Base M Strategy Modeling: Emissions (Revised)

The purpose of this document is to summarize the emission estimates prepared for LADCO's latest (Base M) 2005 base year and 2008, 2009, 2012, and 2018 future year modeling. Base year emissions by state and source sector for Base K (2002) and Base M (2005) are compared in Figure 1. A more detailed state and source sector summary is provided in Attachment 1.

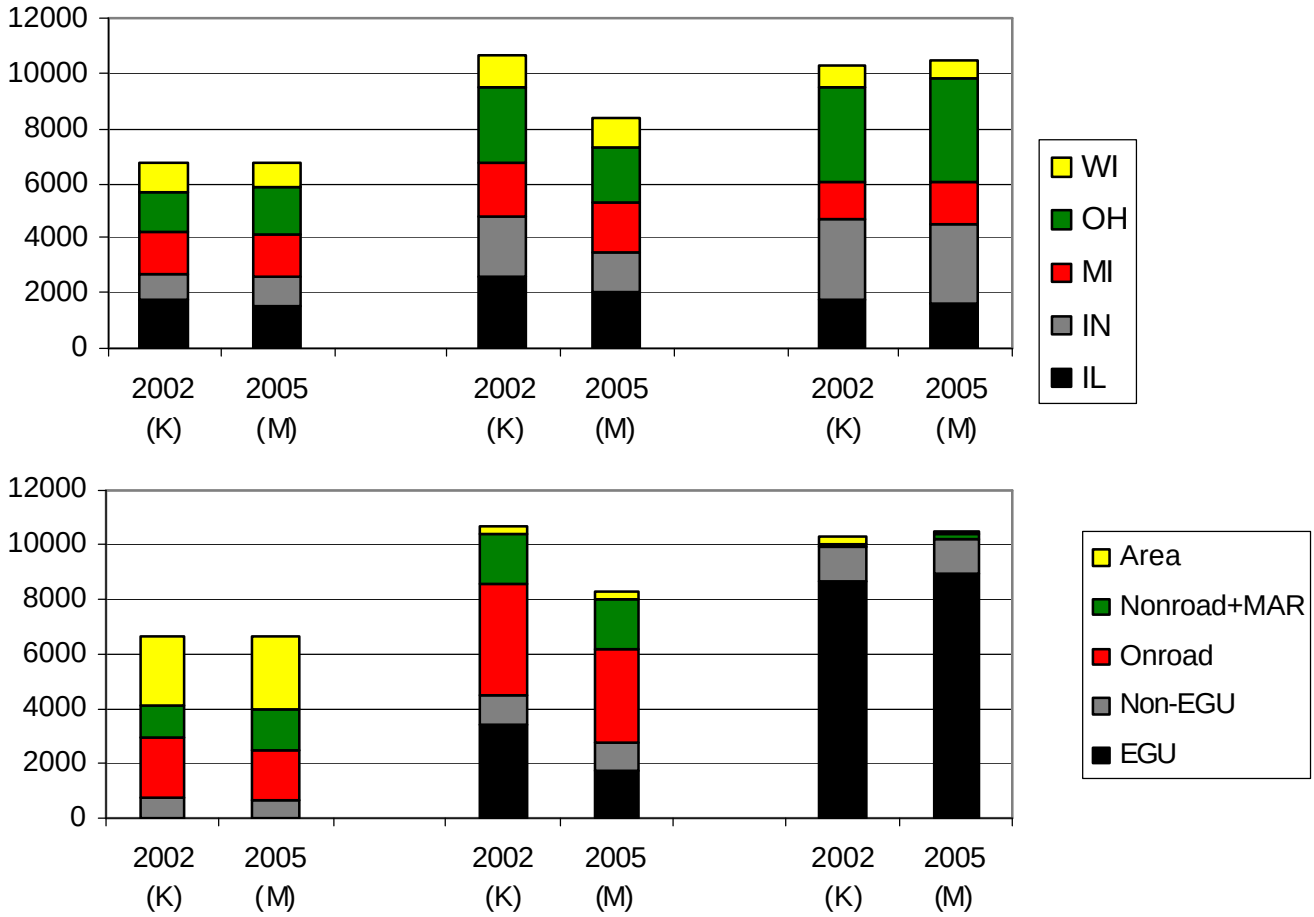

Figure 1. Base K and Base M Emissions for 5-State LADCO Region (TPD, July weekday)

