available to vocational vehicles, which evaluates both zero torque and curb-idle transmission torque. Each regulatory subcategory is given a specific set of drive cycle weightings.

The agencies recognize the limitation of the steady state engine fuel map for transient simulation, and therefore are proposing a transient adjustment factor of 1.05 used only for transient cycle. This means that the simulated transient cycle GEM results (that are generated based on steady-state fuel maps) would be multiplied by 1.05 before being output from the GEM compliance tool. The higher output value would be the official GEM result. The detailed description and justification of this transient correction factor can be viewed in Chapter 4 of the draft RIA.

## Tractor Vehicle Parameters

The agencies are proposing a set of predefined modeling parameters to establish consistent combination tractor models from which tractor manufacturers can compare their vehicle improvements. GEM recognizes nine variations of combination tractors. Class 8 tractors can have day or sleeper cab configurations with low, mid, or high roof heights. Class 7 tractors are only available in a day cab configuration, but also have low, mid, or high roof options. Within GEM, high roof tractors are simulated as pulling a standard box trailer. Mid roof tractors and low roof tractors are simulated as pulling tank and flatbed trailers, respectively. The agencies are proposing that the standard box trailer for high roof tractor simulations also include a skirt, which is represented by the user-defined aerodynamic drag area input, CdA (described in the next section).

Table 1, Table 2, and Table 3 summarize the predefined modeling parameters for Class 8 sleeper cab, Class 8 day cab, and Class 7 tractors, respectively. All Class 8 tractors are modeled with five axles in a 6x4 configuration with two steer tires and eight drive tires. The Class 8 payload is 19 tons. All Class 7 tractors are represented by a four axle tractor in a 4x2 configuration with two steer tires and four drive tires. The Class 7 payload is 12.5 tons. Sleeper cab tractors are assigned drive cycle weightings that are more representative of long-haul driving with 86 percent at 65-MPH, 9 percent at 55-MPH and 5 percent transient. Drive cycle weightings for day cab tractors are more representative of short-haul driving with 64 percent at 65-MPH, 17 percent at 55-MPH, 19 percent transient.

**Table 1 Class 8 Combination Tractor Sleeper Cab Predefined Modeling Parameters**

| Regulatory Subcategory           | Class 8 Combination, Sleeper Cab |          |          |
|----------------------------------|----------------------------------|----------|----------|
| Roof Height                      | High Roof                        | Mid Roof | Low Roof |
| Total Weight (kg)                | 31978                            | 30277    | 30390    |
| Number of Axles                  | 5                                |          |          |
| Default Axle Configuration       | 6x4                              |          |          |
| Payload (tons)                   | 19                               |          |          |
| CARB HHDDT Drive Cycle Weighting | 0.05                             |          |          |
| GEM 55 mph Drive Cycle Weighting | 0.09                             |          |          |
| GEM 65 mph Drive Cycle Weighting | 0.86                             |          |          |

**Table 2 Class 8 Combination Tractor Day Cab Predefined Modeling Parameters**

| Regulatory Subcategory           | Class 8 Combination, Day Cab |          |          |
|----------------------------------|------------------------------|----------|----------|
| Roof Height                      | High Roof                    | Mid Roof | Low Roof |
| Total Weight (kg)                | 31297                        | 29529    | 29710    |
| Number of Axles                  | 5                            |          |          |
| Default Axle Configuration       | 6x4                          |          |          |
| Payload (tons)                   | 19                           |          |          |
| CARB HHDDT Drive Cycle Weighting | 0.19                         |          |          |
| GEM 55 mph Drive Cycle Weighting | 0.17                         |          |          |
| GEM 65 mph Drive Cycle Weighting | 0.64                         |          |          |

**Table 3 Class 7 Combination Tractor Predefined Modeling Parameters**

| Regulatory Subcategory | Class 7 Combination, Day Cab |
|------------------------|------------------------------|
|------------------------|------------------------------|

| Roof Height                      | High Roof | Mid Roof | Low Roof |
|----------------------------------|-----------|----------|----------|
| Total Weight (kg)                | 22679     | 20910    | 21091    |
| Number of Axles                  | 4         |          |          |
| Default Axle Configuration       | 4x2       |          |          |
| Payload (tons)                   | 12.5      |          |          |
| CARB HHDDT Drive Cycle Weighting | 0.19      |          |          |
| GEM 55 mph Drive Cycle Weighting | 0.17      |          |          |
| GEM 65 mph Drive Cycle Weighting | 0.64      |          |          |

Table 4 shows the predefined modeling parameters that are consistent across all tractor types. These common parameters include ambient temperature, efficiencies and accessory powers. The calculations for overall rolling resistance and the distribution of weight savings are also consistent for all modeled tractors.

**Table 4 Common Predefined Modeling Parameters for All Simulated Combination Tractors**

|                                    |  |
|------------------------------------|--|
| Gearbox Efficiency                 | 98% for 1:1 gear ratio, 96% for others   |
| Axle Mechanical Efficiency         | 95.5%  |
| Electrical Accessory Power (W)     | 300  |
| Mechanical Accessory Power (W)     | 1000   |
| Environmental air temperature (°C) | 25   |
| Weight Reduction (lbs)             | Add 1/3*weight reduction to Payload tons   |
| Trailer Tire Crr (kg/t)            | 6.0  |
| Overall Tire Crr (kg/t)            | $= 0.425 \times \text{Trailer Crr} + 0.425 \times \text{Drive Crr} + 0.15 \times \text{Steer Crr}$ |

GEM allows a user to modify or adjust performance information for certain components in order to model and quantify improvements the manufacturer is making to its vehicles. Table 5 lists the user-defined modeling parameters that are recognized in GEM. Phase 2 GEM continues to allow tractor manufacturers to model their vehicle's tire rolling resistances, but also requires each tire's loaded radius. Phase 2 GEM also continues to account for aerodynamic drag, but manufacturers are asked to provide a wind-averaged aerodynamic drag area (CdA), instead of the zero-yaw coefficient of drag (Cd) required in Phase 1. These updates were made in order to more realistically model the rolling resistance and aerodynamic drag the vehicle would experience in real world driving.

In Phase 1, a default engine and transmission were applied to all GEM-simulated combination tractors. Phase 2 GEM requires manufacturers to supply an engine fuel map for each distinct engine used in the modeled vehicles. Additionally, the manufacturer must include specific transmission information to the model. The engine and the transmission information are provided as separate input files with specific requirements, as will be discussed in the Input Files section of this guide.

**Table 5 User-Defined Modeling Parameters for Class 7 and Class 8 Combination Tractors (All Cabs and Roof Heights)**

| Modeling Parameter    | Method of Determining Parameter           |
|-----------------------|---|
| Steer Tire Crr (kg/t) | ISO 28580:2009(E), See 40 CFR 1037.520(c) |



|  |  |
|--|--|
| Drive Tire Crr (kg/t)                        |  |
| Tire Loaded Radius (m)                       | See 40 CFR 1037.520(c)   |
| Aerodynamic Drag Area, CdA (m <sup>2</sup> ) | See 40 CFR 1037.520(b) and 40 CFR 1037.525                     |
| Engine Fuel Map                              | From engine manufacturer or 40 CFR 1065.510                    |
| Transmission                                 | From transmission manufacturer: type, gear number, gear ratios |
| Drive Axle Ratio                             | From axle manufacturer   |

Phase 2 GEM also accounts for additional technologies and vehicle configurations that reduce CO<sub>2</sub> and fuel consumption, but are not easily captured in the vehicle simulation. These reduction values range from 0.5 percent to 2.5 percent and are applied internally to GEM after the vehicle simulation has completed. Manufacturers would indicate if their vehicle includes any of the technology improvements listed in Table 6 by indicating yes or no (Y or N in the input file) and GEM would apply the appropriate emission reduction.

**Table 6 Technology Improvement Options for Tractor Manufacturers**

| <b>Technology Improvement</b>                       | <b>Regulation Reference</b> | <b>Reduction Value</b> |
|---|-----------------------------|------------------------|
| Vehicle Speed Limit                                 | See 40 CFR 1037.520(d)      | Varies                 |
| Weight Reduction (lb)                               | See 40 CFR 1037.520(e)      | Varies                 |
| Single Drive Axle (Class 8 Tractors Only)           | See 40 CFR 1037.520(f)(1)   | 2.5%                   |
| Part Time Single Drive Axle (Class 8 Tractors Only) | See 40 CFR 1037.520(f)(1)   | 2.5% <sup>a</sup>      |
| Low Friction Axle Lubricant                         | See 40 CFR 1037.520(f)(2)   | 0.5%                   |
| Transmissions: AT, AMT, DCT                         | See 40 CFR 1037.520(f)(3)   | 2.0%                   |
| Predictive Cruise Control                           | See 40 CFR 1037.520(f)(4)   | 2.0%                   |
| High Efficiency A/C Compressor                      | See 40 CFR 1037.520(f)(5)   | 0.5%                   |
| Electric Engine Coolant and Power Steering Pumps    | See 40 CFR 1037.520(f)(6)   | 1.0%                   |
| Automatic Tire Inflation System                     | See 40 CFR 1037.520(f)(7)   | 1.0%                   |
| Extended Idle Reduction (Sleeper Cabs Only)         | See 40 CFR 1037.520(f)(8)   | 5.0%                   |

Notes:

<sup>a</sup> Part Time Single Drive Axle reduction is 2.5% over the 55 mph and 65 mph cycles and zero over the CARB HHDDT cycle

## Vocational Vehicle Parameters

The agencies are proposing a set of predefined modeling parameters to establish consistent vocational vehicle models from which manufacturers can compare their vehicle improvements. GEM recognizes nine variations of vocational vehicles based on both vehicle weight class and duty cycle. Class 8 vocational vehicles are considered heavy heavy-duty (HHD). Classes 6 and 7 are medium heavy-duty (MHD), and Classes 2b-5 are considered light heavy-duty (LHD). As seen in Table 7, Table 8, and Table 9, the weight, number of axles, aerodynamic drag area and payload are the same for all of the vehicles within a weight class. Vehicles within each weight class are further categorized using three duty cycles (Regional, Multi-purpose and Urban) by varying the drive cycle weightings associated with each composite duty cycle. The assignment of vocational vehicles to subcategories is described in the regulations at 40 CFR 1037.510, and is based on a combination of vehicle attributes and driveline parameters. The Multi-purpose cycle is the default for vocational vehicles unless the

specified criteria indicate another cycle is more appropriate, or if the certifying manufacturer requests placement in a different subcategory. GEM does not automatically pre-process vocational vehicle inputs to assign vocational vehicles to subcategories, though GEM may be used as a tool to assist in deciding how the criteria of 1037.510 apply to your vehicles. For vocational vehicles with conventional powertrains and engines that are certified over both the FTP and SET, manufacturers will generally need to know the following information in order to decide whether the multi-purpose duty cycle is not the most appropriate for a vocational vehicle: tire revs/mile, rear axle ratio, transmission gear ratios, maximum engine test speed, and primary fuel type.

**Table 7 Vocational HHD Vehicle Predefined Modeling Parameters**

| Regulatory Subcategory              | HHD      |               |       |
|-------------------------------------|----------|---------------|-------|
| Duty Cycle                          | Regional | Multi-Purpose | Urban |
| Total weight (kg)                   | 19051    |               |       |
| Number of Axles                     | 3        |               |       |
| CdA (m <sup>2</sup> )               | 6.86     |               |       |
| Payload (tons)                      | 7.50     |               |       |
| ARB Transient Drive Cycle Weighting | 0.50     | 0.82          | 0.94  |
| GEM 55 mph Drive Cycle Weighting    | 0.28     | 0.15          | 0.06  |
| GEM 65 mph Drive Cycle Weighting    | 0.22     | 0.03          | 0.00  |
| Idle Cycle Weighting                | 0.10     | 0.15          | 0.20  |

**Table 8 Vocational MHD Vehicle Predefined Modeling Parameters**

| Regulatory Subcategory              | MHD      | MHD           | MHD   |
|-------------------------------------|----------|---------------|-------|
| Duty Cycle                          | Regional | Multi-Purpose | Urban |
| Total weight (kg)                   | 11408    |               |       |
| Number of Axles                     | 2        |               |       |
| CdA (m <sup>2</sup> )               | 5.40     |               |       |
| Payload (tons)                      | 5.60     |               |       |
| ARB Transient Drive Cycle Weighting | 0.50     | 0.82          | 0.94  |
| GEM 55 mph Drive Cycle Weighting    | 0.28     | 0.15          | 0.06  |
| GEM 65 mph Drive Cycle Weighting    | 0.22     | 0.03          | 0.00  |
| Idle Cycle Weighting                | 0.10     | 0.15          | 0.20  |

**Table 9 Vocational LHD Vehicle Predefined Modeling Parameters**

| Regulatory Subcategory              | LHD      | LHD           | LHD   |
|-------------------------------------|----------|---------------|-------|
| Duty Cycle                          | Regional | Multi-Purpose | Urban |
| Total weight (kg)                   | 7257     |               |       |
| Number of Axles                     | 2        |               |       |
| CdA (m <sup>2</sup> )               | 5.40     |               |       |
| Payload (tons)                      | 2.85     |               |       |
| ARB Transient Drive Cycle Weighting | 0.50     | 0.82          | 0.94  |
| GEM 55 mph Drive Cycle Weighting    | 0.28     | 0.15          | 0.06  |
| GEM 65 mph Drive Cycle Weighting    | 0.22     | 0.03          | 0.00  |
| Idle Cycle Weighting                | 0.10     | 0.15          | 0.20  |

Table 10 shows the predefined modeling parameters that are consistent across all vocational vehicle types. These common parameters include ambient temperature, efficiencies and accessory powers. It should be noted that GEM will assign all automated manual or dual clutch transmissions a 98 percent efficiency for the gear with a 1:1 ratio and 96 percent efficiency for all others. All gears in an automatic transmission are assumed to have a 98 percent efficiency (pump losses and spin losses are accounted for separately from the gear losses for automatic transmissions). The calculations for overall rolling resistance and the distribution of weight savings are also consistent for all modeled vocational vehicles.

