EXECUTIVE SUMMARY

ES.1 LEGISLATIVE MANDATE

In section 112(n)(1)(A) of the Clean Air Act, as amended (the Act), Congress directs the United States Environmental Protection Agency (EPA) to:

> "... perform a study of the hazards to public health reasonably anticipated to occur as a result of emissions by electric utility steam generating units of ... [hazardous air pollutants] ... after imposition of the requirements of this Act."

Section 112(a)(8) of the Act defines an "electric utility steam-generating unit" as "any fossil-fuel–fired combustion unit of more than 25 megawatts electric (MWe) that serves a generator that produces electricity for sale." A unit that cogenerates steam and electricity and supplies more than one-third of its potential electric output capacity and more than 25 MWe output to any utility power distribution system for sale is also considered an electric utility steam-generating unit (i.e., utility unit).

Section 112(n)(1)(A) also requires that:

- The EPA develop and describe alternative control strategies for hazardous air pollutants (HAPs) that may warrant regulation under section 112; and
- The EPA proceed with rulemaking activities under section 112 to control HAP emissions from utilities if EPA finds such regulation is appropriate and necessary after considering the results of the study.

ES.2 REGULATORY DETERMINATION

This report does not contain a determination as to whether or not regulations to control HAP emissions from utility units are appropriate and necessary. The Agency has deferred the regulatory determination until a later date.

ES.3 OVERVIEW APPROACH TO COMPLETING THE STUDY

The study included numerous separate and interrelated analyses. First, HAP emissions test data were gathered from 52 utility units (i.e., boilers), including a range of coal-, oil-, and natural gas-fired utility units. Second, the emissions test data along with facility specific information (e.g., boiler type, control device, fuel usage) were used to estimate HAP emissions from all 684 utility plants in the United States (U.S.). Third, a screening level hazard/risk assessment was completed to prioritize the HAPs for further analyses. Fourth, various priority HAPs were analyzed for inhalation and multipathway exposures and risks and other potential impacts. In addition, potential control strategies were analyzed for the priority HAPs. The overall summary of the study is presented in Figure ES-1.

This report presents the findings of the study. The primary components of this report are: (1) a description of the industry; (2) an analysis of emissions data; (3) an assessment of hazards and risks due to inhalation exposures to 67 HAPs; (4) assessments of risks due to multipathway (inhalation plus non-inhalation) exposures to four HAPs (radionuclides, mercury, arsenic, and dioxins); and (5) a discussion of alternative control strategies.

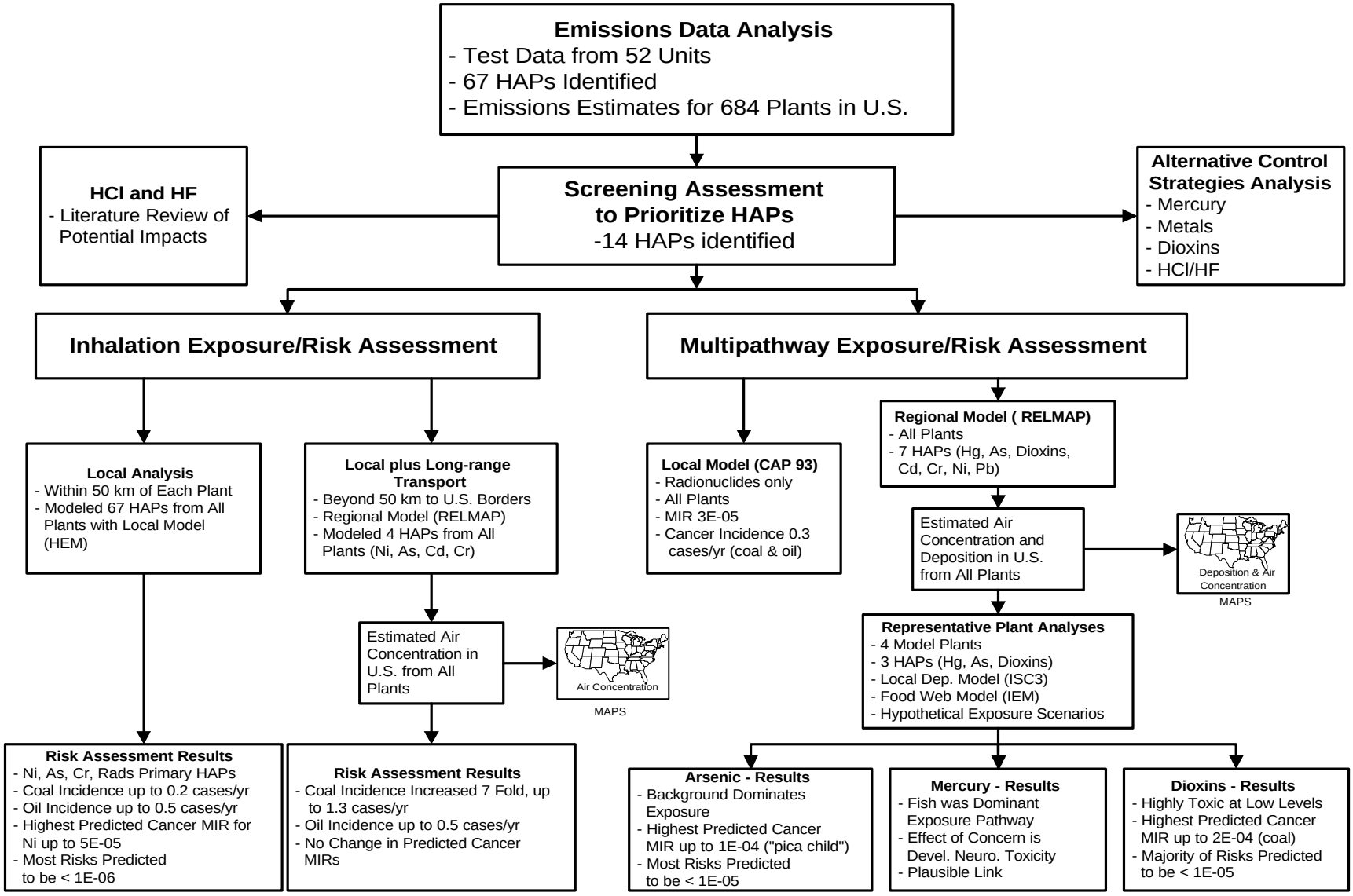
The study was based primarily on two scenarios: (1) 1990 base year emissions; and (2) 2010 emissions. In addition, emissions for 1994 were estimated using the most recent data. The 1990 scenario was chosen since that was the year the Amendments to the Act were passed and was the latest year for which utility operational data were available at the time the study was initiated. The 2010 scenario was selected to meet the section 112(n)(1)(A) mandate to evaluate hazards "after imposition of the requirements of the Act." Primarily, this meant assessing the hazards after the acid rain program is in place. The 2010 scenario also included estimated changes in HAP emissions resulting from projected trends in fuel choices and projected increases in electric power demands. However, the effects of other on-going or potential activities that were not factored into the 2010 projections (e.g., industry restructuring, new ozone and particulate matter [PM] standards, global climate change programs) may result in the 2010 projections being either underestimated or overestimated.

ES.4 EMISSIONS DATA ANALYSIS

A total of 684 utility plants (i.e., utilities) were identified as meeting the criteria for the study in 1990 in the U.S. These utilities are fueled primarily by coal (59 percent of total units), oil (12 percent), or natural gas (29 percent). Many plants have two or more units and several plants burn more than one type of fuel (e.g., contain both coal- and oil-fired units). In 1990, there were 426 plants that burned coal as one of their fuels, 137 plants that burned oil, and 267 plants that burned natural gas.

Emission estimates for the years 1990, 1994, and 2010 were based on emissions test data from 52 units obtained from extensive emission tests by the Electric Power Research Institute (EPRI), the Department of Energy (DOE), the Northern States Power Company, and the EPA. The testing program was designed to test a wide range of facility types with a variety of control scenarios; therefore, the data are considered generally representative of the industry. However, there are uncertainties in the data because of the small sample sizes for specific boiler types and control scenarios.

Figure ES-1. Summary of the Utility Air Toxics Study



These test data provided the basis for estimating average annual emissions for each of the 684 plants. A total of 67 of the 188 HAPs listed in section 112 of the Act were identified in the emissions testing program as potentially being emitted by utilities. Tables ES-1 and ES-2 present estimated emissions for, respectively, a subset of priority HAPs for 1990, 1994, and 2010, and for a set of characteristic boilers for 1994.

Although the EPA used average annual emissions estimates in assessing long-term exposures to individual HAPs on a national basis, emissions test data were not available for each utility in the U.S. Therefore, estimates for individual plants are particularly uncertain. Based on an uncertainty analysis, the average annual emissions estimates are expected to be roughly within a factor of plus or minus three of actual annual emissions. However, even this uncertainty analysis had limitations. For example, the uncertainty analysis did not include data on potential upsets or unusual operating conditions; therefore, the range of uncertainty could be greater.

