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The Projection of Mobile Source Air Toxics from 1996 to 2007: Emissions and Concentrations

DRAFT

Limitations and Uncertainties

This analysis has a number of significant limitations and uncertainties which must be considered in interpreting results. First, although on-highway inventory estimates in 1996 and 2007 for benzene, 1,3-butadiene, formaldehyde, and acetaldehyde were estimated using local data on fuel properties, inspection/maintenance programs, and other input parameters, for other parameters such as average speed, defaults were used. Use of default parameters can result in significant underestimates or overestimates of emissions at the local scale. Also, MOBTOX modeling for these HAPs was done for a limited number of areas (10 urban areas and sixteen geographic regions) and the rest of the country was "mapped" to these modeled areas or regions based on I/M programs, fuel parameters, and temperature regimes. In addition, for some vehicle classes, in particular heavy duty diesel vehicles, toxic emission estimates are based on very limited speciation data. Furthermore, there are considerable uncertainties associated with emission factors, activity, allocation surrogates and speciation data used to develop the nonroad inventories. The EPA has several efforts underway to address these uncertainties. Finally, projection of emissions using surrogates such as VOC and activity introduces significant additional uncertainty into the 2007 inventory.

Spatial allocation of emissions from the county to the census tract level also introduces uncertainty, particularly for nonroad sources. Although there are many types of nonroad equipment, all emissions were grouped into six source categories – 2-stroke gasoline, 4-stroke gasoline, diesel, locomotives, commercial marine vessels, and aircraft – prior to spatial allocation.

There are also uncertainties associated with the application of the ASPEN dispersion model. Gaussian dispersion models such as ASPEN are designed to work with inert pollutants and deal with reactive decay and secondary transformation in a less sophisticated manner than an atmospheric chemistry model. Analyses done as part of the NSATA (EPA, 2001a) suggest ASPEN may be underestimating concentrations for more reactive species. Model to monitor comparisons also suggest ASPEN may significantly underestimate concentrations of metals. Finally, it should be emphasized that this model does not reliably capture localized impacts.

The Projection of Mobile Source Air Toxics from 1996 to 2007: Emissions and Concentrations

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Definition of Acronyms

ASPEN	Assessment System for Population Exposure Nationwide
EFIG	EPA OAQPS Emission Factors and Inventories Group
EPA	U.S. Environmental Protection Agency
EMS-HAP	Emission Modeling System for Hazardous Air Pollutants
HAP	Hazardous Air Pollutant
HDDV	Heavy duty diesel vehicles
HDGV	Heavy duty gasoline vehicles
LDDT	Light duty diesel trucks
LDDV	Light duty diesel vehicles
LDGT	Light duty gasoline trucks, both categories 1 and 2
LDGT1	Light duty gasoline truck category 1
LDGT2	Light duty gasoline truck category 2
LDGV	Light duty gasoline vehicles
MC	Motorcycles
MEK	Methyl ethyl ketone
MTBE	Methyl tertiary butyl ether
NATA	National Air Toxics Assessment
NET	EPA National Emissions Trends inventory
NTI	EPA 1996 National Toxics Inventory
OAQPS	EPA Office of Air Quality Planning and Standards
OTAQ	EPA Office of Transportation and Air Quality
PAH	Polynuclear aromatic hydrocarbons (a subset of POM)
7-PAH	The seven specific PAH that nave been named as animal carcinogens by the International Agency for Research on Cancer (IARC)
POM	Polycyclic Organic Matter
ppm	parts per million
VMT	Vehicle miles traveled
VOC	Reactive volatile organic compounds (excluding methane and other nonreactive compounds)
TOG	Total organic gas

1. Introduction

The Office of Air Quality Planning and Standards' (OAQPS) has conducted an Initial National-Scale Assessment of Air Toxics as part of the National Air Toxics Assessment (NATA) activities in the Urban Air Toxics Program. This effort uses the 1996 National Toxics Inventory (NTI)[1] and the Assessment System for Population Exposure Nationwide (ASPEN)[2] dispersion model to predict nationwide ambient concentrations of toxic air pollutants for the year 1996. EPA has also used the 1996 NTI to predict emissions and ambient concentrations of toxic air pollutants in 2007. This report details the methodologies used to project future emissions of toxic air pollutants from mobile sources, which consist of highway vehicles and other nonroad mobile sources such as lawn mowers and other small engines, nonroad equipment, airports, marine vessels, and railroads.

The Initial National-Scale Assessment effort focuses on 33 toxic air pollutants, also known as hazardous air pollutants, or HAPs, that are judged to present the greatest threat to public health in urban areas. Mobile sources emit 15 of these 33 HAPs. Five of these 15 are gaseous HAPs: acetaldehyde, acrolein, benzene, 1,3-butadiene, formaldehyde. As shown in Figure 1, mobile sources contribute a substantial share of total nationwide emissions of each of these gaseous HAPs.

The remaining ten HAPs emitted by mobile sources (from the list of 33) are trace metals and compounds associated primarily with the particulate phase: arsenic, beryllium,[a] cadmium,[a] chromium, dioxins/furans,[b] lead, manganese, mercury, nickel, and polycyclic organic matter (POM).[c] Figure 2 shows that mobile source emissions of metals, and POM are small in comparison with stationary source emissions. In the case of POM, separate analyses were performed for total POM and for seven polynuclear aromatic hydrocarbons (7-PAH) that have been named as animal carcinogens by the International Agency for Research on Cancer (IARC).

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[a] Beryllium and cadmium were not included in EPA's recently finalized list of mobile source air toxics, because they were all from marine vessels using residual fuel oil, and a profile for stationary industrial and commercial boilers was used to develop this list, rather than actual measurements from a commercial marine engine.

[b] National estimates are not yet available for dioxins and furans from stationary sources.

[c] Estimates of total POM for mobile sources represent the sum of 16 polynuclear aromatic hydrocarbons (16-PAH). The following is a list of compounds included in the 16-PAH category, with asterisks denoting compounds that are also members of 7-PAH: acenaphthene, acenaphthylene, anthracene, benz(a)anthracene,* benzo(a)pyrene,* benzo(b)fluoranthene,* benzo(g,h,i)perylene, benzo(k)fluoranthene,* chrysene,* dibenz(a,h)anthracene,* fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene,* naphthalene, phenanthrene, and pyrene. Mobile source emissions estimates for POM account only for the particulate phase, although some significant POM are emitted in the gaseous phase. The 1999 National Toxicx Inventory will include mobile source gas-phase PAH.

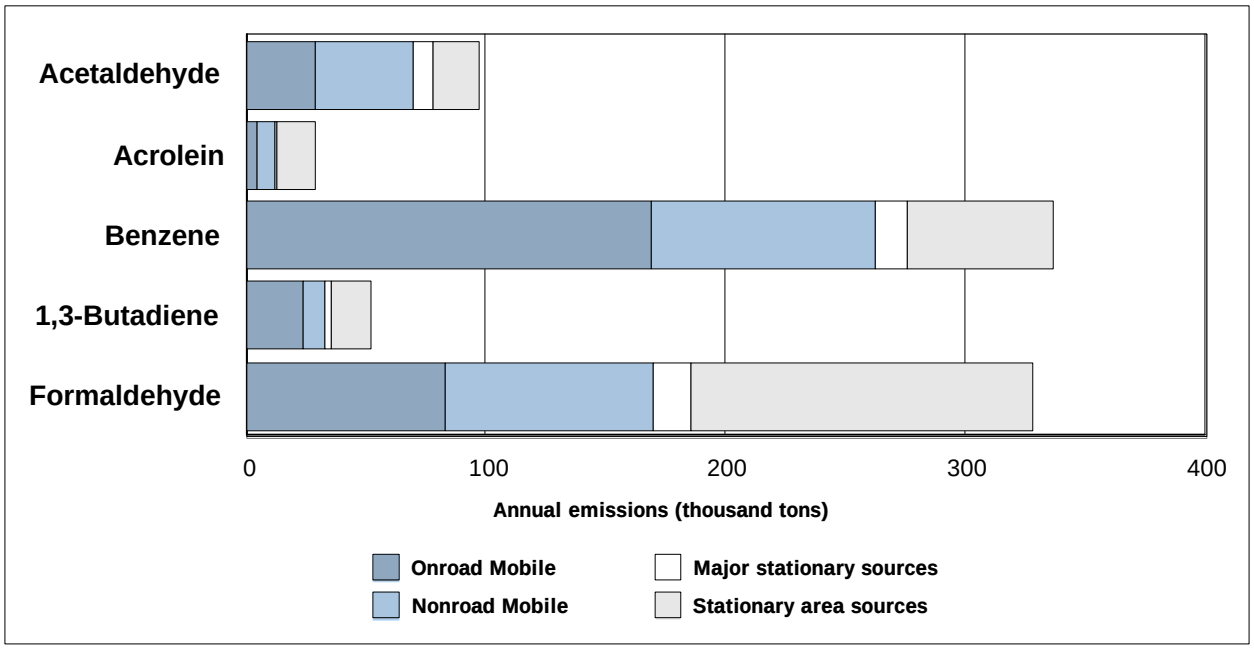

Figure 1. Contribution of Mobile Source Emissions to Total Emissions of Gaseous HAPs
Contiguous 48 States and the District of Columbia (excludes Alaska and Hawaii)

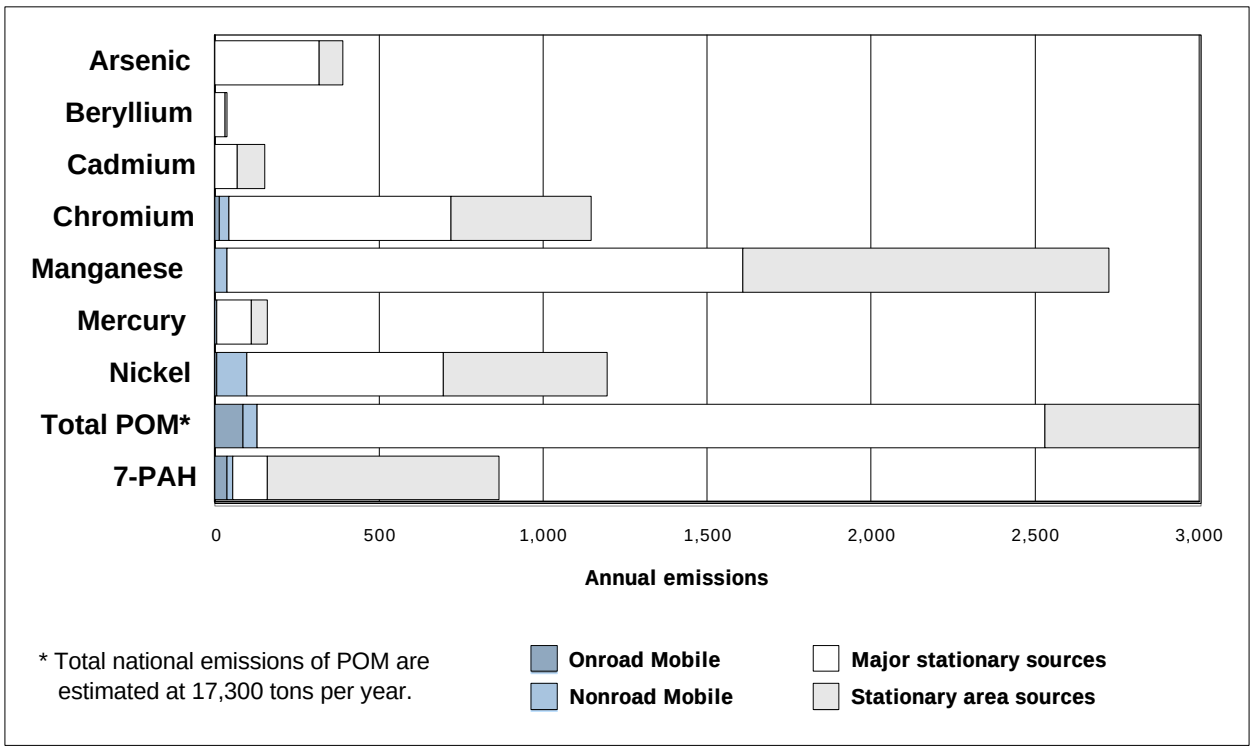

Figure 2. Contribution of Mobile Source Emissions to Total Emissions of HAPs in the Particulate Phase
Contiguous 48 States and the District of Columbia (excludes Alaska and Hawaii)

These seven compounds represent a subset of total POM. Diesel PM was not included in this projection, but it is one of the HAPs of greatest concern. The EPA projected large reductions in exposure to diesel PM over time in its recent 2007 heavy duty rulemaking.[3]

We projected 2007 emissions from mobile sources for the 15 HAPs (with separate estimates for POM and 7-PAH). We also made projections for seven gaseous HAPs which are not on the list of 33, but were of interest to EPA's Office of Transportation and Air Quality (OTAQ). These seven are ethylbenzene, hexane, methyl tert-butyl ether (MTBE), propionaldehyde, styrene, toluene, and xylenes.

In addition to the HAPs that are emitted directly, many gaseous compounds emitted by mobile sources can be converted to HAPs by reactions in the ambient air. For instance, 1-octene, which is present in gasoline, can react in the atmosphere to produce formaldehyde. Some HAP precursors are HAPs themselves (for example, acetaldehyde and MTBE are precursors to formaldehdye) but most are non-HAP volatile organic compounds (VOC). We projected mobile source emissions of precursors pollutants that react to produce formaldehyde, acetaldehyde and propionaldehyde, as these have been identified as HAPs for which secondary formation may account for a significant portion of ambient concentrations.[4] Table 1 gives a list of the HAPs that are projected, including both HAPs that are directly emitted and HAPs that formed indirectly in the atmosphere from mobile source VOC emissions.

The mobile source HAP projections take into account all regulatory programs which are projected to impact on HAP emissions in 2007, including EPA's reformulated gasoline program, the national low emission vehicle program, the Tier 2 motor vehicle emissions standards, and gasoline sulfur control requirements. The recently proposed heavy-duty engine and vehicle standards have not been included, since their impacts on HAP emissions will by realized after 2007. These mobile source standards were put in place primarily to reduce emissions of criteria pollutants;[d] however, they have reduced and will continue to reduce emissions of HAPs significantly.

[d]Criteria pollutants are regulated under National Ambient Air Quality Standards (NAAQS).

Table 1. HAPs Included in Mobile Source Projections

HAP	Direct emissions are projected	Emissions of precursor pollutants are projected
Gaseous HAPs on the NATA list of 33		
Acetaldehyde	✓	✓
Acrolein	✓	✓
Benzene	✓	
1,3-Butadiene	✓	
Formaldehyde	✓	✓
Particulate HAPs on the NATA list of 33		
Arsenic	✓	
Beryllium	✓	
Cadmium	✓	
Chromium	✓	
Dioxins/furans	✓	
Lead	✓	
Manganese	✓	
Mercury	✓	
Nickel	✓	
POM, total	✓	
7-PAH	✓	
Gaseous HAPs not on the NATA list of 33		
Ethylbenzene	✓	
Hexane	✓	
Methyl tert-butyl ether (MTBE)	✓	
Propionaldehyde	✓	✓
Styrene	✓	
Toluene	✓	
Xylenes	✓	

2. Methodologies

We prepared inventories of projected mobile source emissions in 2007 for input into the Emission Modeling System for Hazardous Air Pollutants (EMS-HAP)[5] and the ASPEN dispersion model. Two separate inventories were prepared: the first for HAPs that are directly emitted from mobile sources, and the second for volatile organic compounds (VOC) pollutants that react to form HAPs in the atmosphere (HAP precursors). In both of these cases, we began with a 1996 base year inventory and projected the emissions to 2007. The base year emission data for directly emitted HAPs were obtained from the February 2000 version of the 1996 National Toxics Inventory (NTI).[1] HAP precursor emission data for the base year were obtained from two separate sources: (1) non-HAP VOC came from Version 3 of 1996 National Emissions Trends (NET)[6] inventory, speciated for specific organic compounds; (2) data for HAPs that are precursors to other HAPs came from the 1996 NTI (same version as specified above). The next subsections provide more details on the sources of 1996 emissions data, how we projected the 1996 emissions to 2007, and how we prepared the data for EMS-HAP and ASPEN.

2.1 Emission Inventories for 1996

2.1.1 1996 National Toxics Inventory (NTI)

We obtained the mobile source inventory as a flat text file containing information on all 50 States and the District of Columbia. However, emissions were projected only for the continental U.S. (not Alaska and Hawaii) and the District of Columbia. The 1996 NTI mobile source documentation is in four volumes:[7]

- Documentation for the 1996 Base Year National Toxics Inventory for Aircraft Sources
- Documentation for the 1996 Base Year National Toxics Inventory for Commercial Marine Vessel and Locomotive Mobile Sources
- Documentation for the 1996 Base Year National Toxics Inventory for Nonroad Vehicle and Equipment Mobile Sources
- Documentation for the 1996 Base Year National Toxics Inventory for Onroad Sources

These can be accessed on the EPA web site at http://www.epa.gov/ttn/chief/ei_guide.html#toxic.

