Paper #4-1
BASELINE AND PROJECTIONS OF EMISSIONS FROM END-USE SECTORS

Prepared by the Emissions Team
of the
Carbon and Other End-Use Emissions Subgroup

On September 15, 2011, The National Petroleum Council (NPC) in approving its report, *Prudent Development: Realizing the Potential of North America's Abundant Natural Gas and Oil Resources*, also approved the making available of certain materials used in the study process, including detailed, specific subject matter papers prepared or used by the study's Task Groups and/or Subgroups. These Topic and White Papers were working documents that were part of the analyses that led to development of the summary results presented in the report's Executive Summary and Chapters.

These Topic and White Papers represent the views and conclusions of the authors. The National Petroleum Council has not endorsed or approved the statements and conclusions contained in these documents, but approved the publication of these materials as part of the study process.

The NPC believes that these papers will be of interest to the readers of the report and will help them better understand the results. These materials are being made available in the interest of transparency.

The attached paper is one of 57 such working documents used in the study analyses. Also included is a roster of the Team that developed or submitted this paper. Appendix C of the final NPC report provides a complete list of the 57 Topic and White Papers and an abstract for each. The full papers can be viewed and downloaded from the report section of the NPC website (www.npc.org).

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Abstract

In this report, the carbon and end-use emissions subgroup describes the current and projected ranges for emissions of air pollutants and greenhouse gases (GHG) in the U.S end-use sectors. As part of its efforts, the subgroup reviewed multiple publicly available reports on historical and projected U.S. emissions and concluded that the Energy Information Administration's (EIA) *Annual Energy Outlook 2010* (*AEO2010*) provides the best source of emissions projections for GHGs and power sector sulfur dioxide (SO_2), nitrogen oxides (NO_x), and mercury.

Abbreviations used throughout this document

Item	Abbreviation	Note
British thermal units	Btu	
carbon dioxide	CO_2	measured in tonnes
carbon dioxide equivalent	CO_2e	measured in tonnes
greenhouse gas	GHG	measured in tonnes
metric tonne	tonne	
million (mega)	M	
nitrogen oxides	NO_x	measured in tons
short ton	ton	equivalent to 0.907 tonnes
sulfur dioxide	SO_2	measured in tons
thousand (kilo)	K	
ton or tonne	t	depends on item measured
Watt-hour	Wh	

1. Introduction

a. Scope

In this report, the carbon and end-use emissions subgroup describes the current and projected ranges for emissions of air pollutants and greenhouse gases (GHG) in the U.S end-use sectors. As part of its efforts, the subgroup reviewed multiple publicly available reports on historical and projected U.S. emissions and concluded that the Energy Information Administration's (EIA) *Annual Energy Outlook 2010* (*AEO2010*) provides the best source of emissions projections for GHGs and power sector sulfur dioxide (SO_2), nitrogen oxides (NO_x), and mercury.[1]

b. 2005 baseline year

The subgroup used the *AEO2010* as the source of the 2005 baseline GHG emissions. The 2005 baseline year serves as the reference point with which future emissions projections can be compared. The subgroup selected 2005 as the baseline year primarily to ensure consistency with the Future of Transportation Fuels study being completed in parallel and also since legislation introduced in the 111th Congress employed 2005 as the baseline year.[2] For other pollutants we use a combination of the *AEO2010* and U.S. Environmental Protection Agency (USEPA) reports to arrive at 2005 baseline emissions.

c. Emissions projections

To capture a range of projections, the subgroup selected three cases from the *AEO2010*:

i. Reference case,
ii. High-Economic Growth case, and
iii. Low-Economic Growth case.

All three cases only incorporate existing regulations and legislation and do not assume any major breakthroughs in technology.[3] As noted by the EIA, the "Reference case" represents a "business-as-usual" projection, that is, an economy operating under known technological and demographic trends. Essentially, the "Reference case" provides insight on future energy supply and demand and the associated emissions holding major unknowns such as future energy legislation or regulations constant. While energy and environmental laws will likely change in the next 25 years, the "Reference case" provides a "policy neutral baseline" for decision makers to assess the implications of consumer and emission policies.

[1] Annual Energy Outlook 2010 With Projections to 2035, DOE/EIA-0383(2010), April 2010. *AEO2010* is published in accordance with Section 205c of the U.S. Department of Energy (DOE) Organization Act of 1977 (Public Law 95-91)
[2] S. 1733, Clean Energy Jobs and American Power Act; H.R. 2454, American Clean Energy and Security Act of 2009
[3] *AEO2010* projections are based on Federal, State, and local laws and regulations in effect as of the end of October 2009.

2. 2005 baseline emissions – GHGs

Figure 1 summarizes the 2005 baseline emissions for GHGs as compiled from the *AEO2010*.