ES.5 GENERAL APPROACH TO EXPOSURE AND RISK ASSESSMENT

Most of the risk assessment focused on inhalation exposure. All 67 HAPs were assessed for inhalation exposures, at least at a screening level. For many of the 67 HAPs, inhalation exposure is believed to be the dominant exposure pathway. However, for HAPs that are persistent and/or bioaccumulate, and are toxic by ingestion (or are radioactive), the non-inhalation exposure pathways could be more important. Based on a screening and prioritization assessment, which is described below, the EPA identified four high priority HAPs (radionuclides, mercury, arsenic, dioxins) to assess for non-inhalation exposures. In addition, cadmium and lead were identified as next highest priority. Multipathway assessments are presented for radionuclides, mercury, arsenic, and dioxins. The other two HAPs (lead and cadmium) were examined qualitatively for their potential for multipathway hazards.

ES.6 SCREENING ASSESSMENT

As outlined in Figure ES-1, EPA initially conducted a screening assessment that considered inhalation and non-inhalation exposure routes for all 67 HAPs to identify priority HAPs for more detailed assessment. To screen for inhalation exposures, the EPA used the Human Exposure Model (HEM) to model the 67 HAPs from all 684 utility plants utilizing generally conservative assumptions (i.e., assumptions that are more likely to overestimate rather than underestimate risks) to estimate inhalation risks for maximally exposed individuals (MEIs).

Table ES-1. Nationwide Utility Emissions for Thirteen Priority HAPs[a]

HAP	Nationwide HAP emission estimates (tons per year)[b]								
	Coal			Oil			Natural gas		
	1990	1994	2010	1990	1994	2010	1990	1994	2010
Arsenic	61	56	71	5	4	3	0.15	0.18	0.25
Beryllium	7.1	7.9	8.2	0.46	0.4	0.23	NM[c]	NM	NM
Cadmium	3.3	3.2	3.8	1.7	1.1	0.9	-	-	-
Chromium	73	62	87	4.7	3.9	2.4	-	-	-
Lead	75	62	87	11	8.9	5.4	0.43	0.47	0.68
Manganese	164	168	219	9.3	7.3	4.7	-	-	-
Mercury	46	51	60	0.25	0.2	0.13	0.0015	0.0017	0.024
Nickel	58	52	69	390	320	200	2.2	2.4	3.5
Hydrogen chloride	143,000	134,000	155,000	2,900	2,100	1,500	NM	NM	NM
Hydrogen fluoride	20,000	23,000	26,000	140	280	73	NM	NM	NM
Acrolein	25	27	34	NM	NM	NM	NM	NM	NM
Dioxins[d]	0.000097	0.00012	0.00020	1×10^{-5}	9×10^{-6}	3×10^{-6}	NM	NM	NM
Formaldehyde	35	29	45	19	9.3	9.5	36	39	57

[a] Radionuclides are the one priority HAP not included on this table because radionuclide emissions are measured in different units (i.e., curies per year) and, therefore, would not provide a relevant comparison to the other HAPs shown. Radionuclide emissions are presented in chapter 9.

[b] The emissions estimates in this table are derived from model projections based on a limited sample of specific boiler types and control scenarios. Therefore, there are uncertainties in these numbers (see section ES.4 for discussion).

[c] NM = Not measured.

[d] These emissions estimates were calculated using the toxic equivalency (TEQ) approach, which is based on the summation of the emissions of each congener after adjusting for toxicity relative to 2,3,7,8-tetrachlorodibenzo-p-dioxin (i.e., 2,3,7,8-TCDD).

Table ES-2. Estimated Emissions for Nine Priority HAPs from Characteristic Utility Units (1994; tons per year)[a]

Fuel:	Coal	Oil	Natural gas
Unit size (MWe):	**325**	**160**	**240**
Arsenic	0.0050	0.0062	0.0003
Cadmium	0.0023	0.0014	NC[b]
Chromium	0.11	0.0062	NC
Lead	0.021	0.014	NC
Mercury	0.05	0.0012	NC
Hydrogen chloride	190	9.4	NC
Hydrogen fluoride	14	NC	NC
Dioxins[c]	0.00000013	0.000000023	NC
Nickel	NC	1.7	0.004

[a] There are uncertainties in these numbers. Based on an uncertainty analysis, the EPA predicts that the emissions estimates are generally within a factor of roughly three of actual emissions.
[b] NC = Not calculated.
[c] See footnote d of Table ES-1.

If the MEI risk was above a minimum measure (e.g., exposure greater than one-tenth the inhalation reference concentration [RfC][a] or cancer risk greater than 1 chance in 10 million), then the HAP was chosen for more study. For non-inhalation exposures, the 67 HAPs were prioritized by considering five criteria: (1) persistence; (2) tendency to bioaccumulate; (3) toxicity; (4) emissions quantity; and (5) radioactivity.

Based on this screening assessment, a total of 14 HAPs were identified as priority. Twelve HAPs (arsenic, beryllium, cadmium, chromium, manganese, nickel, hydrogen chloride [HCl], hydrogen fluoride [HF], acrolein, dioxins, formaldehyde, and radionuclides) were identified as priority pollutants for further study based on potential for inhalation exposures and risks. Four of these 12 HAPs (arsenic, cadmium, dioxins, and radionuclides) plus 2 additional HAPs (mercury and lead) were considered priority for multipathway exposure); of these 6 HAPs, 4 (arsenic, mercury, dioxins, and radionuclides) were identified as the highest priority to assess for multipathway exposures and risks. Overall, a total of 14 of the 67 HAPs were considered priority. The other 53 HAPs were not evaluated beyond the screening assessment.

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[a] The RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of the daily inhalation exposure of the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious effects during a lifetime.

ES.7 INHALATION RISK ASSESSMENT -- LOCAL ANALYSIS

The EPA estimated inhalation exposures and risks due to dispersion of HAP emissions within 50 kilometers (km) of each of the 684 plants (i.e., local analysis). For 13 of the 14 priority HAPs, the HEM was used; for radionuclides, the Clean Air Act Assessment Package-1993 (CAP-93) model was used. The HEM exposure modeling conducted for the inhalation risk assessment was very similar to the modeling conducted for the screening assessment. The same default options and same input data were used. However, there is one important difference. For the inhalation risk assessment, a distinction was made between urban and rural locations. If a plant is located in an urban area, it was modeled using the urban mode (i.e., dispersion is assumed to be characteristic of emissions emitted by a facility in an urban location where there are buildings nearby). Dispersion of the pollutant plume in an urban area is expected to exhibit greater turbulence because of heat transfer and obstacles (i.e., large buildings). If a plant is located in a rural location, it was modeled using the rural mode (i.e., dispersion is assumed to be characteristic of a facility located in a rural location). In the screening assessment, all plants were modeled using the urban default because using the urban default typically leads to more conservative (i.e., higher) estimates of human exposures, which is appropriate for a screening assessment. However, using the urban and rural distinction is believed to reflect more realistic conditions.

The cancer risks for all gas-fired plants were well below one chance in one million (i.e., $< 1 \times 10^{-6}$) and no noncancer hazards were identified. Therefore, gas-fired plants are omitted from the following discussions.

In cases where data were missing or incomplete, the EPA had to make various assumptions. A few of these assumptions are more likely to overestimate risks. Other assumptions used are likely to underestimate risks. Based on an uncertainty analysis conducted for this study, it is estimated that these assumptions taken together lead to a reasonable high-end estimate (i.e., conservative, but within the bounds of reasonable estimates) of the risks due to inhalation exposure within 50 km of plants. Within the limits of current scientific information, this approach is, therefore, most likely to overestimate health risks for these pollutants. The uncertainty analysis suggests that the most likely estimated inhalation MIRs (i.e., central tendency MIRs) may be roughly 2 to 10 times lower than the high-end MIRs presented below. The average individual risks due to inhalation exposure to utility HAP emissions for the total exposed U.S. population (roughly 200,000,000 people) are predicted to be roughly 100 to 1000 times lower than the high-end inhalation MIRs.

ES.7.1 Inhalation Cancer Risks for Coal-Fired Utilities Based on Local Analysis (1990)

The vast majority of coal-fired plants (424 of the 426 plants) are estimated to pose lifetime cancer risks (i.e., increased probability of an exposed person getting cancer during a lifetime) of less than 1×10^{-6} due to inhalation exposure to utility HAP emissions. Only two of the 426 plants are estimated to potentially pose inhalation risks greater than 1×10^{-6} (see Figure ES-2).

The increased lifetime cancer MIR due to inhalation exposure to coal-fired utility HAP emissions, based on the local analysis, is estimated to be no greater than 3×10^{-6}. Arsenic and chromium are the HAPs contributing most to the inhalation risks (see Table ES-3). All other HAPs, including radionuclides, were estimated to present inhalation risks less than 1×10^{-6} for coal-fired units.