Base Year Emissions

In mid-2006, LADCO completed modeling analyses for a 2002 base year and several future year control strategies (see "Base K/Round 4 Modeling: Emissions", May 16, 2006 and "Base K/Round 4 Modeling: Summary", August 31, 2006). Following those analyses, a decision was made to conduct additional modeling using a more current base year (2005). The plans for this modeling are reviewed in "Protocol Document: Technical Analyses to Support SIP Development for Ozone, PM2.5, and Regional Haze (Revised)", October 13, 2006.

For on-road, nonroad, ammonia, and biogenic sources, the 2005 emissions were estimated by models. For the other sectors (point sources, area sources, and MAR [commercial marine, aircraft, and railroads), the 2005 emissions were prepared using data supplied by the LADCO States and, for non-LADCO States, data developed by other Regional Planning Organizations. In particular, for the non-LADCO States, a contractor (Alpine, with assistance from MACTEC)

obtained the latest base (2002) and future year emission files (2009, 2018) from the other Regional Planning Organizations. Specifically, the following versions of these emissions files were used here:

MANE-VU: Version 3.1	WRAP: Pre2002d
CENRAP: Base F	VISTAS: Base F

2005 emissions were then estimated by linearly interpolating between the 2002 and 2009 emissions.[1]

Further discussion of the development of the 2005 base year emissions is provided below:

On-road: CONCEPT was run by a contractor (Environ) using transportation data (e.g., VMT and vehicle speeds) supplied by the state and local planning agencies in the LADCO States and Minnesota for 24 networks. These data were first processed with T3 (Travel Demand Modeling [TDM] Transformation Tool) to provide input files for CONCEPT to calculate link-specific, hourly emission estimates. CONCEPT was run with meteorological data for a July and January weekday, Saturday, and Sunday (July 15 – 17 and January 16 – 18). A spatial plots of emissions for July 15 are provided in Figure 2.

For the non-LADCO States, CONCEPT was run by Environ using RPO-based HPMS county-level data (2002 and 2009) and MOBILE6 inputs (2002) compiled by another contractor for VISTAS. HPMS VMT for 2005 were generated by linearly interpolating between the 2002 and 2009 data. The 2002 MOBILE6 inputs were used for the 2005 modeling, with a few adjustments (e.g., fuel sulfur content was set to 30 ppm, as required by the Tier 2/low sulfur regulations).