**Table 10 Common Predefined Modeling Parameters for All Vocational Vehicles**

|   |  |
|---|--|
| Gearbox Efficiency for AMT                | 98% for 1:1 gear ratio, and 96% for others |
| Gearbox Efficiency for AT                 | 98% for all gears                          |
| Axle Mechanical Efficiency                | 95.5%                                      |
| Electrical Accessory Power (W)            | 300  |
| Mechanical Accessory Power (W)            | 1000                                       |
| Environmental Air Temperature (°C degree) | 25   |
| Weight Reduction (lbs)                    | Add 0.5*weight reduction to Payload tons   |
| Overall Tire Crr (kg/t)                   | = 0.7*Drive Crr + 0.3*Steer Crr            |

GEM allows a user to modify or adjust performance information for certain components in order to model and quantify improvements the manufacturer is making to its vehicles. Table 11 lists the user-defined modeling parameters that are recognized in GEM for vocational vehicles. In Phase 1 GEM, vocational vehicle manufacturers were only given the option of changing the rolling resistance of their steer and drive tires. Phase 2 GEM continues to allow vocational vehicle manufacturers to model their vehicle's tire rolling resistances, but also requires each tire's loaded radius. Additionally, Phase 2 GEM requires manufacturers to supply an engine fuel map and specific transmission information to for each distinct engine and transmission in the vehicles being modeled. The engine and the transmission information are provided as separate input files with specific requirements, as will be discussed in the Input Files section of this guide. Note that emergency vehicles are only allowed to adopt lower rolling resistance tires on their steer and drive tires in this proposal. The rest of the parameters do not apply to emergency vehicles.

**Table 11 User-Defined Modeling Parameters for Vocational Vehicles (All Weight Classes)**

| Modeling Parameter     | Method of Determining Parameter                                |
|------------------------|--|
| Steer Tire Crr (kg/t)  | ISO 28580:2009(E), See 40 CFR 1037.520(c)                      |
| Drive Tire Crr (kg/t)  |  |
| Tire Loaded Radius (m) | See 40 CFR 1037.520(c)   |
| Engine Fuel Map        | From engine manufacturer or 40 CFR 1065.510                    |
| Transmission           | From transmission manufacturer: type, gear number, gear ratios |
| Drive Axle Ratio       | From axle manufacturer   |

As is proposed for the tractor model, Phase 2 GEM accounts for additional vocational vehicle technologies that reduce CO<sub>2</sub> and fuel consumption, but are not easily captured in the vehicle simulation. These reduction values range from 0.5 percent to 2.5 percent and are applied internally to GEM after the vehicle simulation has completed. Manufacturers would indicate if their vehicle includes any of the technology improvements listed in Table 12 by indicating yes or no (Y or N in the input file) and GEM would apply the appropriate emission reduction.

**Table 12 Technology Improvement Options for Vocational Vehicle Manufacturers**

| Technology Improvement                            | Regulation Reference      | Reduction Value             |
|---|---------------------------|-----------------------------|
| Weight Reduction (lb)                             | See 40 CFR 1037.520(e)    | Varies                      |
| Power Take Off (g/ton-mile)                       | See 40 CFR 1037.540       | Varies                      |
| HHD Single Drive Axle (6x2) Configuration         | See 40 CFR 1037.520(f)(1) | 2.5%                        |
| HHD Part-time Single Drive Axle 6x2 Configuration | See 40 CFR 1037.520(f)(1) | 0.1% - 1.0% <sup>a</sup>    |
| Low Friction Axle Lubricant                       | See 40 CFR 1037.520(f)(2) | 0.5%                        |
| Transmissions: AMT, DCT (HHD, Regional Only)      | See 40 CFR 1037.520(f)(3) | 2.3%                        |
| Idle Reduction: Start-Stop                        | See 40 CFR 1037.520(f)(8) | Determined by idle fuel map |
| Idle Reduction: Neutral Idle                      | See 40 CFR 1037.520(f)(8) |                             |

Notes:

<sup>a</sup> Based on 2.5% over the 55 mph and 65 mph cycles and zero over the CARB HHDDT cycle

## Trailer Vehicle Parameters

The agencies are proposing an equation-based compliance approach for box trailer manufacturers and they are not required to certify their trailers using GEM. However, the equations for each box trailer subcategory are based on the simulated trailers described in this section. Note that non-box trailers do not use GEM or the GEM-based equation for compliance and a discussion of non-box trailers is not included in this user guide. The following description of the trailer model as it applies to box trailers is included for informational purposes only.

The agencies are proposing a set of predefined modeling parameters to establish consistent tractor-trailer models from which box van trailer manufacturers can compare their vehicle improvements. GEM recognizes four variations of box van based on length. All simulated box vans are modeled as a combination tractor-trailer with a Class 8 high roof tractor. Long box vans (trailers that are longer than 50-feet) are represented by either a 53-foot dry van or a 53-foot refrigerated van in GEM. The tractor-trailer model for long-box vans includes a sleeper cab tractor and is given the same long-haul drive cycle weightings as the Class 8 high roof sleeper cab tractors mentioned previously. GEM models all short box vans (box trailers 50-feet in length and shorter) as a single-axle, solo 28-foot dry van or refrigerated van.

Table 13 and Table 14 summarize the predefined modeling parameters for long and short box vans, respectively. All long box vans are modeled with tandem axles and a payload of 19 tons and drive cycle weightings that are more representative of long-haul driving (i.e., 86 percent at 65-MPH, 9 percent at 55-MPH and 5 percent transient). All short box vans are modeled with a single axle, a payload of 10 tons, and drive cycle weightings more representative of short-haul driving with 64 percent at 65-MPH, 17 percent at 55-MPH, 19 percent transient. The vehicle weight varies between dry vans and refrigerated vans to account for the weight of the

refrigeration unit, and weight also varies proportional to the length of the trailer. The baseline CdA values were obtained from EPA's aerodynamic testing.

**Table 13 Predefined Modeling Parameters for Long Box Trailers**

| Regulatory Subcategory                | Long Box Dry Van           | Long Box Refrigerated Van |
|---------------------------------------|----------------------------|---------------------------|
| Tractor Type                          | C8 Sleeper Cab - High Roof |                           |
| Total weight (kg)                     | 31978                      | 33778                     |
| Baseline CdA Values (m <sup>2</sup> ) | 6.2                        | 6.1                       |
| Number of Axles                       | 5                          |                           |
| Payload (tons)                        | 19                         |                           |
| CARB HHDDT Drive Cycle Weighting      | 0.05                       |                           |
| GEM 55 mph Drive Cycle Weighting      | 0.09                       |                           |
| GEM 65 mph Drive Cycle Weighting      | 0.86                       |                           |

**Table 14 Predefined Modeling Parameters for Short Box Trailers**

| Regulatory Subcategory                | Short Box Dry Van      | Short Box Refrigerated Van |
|---------------------------------------|------------------------|----------------------------|
| Tractor Type                          | C8 Day Cab - High Roof |                            |
| Total weight (kg)                     | 15191                  | 16991                      |
| Baseline CdA Values (m <sup>2</sup> ) | 6.1                    | 6.0                        |
| Number of Axles                       | 4                      |                            |
| Payload (tons)                        | 10                     |                            |
| ARB Transient Drive Cycle Weighting   | 0.19                   |                            |
| GEM 55 mph Drive Cycle Weighting      | 0.17                   |                            |
| GEM 65 mph Drive Cycle Weighting      | 0.64                   |                            |

Table 15 shows the predefined modeling parameters that are consistent across all trailer types. Many of these common parameters are associated with the simulated tractor in the tractor-trailer model. The calculations for overall rolling resistance and the distribution of weight savings are consistent with the calculations for GEM-simulated tractors.

**Table 15 Common Predefined Modeling Parameters for All Box Trailers**

|                                    |   |
|------------------------------------|---|
| Engine Fuel Map                    | 15L - 455 HP  |
| Gear ratio                         | 12.8, 9.25, 6.76, 4.9, 3.58, 2.61, 1.89, 1.38, 1, 0.73  |
| Gearbox Efficiency                 | 98% for 1:1 gear ratio, and 96 for all other gears  |
| Axle Drive Ratio                   | 3.7   |
| Axle Mechanical Efficiency         | 95.5%   |
| Default Tractor Axle Configuration | 6x4   |
| Electrical Accessory Power (W)     | 300   |
| Mechanical Accessory Power (W)     | 1000  |
| Tire Radius (m)                    | 0.5   |
| Steer Tire Crr (kg/t)              | 6.54  |
| Drive Tire Crr (kg/t)              | 6.92  |
| Overall Tire Crr (kg/t)            | $= 0.425 \cdot \text{Trailer Crr} + 0.425 \cdot \text{Drive Crr} + 0.15 \cdot \text{Steer Crr}$ |
| Weight Reduction (lbs)             | Add 1/3*weight reduction to Payload tons  |

GEM allows a user to modify or adjust performance information for certain components in order to model and quantify improvements the manufacturer is making to its vehicles. The trailer program has three user-defined parameters and one pre-defined technology improvement option that has a specified reduction value associated with its use (see Table 16). Trailer manufacturers are able to change their tire rolling resistance, aerodynamic drag and cumulative weight reduction. GEM applies an additional technology improvement value of 1.5 percent for manufacturers that indicate they installed automatic tire inflation systems on their simulated trailer.

**Table 16 User-Defined Modeling Parameters and Technology Improvement Options for Trailers (All Lengths)**

| <b>Modeling Parameter</b>   | <b>Method of Determining Parameter</b>     |
|---|--|
| Trailer Tire Crr (kg/t)   | ISO 28580:2009(E), See 40 CFR 1037.515(b)  |
| Change in Aerodynamic Drag Area, $\Delta C_d A$ (m <sup>2</sup> ) | See 40 CFR 1037.515(c) and 40 CFR 1037.525 |
| Weight Reduction (lb)   | See 40 CFR 1037.515(d)                     |
| Automatic Tire Inflation System                                   | 1.5% if applied, See 40 CFR 1037.515(a)    |

## GEM Input File Structure

As mentioned previously, Phase 2 GEM does not offer a graphical user interface (GUI) for users to provide their vehicle parameters. Instead, inputs are exclusively provided to the model in a .csv file. Phase 2 GEM can be executed using either of two methods. The standard method directly initiates the model by running the executable file. Inputs for the standard method are provided as .csv files. The second method requires use of Microsoft Excel. Users generate an .xlsm input file using the template provided for their given vehicle subcategory and initiate the model by clicking the “RUN GEM” button within the spreadsheet. The button prompts a macro to generate the appropriate .csv file from the spreadsheet provided, and runs the executable. Additionally, the Excel spreadsheet features a “Validate” button which will check the input file for errors without running the executable. All methods provide their results in a .csv output file and an error log .txt file.

Some manufacturers that choose the standard method of running Phase 2 GEM may create a script to automatically generate their input files in .csv format. Others may wish to manually populate their files using a spreadsheet tool, such as Microsoft Excel, to easily view the input fields in a column format, and save the files in a .csv format. Some manufacturers may opt for the Excel-based method of generating inputs and creating the .csv input files through a macro. The following subsections describe the input file structures, which are consistent for each method of running the model. For illustration purposes, the .csv input files in this section are shown in spreadsheet format. The following section, Running GEM, describes the options for running the model.

## Note to Users Creating or Editing .csv Files Using Microsoft Excel

Users may use Microsoft Excel or any other text editor, such as Notepad, to create or edit their input files. Once a file is created, it can be saved by going to “Save As...” and choose *CSV (Comma delimited) (\*.csv)* in the “Save as type:” pull-down menu, as shown in Figure 12. In future saves, or when editing and resaving an existing .csv formatted file, users may receive a warning similar to Figure 13. Select “Yes” to ensure the file is properly saved in .csv format.

