Upstream Oil and Gas Emission Inventories in the Inter-Mountain West

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WRAP/WESTAR

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Overview

- Emission inventories – background
- History of O&G emission inventory development
- WRAP Phase III inventories
- Technical methodology
- Results for an example basin
- Cross-basin comparisons
- Regulatory approach
- Emission inventory issues – improvements and new concepts
Emissions Inventories

• Emissions are what is regulated, not ambient air quality - through:
  
  – Limits on permitted sources and tracking of actual emissions
    • Strategies that address group or types of sources by specifying technology for operations (fuels, turnover of technology) or controls (specified emissions limits)
    • Fees for permitted sources allow regulators to recover costs to issue, inspect, and monitor impacts

  – Reporting and analysis of inventory data allows trend and compliance tracking – done for multiple purposes
    • A heightened effort is required to build and understand a baseline historical period inventory for a modeling study
    • Modeling studies also require projections of future emissions to assess control programs to efficient emissions reduction strategies
WRAP Phase III Inventories

- First regionally-consistent O&G inventory study in the Intermountain West
  - First inventory to cover all criteria pollutants (NOx, VOC, SOx, CO, PM)
- Scope of study includes 9 major basins: South San Juan (NM), North San Juan (CO), Denver-Julesburg (CO), Piceance (CO), Uinta (UT), Southwest Wyoming (WY), Wind River (WY), Powder River (WY), and Williston (MT & ND) Basins
  - All 9 basins completed as of June 2013
  - Production on tribal lands in 5 of 9 Basins
- Baseline inventories developed for 2006 with midterm projections to 2012 or 2015
- Baseline updates to 2008 for WestJump AQMS – more updates planned
Phase III Methodology Diagram

“Unpermitted” sources surveys to O&G producers

Combined survey responses for all participating companies

IHS database (oil and gas production and well and spud counts)

Scaled-up “unpermitted” sources emissions for entire basin

Permit data from State databases and EPA permit data (Title V) or other permit data

Complete oil and gas emissions inventory for entire basin
### Phase III Methodology

- Detailed spreadsheet-based surveys sent to major operators in each basin
- Not all sources surveyed are “unpermitted”

#### 3a. 2006 Recompletions

<table>
<thead>
<tr>
<th>Survey ID</th>
<th>Representative Well</th>
<th>Representative Well ID</th>
<th>No. Wells Represented</th>
<th>Counties</th>
<th>Field</th>
<th>Basin</th>
<th>Volume of Gas Vented (MCF)</th>
<th>Controls Used (Y/N)</th>
<th>Type of Control</th>
<th>Green Completion Control Efficiency</th>
<th>Volume Flared (MCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ex. Well 1</td>
<td>representative</td>
<td>abc-1</td>
<td></td>
<td>Logan</td>
<td></td>
<td>Denver-Julesburg</td>
<td>uncontrolled</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Well 1</td>
<td>representative</td>
<td></td>
<td></td>
<td></td>
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<td>Denver-Julesburg</td>
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<tr>
<td>Well 2</td>
<td>representative</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Denver-Julesburg</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Well 3</td>
<td>representative</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Denver-Julesburg</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Survey respondents in Phase III do not represent all production in a basin.
Scale-up of survey data necessary to capture all activity.
### Phase III Methodology

<table>
<thead>
<tr>
<th>State</th>
<th>Emissions Thresholds (tons/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Mexico</td>
<td>Notice of Intent Required for Facilities with Emissions &gt; 10tpy Criteria Pollutants; Permits Required for Facilities &gt; 25 tpy</td>
</tr>
<tr>
<td>Colorado</td>
<td>Permits Required for All Sources with Emissions &gt; 2 tpy Criteria Pollutants</td>
</tr>
<tr>
<td>Utah</td>
<td>Permits Required for All Sources with Potential to Emit (PTE) &gt; 100 tpy</td>
</tr>
<tr>
<td>Wyoming</td>
<td>Combustion Sources: All Compressor Engines Require Permit; Oil and Gas Process Sources: Variable Depending on Development Region but Not Less than 6 tpy VOC Emissions in Most Areas (Some Sources Require Permits at Any Emissions Levels in JPAD Area or CDA)</td>
</tr>
<tr>
<td>Montana</td>
<td>Permits Required for All Sources with Potential to Emit (PTE) &gt; 25 tpy;</td>
</tr>
<tr>
<td>North Dakota</td>
<td>Permits Required for All Sources with Potential to Emit (PTE) &gt; 100 tpy</td>
</tr>
</tbody>
</table>

