



Clean Air Task Force (CATF) Deaths by Dirty Diesel Map: Health Impacts Methodology

The mortality and morbidity data reported in the interactive Deaths by Dirty Diesel map are derived from the U.S. EPA's CO–Benefits Risk Assessment (COBRA) screening model, a software tool developed to estimate the health impacts and benefits of clean energy policies. The analysis focuses on estimating the impacts from 2023 diesel engine emissions, including highway and off-highway sectors. Together, the direct fine particulate matter (PM), sulfur dioxide, and nitrogen oxide emissions from these sources contribute to ambient concentrations of particulate matter less than 2.5 microns in aerodynamic diameter (PM_{2.5}) – an air pollutant that has been linked to a variety of serious health effects, including asthma attacks, chronic bronchitis, hospital admissions, and premature mortality. COBRA was used to estimate these health impacts from directly-emitted and secondarily-formed PM_{2.5} pollution.

Abt Associates (Abt), which for years has served as one of the U.S. EPA's air quality benefits consultants, developed COBRA in 2002 to support assessments of the human health damages from air pollution and their associated monetized economic damages. The model has been updated periodically, with the current version 4.0 reflecting base-year emissions, calibrations for 2016, and a projection inventory for 2023.

Previously, CATF relied on Abt to assess the health impacts from diesel sources. The earliest analyses in 2005 used the Assessment System for Population Exposure Nationwide (ASPEN) model to estimate the local diesel particulate levels in the U.S. from direct PM diesel engine emissions in 1999. Abt conducted a national study of 2010 projected emissions and the Regional Emissions Modeling System for Acid Deposition (REMSAD) to estimate future diesel PM levels. Health impacts from these two modeled diesel PM results were entered into the Environmental Benefits Mapping and Analysis Program (BenMAP) to determine the corresponding health effects. Results are documented in [Diesel and Health in America: the Lingerin Threat](#) and its companion piece [An Analysis of Diesel Air Pollution and Public Health in America](#). Two follow up analyses were conducted based on U.S. EPA's National Air Toxic Assessments (NATA) for [2002](#) and 2005. These different approaches covering 1999 to 2010 determined that diesel engine emissions led to as many as 30,000 premature deaths each year.

To assess health impacts, [COBRA](#) uses a damage function approach, which involves modeling changes in ambient air pollution levels, calculating the associated change in adverse health effects, such as premature mortality, and then assigning an economic value to these effects. For changes in the concentrations of particulate matter, this is typically done by translating a change in pollutant levels into associated changes in human health effects. These health effects are then translated into economic values. The current version of COBRA is based on 2016 data: (1) model calibration to 2016 baseline, (2) 2016 population estimates, (3) 2016 disease incidence rates, and (4) the most recent concentration-response functions.

To estimate the PM_{2.5}-related damages associated with emissions from diesel engines, COBRA first calculates the impact of emissions on ambient PM_{2.5} levels. Using the results from epidemiological studies, it then estimates the number of adverse health impacts (e.g., premature deaths) due to the associated PM changes and finally calculates the associated

monetized economic damages. This three-step process is the standard approach for evaluating the health and economic benefits of reduced air pollution.

CATF conducted two modeling analyses of diesel emission health impacts using COBRA, one using the baseline of 2016 and a second using projected emissions for 2023, which are the results mapped for this project. The emissions input file was modified to remove all emissions from diesel fueled highway and off-highway vehicles. Emissions for direct PM, nitrogen oxides, and volatile organic compounds declined by 45%, 33%, and 30% respectively. Premature mortality in 2016 from exposure to diesel exhaust ranged from 6,300 to 14,200 and dropped 40% to 3,900 to 8,800 premature deaths in 2023; the low end of this range is from Krewski's concentration-response function and the high end from Lepeule. The maps show the upper end of the range for 2023, although the relative ranking comparisons across U.S. states remain the same for both the low and high mortality estimate.

COBRA calculates the emissions impact on ambient PM_{2.5} levels and applies health impact functions to that change of ambient pollution attributable to diesel exhaust. The health impact functions are derived from concentration-response functions reported in the peer-reviewed, published epidemiological literature. A typical health impact function has four components:

1. an effect estimate, which quantifies the change in health effects per unit of change in a pollutant, and is derived from a particular concentration-response function from an epidemiology study;
2. a baseline incidence rate for the health effect;
3. the affected population; and
4. the estimated change in the concentration of the pollutant.

The result of these functions is an estimated change in the incidence of a particular health effect for a given increment of air pollution. Examples of health effects that have been associated with changes in air pollution levels include premature mortality, hospital admissions for respiratory and cardiovascular illnesses, and asthma exacerbation.

The second step in the damage function approach involves estimated unit values that give the estimated economic value of avoiding a single case of a particular endpoint – a single death, for example, or a single hospital admission. These unit values are derived from the economics literature and come in several varieties.

- For some endpoints, such as hospital admissions, cost of illness (COI) unit values, which estimate the cost of treating or mitigating the effect, were used. COI unit values generally underestimate the true value of reductions in risk of a health effect, since they include hospital costs and lost wages, but do not include any estimate of the value of avoided pain and suffering.
- For other endpoints, such as asthma exacerbation, the model uses willingness to pay (WTP) unit values, which are estimates of willingness to pay to avoid an asthma exacerbation.
- Typically, value of statistical life (VSL) unit values are used for reductions in risk of premature mortality.

Estimating the economic damages of the estimated attribution to health incidence is a simple matter of multiplying by the associated unit value. Finally, the calculation of total damages involves summing estimated damages across all non-overlapping health effects, such as hospital admissions for pneumonia, chronic lung disease, and cardiovascular-related problems.

In summary, after the user provides COBRA emission changes, the model then estimates:

1. the contribution of the emissions to ambient PM_{2.5} levels in each county in the continental United States;
2. the associated attributable number of people incurring various adverse health effects; and
3. the associated economic damages of these adverse health effects.

In addition to the health endpoints provided by COBRA, CATF determined the cancer risk associated with exposure to diesel particulate matter. Analyses of EPA's NATA results for the U.S. suggest that exposure to diesel particulate could post a greater lifetime cancer risk than exposure from all other modeled hazardous air pollutant sources combined. Previously, CATF used a California Air Resources Board (CARB) unit cancer risk estimate of 3×10^{-4} per micrograms per cubic meter (ug/m³) diesel particulate mass; their analysis placed the risk in a range of 10^{-3} to 10^{-5} . In 2015, CARB published an updated risk factor of 8.94×10^{-4} in their review paper of toxic air contaminants in California¹. CATF relied on this more recent value to calculate diesel particulate cancer risk for 2023. Risk calculations simply multiply this unit risk factor by the modeled diesel particulate matter and multiply by 1 million to determine the per million population cancer risk. The national risk was calculated to be 228 lifetime cancers per million from exposure to diesel particulate matter, based on projected 2023 concentrations of 0.26 ug/m³. This represents nearly 80,000 cancer cases across the nation.

¹ "Ambient and Emission Trends of Toxic Air Contaminants in California" *Environ. Sci. Technol.* 2015, 49, 19, 11329–11339.