September 5, 2017

MEMORANDUM

To: Ben Way, Darla Potter; WYDEQ
Tom Moore; WESTAR-WRAP
From: John Grant, Rajashi Parikh, Amnon Bar-Ilan; Ramboll Environ
Subject: National Oil and Gas Emissions Analysis, Task 2: Green River Basin Regional Analysis

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This memorandum describes the Green River Basin[1] oil and gas (O&G) emissions analysis developed as part of the National Oil and Gas Emissions Analysis, Task 2: Regional Analysis. The analysis includes three components:

1. Estimate the fraction of O&G activity accounted for in Subpart W of the Greenhouse Gas Reporting Program (GHGRP).
2. Document produced gas and tank flash composition data collected by the Wyoming Department of Environmental (WYDEQ).
3. Analyze current level of condensate tank controls; estimate capacity for additional control.

O&G Activity Associated with Subpart W Reporting

Subpart W GHGRP information is used to develop several input factors for estimating criteria air pollutant emissions from well sites in the US Environmental Protection Agency's (EPA's) O&G Tool. A critical component for determining the representativeness of input factors estimated from Subpart W data is the fraction of O&G activity captured by companies submitting as part of Subpart W[2]. For the Green River Basin, we estimated the fraction of O&G activity represented by reporting companies (Table 1). Seventeen (17) out of 135 companies listed in the IHS Enerdeq database for the Green River Basin were included in Subpart W reporting, representing 80% of well count, 65% of oil production, and 89% of gas production.

[1] For this analysis the Green River Basin is defined according to the American Association of Petroleum Geologists (AAPG) basin 535. Counties in the Green River Basin which are outside of Wyoming are not considered in this analysis.

[2] Operators that emit more than 25,000 metric tons of GHGs (expressed as carbon dioxide equivalents) are required to report under Subpart W.

Table 1. Green River Basin O&G activity[3,4] represented by Subpart W reporters.

Parameter	Subpart W Reporters [A]	Percent of Basin-wide	Basin-wide
No. of Companies	17	13%	135
Well Count (no. of wells)	10,144	80%	12,665
Oil Production (MBBL/yr[B])	9,086	65%	14,029
Gas Production (BCF/yr[C])	1,223	89%	1,368

[A] As determined from EPA Facility Level Information on GreenHouse gases Tool (FLIGHT) https://ghgdata.epa.gov/ghgp/main.do
[B] thousand barrels per year
[C] billion cubic-feet per year

State of Wyoming Gas Composition Data

WYDEQ staff provided detailed information on gas composition data collected by the State of Wyoming and its use in emission inventory and speciation profile estimation[5]. The summary below is based entirely on the information provided by WYDEQ staff.

The State of Wyoming has collected close to 1600 extended hydrocarbon[6] analyses. The extended hydrocarbon analyses are compiled primarily from compositions submitted by operators as part of New Source Review permitting and also as part of WYDEQ efforts to develop field and formation specific emissions factors, from the Wyoming Oil and Gas Commission (WOGCC), and WYDEQ emission inventory data collection efforts. The extended hydrocarbon analyses are compiled, stored, and processed in an ACCESS database which includes data tables for all data collected along with several tables with ancillary information to describe database fields and units and cross reference field, formation and production information that are used in data analysis. Among the ancillary information stored in the database is:

- The source of each sample (e.g., producing well, tank battery)
- American Petroleum Institute (API) number for each sample
- The producing field and formation associated with each sample

Table 2 shows the six types of samples which are included in the database. The condensate analysis is a liquids analysis and therefore cannot be applied directly in emission inventory calculations; condensate analysis results are used in ProMax[7] or other simulation software to estimate flash gas emissions. Table 3 shows an excerpt of the data available for three example extended hydrocarbon analyses.

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[3] Data supplied by IHS Inc., its subsidiary and affiliated companies; Copyright (2017) all rights reserved.
[4] To be consistent with GHGRP Subpart W reporting, Table 1 includes the following counties: Moffat (CO), Routt (CO), Albany (WY), Carbon (WY), Sublette (WY), and Sweetwater (WY).
[5] Email from Brett Davis (WYDEQ), March 29, 2017.
[6] Extended hydrocarbon analyses include mole fractions for heavier hydrocarbons (typically up to octane) as well as several hazardous air pollutants (HAPs) (e.g., benzene)
[7] https://www.bre.com/ProMax-Main.aspx

Table 2. Sample types and descriptions.