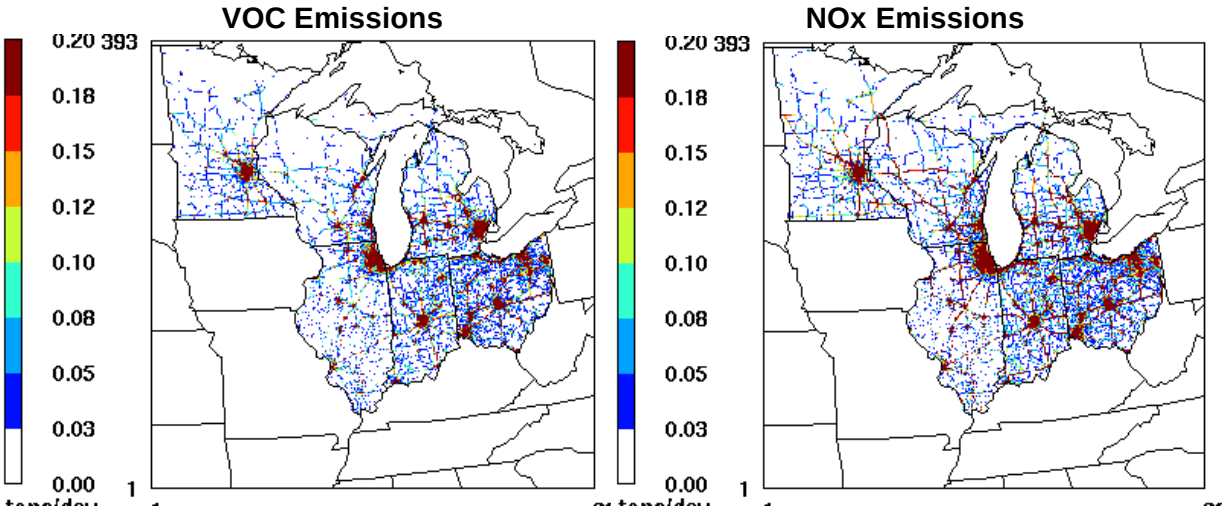

Figure 2. July 15, 2005 motor vehicle emissions for VOC (left) and NOx (right)

[1] Emissions Inventory Assistance: 2005 Base Year Biogenic and Other (non-LADCO) State Emissions", March 12, 2007

Off-road: NMIM2005 was run by Grant Hetherington (Wisconsin DNR):

> Phase 1: Run NMIM2005 for the LADCO states plus Minnesota plus Iowa and Missouri agriculture with Pechan's modifications only[2]. The Pechan modifications that were not incorporated in the default NMIM2005 inputs and need to be incorporated are BSFC emission factor data, Michigan population data, Missouri seasonality data and revised countynrfile, countyyear, countyyearmonth, datasource and gasoline NCD tables that assimilate fuel changes and file references.
>
> Phase 2: Run NMIM2005 for the LADCO states plus Minnesota plus Iowa and Missouri agriculture with Pechan's modifications, revised 2005 LADCO gasoline parameters and a modified SCC table containing PM2.5 corrections for diesel equipment.
>
> *Phase 3: Run NMIM2005 for the LADCO states plus Minnesota plus Iowa and Missouri agriculture with Pechan's modifications, revised 2005 LADCO gasoline parameters, a modified SCC table containing PM2.5 corrections for diesel equipment and AIR's NONROAD.EXE. (Note: it is not clear if Plase 3 was used.)*

Additional off-road sectors (i.e., commercial marine, aircraft, and railroads [MAR]) were handled separately. Aircraft emissions were supplied by the States. Updated information for railroads and commercial marine was prepared by a contractor (Environ).[3] Table 1 compares the new 2005 emissions with the previous 2002 emission estimates. The new 2005 emissions reflect substantially lower commercial marine emissions and lower locomotive NOx emissions.

Table 1. Locomotive and Commercial Marine Emissions for 2002 and 2005 Base Year

	Railroads (TPY)			**Commercial Marine (TPY)**	
	2002	**2005**		**2002**	**2005**
VOC	7,890	7,625		1,562	828
CO	20,121	20,017		8,823	6,727
NOx	182,226	145,132		64,441	42,336
PM	5,049	4,845		3,113	1,413
SO2	12,274	12,173		25,929	8,637
NH3	86	85		----	----

For the non-LADCO States, Alpine developed appropriate emissions files based on data from the other Regional Planning Organizations, as noted above.

[2] "LADCO Nonroad Emissions Inventory Project – Development of Local Data for Construction and Agricultural Equipment", Final Report, September 10, 2004

[3] "LADCO 2005 Locomotive Emissions", Environ, February 2007, and "LADCO 2005 Commercial Marine Emissions", Environ, March 2, 2007

Area: EMS was run by LADCO using 2005 data supplied by the LADCO States and, for the non-LADCO States, using emission files supplied by Alpine based on data from the other Regional Planning Organizations to produce weekday, Saturday, and Sunday emissions for each month. Special attention was given to two source categories: industrial adhesive and sealant solvent emissions and outdoor wood boilers.

Industrial Adhesives and Sealants: The NEI shows this to be a large VOC emissions category in the LADCO States (i.e.., 50,000 TPY) EPA subsequently determined that "(f)or the Region V states, we no longer believe that there are any activities in the Industrial Adhesives and Sealants category (SCC 2440020000) that have not been inventoried either in the point source Industrial Adhesives and Sealants category or under the Consumer and Commercial Adhesives and Sealants nonpoint category (SCC 2460600000 - all adhesives and sealants)." Consequently, this category was omitted from the 2005 regional emissions inventory.