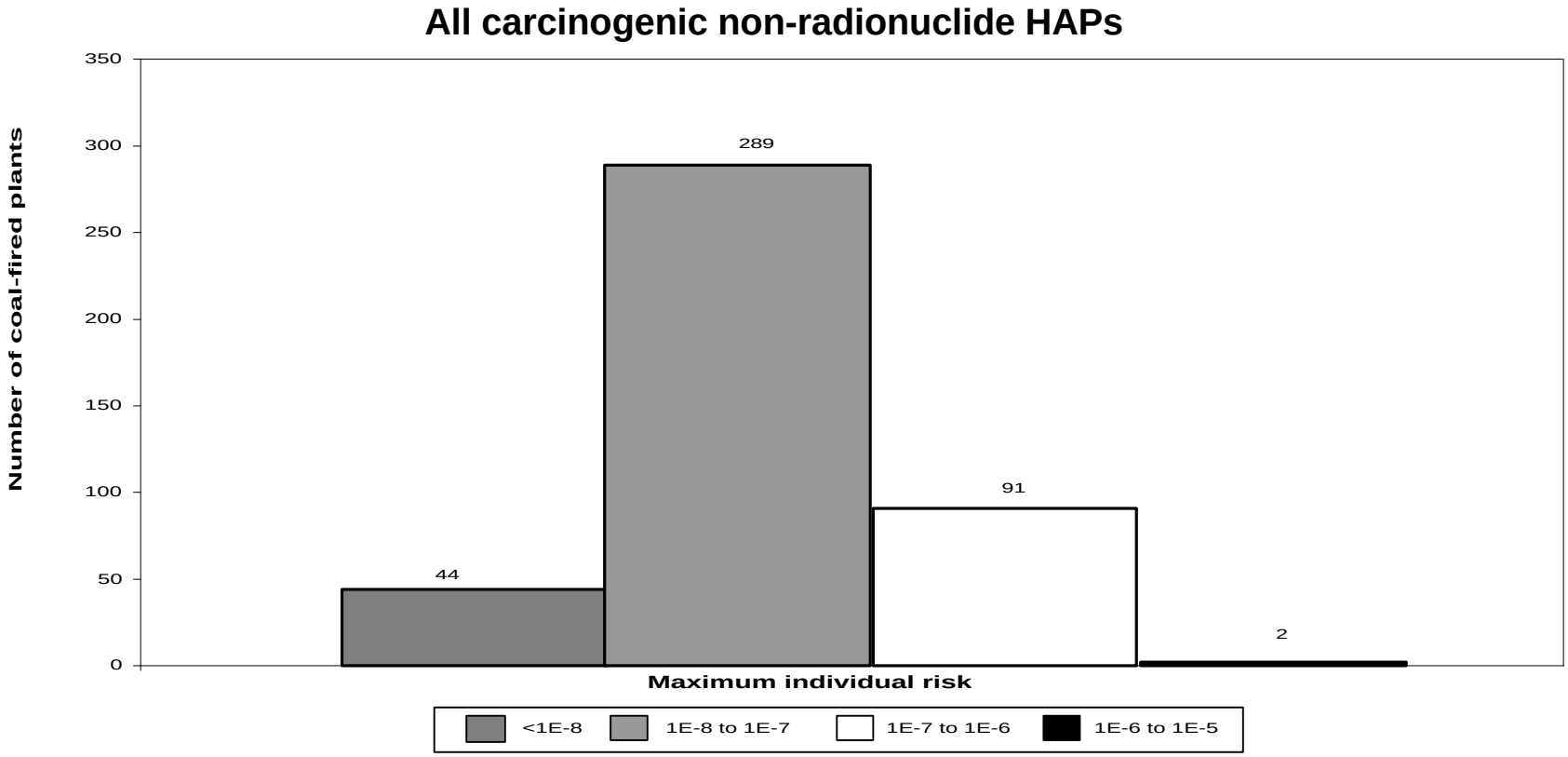
The cancer incidence in the U.S. due to inhalation exposure to HAPs (including radionuclides) from all 426 coal-fired plants **based on the local analysis** is estimated to be no greater than approximately 0.2 cancer case per year (cases/yr), or 1 case every 5 years. However, as described in later sections, the consideration of long-range dispersion of HAPs (beyond 50 km) results in increased estimates for cancer incidence.

ES.7.2 Inhalation Cancer Risks for Oil-Fired Utilities Based on Local Analysis (1990)

The majority of the oil-fired plants (125 of the 137 plants) are estimated to pose inhalation cancer MIRs less than 1×10^{-6}. However, up to 11 of the 137 oil-fired plants are estimated to potentially present inhalation MIRs above 1×10^{-6} (see Figure ES-3). Nickel, arsenic, radionuclides, and chromium are the primary contributors to these cancer risks.

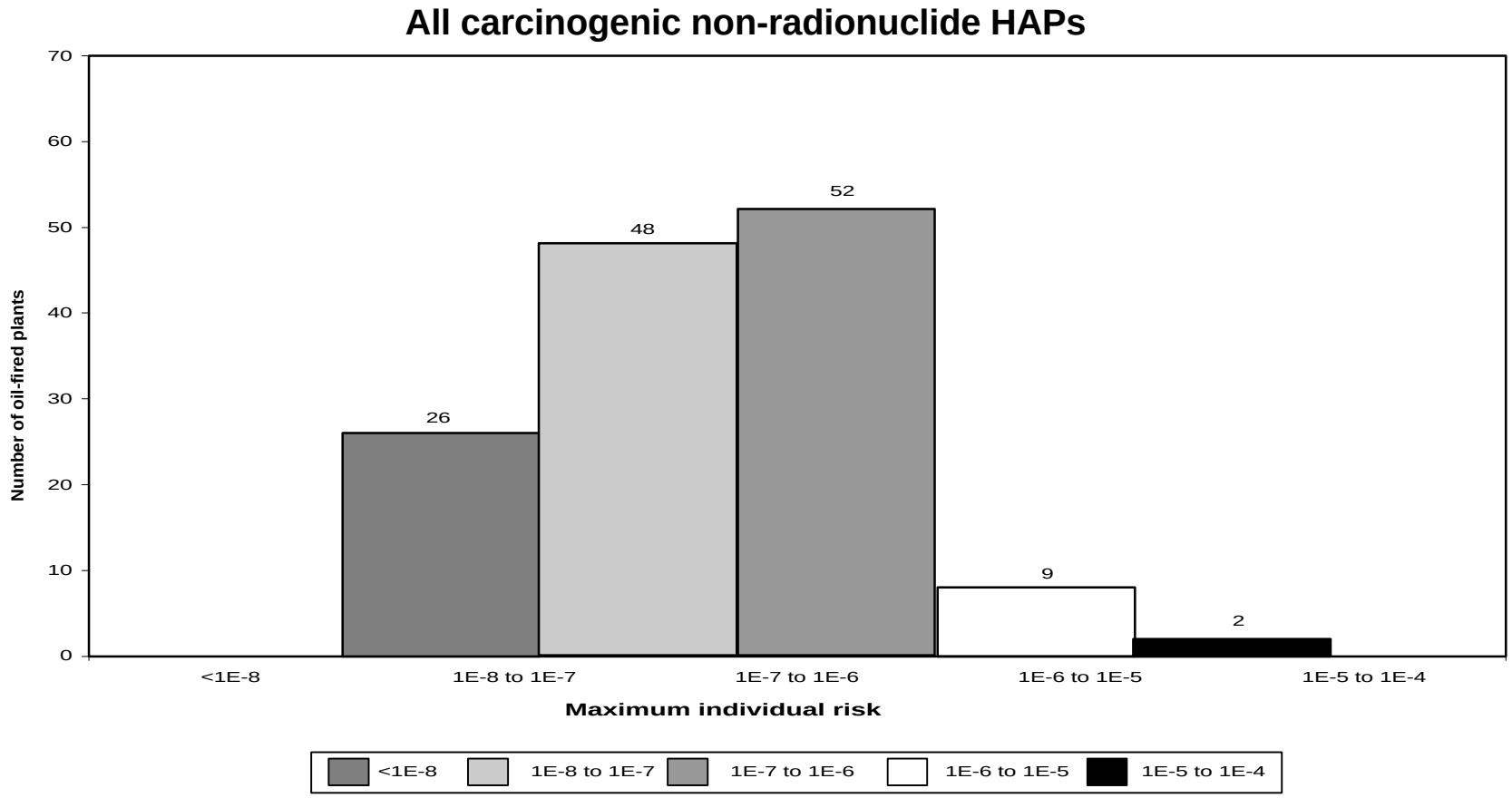
For oil-fired utilities, the highest contribution to the MIRs is from nickel. However, there are substantial uncertainties with the nickel risk estimates. Nickel is emitted in several different forms (e.g., nickel oxides, soluble nickel, sulfidic nickel) and the health effects of these different forms vary, and for some forms are unknown or uncertain. Nickel subsulfide (which is one of the possible forms of sulfidic nickel) is a known human carcinogen and appears to be the most carcinogenic form based on available data. Based on limited data, 3 to 26 percent of the nickel emissions are believed to be sulfidic nickel. It is not known how much of the sulfidic nickel emissions are nickel subsulfide. Several other nickel species (e.g., nickel oxides) are also potentially carcinogenic but the potencies are not known.