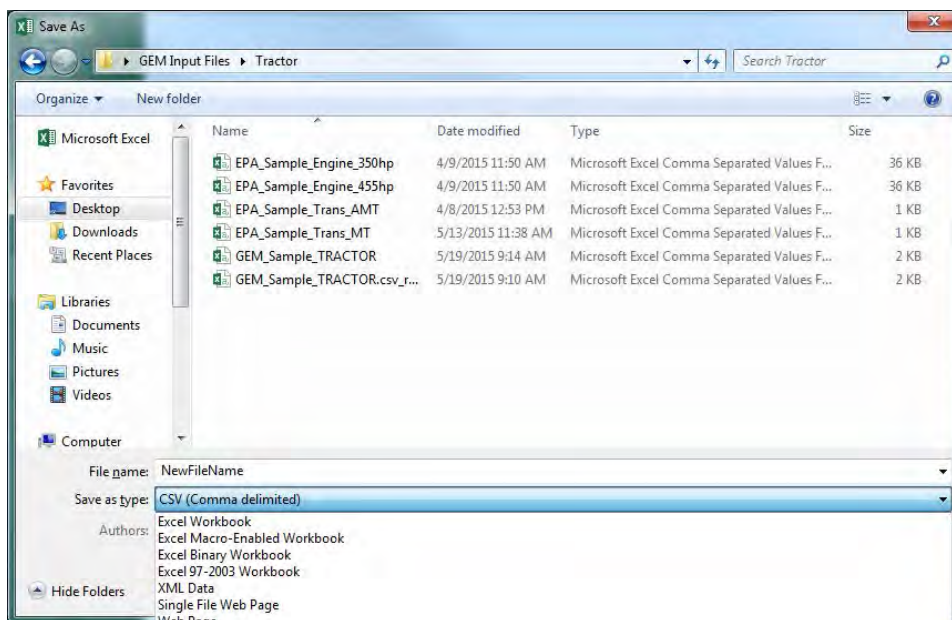


Figure 12: Example "Save As..." Window to Create a Comma Separated Value (.csv) Input File

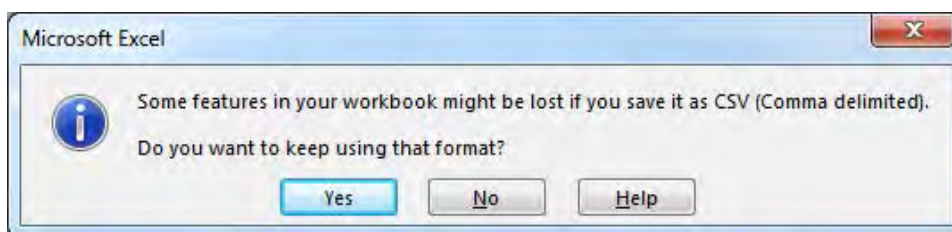


Figure 13: Warning from Microsoft Excel When Saving .csv Files Using Excel – Select “Yes”

## Tractor Input Files

The top of the tractor input file has three lines that list the regulatory category, manufacturer name and model year (see Figure 14). Users complete the second column for each line. The first line must read “Tractor” in order for GEM to run the appropriate vehicle model. Manufacturer name can be in any format, but it should be consistent with other regulatory documents from the manufacturer. Model year should be expressed as a four-digit number.



|                     |         |
|---------------------|---------|
| Regulatory Category | Tractor |
| Manufacturer Name   |         |
| Model Year          |         |

**Figure 14: Tractor Input File Header Information**

The next lines of the tractor input file contain the model inputs. In the first two columns, shown in Figure 15, the user provides a Run ID and the Regulatory Subcategory for each run. The Run ID is a unique value that will be used to identify the run (e.g., vehicle VIN). It can be any combination of letters, numbers and separators such as dash (“-”), periods (“.”), or underscores (“\_”). The Regulatory Subcategory determines which standard is applied for compliance. For tractors, there are 10 regulatory subcategories in GEM and Table 17 shows the naming convention.

|                   |                        |
|-------------------|------------------------|
| Run ID            | Regulatory Subcategory |
| Unique Identifier | (e.g. C8_SC_HR)        |
| TRAC1             | C8_SC_HR               |
| TRAC2             | C7_DC_HR               |
| TRAC3             | C8_DC_LR               |
| TRAC4             | C8_HH                  |
| TRAC_PT1          | C8_SC_MR               |
| TRAC_PT2          | C8_DC_MR               |
| TRAC_PT3          | C7_DC_HR               |

**Figure 15: Tractor Input File Run ID and Regulatory Subcategory Inputs**

**Table 17: Tractor Input File Naming Convention for Tractor Regulatory Subcategories**

| GEM Input Name | Regulatory Subcategory Description            |
|----------------|---|
| C8_SC_HR       | Class 8 Combination, Sleeper Cab - High Roof  |
| C8_SC_MR       | Class 8 Combination, Sleeper Cab - Mid Roof   |
| C8_SC_LR       | Class 8 Combination, Sleeper Cab - Low Roof   |
| C8_DC_HR       | Class 8 Combination, Day Cab - High Roof      |
| C8_DC_MR       | Class 8 Combination, Day Cab - Mid Roof       |
| C8_DC_LR       | Class 8 Combination, Day Cab - Low Roof       |
| C8_HH          | Class 8 Combination, Sleeper Cab - Heavy Haul |
| C7_DC_HR       | Class 7 Combination, Day Cab - High Roof      |
| C7_DC_MR       | Class 7 Combination, Day Cab - Mid Roof       |
| C7_DC_LR       | Class 7 Combination, Day Cab - Low Roof       |

The next columns contain the tractor performance parameters and several vehicle characteristics that are user-defined in GEM. A description of these parameters was given in Table 5 and additional information is available preamble to the proposed Phase 2 rulemaking.

| Aerodynamic                 | Tire               | Steer Axle Tire                         | Drive Axle Tire                         | Drive Axle |
|-----------------------------|--------------------|---|---|------------|
| Aerodynamic Drag Area (CdA) | Loaded Tire Radius | Coefficient of Rolling Resistance Level | Coefficient of Rolling Resistance Level | Ratio      |
| m^2                         | m                  | kg/t                                    | kg/t                                    | #          |
| 6.2                         | 0.5                | 6.5                                     | 6.9                                     | 3.7        |
| 6.4                         | 0.5                | 6.9                                     | 7.3                                     | 3.7        |
| 5.3                         | 0.47               | 6.8                                     | 6.9                                     | 3.82       |
| NA                          | 0.5                | 6.5                                     | 6.9                                     | 3.7        |
| 5.9                         | 0.5                | 6.5                                     | 6.9                                     | 3.37       |
| 5.8                         | 0.5                | 6.2                                     | 6.3                                     | 3.7        |
| 6.1                         | 0.5                | 4.8                                     | 5.1                                     | 2.95       |

**Figure 16: Tractor Input File Performance Parameters and User-Defined Vehicle Characteristics**

There are limits associated with each user-defined input value. Table 18 shows the limits for the five tractor inputs in the model. GEM will produce an error if any of these values are out of the acceptable range.

**Table 18: Minimum and Maximum Limits for User-Defined Values in Tractor Input File**

| User-Defined Parameter      | Units | Minimum Value | Maximum Value |
|-----------------------------|-------|---------------|---------------|
| Aerodynamic Drag Area (CdA) | m^2   | 4.1           | 7.6           |
| Tire Radius                 | m     | 0.3           | 0.6           |
| Steer Axle Tire, Crr        | kg/t  | 4.0           | 8.1           |
| Drive Axle Tire, Crr        | kg/t  | 4.2           | 8.5           |
| Drive Axle Ratio            | #     | 1.8           | 10            |

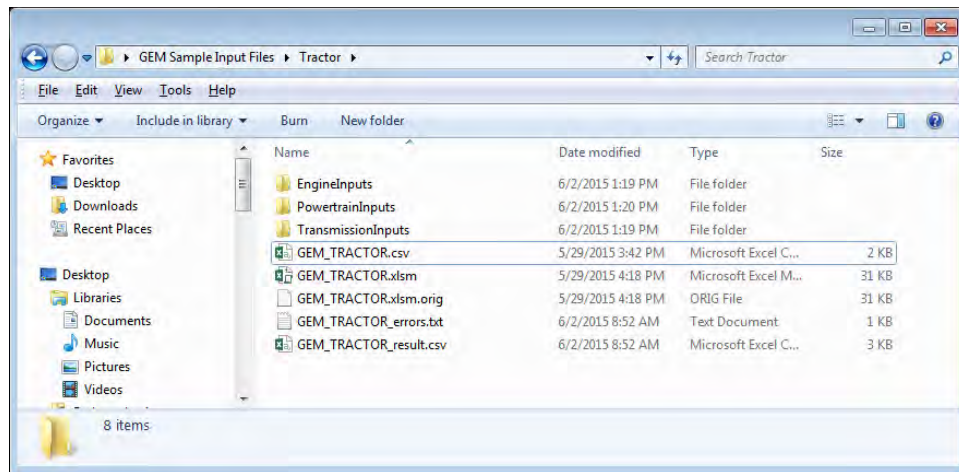
The next columns in the input file are for the engine and transmission file names or the powertrain file name. A description of the content of these supplemental input files is located at the end of this section. The text in the fields of the input file must exactly match the file name, including the .csv extension for the code to run properly. In Figure 17, these supplemental files are located in the same folder as the tractor input file. As a result, only the file name is needed.

Manufacturers may choose to perform powertrain testing to obtain the engine and transmission performance for their GEM simulations. In order to indicate to GEM that powertrain data is provided, users would provide the same powertrain input file name in both the Engine and Transmission file name fields of the tractor input file, as seen in the last three rows of Figure 17

| Engine               | Transmission       |
|----------------------|--------------------|
| Data                 | Data               |
| File Name            | File Name          |
| EPA_Sample_455hp.csv | EPA_Sample_AMT.csv |
| EPA_Sample_350hp.csv | EPA_Sample_AMT.csv |
| EPA_Sample_455hp.csv | EPA_Sample_MT.csv  |
| EPA_Sample_455hp.csv | EPA_Sample_AMT.csv |
| EPA_Sample_PT.csv    | EPA_Sample_PT.csv  |
| EPA_Sample_PT.csv    | EPA_Sample_PT.csv  |
| EPA_Sample_PT.csv    | EPA_Sample_PT.csv  |

**Figure 17: Tractor Input File Reference to Engine, Transmission, and Powertrain Input Files**

Users can also save their engine, transmission, and powertrain input files in separate folders within the same folder as the main vehicle input file, as shown in Figure 18. At this time, the model is not able to reference folders for the supplemental input files located outside of the vehicle input file's directory.



**Figure 18: Option to Save Engine, Powertrain, and Transmission Input Files in Separate Folders**

If the supplemental input files are located in the folders shown in Figure 18, the text in the Engine and Transmission fields of the input file would match the text in Figure 19.

| Engine                             | Transmission                          |
|------------------------------------|---------------------------------------|
| Data                               | Data                                  |
| File Name                          | File Name                             |
| EngineInputs\EPA_Sample_455hp.csv  | TransmissionInputs\EPA_Sample_AMT.csv |
| EngineInputs\EPA_Sample_350hp.csv  | TransmissionInputs\EPA_Sample_AMT.csv |
| EngineInputs\EPA_Sample_455hp.csv  | TransmissionInputs\EPA_Sample_MT.csv  |
| EngineInputs\EPA_Sample_455hp.csv  | TransmissionInputs\EPA_Sample_AMT.csv |
| PowertrainInputs\EPA_Sample_PT.csv | PowertrainInputs\EPA_Sample_PT.csv    |
| PowertrainInputs\EPA_Sample_PT.csv | PowertrainInputs\EPA_Sample_PT.csv    |
| PowertrainInputs\EPA_Sample_PT.csv | PowertrainInputs\EPA_Sample_PT.csv    |

**Figure 19: Tractor Input File Reference to Engine, Transmission, and Powertrain Input Files When Files are Located in Separate Folders**

The next columns in the tractor input file are for the optional technology improvements. These technology improvements were summarized in Table 6. These technology improvement fields cannot be blank in the input file. Users that wish to model their vehicle with weight reduction can enter the cumulative weight reduction value (0 to 10,000 lbs or “NA”) in the first field. The use of a speed limiter is modeled by inserting the speed limit value. Note that GEM does not provide a benefit for speed limiters set above 65 mph. Vehicles without a speed limiter would use the value “NA”. The remaining technology improvements are Boolean values (“Y”

for yes, “N” for no). By default, these inputs are set to “N”. Note that the Single Drive Axle improvement is only available to Class 8 tractors, since Class 7 tractors are only modeled with a single-drive axle, and that Idle Reduction with APU is only available to the Class 8 sleeper cab tractors. Also note that these inputs are case-sensitive. All values of “Y”, “N”, or “NA” must be in UPPERCASE LETTERS. Lowercase letters will produce an error.

**Table 19: Summary of Technology Improvements in Tractor Input File**

| Technology Improvement                                      | Units | Range                         |
|---|-------|-------------------------------|
| Weight Reduction  | lbs   | 0 to 10,000 or “NA”           |
| Speed Limiter   | MPH   | 0 to 65 or “NA”               |
| Single Drive Axle (applies to Class 8 only)                 | Y/N   | Must be "Y" or "N", not blank |
| Part Time Single Drive Axle (applies to Class 8 only)       | Y/N   | Must be "Y" or "N", not blank |
| Low Friction Axle Lubricant                                 | Y/N   | Must be "Y" or "N", not blank |
| Predictive Cruise Control                                   | Y/N   | Must be "Y" or "N", not blank |
| High Efficiency A/C Compressor                              | Y/N   | Must be "Y" or "N", not blank |
| Electric Accessories  | Y/N   | Must be "Y" or "N", not blank |
| Extended Idle Reduction (Class 8 sleeper cab tractors only) | Y/N   | Must be "Y" or "N", not blank |
| Automatic Tire Inflation System                             | Y/N   | Must be "Y" or "N", not blank |

Users may note that Table 19 does not include the technology improvement input from automated transmissions as indicated from Chapter 4 of the draft RIA. This is because GEM is designed in such a way that once users select automated manual, dual clutch or automatic transmission in the transmission input .csv file, the technology improvement input is automatically added into the post processor to get benefits.

