Earth System Sciences, LLC

From: **Nicole Downey, Ph.D. (nicole.downey@earthsystemsciences.com)**
Doug Blewitt, CCM (dougblewitt@comcast.net)

Date: **March 5, 2014**

Subject: **Comments on Sections 2.3.8, 2.3.9 and 2.3.10 of the First Draft Integrated Science Assessment for NO_2**

In chapter 2 of the first draft integrated science assessment (ISA) for NO_2, EPA discusses several significant sources of NOx in the troposphere. Figure 2-2 (pages 2-9) summarizes the primary sources of NOx in the United States in 2008. This figure should be modified to include lightning and should include information on the relative certainty of each source term. Lightning, wildfire, and soil emissions are poorly constrained in global inventories (Jaegle et al. 2005, Schumann and Huntriesen, 2007, Hudman et al. 2010, Hudman et al. 2012, Miyazaki et al. 2013). The document states that 'uncertainties in natural NOx emissions are much larger than for anthropogenic NOx emissions', but does not provide any description of the range of uncertainties. A table summarizing the range of recent estimates and citations should be included in the document. As anthropogenic NOx emissions decrease with the implementation of existing regulations, the lightning, wildfire and soil sources will become more important in the overall inventory and will become more important drivers of human exposure to NO_2. The ISA should spend some time discussing the relative fraction of anthropogenic vs. biogenic NOx emissions, and how that fraction has shifted (and is expected to shift) in the future.

Section 2.3.8 Biogenics and Wildfires

- The discussion of biogenic and wildfire emissions of NOx should be split into two separate sections as these are two of the largest natural NOx sources globally and are fundamentally controlled by different processes.
- The first sentence of section 2.3.8 states that major biogenic sources of NOx in the U.S. include 'controlled biomass burning, vegetation and soil'. This sentence is not

correct. Biogenic sources of NOx in the U.S. include biomass burning (controlled and wildfire) and soil NOx emissions. Vegetation is not a significant direct source of NOx to the atmosphere. Biofuel burning is also a source of NOx to the atmosphere (Jaegle et al. 2005).

- **Wildfire emissions:**
    - There is significant uncertainty with respect to the speciation of fresh and aged fire emissions. Until recently, most authors relied on the emission factors compiled by Andre and Merlet (2001), which were an average of all fire plume emissions. More recently, Akagi et al. (2011) compiled data for fresh plumes, leading to major revisions to emission factors contained in global models such as the Global Fire Emission Database (GFED, van der Werf et al.).
    - Global chemical transport models exhibit significant variability in their treatment of fire NOx emissions, underscoring the uncertainty in the field.
    - Conversion of wildfire NOx to peroxyacetyl nitrate (PAN) implies possible significant downwind impacts to ambient NOx with the thermal decomposition of PAN (Jaffe and Widger, 2012). Due to the longer lifetime of PAN in the atmosphere, this NOx may not be associated with the primary fire plume, and may not be correlated with fire tracers such as aerosols.
    - A discussion regarding the range of uncertainty for estimates in wildfire emissions should be included.
- **Soil emissions:**
    - The paragraph describing soil NOx emissions contains no references and does not adequately address this significant source of NOx to the atmosphere.
    - The ISA states that soil NOx 'emissions are relatively low, comprising only about 6% of total anthropogenic NOx emissions' (pages 2-17). This statement is incorrect. Estimates for the magnitude of the soil source strength vary between 7.4 to 21 Tg N per year at the soil surface, with 4.7-13 Tg N per year entering the troposphere after scavenging by vegetation (Hudman et al. 2010, 2012). Globally, soil NOx emissions are significant and

accounted for 22% of the total NOx emissions in 2000 (Jaegle et al. 2005). The global soil NOx source is therefore of the same magnitude (and possibly larger) than the lightning source.

