Oil and Gas Emission Inventories for the Western States

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Today’s Presentation

• Background
• 2002 Inventory Methodology
• 2018 Inventory Methodology
• Oil and Gas Controls
• Additional Projects
Project Goals

• Evaluate existing inventories
• Develop consistent oil and gas inventory methodology
• Update the baseline (2002) inventory
• Project emissions for future year (2018) inventory
Previous Inventory Coverage, Point

- Facilities extracted:
  - Compressor stations
  - Gas plants
  - Storage tanks
  - Other smaller sources depending upon inventory thresholds
- Inventory thresholds from 1 tpy to 100 tpy
- Irregularities

Well locations were not obtained for California as CARB provided county-level emissions estimates.
Previous Inventory Coverage, Area

• Covered
  – California and Wyoming
  – Colorado and Alaska point source inventories include most sources

• Not covered
  – New Mexico, Montana, Utah, etc…
  – Sources such as drill rigs and pump engines are not included in the existing 2002 inventories
Base Year (2002) Inventory Procedure

• Adopt point source emissions from existing state inventories
• Estimate area source emissions for:
  – Important NOx sources
    • Drill rig engines
    • Natural gas compressor engines
    • CBM pump engines
  – Minor NOx and VOC wellhead processes
• Incorporate emission controls
• Reconcile point and area inventories
Drill Rig Engines
Data Collection

- Drilling companies contacted
- Oil and gas commission data
  - Well depth
  - Spud date – date drilling begins
  - Completion date – date well preparation is finalized
- WYDEQ survey of drilling emissions in Jonah-Pinedale
  - 13.5 tons NOx/well
  - 3.3 tons SO2/well
Drill Rig Engines
Emissions Calculation

1. Adjust emission factor based on the characteristics of a formation

\[ EF_A = EF_J \times \left( \frac{D_A}{D_J} \right) \times \left( \frac{T_A}{T_J} \right) \]

where:
- \( EF_A \) = The emission factor for another formation
- \( EF_J \) = The Jonah-Pinedale emission factor
- \( D_A \) = The average depth of wells drilled in another area
- \( D_J \) = The average depth of wells drilled in Jonah-Pinedale
- \( T_A \) = The duration of drilling in another area
- \( T_J \) = The duration of drilling in Jonah-Pinedale

2. Estimate emissions using formation-specific emission factors

\[ E = EF \times W \]

where:
- \( E \) = The 2002 emission for a given formation
- \( EF \) = The formation specific emission factor
- \( W \) = The number of wells drilled in the formation in 2002.
Natural Gas Compressor Engines
Data Collection

- Compressor operators contacted
- Oil and gas commission data
- Existing inventories
  - New Mexico Oil and Gas Association inventory (2003)
  - BLM environmental impact statements
Natural Gas Compressor Engines

Emissions Calculation

• Emission factor: $2.3 \times 10^{-5}$ tons NOx/MCF, derived from NMOGA inventory

• Activity data: Gas production obtained from oil and gas commissions

Emission Calculation

\[ E = P \times EF \]

Where:
- \( E \) = 2002 NOx emission
- \( P \) = 2002 gas production (MCF)
- \( EF \) = Emission factor, $2.3 \times 10^{-5}$ tons NOx / MCF
CBM Pump Engines
Data Collection

- Wyoming Generator databases
- Field power supply
- Pertinent oil and gas commission data
  - Well depth
  - Water produced
CBM Pump Engines

1: Estimate Engine Activity

- First estimate used scaling of WY activity
- Improved estimate uses engineering calculations and water production
- Assumptions
  - Pump operation
  - Well design

1. Energy in System
   \[ z_i + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + H_p - H_L = z_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2g} \]

Modified Bernoulli

\[ H_p = d + H_L \]

2. Calculate Frictional Losses
   \[ H_L = f \times \frac{L \times V^2}{D \times 2g} \]
   or
   \[ H_L = \frac{V^{1.85} \times L}{(1.318 \times C_d)^{1.85} \times R^{1.17}} \]

Darcy-Weisbach

Hazen-Williams equation

3. Calculate Pump Power
   \[ P = H_p \times Q \times \gamma / 550 \]

4. Calculate Engine Power
   \[ P_e = P / \epsilon_p / \epsilon_g \]
CBM Pump Engines

2: Estimate Engine Emissions

\[ E = \sum_w EF \times (A_w \times H_A + 0.1 \times A_w \times H_I) \]

Where:
- \( E \) = 2002 county NOx emission
- \( EF \) = Emission factor, see table below (g/hp-hr)
- \( A_w \) = Engine power for pumping at county well \( w \) (hp)
- \( H_A \) = Hours of pumping (4,380 hr)
- \( H_I \) = Hours of idling (4,380 hr)

