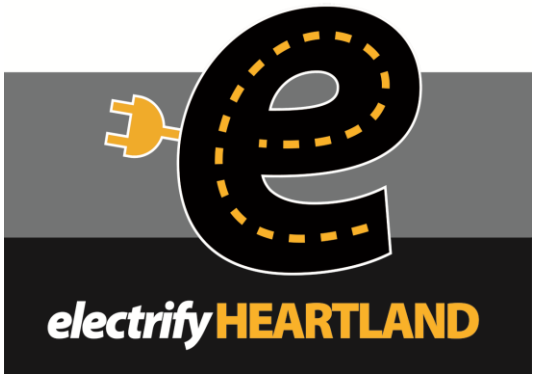
Electrify Heartland Plan

Appendix N: Air Quality



Project title: Kansas – Missouri Community Readiness for EV and EVSE

Funded by: US DOE DE-EE0005551

By: Metropolitan Energy Center

and Kansas City Regional Clean Cities Coalition

With: Black & Veatch

Metropolitan ENERGY CENTER

Kansas City Regional Clean Cities

BLACK & VEATCH

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This work was developed in response to the federal funding opportunity announcement titled Clean Cities Community Readiness and Planning for Plug-in Electric Vehicles and Charging Infrastructure. FOA: DE-FOA-0000451

CFDA Number 81.086

Electrify Heartland Plan

Electrify Heartland Project Abstract

Electrify Heartland is an electric vehicle planning project managed by Metropolitan Energy Center. It is a product of the Greater Kansas City Plug-In Readiness Initiative, co-chaired by Kansas City Regional Clean Cities Coalition. Our goal is to produce a regional plan to prepare public resources and secure the economic and environmental benefits of plug-in vehicles within targeted metro areas with estimated 2.7M population. The targeted metro areas include Kansas City, MO & KS; Jefferson City, MO, Wichita, KS; Salina, KS; Lawrence, KS; and Topeka, KS. (14 Counties: Cass, Clay, Cole, Douglas, Jackson, Johnson, Leavenworth, Miami, Platte, Ray, Saline, Sedgwick, Shawnee, Wyandotte).

Electrify Heartland Steering Committee

Team	Organization	Name
Charging Stations	Initiatives	Troy Carlson
Charging Stations	LilyPadEV	Larry Kinder
Charging Stations	Logios	Gustavo Collantes
Government Policy	Polsinelli Shughart PC	Alan Anderson
Government Policy	Black & Veatch	Bill Roush
Project Administration	Metropolitan Energy Center	Ruth Redenbaugh
Project Administration	Metropolitan Energy Center	Kelly Gilbert
Public Education	Nation Ranch Marketing, Inc.	Bill Patterson
Training	Kansas City Kansas Community College	Bob McGowan
Training	National Electrical Contractors Association	Jim Cianciolo
Utility Grid	Black & Veatch	Sam Scupham
Vehicle & Fleet	University of Missouri at Kansas City	Henry Marsh

Exhibit i-i. Electrify Heartland Steering Committee Members

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Appendix N: Air Quality

Synopsis:

This appendix to the Electrify Heartland Plan describes the importance of clean air legislation and trends over the last thirty years. For further information, the Alternative Fuel Data Center, http://www.afdc.energy.gov/afdc/ provided by the US Department of Energy, illustrates fuel costs and emission comparison of vehicles specified by you. Electric vehicles produce near zero emissions.

Section Author:

Sebastian Ramos, Metropolitan Energy Center

Air Quality Impacts Health

Air quality is an often overlooked concern among vehicle owners, but it is an important health issue because it affects the whole population. Vehicles are the largest source of pollution for the average person. Air quality is affected by exhaust pollutants from various sources, many mobile vehicle sources. Some examples of these are hydrocarbons (also known as volatile organic compounds, or VOCs), nitrogen oxides (NOx), carbon monoxide (CO), carbon dioxide (CO2), benzene, and particulate matter (PM). How do these substances affect the health of the population? Hydrocarbons are toxic and have been related to cancer, NOx is related to acid rain, CO reduces the flow of oxygen, and benzene has been related to anemia, just to name a few examples. Particulate matter consists of very small solid particles and is able to penetrate deep inside the lungs to cause all sorts of issues, with the elderly, young, and people with health issues being most at risk.

