A Comprehensive Oil and Gas Emissions Inventory for the Denver-Julesburg Basin in Colorado

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Overview

- History of oil and gas EI development
- Current effort
- Temporal and geographic scope
- Source categories
- Methodology
- Results
Oil and Gas Production in the Rocky Mountains

- Boom in oil and gas production in this region over the last ten years driven by record prices for crude oil and natural gas
  - Colorado gas production in 1996: 572 billion cubic feet
  - Colorado gas production in 2006: 1.2 trillion cubic feet
- Activity supported by large fleet of equipment at thousands of individual well sites
- Partial inventory of this equipment through state permitting databases
- Wide state-to-state variation in permitting thresholds and source categories permitted
History of Oil and Gas EI’s – WRAP Phase I

• Represented the first regional inventory for the western U.S. to address oil and gas area sources not previously inventoried

• Regionally consistent inventory methodology for oil and gas area sources for all of the western states

• Activity and emissions data obtained primarily through limited participation of industry, other regionally-specific studies and literature

• Base year of 2002 with future year projection for 2018

• Focused primarily on NOx and SOx emissions for regional haze issues
History of Oil and Gas EI’s – WRAP Phase II

- Focused on improving the methodology from the Phase I work for two specific major NOx source categories: compressors and drill rigs
- Utilized direct industry survey to obtain detailed information from the oil and gas companies on this equipment by basin
- Applied regionally consistent methodology for entire WRAP domain, and updated baseline year from 2002 to 2005.
History of Oil and Gas EI’s
– Other Regional Studies

• Ozone precursors study for San Juan and Rio Arriba counties in northwest New Mexico
  • Direct survey data from oil and gas producers
  • Considered major NOx and VOC source categories

• Wyoming state-wide inventory of oil and gas sources

• WRAP Phase I and II, and regional studies limited in scope
  • Did not cover all source categories
  • Did not apply consistent methodology to a broad region (NMED, WY studies)

• Previous studies demonstrated the need for high quality equipment, activity, emissions data directly from the major oil and gas companies
Current Phase III Effort

• Considers every major oil and gas production basin in the Rocky Mountain states, including New Mexico, Utah, Colorado, Wyoming, Montana and North Dakota

• Considers all major oil and gas source categories and all major criteria pollutants: NOx, VOC, CO, PM, SOx

• Updated, regionally consistent methodology which combines state permitted sources databases with direct industry survey for unpermitted and exempt sources

• Makes use of latest oil and gas production and well statistics from commercially available IHS database

• Most detailed oil and gas emissions inventory to date
## 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
- Water Tanks
Geographic and Temporal Scope

- Work presented here focuses on Denver-Julesburg (D-J) Basin in Colorado
- Includes major O&G developments in Weld and Larimer Counties around metropolitan Denver area
- Includes dry gas operations in Yuma County
- Baseline year of 2006 considered, with mid-term and far future year emissions projections
### D-J Basin Oil and Gas Statistics

<table>
<thead>
<tr>
<th>County</th>
<th>Well Count</th>
<th>Spud Count</th>
<th>Gas Production [MCF]</th>
<th>Oil Production [bbl]</th>
<th>Water Production [bbl]</th>
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**Totals**  
16,774 | 1,500 | 234,630,779 | 14,242,088 | 46,758,757
Phase III Methodology Diagram for D-J Basin

- **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 D-J Basin**
- **Air Permit Emission Notice (APENs) database**
- **Colorado Regulation 7 condensate tank reports**
- **Complete oil and gas emissions inventory for entire D-J Basin**
### Sample Unpermitted Source Survey – Completion Venting

#### 3a. 2006 Recompletions

Total Completions Conducted in 2006

#### 2b. Recompletion Details if provided for a representative well(s).

<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) uncontrolled</th>
<th>Controls Used (Y/N)</th>
<th>Type of Control (Flaring / Green Completion)</th>
<th>Green Completion Efficiency</th>
<th>Volume Flared (MCF)</th>
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</table>

- Participating companies are able to present responses either for a single representative well completion, or for a group of completions, or for all completions conducted in 2006.
- Companies are able to provide activity data directly (e.g. vented volume) or an average response will be assigned.
- Controls (such as green completions or flaring) can be indicated.
Estimation Methodology – Drilling/Workover Rigs

\[ E_{drilling, rig} = \sum \frac{EF_i \times HP \times LF \times t_{drilling}}{907,185} \]

- Drilling rig engine emissions factors assumed to be Tier 0 and fully deteriorated
- Typical rig composed of 3-6 engines, each with horsepower ranging from 300-1500 HP
- Engine-specific average load factor used throughout drilling event
- Average drilling time/depth provided by each survey respondent

\[ E_{drilling,TOTAL} = E_{drilling} \times \frac{S_{TOTAL}}{S} \]