- Satellite based estimates of soil NOx emissions generally find that bottom-up inventories underestimate soil emissions in agricultural areas by a factor of 2-4 (References contained in Hudman et al. 2010).
- Hudman et al. (2010) find that 15-40% of the total tropospheric NO_2 column in May to July (2005 to 2008) in the Midwestern United States was due to emissions from soils. This implies that soil NOx emissions are important for ground level NO_2 levels during Spring and Summer.
- Hudman et al. (2010) estimate that ~20% of the soil source is due to chemical fertilizer application, and that the remainder is natural emissions.
- Soil NOx emissions likely dominate rural ambient NOx levels during spring and summer in agricultural areas and grasslands.
- Soil NOx emissions will become a more significant fraction of total NOx emissions as existing regulations are implemented.
- Since 2000, there has been more than a 50% decrease in NOx emissions from stationary and mobile sources (Figure 2-3, NO_2 ISA). Adjusting the Jaegle et al. (2005) estimate for NOx emissions from fuel combustion down by 50%, and holding the soil source constant, implies that the soil NOx source accounts for 21 +- 40% of total NOx emissions in the United States in 2012. Clearly, this is a significant source of NOx to the boundary layer, and warrants further discussion in the ISA.
- Parameterization of soil NOx emissions in global chemical transport models is crude, and likely does not accurately estimate the magnitude or spatial and temporal variability in emissions (Hudman et al. 2012)

Section 2.3.9 Lightning

- Lightning NOx is not included in the National Emissions Inventory (NEI), and is not included in figure 2-2, which summarizes national emissions (as noted by the ISA).

- Overall, the section discussing lightning emissions of NOx underestimates the possible uncertainty in emissions. Lightning emissions of NOx are highly uncertain, with the estimated magnitude of emissions varying from 0.6 to 25 Tg N/yr, with the most likely range between 2 and 8 Tg N/yr (Schumann and Huntrieser, 2007).
- Lightning emissions are important for deposition, as these emissions are concentrated in the upper troposphere and the dominant fate is loss via HNO_3 or NO_3^-.
- Lightning emissions of NOx may be converted to PAN at high altitudes (Hudman et al. 2007). The long range transport and decomposition of PAN may impact surface NOx concentrations.
- Parameterizations of lightning NOx emissions in global chemical transport models is crude, and likely does not accurately estimate the magnitude or vertical distribution of emissions (Schumann and Huntreiser, 2007). These difficulties will lead to uncertainty with respect to the fraction of NOx generated by lightning that is either generated in the lower troposphere, or transported to the lower troposphere, where it may be significant for human exposure.
- As existing regulations limiting NOx emissions are implemented, natural sources such as lightning will become a larger fraction of national emissions.

Section 2.3.10 Oil and Gas Development

Section 2.3.10 of the ISA presents a very simplistic overview of oil and gas NOx emissions and states "The oil and gas production sector is an increasing source of NO_X, with 2008 emission estimates of 400,000 tons nationally". The ISA should mention that these emissions only comprise 2.3 percent of total NOx emissions nationally (EPA 2008). Given recent advances in NOx controls and implementation of several rules related to NOx emissions, the growth in the oil and gas sector may not lead to growth in overall NOx emissions.

EPA has implemented regulations that are being phased in for new and existing sources which will reduce NOx emissions. These regulations place control requirements on NOx emissions from engines (natural gas fired or diesel) which are one of the dominant NOx

sources in the oil and gas production sector. All engines are subject to regulation under one of the following federal rules:

- RICE MACT NIESHAP , Subpart ZZZZ
- NSPS Subpart IIII
- Existing RICE MACT SI Engine NESHAP 2010 Amended Rule
- Existing Engine NESHAP Settlement
- Final Diesel Existing Engine NESHAP
- Consolidated Engine Final Rule NSPS, Subpart JJJJ and Amendments to NESHAP, Subpart ZZZZ

In general, any new or reconstructed engines are subject to either the manufacturer's certification or emissions limits, and all existing engines are subject to a minimum of maintenance to maintain performance as well as record keeping. Additionally, many state and local regulations require more stringent controls than the federal regulations listed here (e.g. Wyoming has strict minor source BACT requirements on all sources as well as requirements for demonstrating compliance with applicable air quality standards).