Sample Type	Media	No. of Samples	Description
Flare Gas [A]	Gas	6	Pressurized gas samples collected from well-site or well-pad flare inlets.
Gas [B]	Gas	629	Pressurized gas samples collected from the separator at well sites, well pads, and tank batteries
Condensate	Liquid	896	Pressurized liquids sample taken from well-site/pad separators
Tank Vapors	Gas	8	Ambient gas samples from tank vapors
Water	Liquid	1	Produced water sample
Production test	Gas	45	Gas samples from well production tests

[A] Primarily associated with tank emissions, but could also include dehydration units and pneumatic pumps.
[B] No analyses available for coalbed methane wells.

Table 3. Example data from WYDEQ database.

Parameter	Description	Sample 1	Sample 2	Sample 3
County	County name	Campbell	Campbell	Campbell
CompanyName	Company name	withheld		
APINumber	Well API number			
WellName	Well name			
Field	O&G Field Name			
Reservoir	O&G Reservoir Name			
SampleDate	Date sample was taken	6/29/2006	8/30/2013	10/31/2013
SampleType	Type of sample	Condensate	Gas	Tank Vapors
SampleP	Sample pressure (psi [A])	35	5	14. 69595
SampleT	Sample temperature (F [B])	88	108	60
FlwTBP	Flow tube pressure	0	0	0
csgP	Casing Pressure	0	0	0
C1	Methane (mol%)	0. 22	72. 69	25. 24
C2	Ethane (mol%)	0. 74	10. 10	6. 73
C3	Propane (mol%)	2. 33	9. 22	25. 14
iC4	IsoButane (mol%)	0. 73	1. 08	9. 86
nC4	Normal Butane (mol%)	3. 62	2. 76	12. 77
iC5	IsoPentane (mol%)	2. 96	0. 60	4. 81
nC5	Normal Pentane (mol%)	4. 27	0. 61	3. 38
cyC5	CycloPentane (mol%)	0. 00	0. 03	0. 00
nC6	Normal Hexane (mol%)	4. 38	0. 17	0. 86
cyC6	CycloHexane (mol%)	0. 00	0. 04	0. 25
C6	Hexanes (mol%)	4. 39	0. 14	1. 56
C7	Heptanes (mol%)	21. 01	0. 10	0. 81
1cyC6	MethylCycloHexane (mol%)	0. 00	0. 04	0. 31
224C5	2,2,4-TrimethylPentane (mol%)	0. 98	0. 01	0. 12
C8	Octanes (mol%)	8. 42	0. 03	0. 27
C9	Nonanes (mol%)	6. 67	0. 00	0. 00
C10	Decanes (mol%)	33. 54	0. 00	0. 00
Bnz	Benzene (mol%)	0. 47	0. 01	0. 02
Tol	Toluene (mol%)	1. 66	0. 02	0. 03

Parameter	Description	Sample 1	Sample 2	Sample 3
EBnz	EthylBenzene (mol%)	0. 03	0. 00	0. 00
Xyl	Xylenes (mixture or m, o, & p) (mol%)	3. 57	0. 01	0. 01
N2	Nitrogen (mol%)	0. 00	1. 04	5. 74
CO2	Carbon Dioxide (mol%)	0. 00	1. 30	2. 09
O2	Oxygen (mol%)	0. 00	0. 00	0. 00
H2S	Hydrogen Sulfide (mol%)	0. 00	0. 00	0. 00
H20	Water (mol%)	0. 00	0. 00	0. 00
molsum	Sum of mol%	100. 00	100. 00	100. 00
SG	Specific Gravity	0. 75	0. 80	1. 47
GrossBTU	Gross Heating value (BTU [C])	5827	1359	2329
NetBTU	Net Heating value (BTU)	5394	0	0
SatBTU	Saturated Heating value (BTU)	0	1335. 18	2289. 20
AVGMW	Average Molecular Weight (grams/mol)	116.02	23.28	42.68
GasCompZ	Gas Compressibility Factor	0	0. 996	0. 984

[A] pounds per square inch
[B] Fahrenheit
[C] British thermal units

Pressurized gas and condensate samples are used in ProMax simulations to estimate emissions from tank flashing, standing/breathing, working, and truck loading. Gas analyses are used in estimation of volatile organic compound (VOC) and hazardous air pollutant (HAP) emissions from pneumatic controllers, pneumatic pumps, venting (e.g., blowdown) and fugitive device emissions. Gas analyses are also used to develop representative emissions speciation profiles.