2.1.2 1996 National Emission Trends (NET) inventory, speciated for particular VOC

Table 2 provides a list of the precursors for the HAPs that are secondarily formed. The majority of these precursors (33 out of 36) are non-HAP species, and are therefore not in the 1996 NTI. We extracted mobile source emission data for the non-HAP VOC species resulting from a speciation of the Version 3 1996 NET inventory. We received this data for the continental U.S. and the District of Columbia. The methods we used to speciate the VOC data from the NET

into the needed non-HAP precursor species are detailed in Appendix D, Section D.1.2 of the EMS-HAP User's Guide.[52]

Table 2. Species Used for Modeling Secondary HAP Formation

	HAP formed from precursor species		
Precursor	formaldehyde	acetaldehyde	propionaldehyde
ethene	X		
propene	X	X	
1-butene	X		X
1-pentene	X		
1-hexene	X		
1-heptene	X		
1-octene	X		
1-nonene	X		
1-decene	X		
isobutene (2methylpropene)	X		
2-methyl-1-butene	X		
3-methyl-1-butene	X		
3-methyl-1-pentene	X		
2,3-dimethyl-1-butene	X		
isoprene	X		
2-ethyl-1-butene	X		
2-methyl-1-pentene	X		
4-methyl-1-pentene	X		
2,4,4-trimethyl-1-pentene	X		
2-butene		X	
2-pentene		X	X
2-hexene		X	
2-heptene		X	
2-octene		X	
2-nonene		X	
2-methyl-2-butene		X	
3-methyl-2-pentene		X	
4-methyl-2-pentene		X	
ethanol		X	
3-hexene			X
1,3-butadiene *	X		
acetaldehyde *	X		
MTBE *	X		
methanol *	X		

* Precursors denoted with asterisks are also HAPs themselves.

2.2 Projected Emissions for 2007

2.2.1 Onroad emissions of gaseous HAPs

2.2.1.1 Benzene, acetaldehyde, formaldehyde, butadiene, and MTBE

We estimated emissions of benzene, acetaldehyde, formaldehyde, 1,3-butadiene, and MTBE in 2007 using projected emissions developed by the EPA OTAQ, along with projections of future vehicle miles traveled in the EPA NET. OTAQ projected county-level emissions in 2007 for the above HAPs from eight vehicle types: light duty gasoline vehicles (LDGV), light duty gasoline truck (LDGT) categories 1 and 2, heavy duty gasoline vehicles (HDGV), motorcycles (MC), light duty diesel vehicles (LDDV), light duty diesel trucks (LDDT), and heavy duty diesel vehicles (HDDV). This projection assumed a 30 ppm cap on sulfur in gasoline nationwide, and implementation of exhaust emission standards for light duty vehicles recently finalized in the Tier 2 mobile source rulemaking. It did not take into account potential phase-out of MTBE usage in the reformulated gasoline program.[8]

Emission factors were calculated using a toxic emission factor model, MOBTOX5b. This model is based on a modified version of MOBILE5b, which estimates emissions of regulated pollutants, and essentially applies toxic fractions to total organic gas (TOG) estimates. The TOG basic emission rates used in this modeling incorporated available elements from MOBILE6 used to develop the VOC inventory for the Tier 2 final rule. The model accounted for differences in toxic fractions between technology groups, driving cycles, and normal versus high emitting vehicles and engines ("high emitters"). Impacts of fuel formulations were also addressed in the modeling.

OTAQ modeled toxic emissions for 10 urban areas and 16 geographic regions. These areas were selected to encompass a broad range of inspection and maintenance (I/M) programs, fuel parameters, and temperature regimes. The intent of the selection process was to best characterize the different combinations needed to perform accurate nationwide toxic emissions estimates. Every county in the country was then "mapped" to one of these modeled areas or regions (i.e., the emission factor for the modeled area was also used for the area "mapped" to it). OTAQ then multiplied the resulting county level emission factors by county-level estimates of total VMT from EPA's Emission Trends Database. VMT were apportioned among the 8 vehicle types using national average fractions (the same in every county). The following VMT fractions were used in the OTAQ projections:

LDGV –	0.395
LDGT1 --	0.383
LDGT2 --	0.127
HDGV –	0.023
LDDV –	0.000
LDDT –	0.002
HDDV –	0.065
MC --	0.005

We used the county-level VMT fractions developed for the recently finalized 2007 heavy duty rule with two changes. First, we consolidated the two LDGT categories into a single vehicle category in order to maintain consistency with the 1996 NTI. Second, we used county-specific estimates for the distribution of VMT among different vehicle categories, in place of the national average values used in the OTAQ projection. These county-specific VMT distributions were obtained from the NET. We used the following equation:

$$E_{\text{cnty i, veh. type j}} = E_{\text{OTAQ, cnty i, veh. type j}} \times \frac{VMTf_{\text{cnty i, veh. type j}}}{VMTf_{\text{OTAQ~natl, veh. type j}}}$$

where:

$E_{\text{cnty i, veh. type j}}$ = projected 2007 onroad emissions of a given pollutant for vehicle type j in county i

$E_{\text{OTAQ, cnty i, veh. type j}}$ = OTAQ's 2007 projected onroad emissions of the given pollutant for vehicle type j in county i

$VMTf_{\text{cnty i, veh. type j}}$ = fraction of VMT for vehicle type j in county i (based on county-level VMT data in the NET)

$VMTf_{\text{OTAQ~natl, veh. type j}}$ = national fraction of VMT for vehicle type j used in OTAQ estimates (see list above)

Light duty gasoline trucks were combined prior to this projection, so the calculation of LDGT emissions can be expressed as follows:

$$E_{\text{cnty i, LDGT}} = [\, E_{\text{OTAQ, cnty i, LDGT1}} + E_{\text{OTAQ, cnty i, LDGT2}} \,] \times \frac{VMTf_{\text{cnty i, LDGT1}} + VMTf_{\text{cnty i, LDGT2}}}{VMTf_{\text{OTAQ natl, LDGT1}} + VMTf_{\text{OTAQ natl, LDGT2}}}$$

The three inventories used in the above equations (NTI, OTAQ, and NET for VMT) did not always mesh at the county-level because of differences in the allocation of national and state-level emissions to counties. In particular, NET VMT fractions could not be calculated for some independent cities in Virginia and for some counties in Arizona and New Mexico. In the Virginia cities, VMT fractions from the surrounding county were used. In cases where county-level VMT fractions could not be computed, default state-level VMT fractions were used. The NTI also reported no HAP emissions in 1996 from motorcycles in five counties where OTAQ estimated a small amount of emissions in 2007 (0.005 tons total for all five counties). Emissions from motorcycles in 2007 were set at zero in these five cases.

2.2.1.2 Other gaseous organic HAPs

We used county-level predictions of VOC emissions to project future emissions of gaseous organic HAPs that are produced by onroad vehicles but are not explicitly addressed by MOBTOX5b. This approach was used for acrolein, ethyl benzene, hexane, propionaldehyde,

styrene, toluene, and xylenes. The EPA Emission Factor and Inventory Group (EFIG) projected onroad VOC emissions for 2007 under the NET emission inventory program.[9] These projections are based on the regulatory impact analysis for the heavy duty engine rulemaking,[10] and include all final and proposed mobile source rules except heavy duty vehicle standards that will begin to take effect in the 2007 model year. (The impact of these standards in 2007 will be small.)

For the gaseous HAPs not covered by MOBTOX5b, we have assumed that emissions are proportional to total VOC emissions for a given vehicle class and set of operating conditions. Therefore these HAPs are assumed to change by the same ratio as VOC between 1996 and 2007. However, this ratio will depend on the vehicle class and the county, since operating conditions change from county to county. The following equation was used:

$$E_{\text{cnty i, veh. type j}} = E_{\text{1996 NTI, cnty i, veh. type j}} \times \frac{E_{\text{2007 VOC, cnty i, veh. type j}}}{E_{\text{1996 VOC, cnty i, veh. type j}}}$$

where:

$E_{\text{cnty i, veh. type j}}$ = projected 2007 onroad emissions of a given pollutant for vehicle type j in county i

$E_{\text{1996 NTI, cnty i, veh. type j}}$ = 1996 NTI onroad emission estimate of the given pollutant for vehicle type j in county i

$E_{\text{2007 VOC, cnty i, veh. type j}}$ = VOC onroad emissions estimate for vehicle type j in county i from the 2007 projected VOC inventory

$E_{\text{1996 VOC, cnty i, veh. type j}}$ = VOC onroad emissions estimate for vehicle type j in county i from the 1996 VOC inventory

Light duty gasoline trucks (LDGT1 and LDGT2) were combined in this calculation, as follows:

$$E_{\text{cnty i, LDGT}} = E_{\text{1996 NTI, cnty i, veh. type j}} \times \frac{E_{\text{2007 VOC, cnty i, LDGT1}} + E_{\text{2007 VOC, cnty i, LDGT2}}}{E_{\text{1996 VOC, cnty i, LDGT1}} + E_{\text{1996 VOC, cnty i, LDGT2}}}$$

NET VOC scaling factors could not be calculated for some independent cities in Virginia and for some counties in Arizona and New Mexico. In the Virginia cities, VOC scaling factors from the surrounding county were used. In cases where county-level VOC factors could not be computed, default state-level VOC factors were used.

2.2.2 Nonroad emissions of gaseous HAPs

We projected nonroad emissions of gaseous HAPs based on NET predictions of VOC emission reductions, using a similar approach to the one described for other gaseous HAPs from onroad vehicles (section 2.2.1.2). The 1996 NTI contains HAP emissions estimates for six broad

nonroad mobile source categories, which correspond roughly to 4-digit area and mobile source (AMS) emissions inventory codes:

Off-highway 2-stroke gasoline engines -	AMS 2260000000
Off-highway 4-stroke gasoline engines -	AMS 2265000000
Off-highway diesel engines -	AMS 2270000000
Aircraft -	AMS 2275000000
Commercial marine vessels -	AMS 2280000000
Railroad diesel engines -	AMS 2285002000

We have assumed that, within a given county, HAP emissions in each of the above broad categories will change by the same ratio as VOC between 1996 and 2007. EPA/EFIG projected county-level nonroad VOC emissions in 2007 under the NET emission inventory program.[9] These projections were developed using an updated version of EPA/OTAQ's NONROAD emission model,[11] which was developed to support the RIA for the recent heavy duty engine rules.[10] The 2007 VOC projections also include OTAQ instructions regarding commercial marine, locomotives and commercial aircraft. The 2007 VOC inventory divides emissions into a more detailed list of emission source categories than the above list (about 60 categories in all). We linked the detailed NET emission categories to the broader NTI categories, excluding those VOC emission categories which do not emit significant quantities of HAPs (such as natural gas combustion engines).

The following equation was used to project county-level emissions of specific HAPs for each of the broad nonroad engine categories listed above:

$$E_{\text{cnty i, category j}} = E_{\text{1996 NTI, cnty i, category j}} \times \frac{E_{\text{2007 VOC, cnty i, category j}}}{E_{\text{1996 VOC, cnty i, category j}}}$$

where:

$E_{\text{cnty i, category j}}$ = projected 2007 nonroad emissions of a given pollutant from category j in county i

$E_{\text{1996 NTI, cnty i, category j}}$ = 1996 NTI nonroad emission estimate of the given pollutant for category j in county i

$E_{\text{2007 VOC, cnty i, category j}}$ = VOC nonroad emissions estimate for category j in county i from the 2007 projected VOC inventory

$E_{\text{1996 VOC, cnty i, category j}}$ = VOC nonroad emissions estimate for category j in county i from the 1996 VOC inventory

County-specific growth factors could not be estimated for marine vessel emissions in nine counties. In these cases, a national average growth factor (1.097) was used.

2.2.3 Onroad emissions of particulate HAPs

Particulate HAP emissions from onroad vehicles consist of POM, dioxins and furans, and various HAP metals, including arsenic, chromium, lead, manganese, mercury, and nickel. Different methodologies were used for POM than for the other HAPs, as discussed in the following two subsections.

2.2.3.1 Polycyclic organic matter

A number of measures are being implemented between 1996 and 2007 to control fine particulate matter ($PM_{2.5}$) emissions from onroad vehicles. EPA/EFIG has projected county-level onroad $PM_{2.5}$ emissions in 2007 under the NET emission inventory program.[9] These projections were developed to support the RIA for the recent heavy duty engine rules.[10] There is generally a reasonable correlation between POM and total carbon emissions.[12] Therefore, emissions of POM were assumed to be reduced by the same ratio as $PM_{2.5}$. The following equation was used:

$$E_{\text{cnty i, veh. type j}} = E_{\text{1996 NTI, cnty i, veh. type j}} \times \frac{PM2.5_{\text{2007, cnty i, veh. type j}}}{PM2.5_{\text{1996, cnty i, veh. type j}}}$$

where:

$E_{\text{cnty i, veh. type j}}$ = projected 2007 onroad emissions of a given pollutant for vehicle type j in county i

$E_{\text{1996 NTI, cnty i, veh. type j}}$ = 1996 NTI onroad emission estimate of the given pollutant for vehicle type j in county i

$PM2.5_{\text{2007, cnty i, veh. type j}}$ = $PM_{2.5}$ estimate for vehicle type j in county i from the 2007 projected VOC inventory

$PM2.5_{\text{1996, cnty i, veh. type j}}$ = $PM_{2.5}$ estimate for vehicle type j in county i from the 1996 VOC inventory

In some cases, $PM_{2.5}$ emissions in 1996 were too small to allow calculation of $PM_{2.5}$ emission ratios. This occurred for motorcycles in 376 counties, for LDDT in 90 counties, and for other vehicle categories in fewer than 10 counties. In most of these cases, we used PM_{10} emission ratios in place of $PM_{2.5}$ ratios. In about 145 counties for motorcycles and 8 counties for LDDT, PM_{10} emissions in 1996 were also too small to compute emission ratios. Emissions of POM in 2007 were assumed to be the same as emissions in 1996 in these situations.

Neither $PM_{2.5}$ emissions nor PM_{10} emissions were available for some independent cities in Virginia and for some counties in Arizona and New Mexico. In the Virginia cities, $PM_{2.5}$ factors from the surrounding county were used. In cases where county-level $PM_{2.5}$ and PM_{10} emissions were not available, default state-level VMT factors were used.

2.2.3.2 Trace metals and dioxins

The emission controls coming online for onroad vehicles between 1996 and 2007 are not expected to have a substantial impact on emissions of HAP metals, which are primarily due to their presence in fuels and lubricants, or from engine wear. Diesel emissions of dioxins and furans may be impacted by new diesel standards, but these impacts are uncertain. Therefore, we have assumed that all HAP emissions from onroad vehicles will increase or decrease in proportion to changes in vehicle usage between 1996 and 2007.

HAP emissions from all gasoline vehicles and light duty diesels were projected based on county-level predictions of future vehicle miles traveled (VMT). The following equation was used:

$$E_{\text{cnty i, veh. type j}} = E_{\text{1996 NTI, cnty i, veh. type j}} \times \frac{VMT_{\text{2007, cnty i, veh. type j}}}{VMT_{\text{1996, cnty i, veh. type j}}}$$

where:

$E_{\text{cnty i, veh. type j}}$ = projected 2007 onroad emissions of a given pollutant for vehicle type j in county i

$E_{\text{1996 NTI, cnty i, veh. type j}}$ = 1996 NTI onroad emission estimate of the given pollutant for vehicle type j in county i

$VMT_{\text{2007, cnty i, veh. type j}}$ = VMT estimate for vehicle type j in county i from the 2007 projected VOC inventory

$VMT_{\text{1996, cnty i, veh. type j}}$ = VMT estimate for vehicle type j in county i from the 1996 VOC inventory

NET VMT factors could not be calculated for some independent cities in Virginia and for some counties in Arizona and New Mexico. In the Virginia cities, VMT factors from the surrounding county were used. In cases where county-level VMT factors could not be computed, default state-level VMT factors were used.

The above equation was not used for heavy duty diesel vehicles (HDDV). Instead, future HAP emissions from HDDV were estimated from the predicted increase total energy output (in horse-power-hours) at a national level. Total energy output for HDDV is projected to increase by 34% between 1996 and 2007. Thus, the following equation was used to project future emissions of particulate HAPs from HDDV:

$$E_{\text{cnty i, HDDV}} = E_{\text{1996 NTI, cnty i, HDDV}} \times 1.34$$

where:

$E_{\text{cnty i, HDDV}}$ = projected 2007 onroad emissions for a given pollutant for HDDV in county i

$E_{\text{1996 NTI, cnty i, HDDV}}$ = 1996 NTI onroad emission estimate for a given pollutant for HDDV in county i

1.34 = Predicted increase in total horse-power-hours for HDDV between 1996 and 2007

2.2.4 Non-road emissions of particulate HAPs

2.2.4.1 Polycyclic organic matter

Emissions of POM from nonroad sources are expected to be reduced by the same ratio as $PM_{2.5}$. EPA/EFIG has projected county-level onroad $PM_{2.5}$ emissions in 2007 under the NET emission inventory program.[9] We used the $PM_{2.5}$ emissions estimates to project emissions of 7-PAH and 16-PAH at the county level for the six broad categories of nonroad emissions in the NTI (listed in section 2.2.2). The following equation was used:

$$E_{\text{cnty i, category j}} = E_{\text{1996 NTI, cnty i, category j}} \times \frac{PM2.5_{\text{2007, cnty i, category j}}}{PM2.5_{\text{1996, cnty i, category j}}}$$

where:

$E_{\text{cnty i, veh. type j}}$ = projected 2007 onroad emissions of a given pollutant for nonroad category j in county i

$E_{\text{1996 NTI, cnty i, veh. type j}}$ = 1996 NTI onroad emission estimate of the given pollutant for nonroad category j in county i

$PM2.5_{\text{2007, cnty i, veh. type j}}$ = $PM_{2.5}$ estimate for nonroad category j in county i from the 2007 projected VOC inventory

$PM2.5_{\text{1996, cnty i, veh. type j}}$ = $PM_{2.5}$ estimate for nonroad category j in county i from the 1996 VOC inventory

Some aircraft and marine vessel emissions estimates in the NTI could not be matched to $PM_{2.5}$ emissions in the NEI because of differences in the methodologies used for allocating emissions from the state level to the county level in the two inventories. These mismatches occurred for for aircraft in about 500 counties and marine vessels in 10 counties. In these cases default state-level $PM_{2.5}$ ratios were used to project PAH emissions.