- Wide variation among states in permitting/reporting thresholds
- Now adding well-level data from EPA Tribal Minor Source reporting requirements
Phase III – Source Categories

- Large Point Sources
  (Gas plants, compressor stations)
- Drill Rigs
- Wellhead Compressor Engines
- CBM Pump Engines
- Heaters
- Pneumatic Devices
- Condensate and Oil Tanks
- Dehydrators
- Completion Venting
- Lateral compressor engines
- Workover Rigs
- Salt-Water Disposal Engines
- Artificial Lift Engines
  (Pumpjacks)
- Vapor Recovery Units (VRU’s)
- Miscellaneous or Exempt Engines
- Flaring
- Fugitive Emissions
- Well Blowdowns
- Truck Loading
- Amine Units (acid gas removal)
- Water Tanks
Intermountain West - Gas Production and Prices

- Intermountain West Gas Production
- Wellhead Gas Prices

Gas Prices ($/MCF)
Gas Production (million cubic feet)

Intermountain West Gas Production
Wellhead Gas Prices
Eastern Utah

2006 Oil and Gas Production

BLM proposed leasing for oil shale development

BLM proposed leasing for tar sands development

“Indian Country” – Regulatory authority controlled by the Tribes and EPA

- Oil Shale Leasing
- Tar Sands Leasing
- “Indian Country”
## Basin Oil and Gas Statistics

### 2008 Production Statistics

<table>
<thead>
<tr>
<th>Basin</th>
<th>Well Count</th>
<th>Oil Production (bbl)</th>
<th>Gas Production (MCF)</th>
<th>Spud Counts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Oil</td>
<td>Non-CBM Gas</td>
<td>CBM</td>
</tr>
<tr>
<td>D-J Basin</td>
<td>20,054</td>
<td>3,620</td>
<td>16,434</td>
<td>0</td>
</tr>
<tr>
<td>Piceance Basin</td>
<td>9,300</td>
<td>644</td>
<td>8,569</td>
<td>87</td>
</tr>
<tr>
<td>North San Juan Basin</td>
<td>2,969</td>
<td>97</td>
<td>1,003</td>
<td>1,869</td>
</tr>
<tr>
<td>South San Juan Basin</td>
<td>21,776</td>
<td>1,670</td>
<td>15,421</td>
<td>4,685</td>
</tr>
<tr>
<td>Wind River Basin</td>
<td>1,389</td>
<td>566</td>
<td>805</td>
<td>18</td>
</tr>
<tr>
<td>Powder River Basin</td>
<td>27,256</td>
<td>7,177</td>
<td>544</td>
<td>19,535</td>
</tr>
<tr>
<td>Southwest Wyoming Basin</td>
<td>11,072</td>
<td>1,143</td>
<td>9,616</td>
<td>313</td>
</tr>
<tr>
<td>Williston Basin*</td>
<td>8,144</td>
<td>6,623</td>
<td>1,518</td>
<td>3</td>
</tr>
</tbody>
</table>

Red figures are greatest value in each column, showing spatial variation in O&G E&P operations
* Williston Basin production statistics are for 2009

- Wide variation in total production of gas and oil/condensate among basins
- Gas production activity is more significant than oil production activity in all basins except the Williston Basin
- Spud counts are surrogates for where greatest exploration and production activity was occurring in 2008
## Basin Inventories