## Vocational Input Files

The top of the vocational input file has three lines that list the regulatory category, manufacturer name and model year (see Figure 20). The first line must read “Vocational” in order for GEM to run the appropriate vehicle model. Manufacturer name can be in any format, but it should be consistent with other regulatory documents from the manufacturer. Model year should be expressed as a four-digit number.

|                     |            |
|---------------------|------------|
| Regulatory Category | Vocational |
| Manufacturer Name   |            |
| Model Year          |            |

**Figure 20: Vocational Input File Header Information**

The next lines of the vocational input file contain the model inputs. In the first two columns, shown in Figure 21, the user provides a Run ID and the Regulatory Subcategory for each run. The Run ID is a unique value that will be used to identify the run (e.g., vehicle VIN). It can be any combination of letters, numbers and separators such as dash (“-”), periods (“.”), or underscores (“\_”). The Regulatory Subcategory determines which standard is applied for

compliance. For vocational, there are 12 regulatory subcategories in GEM and Table 20 shows the naming convention.

| Run ID            | Regulatory Subcategory |
|-------------------|------------------------|
| Unique Identifier | (e.g HHD_R)            |
| VOC1              | HHD_R                  |
| VOC2              | HHD_M                  |
| VOC3              | MHD_R                  |
| VOC4              | LHD_U                  |
| VOC5              | MHD_E                  |
| VOC_PT1           | MHD_M                  |
| VOC_PT2           | MHD_U                  |
| VOC_PT3           | LHD_M                  |

**Figure 21: Vocational Input File Run ID and Regulatory Subcategory Inputs**

**Table 20: Vocational Input File Naming Convention for Vocational Regulatory Subcategories**

| GEM Input Name | Regulatory Subcategory Description |
|----------------|------------------------------------|
| HHD_R          | Heavy-Heavy Duty, Regional         |
| HHD_M          | Heavy-Heavy Duty, Multipurpose     |
| HHD_U          | Heavy-Heavy Duty, Urban            |
| MHD_R          | Medium-Heavy Duty, Regional        |
| MHD_M          | Medium-Heavy Duty, Multipurpose    |
| MHD_U          | Medium-Heavy Duty, Urban           |
| LHD_R          | Light-Heavy Duty, Regional         |
| LHD_M          | Light-Heavy Duty, Multipurpose     |
| LHD_U          | Light-Heavy Duty, Urban            |
| HHD_E          | Heavy-Heavy Duty, Emergency        |
| MHD_E          | Medium-Heavy Duty, Emergency       |
| LHD_E          | Light-Heavy Duty, Emergency        |

The next columns contain the vocational performance parameters and vehicle characteristics that are user-defined in GEM. A description of these parameters was given in Table 12 and additional information is available in the preamble to the proposed Phase 2 rulemaking.

| Tire               | Steer Axle Tire                         | Drive Axle Tire                         | Drive Axle |
|--------------------|---|---|------------|
| Loaded Tire Radius | Coefficient of Rolling Resistance Level | Coefficient of Rolling Resistance Level | Ratio      |
| m                  | kg/t                                    | kg/t                                    | #          |
| 0.48               | 7.7                                     | 7.7                                     | 3.76       |
| 0.48               | 7.7                                     | 7.7                                     | 4.33       |
| 0.46               | 7.7                                     | 7.7                                     | 4.33       |
| 0.38               | 7.7                                     | 7.7                                     | 4.1        |
| NA                 | 7.7                                     | 7.7                                     | NA         |
| 0.48               | 6.5                                     | 6.8                                     | 4.33       |
| 0.48               | 7.1                                     | 7.5                                     | 4.33       |
| 0.48               | 7.1                                     | 7.5                                     | 4.33       |

**Figure 22: Vocational Input File Performance Parameters and User-Defined Vehicle Characteristics**

There are limits associated with each user-defined input value. Table 21 shows the limits for the four vocational inputs in the model. GEM will produce an error if any of these values are out of the acceptable range.

**Table 21: Minimum and Maximum Limits for User-Defined Values in Vocational Input File**

| User-Defined Parameter | Units | Minimum Value | Maximum Value |
|------------------------|-------|---------------|---------------|
| Tire Radius            | m     | 0.2           | 0.7           |
| Steer Axle Tire Crr    | kg/t  | 4.0           | 12.0          |
| Drive Axle Tire Crr    | kg/t  | 4.0           | 12.0          |
| Drive Axle Ratio       | none  | 1.8           | 12.0          |

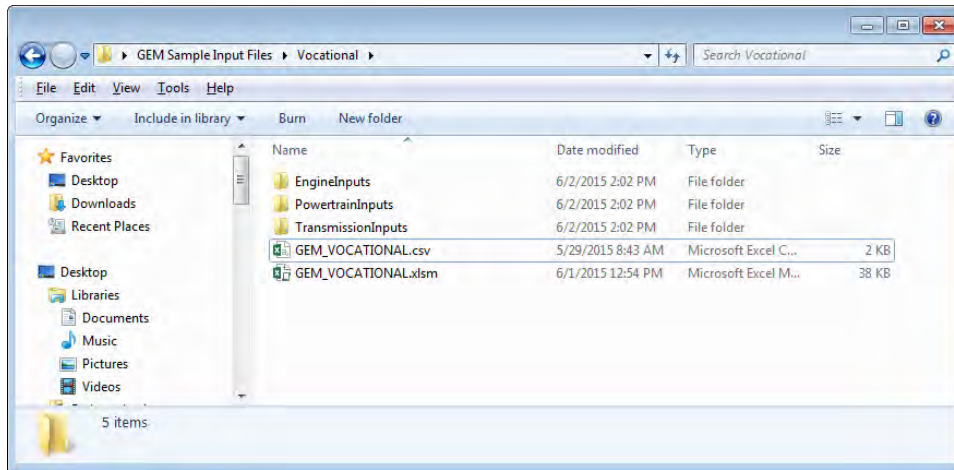
The next columns in the input file are for the engine and transmission file names or the powertrain file name. A description of the content of these supplemental input files is located at the end of this section. The text in the fields of the input file must exactly match the file name, including the .csv extension for the code to run properly. In Figure 23, these engine or transmission files are located in the same folder as the vocational input file. As a result, only the file name is needed.

Manufacturers may choose to perform powertrain testing to obtain the engine and transmission performance for their GEM simulations. In order to indicate to GEM that powertrain data is provided, users would provide the same powertrain input file name in both the Engine and Transmission file name fields of the tractor input file, as seen in the last three columns of Figure 23.

| Engine               | Transmission             |
|----------------------|--------------------------|
| Data                 | Data                     |
| File Name            | File Name                |
| EPA_Sample_455hp.csv | EPA_Sample_MT_10_HHD.csv |
| EPA_Sample_345hp.csv | EPA_Sample_AT_5_HHD.csv  |
| EPA_Sample_270hp.csv | EPA_Sample_AT_5_MLHD.csv |
| EPA_Sample_200hp.csv | EPA_Sample_AT_5_MLHD.csv |
| NA                   | NA                       |
| EPA_Sample_PT.csv    | EPA_Sample_PT.csv        |
| EPA_Sample_PT.csv    | EPA_Sample_PT.csv        |
| EPA_Sample_PT.csv    | EPA_Sample_PT.csv        |

**Figure 23: Vocational Input File Reference to Engine, Transmission, and Powertrain Input Files**

Users can also save their engine, transmission, and powertrain input files in separate folders within the same folder as the main vehicle input file, as shown in Figure 24.



**Figure 24: Option to Save Engine, Powertrain, and Transmission Input Files in Separate Folders**

If the supplemental input files are located in the folders shown in Figure 24, the text in the Engine and Transmission fields of the vocational input file would match the text in Figure 25. Note that the fifth row contains “NA” for both the engine and transmission file names, since the vehicle modeled in the sample file is an emergency vehicle.

| Engine                             | Transmission                                |
|------------------------------------|---|
| Data                               | Data  |
| File Name                          | File Name                                   |
| EngineInputs\EPA_Sample_455hp.csv  | TransmissionInputs\EPA_Sample_MT_10_HHD.csv |
| EngineInputs\EPA_Sample_345hp.csv  | TransmissionInputs\EPA_Sample_AT_5_HHD.csv  |
| EngineInputs\EPA_Sample_270hp.csv  | TransmissionInputs\EPA_Sample_AT_5_MLHD.csv |
| EngineInputs\EPA_Sample_200hp.csv  | TransmissionInputs\EPA_Sample_AT_5_MLHD.csv |
| NA                                 | NA  |
| PowertrainInputs\EPA_Sample_PT.csv | PowertrainInputs\EPA_Sample_PT.csv          |
| PowertrainInputs\EPA_Sample_PT.csv | PowertrainInputs\EPA_Sample_PT.csv          |
| PowertrainInputs\EPA_Sample_PT.csv | PowertrainInputs\EPA_Sample_PT.csv          |

**Figure 25: Vocational Input File Reference to Engine, Transmission, and Powertrain Input Files When Files are Located in Separate Folders**

The next columns in the vocational input file are for the optional technology improvements. These technology improvements were summarized in Table 11. These technology improvement fields cannot be blank in the input file. Users that wish to model their vehicle with weight reduction can enter the cumulative weight reduction value (0 to 10,000 lbs or “NA”) in the first field. The remaining technology improvements are Boolean values (“Y” for yes, “N” for no). By default, these inputs are set to “N”. Note that the Single Drive Axle improvement (also known as axle disconnect) is only available to Heavy Heavy-Duty Regional vehicles. If selected for other vocational subcategories, the input will produce an error. Also, note that the stop-start and neutral idle technologies are mutually exclusive and users will receive an error if both technology options are selected for the same vehicle. If the vocational vehicle will be built with a hybrid PTO and testing was conducted according to 40 CFR 1037.540, then the Delta PTO value obtained from that test procedure may be entered. Also note that these



inputs are case-sensitive. All values of “Y”, “N”, or “NA” must be in UPPERCASE LETTERS. Lowercase letters will produce an error.

**Table 22: Summary of Technology Improvements in Vocational Input File**

| Technology Improvement                            |            |                               |
|---|------------|-------------------------------|
| Delta PTO Fuel                                    | g/ton-mile | 0 ... 30 or “NA”              |
| Weight Reduction                                  | lbs        | 0 ... 10,000 or “NA”          |
| Single Drive Axle (applies to HHD only)           | Y/N        | Must be "Y" or "N", not blank |
| Part Time Single Drive Axle (applies to HHD only) | Y/N        | Must be "Y" or "N", not blank |
| Low Friction Axle Lubricant                       | Y/N        | Must be "Y" or "N", not blank |
| Neutral-Idle                                      | Y/N        | Must be "Y" or "N", not blank |
| Stop-Start  | Y/N        | Must be "Y" or "N", not blank |

Similar to tractors, Table 22 does not include the technology improvement inputs for automated transmissions for HHD Regional vehicles, once users select an automated manual or dual clutch transmission in the transmission input .csv file for HHD Regional vehicles, the technology improvement input is automatically added into the post processor to get benefits. For all subcategories, GEM simulates DCT as AMT.

## Trailer Input Files

The top of the trailer input file has three lines that list the regulatory category, manufacturer name and model year (see Figure 26). The first line must read “Trailer” in order for GEM to run the appropriate vehicle model. Manufacturer name can be in any format, but it should be consistent with other regulatory documents from the manufacturer. Model year should be expressed as a four-digit number.

|                     |         |
|---------------------|---------|
| Regulatory Category | Trailer |
| Manufacturer Name   |         |
| Model Year          |         |

**Figure 26: Trailer Input File Header Information**

The next lines of the trailer input file contain the model inputs. In the first two columns, shown in Figure 27, the user provides a Run ID and the Regulatory Subcategory for each run. The Run ID is a unique value that will be used to identify the run. It can be any combination of letters, numbers and separators such as dash (“-”), periods (“.”), or underscores (“\_”). The Regulatory Subcategory determines which standard is applied for compliance. For trailers, there are four regulatory subcategories modeled in GEM and Table 23 shows the naming convention.

|                   |                        |
|-------------------|------------------------|
| Run ID            | Regulatory Subcategory |
| Unique Identifier | (e.g. LDV)             |
| TRL1              | LDV                    |
| TRL2              | LRV                    |
| TRL3              | SDV                    |

**Figure 27: Trailer Input File Run ID and Regulatory Subcategory Inputs**

**Table 23: Trailer Input File Naming Convention for Trailer Regulatory Subcategory Inputs**

| GEM Input Name | Regulatory Subcategory Description |
|----------------|------------------------------------|
| LDV            | Long Dry Van                       |
| LRV            | Long Refrigerated Van              |
| SDV            | Short Dry Van                      |
| SRV            | Short Refrigerated Van             |

The next columns contain the trailer performance parameters and technology improvement options that are user-defined in GEM. A description of these parameters was given in Table 16 and additional information is available preamble to the proposed Phase 2 rulemaking. Note that the aerodynamic improvement for trailers is measured as a *delta* CdA and not the absolute CdA value used in the proposed tractor program.

| Aerodynamic Improvement (Delta) | Trailer Tire                            | Technology Improvement | Technology Improvement          |
|---------------------------------|---|------------------------|---------------------------------|
| Aerodynamic Drag Area (CdA)     | Coefficient of Rolling Resistance Level | Weight Reduction       | Automatic Tire Inflation System |
| m^2                             | kg/t                                    | lbs                    | Y/N                             |
| 0.3                             | 5.6                                     | 600                    | Y                               |
| 0.1                             | 6.3                                     | 0                      | N                               |
| 0.4                             | 6                                       | 150                    | N                               |

**Figure 28: Trailer Input File Performance Parameters and User-Defined Vehicle Characteristics**

There are limits associated with each user-defined input value. Table 21 shows the limits for the two trailer inputs in the model. GEM will produce an error if any of these values are out of the acceptable range.