2.2.4.2 Trace metals and dioxins

EPA has not estimated the potential impacts on particulate HAP emissions for emission controls coming online for nonroad engines between 1996 and 2007. Therefore, our projections are based on the conservative assumption that particulate HAPs will increase or decrease in proportion to changes in nonroad engine usage between 1996 and 2007. Projections were made based on national average growth factors, using the following equation:

$$E_{\text{cnty i, category j}} = E_{\text{1996 NTI, cnty i, category j}} \times GF_{\text{category j}}$$

where:

$E_{\text{cnty i, veh. type j}}$ = projected 2007 nonroad emissions of a given pollutant for category j in county i

$E_{\text{1996 NTI, cnty i, veh. type j}}$ = 1996 NTI nonroad emission estimate of the given pollutant for category j in county i

$GF_{\text{category j}}$ = VMT estimate for vehicle type j in county i from the 2007 projected VOC inventory

Table 3 gives the estimated national growth factors for the various nonroad emission categories. Growth factors for the 2-stroke, 4-stroke, off-road diesel, and commercial marine categories were calculated based on the predicted change in total energy usage (in horse-power-hours) from the February 2000 version of the NONROAD model.[11] For locomotives, fuel consumption has remained static for many years and OTAQ projects it will continue to do so.

Separate growth factors were used for lead emissions from aircraft. Lead emissions emanate mainly from general aviation, therefore the growth factor for lead is based on the projected increase in fuel usage in general aviation.

Table 3. Growth Factors for Particulate HAP Emissions from Nonroad Engines

Emission category	AMS code	HAP	Growth factor	Basis
2-stroke gasoline engines	2260000000		1.09	Energy output
4-stroke gasoline engines	2265000000		1.15	Energy output
Off highway diesel engines	2270000000		1.38	Energy output
Aircraft	2275000000	Lead	1.11	Fuel consumption for general aviation
Commercial marine vessels	2280000000		1.13	Energy output
Railroad diesel engines	2285002000		1.00	Fuel consumption, assumed constant

2.2.5 Emissions of HAP precursors

HAP precursors which are HAPs themselves were projected as described in Sections 2.2.1 and 2.2.2. Onroad and nonroad emissions of non-HAP precursors were also projected with an approach similar to the approaches used for "other" gaseous HAPs. We began with the 1996 NET inventory for VOC, speciated for individual VOC emissions. As discussed above, EPA/EFIG has projected county-level onroad and nonroad VOC emissions in 2007 under the NET emission inventory program.[9] We assumed that, within a given county and for a given emission source category, emissions of each precursor pollutant will change by the same ratio as VOC between 1996 and 2007. Thus, we assume that engine design and emission control technology do not substantially change the ratio of HAP to VOC for these "other" gaseous HAPs. The following equation was used:

$$E_{\text{cnty i, category j}} = E_{\text{1996, cnty i, category j}} \times \frac{E_{\text{2007 VOC, cnty i, category j}}}{E_{\text{1996 VOC, cnty i, category j}}}$$

where:

$E_{\text{cnty i, category j}}$ = projected 2007 onroad or nonroad emissions of a given pollutant from category j in county i

$E_{\text{1996, cnty i, category j}}$ = 1996 onroad or nonroad emission estimate of the given pollutant for category j in county i

$E_{\text{2007 VOC, cnty i, category j}}$ = VOC onroad or nonroad emissions estimate for category j in county i from the 2007 projected VOC inventory

$E_{\text{1996 VOC, cnty i, category j}}$ = VOC onroad or nonroad emissions estimate for category j in county i from the 1996 VOC inventory

One difference between the projection of VOC precursors and the HAP projections described above is that there was no need to aggregate VOC emissions into the categories used in the NTI for HAPs. Rather, each emission source category included in the NET was projected individually. Thus, onroad emissions were projected separately for LDGT1 and LDGT2. In addition, nonroad emissions were generally projected at the 7-digit AMS level, allowing the differentiation treatment for a much wider array of engines (for instance, 2-stroke recreational vehicles are distinguished from 2-stroke construction equipment). VOC emissions for 2-stroke and 4-stroke recreational vehicles in five Alabama counties were too low for the calculation of detailed scaling factors (at the 7-digit AMS level). In these cases, average VOC factors were applied based on the total emissions from all 2-stroke engines and all 4-stroke engines (the 4-digit AMS level).

2.3 Spatial and Temporal Processing of Emissions

We used EMS-HAP to prepare the projected emissions inventories for dispersion modeling. EMS-HAP performs the following operations for mobile sources:

- Allocates the county-level estimates of aircraft emissions (AMS codes beginning with 227500 or 227505) from the mobile source inventory to the actual locations of commercial and civil airports in each county, and assigns point source variables such as geographic coordinates and stack parameters to each allocated aircraft emission record. (See Chapter 2 of the EMS-HAP User's Guide.[5]) The parameters we used for airports were: IVENT=1 (nonstacked emission point which means that the ASPEN model performs no plume rise calculations), stack height = 5 meters, stack diameter = 1 meter, stack temperature = 395 K, stack velocity = 0.5 meters/seconds (EMS-HAP guide, Section 3.1.2).

- Appends the aircraft emissions estimates to the point sources inventory or (depending on user options) creates a separate point source file containing allocated aircraft emissions. We ran the allocated aircraft emissions from the NTI as a separate point source file through EMS-HAP. We ran the allocated precursor emissions together with the other point source precursor emissions through EMS-HAP.

- Spatially allocates all mobile source county level emissions (which includes all mobile sources other than the air craft emissions that were allocated to point sources) to Census tracts (a typical Census tract covers about 4000 people) using spatial surrogates (See EMS-HAP guide, Section 10.1.2 and Appendix D.8.[5])

- Temporally allocates annual average emissions to eight 3-hour periods in a typical day (midnight to 3 AM, 3 AM to 6 AM, etc.). Each day is assumed to have the same total emissions. (No seasonal or day of week variation is taken into account.) (Chapter 5 of the EMS-HAP guide discusses temporal allocation methods for aircraft modeled as point sources, and Section 10.1.3 gives methodologies other mobile sources. Appendix D.7 of the EMS-HAP guide presents the temporal allocation factors used for mobile sources.[5])

Figure 3 gives an overview of EMS-HAP processing for mobile sources, including the processing of airports as point sources. Figure 4 provides more detail on the allocation of county-level airport emissions to specific locations, and Figure 5 provides more detail on the processing of other mobile source emissions. The User's Guide for EMS-HAP discusses these operations in detail.[5] The options used in processing the 2007 projection inventory are the same as those used in carrying out the 1996 national assessment, as documented in Appendix D of the EMS-HAP User's Guide.

2.4 Ambient Concentration Modeling

Ambient impacts of mobile source emissions were predicted using the ASPEN dispersion model.[2,4] This model is based on the EPA's Industrial Source Complex Long Term model (ISCLT2) which simulates the behavior of the pollutants after they are emitted into the atmosphere. ASPEN uses emissions data and meteorological data to predict the ambient concentrations of HAPs for each Census tract in the contiguous U.S. (including the District of Columbia), and the Virgin Islands and Puerto Rico. For the 2007 mobile source projections, ambient impacts were estimated only for the contiguous U.S.

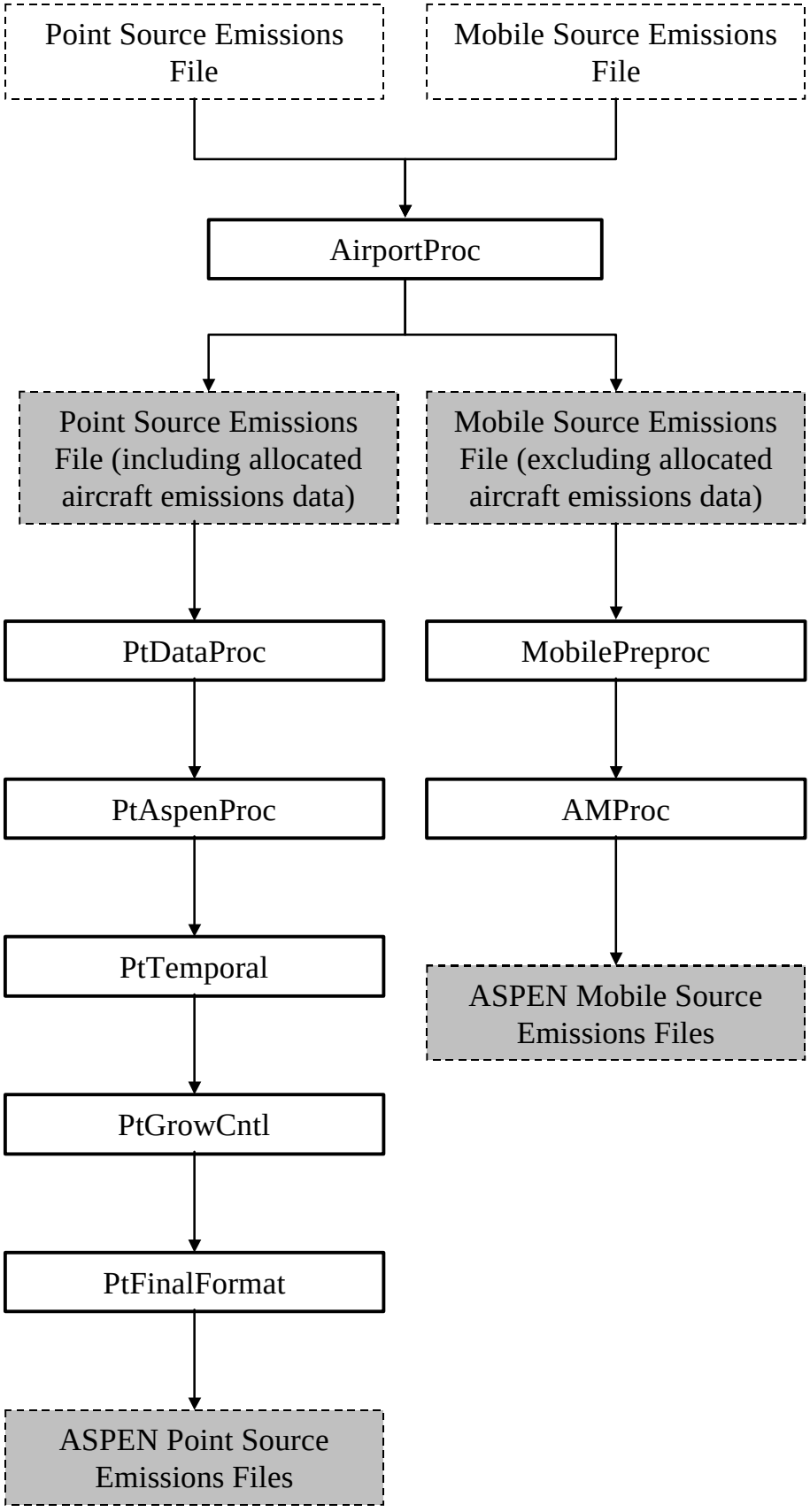

Figure 3. Overview of EMS-HAP Processing of Mobile Sources

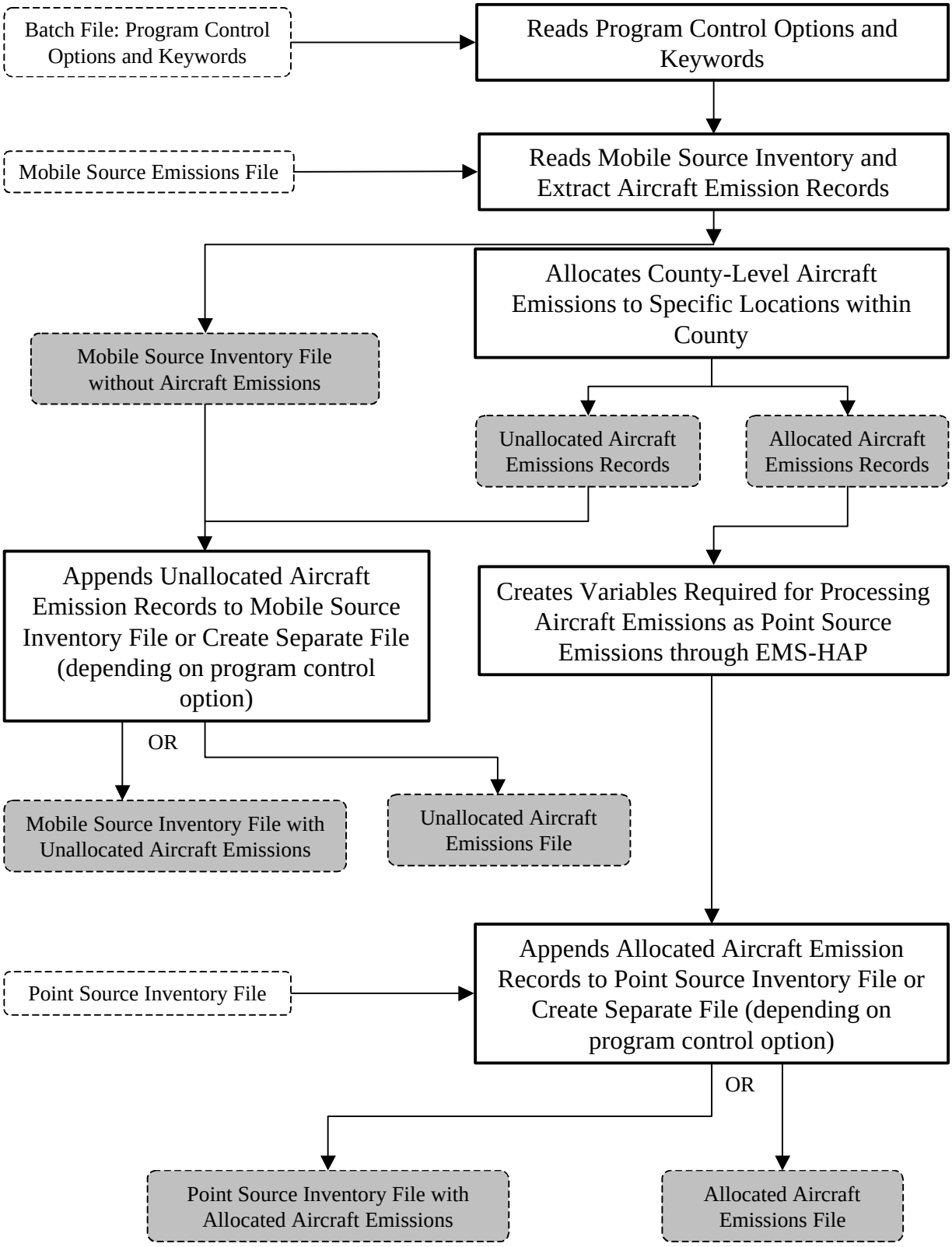

Figure 4. Processing of Airports in EMS-HAP

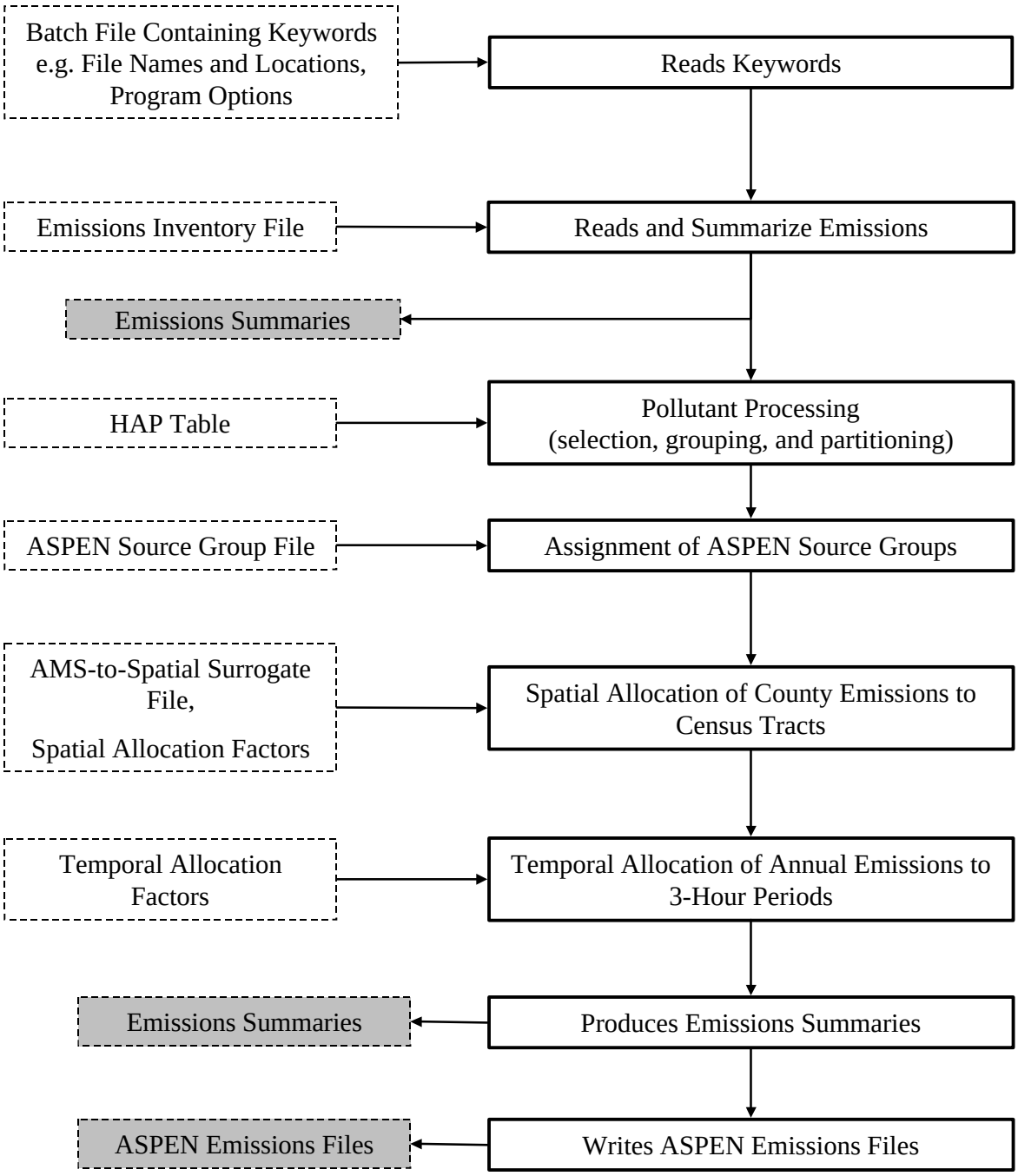

Figure 5. Processing of Other Mobile Sources in EMS-HAP

3. Results

The following sections present the results of HAP emission projections for mobile sources in 2007, and the results of dispersion modeling using the 2007 emission projections.