Recently, the Western Regional Air Partnership (WRAP) completed an analysis of the impact of federal, state and local regulations on air emissions from oil and gas production for selected western basins (Gribovicz 2013). The ISA should use this information to develop estimates of future NOx emissions from selected oil and gas production regions and it can be accessed at: http://www.wrapair2.org/Analysis.aspx.

Drilling rigs are an important source of oil and gas NOx emissions. These sources are unique because they are portable and do not remain in one location for extended periods of time. The typical time to drill an oil and gas well is less than 30 days after which the rig moves to a new location. For pad wells (a well pad that has multiple wells), the rig may stay on the pad for approximately 1 year. The rig will not stay in any one location for a period of 3-years (the averaging time form of the ambient standard). Drilling rigs are subject to the performance standards listed above. The typical life of a drill rig engine is approximately 10 years after which the rig is re-powered with engines that meet current

emission standards. Thus, the engine fleet turnover will drive down NOx emissions.

The ISA should provide a complete regulatory analysis for oil and gas NOx sources. Such an analysis will provide a balanced perspective for the concerns raised about growth in emissions as a result of development.

The ISA cites the following data in support of the premise that oil and gas NOx emissions are growing and important; "Pacsi et al. (2013) estimated that routine operating activities from the Barnett Shale production facility near Dallas, Texas can emit roughly 46 to 30 tons of NO_X/day, depending on the demand for natural gas electricity generation". This information needs to be placed into proper context of total NOx emissions in the Dallas, Texas area. The following table indicates that total weekday NOx emissions projected to the year 2018 are estimated to be 290.12 tons per day. Oil and gas emissions are projected to be 18.04 tons per day (6.2 percent of total week day NOx emissions).

2018 Ten-County DFW Area Anthropogenic Emissions Summary by Source Category

Source Category Description	2018 Summer Weekday Emissions (tons per day)		2018 Summer Weekday Emissions Distribution	
	NO_X	VOC	NO_X	VOC
On-Road	113.21	55.61	39.0%	11.9%
Non-Road	39.87	32.77	13.7%	7.0%
Area	30.76	284.94	10.6%	60.8%
Off-Road – Locomotives	18.90	0.93	6.5%	0.2%
Off-Road – Airports	11.77	3.53	4.1%	0.8%
Oil and Gas - Production	12.21	43.68	4.2%	9.3%
Oil and Gas - Drill Rigs	5.83	0.01	2.0%	0.002%
Point - Electric Utilities	15.02	2.05	5.2%	0.4%
Point - Cement Kilns	17.60	0.80	6.1%	0.2%
Point - Other	24.95	44.24	8.6%	9.4%
Total	290.12	468.56	100.0%	100.0%

Air Quality Division • Future Case Emission Inputs for DFW Photochemical Modeling • Chris Kite • January 31, 2014 • Page 4

(TCEQ 2014)

If the cited NOx projections of 46 to 30 tons per day are correct, oil and gas NOx emissions from the Pacsi (2013) study only represent between 10.3 and 15.8 percent of total projected 2018 emissions.

It is recommended that the estimated emissions cited in the ISA be placed in perspective of total NOx emissions in the region. Based on the above data, these projections indicate that future year NOx emissions from oil and gas are not a large fraction of total NOx emissions and do not demonstrate a large growth in emissions.

The ISA suggests, based on a study by Olaguer (2012), that large NOx emissions from non routine flaring can affect local air quality. "This hypothetical study indicates that flare volumes of 100,000 cubic meters per hour of natural gas over a period of 2 hr can also add over 3 ppb to peak 1-hr ozone somewhat further (>8 km) downwind, once dilution overcomes ozone titration and inhibition by large flare emissions of NOx. The additional peak ozone from the hypothetical flare can briefly exceed 10 ppb about 16 km downwind." This level of gas flaring at a gas plant is not a common occurrence.

To better quantify the potential impacts from oil and gas operations, the ISA should present results from the WRAP WESTJump project (WRAP 2013). This study presents detailed source apportionment analyses for the West. From this analysis it is possible to quantify oil and gas impacts based on 2008 operations. The following table presents ozone impacts in Colorado from western oil and gas operations. The impacts presented are a result of both NOx emissions and VOC emissions.