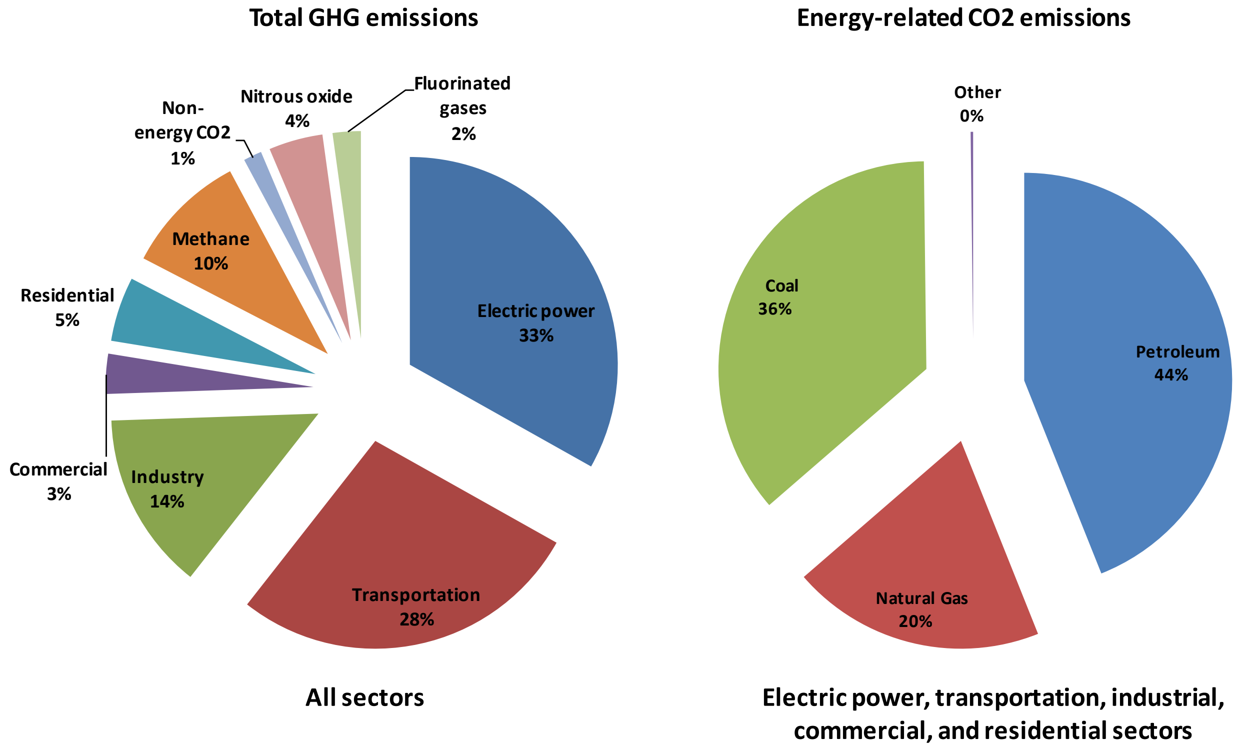
Figure 1 –2005 baseline emissions: GHGs

Emissions	Grouping	2005 baseline		Unit[4]	Source
GHG	Energy-related CO_2	Electric power	2,397	$MtCO_2e$	EIA
		Transportation	1,984		
		Industry	1,004		
		Commercial	225		
		Residential	365		
		Sub-total	5,975		
	Non-energy related CO_2 and other GHGs	Methane	692		
		Non-energy CO_2	103		
		Nitrous oxide	304		
		Fluorinated gases	158		
		Sub-total	1,257		
	Total		**7,231**		

As displayed in Figure 1 and Figure 2, the electric power sector emitted about one-third of total U.S. GHG emissions. The transportation sector accounted for 28 percent of total U.S. GHG emissions. Also displayed in Figure 2 is the energy-related CO_2 emissions split by fuel. CO_2 emissions resulting from petroleum combustion make up 44 percent of energy-related CO_2 emissions, more than coal (36 percent) and natural gas (20 percent). Whereas coal is predominantly used in the electric power sector, petroleum is used extensively in absolute and percentage terms in the transportation and industrial sectors.

[4] Million metric tonnes of carbon dioxide equivalent

Figure 2 – 2005 baseline emissions: emissions breakdown by sector and fuel



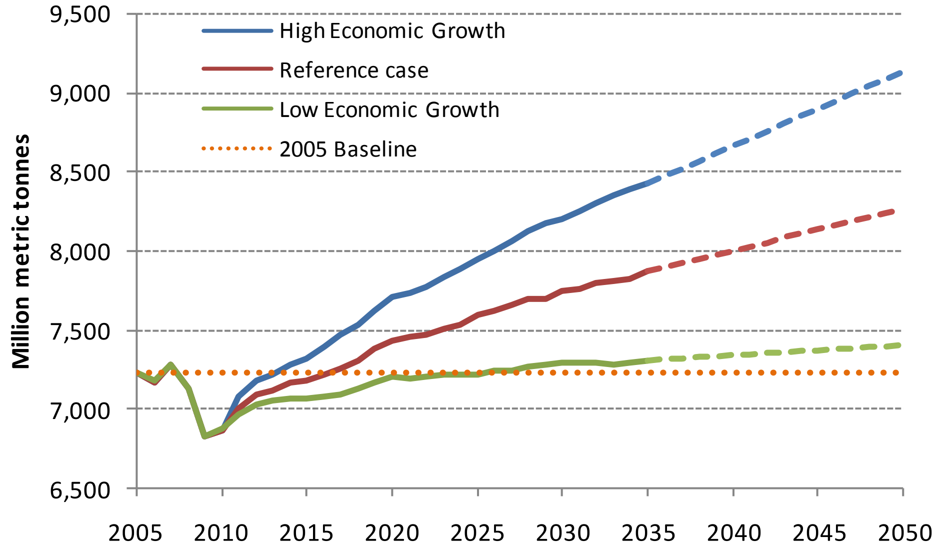
3. Emissions projections – GHGs

a. The Reference case

Figure 3 displays GHG emissions projections in the U.S. By 2015, emissions are projected to rise to about 7,200 million metric tonnes of carbon dioxide equivalent per year (7,200 $MtCO_2e$/year). Eighty-percent of GHG emissions are expected to come from energy-related CO_2 with the remainder coming from methane (10 percent), non-energy CO_2 (2 percent), nitrous oxide (5 percent), and fluorinated gases (4 percent).[5] By 2035, emissions are projected to rise to about 7,900 $MtCO_2e$/year with minimal changes in the percentage share by gas.