Outdoor Wood Boilers: Over the past several years, the installation and operation of outdoor wood boilers for residential use has increased dramatically in many northern states. Relying on an emission estimation methodology prepared by Bart Sponseller (Wisconsin DNR), emissions were calculated by the other states for this category.

For the non-LADCO States, a contractor (Alpine, with assistance from MACTEC) estimated 2005 emissions by linearly interpolating between the 2002 and 2009 emissions developed by the other RPOs.

Point-EGU: EMS was run by LADCO using 2005 data supplied by the LADCO States and, for the non-LADCO States, using emission files supplied by Alpine based on data from the other Regional Planning Organizations to produce weekday, Saturday, and Sunday emissions for each month.

The annual and summer season EGU emissions were temporalized for modeling purposes using profiles prepared by Scott Edick (Michigan DEQ) based on CEM data for the period 2002 – 2005.

Point-Non-EGU: EMS was run by LADCO using 2005 data supplied by the LADCO States (and, for the non-LADCO States, using emission files supplied by Alpine based on data from the other Regional Planning Organizations) to produce weekday, Saturday, and Sunday emissions for each month. EGUs were removed from the point source file.

Other improvements to the base year inventory included:

Canadian Emissions: Previous modeling inventories for Canadian sources were flawed due to problems with emissions (e.g., LADCO inventories omitted ammonia emissions) or stack parameters (e.g., VISTAS inventories failed to include proper stack parameters, resulting in emissions getting dumped in the surface layer of the model). For Base M, Scott Edick (Michigan DEQ) processed the 2005 Canadian National Pollutant Release Inventory (NPRI). Specifically, a subset of the NPRI data which are relevant to the air quality modeling were reformatted. A number of emission reports are available on the LADCO website (http://www.ladco.org/tech/emis/basem/canada/index.htm). Circle plot of point source emissions are presented in Figure 3.