4.1 Projected Emissions in 2007

Table 4 summarizes the results of mobile source HAP emission projections. Results are provided for gaseous HAPs, particulate HAPs, and HAP precursors. The table gives estimated emissions in the 1996 NTI, projected emissions in 2007, and the resulting change in emissions. Separate estimates are given for onroad and nonroad emissions. Separate estimates are also given for each of the HAPs that are directly emitted, but precursor emissions are lumped together into an aggregate estimate for each HAP that is produced. The lumped precursor emissions shown in the table are a straight sum of each of the precursors (nonHAP and HAP) that form that particular HAP; these sums do not account for the different reactivities or molar yields of the individual precursors, and therefore do not reflect the reactivity and molar yield-weighted precursor mass that is input into the ASPEN model. It should also be noted that not all of the precursor emissions will be converted to HAPs in the atmosphere.

As Table 4 shows, reductions of 24 to 50% are projected for all of the gaseous HAPs, both for onroad vehicles and nonroad engines. Metal emissions are projected to increase by 5 to 36% from 1996, but these emissions are three orders of magnitude lower than the projected emissions of gaseous HAPs. Emissions of HAP precursors are projected to decrease substantially for both onroad and nonroad sources.

Tables 5 through 7 give national projections of onroad emissions from the different vehicle types for gaseous HAPs, particulate HAPs, and HAP precursors, respectively. Each table gives estimated emissions in 1996, projected emissions in 2007, and the resulting change in emissions. For comparison, the projected changes in VMT are also shown for the different vehicle categories.

Table 5 shows that emissions of gaseous HAPs are projected to decrease substantially despite increases in overall VMT. The projected reductions in gaseous HAP emissions are driven mainly by the projected reductions for LDGV and LDGT, although emission reductions are projected for all of the categories except MC. LDGT emissions of gaseous HAPs are projected to decrease by 12 to 60% despite an increase of over 100% in VMT. LDDV usage is expected to be phased out by 2007.

As shown in Table 6, the projected changes in particulate HAP emissions match projected changes in VMT, with the exception of heavy duty categories. In these categories, particulate HAP emissions are expected to increase in proportion to total power usage (in horse-power-hours). The phaseout of LDDV results in reductions in overall emissions for arsenic and mercury. However, this result stems mainly from differences between the speciation factors used for LDDV

Table 4. Summary of Mobile Source Emission Projection Results for the Contiguous 48 States and the District of Columbia
(excludes Alaska and Hawaii)

	Estimated 1996 emissions (tons/year)			Projected 2007 emissions (tons/year)			Change in emissions (%)		
	Onroad	Nonroad	All mobile	Onroad	Nonroad	All mobile	Onroad	Nonroad	All mobile
Gaseous HAPs									
Acetaldehyde	28,567	40,126	68,692	16,540	25,000	41,539	-42	-38	-40
Acrolein	4,932	7,226	12,159	3,008	5,019	8,026	-39	-31	-34
Benzene	167,488	91,330	258,818	83,545	63,515	147,060	-50	-30	-43
1,3-Butadiene	23,393	9,242	32,635	11,203	6,832	18,035	-52	-26	-45
Ethyl benzene	80,313	56,493	136,805	44,046	40,931	84,977	-45	-28	-38
Formaldehyde	82,663	85,030	167,693	41,718	54,483	96,201	-50	-36	-43
Hexane	62,854	39,129	101,983	34,921	28,126	63,048	-44	-28	-38
MTBE	65,106	53,936	119,043	25,092	31,846	56,939	-61	-41	-52
Propionaldehyde	5,478	6,819	12,297	3,423	4,481	7,904	-38	-34	-36
Styrene	16,227	3,230	19,457	8,995	2,464	11,459	-45	-24	-41
Toluene	546,536	228,611	775,147	299,656	165,908	465,564	-45	-27	-40
Xylenes	309,117	234,043	543,160	169,481	171,076	340,557	-45	-27	-37
Total gaseous HAPs	1,392,674	855,215	2,247,889	741,628	599,681	1,341,309	-47	-30	-40
Particulate HAPs									
Total POM	90.1	40.4	130.5	59.5	44.1	103.6	-54	9	-34
7-PAH	41.5	17.0	58.5	27.4	18.1	45.5	-54	6	-41
Arsenic	0.3	1.9	2.2	0.1	2.1	2.3	-55	13	5
Beryllium	0	0.02	0.02	0.0	0.02	0.0	na	13	13
Cadmium	0	0.26	0.26	0.0	0.3	0.3	na	13	13
Chromium	13.4	34.0	47.4	16.2	43.6	59.8	21	28	26
Dioxins/Furans	0.00013	0.0	0.00013	0.00017	0.0	0.00017	36	na	36
Lead	18.9	527.2	546.1	22.0	585.2	607.2	17	11	11
Manganese	5.8	34.9	40.7	7.0	44.7	51.7	21	28	27
Mercury	0.2	6.6	6.8	0.1	9.0	9.1	-21	36	34
Nickel	10.6	87.9	98.5	13.0	101.5	114.5	23	15	16
Total particulate HAPs	139	733	872	100	831	930	-28	13	7
Precursors									
Acetaldehyde precursors [a]	308,307	152,458	460,765	191,847	103,679	295,526	-38	-32	-36
Acrolein precursors [a]	23,393	9,242	32,635	11,203	6,832	18,035	-52	-26	-45
Formaldehyde precursors [a]	768,247	535,136	1,303,383	465,635	382,155	847,791	-39	-29	-35
Propionaldehyde precursors [a]	77,489	38,420	115,909	48,157	27,156	75,313	-38	-29	-35

[a] HAP precursor emissions estimates include some precursors that are themselves HAPs. Not all of the mass of precursor emissions is converted to HAPs.
na = not applicable, emissions were 0 or not reported in 1996

Table 5. Gaseous HAP Emission Projections for Different Onroad Vehicle Categories

Contiguous 48 States and the District of Columbia (excludes Alaska and Hawaii)

HAP	LDGV	LDGT	HDGV	MC	LDDV[a]	LDDT	HDDV	Total onroad
Estimated 1996 emissions (tons)								
Acetaldehyde	10,011	8,534	1,912	201	224	115	7,570	28,567
Acrolein	1,991	962	906	1	58	19	995	4,932
Benzene	87,768	66,010	9,462	936	364	187	2,760	167,488
1,3-Butadiene	10,682	8,822	1,756	281	164	84	1,604	23,393
Ethyl benzene	51,640	24,492	3,541	27	33	11	569	80,313
Formaldehyde	26,426	24,816	9,069	736	702	362	20,554	82,663
Hexane	40,166	17,683	3,301	19	91	30	1,564	62,854
MTBE	36,665	24,502	3,077	862	0	0	0	65,106
Propionaldehyde	1,955	952	122	1	304	101	2,043	5,478
Styrene	10,428	5,100	50	6	35	12	597	16,227
Toluene	352,924	168,785	23,663	184	53	18	910	546,536
Xylenes	199,049	95,150	13,347	105	79	26	1,362	309,117
Projected 2007 emissions (tons)								
Acetaldehyde	2,631	4,643	1,180	280	0	21	7,785	16,540
Acrolein	738	832	577	2	0	10	850	3,008
Benzene	27,187	45,201	7,122	1,161	0	35	2,839	83,545
1,3-Butadiene	3,044	5,444	687	363	0	16	1,649	11,203
Ethyl benzene	19,662	21,582	2,279	32	0	6	485	44,046
Formaldehyde	5,394	9,961	4,224	933	0	67	21,140	41,718
Hexane	15,609	15,790	2,150	22	0	16	1,335	34,921
MTBE	9,127	12,902	2,310	754	0	0	0	25,092
Propionaldehyde	728	825	78	1	0	53	1,738	3,423
Styrene	3,957	4,486	30	7	0	6	510	8,995
Toluene	134,498	148,910	15,245	217	0	9	777	299,656
Xylenes	75,733	83,860	8,587	124	0	14	1,163	169,481
Projected change (%)								
Acetaldehyde	-74	-46	-38	39	-100	-82	3	-42
Acrolein	-63	-14	-36	18	-100	-48	-15	-39
Benzene	-69	-32	-25	24	-100	-82	3	-50
1,3-Butadiene	-72	-38	-61	29	-100	-82	3	-52
Ethyl benzene	-62	-12	-36	18	-100	-48	-15	-45
Formaldehyde	-80	-60	-53	27	-100	-82	3	-50
Hexane	-61	-11	-35	18	-100	-48	-15	-44
MTBE	-75	-47	-25	-13	na	na	na	-61
Propionaldehyde	-63	-13	-36	18	-100	-48	-15	-38
Styrene	-62	-12	-40	18	-100	-48	-15	-45
Toluene	-62	-12	-36	18	-100	-48	-15	-45
Xylenes	-62	-12	-36	18	-100	-48	-15	-45
Change in VMT (%)	-14	104	44	44	-100	-6	44	27

[a] LDDV usage is expected to be phased out by 2007.

na = not applicable, emissions were 0 or not reported in 1996

Onroad vehicle categories:

LDGV - Light duty gasoline vehicles
LDGT - Light duty gasoline trucks
HDGV - Heavy duty gasoline vehicles
MC - Motorcycles
LDDV - Light duty diesel vehicles
LDDT - Light duty diesel trucks
HDDV - Heavy duty diesel vehicles

Table 6. Particulate HAP Emission Projections for Different Onroad Vehicle Categories

Contiguous 48 States and the District of Columbia (excludes Alaska and Hawaii)

HAP	LDGV	LDGT	HDGV	MC	LDDV[a]	LDDT	HDDV	Total onroad
Estimated 1996 emissions (tons)								
Total POM	54.2	23.8	3.2	0.62	0.33	0.36	7.6	90.1
7-PAH	24.6	10.9	1.6	0.28	0.15	0.10	4.1	41.6
Arsenic	0.0	0.0	0.0	0.00	0.15	0.04	0.1	0.3
Chromium	8.5	3.6	0.5	0.00	0.15	0.04	0.5	13.4
Dioxins/Furans	0.0	0.0	0.0	0.00	0.00	0.00	0.00012	0.0
Lead	13.9	5.0	0.0	0.00	0.00	0.00	0.0	18.9
Manganese	2.8	1.2	1.1	0.00	0.23	0.06	0.3	5.8
Mercury	0.0	0.0	0.1	0.00	0.08	0.02	0.0	0.2
Nickel	6.2	2.6	0.6	0.00	0.08	0.02	1.1	10.6
Projected 2007 emissions (tons)								
Total POM	28.8	23.2	2.1	1.56	0.00	0.11	3.7	59.5
7-PAH	13.1	10.6	0.9	0.70	0.00	0.03	2.0	27.4
Arsenic	0.0	0.0	0.0	0.00	0.00	0.04	0.1	0.1
Chromium	7.3	7.4	0.8	0.00	0.00	0.04	0.7	16.2
Dioxins/Furans	0.0	0.0	0.0	0.00	0.00	0.00	0.00017	0.0
Lead	11.9	10.1	0.0	0.00	0.00	0.00	0.0	22.0
Manganese	2.4	2.5	1.6	0.00	0.00	0.06	0.4	7.0
Mercury	0.0	0.0	0.1	0.00	0.00	0.02	0.0	0.1
Nickel	5.3	5.4	0.9	0.00	0.00	0.02	1.4	13.0
Projected change (%)								
Total POM	-47	-2	-35	152	-100	-70	-51	-34
7-PAH	-47	-2	-39	149	-100	-70	-50	-34
Arsenic	na	na	na	na	-100	-6	34	-55
Chromium	-14	104	44	na	-100	-6	34	21
Dioxins/Furans	na	na	na	na	-100	na	38	na
Lead	-14	104	na	na	na	na	na	17
Manganese	-14	104	44	na	-100	-6	34	21
Mercury	na	na	44	na	-100	-6	na	-21
Nickel	-14	104	44	na	-100	-6	34	23
Change in VMT (%)	-14	104	44	44	-100	-6	44	27

[a] LDDV usage is expected to be phased out by 2007.

na = not applicable, emissions were 0 or not reported in 1996

Table 7. HAP Precursor Emission Projections for Different Onroad Vehicle Categories
Contiguous 48 States and the District of Columbia (excludes Alaska and Hawaii)

HAP produced	LDGV	LDGT	HDGV	MC	LDDV[a]	LDDT	HDDV	Total onroad
Estimated 1996 emissions (tons)								
Acetaldehyde	156,959	111,274	17,558	2,306	924	411	18,874	308,307
Acrolein	10,682	8,822	1,756	281	164	84	1,604	23,393
Formaldehyde	372,220	274,481	36,985	4,820	3,587	1,623	74,530	768,247
Propionaldehyde	39,589	28,001	4,463	590	222	99	4,527	77,489
Projected 2007 emissions (tons)								
Acetaldehyde	62,080	33,879	11,459	2,993	0	218	16,145	191,847
Acrolein	3,044	5,444	687	363	0	16	1,649	11,203
Formaldehyde	139,631	93,524	23,793	5,868	0	793	65,341	465,635
Propionaldehyde	15,656	8,527	2,914	766	0	52	3,872	48,157
Projected change (%)								
Acetaldehyde	-60	-70	-35	30	-100	-47	-14	-38
Acrolein	-72	-38	-61	29	-100	-82	3	-52
Formaldehyde	-62	-66	-36	22	-100	-51	-12	-39
Propionaldehyde	-60	-70	-35	30	-100	-47	-14	-38
Change in VMT (%)	-14	104	44	44	-100	-6	44	27

[a] LDDV usage is expected to be phased out by 2007.

and HDDV, which may be result from uncertainties in the original tests and the fact that the data on HDDV were collected in a much more recent study.

The results shown in Table 7 for HAP precursors are similar to the results for gaseous HAPs. Again, emissions are projected to decrease despite increases in overall VMT, and reductions are seen for most vehicle categories (except MC).

Tables 8 through 10 give national projections of emissions from the different nonroad categories for gaseous HAPs, particulate HAPs, and HAP precursors, respectively. Table 8 shows significant reductions (24 to 41%) in gaseous HAP emissions, driven mainly by the 2-stroke gasoline engine, 4–stroke gasoline engine, and nonroad diesel engine categories. For particulate HAPs (Table 9), emissions increases ranging from 11 to 36% are projected, driven primarily by the nonroad diesel engine category. HAP precursor emissions (Table 10) are projected to decrease significantly, driven by the 2-stroke, 4-stroke, and nonroad diesel categories.

Tables 11 through 13 give state-level projections of mobile source emission changes for gaseous HAPs, particulate HAPs, and HAP precursors. For each pollutant and each state, the tables give the predicted change in total mobile source emissions between 1996 and 2007. Table 11 shows reductions in almost all of the gaseous HAPs for all states. The one exception is MTBE, where emissions in states that did not use the additive in reformulated gasoline were already low in 1996. It should be noted that our projections did not take into account potential phase-out of MTBE usage in the reformulated gasoline program. The magnitudes of percentage reductions for gaseous HAPs vary from state to state, because of differences in the relative importance of the various onroad vehicle categories and nonroad engine categories.