[5] Fluorinated gases include HFCs and other ODS substitutes, PFCs and SF6

Figure 3 –Emissions projections: GHGs



Note: dashed-continuations represent linear extrapolation of AEO projections based on 2026-2035 values

Projected GHG emissions in 2015 and 2035 are 1 percent lower and 9 percent higher than 2005 baseline emissions, respectively. The drop in emissions mostly results from the recent economic recession that is expected to have lasting impact on the level of GHG emissions due to declines in industrial activity, miles traveled, and electricity demand. GHG emissions are expected to remain below 2005 baseline level until 2017.

While the *AEO2010* provides projections through 2035, the subgroup uses the least squares method to calculate a straight line extrapolation to 2050. The known "y-values" are the emissions projections between 2026 and 2035, the last ten years of the time-horizon. This is merely an illustrative view of what emissions may look like between 2036 and 2050 and is not a substitute for the dynamic modeling employed by the *AEO2010*. The extrapolations are represented as the dashed-continuations of *AEO2010* projections.

b. Range of greenhouse gas emissions projections

Figure 4 provides a further breakdown of emissions projections by sector. While non-energy related CO_2 and other GHGs emissions projections vary among the three cases, the variability of energy-related CO_2 emissions projections account for the majority of the variability in total U.S. GHG emissions projections.

Figure 4 – Emissions projections: GHG breakdown

Grouping	Case	Sector	2005	2015	2035	2050*
Energy-related CO_2	High	Electric power	2,397	2,298	2,816	3,242
	Reference			2,277	2,634	2,925
	Low			2,250	2,422	2,590
	High	Transportation	1,984	1,974	2,324	2,554
	Reference			1,914	2,115	2,260
	Low			1,863	1,918	1,956
	High	Industry	1,004	1,031	1,126	1,170
	Reference			988	1,001	997
	Low			951	884	831
	High	Commercial	225	224	255	284
	Reference			222	245	262
	Low			221	238	255
	High	Residential	365	332	344	349
	Reference			329	324	313
	Low			327	306	284
	High	Sub-total	5,974	5,859	6,865	7,600
	Reference			5,731	6,320	6,757
	Low			5,613	5,768	5,915
Non-energy related CO_2 and other GHGs	High	Other	1,257	1,457	1,568	1,533
	Reference			1,452	1,552	1,511
	Low			1,446	1,537	1,489
Total	High	Total GHG	7,231	7,316	8,433	9,133
	Reference			7,182	7,872	8,268
	Low			7,059	7,304	7,405

Note: values in $MtCO_2e$, 2050 figures based on extrapolation

4. 2005 baseline emissions – SO_2, NO_x and mercury

The *AEO2010* only provides SO_2, NO_x and mercury emissions data for the electric power sector. As shown in Figure 5, other sectors contribute to the totals of those emissions; therefore, we use the USEPA to provide the 2005 baseline SO_2, NO_x, and mercury emissions.[6,7]

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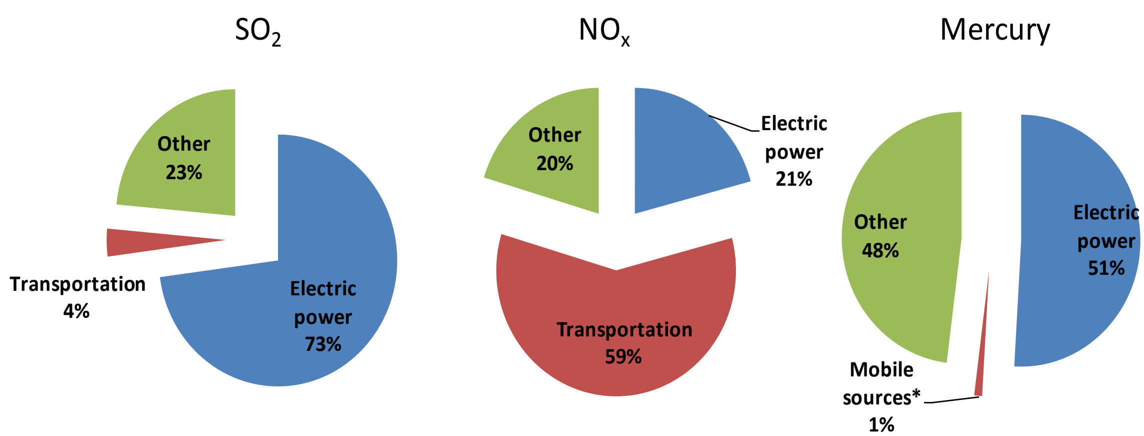
[6] SO_2 and NO_x emissions data can be found at http://www.epa.gov/air/emissions/index.htm