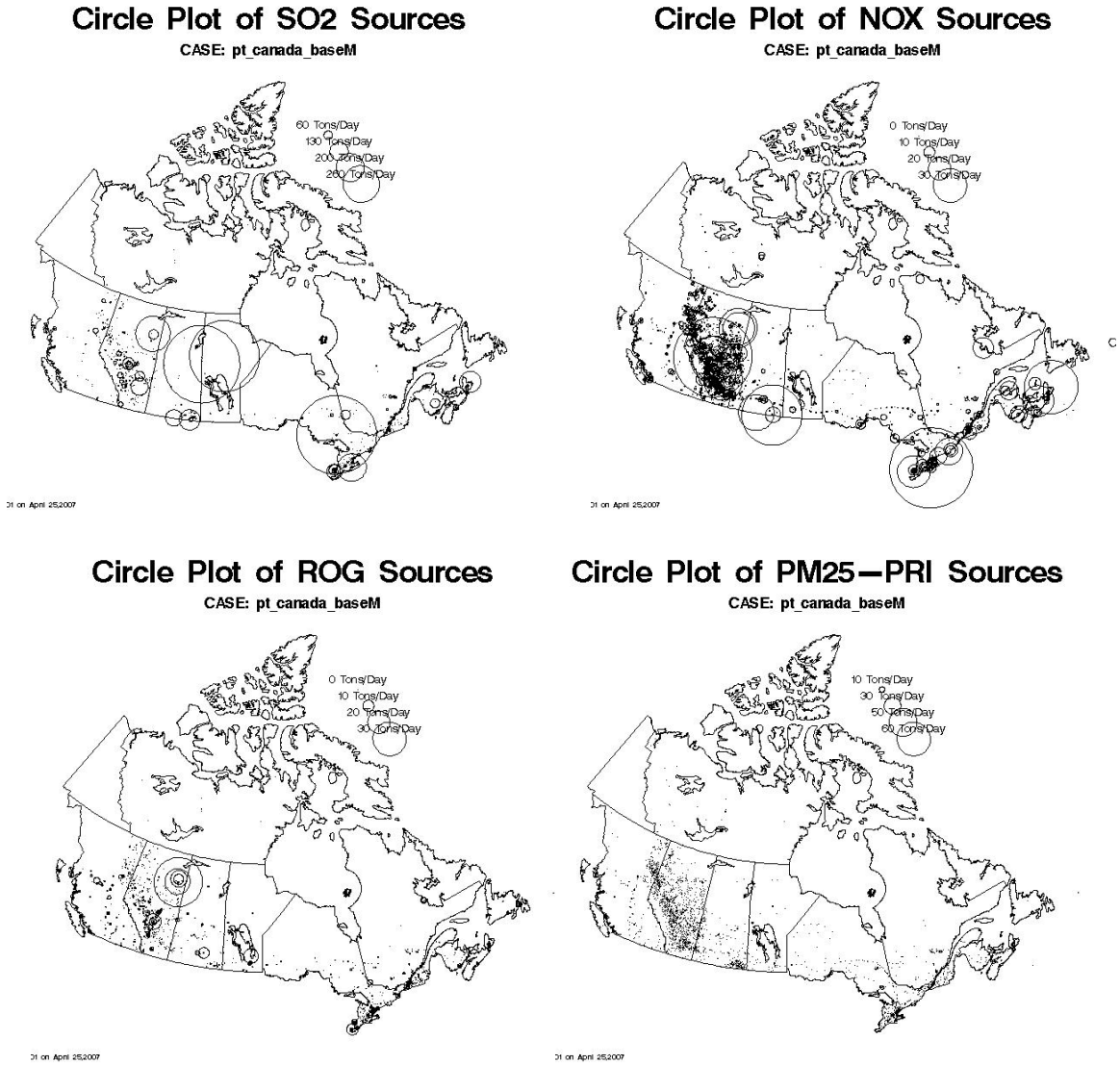

Figure 3. Base year emission plots for Canada

Biogenic Emissions: A contractor (Alpine) provided an updated version of the CONCEPT/MEGAN[4] (Model of Emissions of Gases and Aerosols from Nature) biogenics model, which was used to produce base year biogenic emission estimates. Model improvements included: (a) reduced model run times, (b) improved ability to run successive days, and (c) enhanced meteorological input processing[5].

Compared to the previous (EMS/BIOME) emissions, there is more regional isoprene using MEGAN compared to the BIOME estimates used for Base K (see Figure 4). Also, with the secondary organic aerosol updates to the CAMx air quality model, Base M includes emissions for monoterpenes and sesquiterpenes, which are pre-cursors of secondary PM2.5 organic carbon mass

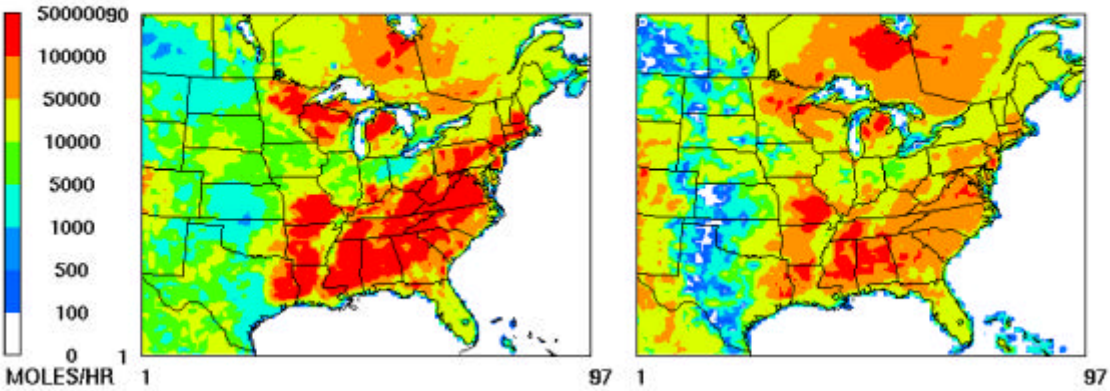

Figure 4. Isoprene emissions for Base M (left) v. Base K (right)

Ammonia Emissions: The CMU-based 2002 (Base K) ammonia emissions were projected to 2005 using growth factors from the Round 4 emissions modeling. These emissions were then adjusted by applying temporal factors by month based on the process-based ammonia emissions model. A plot of the average daily emissions by state and month is provided in Figure 5.

