Readme file for the spreadsheet Damage\_Values\_application-v6-2025.06.11.xlsx

*Disclaimer: While this spreadsheet has been cleared by the U.S. EPA, users should note that the intent is to provide an example of how air quality-related health damage factors can be integrated into GCAM-USA. These damage factors represent complex nonlinear atmospheric transport and chemistry processes with linear damage values. As a result, these factors are intended to be used for research and screening purposes. Applications using these factors should be adequately caveated. Users are responsible for determining the utility of this spreadsheet for their own applications and ensuring coverage of damage factors across technologies. Neither the U.S. EPA nor the spreadsheet authors can assume responsibility for modification, content, output, or usage.*

The purpose of this spreadsheet is to demonstrate the transformation of health damage factors derived from the U.S. EPA's CO-Benefits Risk Assessment (COBRA) tool into the format needed to be used with the Global Change Analysis Model USA (GCAM-USA) versions 7.0 and 7.1.

The "Damage\_Values" tab includes state-, emissions source category-, and pollutant-specific air pollutant-related health damage coefficients, in units of (1990$s/tonne). An emission source category (also referred to as a source category below) is a grouping of technologies assumed to have similar impacts because of emissions intensity and characteristics of their release (low vs. elevated) that may impact human exposure.

The source categories used in this analysis include:

* ''EGU Coal" - coal-fired electric generating units that have relatively high emissions intensity and release emissions via a tall stack
* "EGU Other" - gas-, fuel oil-, and other electric generating units, including turbines, which may be smaller in size and emissions than coal-fired EGUs
* "Fuels" - emission sources associated with oil and gas production and refining
* "Building" - emission sources associated with residential, commercial, and institutional buildings
* "Industry" - Large industrial sources, including manufacturing, chemical production, etc.
* "Highway" - Onroad passenger and freight vehicles
* "Off-highway" - Air, locomotive, marine, construction, and agricultural vehicles
* "Other Point" -Other large emission sources that do not fall within the categories above
* "Other Area" -Other small emission sources that do not fall within the categories above

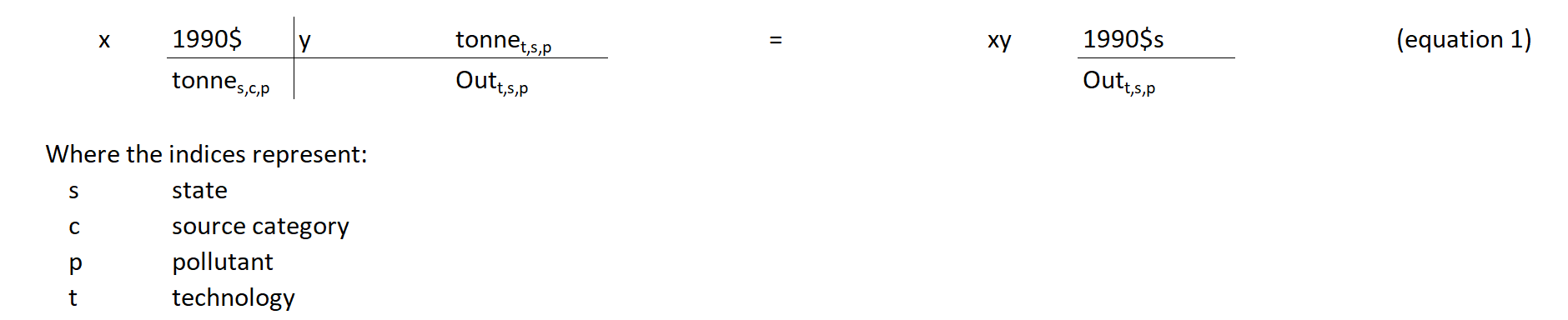
The state-, pollutant-, and source-category-specific damage values on the tab were created in several steps performed upstream of the application of this spreadsheet but summarized here. A 2023 emission inventory is embedded in desktop COBRA v5.2. Emission sources in that inventory were assigned to the categories listed above. Next, a script was written that generates a large set of alternative emissions scenarios for use in COBRA. These alternative scenarios each involve a 10% perturbation of the one combination of state, pollutant (NOx, SO2, or PM2.5), source category, and analysis year (2030 to 2050 in 5-yr increments). The result was input emission files for over 6000 runs of COBRA, which were then performed using desktop COBRA’s batch function. COBRA predicted the monetized damages (or benefits) for each of these runs, compared to an unperturbed scenario. For background information and a detailed description of the calculation of the damage values used here, please see the document "Description-Damage-Factor-Calculation-2025.06.10.pdf" and the associated Readme file. We also need damage values for 2015 through 2025, so the "Damage\_Values" tab includes the calculations to extrapolate values for these years.