Figure ES-2. Number of Coal-Fired Utilities Posing Various Levels of Maximum Individual Risks (By Levels of MIR)



Note: The high-end maximum individual risks (MIRs) are presented as exponents in this figure. For example, an increased cancer risk of one chance in one million (i.e., 1 x 10^{-6}) is shown as 1E-6 in this Figure. The figure shows that 91 plants are estimated to pose an MIR between 1 x 10^{-7} and 1 x 10^{-6}.

Figure ES-3. Number of Oil-Fired Utilities Posing Various Levels of Maximum Individual Risks (By Levels of MIR)



Note: The MIRs are presented as exponents in this figure. For example, an increased cancer risk of 1 x 10^{-6} is shown as 1E-6 here. The figure shows there are 9 oil-fired plants with estimated MIRs between 1 x 10^{-6} and 1 x 10^{-5}.

Table ES-3. Summary of High-End Inhalation Cancer Risk Estimates from Local Analysis for Coal-Fired Utilities for the Year 1990

HAP	Highest Cancer MIR[a]	Population with lifetime risk > 1 x 10^{-6}	Number plants with MIR > 1 x 10^{-6}
Arsenic	2 x 10^{-6}	850	2
Chromium	1 x 10^{-6}	110	1
Total[b] (Aggregate of HAPs)	3 x 10^{-6}	850	2

[a] Estimated lifetime maximum individual risk (MIR) due to inhalation exposure for the "highest risk" coal-fired plant. Based on an uncertainty analysis, these estimates are considered reasonable high-end estimates (see section ES.7.4 for discussion).

[b] Estimated risk due to inhalation of the aggregate of HAPs assuming additivity of risk for 26 individual carcinogenic HAPs.

To evaluate the range of potential risks due to nickel emissions, the EPA estimated risks using various assumptions for nickel cancer potency (presented in chapter 6). For example, assuming the nickel mix is 50 percent as carcinogenic as nickel subsulfide, the highest inhalation cancer MIR due to the aggregate of HAP emissions from the highest risk oil-fired utility plant is estimated to be 6 x 10^{-5}. Assuming the nickel mix is 10 percent as carcinogenic as nickel subsulfide, the highest inhalation cancer MIR due to the aggregate of HAP emissions from the highest risk oil-fired utility plant is approximately 3 x 10^{-5}. The values in Table ES-4 and Figure ES-3 are based on the conservative assumption that the nickel mix is 50 percent as carcinogenic as nickel subsulfide.

Estimated risks due to inhalation exposure for a subset of HAPs based on the local analysis are presented in Table ES-4. All other HAPs analyzed were estimated to pose inhalation cancer risks below 1 x 10^{-6} for all 137 oil-fired plants.

The cancer incidence in the U.S. due to inhalation exposure to HAP emissions (including radionuclides) from all 137 oil-fired utilities, based on the local analysis, is estimated to be no greater than 0.5 cancer case/yr.

ES.7.3 Inhalation Cancer Risks Based on Long-Range Transport

In addition to the above analyses, the EPA conducted long-range transport analyses to assess emissions dispersion and exposures on a national scale for 1990. The Regional Lagrangian Model of Air Pollution (RELMAP) was used to estimate the dispersion of HAP emissions from the facility stack out to the borders of the continental U.S. This is in contrast to the HEM, which estimates dispersion and air concentrations within 50 km of the source.

Table ES-4. Summary of High-end Inhalation Cancer Risk Estimates Based on Local Analysis for Oil-Fired Utilities for the Year 1990

HAP	Highest MIR[a]	Population with lifetime risk > 1 x 10^{-6}	Number plants with MIR > 1 x 10^{-6}
Nickel[b]	5 x 10^{-5}	110,000	11
Arsenic	1 x 10^{-5}	2,400	2
Radionuclides	1 x 10^{-5}	2,400	2
Chromium	5 x 10^{-6}	2,300	1
Cadmium	2 x 10^{-6}	45	1
Total[c] (aggregate)	6 x 10^{-5}	110,000	11

[a] Estimated lifetime maximum individual risk (MIR) due to inhalation exposure for the "highest risk" oil-fired plant. Based on an uncertainty analysis, these estimates are considered reasonable high-end estimates (see section ES.7.4 for discussion).

[b] The estimates for nickel and total HAPs are based on the assumption that the mix of nickel compounds is 50 percent as carcinogenic as nickel subsulfide.

[c] Estimated risk due to inhalation of the aggregate of HAPs assuming additivity of risk for 14 individual carcinogenic HAPs.

The RELMAP modeling was conducted for all coal- and oil-fired utilities, but was limited to mercury, cadmium, chromium, arsenic, nickel, lead, and dioxins. Only inhalation exposures to the carcinogenic HAPs are discussed in this section. Deposition and multipathway concerns are discussed elsewhere in this report. The long-range transport modeling indicates that the local HEM analysis alone does not account for a substantial percentage of the population exposures due to coal-fired utility emissions. A comparison of the HEM results to the RELMAP results indicates a significant portion of emissions disperse further than 50 km, as would be expected for these HAPs, which are mostly fine particulate substances emitted from elevated stacks.

The RELMAP results for arsenic, cadmium, chromium, and nickel (which are emitted mainly as PM) were used to estimate the potential long-range transport inhalation exposures for other carcinogenic HAPs. Using this methodology, the highest cancer incidence due to inhalation exposure to HAPs from coal-fired utilities considering both local and long-range transport is estimated to be up to 1.3 cases/yr, which is about 7 times greater than the incidence estimated in the local analysis alone. The cancer incidence for oil-fired utilities did not change (see Table ES-5).

Table ES-5. Summary of High-End Inhalation Risk Estimates Due to Local and Long-Range Transport

LOCAL IMPACTS (dispersion within 50 km of each utility plant)[d]				
	OIL-FIRED PLANTS		**COAL-FIRED PLANTS**	
Pollutant	Maximum individual risk (MIR)	Annual increased cancer Incidence	Maximum individual risk (MIR)	Annual increased cancer incidence
Radionuclides	1×10^{-5}	0.2	2×10^{-8}	0.1
Nickel[a]	5×10^{-5}	0.2	7×10^{-7}	0.005
Chromium	5×10^{-6}	0.02	1×10^{-6}	0.02
Arsenic	1×10^{-5}	0.04	2×10^{-6}	0.05
Cadmium	2×10^{-6}	0.005	2×10^{-7}	0.0006
All Others[b]	8×10^{-7}	0.005	8×10^{-7}	0.004
Total[c]	6×10^{-5}	0.5	3×10^{-6}	0.2
LOCAL PLUS LONG-RANGE IMPACTS (dispersion from utility emission points to borders of continental U.S.)				
	OIL-FIRED PLANTS		COAL-FIRED PLANTS	
Pollutant	Maximum individual risk (MIR)	Annual increased cancer incidence	Maximum individual risk (MIR)	Annual increased cancer incidence
Radionuclides	1×10^{-5}	0.2	Not estimated	0.7
Nickel[a]	5×10^{-5}	0.2	1×10^{-8}	0.038
Chromium	5×10^{-6}	0.02	2×10^{-6}	0.15
Arsenic	1×10^{-5}	0.05	3×10^{-6}	0.37
Cadmium	2×10^{-6}	0.006	3×10^{-7}	0.005
All Others[b]	8×10^{-7}	0.006	1×10^{-6}	0.028
Total[c]	6×10^{-5}	0.5	4×10^{-6}	1.3

[a] Assumes that the nickel mixture is 50 percent as carcinogenic as nickel subsulfide.
[b] Estimated risks due to exposure to all remaining HAPs analyzed (i.e., excluding nickel, arsenic, chromium, cadmium, and radionuclides).
[c] Aggregate risk (risk due to inhalation exposure to all carcinogenic HAPs, assuming additivity of risks).
[d] There are uncertainties associated with these risk estimates. See sections ES.7.4 for discussion.

A comparison between the HEM local dispersion results and the long-range transport modeling results indicates that long-range transport is much less important for the MIR than it is for cancer incidence. For example, the MIR from the local analyses for coal-fired utilities (i.e., inhalation risk of 3×10^{-6}) is predicted to increase by roughly 10 to 20 percent to about 4×10^{-6} when ambient concentrations are added from long-range transport of arsenic from all

other utilities in the continental U.S. For oil-fired utilities, the long-range transport of HAPs has no impact on the highest inhalation MIR because of the remote location of the two highest risk oil-fired plants.

ES.7.4 Uncertainties with the Inhalation Cancer Risk Assessment

There are several areas of uncertainty in the inhalation risk assessment including: (1) the impacts of long-range transport; (2) the emissions and health effects of different forms of chromium and nickel; (3) the use of a linear non-threshold high-to-low dose extrapolation model for estimating cancer risks at low exposure concentrations; (4) the impacts of episodic releases resulting from upsets or unusual operating conditions; (5) how residence times and activity patterns impact the exposures; (6) the impacts on sensitive subpopulations; (7) the impacts of background exposures; and (8) the risk of complex pollutant mixtures.