**Table 24: Minimum and Maximum Limits for User-Defined Values in Trailer Input File**

| User-Defined Parameter               | Units | Minimum Value | Maximum Value |
|--------------------------------------|-------|---------------|---------------|
| Aerodynamic Drag Area (CdA)          | m^2   | 0             | 2             |
| Tire Rolling Resistance Level (TRRL) | kg/t  | 3             | 7             |

The technology improvement fields cannot be blank in the input file. Users that wish to model their vehicle with weight reduction can enter the cumulative weight reduction value (0 to 10,000 lbs or “NA”) in the first field. The automatic tire inflation input is a Boolean (“Y” for yes, “N” for no). By default, this inputs is set to “N”. Note that these inputs are case-sensitive.

All values of “Y”, “N”, or “NA” must be in UPPERCASE LETTERS. Lowercase letters will produce an error.

**Table 25: Summary of Technology Improvements in Trailer Input File**

| Technology Improvement          | Units | Range                         |
|---------------------------------|-------|-------------------------------|
| Weight Reduction                | lbs   | 0 to 10,000 or “NA”           |
| Automatic Tire Inflation System | none  | Must be "Y" or "N", not blank |

## Supplemental Input Files

Tractor and vocational vehicle manufacturers are required to generate either separate engine and transmission input files, or a single powertrain input file for GEM. These files must be in .csv format to be properly read by the model. The GEM installation file includes a template for these supplemental input files. A vehicle manufacturer would generate a separate engine and transmission file for each engine and transmission used in its vehicles or separate powertrain files for each engine and transmission combination tested. We recommend that the manufacturers choose a consistent naming convention that provides unique file names for these input files. An example naming convention for each file type is provided in Table 26. However, manufacturers are free to choose their own naming convention for all of their input files.

**Table 26 Example Naming Convention for GEM Input Files**

| Input File Type | Example Naming Convention                                |
|-----------------|--|
| Engine          | MfrName_FuelType_ModelYear_ModelName_CalibrationID.csv   |
| Transmission    | MfrName_TransType_Gears_ModelName_CalibrationID.csv      |
| Powertrain      | MfrName_EngineName_TransName_ModelYear_CalibrationID.csv |

## Engine Input File for Tractor and Vocational Vehicles

The first row of the GEM input file for engines shows the GEM version, and manufacturers would fill in the fourth row with the Manufacturer Name, Combustion Type, Fuel Type, Family Name, and Calibration ID, as shown in Figure 29. The manufacturer can choose any Manufacturer Name, Family Name and Calibration ID, but the names should be consistent with other regulatory documents from the manufacturer. Combustion Type and Fuel Type have specific options for a manufacturer to choose.

|                       |   |                                 |                     |                |
|-----------------------|---|---------------------------------|---------------------|----------------|
| GEM Engine Definition |   |                                 |                     |                |
| Manufacturer Name     | Combustion Type                         | Fuel Type                       | Family Name         | Calibration ID |
| (e.g. Cummins)        | (Compression Ignition / Spark Ignition) | (Diesel / Gasoline / LNG / CNG) | (e.g. abcd12345efg) | (e.g. 123abc)  |
| EPA                   | Compression Ignition                    | Diesel                          | GENERIC             | 1              |

**Figure 29: Sample Engine Input File Header Information**

The manufacturer then specifies the single engine idle speed point (in RPM) at curb idle transmission torque (CITT), the engine full-load torque curve, and the engine motoring torque curve. Torque curves are specified in RPM and Nm, and procedures for producing the torque

curves, including the number of speed and torque points to measure, are specified in 40 CFR 1065.510. Finally the manufacturer provides the four-point engine idle fuel map and the 143-point engine fuel map. The speed, torque, and fuel rate in the fuel maps are specified in RPM, Nm, and g/s, respectively. Procedures for generating the idle and full engine fuel maps are specified in 40 CFR 1036.535 and 1065.510. Figure 30 shows a summary of the sample engine input file included with Phase 2 GEM.

|                               |        |             |
|-------------------------------|--------|-------------|
| Engine Idle Speed at CITT     |        |             |
| RPM                           |        |             |
| 750                           |        |             |
|                               |        |             |
| Engine Full Load Torque Curve |        |             |
| Speed                         | Torque |             |
| RPM                           | Nm     |             |
| 0                             | 0      |             |
| 750                           | 440    |             |
| 907                           | 580    |             |
| 1055                          | 690    |             |
| :                             | :      |             |
| :                             | :      |             |
| :                             | :      |             |
| 2601                          | 0      |             |
| Engine Motoring Torque Curve  |        |             |
| Speed                         | Torque |             |
| RPM                           | Nm     |             |
| 0                             | -129   |             |
| 750                           | -129   |             |
| 907                           | -129   |             |
| 1055                          | -130   |             |
| :                             | :      |             |
| :                             | :      |             |
| :                             | :      |             |
| 2700                          | -199   |             |
| Engine Idle Fuel Map          |        |             |
| Speed                         | Torque | Fuel Rate   |
| RPM                           | Nm     | grams / sec |
| 600                           | 17     | 0.21        |
| 700                           | 17     | 0.23        |
| 600                           | 88     | 0.46        |
| 700                           | 88     | 0.50        |
| Engine Fuel Map               |        |             |
| Speed                         | Torque | Fuel Rate   |
| RPM                           | Nm     | grams / sec |
| 750                           | 0      | 0.2         |
| 750                           | 44     | 0.35        |
| 750                           | 88     | 0.53        |
| :                             | :      | :           |
| :                             | :      | :           |
| :                             | :      | :           |
| 2218                          | 642    | 8.41        |

**Figure 30: Sample Engine Input File Engine Characteristics**

### Transmission Input File for Tractor and Vocational Vehicles

The first row of the GEM input file for transmissions shows the GEM version, and manufacturers would fill in the fifth row with the transmission's Manufacturer Name, Type, and Model Name (see Figure 31). The vehicle manufacturer can choose any Manufacturer Name and Model Name for the transmission, but it should remain consistent with other regulatory documents. The transmission Type has specific options for the manufacturer to choose.

| GEM Transmission Definition |                       |             |
|-----------------------------|-----------------------|-------------|
| Manufacturer Name           | Type                  | Model Name  |
| (e.g. Eaton)                | (AMT / MT / AT / DCT) | (e.g. 7100) |
| EPA                         | AT                    | HHD         |

**Figure 31: Sample Transmission Input File Header Information**

Vehicle manufacturers would provide the gear ratios for their specific transmission, as seen in the sample shown in Figure 32. If the transmission is an automatic transmission that has a lockup gear other than the one programmed in the GEM shift strategy, the benefits of this will not be recognized unless a powertrain test is conducted.

| Transmission Gears |            |
|--------------------|------------|
| Gear Number        | Gear Ratio |
| 1                  | 4.7        |
| 2                  | 2.21       |
| 3                  | 1.53       |
| 4                  | 1          |
| 5                  | 0.76       |

**Figure 32: Sample Transmission Input File Transmission Gear Ratio Information**

### Optional Powertrain Input File for Tractor and Vocational Vehicles

Users may opt to use engine and transmission performance data obtained from a powertrain test in their GEM runs. Procedures for generating the data to populate a powertrain input file can be found in 40 CFR 1037.550. This section summarizes the input file format.

The first row of the GEM input file from powertrain testing show the GEM version and manufacturers would fill in the fifth, ninth, and thirteenth rows with the relevant information about the engine, transmission and powertrain, respectively. Figure 33 shows the header information required by the model.

|  |  |  |                                    |                                 |
|--|--|--|------------------------------------|---------------------------------|
| GEM Powertrain Definition                      |  |  |                                    |                                 |
| Engine Manufacturer Name<br>(e.g. Cummins)     | Combustion Type<br>(Compression Ignition / Spark Ignition) | Fuel Type<br>(Diesel / Gasoline / LNG / CNG)                       | Family Name<br>(e.g. abcd12345efg) | Calibration ID<br>(e.g. 123abc) |
| Cummins  | Compression Ignition                                       | Diesel   | ISX                                | CAL1                            |
| Transmission Manufacturer Name<br>(e.g. Eaton) | Type<br>(AMT / MT / AT / DCT)                              | Gears<br>Number  | Model Name<br>(e.g. 7100)          |                                 |
| Eaton  | AMT  | 10   | ULTRASHIFT13LAS                    |                                 |
| Powertrain Family Name<br>(e.g. abcd12345efg)  | Calibration ID<br>(e.g. 123abc)                            | Powertrain Test Configuration<br>(1: Trans. Output, 2: Wheel Hubs) |                                    |                                 |
| SmartAdvantage                                 | CAL1   | 1  |                                    |                                 |

**Figure 33: Sample Powertrain Input File Header Information**

The next rows of the powertrain input file, as seen in Figure 34, include the engine idle fuel rate and the powertrain performance information from the 55-MPH, 65-MPH, and Transient drive cycle tests. Users would supply the cycle work, output speed/vehicle speed, and fuel mass according to the procedures outlined in 40 CFR 1037.550(o).

|                       |             |           |
|-----------------------|-------------|-----------|
| Engine Idle Fuel Rate |             |           |
| grams / sec           |             |           |
| 0.576                 |             |           |
| 55 MPH Cruise         |             |           |
| Powertrain Cycle Work | N/V         | Fuel Mass |
| kWh                   | rev / meter | grams     |
| 25.28                 | 0.86        | 5031      |
| 25.25                 | 0.93        | 5050      |
| :                     | :           | :         |
| :                     | :           | :         |
| :                     | :           | :         |
| 18.85                 | 1.00        | 3845      |
| 65 MPH Cruise         |             |           |
| Powertrain Cycle Work | N/V         | Fuel Mass |
| kWh                   | rev / meter | grams     |
| 29.49                 | 0.86        | 5780      |
| 29.62                 | 0.93        | 5865      |
| :                     | :           | :         |
| :                     | :           | :         |
| :                     | :           | :         |
| 21.32                 | 1.00        | 4371      |
| Transient             |             |           |
| Powertrain Cycle Work | N/V         | Fuel Mass |
| kWh                   | rev / meter | grams     |
| 8.28                  | 0.86        | 2012      |
| 8.41                  | 0.93        | 2027      |
| :                     | :           | :         |
| :                     | :           | :         |
| :                     | :           | :         |
| 8.01                  | 1.00        | 1930      |

**Figure 34: Sample Powertrain Input File Performance Information**

## GEM Output File Structure

An output file will be generated when the vehicle simulation completes and it is automatically saved to the same location as the input file. As will be described in the following section, the output file naming convention depends on the method chosen to run GEM. If users run GEM from the Start Menu or command prompt, the output file name will be given the same name as the input file with a “\_result.csv” extension. If users choose to run GEM using the Excel macro template, the output file will be renamed to match the date and time of the simulation, in the format: GEM\_YYYYMMDD\_HHmmSS\_result.csv. During the simulation using either method, an error log file will be generated, even if there are no errors, with the same base name as the output file, except that the “\_result.csv” extension would be replaced with a “\_errors.txt” extension.

Each output file is identical to the input file for the vehicle modeled, except that the last columns of the .csv file are populated with the model’s results. Figure 35 shows the results of an example simulation. The results fields are the same for each vehicle type, but their column location in the file varies. The first result column indicates the date and time when the simulation was performed. The next two columns are the raw GEM CO<sub>2</sub> emissions and fuel consumption values. The next two columns are the Family Emissions Limit (FEL) values EPA and NHTSA will use for compliance. EPA’s CO<sub>2</sub> results are integer values. NHTSA’s fuel consumption results are calculated from those CO<sub>2</sub> integer values, and are reported with four decimal place precision to ensure consistency between the agencies’ results.

| Date/Time of Run<br>YYYY_MMDD_HHMMSS | GEM CO2 Emissions<br>g CO2/ton-mile | GEM Consumption<br>gal/1000 ton-mile | FEL CO2 Emissions<br>g CO2/ton-mile | FEL Fuel Consumption<br>gal/1000 ton-mile | Subfamily<br>Name | Subfamily FEL<br>g CO2/ton-mile | Subfamily Volume<br># |
|--------------------------------------|-------------------------------------|--------------------------------------|-------------------------------------|---|-------------------|---------------------------------|-----------------------|
| 2015-0602 08:50:58                   | 79.41483702                         | 7.80106454                           | 79                                  | 7.7603                                    |                   |                                 |                       |
| 2015-0602 08:51:09                   | 113.4204621                         | 11.14149922                          | 113                                 | 11.1002                                   |                   |                                 |                       |
| 2015-0602 08:51:22                   | 83.93181444                         | 8.24477549                           | 84                                  | 8.2515                                    |                   |                                 |                       |
| 2015-0602 08:51:33                   | 50.47378154                         | 4.95813178                           | 50                                  | 4.9116                                    |                   |                                 |                       |
| 2015-0602 08:51:43                   | 73.92637368                         | 7.26192276                           | 74                                  | 7.2692                                    |                   |                                 |                       |
| 2015-0602 08:51:52                   | 82.33588608                         | 8.08800453                           | 82                                  | 8.0550                                    |                   |                                 |                       |
| 2015-0602 08:51:58                   | 103.9311183                         | 10.20934365                          | 104                                 | 10.2161                                   |                   |                                 |                       |

**Figure 35: Example Results Columns in GEM Output File**

The final three columns of the output file are left blank by the model. Manufacturers would manually add the appropriate subfamily name, target FEL for the given subfamily, and the volume of vehicles that will use the resulting FEL value prior to submitting their output file for compliance.