Of the sources of vehicle exhaust, diesel vehicles emit the most particles. Though gasoline vehicles put out less per vehicle, they emit an overall volume higher than diesel vehicles. Short term exposure to diesel causes irritation in the eyes, throat, and other sensitive areas. Longer term exposure to diesel exhaust has been related to chronic respiratory problems. Of all the health effects, however, the worst known to be related to diesel exhaust is lung cancer, as it is a known carcinogen. Along with this, it has been known to aggravate existing conditions such as asthma. Over time, air quality has improved due to the U.S. Environmental Protection Agency's (EPA) regulation of emissions, which led to them being reduced at the tail pipe. Programs such as the National Clean Diesel Campaign are dedicated to reducing harmful diesel emissions and encouraging the development of cleaner technologies.

The EPA has begun to finalize rules that will reduce air pollution at a predicted 330,000 tons by 2030. Similar initiatives have been successful in the past. For instance, lead was formerly a huge polluter in gasoline, but it has been phased out since 1970 and is now almost totally gone. Of all the applicable laws and regulations, the 1970 Clean Air Act is the most comprehensive.

Economic Benefits and Air Quality Trends

The economic benefits of air regulation are numerous. The Clean Air Act alone had an estimated $22.2 trillion dollars in benefits from 1970 to 1990, while the cost was estimated to be $523 billion. The Clean Air Act Amendments further added almost $700 billion in benefits while costing $180 billion in compliance, from 1990-2010. Government agencies tend to estimate the maximum possible cost of its regulations, and correspondingly the EPA overestimates the cost of compliance over time. Technology improves and gets more efficient, and companies find cheaper ways to comply with the laws. Better air quality benefits the economy also by improving public health and agricultural quality, thus increasing work productivity and decreasing the amount of sick days taken, as well as work related illnesses. Below, you can see more effects of regulation on air quality over the years.

Economic Benefits of the Clean Air Act

Monetized Benefits and Costs of the Clean Air Act			
Study	**Benefits**	**Costs**	**Benefit-Cost Ratio**
CAA 1970 through 1990 *EPA retrospective study (1990 dollars)*	$22.2 trillion*	$523 billion	42:1
CAAA 1990 through 2010 *EPA prospective study (1990 dollars)*	$690 billion*	$180 billion	4:1
Stratospheric Ozone Protection *EPA prospective study (1990 dollars)*	$530 billion*	$27 billion	20:1

* Central estimate.

Exhibit N-1: Economic Benefits of the Clean Air Act[1]

[1] Small Business Majority. http://www.smallbusinessmajority.org/pdf/Benefits_of_CAA_100410.pdf

Percent Change in Air Quality

	1980 vs 2010	1990 vs 2010	2000 vs 2010
Carbon Monoxide (CO)	-82	-73	-54
Ozone (O3) (8-hr)	-28	-17	-11
Lead (Pb)	-90	-83	-62
Nitrogen Dioxide (NO2) (annual)	-52	-45	-38
PM10 (24-hr)	---	-38	-29
PM2.5 (annual)	---	---	-27
PM2.5 (24-hr)	---	---	-29
Sulfur Dioxide (SO2) (24-hr)	-76	-68	-48

Exhibit N-2: Percent Change in Air Quality[2]

Notes:

1. Trend data not available
2. Negative numbers indicate improvements in air quality

Percent Change in Emissions

	1980 vs 2010	1990 vs 2010	2000 vs 2010
Carbon Monoxide (CO)	-71	-60	-44
Lead (Pb)	-97	-60	-33
Nitrogen Oxides (NOx)	-52	-48	-41
Volatile Organic Compounds (VOC)	-63	-52	-35
Direct PM_{10}	-83	-67	-50
Direct $PM_{2.5}$	---	-55	-55
Sulfur Dioxide (SO_2)	-69	-65	-50

Exhibit N-3: Percent Change in Emissions[3]

Notes:

1. Trend data not available
2. Direct PM_{10} emissions for 1980 are based on data since 1985
3. Negative numbers indicate reductions in emissions

[2] EPA Air Quality Trends. http://www.epa.gov/airtrends/aqtrends.html
[3] Ibid.