[7] Mercury emissions data can be found at http://cfpub.epa.gov/eroe/index.cfm?fuseaction=detail.viewReference&ch=46&lShowInd=0&subtop=341&lv=list.listByChapter&r=216615

Figure 5 – 2005 baseline emissions: SO_2, NO_x, and Mercury

Emissions	2005 baseline		Unit	Source
SO_2	Electric power	10	million tons	USEPA
	Transportation	1		
	Other	3		
	Total	**14**		
NO_x	Electric power	4	million tons	
	Transportation	11		
	Other	4		
	Total	**18**		
Mercury	Electric power	52	tons	
	Transportation	1		
	Other	49		
	Total	**103**		

Figure 6 – 2005 baseline emissions: emissions breakdown by sector



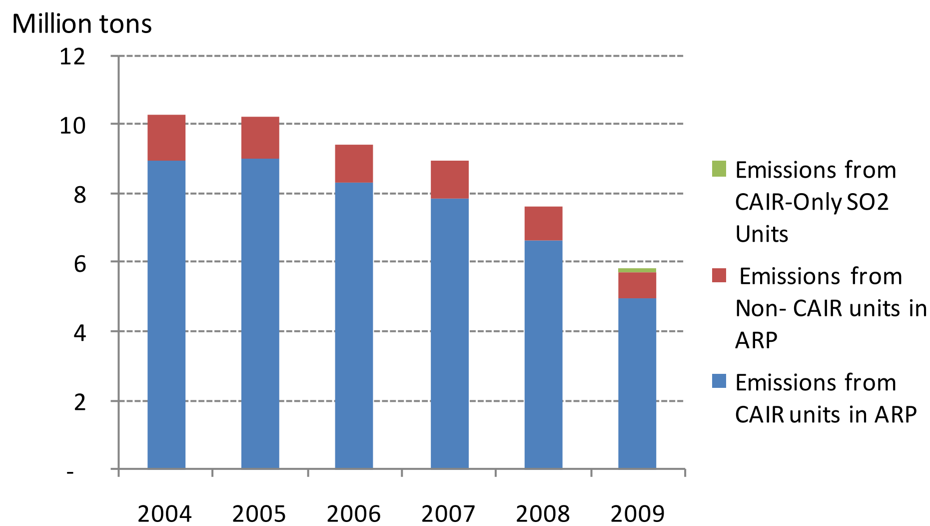
Note: Mercury mobile source emissions are estimated

In 2005, over 73 percent of the SO_2 emissions came from electric power plants. However, as shown in Figure 7 and Figure 8, SO_2 emissions in the electric power sector decreased by 43 percent between 2005 and 2009. This is mainly due to the impact of the Acid Rain Program (ARP) and the CAIR SO_2 rules, but also due to the economic recession as noted earlier. Over 3,321 units are subject to the CAIR SO_2 program.

Mercury emissions in the U.S. were about 103 tons with the electric sector contributing 51 percent of those emissions. According to the EPA, coal fired power plants are the largest source of "human-caused mercury air emissions" accounting for 50 percent of the total U.S. man-made mercury emissions (Figure 6 and Figure 11). Other sources of emissions include industrial boilers, hazardous waste, electric arc furnaces, cement kilns and gold mining. Analysis of mercury emissions from U.S. sources, including coal-fired power plants, shows that about

2/3 of this emitted mercury leaves the United States permanently and enters the global atmospheric pool. In fact, of the 140-170 tons per year of mercury currently being deposited onto the United States mainland, more than 1/3 originates in other countries. [8,9]

Figure 7 – SO_2 Emissions from ARP and CAIR Annual SO_2 Program Sources 2004 – 2009[10]



The transportation sector accounts for over 59 percent of the total NO_x emissions in the U.S. with the power sector accounting for about 21 percent of the emissions in 2005. As noted in Figure 8, NO_x emissions in the electric power sector had decreased by 18 percent from 2005 levels in 2008 due to the impact of CAIR and the economic recession, similar to SO_2 emissions.

5. Emissions projections – SO_2, NO_x and Mercury: the electric power sector

The *AEO2010* considers the Clean Air Interstate Rule (CAIR),[11] which aims to control sulfur dioxide (SO_2) and nitrogen oxides (NO_x) emissions. Since the Clean Air Mercury Rule (CAMR) was vacated in 2008, it is not explicitly modeled; however, the *AEO2010* does reflect state mercury regulations, which result in significant declines in mercury emissions.