The uncertainty analysis indicates that the inhalation cancer MIRs and incidence estimates presented above are reasonable high-end estimates of the risks due to inhalation exposure within 50 km of each plant. That is, the estimates are considered generally conservative (i.e., predicted to be roughly the 90th to 95th percentile). The uncertainty analysis suggests that the most likely estimated inhalation MIRs (i.e., central tendency MIRs) may be roughly 2 to 10 times lower than the high-end MIRs presented above. The average individual risks due to inhalation exposure to utility HAP emissions for the total exposed U.S. population (roughly 200,000,000 people) are predicted to be roughly 100 to 1,000 times lower than the high-end inhalation MIRs.

ES.7.5 Summary of the Inhalation Cancer Risks

For the majority of utility plants (approximately 671 of the 684 plants), the estimated inhalation cancer risks due to HAP emissions are less than 1×10^{-6}. However, several plants (2 coal plants and up to 11 oil plants) are estimated to potentially pose inhalation cancer risks above 1×10^{-6}. One oil plant is estimated to pose a high-end inhalation cancer MIR of up to 6×10^{-5}. Based on the assessment, no greater than 1.8 cancer cases/yr are estimated to occur in the U.S. due to inhalation exposure to HAP emissions from all coal- and oil-fired utilities. Further research and evaluation may be needed to more comprehensively assess the inhalation cancer risks, especially to reduce the uncertainties associated with the nickel risk estimates.

ES.7.6 Inhalation Noncancer Risks

The EPA also assessed noncancer risks (i.e., health effects other than cancer) due to short- and long-term inhalation exposure. Manganese, HCl, HF, and acrolein were found to be the four HAPs of highest potential concern for noncancer effects.

Based on modeling HAPs for all 684 plants with the HEM, estimated long-term ambient HAP concentrations were generally 100 to 10,000 times below the RfC or similar benchmark. The highest estimated long-term ambient HAP concentration was 10 times below the RfC.

Using a short-term air dispersion model that considers all reasonable meteorological conditions, EPA modeled maximum one-hour

concentrations for three HAPs (HCl, HF, and acrolein). The highest short-term exposure was 140 times below the acute reference level.

ES.8 MERCURY MULTIPATHWAY ASSESSMENT

ES.8.1 Background Discussion for Mercury

Mercury cycles in the environment as a result of natural and human (anthropogenic) activities. The amount of mercury mobilized and released into the biosphere has increased since the beginning of the industrial age. Most of the mercury in the atmosphere is elemental mercury vapor, which circulates in the atmosphere for up to a year, and hence can be widely dispersed and transported thousands of miles from likely sources of emission. After it deposits, mercury commonly is emitted back to the atmosphere either as a gas or associated with particles, to be re-deposited elsewhere. As it cycles between the atmosphere, land, and water, mercury undergoes a series of complex chemical and physical transformations, many of which are not completely understood.

Mercury is a persistent element and bioaccumulates in the food web. Mercury accumulates most efficiently in the aquatic food web. Predatory organisms at the top of the food web generally have higher mercury concentrations. Nearly all of the mercury that accumulates in fish tissue is methylmercury. Inorganic mercury, which is less efficiently absorbed and more readily eliminated from the body than methylmercury, does not tend to bioaccumulate.

Fish consumption dominates the pathway for human and wildlife exposure to methylmercury. The EPA's 1997 Mercury Study Report to Congress supports a plausible link between anthropogenic releases of mercury from industrial and combustion sources in the U.S. and methylmercury in fish. However, these fish methylmercury concentrations also result from existing background concentrations of mercury (which may consist of mercury from natural sources, as well as mercury which has been re-emitted from the oceans or soils) and deposition from the global reservoir (which includes mercury emitted by other countries). Given the current scientific understanding of the environmental fate and transport of this element, it is not possible to quantify how much of the methylmercury in fish consumed by the U.S. population is contributed by U.S. emissions relative to other sources of mercury (such as natural sources and re-emissions from the global pool). As a result, it cannot be assumed that a change in total mercury emissions will be linearly related to any resulting change in methylmercury in fish, nor over what time period these changes would occur. This is an area of ongoing study.

ES.8.2 Methylmercury Health Effects

Epidemics of mercury poisoning following high-dose exposures to methylmercury in Japan and Iraq demonstrated that neurotoxicity is the health effect of greatest concern when methylmercury exposure occurs to the developing fetus. Dietary methylmercury is almost completely absorbed into the blood and distributed to all tissues including the brain; it also readily passes through the placenta to the fetus and fetal brain. The reference dose (RfD) is an amount of methylmercury, which when ingested daily over a lifetime is anticipated to be without

adverse health effects to humans, including sensitive subpopulations. At the RfD or below, exposures are expected to be safe. The risk following exposures above the RfD is uncertain, but risk increases as exposures to methylmercury increase.

Extrapolating from the high-dose exposures that occurred in the Iraq incident, the U.S. EPA derived a RfD for methylmercury of 0.1 microgram per kilogram body weight per day (µg/kg bw/day). While the U.S. EPA was advised by scientific reviewers to employ this RfD for this analysis, new data are emerging. Currently ongoing are two large epidemiology studies in the Seychelle Islands and in the Faroe Islands that were designed to evaluate childhood development and neurotoxicity in relation to fetal exposures to methylmercury in fish-consuming populations. Because of various limitations and uncertainties in all of the available data, the U.S. EPA and other Federal agencies intend to participate in an interagency review of the human data on methylmercury, including the most recent studies from the Seychelle Islands and the Faroe Islands. The purposes of this review are to refine the estimates of the level of exposure to mercury associated with subtle neurological endpoints and to further consensus between all of the Federal agencies. After this process, the U.S. EPA will determine if a change in the RfD for methylmercury is warranted. (Note: see the 1997 EPA *Mercury Study Report to Congress* for further discussion and assessment of mercury health effects and public health impacts).

ES.8.3 Mercury Multipathway Exposure Assessment

Mercury was considered highest priority for multipathway exposure analysis. To assess the transport and deposition of mercury emissions from utilities and to estimate concentrations in environmental media and biota, three modeling efforts were undertaken: (1) long-range modeling, (2) local scale modeling, and (3) modeling of environmental concentrations. The RELMAP was used to predict long-range dispersion and deposition across the U.S. For the local analysis, a model designed to predict deposition of HAPs within 50 km, the Industrial Source Complex Version 3 (ISC3) air dispersion model, was used. Next, the EPA's Indirect Exposure Model Version 2M (IEM-2M) was used to estimate mercury environmental concentrations and human exposures. Hypothetical exposure scenarios were evaluated for four model plants (a large coal-fired, a medium coal-fired, a small coal-fired, and a medium oil-fired utility boiler). The analysis included three types of plant locations: (1) rural (agricultural), (2) near lakes (lacustrine), and (3) urban. Three human fish consumption scenarios were considered.

The modeling provided information on whether local and/or long-range transport of mercury is significant in a variety of scenarios. The models indicate that most of the mercury from utilities is transported further than 50 km from the source. The fate and transport models provided an assessment of potential inhalation and ingestion exposures.

ES.8.4 Summary of Mercury Assessment Results for Utilities

Recent estimates of annual total global mercury emissions from all sources (natural and anthropogenic) are about 5,000 to 5,500 tons per year (tpy). Of this total, about 1,000 tpy are estimated to be natural emissions and about 2,000 tpy are estimated to be contributions through

the natural global cycle of re-emissions of mercury associated with past anthropogenic activity. Current anthropogenic emissions account for the remaining 2,000 tpy. Point sources such as fuel combustion; waste incineration; industrial processes (e.g., chlor-alkali plants); and metal ore roasting, refining, and processing are the largest point source categories on a world-wide basis.

For the year 1994, coal-fired utilities were estimated to emit approximately 51 tpy of mercury in the U.S., which is estimated to be 33 percent of the 158 tpy of airborne anthropogenic emissions of mercury in the U.S. If one assumes that current anthropogenic activity represents between 40 and 75 percent of the total airborne emissions (anthropogenic plus other emissions [e.g., natural emissions]), one can calculate that U.S. utilities emit roughly 13 to 26 percent of the total (natural plus anthropogenic) airborne emissions of mercury in the U.S.

Given the global estimates of 5,000 to 5,500 tpy (which are highly uncertain), U.S. anthropogenic mercury emissions are estimated to account for roughly 3 percent of the global total, and U.S. utilities are estimated to account for roughly 1 percent of total global emissions.

A computer simulation of long-range transport of mercury emissions from all U.S. sources conducted for the EPA's 1997 Mercury Study Report to Congress suggests that about one-third (~ 52 tons) of the 158 tpy of U.S. anthropogenic emissions are deposited, through wet and dry deposition, within the lower 48 States. The remaining two-thirds (~ 107 tons) is transported outside of U.S. borders where it diffuses into the global reservoir. In addition, the computer simulation suggests that another 35 tons of mercury from the global reservoir is deposited for a total deposition of roughly 87 tpy in the U.S. Although this type of modeling is uncertain, the simulation suggests that about three times as much mercury is being added to the global reservoir from U.S. sources as is being deposited from it. What is not uncertain is that additional emissions to air will contribute to levels in the global reservoir and deposition to water bodies.

