

The Greenhouse Gas Life Cycle Energy Emissions Model (GLEEM) Readme File

This readme file describes how to process the 2023 version of GLEEM. To learn about the model, its inputs, and its assumptions, go to <https://www.boem.gov/environment/GLEEM> download the Technical Report.

This model was built on a Linux platform using Bash for shell scripts and a Fortran 95 compiler. To run the model for a particular scenario, there are

- Two input files that must be updated for each project (see **Section 1**)
- Four input files that must be updated annually (see **Section 3**)

However, see **Section 3.2** if only certain types of fuel (motor gasoline, aviation fuel, etc.) are expected to be produced for a particular scenario. If the analysis is to include substituted emissions, there are

- Two input files that must be updated for each project (see **Section 2**)

Finally, see **Section 4** for a description of the output files.

To process the model, execute the following command:

```
bash GHGLifecycleModel.bsh
```

1 Updates for Each Model Run

The two files where data must be updated for a particular scenario (**Section 1.1** and **1.2**) contain the expected production (prod_****.txt) from all sources of energy, and onsite emissions (onem_****.txt) for the production of that energy. In both cases, “****” can be any combination of four letters or numbers to help identify individual lease sales, projects, or program areas. However, they must match exactly for each pair of files. Both files are required; however, if you do not want to include onsite emissions, onem_****.txt, columns can be entered as 0. A user can create multiple prod_****.txt and onem_****.txt files, if needed, so long as the “****” match for each pair.

1.1 GHGModel/Input/Project/prod_****.txt

This data must be entered without decimal points and must match the spacing **exactly**, as shown below, with the first column ending on the 4th character, the second column ending on the 17th character, the third column ending on the 30th character, and the fourth column ending on the 40th character. Multiple lines (up to 999) can be entered to show multiple leases, years, or other categories that the user wishes to be processed discretely. Enter 0 for any fuel that the project will not produce.

```
SMPL 13514300016      142912      1926438
```

The input data for prod is as follows, from left to right:

Column 1: Year, subarea or other user selected code (up to four characters, must match other input files)

Column 2: Oil expected to be produced, in barrels (bbls)

Column 3: Natural gas expected to be produced, in thousands of square cubic feet (mcf)

Column 4: Coal expected to be produced, in short tons

1.2 GHGModel/Input/Program/onem_****.txt

This data must be entered without decimal points and must match the spacing **exactly**, as shown below, with the first column ending on the 4th character, the second column ending on the 17th character, the third column ending on the 30th character, and the fourth column ending on the 43rd character. Multiple lines can be entered, if needed. The order of these lines must match the prod_****.txt file.

```
SMPL      35563650      241      2
```

The input data for onem is as follows, from left to right:

Column 1: Year or subarea (up to four characters, must match other input files)

Column 2: Onsite carbon dioxide emissions, in metric tons

Column 3: Onsite methane emissions, in metric tons

Column 4: Onsite nitrogen dioxide, in metric tons

2 Updates for Each Model Run With Substitutions

The file described in **Section 2.1** provides the model with substitution rates for the oil, gas, and coal being calculated. **Section 2.2**'s file is similar to the one from the previous section, but now the onsite emissions are the emissions from the substituted fuels.

2.1 GHGModel/Input/Substitutes/substitution_rate.txt

This data must be entered with two decimal points and must match the spacing **exactly** in the second and subsequent rows, as shown below, with the first column ending on the 19th character, the second column ending with the 25th character, and the last column ending on the 31st character.

```
\Subs Prod>   Oil  NGas  Coal
Oil           94.70  3.80  0.00
Natural Gas   1.70 85.20  0.00
Coal          0.40  1.20  0.00
Nuclear       0.00  0.00  0.00
Renewables    3.20  9.80  0.00
```

Substitution rates are in percentages. Each column represents the resource expected to be produced. The rows show the resource expected to be substituted if production on the proposed project does not occur. For instance, the last line shows renewables are expected to replace 3.2% of the oil and 9.8% of the natural gas from the project. If reduced consumption is expected, columns do not need to total up

to 100%. Do not change or add rows, and note that—other than for oil, natural gas, and coal emissions are not calculated for any of the other fuels. See model documentation for more information.

2.2 GHGModel/Input/Substitutes/onem_****.txt

This data must be entered without decimal points and must match the spacing **exactly**, as shown below, with the first column ending on the 4th character, the second column ending with the 17th character, the 3rd column ending on the 30th character, and the fourth column ending on the 43rd character.

```
SMPL      35563650      241      2
```

The input data for onem is as follows:

Column 1: Year or subarea (up to four characters, must match other input files)

Column 1: Onsite carbon dioxide emissions, in metric tons

Column 2: Onsite methane emissions, in metric tons

Column 3: Onsite nitrogen dioxide, in metric tons

This file contains the expected onsite emissions for the production of substituted sources of energy. The “****” can be any combination of four letters or numbers to help identify individual lease sales, projects, or program areas. However, the characters must match exactly with the prod and onem files described in **Section 1**. The user can enter a maximum of 999 rows, and the order of the rows must match the files described in **Section 1**. If you do not want to include onsite emissions, the columns can be entered as 0.

3 Annual Update

The files described in this section are updated annually. These updates provide the model with the most recent consumption and emission rates for fuels. As an alternative to manually updating the files, downloading the most recent version of the model will include the most recent consumption and emissions rates. See model documentation for information about the ‘zero’ midstream carbon dioxide and nitrous oxide emissions for coal.