Table 8. Gaseous HAP Emission Projections for Different Nonroad Engine Categories

Contiguous 48 States and the District of Columbia (excludes Alaska and Hawaii)

HAP	2-Stroke gasoline	4-Stroke gasoline	Nonroad diesel	Marine diesel	Railroad	Airports	Total nonroad
Estimated 1996 emissions (tons)							
Acetaldehyde	2,900	2,818	32,278	3	0	2,127	40,126
Acrolein	511	470	4,996	77	167	1,006	7,226
Benzene	43,951	37,439	8,839	0	0	1,101	91,330
1,3-Butadiene	3,016	4,554	809	0	0	863	9,242
Ethyl benzene	40,539	14,308	1,347	44	96	159	56,493
Formaldehyde	4,541	8,576	64,994	23	0	6,896	85,030
Hexane	26,552	11,463	691	121	263	40	39,129
MTBE	26,286	27,651	0	0	0	0	53,936
Propionaldehyde	420	1,262	4,281	134	291	431	6,819
Styrene	2,147	482	258	46	100	196	3,230
Toluene	166,494	54,571	6,502	70	153	821	228,611
Xylenes	180,516	48,038	4,608	105	229	546	234,043
Projected 2007 emissions (tons)							
Acetaldehyde	2,191	1,781	18,323	4	0	2,701	25,000
Acrolein	385	297	2,836	84	139	1,277	5,019
Benzene	33,137	23,962	5,017	0	0	1,399	63,515
1,3-Butadiene	2,350	2,927	459	0	0	1,096	6,832
Ethyl benzene	30,684	9,154	765	48	79	202	40,931
Formaldehyde	3,399	5,406	36,895	25	0	8,758	54,483
Hexane	19,816	7,518	392	132	218	50	28,126
MTBE	15,045	16,801	0	0	0	0	31,846
Propionaldehyde	317	798	2,430	147	242	547	4,481
Styrene	1,629	306	147	50	83	249	2,464
Toluene	125,925	35,046	3,691	77	127	1,042	165,908
Xylenes	136,767	30,694	2,616	115	190	694	171,076
Projected change (%)							
Acetaldehyde	-24	-37	-43	10	na	27	-38
Acrolein	-25	-37	-43	10	-17	27	-31
Benzene	-25	-36	-43	10	na	27	-30
1,3-Butadiene	-22	-36	-43	na	na	27	-26
Ethyl benzene	-24	-36	-43	10	-17	27	-28
Formaldehyde	-25	-37	-43	10	na	27	-36
Hexane	-25	-34	-43	10	-17	27	-28
MTBE	-43	-39	na	na	na	na	-41
Propionaldehyde	-25	-37	-43	10	-17	27	-34
Styrene	-24	-37	-43	10	-17	27	-24
Toluene	-24	-36	-43	10	-17	27	-27
Xylenes	-24	-36	-43	10	-17	27	-27

na = not applicable, emissions were 0 or not reported in 1996

Table 9. Particulate HAP Emission Projections for Different Nonroad Engine Categories

Contiguous 48 States and the District of Columbia (excludes Alaska and Hawaii)

HAP	2-Stroke gasoline	4-Stroke gasoline	Nonroad diesel	Marine diesel	Railroad	Airports	Total nonroad
Estimated 1996 emissions (tons)							
Total POM	23.8	7.2	2.7	0.8	0.00	5.8	40.3
7-PAH	12.4	3.8	0.8	0.008	0.00	0.1	17.0
Arsenic	0.0	0.0	0.0	1.9	0.01	0.0	1.9
Beryllium	0.0	0.0	0.0	0.0	0.00	0.0	0.0
Cadmium	0.0	0.0	0.0	0.3	0.00	0.0	0.3
Chromium	1.6	1.5	21.1	9.8	0.09	0.0	34.0
Lead	0.0	0.0	0.0	1.0	0.00	526.1	527.2
Manganese	3.2	2.9	21.1	7.7	0.05	0.0	34.9
Mercury	0.3	0.2	6.0	0.1	0.00	0.0	6.6
Nickel	1.9	1.7	9.0	75.1	0.17	0.0	87.9
Projected 2007 emissions (tons)							
Total POM	28.7	4.7	2.1	0.9	0.00	7.7	44.1
7-PAH	14.9	2.5	0.6	0.009	0.00	0.1	18.1
Arsenic	0.0	0.0	0.0	2.1	0.01	0.0	2.1
Beryllium	0.0	0.0	0.0	0.0	0.00	0.0	0.0
Cadmium	0.0	0.0	0.0	0.3	0.00	0.0	0.3
Chromium	1.7	1.7	29.1	11.0	0.09	0.0	43.6
Lead	0.0	0.0	0.0	1.2	0.00	584.0	585.2
Manganese	3.4	3.4	29.1	8.7	0.05	0.0	44.7
Mercury	0.3	0.3	8.3	0.1	0.00	0.0	9.0
Nickel	2.0	2.0	12.5	84.9	0.17	0.0	101.5
Projected change (%)							
Total POM	21	-35	-22	8	na	34	18
7-PAH	20	-35	-22	6	na	34	12
Arsenic	na	na	na	13	0	na	13
Beryllium	na	na	na	13	na	na	13
Cadmium	na	na	na	13	na	na	13
Chromium	9	15	38	13	0	na	28
Lead	na	na	na	13	na	11	11
Manganese	9	15	38	13	0	na	28
Mercury	9	15	38	13	na	na	36
Nickel	9	15	38	13	0	na	15

na = not applicable, emissions were 0 or not reported in 1996

Table 10. HAP Precursor Emission Projections for Different Nonroad Engine Categories

Contiguous 48 States and the District of Columbia (excludes Alaska and Hawaii)

HAP produced	2-Stroke gasoline	4-Stroke gasoline	Nonroad diesel	Marine diesel	Railroad	Airports	Total nonroad
Estimated 1996 emissions (tons)							
Acetaldehyde	37,737	50,688	32,331	2,562	3,451	25,688	152,458
Acrolein	3,016	4,554	809	0	0	863	9,242
Formaldehyde	70,119	188,082	145,045	8,814	11,951	111,124	535,136
Propionaldehyde	12,549	7,707	7,754	655	828	8,927	38,420
Projected 2007 emissions (tons)							
Acetaldehyde	19,721	30,761	17,962	2,810	3,455	28,969	103,679
Acrolein	2,350	2,927	459	0	0	1,096	6,832
Formaldehyde	39,401	114,398	80,981	9,671	11,964	125,739	382,155
Propionaldehyde	6,558	4,677	4,308	718	829	10,067	27,156
Projected change (%)							
Acetaldehyde	-48	-39	-44	10	0	13	-32
Acrolein	-22	-36	-43	na	na	13	-26
Formaldehyde	-44	-39	-44	10	0	13	-29
Propionaldehyde	-48	-39	-44	10	0	13	-29

na = not applicable, emissions were 0 or not reported in 1996

Table 11. Projected State-Level Changes in Total Mobile Source Emissions of Gaseous HAPs (%)

State	Acetal-dehyde	Acrolein	Benzene	1,3-Butadiene	Ethyl-benzene	Formal-dehyde	Hexane	MTBE	Propion-aldehyde	Styrene	Toluene	Xylenes
Alabama	-46	-34	-47	-48	-33	-49	-33	4	-34	-30	-32	-33
Arizona	-37	-29	-59	-46	-39	-38	-38	-84	-33	-35	-38	-39
Arkansas	-43	-31	-45	-45	-31	-46	-32	6	-32	-29	-31	-31
California	-31	-40	-37	-41	-58	-42	-57	-70	-41	-59	-60	-58
Colorado	-50	-25	-59	-62	-34	-46	-35	-38	-29	-35	-35	-33
Connecticut	-42	-52	-50	-48	-66	-44	-65	-43	-51	-71	-69	-67
Delaware	-48	-40	-50	-63	-46	-49	-43	-51	-40	-44	-45	-45
District of Columbia	-46	-47	-54	-50	-60	-48	-59	-45	-46	-60	-61	-60
Florida	-38	-27	-42	-41	-31	-39	-30	-8	-30	-26	-29	-31
Georgia	-42	-35	-48	-47	-47	-44	-47	-2	-37	-47	-48	-48
Idaho	-45	-28	-50	-54	-27	-47	-28	-11	-30	-28	-28	-26
Illinois	-37	-36	-43	-40	-47	-38	-47	-60	-38	-50	-49	-47
Indiana	-44	-38	-48	-48	-41	-48	-41	-57	-37	-41	-42	-40
Iowa	-41	-34	-42	-45	-29	-48	-31	-90	-34	-34	-32	-28
Kansas	-42	-33	-47	-49	-36	-49	-36	-89	-32	-34	-36	-37
Kentucky	-44	-34	-49	-50	-38	-48	-38	-58	-35	-36	-38	-38
Louisiana	-40	-27	-43	-45	-31	-43	-31	-0	-28	-31	-32	-31
Maine	-32	-32	-26	-26	-26	-34	-26	-21	-31	-34	-29	-26
Maryland	-41	-35	-51	-47	-51	-44	-51	-46	-37	-53	-53	-51
Massachusetts	-41	-38	-51	-46	-52	-44	-52	-44	-38	-55	-55	-52
Michigan	-34	-32	-31	-33	-24	-40	-25	-69	-33	-30	-26	-23
Minnesota	-31	-26	-22	-25	-17	-34	-19	-72	-28	-25	-20	-16
Mississippi	-45	-34	-46	-47	-31	-48	-31	3	-34	-29	-30	-31
Missouri	-36	-26	-47	-46	-42	-42	-42	-89	-32	-41	-43	-42
Montana	-45	-26	-49	-53	-23	-47	-25	-13	-26	-28	-26	-22
Nebraska	-42	-31	-46	-48	-36	-48	-36	-90	-30	-35	-37	-36
Nevada	-42	-26	-59	-54	-39	-40	-39	-47	-29	-35	-39	-39
New Hampshire	-36	-34	-30	-31	-24	-40	-25	-35	-33	-33	-27	-23
New Jersey	-38	-45	-47	-44	-63	-40	-63	-42	-47	-67	-66	-64
New Mexico	-53	-27	-65	-67	-33	-49	-33	-5	-29	-29	-32	-33
New York	-35	-35	-39	-37	-43	-36	-42	-39	-35	-47	-45	-42
North Carolina	-43	-29	-45	-45	-34	-45	-33	2	-32	-31	-33	-34
North Dakota	-40	-30	-43	-44	-36	-46	-36	-90	-30	-38	-38	-36
Ohio	-45	-39	-50	-50	-44	-49	-45	-61	-39	-46	-46	-44
Oklahoma	-46	-31	-47	-62	-33	-49	-33	-68	-31	-30	-32	-33
Oregon	-45	-38	-46	-45	-42	-45	-42	-100	-38	-43	-44	-42
Pennsylvania	-39	-36	-41	-37	-43	-40	-44	-41	-39	-46	-45	-42
Rhode Island	-40	-42	-52	-47	-61	-43	-61	-46	-42	-63	-63	-61
South Carolina	-44	-33	-45	-45	-31	-46	-31	8	-34	-28	-30	-31
South Dakota	-37	-30	-38	-40	-30	-43	-31	-89	-32	-36	-33	-29
Tennessee	-44	-33	-47	-47	-33	-47	-34	-23	-34	-30	-32	-33
Texas	-41	-33	-46	-56	-41	-43	-41	-32	-38	-41	-41	-41
Utah	-50	-26	-55	-61	-30	-46	-31	-10	-28	-32	-32	-30
Vermont	-29	-29	-20	-21	-18	-32	-19	34	-27	-29	-22	-17
Virginia	-37	-29	-45	-38	-41	-39	-41	-43	-34	-39	-41	-41
Washington	-42	-29	-45	-42	-36	-41	-35	-100	-32	-33	-35	-36
West Virginia	-45	-37	-51	-52	-39	-50	-39	-59	-37	-37	-39	-39
Wisconsin	-32	-35	-26	-29	-22	-37	-24	-41	-36	-33	-26	-21
Wyoming	-45	-23	-49	-54	-23	-48	-25	-16	-22	-30	-27	-22
Contiguous 48	-40	-34	-43	-45	-38	-43	-38	-52	-36	-41	-40	-37

Table 12. Projected State-Level Changes in Total Mobile Source Emissions of Particulate HAPs (%)

State	Total POM	PAH-7	Ar-senic	Beryl-lium	Cad-mium	Chro-mium	Di-oxins	Lead	Man-ganese	Mer-cury	Nickel
Alabama	-33	-33	6	13	13	24	27	11	25	33	15
Arizona	-28	-30	-51	na	na	34	27	27	32	35	32
Arkansas	-30	-32	-26	13	13	28	27	15	29	34	23
California	-23	-25	1	13	13	29	27	21	29	34	19
Colorado	-19	-24	-48	na	na	32	27	23	31	34	29
Connecticut	-34	-35	0	13	13	27	-4	14	28	34	18
Delaware	-22	-43	9	13	13	22	23	17	23	33	14
District of Columbia	-20	-20	-51	13	13	32	27	21	31	35	29
Florida	-23	-26	5	13	13	30	27	26	29	34	18
Georgia	-28	-32	-10	13	13	30	23	21	30	34	21
Idaho	-4	-4	-49	na	na	31	27	20	31	34	28
Illinois	-20	-24	-7	13	13	28	27	14	29	34	20
Indiana	-31	-32	3	13	13	25	27	12	26	34	16
Iowa	-25	-25	-50	na	na	27	27	10	29	34	24
Kansas	-33	-34	-47	na	na	29	27	14	30	34	25
Kentucky	-29	-33	-11	13	13	27	27	13	28	34	19
Louisiana	-24	-27	12	13	13	17	27	13	17	32	13
Maine	3	9	8	13	13	24	14	14	25	34	15
Maryland	-18	-21	5	13	13	27	27	17	27	34	16
Massachusetts	-21	-16	0	13	13	27	16	14	28	34	18
Michigan	-7	-5	5	13	13	24	27	10	26	34	16
Minnesota	-4	-3	8	13	13	24	27	15	25	34	15
Mississippi	-33	-33	7	13	13	23	27	12	24	34	15
Missouri	-28	-32	1	13	13	26	27	14	27	34	17
Montana	-9	-8	-43	na	na	30	27	19	30	34	26
Nebraska	-31	-32	-41	na	na	28	27	14	29	34	24
Nevada	-17	-26	-50	na	na	36	27	35	33	35	35
New Hampshire	1	1	-5	13	13	28	13	16	29	34	19
New Jersey	-26	-27	0	13	13	28	-19	13	28	34	18
New Mexico	-28	-33	-51	na	na	31	27	22	31	34	29
New York	-17	-18	7	13	13	25	24	8	27	34	16
North Carolina	-23	-25	-15	13	13	30	27	20	30	34	22
North Dakota	-24	-25	-45	na	na	27	27	10	29	34	23
Ohio	-31	-33	4	13	13	25	27	11	26	34	16
Oklahoma	-33	-35	-32	13	13	28	27	14	29	34	23
Oregon	-18	-17	6	13	13	27	27	19	27	34	16
Pennsylvania	-23	-27	6	13	13	25	27	11	26	34	16
Rhode Island	-30	-33	6	13	13	26	-16	12	27	34	16
South Carolina	-30	-31	-5	13	13	28	27	18	29	34	20
South Dakota	-19	-20	-53	na	na	29	27	16	30	34	27
Tennessee	-32	-33	-2	13	13	28	27	17	28	34	18
Texas	-21	-25	10	13	13	24	27	19	24	34	15
Utah	-14	-17	-51	na	na	34	27	28	32	35	32
Vermont	12	10	-53	na	na	30	26	17	30	34	27
Virginia	-25	-26	6	13	13	25	27	17	26	34	16
Washington	-16	-16	9	13	13	26	27	22	26	34	15
West Virginia	-36	-37	8	13	13	23	27	10	24	34	15
Wisconsin	-4	-2	-24	13	13	28	27	14	29	34	22
Wyoming	-12	-11	-38	na	na	26	27	14	28	33	23
Contiguous 48	-21	-22	5	13	13	26	25	16	27	34	16

na = not applicable, emissions were 0 or not reported in 1996

Table 13. Projected State-Level Changes in Total Mobile Source Emissions of HAP Precursors (%)

State	Acetaldehyde	Acrolein	Formaldehyde	Propion-aldehyde
Alabama	-26	-48	-25	-25
Arizona	-28	-46	-26	-27
Arkansas	-27	-45	-26	-26
California	-49	-41	-50	-48
Colorado	-29	-62	-28	-28
Connecticut	-55	-48	-48	-54
Delaware	-37	-63	-39	-37
District of Columbia	-33	-50	-26	-27
Florida	-24	-41	-21	-22
Georgia	-42	-47	-38	-41
Idaho	-26	-54	-26	-24
Illinois	-38	-40	-35	-37
Indiana	-36	-48	-35	-35
Iowa	-35	-45	-35	-34
Kansas	-31	-49	-31	-30
Kentucky	-33	-50	-35	-33
Louisiana	-29	-45	-25	-29
Maine	-31	-26	-28	-30
Maryland	-44	-47	-40	-43
Massachusetts	-45	-46	-41	-44
Michigan	-35	-33	-35	-35
Minnesota	-31	-25	-30	-29
Mississippi	-25	-47	-23	-23
Missouri	-35	-46	-34	-35
Montana	-29	-53	-28	-28
Nebraska	-32	-48	-31	-31
Nevada	-29	-54	-24	-28
New Hampshire	-32	-31	-31	-31
New Jersey	-48	-44	-42	-48
New Mexico	-22	-67	-23	-21
New York	-46	-37	-40	-45
North Carolina	-28	-45	-27	-27
North Dakota	-35	-44	-32	-34
Ohio	-43	-50	-41	-43
Oklahoma	-27	-62	-27	-26
Oregon	-40	-45	-38	-40
Pennsylvania	-42	-37	-41	-42
Rhode Island	-46	-47	-43	-46
South Carolina	-26	-45	-25	-25
South Dakota	-36	-40	-34	-36
Tennessee	-27	-47	-28	-27
Texas	-34	-56	-32	-34
Utah	-30	-61	-29	-29
Vermont	-38	-21	-35	-37
Virginia	-34	-38	-33	-33
Washington	-30	-42	-28	-29
West Virginia	-32	-52	-32	-31
Wisconsin	-41	-29	-40	-41
Wyoming	-29	-54	-29	-28
Contiguous 48	-36	-45	-35	-35

na = not applicable, emissions were 0 or not reported in 1996

Particulate HAP emissions (Table 12) are projected to increase for most compounds in most states. One exception is arsenic, where reductions as a result of the phaseout of LDDV offset increases from other emission categories in some states. If only onroad emissions were considered, a similar situation would be seen with mercury, but in this case the reductions in LDDV emissions are entirely offset by emissions increases from the nonroad categories. In the case of dioxin, increases of about 27% are projected from most states, largely as a result of increases in HDDV traffic. However, the dioxin emissions increases from HDDV are offset by reductions from LDDV in some of the more urban states, especially Rhode Island, New Jersey, and Connecticut. Projected reductions in HAP precursors in Table 13 are similar to the projected reductions for gaseous HAPs.

Figures 6 through 10 show the county-level distributions of projected emission reductions for acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde, respectively. These are the HAPs from the NATA list of 33 for which mobile sources contribute the largest share of national emissions. Each figure shows the percentage change in emissions between 1996 and 2007, accounting for projected emission controls and changes in VMT and nonroad activity. Overall emission reductions vary from state to state and from county to county, depending on the projected increases in VMT and nonroad activity and on the county-specific mix of onroad vehicle categories and nonroad engine categories. As Figures 6 through 10 show, emission controls more than offset projected increases VMT and nonroad activity for all of the above pollutants. For comparison, Figure 11 shows projected increases in VMT at the county level.