Long-range transport modeling conducted as part of this Utility Study predicts that approximately 30 percent (15 tpy) of the utility mercury emissions deposit in the continental U.S. The estimated annual deposition rates resulting from utility mercury emissions range from 0.5 to greater than 10 micrograms per square meter. Long-range transport modeling also predicts that the highest deposition occurs in the eastern half of the U.S., particularly areas such as southeastern Great Lakes and Ohio River Valley, central and western Pennsylvania, large urban areas in the eastern U.S. (e.g., Washington, D.C., New York City) and various locations in the vicinity of large coal-fired utilities. Based on the limited available receptor monitoring data, the RELMAP model seems to be accurate within a factor of plus or minus 2. That is, the RELMAP model seems to over- and underestimate mercury values within a factor of two and appears to be relatively unbiased in its predictions.

The modeling assessment in conjunction with available scientific knowledge, supports a plausible link between anthropogenic mercury emissions and mercury found in freshwater fish. As noted above, there

are many sources of mercury emissions worldwide, both natural and anthropogenic. The coal-fired utilities are one category of the mercury sources.

Mercury is considered the highest priority for multipathway analyses because it is an environmentally persistent, toxic element. Mercury is deposited to soil and terrestrial vegetation but at levels that do not result in human exposures likely to be detrimental to health through terrestrial exposure pathways. However, in its methylated form mercury bioaccumulates in the food web (especially the aquatic food web). Modeling results suggest that most of the mercury emitted to the atmosphere is deposited more than 50 km away from the source, especially sources that have tall stacks. As stated above, the modeling assessment from the Mercury Study in conjunction with available scientific knowledge, supports a plausible link between anthropogenic mercury emissions and mercury found in freshwater fish. Additional emissions to air will contribute to levels in the global reservoir and deposition to water bodies. As a result, mercury emissions from utility units may add to the existing environmental burden.

At this time, the available information, on balance, indicates that utility mercury emissions are of sufficient potential concern for public health to merit further research and monitoring. The EPA recognizes that there are substantial uncertainties that make it difficult to quantify the magnitude of the risks due to utility mercury emissions, and that further research and/or evaluation would be needed to reduce these uncertainties. Remaining questions include the following: (1) what is the quantitative relationship between a change in U.S. mercury emissions and the resulting change in methylmercury levels in fish; (2) what are the actual consumption patterns and estimated methylmercury exposures of the subpopulations of concern; (3) what are the actual mercury levels in a statistically valid and representative sample of the U.S. population and susceptible subpopulations; (4) what exposure levels are likely to result in adverse health effects; (5) what affects the formation of methylmercury in waterbodies and its bioaccumulation in fish; (6) how much mercury is emitted from natural sources and past anthropogenic sources; and (7) how much mercury is removed during coal cleaning and other ongoing practices for pollution control. New data that could reduce some of the uncertainties are likely to become available in the next several years, and EPA plans to review and consider these data, as appropriate, in future decisions.

Regarding potential methods for reducing mercury emissions, the EPA has not identified any demonstrated add-on control technologies currently in use in the U.S. that effectively remove mercury from utility emissions. (However, there may be add-on control technologies used in other source categories that effectively reduce mercury emissions.) Based on available data, total mercury removal by existing PM control devices on coal-fired utilities varies considerably, ranging from 0 to 82 percent removal (with a median efficiency of 15 percent removal) for cold-side electrostatic precipitators (ESPs), and from 0 to 73 percent removal (with a median efficiency of 8 percent removal) for fabric filters. Also, hot-side ESPs exhibited no mercury control. Existing flue gas desulfurization (FGD) units exhibit limited mercury

control, ranging from 0 to 62 percent removal, with a median removal of 23 percent. The mercury control efficiency of FGD units is a function of several factors including temperature, plant configuration, and type of coal. Pilot-scale studies have shown that mercury removal can be enhanced through the use of activated carbon injection. However, the limited results to date utilizing carbon injection are inconsistent and more data and research are needed. Other various pollution prevention strategies, such as coal cleaning, have shown some effectiveness in reducing utility emissions of mercury. Conventional coal cleaning removes, on average, approximately 21 percent of the mercury contained in the coal. Also, fuel switching, such as switching from coal to natural gas, would result in decreased emissions of mercury.

ES.9 SCREENING LEVEL MULTIPATHWAY ASSESSMENT FOR ARSENIC

Arsenic is a naturally occurring element found normally, in various concentrations, in soil. In addition, arsenic can also be naturally present in other media (e.g., various food sources and water). Arsenic levels have been measured in a variety of foods. Even though shellfish and other marine foods contain the greatest concentrations of total arsenic, much of the arsenic present in fish and shellfish exists in the less toxic organic form. Other food products, such as meats, rice, and cereals, contain higher percentages, and often higher total amounts, of inorganic arsenic, which is the form of primary toxicological concern.

Arsenic is also naturally present in trace amounts in coal and oil. When coal or oil are burned, some of this naturally occuring arsenic is released to the atmosphere. The quantity of arsenic released from any utility plant is dependent on many factors including the concentration of arsenic in the fuel, control device efficiency, and other factors.

Utilities emit about 62 tpy of arsenic nationwide, about 3 to 4 percent of the total anthropogenic arsenic emissions in the U.S. Because of its chemical and physical characteristics, arsenic emitted to the atmosphere may be transported to other environmental media (soil or water), thus allowing non-inhalation exposures to occur.

ES.9.1 Exposure Modeling

It was not possible to model every utility plant for arsenic multipathway exposures. Therefore, a screening level model plant approach was used. Four model plants (i.e., a large coal-fired, a medium coal-fired, a small coal-fired, and a medium oil-fired utility boiler) were designed to characterize typical utility plants. In taking the model plant approach, it was realized that there would be a great deal of uncertainty surrounding the predicted fate and transport of arsenic as well as the exposures. However, the assessment was useful for estimating potential risks due to utility arsenic emissions. Three models were used to predict environmental arsenic concentrations and exposure: the RELMAP, the ISC3, and the Indirect Exposure Model Version 2 (IEM-2). These models were used to predict the fate and transport of arsenic emissions and to estimate human exposures to arsenic through multiple exposure routes, including food consumption, water ingestion, and inhalation. Three basic exposure scenarios were considered: a

subsistence farmer (adult and child), a subsistence fisher (adult and child), and a pica child (i.e., a child that ingests significant quantities of soil). These scenarios were considered because they represent possible high-end scenarios for exposure to arsenic.

ES.9.2 Health Effects of Arsenic

Inhalation exposure to inorganic arsenic has been strongly associated with lung cancer in humans. Human exposure to inorganic arsenic, via ingestion, has been associated with an increased risk of several types of cancer, including skin, bladder, liver, and lung cancers. Oral exposure to inorganic arsenic has also been associated with noncancer effects, including effects to the central nervous system, cardiovascular system, liver, kidney, and blood.

ES.9.3 Approach for Estimating Screening Level Arsenic Risks

Increased cancer risks were estimated for each hypothetical scenario, for the four model plants, each of which was placed in two different hypothetical locations (i.e., an eastern humid site and a dry western site). For each of the exposure scenarios, except for the pica child, it is assumed that the hypothetical person is exposed for 30 years. For the pica child, it is assumed that exposure occurs for 7 years. Risks were estimated by multiplying the estimated intakes of arsenic by the EPA's cancer potency factor for arsenic.

ES.9.4 Screening Level Arsenic Risk Assessment Results

The results of the screening level multipathway arsenic exposure assessment provide an indication of the potential hazards and risks that may occur due to emissions from a utility plant. However, the results are not applicable to any particular plant. There are uncertainties and limitations to the analysis.

Exposures to inorganic arsenic due to background levels and due to emissions from the model utility boilers were predicted to be mainly through the ingestion of grains. Exposure to inorganic arsenic through the ingestion of fish was not predicted to be a major pathway of exposure because there is considerable evidence that little of the total arsenic in fish tissue is inorganic arsenic. Soil ingestion is the major route of exposure to inorganic arsenic for the pica child.

ES.9.4.1 Arsenic Cancer Risks. The cancer risks due to multipathway exposures to inorganic arsenic, as estimated in the model plant analysis using hypothetical scenarios, due to utility emissions alone (no background) were estimated to range from 4×10^{-7} to 1×10^{-4}. The highest estimated risk (1×10^{-4}) was for a pica child assumed to be living at the point of maximum deposition. The arsenic emissions from the large coal-fired model utility boiler at the eastern humid site were estimated to pose this highest risk for the pica child. When the risk from background exposure (2×10^{-4}) is added to the maximum risk from utility exposure, the risk for the pica child is estimated to be up to 3×10^{-4}. The "pica child" is considered a high-end, conservative scenario.

Background exposures were estimated to dominate the exposures and risks in all scenarios. When considering only the arsenic emissions from the model utility units (not including background), in all

scenarios it was the large coal-fired unit that was estimated to pose the greatest multipathway risks and the medium coal-fired unit was estimated to pose the next highest risks. The small coal-fired unit and the oil-fired unit were estimated to present lower risks.

ES.9.4.2 Uncertainty Discussion. There are uncertainties associated with the cancer risk estimates from arsenic. The analysis was based on model plants and hypothetical constructs; therefore, the results are not applicable for any specific utility plant. Further analyses are needed to better characterize the risks posed by arsenic emissions from utilities. A few uncertainties are discussed here.