WYDEQ collaborated with EPA to develop 24 speciation profiles for SPECIATE[8] (summarized in Table 4) based on their database of extended hydrocarbon analyses. WYDEQ groups emission factors by producing fields and formations based on gas to oil ratios and gas to water ratios. However, per SPECIATE data requirements, profiles were developed for SPECIATE based on modified groupings along county boundaries. WYDEQ recommended use of developed speciation profiles only in counties where samples were taken. Of the 24 speciation profiles, 9 profiles are for raw gas at gas wells, 11 are for raw gas at oil wells, 3 are condensate tank profiles, and 1 is an oil tank profile.

Table 4. SPECIATE profiles developed based on State of Wyoming extended gas composition data.

County	Well Type	Gas Analysis	Oil Tank Vapor Analysis (< 40° API)	Condensate Tank Vapor Analysis (> 40° API)
Campbell	Gas Well	✓		
	Oil Well	✓	✓	✓
Carbon	Gas Well	✓		
Converse	Gas Well	✓		
	Oil Well	✓		✓
Crook	Oil Well	✓		

[8] https://www.epa.gov/air-emissions-modeling/speciate-version-45-through-40

County	Well Type	Gas Analysis	Oil Tank Vapor Analysis (< 40° API)	Condensate Tank Vapor Analysis (> 40° API)
Fremont	Gas Well	✓		
	Oil Well	✓		
Hot Springs	Gas Well	✓		
Johnson	Oil Well	✓		
Laramie	Oil Well	✓		
Lincoln	Gas Well	✓		
	Oil Well	✓		
Niobrara	Oil Well	✓		
Sublette	Gas Well	✓		
	Oil Well	✓		
Sweetwater	Gas Well	✓		✓
	Oil Well	✓		
Uinta	Gas Well	✓		
Weston	Oil Well	✓		

Future Controls

WYDEQ collects detailed emissions data from point and nonpoint O&G emission sources which are submitted to the national emission inventory (NEI) on a triennial basis[9]. We analyzed the fraction of WYDEQ 2014 nonpoint source condensate tank emissions (SCC 2310021010) in the Green River Basin that are controlled and potential future control associated with condensate tanks.

Future year emissions are typically forecast as follows:

$$E_{FY} = E_{BY} * GF * CF$$

Where:

- E_{FY} = Future year emissions
- E_{BY} = Base year emissions
- GF = future year activity growth factor
- CF = future year emission control factor

In this analysis we perform calculations based on the detailed emissions (by county, source classification code [SCC], and control status) provided by WYDEQ to estimate future year control factors for the Green River Basin. We assume that existing base year emissions remain constant from the base to future year and that emissions added from the base to future year are controlled with 98% efficiency.

[9] Emails from Ben Way (WYDEQ), May 3, 2017 and May 10, 2017.

Base year emissions are estimated as follows:

$$E_{BY} = C_{BY} + U_{BY}$$

Where:

C_{BY} = Controlled emissions in the base year (tons per year; tpy)
U_{BY} = Uncontrolled emissions in the base year (tpy)

Potential base year emissions if no sources were controlled are estimated as follows:

$$P_{BY} = U_{BY} + C_{BY}/CF_{BY}$$

Where:

P_{BY} = Potential emissions in the base year if all emissions were uncontrolled (tpy)
CF_{BY} = Control factor for controlled emissions in the base year (unitless)

Emissions added from the base year to the future year are estimated as follows:

$$A_{FY} = P_{BY} \times (GF - 1) \times (1 - CE_{FY})$$

Where:

A_{FY} = Added emissions in the future year (tpy)
CE_{FY} = Control efficiency for emissions added between base year and future year (unitless)

We developed a hypothetical 2028 forecast for condensate tank VOC emissions. The O&G activity growth factor was set to 1.55 based on crude oil forecasts to 2028 in the Energy Information Administration (EIA) Annual Energy Outlook (AEO) 2017[10] for the Dakotas/Rocky Mountains oil and gas supply region. Existing base year emissions were assumed unchanged from the base to future year. Emissions added from the base to future year were assumed controlled by 98%. Table 5 shows the results of the 2028 forecast.