4.2 Projected Ambient Impacts

This section gives modeling results for five organic HAPs - acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde - and eight HAP metals - arsenic, beryllium, cadmium, chromium, lead, manganese, mercury, and nickel. Although future emissions have been projected for an additional seven organic HAPs that are of interest for mobile sources, these HAPs are not currently included in the NATA modeling effort. Modeling results also are not yet available for POM (16-PAH and 7-PAH) and dioxins/furans.

Table 14 summarizes nationwide (excluding Alaska and Hawaii) ambient HAP concentration impacts for mobile source emissions in 1996 and 2007. The table gives average ambient concentrations in 1996 and 2007 for onroad mobile sources, nonroad mobile sources, and the sum of onroad and nonroad mobile sources. The averages shown in the table are the average of all the census tract ambient concentrations in the 48 States and the district of Columbia (60,803 census tracts). The median mobile source census tract concentrations are also given for each HAP for 1996 and 2007. Median ambient impacts are also given for all mobile sources in 1996and 2007. For comparison, Table 14 also shows the average and median ambient impacts of all anthropogenic sources - stationary and mobile - in the 1996 base year. The ambient impacts are based on the ASPEN dispersion model, which takes into account the dispersion and decay of HAP emissions, as well as HAPs formed from secondary reactions of precursor pollutants. The concentrations given in Table 14 represent the total impacts of both directly emitted HAPs and HAPs formed from precursor pollutants.

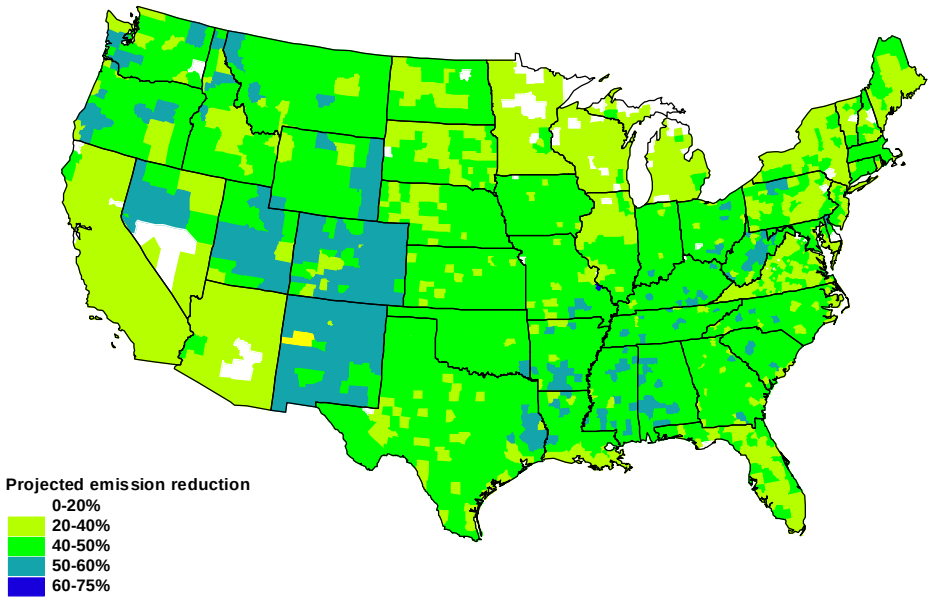

Figure 6. Projected county-level mobile source emission reductions for acetaldehyde

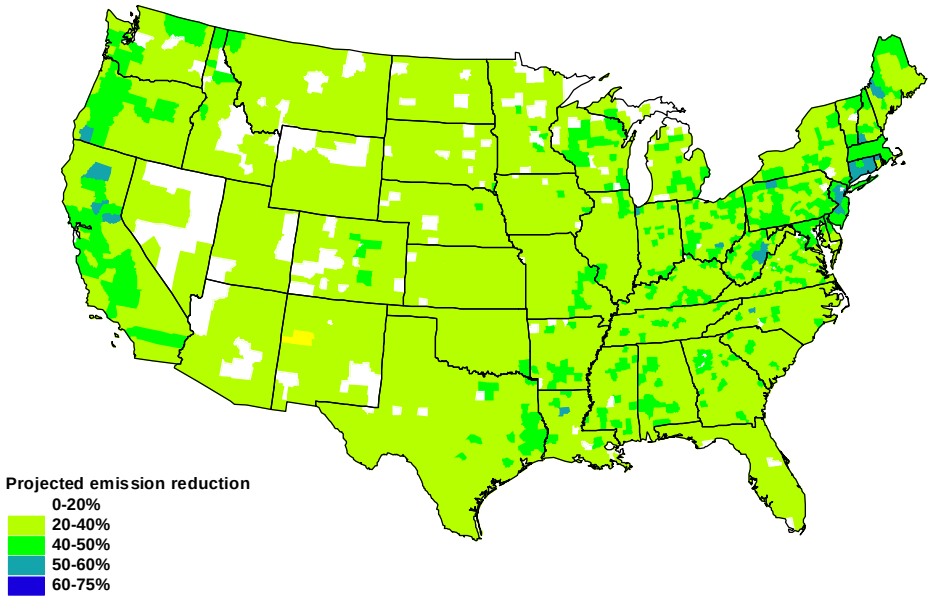

Figure 7. Projected county-level mobile source emission reductions for acrolein

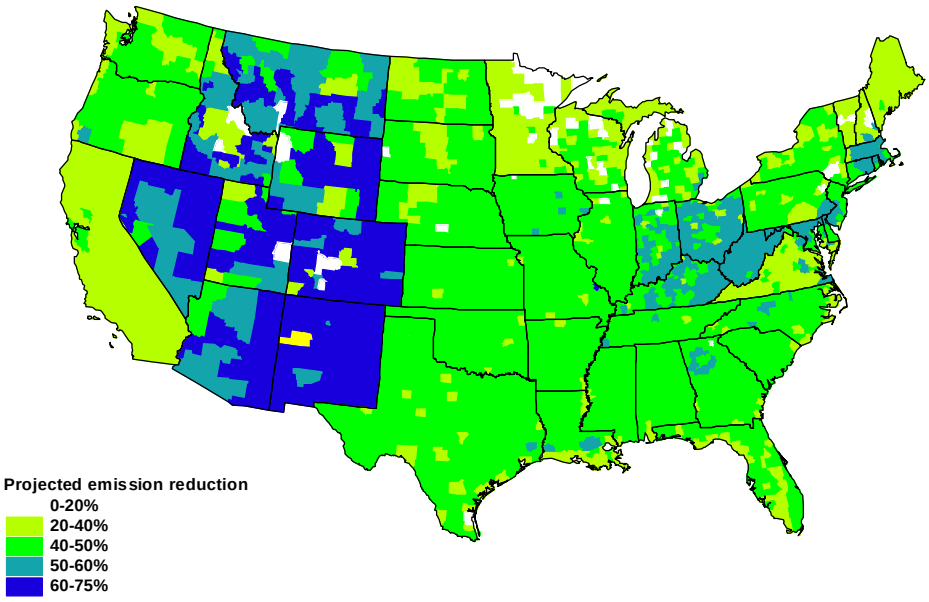

Figure 8. Projected county-level mobile source emission reductions for benzene

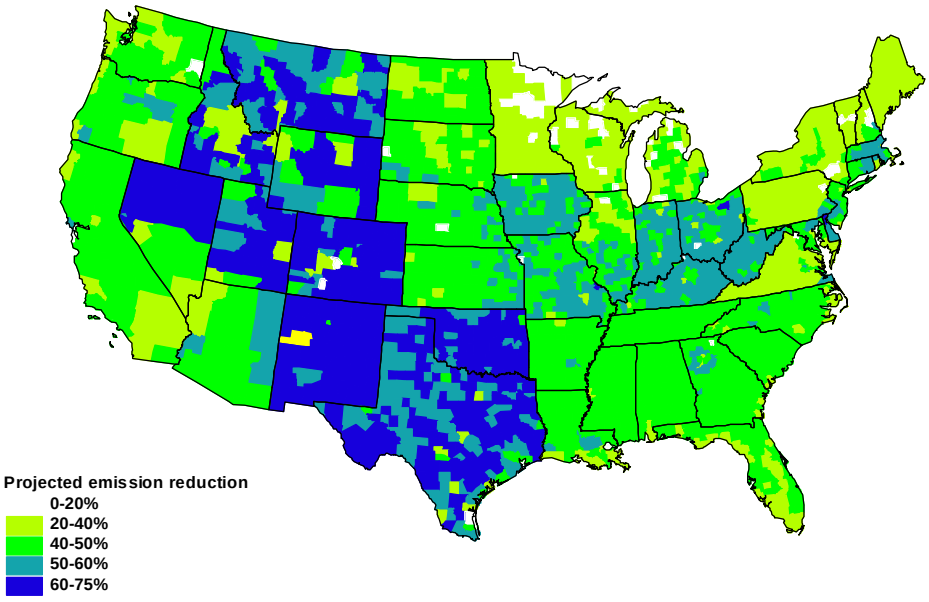

Figure 9. Projected county-level mobile source emission reductions for 1,3-butadiene

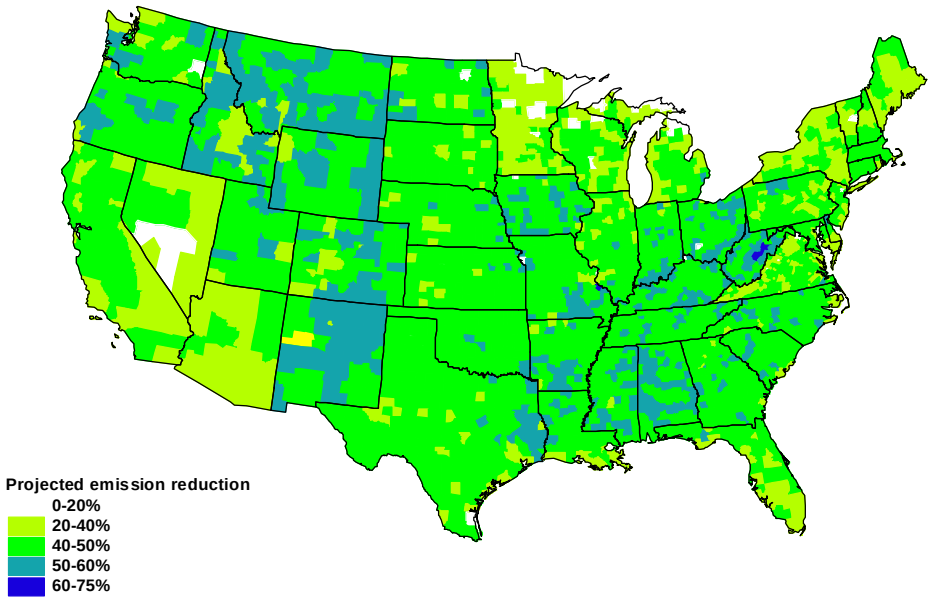

Figure 10. Projected county-level mobile source emission reductions for formaldehyde

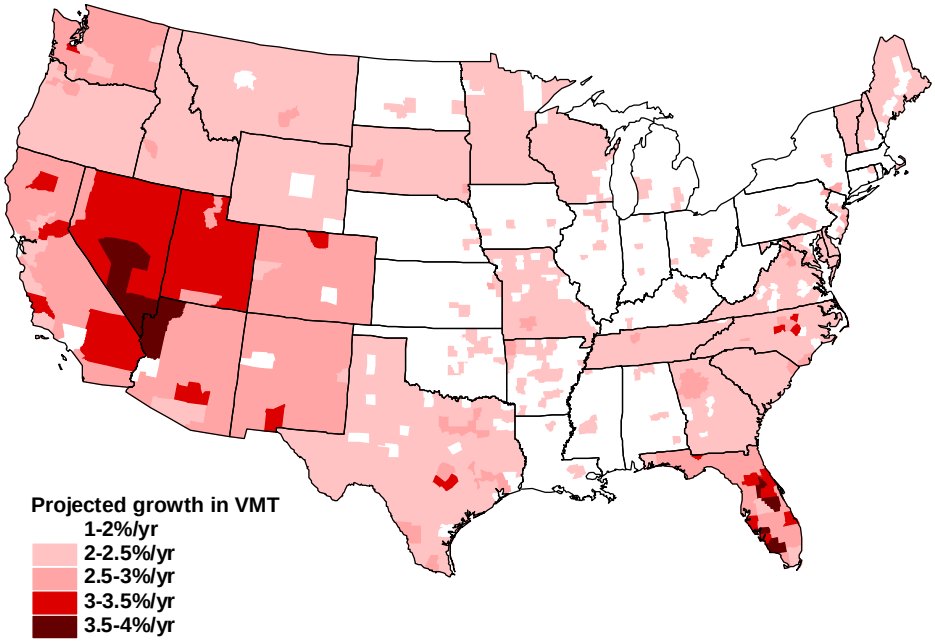

Figure 11. Projected increase in total vehicle miles traveled

Table 14. Summary of Projected Nationwide Ambient Impacts from Mobile Sources

(excluding Alaska and Hawaii)[a]

HAP	Average modeled ambient impacts for mobile sources in 1996 (µg/m^3)			Average modeled impacts for mobile sources in 2007 (µg/m^3)			Median modeled impacts for all mobile sources (µg/m^3)		Total modeled impacts of all sources (stationary plus mobile sources) for 1996 (µg/m^3)	
	Onroad	Nonroad	All mobile	Onroad	Nonroad	All mobile	1996	2007	Average	Median
Gaseous HAPs										
Acetaldehyde	4.0e-01	2.7e-01	6.7e-01	2.2e-01	1.9e-01	4.1e-01	4.5e-01	2.9e-01	7.4e-01	5.2e-01
Acrolein	4.5e-02	4.0e-02	8.5e-02	2.2e-02	3.1e-02	5.2e-02	5.4e-02	3.1e-02	1.1e-01	7.9e-02
Benzene	5.6e-01	2.3e-01	7.9e-01	2.8e-01	1.5e-01	4.3e-01	6.4e-01	3.4e-01	9.1e-01	7.3e-01
Butadiene	5.0e-02	1.7e-02	6.7e-02	2.4e-02	1.2e-02	3.6e-02	5.2e-02	2.7e-02	8.0e-02	6.0e-02
Formaldehyde	3.8e-01	4.8e-01	8.6e-01	1.8e-01	3.4e-01	5.2e-01	5.1e-01	2.9e-01	1.0e+00	6.5e-01
Particulate HAPs										
Arsenic	7.0e-07	7.6e-06	8.3e-06	3.0e-07	8.6e-06	8.9e-06	8.0e-07	4.0e-07	1.6e-04	6.8e-05
Beryllium	0.0e+00	1.0e-07	1.0e-07	0.0e+00	1.0e-07	1.0e-07	0.0e+00	0.0e+00	3.1e-05	1.1e-05
Cadmium	0.0e+00	9.0e-07	9.0e-07	0.0e+00	1.1e-06	1.1e-06	0.0e+00	0.0e+00	1.9e-04	4.1e-05
Chromium	4.2e-05	1.4e-04	1.8e-04	5.0e-05	1.8e-04	2.3e-04	7.8e-05	9.9e-05	3.4e-03	8.5e-04
Lead	5.9e-05	3.5e-03	3.5e-03	6.8e-05	3.7e-03	3.8e-03	4.8e-04	5.3e-04	5.8e-03	1.8e-03
Manganese	1.7e-05	1.4e-04	1.6e-04	2.1e-05	1.8e-04	2.0e-04	6.3e-05	8.1e-05	4.4e-03	2.2e-03
Mercury	6.0e-07	2.9e-05	3.0e-05	5.0e-07	4.0e-05	4.0e-05	1.1e-05	1.4e-05	2.0e-04	7.6e-05
Nickel	3.3e-05	3.2e-04	3.5e-04	4.0e-05	3.7e-04	4.1e-04	6.2e-05	7.7e-05	2.3e-03	9.8e-04

[a] Ambient impacts are expressed in scientific notation: 1.0e-03 = 1.0 x 10^{-3} = 0.0010

As Table 14 shows, average and median ambient impacts from both onroad and nonroad sources are projected to decline substantially between 1996 and 2007 for organic HAPs. For metal HAPs, the combined impact of onroad and nonroad emissions is projected to increase in all cases. However, contribution of mobile sources to the total manmade ambient impact is much smaller for HAP metals than for organic HAPs.

Table 15 gives the same information as Table 14, but broken out between urban and rural counties. This table shows that the substantial nationwide decreases in gaseous HAP impacts are spread across both urban and rural areas. Likewise, small net increases in metal HAP impacts concentrations are predicted in both urban and rural areas. Table 15 also shows that ambient HAP concentrations are considerably higher in urban areas than in rural areas, because of the increased density of both mobile and stationary emission sources in an urban setting.

Table 16 summarizes the projected changes in ambient impact, in terms of percentage reductions on an overall national basis. For comparison, the table also gives the projected changes in nationwide direct HAP emissions. As the table shows, the projected changes in modeled ambient concentrations are similar to the projected changes in direct HAP emissions, but they are not identical, especially for the organic HAPs. A number of factors can cause the projected change in the ambient impact of a given HAP to differ from the corresponding change in direct emissions. These include decay reactions for organic HAPs, the formation of organic HAPs from precursor pollutants, and differences in the spatial distributions of ambient impacts and emission reductions.

Table 17 summarizes the projected changes in ambient HAP impacts for urban and rural counties. The projected changes are similar for urban and rural counties. The one exception is arsenic, where the average ambient impact is projected to increase by 5% in urban counties, and decrease by 4% in rural counties. This is because the decreases in arsenic from LDDV generally offset increases in from HDDV and diesel marine vessels. Diesel marine vessels, which account for the greatest increases in arsenic emissions, are concentrated in urban port areas.