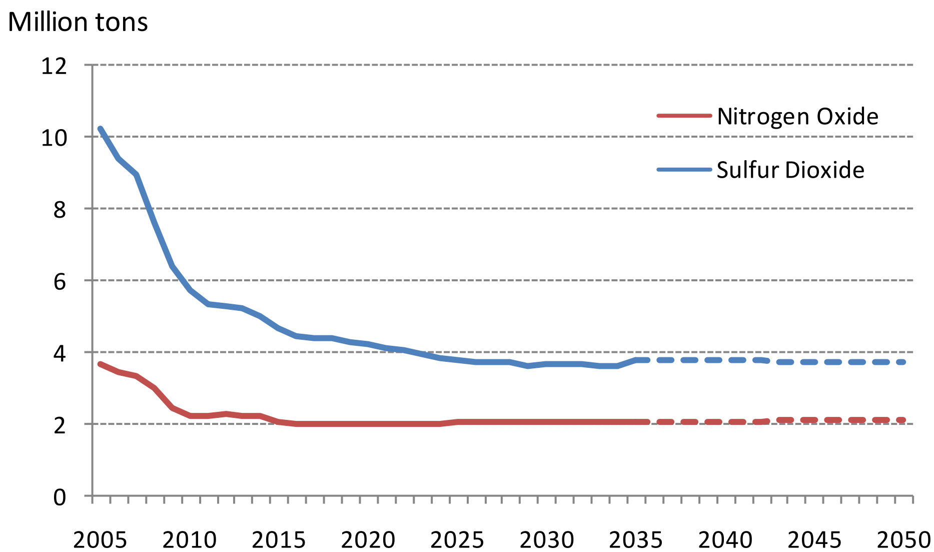
a. Emissions projections: SO_2 and NO_x – the electric power sector

Figure 8 displays the *AEO2010* SO_2 and NO_x emissions projections for the electric power sector through 2035 (with an extrapolation to 2050). As shown, SO_2 and NO_x emissions are expected to continue to decline as a result of CAIR. Although not shown in the chart, further reductions may also be forthcoming with the expected implementation of the Transport Rule (as discussed

[8] http://my.epri.com/portal/server.pt?Abstract_id=000000000001018762
[9] The Global Atmospheric Mercury Assessment: Sources, Emissions and Transport, UNEP, December, 2008
[10] http://www.epa.gov/airmarkets/progress/CAIR_09/CAIR_1.html
[11] CAIR was designed to cap SO_2 emissions at 2.5 million tons and NO_x at 1.3 million tons in 28 states and the District of Columbia. AEO2010 incorporates the December 23, 2008 decision by the D.C. Circuit Court remanding the CAIR rules and assumes the long-term reduction CAIR goals will be met by the cap-and-trade program.

below). As the limits tighten under the Transport Rule, electric generating units will continue to install emissions controls, switch to low-sulfur coal, and improve efficiency, among other things.

Figure 8 – Emissions projections: SO_2 and NO_x, electric power sector



b. Proposed regulations – SO_2 and NO_x

EPA has proposed or is under court mandate to propose new regulations to regulate SO_2, NO_x and hazardous air pollutants from various emission sources, including electric power plants. While this section is not intended to provide a comprehensive overview of these regulations, the report attempts to provide additional information on potential emission reductions from these proposed rules. As discussed above, *AEO2010* does not incorporate these proposed or pending regulations.

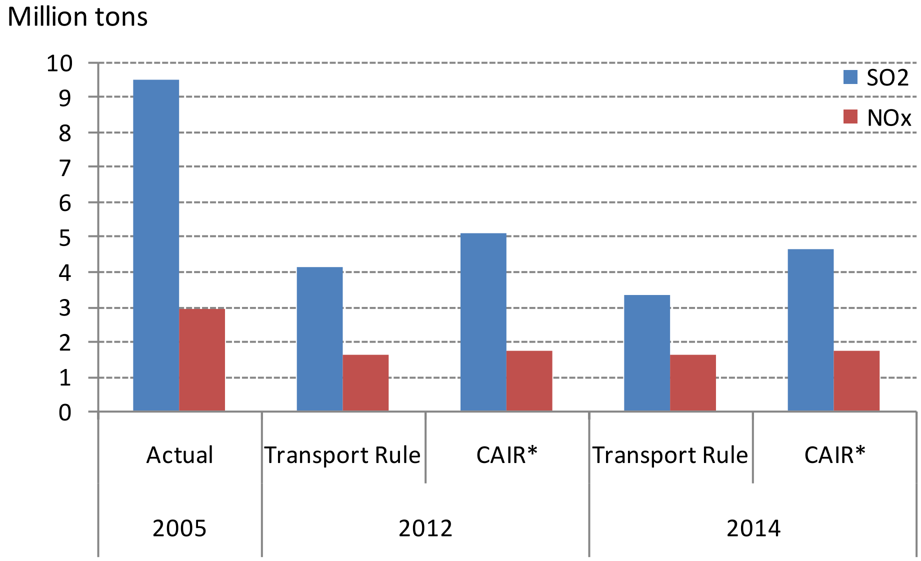
c. Transport Rule

On July 6, 2010, the USEPA proposed the Transport Rule to reduce SO_2 and NO_x emissions from power plants in 31 states and the District of Columbia.[12] The Transport Rule would replace the CAIR rule and would require additional emissions reductions beyond CAIR. While the EPA projects annual reductions of approximately 6.3 million tons of SO_2 and 1.4 million tons of NO_x by 2014 relative to the 2005 baseline, the proposed Transport Rule would cap the SO_2 emissions at 2.6 million tons per year and NO_x emissions at 1.3 million tons per year.[13] The EPA estimates that the proposed Transport Rule will result in greater reductions relative to the CAIR rule as shown in Figure 9.[14] Under the Transport Rule, the 2012 SO_2 emissions would be 1.0 million tons less than under CAIR and 2014 SO_2 emissions would be 1.3 million tons less. Annual and seasonal NO_x emissions would be 0.1 million tons less in both 2012 and 2014. As explained

[12] Federal Register, Vol. 75, No. 147 /45210-45465. http://www.gpo.gov/fdsys/pkg/FR-2010-08-02/pdf/2010-17007.pdf#page=1
[13] http://www.epa.gov/airtransport/actions.html#jul10, Overview Presentation 7/26/10, page 9
[14] http://www.epa.gov/airtransport/pdfs/TransportRule.pdf, page 36

earlier, the *AEO2010* incorporates CAIR but does not reflect the recently proposed Transport Rule.