[10] Annual Energy Outlook 2017, Table: Lower 48 Crude Oil Production and Wellhead Prices by Supply Region, Reference Case , Accessed online July 2017 at https://www.eia.gov/outlooks/aeo/tables_ref.php

Table 5. Green River Basin 2028 hypothetical VOC emission forecast scenario for condensate tanks[11].

County	VOC Emissions (tpy)					
	Controlled [A]	Uncontrolled	Total	Controlled [A]	Uncontrolled	Total
	Base Year 2014 (actual)			**Base Year 2014 (potential uncontrolled)**		
Carbon	56	3396	3452	2784	3396	6179
Lincoln	7	3904	3912	371	3904	4275
Sublette	440	1849	2289	22022	1849	23871
Sweetwater	301	6866	7167	15057	6866	21922
Uinta	30	1421	1451	1485	1421	2906
Basin-wide	**834**	**17436**	**18271**	**41718**	**17436**	**59154**
	Added Future Year 2028 (actual)			**Added Future Year 2028 (potential uncontrolled)**		
Carbon	68	0	68	3409	0	3409
Lincoln	47	0	47	2358	0	2358
Sublette	263	0	263	13168	0	13168
Sweetwater	242	0	242	12093	0	12093
Uinta	32	0	32	1603	0	1603
Basin-wide	**653**	**0**	**653**	**32631**	**0**	**32631**
	Total Future Year 2028 (actual)			**Total Future Year 2028 (potential uncontrolled)**		
Carbon	124	3396	3520	6192	3396	9588
Lincoln	55	3904	3959	2729	3904	6634
Sublette	704	1849	2553	35189	1849	37038
Sweetwater	543	6866	7409	27150	6866	34015
Uinta	62	1421	1483	3088	1421	4509
Basin-wide	**1487**	**17436**	**18923**	**74348**	**17436**	**91784**

[A] WYDEQ database includes flaring control (98% efficiency) and vapor recovery unit control (100% efficiency for all hour operated). In this analysis, we assumed that all base year and future year controlled emissions were controlled at 98% control efficiency.

Table 6 shows future year control factors and percent emission reductions resulting from base and future year controls. The percent of emissions reduced by controls in the base year is estimated to be in the range of 9% to 90% by county; the percent of emissions reduced by controls in the future year is estimated to be in the range of 40% to 93%. Considering the wide range in the fraction of emissions controlled in the base year, future year control factor variation is relatively small (0.65 to 0.72).

[11] Table 5 estimates are rounded to the nearest whole number; calculations made with the values in Table 5 may not replicate exactly due to rounding of source data values.

Table 6. Green River Basin 2028 hypothetical control factors and percent emission reductions.

Green River Basin County	Future Year Control Factor	Base Year Percent of Emissions Reduced by Controls	Future Year Percent of Emissions Reduced by Controls
Carbon	0.66	44%	63%
Lincoln	0.65	9%	40%
Sublette	0.72	90%	93%
Sweetwater	0.67	67%	78%
Uinta	0.66	50%	67%
Basin-wide	**0.67**	**69%**	**79%**

The percent of emissions reduced by controls in the base year is an important input for making estimates of the future year control factor. We extended the above analysis to several growth factors and varying estimates of the percent of emissions reduced by control in the base year (Figure 1). Greater emissions control in the base year is associated with control factors that are closer to one (i.e., smaller reductions from the base to future year as a result of emissions control). If a county were to have 78% of emissions reduced by control in the base year and a future year growth factor of 1.55, then a control factor smaller than 0.68 would result in control beyond 98% control of emissions added from the base to the future year. For counties with high levels of emissions control (as a result of New Source Performance Standard (NSPS) OOOO and/or local/federal regulations) the limits of applying generalized state- or national-level future year control factors should be considered carefully when developing emissions forecasts. In counties with high levels of control, consultation with local agencies to understand current control levels could help to ensure the reasonableness of generalized control factors in those counties.