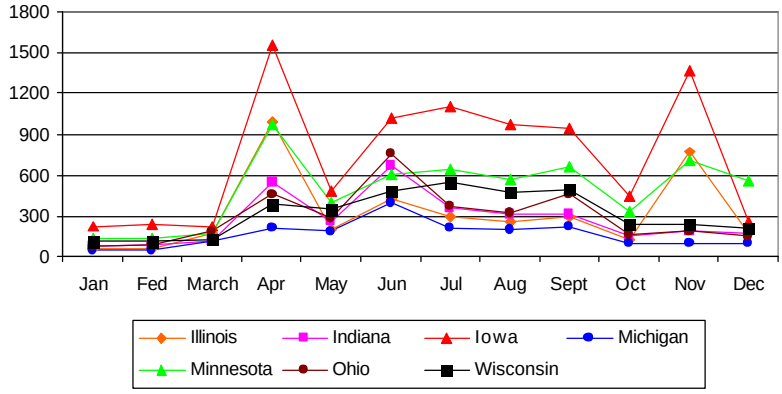

Figure 5. Average daily ammonia emissions for Midwest States by month (2005)

[4] See http://bai.acd.ucar.edu/Megan/

[5] Subsequent to deliver of the updated CONCEPT/MEGAN model, it was found that more recent data sets and model formulations were available. Consequently, additional model improvements were undertaken. Compared to the initial updated model, the revised model reflects lower emissions for several organic aerosol species and NOx.

Future Year Emissions

Emission inventories were developed for two future years: 2009 and 2018[6]. For on-road, nonroad, and EGU sources, the future year emissions were estimated by models (i.e., CONCEPT, NMIM2005, and IPM, respectively) and then processed by LADCO with EMS.

For other sectors (area, MAR, and non-EGU point sources) the future year emissions for the LADCO States were derived by applying growth and control factors to the base year inventory. These factors were developed by a contractor (E.H. Pechan).[7] For the non-LADCO States, future year emission files were supplied by Alpine based on data from the other Regional Planning Organizations.

Growth factors were based initially on EGAS (version 5.0), and were subsequently modified (for select, priority categories) by examining emissions activity data. The categories which show the largest resulting growth factors include:

Category	2005-2009	2005-2018
Industrial residual oil	-49.4%	-49.6%
Comm/consumer solvents	-10.5%	-15.6%
Architectural coatings	- 9.9%	- 9.3%
Auto refinishing	-12.9%	-38.9%
Ag – dairy cattle (NH3)	-10.2%	-39.0%
Outdoor wood boilers	+78.0%	+84.5%

[6] A 2008 proxy inventory was prepared to support a preliminary 2008 modeling analysis to assess attainment for the basic nonattainment areas (i.e, for areas with a 2009 attainment date, the appropriate panning year is 2008). This inventory reflects the following assumptions:

On-road: scale 2005 base year emissions using the Base K 2002 – 2009 trend (except for the Cincinnati-Dayton area, where 2008 emissions were generated using CONCEPT and 2008 data supplied by the local planning agency)

Off-road and area: scale 2005 base year emissions using the Base K 2002-2009 trend

Point – EGU: use 2005 base year emissions, with slight adjustment (-10%)

Point – Non-EGU: use 2005 base year emissions (note: Base K 2002-2009 trend suggests little change)

Biogenics: use new 2005 base year emissions

A 2012 proxy inventory was prepared to support a preliminary 2012 modeling analysis to assess the effect of further emission reductions from existing controls. This inventory was derived by interpolating between 2009 and 2018 emissions for all sectors, except point sources (for which, the 2009 emissions were used).