## Running GEM

There are three options for running GEM. The first option directly accesses the program’s executable file via the Start Menu folders, the Start Menu search, or a GEM icon on the computer’s desktop screen. This first option initiates the GEM graphical user interface (GUI) to select and run the model. The second option uses the command prompt, which can also initiate the GEM GUI, but has the option to suppress it. The third option uses a Microsoft Excel macro to convert a spreadsheet template into the appropriate input files and run the executable with the GEM GUI. Each of these options is described in the following sections.



## Preparing for GEM Runs

Prior to running GEM, it is important to locate all of the necessary input files. Many computers will produce warnings if the users try to make changes to files in the installation folder if it is located in the C:\Program Files directory. It is recommended that users save a copy of the input file templates from the installation folder (i.e., C:\Program Files\US EPA\Phase 2 GEM\Sample Input Files – RELOCATE BEFORE USE) to a location on their hard drive (e.g., C:\Documents and Settings\UserName\My Documents). These files can then be changed as needed to reflect the users' specific vehicles. See the previous sections for a description of the input files.

## Special Instructions for Heavy-Haul Tractor Manufacturers

Tractors that qualify for the heavy-haul regulatory subcategory designation have special instructions for their vehicle input file. These tractors are not required to perform aerodynamic testing to obtain an aerodynamic drag area, CdA, for their GEM input. As a result, users are instructed to use a CdA value of "NA" for all heavy-haul tractors. This value is added to the third column of the tractor vehicle input file. All other fields should be populated using the same instructions provided previously for tractors.

## Special Instructions for Vocational Emergency Vehicle Manufacturers

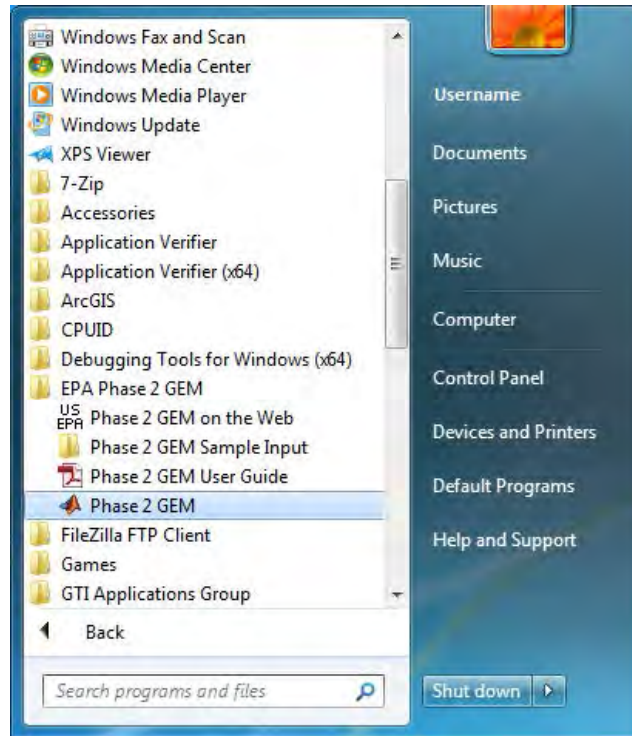
Vocational vehicles that qualify for the emergency vehicle regulatory subcategory designation also have special instructions for their vehicle input file. These manufacturers are only allowed to apply lower rolling resistance tires to their steer and drive tires. They do not have to provide engine or transmission information, and do not have the option of applying technology inputs. If the Regulatory Subcategory field in the vehicle input file is populated with an emergency vehicle (i.e., HHD\_E, MHD\_E, or LHD\_E), users must fill-in the remaining fields in the file with "NA" or "N" as appropriate. See the sample input file for vocational vehicles for an example.

## Accessing Output Files

Output files from the GEM simulations are automatically saved in the same location as the input files. They can be identified by their "\_result.csv" or "\_errors.txt" file extensions. Identical output files are generated for each of the methods described below.

## Running GEM Using the Start Menu and Desktop Icon

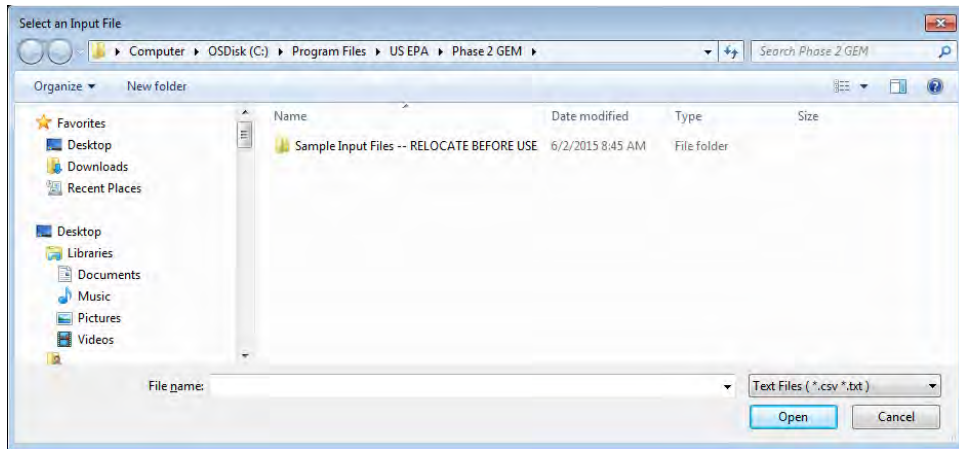
Users can access the Phase 2 GEM executable from the Start Menu. Go to Programs > EPA Phase 2 GEM > Phase 2 GEM as shown in Figure 36.



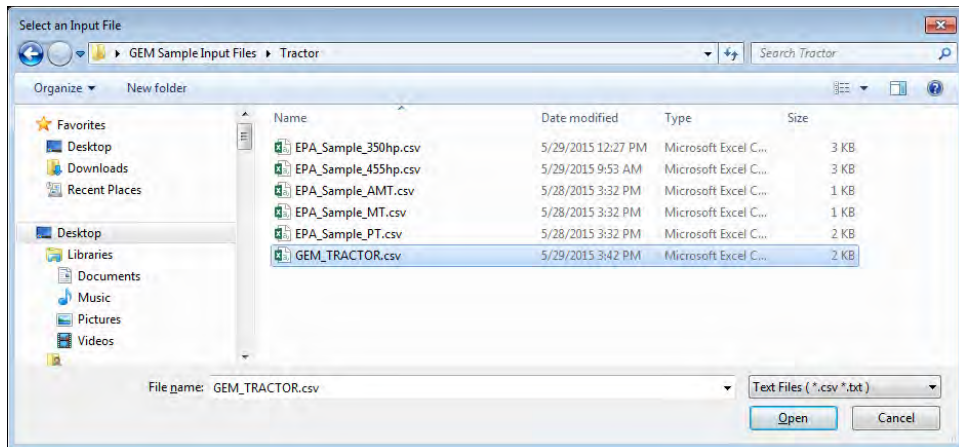
**Figure 36: How to Access Phase 2 GEM from the Start Menu**

Alternatively, users can access the executable by typing “Phase 2 GEM” in the *Search programs and files* box located at the bottom of the Start Menu, and hitting “Enter”. If users select the option – “Create Desktop Icon” during installation, users can double click the icon (shown previously in Figure 6) to run GEM as well to initiate the program.

Once the executable is selected, a window will ask the user to select an input file, as shown in Figure 37. By default, the program will first look in the installation folder. As mentioned previously, all of the input files are in a separate location to avoid permissions warnings, and the necessary transmission and engine input files are located in the same directory as the input file to be run. In this example, we are storing our files on the Desktop. Select the appropriate input file (GEM\_Sample\_TRACTOR.csv in Figure 38) to begin the simulation.

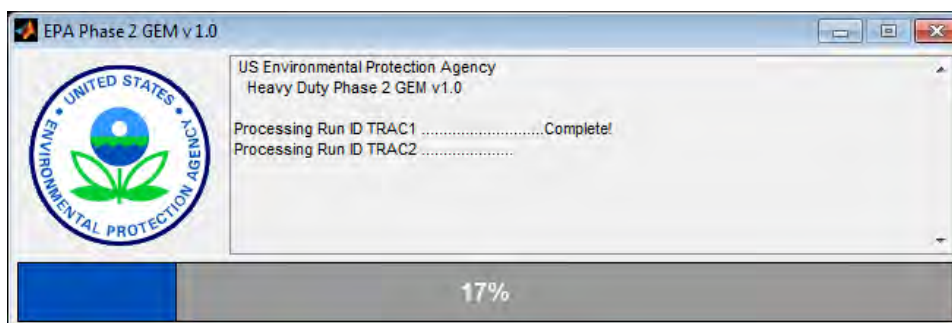


**Figure 37: Popup Window to Select an Input File Using the Start Menu Option; Defaults to Installation Folder**



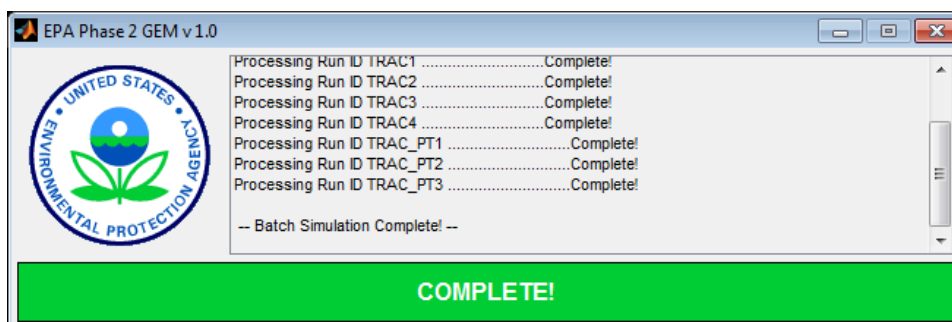
**Figure 38: Location of Input Files for Example GEM Simulations**

Once the input file is selected, the program will begin to run. A status window will step through each configuration as it runs, as shown in Figure 39. At any point in the simulation, users can stop the model by clicking the red “X” at the top right corner of the status window. A new window will appear that asks “Cancel current simulation?” If the user chooses “Yes”, it will stop execution (once the current simulation has completed, which may take a few seconds) and produce an output file with only the configurations that completed.



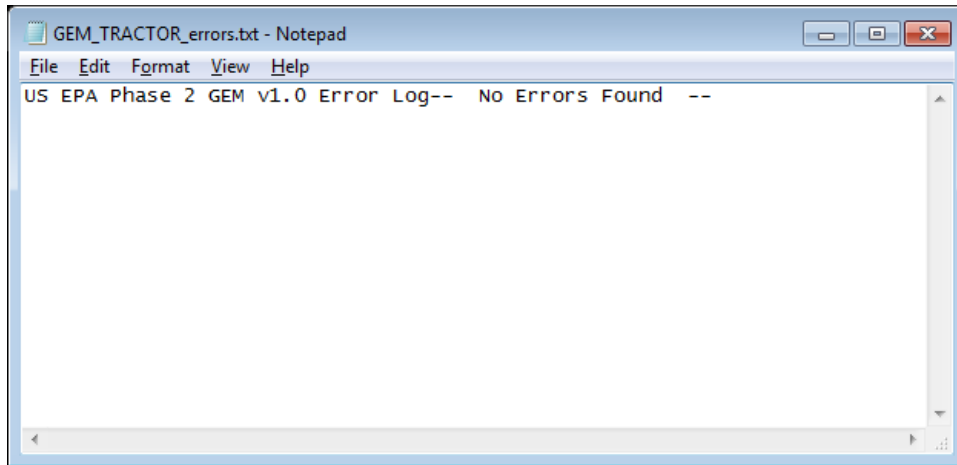
**Figure 39: Sample Status Window Showing Progress of GEM Simulations**

The status window will indicate when the simulations are complete with a window similar to Figure 40. The resulting output file will be saved in the same location as the input file, and will be given the same name as the input file with a “\_result.csv” extension added to the end (“GEM\_Sample\_TRACTOR\_result.csv” in this example). When the simulation is complete, users can close the status window by clicking the red “X” in the top right corner of the window.



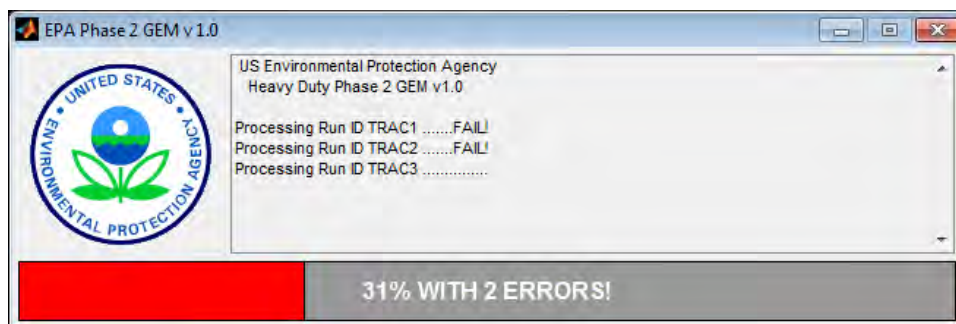
**Figure 40: Sample Status Window Showing Complete GEM Simulations**

This first example simulation completed without any errors. No errors were produced in the status window or the error log, shown in Figure 41, provides confirmation.