This table presents modeled ozone source apportionment results for the highest modeled ozone concentration at selected monitors in Denver, CO and indicates that for all Colorado oil and gas sources operating in 2008, modeled impacts were less than 3 ppb. The oil and gas contribution for these cases was less than 4 percent of total impacts. These results suggest that oil and gas does not have as large of a contribution to total ozone as suggested

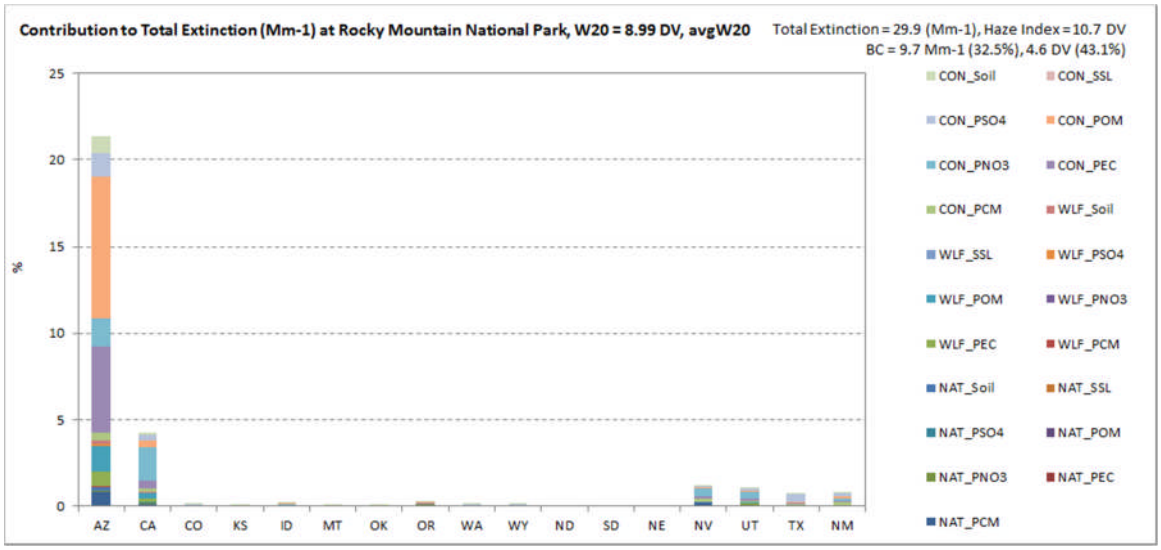
in the ISA.

Table 1. WESTJump Modeled Ozone Source Apportionment for Monitors in Denver, CO
Oil and Gas Contributions are Indicated in Light Blue