3.1 GHGModel/Input/Parameters/overall_parameters.txt

This data must be entered with decimal points and must match the spacing **exactly**, as shown below, with the first column ending on the 4th character, the second column ending on the 10th character, the third column ending on the 15th character, the fourth column ending on the 24th character, and the fifth column ending on the 30th character.

```
4.22 0.04 0.04 7076255 0.019
27.7 2.65 0.02 32318000 0.034
0.00 0.21 0.00 512744 0.001
```

This file needs to be updated each year. This file describes the US energy market, with the first line describing oil, the second line natural gas, and the third coal.

Column 1: Midstream carbon dioxide, in million metric tons

Column 2: Midstream methane, in million metric tons

Column 2: Midstream nitrous oxide, in thousand metric tons

Column 4: National oil refinery (thousands of barrels of oil), natural gas systems (millions of cubic feet), and coal (thousands of short tons) inputs

Column 5: Resources not combusted (ratio of not combusted resources to consumed resources)

Data comes from the following websites:

- Oil, Natural Gas, and Coal facility Emissions:
<https://www.epa.gov/system/files/documents/2023-04/US-GHG-Inventory-2023-Main-Text.pdf>
- Midstream processing and not combusted Oil, Natural Gas, and Coal Inputs:
<https://www.eia.gov/totalenergy/data/monthly/archive/00352303.pdf>

3.2 GHGModel/Input/Parameters/consemis_****.txt

This data must be entered with decimal points and must match the spacing **exactly**, as shown below, with the first column ending on the 21st character, the second ending on the 29th character, the third column ending on the 37th character, the fourth ending on the 48th character, and the fifth column ending on the 59th character.

Asphalt/Road Oil	369	11.91	0.00047	0.00009
Aviation Gasoline	12	8.13	0.00036	0.00007
Distillate Fuel Oil	3955	10.42	0.00042	0.00008
Jet Fuel	1557	9.75	0.00041	0.00008
Kerosene	4	10.15	0.00041	0.00008
Propane	1178	5.72	0.00027	0.00005
Propylene	386	6.17	0.00027	0.00005
HydroGasLiquids	2811	5.68	0.00028	0.00006
Lubricants	110	10.69	0.00043	0.00009
Motor Gasoline	8761	8.78	0.00038	0.00008
Residual Fuel Oil	339	10.74	0.00044	0.00009
Other	1379	10.49	0.00042	0.00008

There are three consemis (consumption and emissions) files. One each for oil, natural gas, and coal, where **** is replaced with oils, ngas, and coal respectively. Pictured above is the consemis_oils.txt file, but the other files are structured the same way. Only enter the types of products expected to be produced from the project. If unknown, it is recommended that the user apply the full suite of products. Note that this file will be used for substitute sources. For example, if a natural gas project is expected to result in substitutes from coal, then the coal file will be relevant to the calculations and therefore may need adjustment, even if a project is only expected to produce natural gas. From left to right for each line:

Column 1: Name of fuel type

Column 2: Annual consumption (thousands of barrels for oil, millions of cubic feet for natural gas, and thousands of short tons for coal)

Column 3: Carbon Dioxide (kg/gallon for oil, kg/cubic square feet for natural gas, and kg/short ton for coal)

Column 4: Methane (kg/gallon for oil, kg/cubic square feet for natural gas, and kg/short ton for coal)

Column 5: Nitrous oxide (kg/gallon for oil, kg/cubic square feet for natural gas, and kg/short ton for coal)

Data comes from the following websites:

- Oil, Natural Gas, and Coal Consumption: <https://www.eia.gov/totalenergy/data/monthly/archive/00352303.pdf>
- Emission factors come from: https://www.epa.gov/system/files/documents/2022-04/ghg_emission_factors_hub.pdf

4 Model Output

The following two subsections describe where data output is placed for program emissions (**Section 4.1**) and the substitute emissions (**Section 4.2**), and how each is structured. Unlike the previous sections, this data will be generated by processing the model. To process the model, execute the following:

```
bsh GHGModel/GHGLifecycleModel.bsh
```

It is strongly recommended these numbers be rounded to the nearest 1,000 metric tons when presenting the output to avoid suggesting a higher degree of accuracy than actually exists within the model and the inputs. There are four different types of output file. Total (totl), upstream (upst), midstream (mdst) and downstream (dnst) files are generated for both the project being analyzed, and the substitution analysis. These files are identical, with the exception of the mids file, which does not include a nitrous oxide column. The totl file is the summation of the other three files. See model documentation for details. Each files "*****" is the user generated code discussed in **Section 1 and 2**.

4.1 GHGModel/Output/Project/totl_****.txt

GHGModel/Output/Project/upst_**.txt**

GHGModel/Output/Project/mdst_**.txt**

GHGModel/Output/Project/dnst_**.txt**

```
SMPL      559586304.      557450560.      31263.      4544.
```

Column 1: Year or subarea (up to four characters, will match the codes used in the input files)

Column 2: Carbon dioxide equivalent, in metric tons

Column 3: Carbon dioxide, in metric tons

Column 4: Methane, in metric tons

Column 5: Nitrous oxide, in metric tons

4.2 GHGModel/Output/Substitutes/totl_**.txt**

GHGModel/Output/Substitutes/upst_**.txt**

GHGModel/Output/Substitutes/mdst_**.txt**

GHGModel/Output/Substitutes/dnst_**.txt**

SMPL 535104704. 532843776. 39771. 4251.

Column 1: Year or subarea (up to four characters, will match the codes used in the input files)

Column 2: Carbon dioxide equivalent, in metric tons

Column 3: Carbon dioxide, in metric tons

Column 4: Methane, in metric tons

Column 5: Nitrous oxide, in metric tons