[7] "Development of 2005 Base Year Growth and Control Factors for Lake Michigan Air Directors Consortium", Final Report, September 2007

Control factors were prepared for the following area, MAR, and non-EGU point source existing ("on the books") controls[8]:

Area/MAR

- VOC solvent categories (consumer solvents, AIM, and aerosol coatings)
- Portable fuel containers
- Woodstoves
- Stage II
- Locomotives and marine vessels (proposed rule)

Non-EGU Point

- NOx SIP call (IL RICE only)
- MACT[9]
- Consent decrees (refineries, ethanol plants, and ALCOA)[10]
- Other (Illinois and Ohio NOx RACT[11], and BART in IN and WI)

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[8] "On the books" control measures includes the following:

On-Highway Mobile Sources

- Tier II/Low sulfur fuel
- Inspection/Maintenance programs (nonattainment areas)
- Reformulated gasoline (nonattainment areas)

Off-Highway Mobile Sources

- Federal control programs incorporated into NONROAD model (e.g., nonroad diesel rule), plus the evaporative Large Spark Ignition and Recreational Vehicle standards
- Heavy-duty diesel (2007) engine standard/Low sulfur fuel
- Federal railroad/locomotive standards
- Federal commercial marine vessel engine standards

Area Sources

- Consumer solvents
- AIM coatings
- Aerosol coatings
- Portable fuel containers

Power Plants

- Title IV (Phases I and II)
- NOx SIP Call
- Clean Air Interstate Rule
- Clean Air Mercury Rule

Other Point Sources

- VOC 2-, 4-, 7-, and 10-year MACT standards
- Combustion turbine MACT
- Industrial boiler/process heater/RICE MACT

[9] E.H. Pechan's original control file included EPA-default control factor information. Alternative control factors were developed by Wisconsin for a few MACT categories, and were also applied to the other four LADCO States.

[10] E.H. Pechan's original control file included control factors for three sources in Wayne County, MI. These control factors were not applied in the regional-scale modeling to avoid double-counting with the State's local-scale analysis for PM2.5

[11] WI believes that NOx RACT for their sources is already included in the 2005 basecase and EGU "will do" scenario, and IN provided NOx RACT information for inclusion as a no-EGU "may do" scenario.

Further discussion of the development of the future year emissions is provided below:

On-road: Similar to the base year modeling, CONCEPT was run using transportation data (e.g., VMT and vehicle speeds) supplied by the state and local planning agencies for 2009 and 2018. CONCEPT was only run with meteorological data for the July weekday. The emissions for Saturday and Sunday were derived by using scaling factors based on the 2005 emissions. The state-level emissions for the five LADCO States plus Minnesota are summarized in Table 2[12].

For the non-LADCO States, CONCEPT was run by Environ using HPMS county-level data and MOBILE6 inputs compiled by another contractor for VISTAS. Note, the emissions modeling for IA, MO, and OK was redone for 2009 to reflect the state-developed registration distribution data. (The initial modeling for 2009 used national default values for registration distribution assumed by VISTAS' contractor. CENRAP's contractor developed emissions inventories for 2002 and 2018 using the state-developed data. For consistency, Environ's remodeling for these three states for 2009 also used the state-developed data.)

Table 2. Summary of On-road Emissions (TPD – July 15, 2005)