Figure 9 – EPA estimates of proposed SO_2 and NO_x emissions limits



Note: CAIR figures are interpolations from analysis originally done for 2010 and 2015; this CAIR scenario has slight differences from the final CAIR

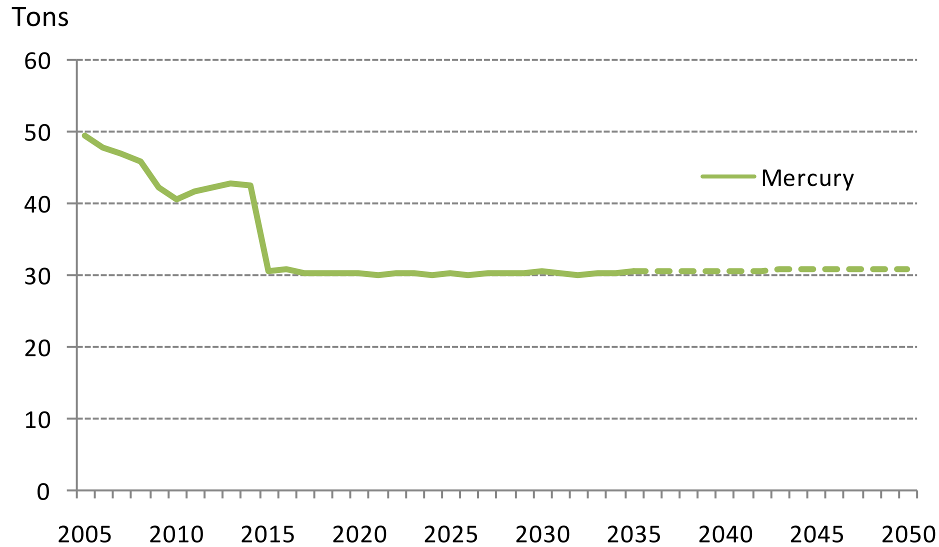
The Transport Rule, though primarily focused on SO_2 and NO_x, may have collateral reductions of GHGs due to the retirement of older, inefficient coal power plants. The EPA estimates that the Transport Rule has the potential to lower CO_2 emissions by 15.3 million tonnes primarily due to reductions in coal and fuel oil use and greater reliance on natural gas and "non-fossil sources of electric generation."[15]

d. Emissions projections: Mercury – the electric power sector

Like SO_2 and NO_x, the subgroup uses the *AEO2010* projections for mercury emissions. As shown in Figure 10, mercury emissions in the electric power sector declined 7 percent between 2005 and 2008. Mercury emissions are projected to continue to decline due to increased installation of SO_2 and NO_x controls (a collateral benefit of these installations is reduced mercury emissions) and State-mandated controls. Emissions eventually level off as these projections do not reflect CAMR or any increased stringency of existing State mercury regulations.

[15] Regulatory Impact Analysis for the Proposed Federal Transport Rule, Page 262