CO_Adams0600			CO_Chaffee0001			CO_Denver0002		
Rank = 1			Rank = 1			Rank = 1		
(1) 08/03/08			(1) 06/13/08			(1) 05/07/08		
Source Group	Conc (ppb)	Percent of Total	Source Group	Conc (ppb)	Percent of Total	Source Group	Conc (ppb)	Percent of Total
O&G:WY 0.1%	0.039	0.05%	O&G:WY 0.0%	0.028	0.04%	O&G:WY 1.0%	0.749	0.99%
O&G:UT 0.5%	0.411	0.54%	O&G:UT 0.1%	0.082	0.10%	O&G:UT 0.2%	0.184	0.24%
O&G:CO 2.0%	1.532	2.00%	O&G:CO 0.1%	0.095	0.12%	O&G:CO 3.7%	2.792	3.70%
O&G:NM 1.0%	0.739	0.96%	O&G:NM 0.0%	0.001	0.00%	O&G:NM 0.1%	0.066	0.09%
O&G:Rem 0.2%	0.124	0.16%	O&G:Rem 0.0%	0.015	0.02%	O&G:Rem 0.2%	0.156	0.21%
PT:WY 0.1%	0.088	0.11%	PT:WY 0.1%	0.04	0.05%	PT:WY 2.1%	1.59	2.10%
PT:UT 1.2%	0.931	1.21%	PT:UT 0.4%	0.32	0.41%	PT:UT 0.8%	0.64	0.84%
PT:CO 7.9%	6.067	7.90%	PT:CO 0.0%	0.03	0.04%	PT:CO 3.3%	2.45	3.25%
PT:NM 2.5%	1.926	2.51%	PT:NM 0.0%	0.00	0.00%	PT:NM 0.1%	0.10	0.13%
PT:Rem 3.6%	2.740	3.57%	PT:Rem 0.4%	0.32	0.41%	PT:Rem 1.4%	1.03	1.37%
MV:WY 0.1%	0.108	0.14%	MV:WY 0.1%	0.06	0.08%	MV:WY 1.8%	1.32	1.75%
MV:UT 1.0%	0.765	1.00%	MV:UT 1.1%	0.90	1.14%	MV:UT 1.2%	0.89	1.18%
MV:CO 19.1%	14.662	19.10%	MV:CO 0.7%	0.52	0.66%	MV:CO 13.8%	10.38	13.77%
MV:NM 2.1%	1.630	2.12%	MV:NM 0.0%	0.00	0.00%	MV:NM 0.1%	0.07	0.09%
MV:Rem 9.9%	7.566	9.85%	MV:Rem 2.5%	1.99	2.51%	MV:Rem 5.1%	3.85	5.10%
AR:WY 0.0%	0.001	0.00%	AR:WY 0.0%	0.00	0.00%	AR:WY 0.1%	0.06	0.08%
AR:UT 0.1%	0.041	0.05%	AR:UT 0.1%	0.09	0.12%	AR:UT 0.2%	0.19	0.25%
AR:CO 1.2%	0.917	1.19%	AR:CO 0.0%	0.00	0.00%	AR:CO 4.6%	3.51	4.65%
AR:NM 0.1%	0.054	0.07%	AR:NM 0.0%	0.00	0.00%	AR:NM 0.0%	0.01	0.01%
AR:Rem 0.7%	0.522	0.68%	AR:Rem 0.3%	0.27	0.34%	AR:Rem 0.6%	0.46	0.61%
NAT 7.3%	5.598	7.29%	NAT 7.2%	5.73	7.24%	NAT 2.5%	1.90	2.52%
Fires 0.7%	0.528	0.69%	Fires 0.0%	0.00	0.01%	Fires 0.1%	0.06	0.08%
Can/Mex 1.0%	0.748	0.97%	Can/Mex 3.8%	3.03	3.83%	Can/Mex 0.6%	0.47	0.63%
BC 37.8%	29.040	37.82%	BC 82.9%	65.59	82.89%	BC 56.3%	42.49	56.35%
Total	76.777	100.00%	Total	79.13	100.00%	Total	75.40	100.00%

The ISA infers that oil and gas NOx emissions may have a large contribution to impaired visibility in adjacent Class I Areas (Rodriguez et al. 2009). The Rodriguez (2009) reference should be replaced with information from the WRAP WESTJump study. The following figure from the WESTJump results indicates that all Colorado sources (not simply Colorado oil and gas emissions) have a deminimus impact on secondary PM NO3 in Rocky Mountain National Park.

Figure 1.



Emissions from oil and gas operations within a basin will change over time as a result of production decline. Production decline will affect the amount of compression needed to transport the gas (via gathering systems) from well sites to gas processing plants. The following figures present results from an analysis of projected changes in NOx emissions as a result of infield drilling and production decline. This example is from a coal bed methane infill project conducted as part of the Southern Ute Environmental Assessment in southern Colorado (AQRM 2009). Figure 2 presents the change in natural gas production over time and indicates the change in production from existing wells and new gas from infill wells. Figures 3 and 4 present estimates of compressor capacity needed to produce the gas and the resulting NOx emissions. These figures were based on an estimate of the hp/mmscf

listed in Table 1 and include engine regulations that were in effect at the time. The spike in compressor capacity in the year 2020 was a result of a change in gathering system pressure needed as the reservoir declined.