Tables 18 and 19 give state-level projections of changes in mobile source ambient impacts for gaseous HAPs and particulate HAPs, respectively. For each pollutant and each state, the tables give the predicted change in total mobile source ambient impact between 1996 and 2007. Table 18 shows reductions in all of the five gaseous HAPs for all states. The magnitudes of percentage reductions in ambient impacts for gaseous HAPs range from 17% less (for acetaldehyde in Colorado) to 26% more (for acrolein in Connecticut) than the corresponding state level reduction in direct HAP emissions (From Table 11). As noted earlier, a number of factors can cause these differences, including decay reactions for organic HAPs, the formation of organic HAPs from precursor pollutants, and differences in the spatial distributions of ambient impacts and emission reductions.

Ambient levels of HAP metals (Table 19) are projected to increase for most compounds in most states. These increases are similar to the projected increases in emissions (Table 12). The one exception is arsenic, where reductions as a result of the phaseout of LDDV offset increases from other emission categories in some states.

Table 15. Projected Average Ambient Impacts from Mobile Sources in Urban and Rural Counties

Contiguous 48 states and the District of Columbia (excludes Alaska and Hawaii)

	Average modeled ambient impacts for mobile sources in 1996 (µg/m³)			Average modeled ambient impacts for mobile sources in 2007 (µg/m³)			Median modeled impacts for all mobile sources (µg/m³)		Total modeled impacts of all sources (stationary and mobile) for 1996 (µg/m³)	
HAP	Onroad	Nonroad	All mobile	Onroad	Nonroad	All mobile	1996	2007	Average	Median
Urban counties										
Gaseous HAPs										
Acetaldehyde	4.8e-01	3.3e-01	8.1e-01	2.6e-01	2.3e-01	5.0e-01	6.1e-01	3.7e-01	9.0e-01	6.8e-01
Acrolein	5.5e-02	4.9e-02	1.0e-01	2.6e-02	3.8e-02	6.4e-02	7.3e-02	4.1e-02	1.3e-02	9.6e-02
Benzene	6.7e-01	2.8e-01	9.5e-01	3.3e-01	1.8e-01	5.1e-01	8.2e-01	4.3e-01	1.1e+00	9.3e-01
Butadiene	6.1e-02	2.0e-02	8.1e-02	2.9e-02	1.4e-02	4.3e-02	6.8e-02	3.5e-02	9.3e-02	7.3e-02
Formaldehyde	4.6e-01	5.9e-01	1.1e+00	2.2e-01	4.2e-01	6.4e-01	7.0e-01	4.0e-01	1.2e+00	8.2e-01
Particulate HAPs										
Arsenic	7.7e-07	9.5e-06	1.0e-05	3.6e-07	1.1e-05	1.1e-05	1.6e-06	1.2e-06	1.9e-04	8.7e-05
Beryllium	0.0e+00	8.3e-08	8.3e+08	0.0e+00	9.4e+08	9.4e-08	2.8e-09	3.1e-09	3.7e-05	1.4e-05
Cadmium	0.0e+00	1.2e-06	1.2e-06	0.0e+00	1.3e-06	1.3e-06	3.9e-08	4.4e-08	2.2e-04	6.0e-05
Chromium	5.0e-05	1.7e-04	2.2e-04	6.0e-05	2.2e-04	2.8e-04	1.1e-04	1.4e-04	4.1e-03	1.3e-03
Lead	7.0e-05	4.3e-03	4.4e-03	8.0e-05	4.6e-03	4.7e-03	1.0e-03	1.1e-03	7.0e-03	2.9e-03
Manganese	2.1e-05	1.7e-04	2.0e-04	2.5e-05	2.3e-04	2.5e-04	9.3e-05	1.2e-04	4.9e-03	2.7e-03
Mercury	6.7e-07	3.6e-05	3.7e-05	5.5e-07	4.9e-05	5.0e-05	1.5e-05	2.0e-05	2.3e-04	1.1e-04
Nickel	3.9e-05	4.0e-04	4.4e-04	4.7e-05	4.6e-04	5.1e-04	1.1e-04	1.3e-04	2.7e-03	1.4e-03
Rural counties										
Gaseous HAPs										
Acetaldehyde	7.9e-02	3.3e-02	1.1e-01	5.4e-02	2.2e-02	7.6e-02	8.7e-02	5.8e-02	1.6e-01	1.2e-01
Acrolein	9.9e-03	5.0e-03	1.5e-02	5.4e-03	3.4e-03	8.8e-03	1.1e-02	6.4e-03	4.2e-02	3.4e-02
Benzene	1.2e-01	5.1e-02	1.8e-01	6.5e-02	4.0e-02	1.0e-01	1.2e-01	6.4e-02	2.5e-01	1.8e-01
Butadiene	1.1e-02	3.6e-03	1.5e-02	5.8e-03	2.8e-03	8.6e-03	8.6e-03	4.7e-03	2.8e-02	1.6e-02
Formaldehyde	7.9e-02	5.5e-02	1.3e-01	4.3e-02	3.5e-02	7.8e-02	1.0e-01	5.8e-02	3.9e-01	2.1e-01
Particulate HAPs										
Arsenic	1.8e-07	4.9e-07	6.7e-07	7.7e-08	5.6e-07	6.3e-07	1.3e-07	6.5e-08	6.1e-05	1.4e-05
Beryllium	0.0e+00	4.1e-09	4.1e-09	0.0e+00	4.6e-09	4.6e-09	0.0e+00	0.0e+00	8.7e-06	1.3e-06
Cadmium	0.0e+00	5.7e-08	5.7e-08	0.0e+00	6.4e-08	6.4e-08	0.0e+00	0.0e+00	7.1e-05	4.7e-06
Chromium	1.2e-56	1.4e-05	2.5e-05	1.4e-05	1.8e-05	3.2e-05	1.7e-05	2.1e-05	6.7e-04	7.5e-05
Lead	1.6e-05	1.7e-04	1.8e-04	1.9e-05	1.7e-04	1.9e-04	1.9e-05	2.2e-05	9.9e-04	1.6e-04
Manganese	4.7e-06	1.4e-05	1.9e-05	5.7e-06	1.9e-05	2.4e-05	1.2e-05	1.6e-05	2.3e-03	4.2e-04
Mercury	1.6e-07	3.3e-06	3.4e-06	1.3e-07	4.4e-06	4.6e-06	2.3e-06	3.0e-06	6.3e-05	1.0e-05
Nickel	9.0e-06	2.2e-05	3.1e-05	1.1e-05	2.6e-05	3.7e-05	1.1e-05	1.4e-05	5.8e-04	1.0e-04

Table 16. Projected Changes in Ambient Concentrations - Nationwide Estimates

Contiguous 48 States and the District of Columbia (excludes Alaska and Hawaii)

	Change in modeled average ambient impact from 1996 to 2007 (%)			Change in median impact - all mobile	Change in emissions from 1996 to 2007 (%)		
HAP	Onroad	Nonroad	All mobile	(%)	Onroad	Nonroad	All mobile
Gaseous HAPs							
Acetaldehyde	-45	-29	-39	-36	-42	-38	-40
Acrolein	-52	-24	-39	-43	-39	-31	-34
Benzene	-50	-36	-46	-46	-50	-30	-43
1,3-Butadiene	-52	-28	-46	-48	-52	-26	-45
Formaldehyde	-52	-30	-40	-43	-45	-28	-38
Particulate HAPs							
Arsenic	-54	13	8	-44	-55	13	5
Beryllium	na	13	13	13	na	13	13
Cadmium	na	13	13	13	na	13	13
Chromium	19	29	27	27	21	28	26
Lead	14	6	6	10	17	11	11
Manganese	19	29	28	28	21	28	27
Mercury	-17	36	35	33	-21	36	34
Nickel	20	16	16	25	23	15	16

na - not applicable, impact was 0 or insignificant in 1996

Table 17. Projected Changes in Ambient Concentrations - Urban and Rural Counties

Contiguous 48 States and the District of Columbia (excludes Alaska and Hawaii)

	Change in modeled average ambient impact in **urban counties** from 1996 to 2007 (%)				Change in modeled average ambient impact in **rural counties** from 1996 to 2007 (%)			
HAP	Average onroad	Average nonroad	Average all mobile	Median all mobile	Average onroad	Average nonroad	Average all mobile	Median all mobile
Gaseous HAPs								
Acetaldehyde	-39	-31	-36	-37	-31	-37	-33	-32
Acrolein	-50	-27	-42	-43	-47	-34	-43	-44
Benzene	-51	-35	-47	-47	-49	-23	-42	-42
1,3-Butadiene	-52	-32	-47	-48	-51	-23	-45	-44
Formaldehyde	-50	-32	-42	-42	-46	-38	-43	-42
Particulate HAPs								
Arsenic	-55	13	7	5	-56	13	-4	-4
Beryllium	na	13	13	13	na	13	13	13
Cadmium	na	13	13	13	na	13	13	13
Chromium	21	27	25	25	20	31	26	26
Lead	16	6	6	9	15	2	4	10
Manganese	21	27	26	26	20	31	28	28
Mercury	-16	36	34	34	-16	36	34	34
Nickel	22	15	16	16	21	17	18	18

na - not applicable, impact was 0 or insignificant in 1996

Table 18. Projected State-Level Changes in Total Mobile Source Ambient Impacts for Organic HAPs (%)

State	Acetaldehyde	Acrolein	Benzene	Butadiene	Formaldehyde
Alabama	-29	-44	-47	-48	-45
Arizona	-26	-29	-59	-44	-29
Arkansas	-26	-40	-46	-46	-41
California	-42	-37	-37	-43	-40
Colorado	-44	-56	-65	-69	-47
Connecticut	-51	-51	-49	-48	-46
Delaware	-43	-51	-52	-64	-49
District of Columbia	-43	-42	-53	-48	-44
Florida	-21	-35	-44	-43	-35
Georgia	-46	-48	-49	-49	-47
Idaho	-32	-48	-57	-59	-46
Illinois	-36	-32	-44	-38	-31
Indiana	-37	-45	-49	-49	-46
Iowa	-34	-41	-46	-48	-46
Kansas	-31	-43	-48	-50	-46
Kentucky	-35	-43	-50	-51	-46
Louisiana	-28	-36	-45	-46	-41
Maine	-28	-25	-29	-25	-30
Maryland	-43	-40	-54	-49	-42
Massachusetts	-45	-45	-54	-49	-45
Michigan	-37	-42	-44	-45	-43
Minnesota	-33	-35	-31	-35	-39
Mississippi	-26	-43	-46	-47	-43
Missouri	-36	-35	-48	-47	-40
Montana	-34	-44	-53	-55	-46
National	-39	-39	-46	-46	-40
Nebraska	-33	-41	-48	-49	-47
Nevada	-26	-32	-58	-51	-30
New Hampshire	-35	-39	-42	-40	-40
New Jersey	-43	-39	-46	-43	-38
New Mexico	-30	-50	-65	-68	-45
New York	-42	-35	-44	-41	-36
North Carolina	-29	-41	-48	-47	-42
North Dakota	-33	-36	-43	-44	-44
Ohio	-43	-47	-51	-51	-48
Oklahoma	-27	-50	-48	-64	-44
Oregon	-41	-39	-48	-46	-41
Pennsylvania	-44	-41	-49	-44	-44
Rhode Island	-44	-46	-54	-49	-44
South Carolina	-25	-41	-45	-45	-41
South Dakota	-32	-37	-42	-44	-43
Tennessee	-29	-43	-48	-48	-44
Texas	-37	-43	-48	-55	-40
Utah	-42	-50	-61	-66	-47
Vermont	-34	-29	-27	-26	-34
Virginia	-36	-36	-50	-42	-39
Washington	-28	-26	-46	-41	-31
West Virginia	-35	-46	-51	-52	-47
Wisconsin	-43	-41	-39	-39	-41
Wyoming	-42	-48	-59	-62	-55
Contiguous 48	-39	-39	-46	-46	-40

Table 19. Projected State-Level Changes in Total Mobile Source Ambient Impacts for Particulate HAPs (%)

State	Arsenic	Beryl-lium	Cadmium	Chro-mium	Lead	Man-ganese	Mercury	Nickel
Alabama	9	13	13	22	8	24	34	15
Arizona	-55	na	na	32	3	30	33	31
Arkansas	-9	13	13	27	3	28	34	20
California	4	13	13	28	6	28	35	18
Colorado	-47	na	na	30	8	29	33	27
Connecticut	3	13	13	26	8	27	34	17
Delaware	11	13	13	19	10	21	33	13
District of Columbia	-31	13	13	34	11	34	36	30
Florida	10	13	13	26	8	25	34	15
Georgia	-7	13	13	30	11	30	34	21
Idaho	-53	na	na	31	3	30	34	29
Illinois	6	13	13	25	6	25	34	16
Indiana	7	13	13	24	6	25	34	15
Iowa	-51	na	na	25	3	27	33	22
Kansas	-29	13	13	28	9	29	34	23
Kentucky	8	13	13	23	3	25	34	15
Louisiana	12	13	13	16	5	17	31	13
Maine	10	13	13	23	-0	24	34	15
Maryland	11	13	13	22	7	22	34	14
Massachusetts	7	13	13	26	10	27	35	16
Michigan	6	13	13	25	7	27	35	16
Minnesota	-1	13	13	30	8	30	35	20
Mississippi	11	13	13	20	4	21	33	14
Missouri	10	13	13	23	6	24	34	14
Montana	-49	na	na	27	1	26	31	24
National	8	13	13	27	6	28	35	16
Nebraska	-37	na	na	27	6	28	34	23
Nevada	-55	na	na	36	4	30	30	34
New Hampshire	-3	13	13	27	3	28	34	19
New Jersey	5	13	13	28	8	29	35	17
New Mexico	-54	na	na	29	2	28	30	27
New York	-17	13	13	32	6	33	36	26
North Carolina	-20	13	13	30	5	30	34	24
North Dakota	-56	na	na	22	3	23	30	19
Ohio	8	13	13	25	7	26	35	15
Oklahoma	-16	13	13	27	6	29	34	21
Oregon	11	13	13	22	7	23	34	14
Pennsylvania	11	13	13	21	7	23	34	14
Rhode Island	6	13	13	24	4	25	34	16
South Carolina	2	13	13	27	3	28	34	18
South Dakota	-60	na	na	27	-2	26	30	24
Tennessee	3	13	13	27	5	28	34	17
Texas	10	13	13	23	7	23	34	15
Utah	-53	na	na	34	9	32	35	32
Vermont	-55	13	13	29	-3	31	34	27
Virginia	10	13	13	23	1	24	34	15
Washington	11	13	13	20	6	20	30	14
West Virginia	11	13	13	19	3	20	33	14
Wisconsin	-6	13	13	27	5	28	34	19
Wyoming	-50	na	na	21	-5	22	28	18
Contiguous 48	8	13	13	27	6	28	35	16

na - not applicable, impact was 0 or insignificant in 1996

Figure 12 shows the county-level distribution for the percentage change between 1996 and 2007 of the average ambient impacts for acetaldehyde from mobile sources. Figure 13 shows estimated acetaldehyde impacts (in terms of ambient concentration) from mobile sources in 2007. Figures 14 and 15 give similar distributions for acrolein, Figures 16 and 17 for benzene, Figures 18 and 19 for 1,3-butadiene, and Figures 20 and 21 for formaldehyde, respectively.