### 2008 Emission Inventories

<table>
<thead>
<tr>
<th>Basin</th>
<th>NOx</th>
<th>VOC</th>
<th>CO</th>
<th>SOx</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-J Basin</td>
<td>22,165</td>
<td>100,622</td>
<td>14,367</td>
<td>115</td>
<td>717</td>
</tr>
<tr>
<td>Uinta Basin</td>
<td>15,508</td>
<td>97,302</td>
<td>11,569</td>
<td>431</td>
<td>716</td>
</tr>
<tr>
<td>Piceance Basin</td>
<td>20,113</td>
<td>45,714</td>
<td>11,520</td>
<td>519</td>
<td>1,812</td>
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<tr>
<td>North San Juan Basin</td>
<td>5,917</td>
<td>2,187</td>
<td>6,456</td>
<td>30</td>
<td>72</td>
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<tr>
<td>South San Juan Basin</td>
<td>42,233</td>
<td>54,469</td>
<td>23,602</td>
<td>273</td>
<td>557</td>
</tr>
<tr>
<td>Wind River Basin</td>
<td>1,335</td>
<td>10,993</td>
<td>2,062</td>
<td>1,276</td>
<td>31</td>
</tr>
<tr>
<td>Powder River Basin</td>
<td>20,980</td>
<td>14,787</td>
<td>15,445</td>
<td>596</td>
<td>666</td>
</tr>
<tr>
<td>Southwest Wyoming Basin</td>
<td>23,824</td>
<td>87,374</td>
<td>16,024</td>
<td>6,030</td>
<td>679</td>
</tr>
<tr>
<td>Williston Basin*</td>
<td>14,387</td>
<td>357,798</td>
<td>18,765</td>
<td>2,081</td>
<td>1,045</td>
</tr>
</tbody>
</table>

* Williston Basin emissions are for 2009

- Wide variation in inventories among basins
- Drivers for variations include production types (liquid vs. gas, CBM vs. non-CBM, sour vs. sweet gas), regulatory control levels, intensity of activity
Results – Example NOx Emissions Breakdown By Source Category

**Southwest Wyoming Basin**
- Compressor Engines: 54%
- Drill rigs: 24%
- Heaters: 12%
- Other Categories: 6%
- Dehydrator: 2%

**Powder River Basin**
- Compressor engines: 44%
- Drill rigs: 27%
- Heaters: 2%
- Artificial Lift: 2%
- Miscellaneous engines: 20%
- Other Categories: 5%
- Other: 6%

NOx emissions primarily comprised of compressor engines (central and wellhead) and drill rigs for basins in which active drilling was occurring.
VOC emissions sources vary significantly from basin to basin – tank flashing, dehydration and pneumatic devices are consistently large source categories in most basins, but for CBM dominant basins other categories are significant.
Cross-Basin – NOx Emissions

<table>
<thead>
<tr>
<th>Basins</th>
<th>NOx Emissions (tons/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DJ</td>
<td>22,000</td>
</tr>
<tr>
<td>Piceance</td>
<td>19,000</td>
</tr>
<tr>
<td>Uinta</td>
<td>15,000</td>
</tr>
<tr>
<td>North San Juan</td>
<td>5,000</td>
</tr>
<tr>
<td>South San Juan</td>
<td>45,000</td>
</tr>
<tr>
<td>Wind River</td>
<td>1,000</td>
</tr>
<tr>
<td>Powder River</td>
<td>21,000</td>
</tr>
<tr>
<td>South West Wyoming</td>
<td>24,000</td>
</tr>
<tr>
<td>Williston</td>
<td>14,000</td>
</tr>
</tbody>
</table>
Per well NOx emissions relatively consistent across basins – differences mainly due to usage of compression and centralized vs. wellhead compression
Per unit gas production VOC emissions vary widely across basins – differences due to levels of liquid hydrocarbon production (oil and condensate) and VOC content of produced gas.
Per unit gas production VOC emissions vary widely across basins – differences due to levels of liquid hydrocarbon production (oil and condensate) and VOC content of produced gas.
South San Juan Basin – 2006 NOx Emissions Contribution by Designation

- **Tribal NOx Emissions**: 3,287 tons/yr
  - Permitted Emissions: 1,341 tons/yr
  - Non-permitted Emissions: 1,946 tons/yr
- **Non-Tribal NOx Emissions**: 38,788 tons/yr
  - Permitted Emissions: 11,054 tons/yr
  - Non-permitted Emissions: 27,734 tons/yr

South San Juan Basin – 2006 VOC Emissions Contribution by Designation

- **Tribal VOC Emissions**: 6,923 tons/yr
  - Permitted Emissions: 427 tons/yr
  - Non-permitted Emissions: 6,496 tons/yr
- **Non-Tribal VOC Emissions**: 53,774 tons/yr
  - Permitted Emissions: 4,969 tons/yr
  - Non-permitted Emissions: 48,805 tons/yr
North San Juan Basin – 2006 NOx Emissions Contribution by Designation