- Combined drilling rig emissions from all survey responses scaled to basin-wide emissions by ratio of total spuds in the basin to total spuds by all participating companies
Estimation Methodology – Condensate Tanks

- Large condensate tanks (>730 barrel/yr) already permitted by CDPHE
- Average tanks characteristics fed into E&P Tanks 4.0 to obtain flashing emissions factor [lb-VOC/barrel-liquid]

\[ E_{\text{exempt,tank,outside}} = \frac{P_{\text{exempt,tank}} \times EF_{\text{exempt,tank}}}{2000} \]

- Combined small condensate tank emissions from all survey responses scaled to basin-wide emissions by multiplying derived emissions factor by total production from unpermitted tanks

- Typical small condensate tank EF derived by defining average tank characteristics
Estimation Methodology – Vented Sources

\[ E_{\text{venting}} = V_{\text{vented,TOTAL}} \times 1000 \times MW_{\text{VOC}} \times R \times Y_{\text{VOC}} \]

- Applies to venting source categories such as pneumatic devices, fugitive emissions, and blowdowns/completions
- Total vented volume derived by summing total device count and vent rate per device, or total event count and vent rate per event
- Total device or event counts summed from all survey responses
- Average VOC mass fraction of produced gas derived from natural gas composition survey request

\[ E_{\text{venting,BASIN}} = E_{\text{venting,TOTAL}} \frac{W_{\text{TOTAL}}}{W} \]

- Combined venting emissions from all survey responses scaled to basin-wide emissions by ratio of total wells in the basin to total wells owned by all participating companies (fugitives/pneumatics), or total gas production in the basin to total gas production owned by all participating companies (well blowdowns)
Results – Criteria Pollutant Emissions

- Oil and gas production a significant source of NOx, VOC, CO emissions
- SOx and PM emissions minor and primarily driven by drill/workover rig engines
- Emissions dominated by oil and gas activity in Weld County
- Limited dry gas activity in Yuma County also contributing significantly to basin total

<table>
<thead>
<tr>
<th>County</th>
<th>NOx [tons/yr]</th>
<th>VOC [tons/yr]</th>
<th>CO [tons/yr]</th>
<th>SOx [tons/yr]</th>
<th>PM [tons/yr]</th>
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<td>158</td>
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<td><strong>Totals</strong></td>
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<td><strong>81,758</strong></td>
<td><strong>12,941</strong></td>
<td><strong>226</strong></td>
<td><strong>636</strong></td>
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</table>
Results – NOx Emissions By Source Category

- NOx emissions dominated by compressor engines (central and wellhead) and drill rigs.
Top VOC source categories include condensate tanks, pneumatic devices and fugitives
Results – Permitted vs. Unpermitted NOx Emissions

- 44% of basin total NOx emissions from unpermitted sources
Results – Permitted vs. Unpermitted VOC Emissions

- 45% of basin total VOC emissions from previously un inventoried unpermitted sources

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Conclusions and Next Steps

• Methodology of current Phase III built on previous WRAP Phase I and II regional studies – high quality regionally-specific data obtained from detailed survey outreach to all major oil and gas companies in the D-J Basin

• Resulting inventory is the most detailed oil and gas inventory for a single basin, including most major and minor NOx and VOC source categories

• Inventory results show that approximately 45% of NOx and VOC emissions are from unpermitted sources

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Phil Schlagel, Anadarko Petroleum

Brian Lockard, Noble Energy

Scott Mason, Encana USA

Questions?
Estimation Methodology – Heaters and Boilers

\[ E_{heater} = EF_{heater} \times Q_{heater} \times \frac{HV_{local}}{HV_{rated}} \times t_{annual} \times hc \]

- Heater emissions factors taken from AP-42 for natural-gas fired external combustion sources
- Heater firing rate in [BTU/hr] provided for various heater types by survey respondents
- Heater firing rates corrected for local variations in heat content of gas
- Annual heater usage concentrated in the winter months

\[ E_{heater,TOTAL} = E_{heater,companies} \times \frac{W_{TOTAL}}{W} \]

- Combined heater emissions from all survey responses scaled to basin-wide emissions by ratio of total wells in the basin to total wells owned by all participating companies
Estimation Methodology – Misc. Engines

\[ E_{\text{engine}} = \frac{EF_i \times HP \times LF \times t_{\text{annual}}}{907,185} \]

- Considers various miscellaneous engines such as unpermitted wellhead compressors, pumps, VRU’s
- All engines assumed to be operating 8760 hr/yr unless specific survey response data is provided
- Emissions factors and load factors either provided directly by survey respondents or use NONROAD defaults
- Combined engine emissions from all survey responses scaled to basin-wide emissions by ratio of total wells in the basin to total wells owned by all participating companies
- Similar methodology to that of WRAP Phase II