National Emissions Estimates (fires and dust excluded) for Common Pollutants and their Precursors

	Millions of Tons Per Year						
	1980	1985	1990	1995	2000	2005	2010
Carbon Monoxide (CO)	178	170	144	120	102	81	57
Lead	0.074	0.023	0.005	0.004	0.003	0.002	0.002
Nitrogen Oxides (NOx)	27	26	25	25	22	19	13
Volatile Organic Compounds (VOC)	30	27	23	22	17	18	11
Particulate Matter (PM)							
PM10	6	4	3	3	2	2	1
PM2.5	NA	NA	2	2	2	1	0.9
Sulfur Dioxide (SO2)	26	23	23	19	16	15	8
Totals	267	250	220	191	161	136	90

Exhibit N-4: National Emissions Estimates for Common Pollutants and Precursors[4]

Notes:

1. In 1985 and 1996 EPA refined its methods for estimating emissions. Between 1970 and 1975, EPA revised its methods for estimating PM emissions.
2. The estimates for 2005 and beyond are from the final version 2 of the 2005 NEI.
3. For CO, NO_x, SO_2 and VOC emissions, fires are excluded because they are highly variable; for direct PM emissions both fires and dust are excluded.
4. PM estimates do not include condensable PM.
5. EPA has not estimated $PM_{2.5}$ emissions prior to 1990.
6. The 1999 estimate for lead is used for 2000, and the 2002 estimate for lead is used for 2005 and 2010.
7. $PM_{2.5}$ emissions are not added when calculating the total because they are included in the PM_{10} estimate.

Missouri Air Quality Data

Let's take a look at Missouri's air quality emissions data over a 12-year period.

[4] EPA Air Quality Trends. http://www.epa.gov/airtrends/aqtrends.html

Missouri Emission Trends (VOC)

	Annual Emissions (Tons)											
Source Category	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Electric Utility Coal Fuel Combustion	1,350	1,416	1,425	1,410	1,685	1,888	748	753	745	703	719	762
Electric Utility Non-Coal Fuel Combustion	132	156	161	134	138	144	105	101	104	94	76	78
Industrial Fuel Combustion	883	896	906	849	842	836	831	832	828	824	822	821
Other Fuel Combustion	94,359	30,121	30,136	26,055	23,928	21,801	19,675	19,180	18,684	18,189	17,694	17,199
Industrial Processes	185,622	168,603	174,876	167,954	164,355	160,755	157,156	155,861	154,567	153,272	151,978	150,683
Highway Vehicles	138,187	130,923	122,274	124,100	116,349	108,598	101,668	96,186	90,703	85,221	79,738	74,256
Off-highway Vehicles	55,985	55,490	54,948	66,716	65,212	63,707	62,202	59,761	57,319	54,877	52,436	49,994
Miscellaneous	5,823	3,700	1,470	3,253	21,239	39,225	3,887	58,745	70,322	62,247	75,856	75,856
Total	482,341	391,305	388,198	390,471	393,748	396,954	346,272	391,418	393,273	375,428	379,320	389,850

	Annual Emissions (Percent of Total)											
Source Category	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Electric Utility Coal Fuel Combustion	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Utility Non-Coal Fuel Combustion	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Industrial Fuel Combustion	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Other Fuel Combustion	20%	8%	8%	7%	6%	5%	6%	5%	5%	5%	5%	5%
Industrial Processes	38%	43%	45%	43%	42%	40%	45%	40%	39%	41%	40%	41%
Highway Vehicles	29%	33%	32%	32%	30%	27%	29%	25%	23%	23%	21%	20%
Off-highway Vehicles	12%	14%	14%	17%	17%	16%	18%	15%	15%	15%	14%	14%
Miscellaneous	1%	1%	0%	1%	5%	10%	1%	15%	18%	17%	20%	21%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Exhibit N-5: Missouri Emission Trends, volatile organic compounds (VOCs)[5]