- **Tribal NOx Emissions (tons/yr)**: 4,862
  - Permitted Emissions: 0
  - Non-permitted Emissions: 4,862
- **Non-Tribal NOx Emissions (tons/yr)**: 838
  - Permitted Emissions: 757
  - Non-permitted Emissions: 81

North San Juan Basin – 2006 VOC Emissions Contribution by Designation

- **Tribal VOC Emissions (tons/yr)**: 2,064
  - Permitted Emissions: 0
  - Non-permitted Emissions: 2,064
- **Non-Tribal VOC Emissions (tons/yr)**: 83
  - Permitted Emissions: 61
  - Non-permitted Emissions: 22

Basin-wide NOx Emissions (tons/yr): 5,700
Basin-wide VOC Emissions (tons/yr): 2,147
Uinta Basin – 2006 NOx Emissions Contribution by Designation

- Tribal:
  - NOx Emissions (tons/yr) - 9,962
  - Permitted Emissions - 2,339
  - Non-permitted Emissions - 7,622

- Non-Tribal:
  - NOx Emissions (tons/yr) - 3,131
  - Permitted Emissions - 0
  - Non-permitted Emissions - 3,131

Uinta Basin – 2006 VOC Emissions Contribution by Designation

- Tribal:
  - VOC Emissions (tons/yr) - 55,370
  - Permitted Emissions - 1,320
  - Non-permitted Emissions - 54,049

- Non-Tribal:
  - VOC Emissions (tons/yr) - 16,176
  - Permitted Emissions - 0
  - Non-permitted Emissions - 16,176
Wind River Basin – 2006 NOx
Emissions Contribution by Designation

Tribal 19%

Basin-wide NOx Emissions (tons/yr) - 1,814
Tribal NOx Emissions (tons/yr) - 337
Permitted Emissions - 217
Non-permitted Emissions - 119

Non-Tribal 81%
Non-Tribal NOx Emissions (tons/yr) - 1,478
Permitted Emissions - 550
Non-permitted Emissions - 928

Wind River Basin – 2006 VOC
Emissions Contribution by Designation

Tribal 27%

Basin-wide VOC Emissions (tons/yr) - 11,981
Tribal VOC Emissions (tons/yr) - 3,196
Permitted Emissions - 97
Non-permitted Emissions - 3,099

Non-Tribal 73%
Non-Tribal VOC Emissions (tons/yr) - 8,786
Permitted Emissions - 421
Non-permitted Emissions - 8,364
Williston Basin – 2009 NOx Emissions Contribution by Designation

- Tribal NOx Emissions (tons/yr) - 1,114
  - Permitted Emissions - 64
  - Non-permitted Emissions - 1,050
- Non-Tribal NOx Emissions (tons/yr) - 13,273
  - Permitted Emissions - 4,142
  - Non-permitted Emissions - 9,131

Williston Basin – 2009 VOC Emissions Contribution by Designation

- Tribal VOC Emissions (tons/yr) - 24,802
  - Permitted Emissions - 18
  - Non-permitted Emissions - 24,784
- Non-Tribal VOC Emissions (tons/yr) - 332,996
  - Permitted Emissions - 1,815
  - Non-permitted Emissions - 331,180

Basin-wide NOx Emissions (tons/yr) - 14,387
- Tribal NOx Emissions (tons/yr) - 1,114
  - Permitted Emissions - 64
  - Non-permitted Emissions - 1,050
- Non-Tribal NOx Emissions (tons/yr) - 13,273
  - Permitted Emissions - 4,142
  - Non-permitted Emissions - 9,131

Basin-wide VOC Emissions (tons/yr) - 357,798
- Tribal VOC Emissions (tons/yr) - 24,802
  - Permitted Emissions - 18
  - Non-permitted Emissions - 24,784
- Non-Tribal VOC Emissions (tons/yr) - 332,996
  - Permitted Emissions - 1,815
  - Non-permitted Emissions - 331,180

Non-Tribal: 92% Tribal: 8%

Non-Tribal: 93% Tribal: 7%
Projections of Future Emissions – Background

• Need
  • Air quality planning to correct violations of health and welfare standards
  • To prevent violations of standards and to reduce exposure
  • Account for state and federal regulations “on the books and on the way”
  • Effectively consider “known future” to estimate additional costs and benefits of additional control options