Year	State	CO-tpd	TOG-tpd	NOx-tpd	PM2.5-tpd	SO2-tpd	NH3-tpd	Sum of VMT
2005	IL	3,684.3	341.5	748.2	12.9	9.6	35.9	344,087,819.6
	IN	3,384.9	282.0	541.1	8.9	11.1	25.7	245,537,231.9
	MI	4,210.3	351.9	722.0	12.4	13.9	35.3	340,834,025.9
	MN	2,569.1	218.7	380.5	6.3	7.6	17.7	170,024,599.7
	OH	6,113.4	679.8	933.6	16.2	18.8	36.5	360,521,068.6
	WI	2,206.0	175.1	457.5	7.8	9.2	19.7	189,123,964.3
Total		22,168.0	2,049.0	3,782.9	64.5	70.2	170.8	1,650,128,709.9
2009	IL	2,824.4	268.0	527.8	10.1	4.2	38.9	372,132,591.1
	IN	2,839.5	234.9	401.9	6.7	2.8	26.1	249,817,026.3
	MI	3,172.0	269.2	500.9	9.2	4.0	37.1	356,347,010.5
	MN	2,256.8	206.3	307.5	5.1	2.3	21.5	204,443,017.8
	OH	4,619.2	423.7	693.5	11.8	4.7	39.5	387,428,127.2
	WI	1,673.4	119.4	322.1	5.7	2.3	20.6	197,729,964.9
Total		17,385.3	1,521.5	2,753.6	48.7	20.3	183.6	1,767,897,737.8
2018	IL	2,084.7	151.5	200.7	6.3	3.7	43.1	413,887,887.3
	IN	2,217.3	138.4	173.0	4.4	2.6	30.2	288,042,232.1
	MI	2,434.3	163.5	204.1	5.9	3.6	40.5	388,128,431.8
	MN	1,799.6	123.1	137.1	3.6	2.2	24.9	237,022,213.7
	OH	3,361.5	242.5	274.1	6.8	4.0	43.1	421,694,093.4
	WI	1,255.5	68.4	138.5	3.9	2.0	22.2	218,277,167.5
Total		13,152.9	887.5	1,127.5	30.8	18.1	203.9	1,967,052,025.8

[12] For northeastern IL (CATS region), 2009 and 2018 emissions were increases by 9% and 8%, respectively, to reflect newer transportation modeling by CATS.

Off-road: Similar to the base year inventory, NMIM2005 was run by Grant Hetherington (Wisconsin DNR) to produce the future year inventories, with updated growth factors by E.H. Pechan.

Point-EGU: Future year emissions were based on EPA's IPM3.0 modeling[13]. Three CAIR scenarios were addressed:

- 5a: EPA's IPM3.0 was assumed as the future year base for EGUs.
- 5b: EPA's IPM3.0, with several "will do" adjustments identified by the States. These adjustments should reflect a legally binding commitment (e.g., signed contract, consent decree, or operating permit).
- 5c: EPA's IPM3.0, with several "may do" adjustments identified by the States. These adjustments reflect less rigorous criteria, but should still be some type of public reality (e.g., BART determination or press announcement).

Table 3 summarizes the SO2 and NOx emissions for the three scenarios. The net effect is a small change (increase) in regional SO2 and NOx emissions.

[13] The second set of new IPM runs by EPA were used. These runs were performed at the request of the RPOs and reflect the addition of run years 2012 and 2018, and the use of four load segments for 2032 to decrease model size (instead of six segments). Comparing the results in this run with EPA's initial v3.0, showed small differences Below is a quick summary of the run year differences.

EPA Base Case for IPM v.3.0
2010: 2009-2012
2015: 2013-2017
2020: 2018-2022
2025: 2023-2027
2032: 2028-2035

Base Case RPO Run for IPM v3.0 (added 2012 and 2018 run years, 2020 run year merged with the 2025 run year, and four load segments used for the 2032 run year)
2010: 2009-2011
2012: 2012-2012
2015: 2013-2017
2018: 2018-2019
2025: 2020-2028
2032: 2029-2035

Table 3. Comparison of EGU Emissions for Base (5a), Will Do (5b), and Will Do (5c) Scenarios

	2010				2018		
SO2	**5a**	**5b**	**5c**		**5a**	**5b**	**5c**
IL	958	881	881		869	433	433
IN	1033	1318	1318		1036	1194	1194
MI	667	667	667		725	725	725
OH	1326	1410	1410		983	1127	1127
WI	460	460	421		435	499	235
	4444	4736	4697		4048	3978	3714
MN	162	148	148		187	167	157
NOx	**5a**	**5b**	**5c**		**5a**	**5b**	**5c**
IL	275	247	247		224	195	195
IN	370	372	372		255	266	266
MI	242	242	242		243	243	243
OH	281	305	305		285	310	310
WI	165	164	155		176	172	145
	1333	1330	1321		1183	1186	1159
MN	116	142	142		132	157	125

ATTACHMENT 1

Emissions Summaries