Missouri Emission Trends (NOx)

	Annual Emissions (Tons)											
Source Category	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Electric Utility Coal Fuel Combustion	185,571	161,898	147,673	143,406	168,087	166,982	123,877	115,539	107,896	88,091	53,695	57,654
Electric Utility Non-Coal Fuel Combustion	3,742	3,820	3,838	4,735	5,221	5,477	4,069	3,963	4,486	3,989	2,653	2,717
Industrial Fuel Combustion	31,962	31,844	33,131	23,021	23,150	23,278	23,406	23,369	23,329	23,289	23,250	23,211
Other Fuel Combustion	14,661	14,743	14,947	14,195	14,184	14,173	14,162	14,125	14,088	14,051	14,014	13,977
Industrial Processes	22,639	21,347	22,680	29,964	29,826	29,689	29,552	29,495	29,437	29,380	29,323	29,266
Highway Vehicles	215,990	212,108	195,559	200,378	186,912	173,446	240,506	227,732	214,958	202,184	189,410	176,636
Off-highway Vehicles	121,024	120,954	121,164	132,580	130,150	127,720	125,291	121,434	117,578	113,721	109,865	106,009
Miscellaneous	1,495	1,637	620	1,952	3,814	5,675	2,093	6,265	6,874	6,043	7,575	7,575
Total	597,084	568,353	539,613	550,230	581,344	546,441	582,958	541,922	518,647	480,749	429,786	417,045

	Annual Emissions (Percent of Total)											
Source Category	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Electric Utility Coal Fuel Combustion	31%	28%	27%	26%	30%	31%	22%	21%	21%	18%	12%	14%
Electric Utility Non-Coal Fuel Combustion	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Industrial Fuel Combustion	5%	6%	6%	4%	4%	4%	4%	4%	4%	5%	5%	6%
Other Fuel Combustion	2%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Industrial Processes	4%	4%	4%	5%	5%	5%	5%	5%	6%	6%	7%	7%
Highway Vehicles	36%	37%	36%	36%	33%	32%	43%	42%	41%	42%	44%	42%
Off-highway Vehicles	20%	21%	22%	24%	23%	23%	22%	22%	23%	24%	26%	25%
Miscellaneous	0%	0%	0%	0%	1%	1%	0%	1%	1%	1%	2%	2%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Exhibit N-6: Missouri Emission Trends, NOx[6]

[5] Midwest Ozone Group.
http://www.midwestozonegroup.com/files/AQTrendsSummary_Missouri_.pdf

Missouri Emission Trends (SO_2)

	Annual Emissions (Tons)											
Source Category	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Electric Utility Coal Fuel Combustion	277,492	250,228	255,177	263,849	315,298	357,219	283,458	271,108	266,564	265,418	245,268	239,631
Electric Utility Non-Coal Fuel Combustion	6,552	5,188	6,012	2,835	3,694	4,850	3,283	2,945	3,059	2,732	3,080	2,967
Industrial Fuel Combustion	31,072	30,884	33,011	42,767	42,859	42,952	43,045	43,044	43,043	43,042	43,041	43,041
Other Fuel Combustion	12,220	12,421	12,638	11,720	11,856	11,991	12,127	12,124	12,120	12,116	12,113	12,109
Industrial Processes	79,373	83,002	89,302	85,295	78,400	71,506	64,611	61,087	57,562	54,037	50,513	46,988
Highway Vehicles	8,154	6,444	6,497	6,148	5,515	4,883	5,339	4,664	3,989	3,314	2,639	1,964
Off-highway Vehicles	12,515	12,704	12,759	13,753	12,726	11,700	10,674	9,366	8,059	6,751	5,443	4,136
Miscellaneous	74	417	138	551	1,386	2,221	591	2,639	2,989	2,622	3,280	3,280
Total	427,461	401,287	416,534	426,917	471,736	507,323	423,128	408,977	397,384	390,033	365,377	364,116