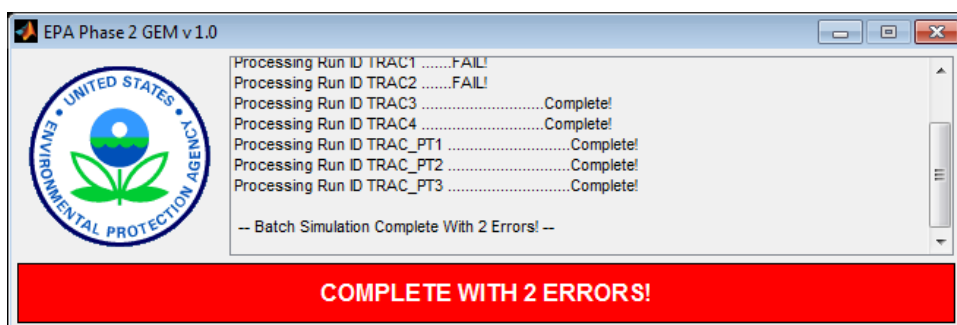


**Figure 41: Sample Error Log with No Errors from Simulation**

If an error occurs in any simulations, the window will indicate the configurations that failed and the model will continue to the next simulation. In the example of Figure 42, Run ID “TRAC1” and “TRAC2” failed. The runs with errors are displayed in the status window and indicated in the resulting output file, as seen in Figure 43 and Figure 44. Additionally, GEM will produce a separate file, shown in Figure 45, with an extension of “\_errors.txt” that lists details about any errors in a set of simulations.



**Figure 42: Sample Status Window Showing Progress of GEM Simulations with Failed Runs**



**Figure 43: Sample Status Window Showing Complete and Failed Simulations**

The image shows an Excel spreadsheet titled 'GEM\_TRACTOR\_wErrors\_result.csv'. The spreadsheet contains a table with columns for various tractor specifications and error status. Two rows are highlighted in red, indicating errors.

| Regulatory Category                         | Tractor                            | Manufacturer Name | Model Year  | GEM Vers P2 v1.0 | Aerodynamic Tire | Steer Axle Drive Axle | Drive Axle           | Engine Data  | Transmiss Data | Technology  | Technology | Technology | Technology | Technology | Technology | Technology |
|---|------------------------------------|-------------------|-------------|------------------|------------------|-----------------------|----------------------|--------------|----------------|-------------|------------|------------|------------|------------|------------|------------|
| Run ID                                      | Regulatory Aerodynamic Loaded Tire | Coefficient       | Coefficient | Ratio            | File Name        | File Name             | Weight Re Vehicle Sp | Single Driv  | Part Time      | Low Frictic | Predictive |            |            |            |            |            |
| Unique Ide (e.g. C8_Sm2                     | m                                  | kg/t              | kg/t        | #                |                  |                       | lbs                  | MPH or N/Y/N | Y/N            | Y/N         | Y/N        |            |            |            |            |            |
| TRAC1 -- ERROR: see error file for details! |                                    |                   |             |                  |                  |                       |                      |              |                |             |            |            |            |            |            |            |
| TRAC2 -- ERROR: see error file for details! |                                    |                   |             |                  |                  |                       |                      |              |                |             |            |            |            |            |            |            |
| TRAC3 C8_DC_LF                              | 5.3                                | 0.47              | 6.8         | 6.9              | 3.82 EPA_Sam     | EPA_Sam               | 0                    | 60 N         | N              | N           | N          |            |            |            |            |            |
| TRAC4 C8_HH                                 | 5                                  | 0.5               | 6.5         | 6.9              | 3.7 EPA_Sam      | EPA_Sam               | 0 NA                 | N            | Y              | N           | N          |            |            |            |            |            |
| TRAC_PT C8_SC_MI                            | 5.9                                | 0.5               | 6.5         | 6.9              | 3.37 EPA_Sam     | EPA_Sam               | 0 NA                 | N            | N              | N           | Y          |            |            |            |            |            |
| TRAC_PT C8_DC_MI                            | 5.8                                | 0.5               | 6.2         | 6.3              | 3.7 EPA_Sam      | EPA_Sam               | 0 NA                 | N            | N              | N           | N          |            |            |            |            |            |
| TRAC_PT C7_DC_HF                            | 6.1                                | 0.5               | 4.8         | 5.1              | 2.95 EPA_Sam     | EPA_Sam               | 700 NA               | N            | N              | Y           | N          |            |            |            |            |            |

Figure 44: Example Output File with Two Errors

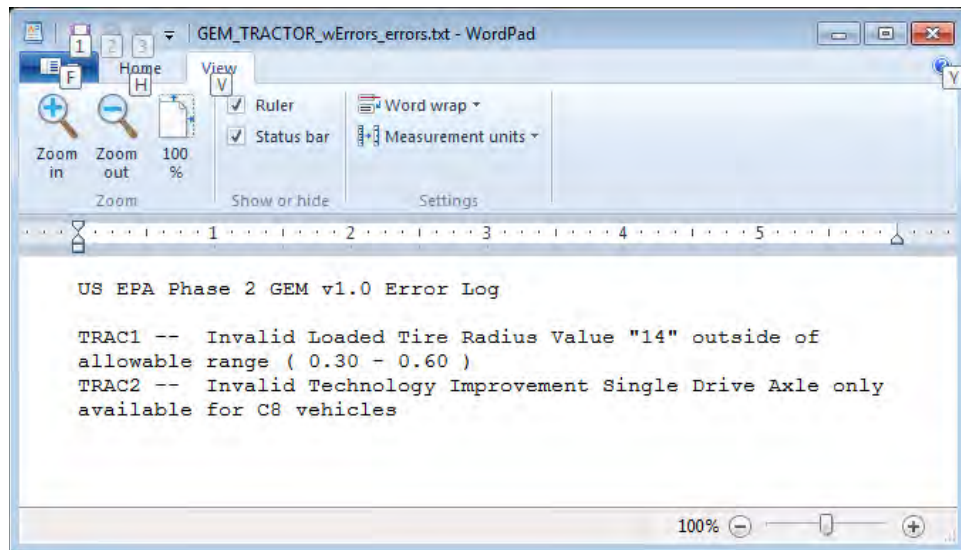
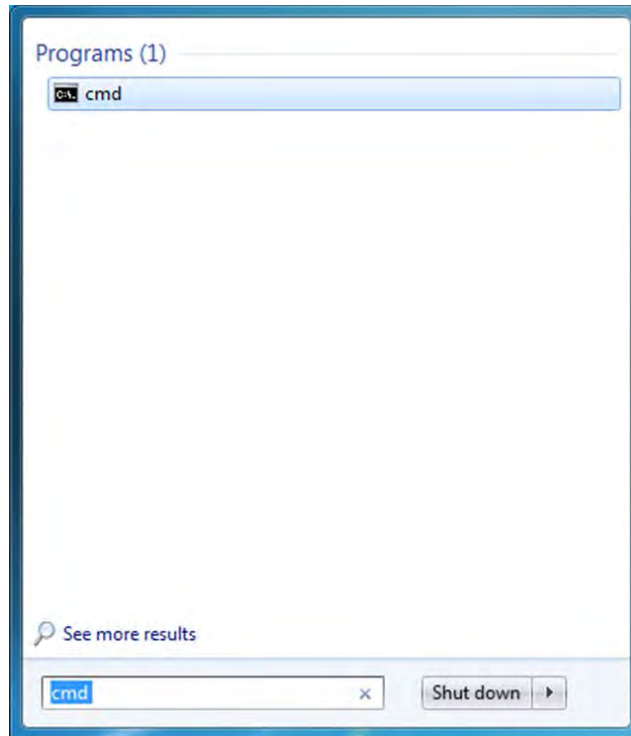


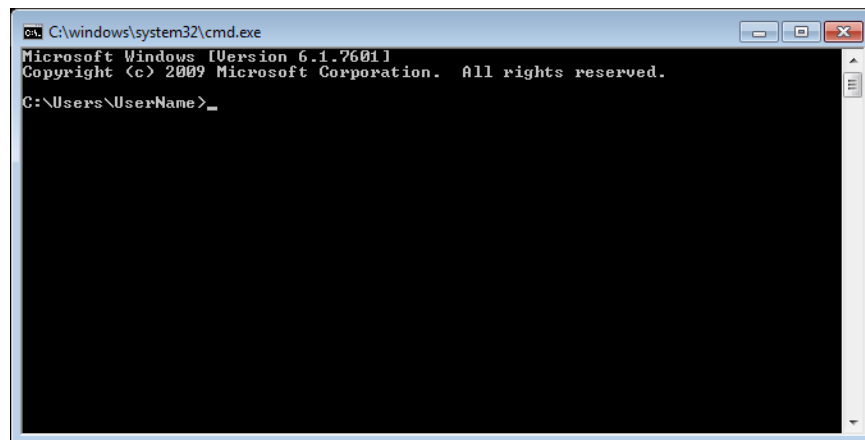
Figure 45: Example Error Log Resulting from Failed Configurations

## Running GEM Using the Command Prompt

Users can also initiate GEM using the command prompt. As seen in Figure 46, the command prompt can be found using the Start Menu's *Search programs and files* feature. Once the executable cmd.exe is selected, a command window similar to the one shown in Figure 47 will display.



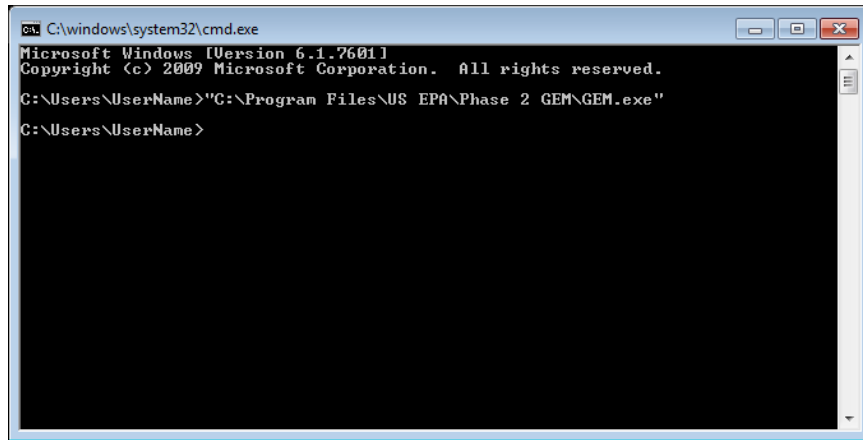
**Figure 46: Initiating the Command Prompt from the Start Menu Search Bar**



**Figure 47: Windows Command Prompt Window**

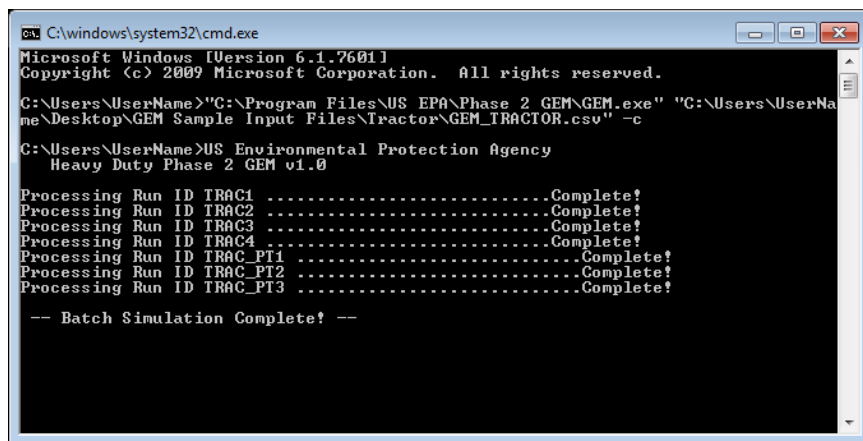
Users can use the command line to run GEM using the GUI by typing the location and name of the GEM executable as shown in Figure 48. Note that Windows requires quotation marks (“ ”) surrounding folder and file names that contain spaces. Users would then be prompted to select the input file as seen previously in Figure 37 and be shown the progress of the code as shown in Figure 39 and Figure 40.





**Figure 48: Command Prompt to Initiate GEM with the GUI Option**

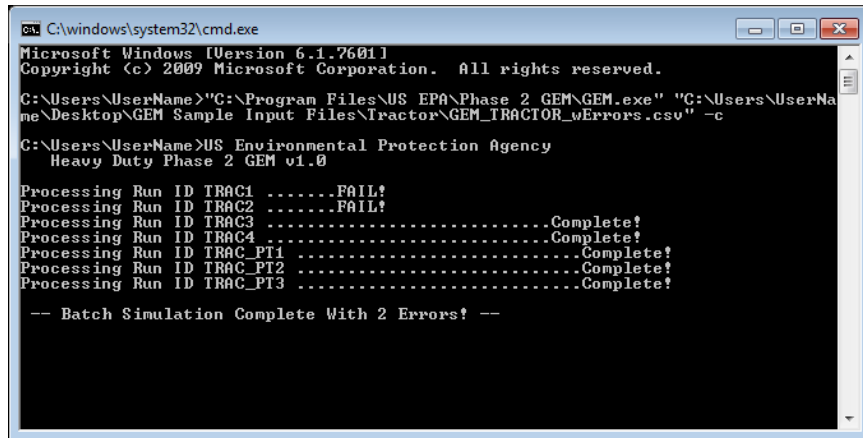
Alternatively, users have the option of bypassing use of the GUI by including the location and name of the input file, and adding “-c” to the end of the command, as shown in Figure 49. In this example, the executable is stored in the default Program Files location and the input files are located in a folder on the desktop. Also seen in Figure 49, the output generally shown in the GEM status window is displayed in the command window instead.