• Scope
  • Change across all source categories from baseline actual emissions into the future
  • Anthropogenic sources affected by
    • Economic factors
    • Changes in technology
    • Emerging standards
  • Biogenic or natural sources
    • Not as well understood
    • Affected by climate change and other factors
    • Usual practice is hold future projections constant
Western ozone and PM precursors - key emissions sources

- Power plants decreasing markedly
- Mobile sources controlled and emission rates decreasing markedly through federal rules and state testing programs
- Fire activity and effects are huge (among the largest air pollution sources in the West), receiving intensive study
  - Deterministic & Empirical Assessment of Smoke’s Contribution to Ozone (DEASCO$_3$)
  - Prescribed and Other Fire Emissions: Particulate Matter Deterministic & Empirical Tagging & Assessment of Impacts on Levels (PMDETAIL)
  - Others….
- Biogenics (natural plant sources)
- Oil and gas………..
  - Phase III study
  - Emissions Inventories for Williston and MT North Central (Great Plains) Basins
Power Plant Emissions Trends – Western Interconnect

Data Source: EPA Clean Air Markets Division
U.S. Wildfire and Prescribed Fires Acres Burned - 1990 through 2011

2012 and 2013 right behind 2006 in wildfire acres burned
Projections - Methodology

• No standardized methodology for conducting projections – each inventory study has used different approaches (RMPs, NEPA projects, regional inventories)

• Phase III inventories use a three-step approach:
  1. Activity scaling factors
  2. “Uncontrolled” projections
  3. State and federal regulatory control requirements

• Activity scaling requires input from operators on planned activities and/or analyzes trends and/or relies on industry studies

• State and federal regulatory control requirements complex
Projections - Methodology

- Operators queried for planned drilling activities
- Well decline data gathered to generate basin-average curves
- Production projections constructed from operator data/historic trends
Emissions projections are complex mix of growth or decline factors and controls from natural equipment turnover and state/federal regulations.
State regulations vary widely from state to state in emission source categories regulated and levels of control required.
### Regulatory Approaches – Point vs. Area

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Better spatial resolution</td>
<td>Resource intensive (to states and industry)</td>
</tr>
<tr>
<td>Gather actual emissions/actual usage</td>
<td>Resource intensive to process</td>
</tr>
<tr>
<td>Improved accuracy of emissions</td>
<td>Factor approach still used for minor sources</td>
</tr>
</tbody>
</table>

- Expect improvement in spatial resolution and accuracy of emissions data from point sources but significant effort to process and track
- **Colorado (APENs) and Wyoming (site surveys) already doing this**
Issues and New Concepts – Missing Categories

Produced water (evaporation) ponds

- Emission factors uncertain and highly dependent on composition, production type
- Seasonal/diurnal variations
- See for example Utah State University work to characterize emissions in Uinta Basin
Issues and New Concepts – Missing Categories

Field gathering pipelines

• Lack of data on extent of pipeline infrastructure within fields
• Pipeline companies historically not part of the inventory process
Issues and New Concepts – Missing Categories

Midstream sources

- Midstream sources not always captured in inventories – state reporting thresholds
- Midstream sources on tribal lands
- Midstream companies historically not part of the inventory process
Issues and New Concepts – Missing Categories

Mobile sources

- Trucking and off-road equipment likely underestimated in existing mobile inventories
- Activities dispersed throughout basins and among basins
- See for example P3 study in Piceance Basin

As operators and regulators move to other systems to produce and move products and by-products (train, pipelines and electrification) and away from trucks and diesel/field gas combustion, new data is needed.
**Issues and New Concepts – Skewness**

- Poorly performing and “non-average” sources could have significantly higher emissions than estimated in inventories.
- Analogous to “smoking vehicles” in mobile source inventories.
- Statistical sampling/monitoring of sources needed to develop methods to represent this in inventories.
- See for example NOAA monitoring in Uinta Basin and CDPHE capture efficiency adjustments.
Closing

- Technology for exploration and production has changed
- Physical scope of production, variation in production activities
- Oil and gas cost and benefit
- Clean Air Act structure
- Existing vs. future development
- Source category efforts toward continued collaborative study
Acknowledgements

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Western Regional Air Partnership | www.wrapair2.org