	Annual Emissions (Percent of Total)											
Source Category	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Electric Utility Coal Fuel Combustion	65%	62%	61%	62%	67%	70%	67%	67%	67%	68%	67%	66%
Electric Utility Non-Coal Fuel Combustion	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Industrial Fuel Combustion	7%	8%	8%	10%	9%	8%	10%	11%	11%	11%	12%	12%
Other Fuel Combustion	3%	3%	3%	3%	3%	2%	3%	3%	3%	3%	3%	3%
Industrial Processes	19%	21%	21%	20%	17%	14%	15%	15%	14%	14%	14%	13%
Highway Vehicles	2%	2%	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Off-highway Vehicles	3%	3%	3%	3%	3%	2%	3%	2%	2%	2%	1%	1%
Miscellaneous	0%	0%	0%	0%	0%	0%	0%	1%	1%	1%	1%	1%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Exhibit N-7: Missouri Emission Trends, SO_2[7]

Missouri Emission Trends ($PM_{2.5}$)

	Annual Emissions (Tons)											
Source Category	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Electric Utility Coal Fuel Combustion	8,653	7,115	7,435	5,851	7,122	8,043	5,533	5,501	5,411	5,128	4,802	4,857
Electric Utility Non-Coal Fuel Combustion	561	488	551	134	130	138	54	56	60	56	52	49
Industrial Fuel Combustion	774	789	829	1,892	1,913	1,934	1,955	1,955	1,954	1,954	1,953	1,953
Other Fuel Combustion	10,849	11,559	11,588	12,197	12,201	12,204	12,206	11,935	11,664	11,393	11,122	10,851
Industrial Processes	22,251	19,618	21,673	18,896	18,660	18,425	17,927	17,859	17,791	17,724	17,656	17,588
Highway Vehicles	4,852	4,390	4,045	3,819	3,600	3,382	7,021	6,602	6,184	5,766	5,348	4,929
Off-highway Vehicles	7,959	7,803	7,654	8,180	7,935	7,691	7,446	7,181	6,916	6,651	6,386	6,121
Miscellaneous	158,304	156,077	153,973	99,155	106,699	114,243	98,937	119,612	123,802	120,609	126,077	126,077
Total	214,202	207,839	207,748	150,124	158,261	166,060	151,080	170,703	173,782	168,280	173,397	172,428

	Annual Emissions (Percent of Total)											
Source Category	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Electric Utility Coal Fuel Combustion	4%	3%	4%	4%	5%	5%	4%	3%	3%	3%	3%	3%
Electric Utility Non-Coal Fuel Combustion	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Industrial Fuel Combustion	0%	0%	0%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Other Fuel Combustion	5%	6%	6%	8%	8%	7%	8%	7%	7%	7%	6%	6%
Industrial Processes	10%	9%	10%	13%	12%	11%	12%	10%	10%	10%	10%	10%
Highway Vehicles	2%	2%	2%	3%	2%	2%	5%	4%	4%	3%	3%	3%
Off-highway Vehicles	4%	4%	4%	5%	5%	5%	5%	4%	4%	4%	4%	4%
Miscellaneous	74%	75%	74%	66%	67%	69%	65%	70%	71%	71%	73%	73%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Exhibit N-8: Missouri Emission Trends, $PM_{2.5}$[8]

[6] Midwest Ozone Group.
http://www.midwestozonegroup.com/files/AQTrendsSummary_Missouri_.pdf
[7] Ibid.

Vehicle Emissions and Electricity Emissions Compared

Using the following data, we can begin to compare the emissions from average gasoline cars and trucks to zero tailpipe emission passenger car powered by electricity.