Table 1. Compression Requirements as a Function of Pressure

Phase	Gathering Pressure	HP/mscfd
1	50-100 psi	0.18
2	30-80 psi	0.24
3	2-20 psi	0.46

Figure 2.

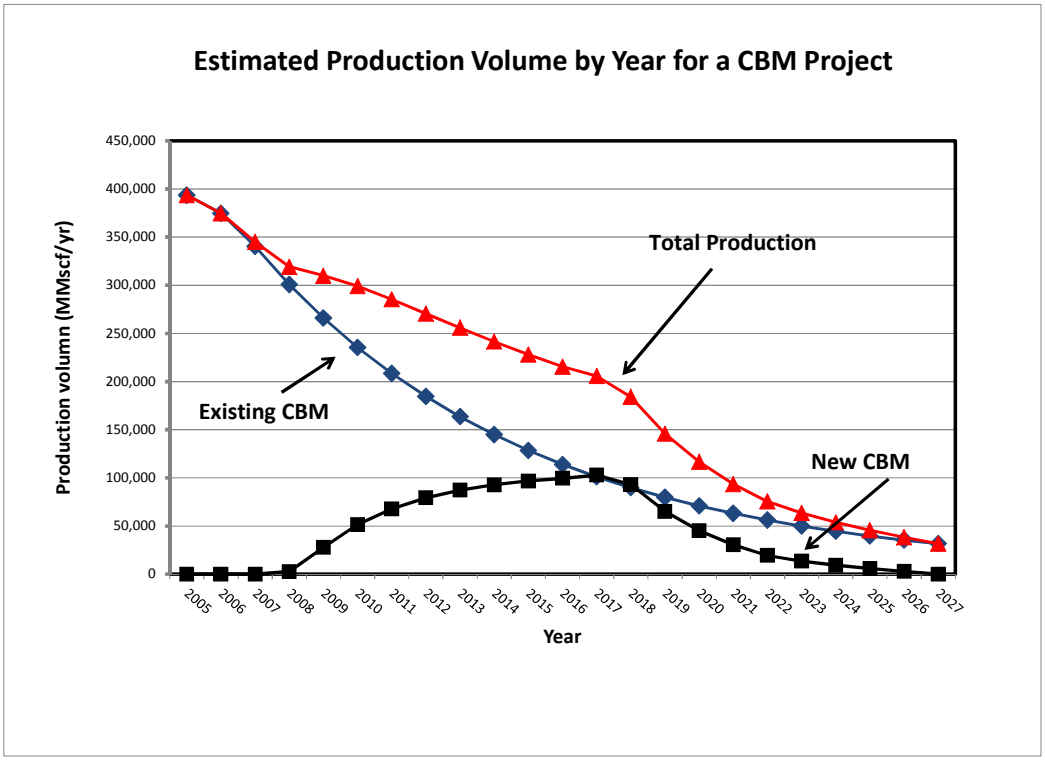


Figure 3.