There are eight categories of damage values in the table on the “Damage\_Values” tab. Each is described briefly below. Values indicated with a “\*” are directly output by COBRA and we refer users to the COBRA documentation for a more detailed definition and description of underlying assumptions.

* "dpt\_o3"\* - mortality-related damages associated with ozone exposure
* "dpt\_pm\_lo"\* - low estimate of mortality-related damages associated with exposure to PM2.5
* "dpt\_pm\_hi"\* - high estimate of mortality-related damages associated with exposure to PM2.5
* "dpt\_pm\_avg" -average between the high and low PM estimates
* "dpt\_mort\_avg" -sum of the dpt\_o3 and dpt\_pm\_avg
* “dpt\_total\_lo”\* – estimate of total damages (mortality and non-mortality) for O3 and PM, assuming low PM estimates
* “dpt\_total\_hi”\* – estimate of total damages (mortality and non-mortality) for O3 and PM, assuming high PM estimates
* “dpt\_total\_avg” – average between dpt\_total\_lo and dpt\_total\_hi

The remaining part of this Readme discusses how these costs are translated into inputs to GCAM-USA.

The damage factors are represented in the table as dollars-per-metric tonne (in 1990$s). To apply the damage values within GCAM-USA, they must be converted to 1990$s per unit of technology output, illustrated in Equation 1.



In most instances, the unit of output is exajoules (EJ); however, output units can also vary by sector. For example, output of passenger vehicles is pass-km and output of clothes dryers is cycles.

GCAM does not automatically report the emission factors it uses. Instead, here we calculate output-based emission factors by querying the model results for emissions by technology and vintage, then divide by output by technology and vintage. Developing factors by vintage is important since emission factors can change by vintage, either based on exogenous assumptions (e.g., due to New Source Performance Standards) or endogenous calculations (e.g., application of controls determined by a marginal abatement curve).

The queries used to develop these data are included in the "Main\_queries\_GLIMPSE-7p0.xml" and "Main\_queries\_GLIMPSE-7p1.xml" files, which are released with GLIMPSE:

* "GLIMPSE/GCAM-USA">"Other">"for damage analysis calculations">"Emissions by tech and vintage (excluding resource production)"
* "GLIMPSE/GCAM-USA">"Other">"for damage analysis calculations">"Primary outputs by tech and vintage"

These queries were applied to the results of a decarbonization scenario in GCAM-USA 7.1. A decarbonization scenario was chosen since placing a price on carbon results in market shares for some technologies that are not available without a carbon-pricing incentive (e.g., carbon capture), resulting in a fuller listing of technologies. Results from the queries are stored on the "EmissionsByVintage" and "PriOutputByVintage" tabs. Note that it is possible that some technologies are not included in these lists and thus will not have damage factors applied.

If the data within the "Damage\_Values", "EmissionsByVintage", or "PriOutputByVintage" tabs have been modified (e.g., new scenario results have been pasted to those tabs), please refresh the data in "CalculatedDVs" tab by right-clicking on the pivot table (at the far left of "CalculatedDVs" and choosing "Refresh").

An important step in mapping these damage factors to emissions sources within GCAM is the development of a sector-to-category crosswalk. The "XWalk" includes this crosswalk, using the emission source categories listed above.