Exposure to arsenic through the ingestion of tap or well water was not included in this assessment. The exposure modeling assessment was based on a model plant analysis, hypothetical scenarios, and incorporated data with varying degrees of uncertainty. Also, there are uncertainties associated with the health effects data for arsenic. For example, the animal ingestion studies have not clearly shown an association between arsenic ingestion exposure and cancer.

ES.10 DIOXIN SCREENING LEVEL MULTIPATHWAY ASSESSMENT

The highest MEI inhalation cancer risk due to dioxin emissions from any utility plant based on the HEM analysis (described in section ES.7) was estimated to be 1×10^{-7}. The EPA estimates that coal-fired utilities emit 0.2 pounds per year (lb/yr) of dioxin (toxic equivalents, TEQ) and that oil-fired utilities emit 0.01 lb/yr. These estimates combined are roughly 1 percent of the nationwide anthropogenic dioxin emissions. However, dioxin emissions data were only available for twelve utility plants and 42 percent of the measurements were below the minimum detection limit. Moreover, dioxins are not part of the naturally occuring fossil fuel. They are formed in highly complicated reactions which may occur with unknown frequency during combustion. Therefore, the emissions data for dioxins from utilities, which are the basis of exposure modeling, are considered more uncertain than the emissions data for many of the other HAPs.

For the screening level multipathway analysis, the transport, deposition, multipathway exposures, and human cancer risks were assessed for utility emissions of polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), collectively referred to as dioxins. Atmospheric deposition of dioxin emissions can be important because dioxins tend to persist in the environment and bioaccumulate in the food web. Environmental persistence and bioaccumulation, coupled with carcinogenic effects at very low levels, make multipathway exposure an important consideration for dioxins.

ES.10.1 Methods

The basic approach for estimating screening level multipathway exposures to dioxins was similar to the methods described above for mercury and arsenic. However, there were some differences. The EPA's ISCST3 model was used to predict deposition and air concentrations of dioxins within 50 km of each of four model plants. Model plants were selected to represent both large and small coal- and oil-fired utilities. A modified version of the IEM spreadsheet model was used to

estimate environmental concentrations, exposures to the environmental concentrations for 16 hypothetical human scenarios, and the resulting cancer risks. Pathways assessed include inhalation, dermal contact with soil, and ingestion of water, soil, fish, plants, and animals.

ES.10.2 Results

Since the analysis was based on model plants, using hypothetical scenarios, the results are not applicable to any specific plant and contain substantial uncertainties about the risks due to dioxin emissions. Total modeled screening level lifetime cancer risks related to multipathway exposure to dioxins for the four-model plant analysis ranged from 1×10^{-10} to 2×10^{-4}. The results of this analysis indicate that the exposures and risks due to fish consumption are the highest of all pathways considered. The highest modeled result of 2×10^{-4} lifetime cancer risk was obtained for the subsistence fisher exposure scenario. In all modeled scenarios, the non-inhalation exposures were at least one order of magnitude larger than the inhalation exposures, thus demonstrating the potential significance of including multipathway exposure analysis in the risk assessments for pollutants that are environmentally persistent and tend to bioaccumulate. Also, unlike the results for arsenic, modeled exposures to dioxins for each pathway exceed the background exposure estimates for dioxins.

ES.10.3 Uncertainty Discussion

Several sensitivity analyses were completed for the screening level multipathway assessment of utility dioxin risks to assess the reasonableness of the results. The assumptions with the greatest impact on the predicted risk to the subsistence fisher were those made about the biota-sediment accumulation factor. This sensitivity analysis suggests that the modeling results are reasonable for a screening level analysis.

ES.11 MULTIPATHWAY ASSESSMENT FOR RADIONUCLIDES

Radionuclide emissions from utilities may result in human exposure from multiple pathways including: (1) external radiation exposure from radionuclides suspended in air or deposited on the ground, and (2) internal exposure from the inhalation of airborne contaminants or ingestion of contaminated food. The CAP-93 model was used to estimate multipathway exposures and risks due to radionuclide emissions to humans within 50 km of all 684 utilities. However, this assessment did not use site-specific data for the non-inhalation exposure analysis, but rather relied on various generic assumptions and general input data.

Based on the CAP-93 modeling, 667 of the 684 plants are estimated to pose multipathway risks less than 1×10^{-5}. The highest estimated multipathway radiation exposure for the MEI due to radionuclide emissions from utilities was predicted to be 1.5 millirems (mRems) per year, which is estimated to pose an increased cancer risk of 3×10^{-5}. Seventeen plants (13 coal- and 4 oil-fired plants) were estimated to pose multipathway risks between 1×10^{-5} and 3×10^{-5}. The estimated cancer incidence in the U.S., due to emissions and dispersion of radionuclides within 50 km of each utility, is estimated to be 0.3 cancer deaths/yr. The cancer incidence appears to be mostly due to inhalation exposure. The non-inhalation exposures contribute only

slightly to the incidence. The non-inhalation exposure pathways have a greater impact on the MEIs, especially for coal-fired plants.

The risks due to exposure to radionuclides from utilities are substantially lower than the risks due to natural background radiation. The average exposure to natural background radiation (excluding radon) for the U.S. population has been estimated to be roughly about 100 mRems per year, which is about 67 times higher than the highest exposure due to utility radionuclide emissions.

ES.12 QUALITATIVE MULTIPATHWAY EXPOSURE ASSESSMENT

The EPA recognizes that non-inhalation exposure pathways could be important for additional HAPs that are persistent and tend to bioaccumulate. A few additional HAPs that were not modeled for multipathway exposures are discussed below.

ES.12.1 Cadmium and Lead

Cadmium emissions from the vast majority of plants (683 of the 684 plants) are estimated to pose inhalation risks less than 10^{-6}, and the highest modeled air concentration of lead was 200 times below the national ambient air quality standard (NAAQS). Cadmium and lead are persistent, may bioaccumulate, and are toxic by ingestion. However, since the emission quantities and inhalation risks are relatively low, the EPA does not plan to conduct future evaluations of multipathway exposures of cadmium and lead from utilities.

ES.12.2 Nickel and Chromium

Nickel and chromium were not considered to be priority for non-inhalation exposures. At relatively high oral doses, nickel and chromium do cause noncancer toxicity. However, there are considerable uncertainties about the noncancer toxicity of nickel and chromium at relatively low ingestion doses (below the toxic threshold). Also, it is uncertain whether they pose a carcinogenic risk by ingestion. Hence, EPA does not plan to assess multipathway exposures for nickel and chromium for utilities.

ES.13 POTENTIAL IMPACTS OF HYDROGEN CHLORIDE AND FLUORIDE

No exceedances of the health benchmarks (e.g., RfCs) for HCl or HF were identified in the inhalation exposure assessment. However, emissions of HCL and HF may contribute to acid deposition and, to a lesser extent to PM fine and visibility problems. To the extent that these emissions may contribute to such problems, they could be addressed through other Titles of the Act.

ES.14 ALTERNATIVE CONTROL AND PREVENTION STRATEGIES

There are numerous potential alternative control strategies for reducing HAPs. These include precombustion controls (e.g., fuel switching, coal switching, coal cleaning, coal gasification), combustion controls, post combustion controls (e.g., PM controls, SO_2 controls), and approaches that prevent pollution by improving efficiency in supply (e.g., promoting energy efficiency in combustion) or demand (e.g., demand side management [DSM], pollution prevention, energy

conservation). The degree of feasibility, cost, and effectiveness of each of these potential control technologies varies. For example, coal cleaning tends to remove at least some of all the trace metals, with lead concentrations being removed to the greatest extent (averaging approximately 55 percent removal) and mercury being removed the least (averaging approximately 21 percent). Existing PM controls tend to effectively remove the trace metals (with the exception of mercury) while FGD units remove trace metals less effectively and exhibit more variability. Fuel switching (e.g., switching from coal to natural gas) could result in substantial reductions in HAP emissions. There are few existing data that show the HAP reduction effectiveness of DSM, pollution prevention, and energy conservation. These control strategies need to be examined further for technical and economic considerations.

ES.15 OTHER ISSUES AND FINDINGS

ES.15.1 Emissions and Risks for the Year 2010

In addition to the 1990 analysis, the EPA also estimated emissions and inhalation risks for the year 2010. There are substantial data gaps and uncertainties in the projections to the year 2010. However, the approach utilized is reasonable given the limitations of data to complete such projections.