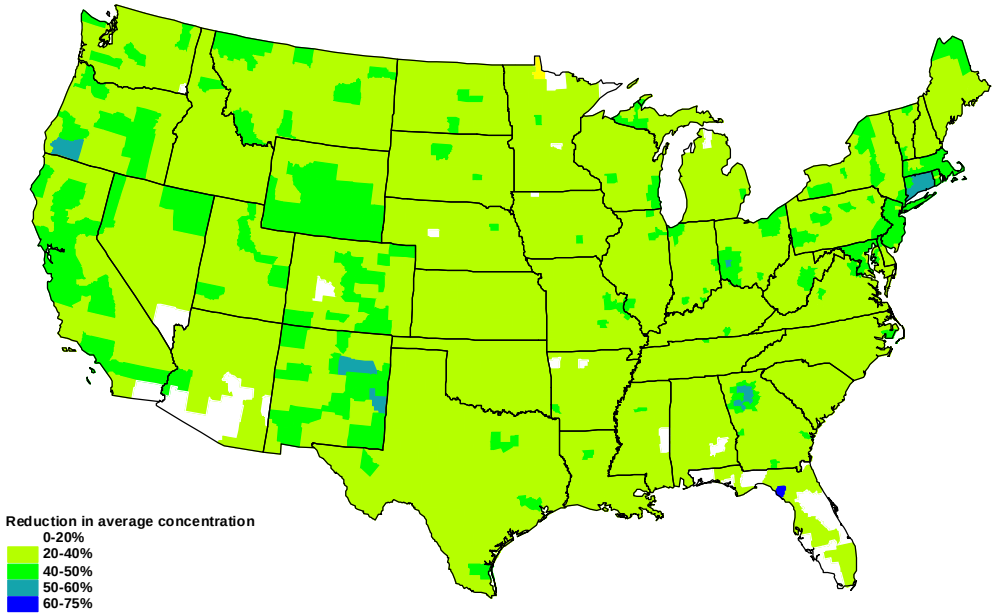

Figure 12. Projected mobile source ambient impact reductions for acetaldehyde

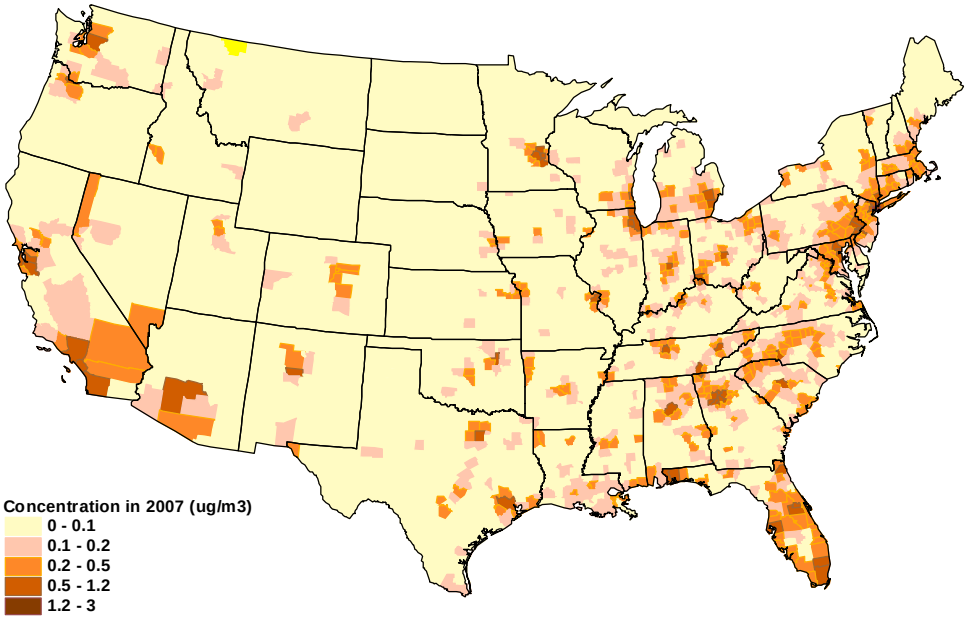

Figure 13. Projected mobile source ambient impacts for acetaldehyde in 2007

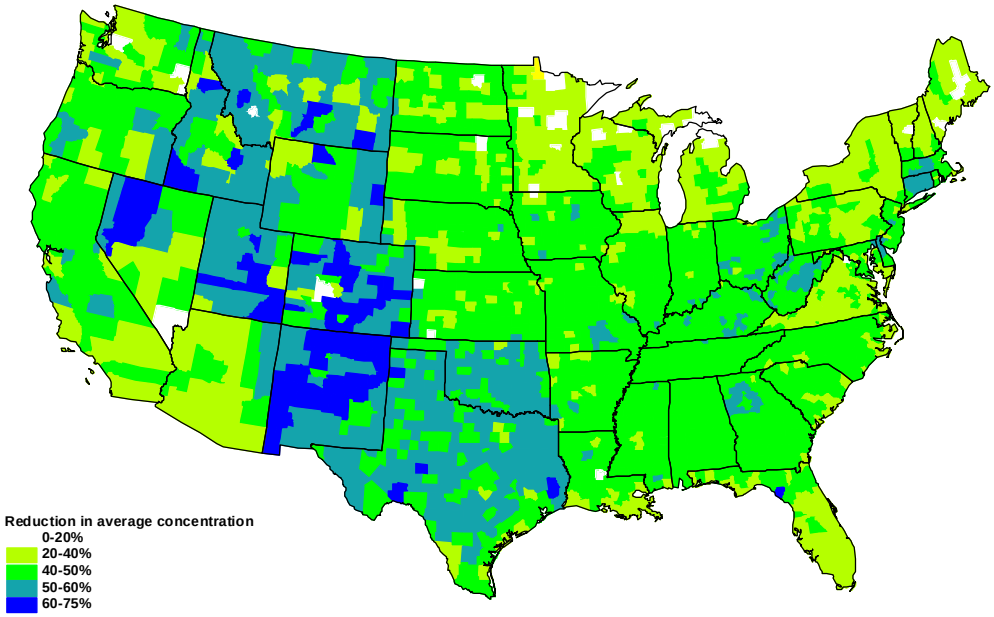

Figure 14. Projected mobile source ambient impact reductions for acrolein

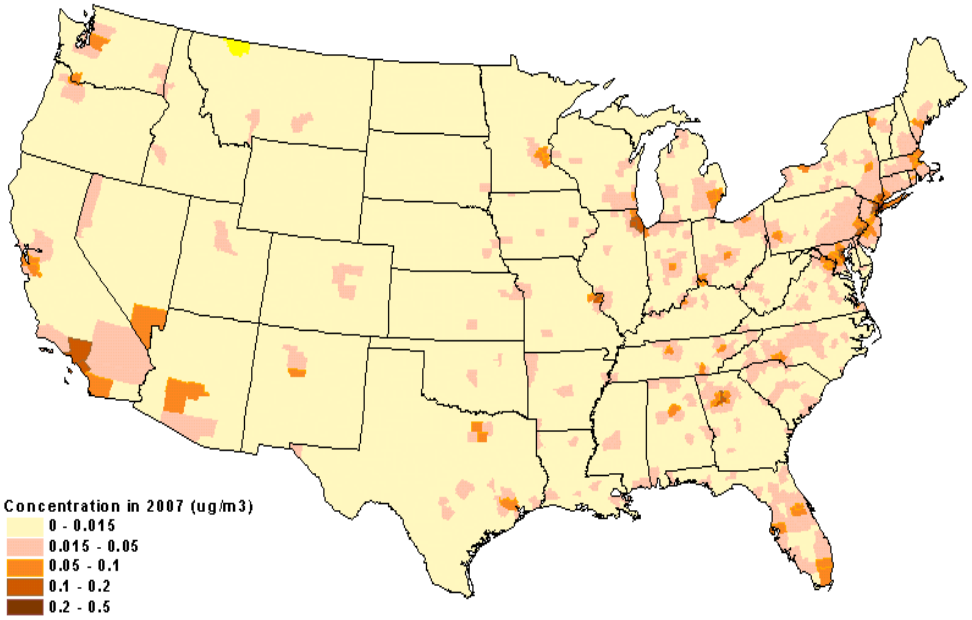

Figure 15. Projected mobile source ambient impacts for acrolein in 2007

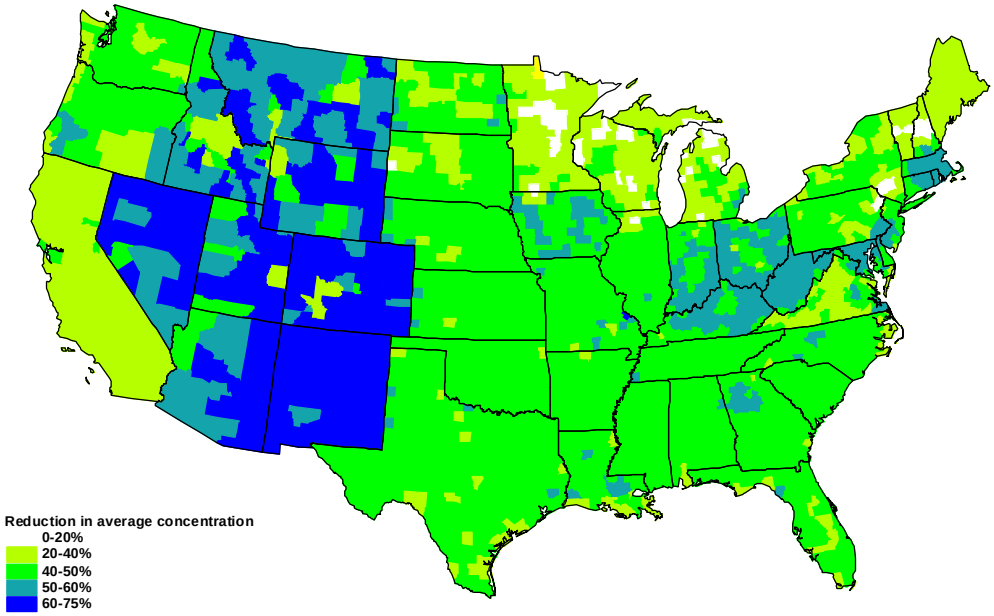

Figure 16. Projected mobile source ambient impact reductions for benzene

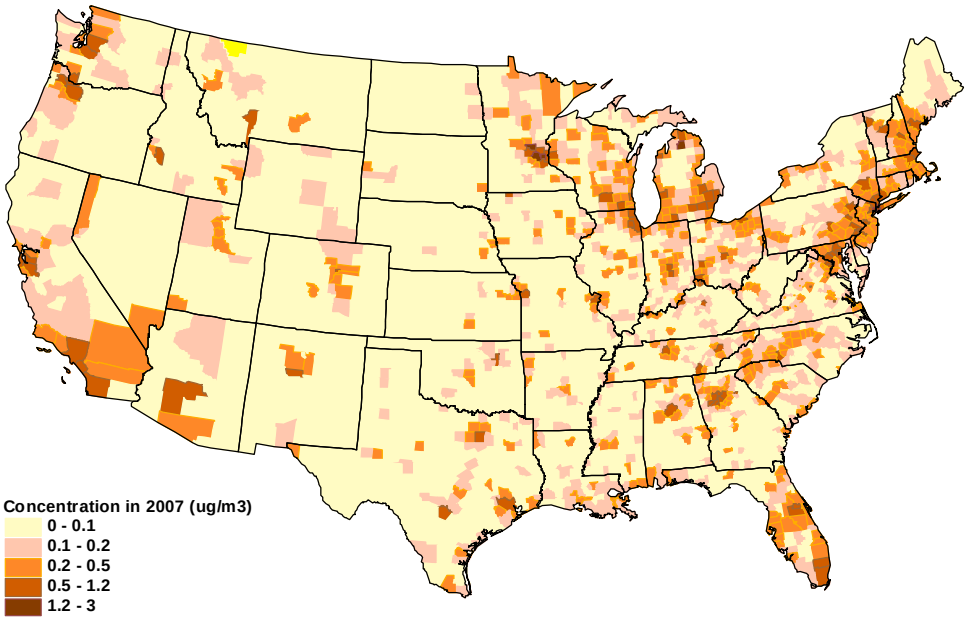

Figure 17. Projected mobile source ambient impacts for benzene in 2007

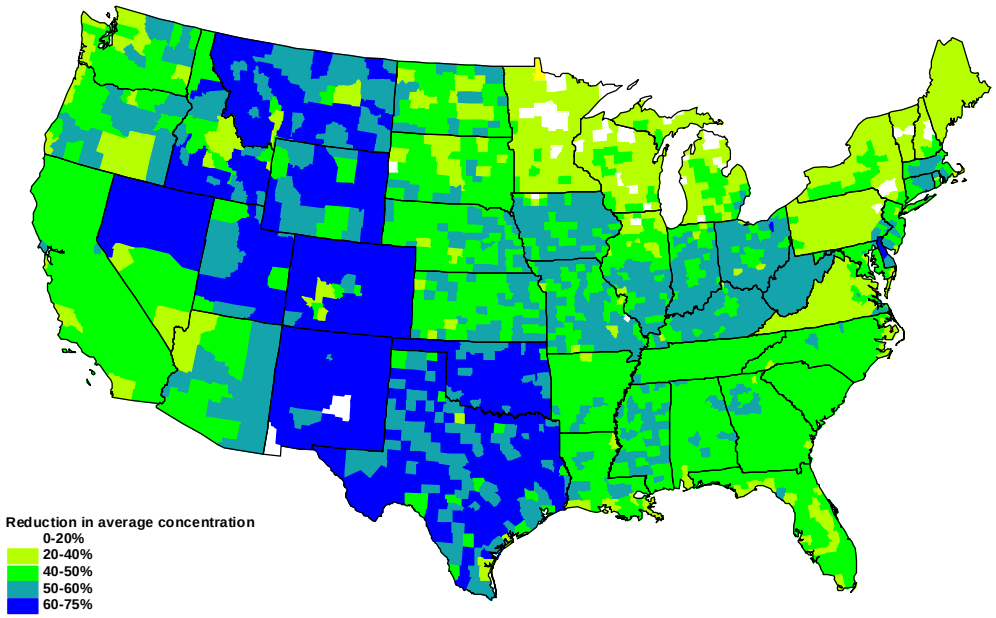

Figure 18. Projected mobile source ambient impact reductions for 1,3-butadiene

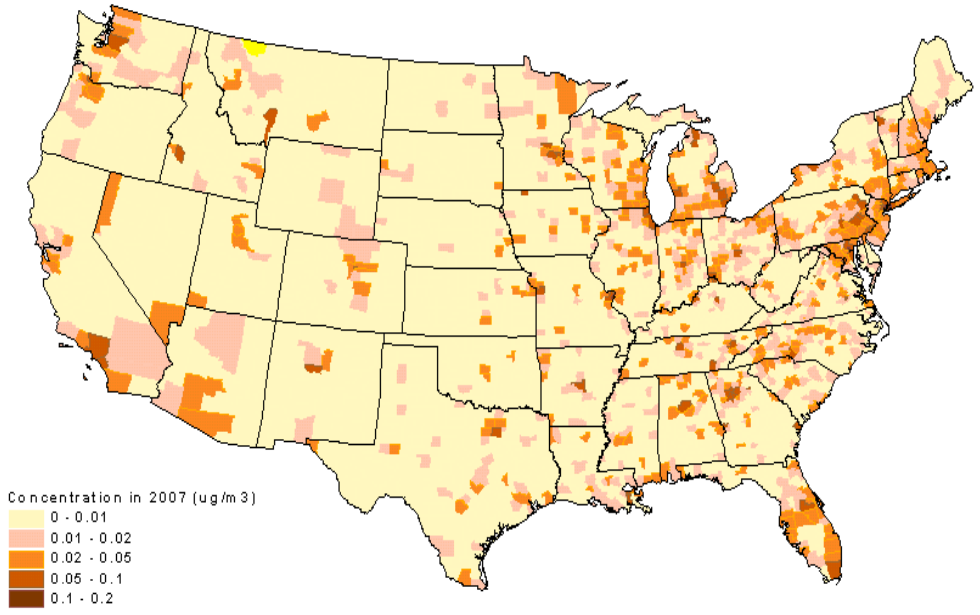

Figure 19. Projected mobile source ambient impacts for 1,3-butadiene in 2007

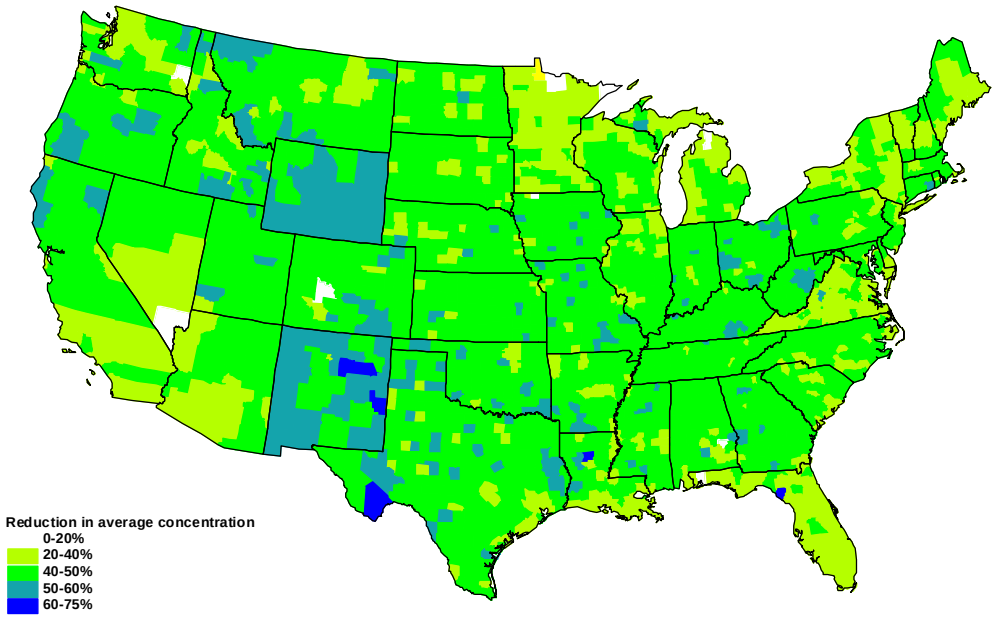

Figure 20. Projected mobile source ambient impact reductions for formaldehyde

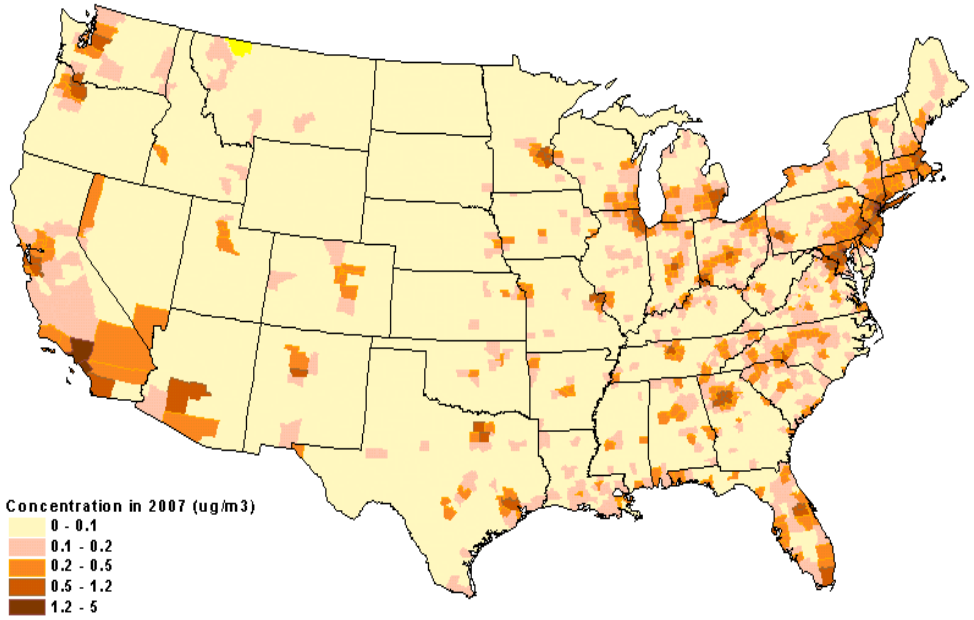

Figure 21. Projected mobile source ambient impacts for formaldehyde in 2007

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