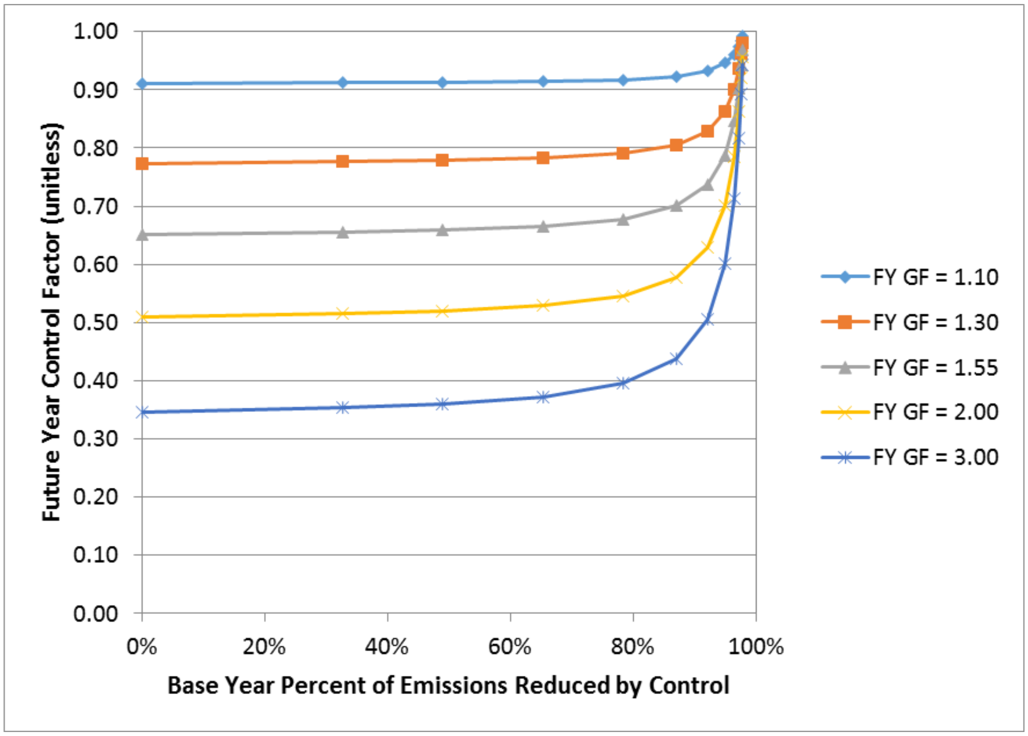

Figure 1. Hypothetical future year control factor versus base year control assumptions for several future year growth factor (FY GF) estimates.

Recommendations

Although Subpart W GHGRP data is based on a small fraction of producers in the Green River Basin, those producers account for 65% to 90% of O&G activity. Emission inventory input factors based on the Subpart W estimates for the Green River Basin are likely to be representative estimates if well site equipment configuration and operations for larger operators that report as part of Subpart W are similar to those of smaller, non-reporting operators. If smaller operators not included in the Subpart W have higher emissions than reporting operators as a result of factors such as poor maintenance practices, older equipment, or lack of centralized equipment, then these smaller operators could account for a large fraction of emissions and Subpart W input factors may not be representative.

WYDEQ has performed extensive data collection of extended gas analyses which are used in emission inventory calculations and have also been used to develop SPECIATE profiles. Such a large dataset of gas analyses is unique and is expected to enhance the Wyoming O&G emission inventory and air quality modeling.

The effect of base year emissions control on future year forecasts was analyzed for a case in which future added emissions are controlled, but base year emissions are not controlled. Especially for highly controlled source categories, the reasonableness of emissions control factors should be evaluated so that future year emissions are not reduced below feasible levels of control. In counties with high levels of control, consultation with local agencies to understand current control levels could help to ensure the reasonableness of generalized control factors in those counties.