Average Annual Emissions from a Passenger Car

Component	Emission Rate and Fuel Consumption per mile (mi)[1]	Calculation	Total Annual Pollution Emitted and Fuel Consumed
Hydrocarbons	2.80 grams (g)	(2.80 g/mi) x (12,500 mi) x (1 lb/454 g)	**77.1 pounds of hydrocarbons**
Carbon Monoxide	20.9 grams	(20.9 g/mi) x (12,500 mi) x (1 lb/454g)	**575 pounds of carbon monoxide**
Oxides of Nitrogen	1.39 grams	(1.39 g/mi) x (12,500 mi) x (1 lb/454g)	**38.2 pounds of oxides of nitrogen**
Carbon Dioxide[2]	0.916 pound (lb)	(0.916 lb/mi) x (12,500)	**11,450 pounds of carbon dioxide**
Gasoline	0.0465 gallon	(0.0465 gallon/mi) x (12,500 mi)	**581 gallons of gasoline**

Exhibit N-9: Average Annual Emissions from a Passenger Car

Average Annual Emission from a Light Truck

Component	Emission Rate and Fuel Consumption per mile (mi)[1]	Calculation	Total Annual Pollution Emitted and Fuel Consumed[3]
Hydrocarbons	3.51 grams (g)	(3.51 g/mi) x (14,000 mi) x (1 lb/454 g)	**108 pounds of hydrocarbons**
Carbon Monoxide	27.7 grams	(27.7 g/mi) x (14,000 mi) x (1 lb/454g)	**854 pounds of carbon monoxide**
Oxides of Nitrogen	1.81 grams	(1.81 g/mi) x (14,000 mi) x (1 lb/454g)	**55.8 pounds of oxides of nitrogen**
Carbon Dioxide[2]	1.15 pounds (lb)	(1.15 lb/mi) x (14,000 mi)	**16,035 pounds of carbon dioxide**
Gasoline	0.0581 gallon	(.0.581 gallon/mi) x (14,000 mi)	**813 gallons of gasoline**

Exhibit N-10: Average Annual Emission from a Light Truck

Comparing the Region's Electricity to the National Average

EMISSIONS RATE COMPARISON

[8] Midwest Ozone Group.
http://www.midwestozonegroup.com/files/AQTrendsSummary_Missouri_.pdf

2

What Are the Emissions in My Area?

This chart compares the average emissions rates (lbs/MWh) in your geographical region to the national average emissions rates (lbs/MWh) for nitgrogen oxide, sulfur dioxide, and carbon dioxide.

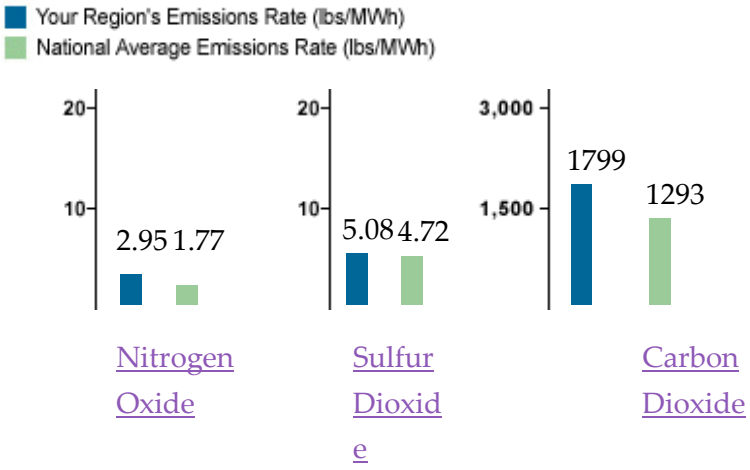

Exhibit N-11: Emissions Rate Comparison – Kansas City to National Average[9]

You can see the average air quality emissions for electricity generation in our planning area are higher than the U.S. average, but as seen in Section 9.3.1 of the Electrify Heartland Plan, EVs nevertheless have a better emission profile than the most efficient hybrids. In addition, the electricity generation mix in our planning area continues to change, as more wind energy is produced.

Links and Further Reading

http://www.epa.gov/otaq/transport.htm
http://esciencenews.com/articles/2012/03/20/study.shows.air.emissions.near.fracking.sites.may.impact.health
http://revolutionbiofuel.net/need_to_kNOW/resources/HEALTH_ASSESSMENT_DIESEL.PDF
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