The "CalculatedDVs" is a tab on which state-, technology-, and pollutant-specific damage factors for use in GCAM are developed. Steps in this calculation include:

* dividing each technology vintage's emissions of NOx, PM2.5, and SO2 by its primary output to calculate vintage-specific emission factors
* based on the technology's emission source category, extracting the associated damage values from the "Damage\_Values" tab
* multiplying the emission factor by the associated damage value, producing an output-based damage factor (e.g., see equation 1)

While damage factors could be created for any of the 8 types of damages listed above, we have chosen to develop factors for only three: “dpt\_o3”, “dpt\_pm\_avg”, and “dpt\_total\_avg” (corresponding to O3 mortality costs, PM2.5 mortality costs, and total mortality and non-mortality costs for O3 and PM2.5 combined.) Column with these damage factors have the headers “df\_o3”, “df\_pm\_avg”, and “df\_tot\_avg”, respectively.

The purpose of the calculations on the "prep\*" tabs is to sum the pollutant-specific damage-per-output values across emitted pollutants (e.g., NOx, SO2, PM) to produce a total damage-per-output value. There are three such tabs since the sectoral structure in GCAM is slightly different for the transportation, power sector, and other sectors. Again, if data from any tab to the left of these has changed, we recommend refreshing the data in each of the "prep\*" tab pivot tables.

The tabs beginning with "damage" include the data that will be saved to a CSV file for use in the GLIMPSE CSVtoXML conversion program:

* "damageO3-Egu" - Factors representing O3 damages for emissions from electricity generating units (i.e., the power sector)
* "damageO3-Trn" - Factors representing O3 damages for emissions from transportation sector
* "damageO3-Oth" - Factors representing O3 damages for emissions from other sectors, including buildings and industry
* "damageTotAvg-Egu" - Factors representing the sum of PM2.5 and O3 damages for emissions from electricity generating units (i.e., the power sector)
* "damageTotAvg-Trn" - Factors representing the sum of PM2.5 and O3 damages for emissions from the transportation sector
* "damageTotAvg-Oth" - Factors representing the sum of PM2.5 and O3 damages for emissions from other sectors, including buildings and industry
* "damagePMAvg-Egu" - Factors representing PM2.5 damages for emissions from electricity generating units (i.e., the power sector)
* "damagePMAvg-Trn" - Factors representing PM2.5 damages for emissions from transportation sector
* "damagePMAvg-Oth" - Factors representing PM2.5 damages for emissions from other sectors, including buildings and industry

The data on the "damage\*" tabs has been formatted to be processed by the GLIMPSE CSV-to-XML tool. The tabs can be converted to CSV files in several ways. One is to traverse to the desired tab, then choose "Save As" and save the tab contents to a CSV file. Alternatively, a macro has been added to the worksheet to automate the process of generating CSV files from each tab.

To run the macro, select the "Developer" tab, click on the "Macros" button, then execute the "SaveTabsAsCSVs" macro. This will export all tabs to CSVs (e.g., including this Readme tab). However, only the tabs starting with “damage” represent the CSVs that include damage factors. These CSVs can be added to the GLIMPSE Scenario Component Library for inclusion in scenarios. O3 and PM2.5 damages will be reported in emission queries under the emission species “O3DAM” and “PMDAM”, respectively. Total damages will be reported as “Damages”. While the units will be displayed as “Tg”, the actual units are millions of 1990$s.

Here is an illustrative set of GCAM-USA results generated using the damage factors, comparing damages associated with a Decarbonization and Reference Case.

The difference represents changes in damages (e.g., benefits in 2050 are $189 billion in 1990$s).

National total damages ($mil; 1990$s)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| scenario | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
| Decarbonization | 379,000 | 336,000 | 333,000 | 339,000 | 343,000 | 352,000 | 367,000 | 363,000 |
| Reference | 379,000 | 336,000 | 347,000 | 359,000 | 386,000 | 435,000 | 499,000 | 552,000 |
| Difference | - | - | (14,000) | (20,000) | (43,000) | (83,000) | (132,000) | (189,000) |