Figure 10 – Emissions projections: Mercury, electric power sector



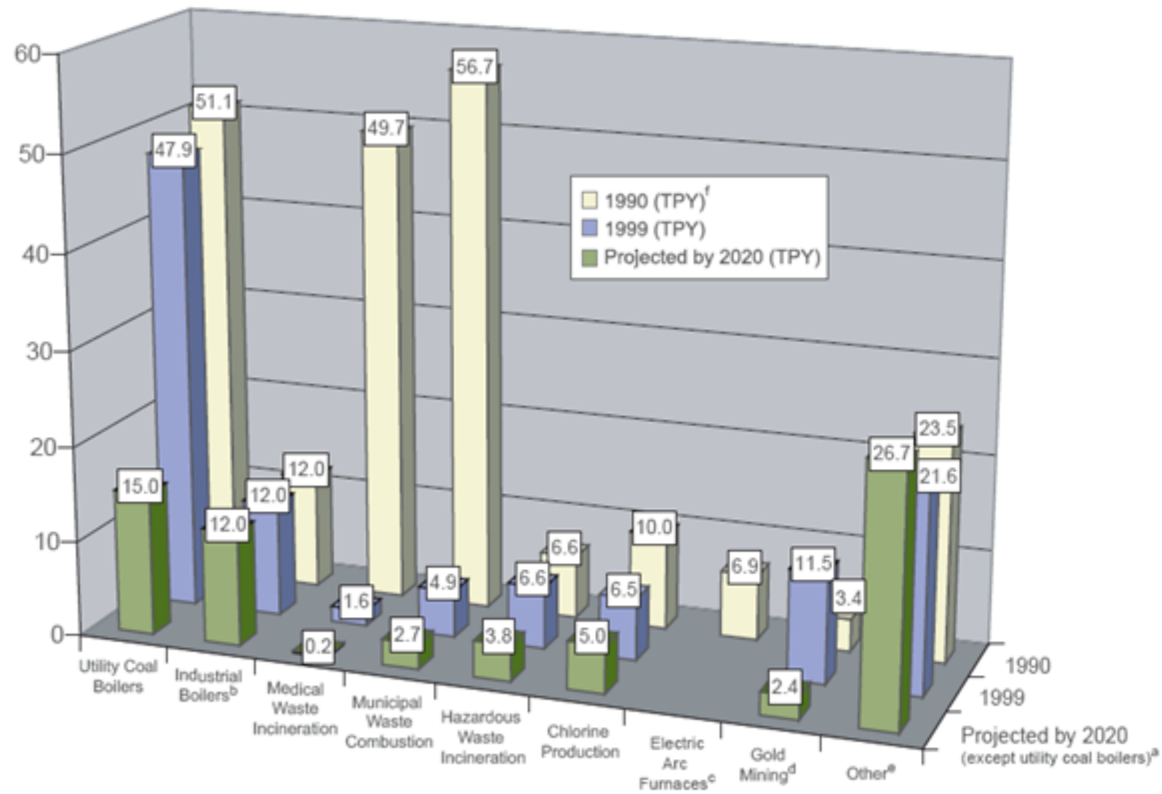
e. Mercury regulations

Since 1990 EPA has focused most of its mercury reductions efforts on municipal waste combustors, medical waste incinerators, hazardous waste combustors, industrial boilers, cement plants and coal fired power plants.[16] In 2010, EPA finalized Maximum Available Control Technology (MACT) standards for cement plants,[17] which aim to reduce mercury emissions by a total of about 16,600 pounds per year by 2013. On April 15, 2010, the EPA proposed MACT rules for gold ore processing and production that aim to reduce mercury emissions by 0.7 tons per year. On April 29, 2010, the EPA also proposed MACT rules for industrial boilers. The EPA plans to finalize MACT standards for coal and oil fired electric generating units by November 16, 2011,[18] which will replace the CAMR that was vacated by the D.C. Circuit.[19] CAMR capped mercury emissions in 2018 from coal-fired power plants to 15 tons. It is expected that the Utility MACT rule will achieve comparable or steeper reductions than the CAMR.

Little literature is available in the public domain concerning future mercury emissions as a result of uncertainty about forthcoming regulations. A 2006 USEPA report titled "EPA's Roadmap for Mercury" projects that U.S. mercury emissions will be 68 tons per year in 2020 (Figure 11), of which, 15 tons is emitted from the electric power sector, reflecting the CAMR cap, which will not go into effect as a result of the D.C. Circuit decision.[20]

[16] http://www.epa.gov/mercury/regs.htm
[17] http://www.epa.gov/ttn/oarpg/t1/fr_notices/portland_cement_fr_080910.pdf
[18] http://www.epa.gov/air/mercuryrule/
[19] State of New Jersey et al. v. EPA, February 8, 2008
[20] http://www.epa.gov/mercury/roadmap.htm

Figure 11 – Air Emissions Data for Mercury



[a]Fifteen tons per year will be acheived when full implementation of the Clean Air Mercury Rule is achieved, which may exceed 2020.
[b]Growth in this sector is being offset by regulation.
[c]Electric Arc Furnaces data not available for 1999. The 2002 estimate is 10 tons per year.
[d]The 1990 emissions estimate is a preliminary estimate and is based on back calculations and assumptions using data from 1999 along with information about types of processes, production rates, and ores used in 1990 compared to 1999.
[e]These projected emissions do not account for reductions from non-regulatory actions described elsewhere in the Roadmap.
[f]1 ton equals 0.9070 metric ton

As of October 2005, 22 States have mercury action plans (Figure 12).[21]

[21] **2005 Compendium of States' Mercury Activities,** October 2005. http://www.ecos.org/section/committees/cross_media/quick_silver/2005_mercury_compendium1/