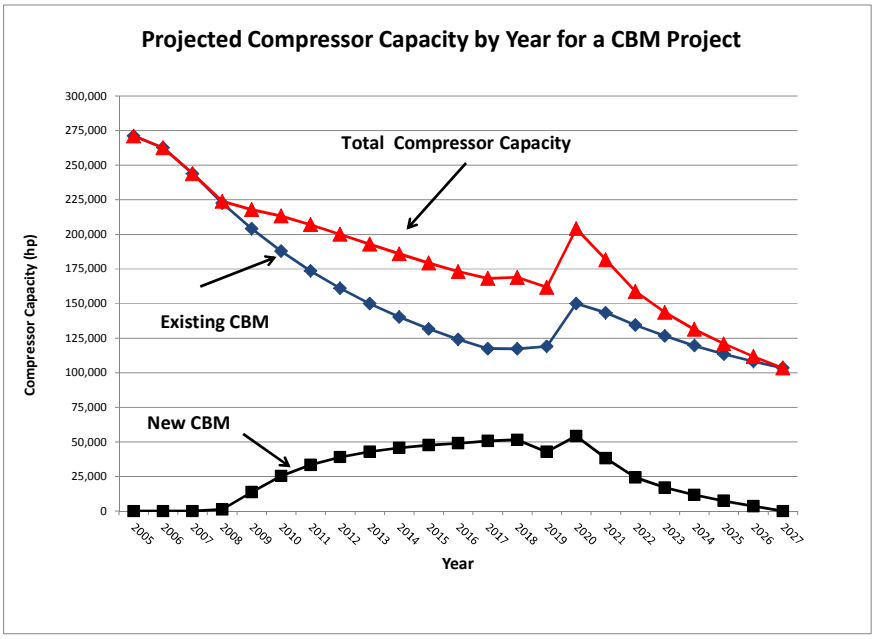
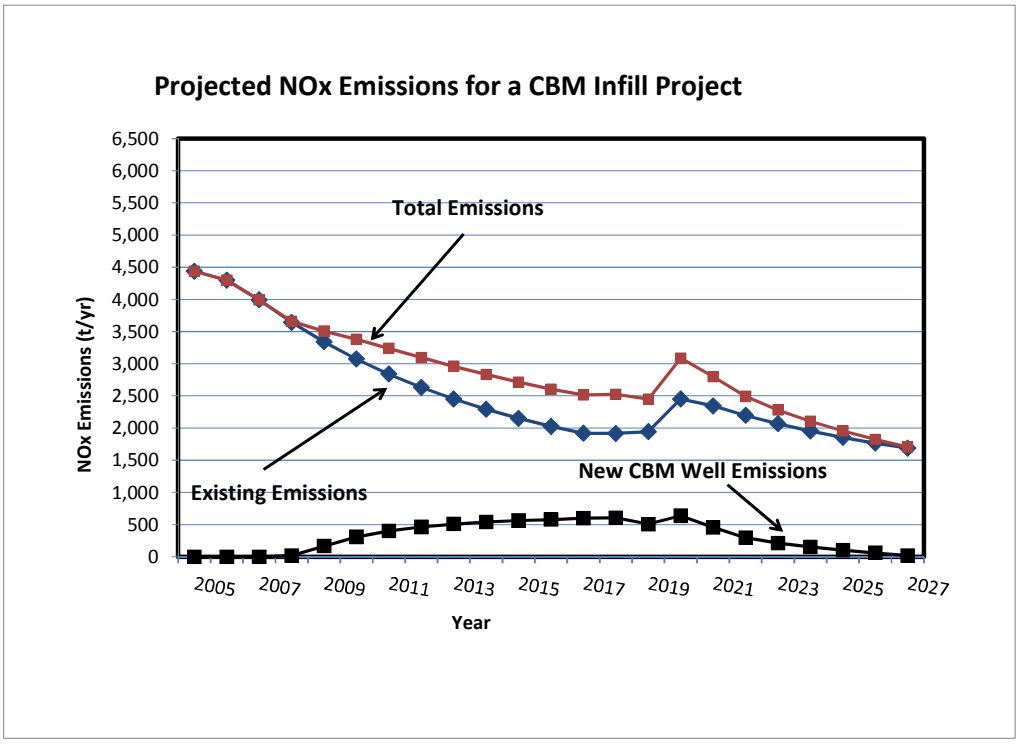


Figure 4.



In conclusion, we find that the discussion surrounding oil and gas sources of NOx is incomplete. We suggest that EPA evaluate the overall impact of oil and gas NOx emissions to total NOx emissions, and complete a more thorough review of likely trends in oil and gas sources under current and pending regulations.

References:

Akagi, S. K., Yokelson, R. J., Wiedinmyer, C., Alvarado, M. J., Reid, J. S., Karl, T., Crounse, J. D., and Wennberg, P. O. (2010) Emission factors for open and domestic biomass burning for use in atmospheric models, *Atmospheric Chemistry and Physics, Discussions*, **10**, 27523–27602, doi:10.5194/acpd-10-27523-2010.

AQRM 2009. Air Quality Impact Assessment Technical Support Document Southern Ute Indian Tribe Coal Bed Methane 80-Acre Infill Development Environmental Assessment, BLM.