Based on EPA's assessment for this report, HAP emissions from coal-fired utilities are predicted to increase by 10 to 30 percent by the year 2010. Predicted changes that were included in the 2010 emissions projections include the installation of scrubbers for a small number of facilities, the closing of a few facilities, and an increase in fuel consumption of other facilities. However, based on EPA's exposure modeling analysis for the year 2010, the inhalation risks in 2010 for coal-fired utilities are estimated to be roughly equivalent to the 1990 inhalation risks. For oil-fired plants, emissions and inhalation risks are estimated to decrease by 30 to 50 percent by the year 2010. Multipathway risks for 2010 were not assessed. Utilization of add-on controls to comply with the acid rain program are not expected to significantly impact on HAP emissions due to their limited numbers and limited HAP control efficiency improvement. However, if additional actions are taken to reduce emissions of criteria pollutants, acid rain precursors, or global warming compounds (e.g., use of fuel switching or add-on controls to reduce SO_x, NO_x, and/or carbon dioxide emissions), these actions could result in reductions in HAP emissions. For example, analyses performed to assess compliance with the revised NAAQS for ozone and PM indicate that mercury emissions in 2010 may be reduced by approximately 16 percent (11 tpy) over those projected in this report. Other potential (but unknown) actions (e.g., repowering, restructuring) may have a significant impact on HAP emissions; however, these unknowns were not included in the 2010 projection.

ES.15.2 Peer Review

Draft versions of Chapters 1 through 9 and 13 of this report and draft technical support documents were reviewed by many non-EPA scientists representing industry, environmental groups, academia, and other parties. Chapters 10, 11, and 12 are new chapters produced in response to major comments from the reviewers. EPA held a scientific peer review meeting and also a public meeting in July 1995 to obtain

comments from reviewers. In February, April, and September 1996, all sections of the draft report underwent additional review by EPA, State and local Agencies, and other Federal Agencies. Additional review occurred during 1997. The EPA has revised the report, as appropriate, based on the reviewers' comments. However, there were several comments that could not be fully addressed because of limitations in data, methods, and resources. In addition, there were some comments that EPA did not agree with. Also, the new chapters (10 to 12) have only undergone a limited review. Draft versions of this report, along with all the comments received, have been submitted to the public docket (A-92-55) at the following address: U.S. EPA, Air and Radiation Docket and Information Center, mail code 6102, 401 M Street, S.W., Washington, D.C. 20460; telephone number (202) 260-7548. Materials are available for public review at the docket center or copies may be mailed (for a fee) on request by calling the above number.

ES.15.3 Industry Report

If alternative methods and assumptions were used to study the HAP emissions from utilities, the results would likely be somewhat different. To assess the impact of using alternative assumptions and methods, it is useful to compare the EPA study with a similar study completed by the EPRI.

The EPRI prepared a report, entitled "Electric Utility Trace Substances Synthesis Report," (November 1994) that paralleled the EPA's study. Many of the same emissions data were used and similar risk assessment methods were utilized. The EPRI study concluded that cancer inhalation risks are below 1×10^{-6} for all utilities, and noncancer inhalation risks are well below Federal threshold levels for all utilities. Population inhalation risks were determined by the EPRI to be insignificant (less than 0.1 cancer case/year). Case studies at four plants found that multimedia risks, including mercury, are below levels of concern.

The EPRI's risk estimates are generally similar to, but in several cases lower than, those of EPA. Differences between the studies include: (1) EPA's use of a higher unit risk factor for arsenic; (2) EPA's assumption that nickel was carcinogenic (EPRI assumed nickel was not carcinogenic); (3) EPA's evaluation of exposure beyond 50 km to all locations in the U.S. (EPRI did not attempt this analysis); (4) EPRI's radionuclide analysis was based on several model plants, while the EPA evaluated every plant in the U.S.; and (5) the EPRI assumed that chromium emissions were five percent chromium VI (the carcinogenic form), while EPA assumed that 11 percent (for coal-fired plants) and 18 percent (for oil-fired plants) were chromium VI. In addition, the EPRI mercury multimedia study considered only the local impact from four plants (not worst-case) and did not include potential impacts of total nationwide utility mercury emissions and contributions to total environmental loadings.

ES.15.4 Potential Environmental Impacts Not Included in Study

There are other potential environmental issues associated with utilities not assessed in this report. These include: (1) the impacts of criteria pollutants (SO_2, NO_x, PM, carbon monoxide, and ozone) or acid rain precursors (SO_2 and NO_x), which are studied and regulated under

other sections of the Act; (2)an assessment of ecological impacts of HAPs; (3) the impacts of carbon dioxide emissions and climate; and (4) the impacts resulting from restructuring, mining, drilling, solid waste disposal, transmission, transportation, or other activities associated with electric power generation. These issues and potential impacts were not assessed because they were considered beyond the scope of this study as mandated by Section 112(n) of the Act.

ES.15.5 Link to Particulate Matter

Arsenic, cadmium, chromium, lead, nickel, radionuclides, and several other HAPs are emitted primarily as PM. Consequently, these HAPs may contribute to PM emissions and PM health concerns, especially from poorly controlled coal-fired units and uncontrolled oil-fired units (about two-thirds of oil-fired units are uncontrolled for PM). Impacts for PM were not addressed in this study, but are being studied under Title I of the Act. If additional controls of PM emissions are utilized, this could result in reductions in HAP emissions.

ES.16 OVERALL TECHNICAL SUMMARY AND CONCLUSIONS

Based on available information and current analyses, the EPA believes that mercury from coal-fired utilities is the HAP of greatest potential concern and merits additional research and monitoring. There are uncertainties regarding the extent of risks due to mercury exposures including those from utility emissions. Further research and evaluation are needed to gain a better understanding of the risks and impacts of utility mercury emissions. In addition, further research and evaluation of potential control technologies and strategies for mercury are needed.

For a few other HAPs, there also are still some remaining potential concerns and uncertainties that may need further study. First, the screening multipathway assessments for dioxins and arsenic suggest that these two HAPs are of potential concern (primarily from coal-fired plants); however, further evaluations and review are needed to better characterize the impacts of dioxins and arsenic emissions from utilities. Second, nickel emissions from oil-fired utilities are of potential concern, but significant uncertainties still exist with regards to the nickel forms emitted from utilities and the health effects of those various forms. The impacts due to HAP emissions from gas-fired utilities are negligible based on the results of this study; therefore, the EPA feels that there is no need for further evaluation of the risks of HAP emissions from natural gas-fired utilities.

ES.17 AREAS FOR FURTHER RESEARCH AND ANALYSIS

There are many uncertainties and data gaps described throughout this report. This section summarizes several important areas in which further research or scientific work may be needed.

ES.17.1 Emissions Data for Dioxins

Emissions data for dioxin compounds were available from less than 12 utility plants. Many of the measurements were near the detection limits. Therefore, there are greater uncertainties with the dioxin emissions than for the other HAPs. Research may be needed to gain a better understanding of the dioxin emissions from utilities and the

dioxin formation, if any, in various utility boiler types (e.g., units with cold-side or hot-side ESPs).

ES.17.2 Speciation of Nickel

There are significant uncertainties regarding the forms of nickel emitted from oil-fired utilities and their associated health effects. Research would be useful to determine the emissions quantities of various nickel forms and the health effects of various nickel forms.

ES.1.7.3 Multipathway Risk Assessment

Further work may be needed to better characterize the risks due to multipathway exposure to certain HAPs (e.g., arsenic and dioxins).

ES.17.4 Local, Regional, and Long-range Transport Exposures

Further modeling and evaluation may be needed to better characterize the impacts of local, regional, and long-range transport of HAPs from utilities.

ES.17.5 Mercury

There are numerous areas regarding mercury that may need further research, study, or evaluation. A few potential areas for further study include the following:

(1) additional data on mercury content of various types of coal;

(2) improved methods for measuring mercury levels in water;

(3) the impact of reducing mercury emissions from coal-fired facilities on the bioaccumulation of mercury in fish;

(4) statistically valid and reliable estimates of methylmercury exposure levels in the U.S. population and susceptible subpopulations, as measured in human hair;

(5) the occupational, dietary and behavioral factors that affect mercury exposures for people who are determined to be exposed above a threshold of concern;

(6) the human health and environmental benefits that would be expected by reducing mercury emissions from U.S. utilities;

(7) control technologies or pollution prevention options that are available, or will be available, that could potentially reduce mercury emissions and what are the costs of those options;

(8) how do other regulations, programs and activities (e.g., acid rain program, electricity restructuring, NAAQSs, and climate change) affect mercury emissions; and

(9) additional data on mercury emissions (e.g., how much is emitted from various types of units, how much is divalent vs elemental mercury, and how do factors such as conrol device, fuel type, and plant configuration affect emissions and speciation).

Several additional uncertainties and potential areas for further research on mercury are discussed in other sections of this report.

ES.17.6 Projections to the Year 2010

There are significant uncertainties and unknowns in the emissions and risk projections made to the year 2010 (e.g., impact of electricity restructuring; impact of State efforts to regulate such restructuring; impact of any climate change abatement initiatives). Research and evaluation in these areas may be needed.

ES.17.7 Ecological Risks

The effects of HAPs on wildlife, endangered species, and terrestrial and aquatic ecosystems were not evaluated in this study. Although not mandated by section 112(n)(1)(A), further evaluation of ecological risks due to HAP emissions would be needed to fully evaluate the impacts of utility HAP emissions.

ES.17.8 Criteria Pollutant and Acid Rain Programs

Further evaluation is needed to assess the impacts of the Acid Rain and Criteria Pollutant programs (e.g., impact of revisions to the PM-fine and ozone NAAQS; impact of Ozone Transport Assessment Group [OTAG] activities) on HAP emissions, especially for mercury.