Figure 12 – States regulating Mercury emissions

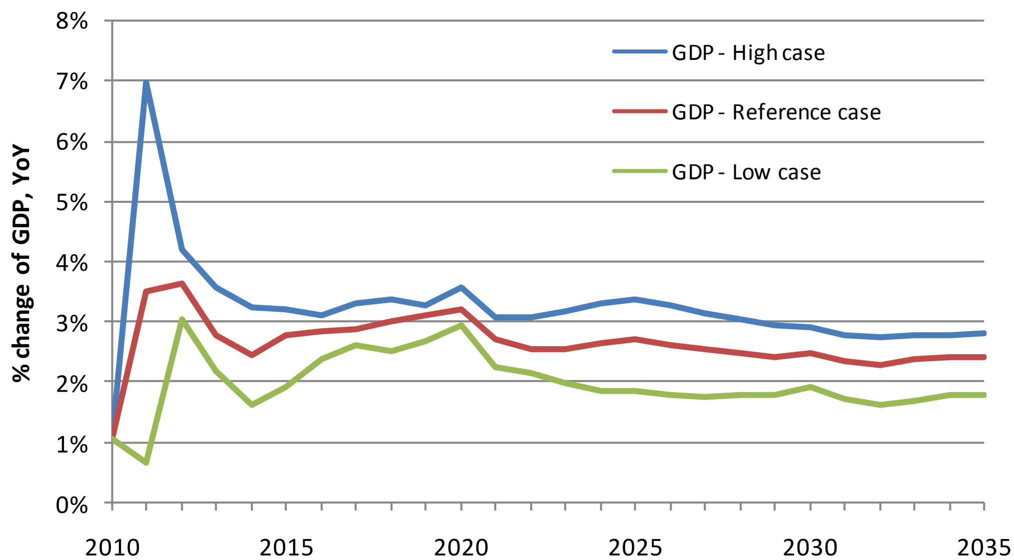
	Coal-Fired Power Plants	Electric Arc Furnaces	Industrial Boilers	Steel Recycling Facilities	Sewage Sludge Incinerators	Wastewater Treatment	Chlor-alkali Plants	Municipal Solid Waste Incinerators	Medical Waste Incinerators	Mining	Cement kilns
Arizona						✓				✓	
Arkansas	✓			✓		✓	✓		✓		✓
California											✓
Connecticut	✓							✓	✓		
Delaware	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Florida								✓	✓		
Georgia						✓					
Indiana					✓			✓	✓		✓
Kentucky			✓	✓	✓	✓	✓				✓
Louisiana		✓		✓			✓	✓	✓		
Maine			✓	✓		✓		✓			✓
Maryland		✓	✓	✓	✓		✓	✓	✓		✓
Massachusetts	✓					✓					
Michigan						✓		✓	✓		
Minnesota						✓		✓	✓		
Montana	✓		✓								✓
New Hampshire								✓	✓		
New Jersey	✓	✓						✓	✓		
New York		✓		✓		✓		✓			
North Carolina					✓			✓	✓		
Oregon			✓					✓			
Pennsylvania						✓					
Rhode Island									✓		
South Carolina	✓	✓	✓		✓		✓	✓	✓		✓
South Dakota						✓					
Texas	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Virginia	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
Washington						✓	✓	✓			
West Virginia						✓					
Wisconsin	✓					✓					
Wyoming						✓				✓	
Total	10	8	9	8	8	18	9	18	16	5	17

6. Assumptions, inputs and methodologies

The rate of economic growth has the largest impact on GHG emissions of the 38 cases modeled by EIA in the *AEO2010*. All of the other cases are within the range of the Low and High Economic Growth cases. [22]

Figure 13 displays the year-over-year GDP growth rates for all three cases in the *AEO2010*. GDP is projected to grow by 1 percent in 2010 in the Reference case and Low and High Economic Growth cases. On average, GDP grows by 2.5 percent per year from 2008 to 2035 in the Reference case and about 1 percent lower in the Low Economic Growth case and 1 percent higher in the High Economic Growth case.

Figure 13 – Real GDP growth rates



GDP and other macroeconomic variables are developed in the EIA's Macroeconomic Activity Module (MAM). These variables eventually feed into sector-specific modules, which in turn project energy consumption and the resulting emissions based on different emissions factors. Aside from GDP, each sector has a number of variables that are also important to energy consumption and the resulting emissions (Figure 14). While GDP and population are expected to grow through 2035, each sector becomes more energy-efficient, and therefore, less carbon-intensive. The residential, commercial, and industrial sectors require less energy input per unit specific to its sector. Additionally, while the number of vehicle miles traveled increases, increasingly stringent corporate average fuel economy (CAFE) standards require new vehicles to travel farther per gallon of consumption. Last, combined growth in and natural gas generation is projected to outpace growth of coal generation, resulting in lower carbon intensity in the electric power sector.

[22] The complete list of scenarios can be found at http://www.eia.doe.gov/oiaf/aeo/tablebrowser/.

Figure 14 – Influences on energy-related CO_2 and GHG emissions projections by case

Sector	Variable	Units	Scenario	2005	2015	2035
All	Real gross domestic product	billion 2000 chain-weighted dollars	High		14,084	25,918
			Reference	**10,990**	13,289	22,362
			Low		12,563	18,820
All	Population	millions of persons	High		333	433
			Reference	**297**	327	391
			Low		322	352
Residential	Total homes	millions of homes	High		123	158
			Reference	**111**	121	147
			Low		120	136
Residential	Energy consumption intensity	million Btu per household	High		177	163
			Reference	**195**	176	163
			Low		176	165
Commercial	Total floor space	billion square feet	High		87	120
			Reference	**74**	85	111
			Low		83	102
Commercial	Energy consumption intensity	thousand Btu per square foot	High		232	214
			Reference	**241**	232	220
			Low		234	230
Industrial	Value of shipments	billion 2000 dollars	High		6,444	9,397
			Reference	**5,702**	6,044	7,786
			Low		5,673	6,252
Industrial	Energy consumption per dollar shipment	thousand Btu per 2000 dollar	High		5	4
			Reference	**6**	5	4
			Low		5	5
Transportation	Light duty vehicles (<8,500 pounds)	billion vehicle miles traveled	High		2,990	4,598
			Reference	**2,645**	2,916	4,203
			Low		2,861	3,855
Transportation	New light-duty vehicle CAFE standard	miles per gallon	High		32	36
			Reference	**24**	32	36
			Low		32	36
Electric	Total generation	billion KWh	High		4,387	5,749
			Reference	**4,055**	4,280	5,259
			Low		4,187	4,766
Electric	CO_2 intensity	tCO_2 per MWh	High		0.52	0.49
			Reference	**.59**	0.53	0.50
			Low		0.54	0.51