**Figure 49: Command Prompt to Initiate GEM and Directly Apply Input Files (no GUI Option)**

Similar to the Start Menu method, the command window will display errors if they occur in the simulation, as shown in Figure 50. Also, an identical error log file as was shown in Figure 45 is generated to show the specifics of the errors.





```
C:\windows\system32\cmd.exe
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation. All rights reserved.

C:\Users\UserName>"C:\Program Files\US EPA\Phase 2 GEM\GEM.exe" "C:\Users\UserName\Desktop\GEM Sample Input Files\Tractor\GEM_Tractor_wErrors.csv" -c

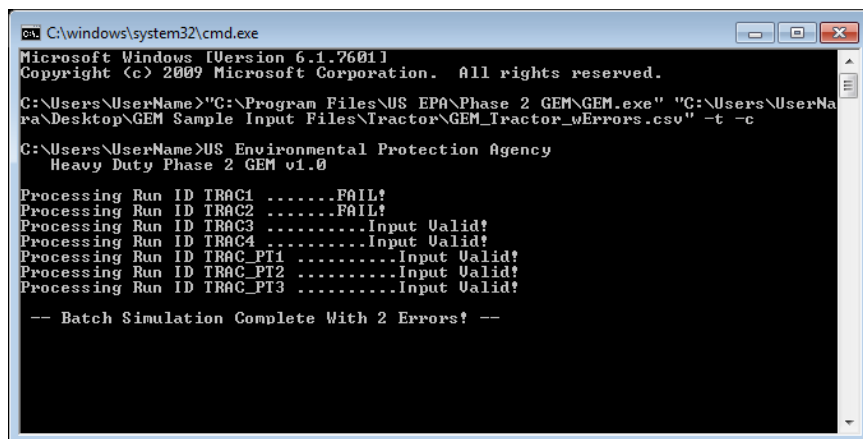
C:\Users\UserName>US Environmental Protection Agency
Heavy Duty Phase 2 GEM v1.0

Processing Run ID TRAC1 .....FAIL!
Processing Run ID TRAC2 .....FAIL!
Processing Run ID TRAC3 .....Complete!
Processing Run ID TRAC4 .....Complete!
Processing Run ID TRAC_PT1 .....Complete!
Processing Run ID TRAC_PT2 .....Complete!
Processing Run ID TRAC_PT3 .....Complete!

-- Batch Simulation Complete With 2 Errors! --
```

Figure 50: Command Prompt Display When an Input File Contains Errors

Users can also proactively check if their output file contains errors by including “-t” in their command to initiate GEM, as shown in Figure 51. This option will not run this simulation. Instead, it simply warns the user which runs contain errors. The validation information is repeated in the “\_results.csv” file that is generated, as shown in Figure 52. An error log (with extension “\_errors.txt”) is also created to provide more specific information about the errors.



```
C:\windows\system32\cmd.exe
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation. All rights reserved.

C:\Users\UserName>"C:\Program Files\US EPA\Phase 2 GEM\GEM.exe" "C:\Users\UserName\Desktop\GEM Sample Input Files\Tractor\GEM_Tractor_wErrors.csv" -t -c

C:\Users\UserName>US Environmental Protection Agency
Heavy Duty Phase 2 GEM v1.0

Processing Run ID TRAC1 .....FAIL!
Processing Run ID TRAC2 .....FAIL!
Processing Run ID TRAC3 .....Input Valid!
Processing Run ID TRAC4 .....Input Valid!
Processing Run ID TRAC_PT1 .....Input Valid!
Processing Run ID TRAC_PT2 .....Input Valid!
Processing Run ID TRAC_PT3 .....Input Valid!

-- Batch Simulation Complete With 2 Errors! --
```

Figure 51: Command Prompt to Check Errors Prior to Running GEM

| Regulatory Category                         | Tractor                |                             |                    |   |
|---|------------------------|-----------------------------|--------------------|---|
| Manufacturer Name                           |                        |                             |                    |   |
| Model Year                                  |                        |                             |                    |   |
| GEM Version                                 | P2_v1.0                | Aerodynamic                 | Tire               | Steer Axle Tire                         |
| Run ID                                      | Regulatory Subcategory | Aerodynamic Drag Area (CdA) | Loaded Tire Radius | Coefficient of Rolling Resistance Level |
| Unique Identifier                           | (e.g. C8_SC_HR)        | m²                          | m                  | kg/t                                    |
| TRAC1 -- ERROR: see error file for details! |                        |                             |                    |   |
| TRAC2 -- ERROR: see error file for details! |                        |                             |                    |   |
| TRAC3 -- Input Validated                    |                        |                             |                    |   |
| TRAC4 -- Input Validated                    |                        |                             |                    |   |
| TRAC_PT1 -- Input Validated                 |                        |                             |                    |   |
| TRAC_PT2 -- Input Validated                 |                        |                             |                    |   |
| TRAC_PT3 -- Input Validated                 |                        |                             |                    |   |
|   |                        |                             |                    |   |
|   |                        |                             |                    |   |
|   |                        |                             |                    |   |
|   |                        |                             |                    |   |
|   |                        |                             |                    |   |
|   |                        |                             |                    |   |
|   |                        |                             |                    |   |
|   |                        |                             |                    |   |
|   |                        |                             |                    |   |

**Figure 52: Resulting Output File from GEM Input Validation**

## Running GEM from Microsoft Excel

GEM can also be initiated using the Microsoft Excel templates and their embedded macros. This option requires more user-interaction, but does have some helpful features to catch errors before running the model. The template files that include the GEM macro are saved for each vehicle category as “Microsoft Excel Macro-Enabled Worksheets”, with a file extension of “.xlsm”.

When the Excel template is first opened, users may get a warning at the top of the file, similar to the warning shown in yellow in Figure 53. Users should select the “Enable Content” button to ensure that GEM will run properly from this macro.



**Figure 53: Warning in Macro-Based GEM Files; Click the “Enable Content” Button to Run the Model**

Figure 54 shows the layout of the macro-enabled example input file for tractors. This input file layout in the first tab (labeled “GEM Data”) is identical to the layout of the tractor input file discussed in previous sections, except that this file includes “Validate” and “RUN GEM” buttons in cells A4 and B4. This file also includes two additional tabs that provide additional input for the user. The “Naming Structure” tab provides the naming convention for the regulatory subcategories. These names are the same as those seen in Table 17, Table 20, and Table 23 for the tractor, vocational and trailer categories, respectively. The “Input Limits” tab describes the input value ranges associated with each of the input fields.

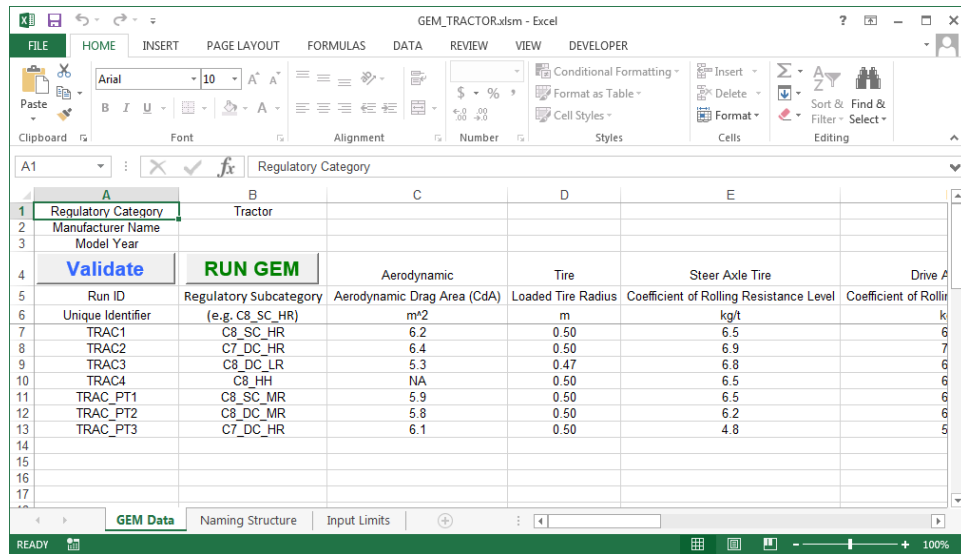


Figure 54: Sample Microsoft Excel Macro Input File

Users have two options to check for errors prior to running the model. The Excel macro is designed to catch some errors by displaying the erroneous fields with text that is red and crossed-out. If the user enters an input value that is out of range, uses lowercase letter, or repeats a unique identifier, the value will be replaced with red text with a line through it (see Figure 55).

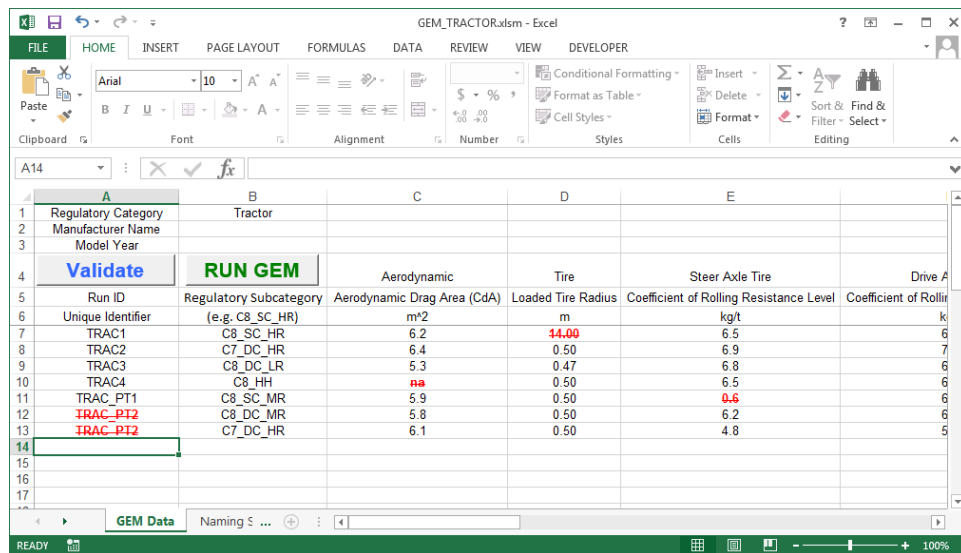
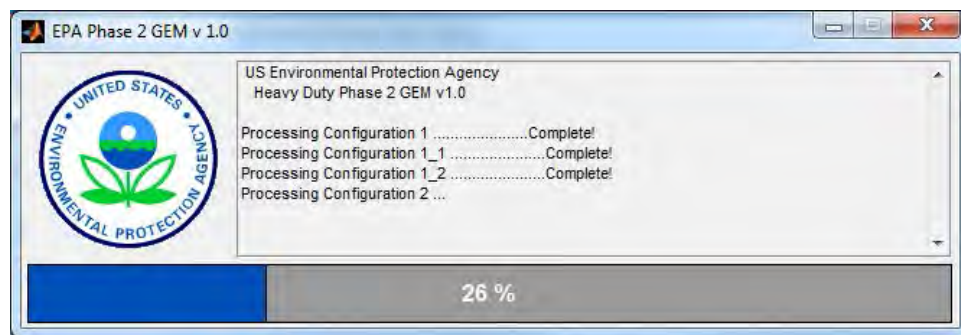


Figure 55: Sample Microsoft Excel Input File with Errors

Users can also click on the “Validate” button in cell A4 to check for errors. Once the validation process is complete, the “\_result.csv” and “\_errors.txt” files will automatically be displayed. If a user does not fix errors identified in either of these methods, the model will still

run, but will produce errors in the output file and no certification results will be available for those runs. The macro will not provide a warning for mistyped supplemental file names (i.e., engine, transmission, or powertrain files) or incorrect file paths. Instead, it will produce a failed run for that simulation and the error message will note that it could not locate the file. Also, the model will not produce an error if a unique identifier is repeated, as seen in Figure 55 for the unique identifier “TRAC\_PT2”.

Once the inputs are properly specified in Excel, the user clicks the “RUN GEM” button to initiate the program. Please be patient. It may take a few seconds to begin. Users cannot make changes to the input file and may have limited access to Excel until the simulations are complete. Users can stop the simulation at any point by clicking the red “X” in the upper right corner of the status window. Users will be presented with a window to confirm that they want to end the simulation. The results and error logs will still be generated for the simulations that completed before the user chose to stop the model.



**Figure 56: Status Window to Show Progress of GEM Simulations**

Once complete, the result and error files will automatically be opened. When using the GEM Excel Macro, the output files will be renamed to match the date and time of the simulation, in the format: GEM\_YYYYMMDD\_HHmmSS\_result.csv. The error file is saved with the same timestamp and a “\_errors.txt” extension.

## Final Notes

For more information on the rule, please see Docket EPA-HQ-OAR-2014-0827 available at <http://www.regulations.gov>.

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<sup>1</sup>“Peer Review of the Greenhouse gas Emissions Model (GEM) and EPA’s Response to Comments,” Docket # EPA-420-R-15-009, June 2015.