EPA 2008. Environmental Protection Agency National Emissions Inventory. (2008). Version 3. www.epa.gov/ttnchie1/net/2008inventory.html

Gribovicz, L. (2013). Analysis of States' and EPA Oil and Gas Air Emissions Control Requirements for Selected Basins in the Western United States (2013 Update) http://www.wrapair2.org/Analysis.aspx

Hudman, R.C., A.R. Russell, L.C. Valin and R.C. Cohen. (2010) Interannual variability in soil nitric oxide emissions over the United States as viewed from space. *Atmospheric Chemistry and Physics,* **10,** 13029-13053.

Hudman, R.C., D.J. Jacob, S. Turquety, E.M. Leibensperger, L.T. Murray, S. Wu, A.B. Gilliland, M. Avery, T.H. Bertram, W. Brune, R.C. Cohen, J.E. Dibb, F.M. Flocke, A. Fried, J. Holloway, J. A. Neuman, R. Orville, A. Perring, X. Ren, G.W. Sachse, H.B. Singh, A. Swanson and P.J. Wooldridge. (2007) Surface and lightning sources of nitrogen oxides over the United States: Magnitudes, chemical evolution and outflow. *Journal of Geophysical Research, Atmospheres,* **112,** D12S05.

Hudman, R.C., N.E. Moore, A.K. Mebust, R.V. Martin, A.R. Russell, L.C. Valin and R.C. Cohen. (2012) Steps toward a mechanistic model of global soil nitric oxide emissions: implementation and space based constraints. *Atmospheric Chemistry and Physics,* **12,** 7779-7795.

Jaegle, L., L. Steinberger, R.V. Martin and K. Chance. (2005) Global partitioning of NOx sources using satellite observations: Relative roles of fossil fuel combustion, biomass burning and soil emissions. *Faraday Discuss,* **130,** p 407-423.

Jaffe, D.A. and N.L. Wigder. (2012) Ozone production from wildfires: A critical review. *Atmospheric Environment,* **51**, p1-10.

Miyazaki, K., H.J. Eskes, K. Sudo and C. Zhang. (2013) Global lightning NOx production estimated by an assimilation of multiple satellite datasets. *Atmospheric Chemistry and Physics, Discussions,* **13,** 29203-29261.

Olaguer, EP. (2012). The potential near-source ozone impacts of upstream oil and gas industry emissions. J Air Waste Manag Assoc 62: 966-977. http://dx.doi.org/10.1080/10962247.2012.688923

Pacsi, AP; Alhajeri, NS; Zavala-Araiza, D; Webster, MD; Allen, DT. (2013). Regional air quality impacts of increased natural gas production and use in Texas. Environ Sci Technol 47: 3521-3527. http://dx.doi.org/10.1021/es3044714

Rodriguez, MA; Barna, MG; Moore, T. (2009). Regional impacts of oil and gas development on ozone formation in the western United States. J Air Waste Manag Assoc 59: 1111-1118. http://dx.doi.org/10.3155/1047-3289.59.9.1111

Schumann and Huntreiser. (2007) The global lightning-induced nitrogen oxides source. *Atmospheric Chemistry and Physics,* **7,** 3823-3907.

TCEQ 2014. Development of 2018 Future Case Emission Inventory Inputs for Dallas-Fort Worth (DFW) Area Photochemical Modeling, DFW State Implementation Plan (SIP) Technical Information Meeting Arlington, Texas January 31, 2014

WRAP 2013. WESTJump Project Results, http://www.wrapair2.org/WestJumpAQMS.aspx

van der Werf, G. R., Randerson, J. T., Giglio, L., Collatz, G. J., Mu, M., Kasibhatla, P. S., Morton, D. C., DeFries, R. S., Jin, Y., and van Leeuwen, T. T. (2010) Global fire emissions and the contribution of deforestation, savanna, forest, agricultural, and peat fires (1997-2009), *Atmospheric Chemistry and Physics,* **10**, 11707-11735, doi:10.5194/acp-10-11707-2010