<table>
<thead>
<tr>
<th>States</th>
<th>Engine EF</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado &amp; New Mexico</td>
<td>12 g/hp-hr</td>
<td>NONROAD 2004</td>
</tr>
<tr>
<td>Wyoming</td>
<td>6.1 g/hp-hr*</td>
<td>WY DEQ</td>
</tr>
</tbody>
</table>

*Natural gas engines in Wyoming are controlled
Minor NOx & VOC Wellhead Processes Data Collection

- WYDEQ emission factors
  - Glycol dehydrators
  - Completions, flaring & venting
  - Heaters
  - Tanks
  - Pneumatic devices
- State control requirements
- Alternative local emission factors
- Oil and gas commission production data
Minor NOx & VOC Wellhead Processes

Emissions Calculations

- Divided production between oil wells and gas wells based on OGC data
- Estimated emissions at oil wells by combining production with WYDEQ oil well emission factors*
- Estimated emissions at gas wells by combining production with WYDEQ gas well emission factors*

*If provided, alternate local factors were used

Calculation of Wellhead Emissions for Individual Wells

**Gas Well**

\[ E = \sum_i (P_g \times EF_{g,i}) + \sum_j (P_c \times EF_{c,j}) + \text{SUM}(EF_w) \]

Where:
- \( E \) = The 2002 emission
- \( P_g \) = 2002 gas production
- \( EF_{g,i} \) = Emission factor for gas process \( i \)
- \( P_c \) = 2002 condensate production
- \( EF_{c,j} \) = Emission factor for condensate process \( j \)
- \( EF_w \) = Per well emission factor

**Oil Well**

\[ E = \sum_i (P_o \times EF_{g,i}) + \text{SUM}(EF_w) \]

Where:
- \( E \) = The 2002 emission
- \( P_o \) = 2002 oil production
- \( EF_{o,i} \) = Emission factor for oil process \( i \)
- \( EF_w \) = Per well emission factor
## Point vs. Area Reconciliation

<table>
<thead>
<tr>
<th>States</th>
<th>Inventory Thresholds</th>
<th>Reconciliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alaska</td>
<td>PTE 100 TPY</td>
<td>Smaller equipment grouped in large facilities</td>
</tr>
<tr>
<td>Nevada</td>
<td>5 TPY</td>
<td>No compressor engines included in State’s inventory =&gt; no reconciliation required</td>
</tr>
<tr>
<td>Colorado</td>
<td>2 TPY actual emissions</td>
<td>Removed compressor, condensate tank and dehydrator emissions from area source inventory</td>
</tr>
<tr>
<td>North Dakota &amp; Oregon</td>
<td>PTE 100 TPY</td>
<td>Gathered additional data from states to include sources with a PTE between 25 and 100 TPY</td>
</tr>
<tr>
<td>South Dakota &amp; Utah</td>
<td>PTE 100 TPY</td>
<td>Created scaling factor based on NM point inventory and gas production</td>
</tr>
<tr>
<td>Other States</td>
<td>PTE 25 TPY</td>
<td>No reconciliation required.</td>
</tr>
</tbody>
</table>

**Background**

- **2002 Inventory Methodology**
- **2018 Inventory Methodology**
- **Oil and Gas Controls**
- **Additional Projects**
## 2002 Oil and Gas Emissions

### VOC Emissions (tpy)

<table>
<thead>
<tr>
<th>Source Type</th>
<th>WRAP Total</th>
<th>Oil Wells</th>
<th>Gas Wells</th>
<th>Condensate Tanks</th>
<th>Area Source Total</th>
<th>Point Source Total</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRAP Total</td>
<td></td>
<td>36,550</td>
<td>215,662</td>
<td>103,792</td>
<td>374,715</td>
<td>93,371</td>
<td>468,087</td>
</tr>
</tbody>
</table>

### NOx Emissions (tpy)

<table>
<thead>
<tr>
<th>Source Type</th>
<th>WRAP Total</th>
<th>Compressor Engines</th>
<th>Drill Rigs</th>
<th>Wellhead</th>
<th>CBM Pump Engines</th>
<th>Area Source Total</th>
<th>Point Source Total</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRAP Total</td>
<td></td>
<td>54,828</td>
<td>21,536</td>
<td>42,800</td>
<td>3,141</td>
<td>130,376</td>
<td>181,191</td>
<td>311,566</td>
</tr>
</tbody>
</table>

### Change in 2002 Oil and Gas NOx Emissions

<table>
<thead>
<tr>
<th>WRAP Oil and Gas Inventory</th>
<th>Oil and Gas in Previous Inventory</th>
<th>Change in Oil and Gas Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRAP Total</td>
<td>311,566</td>
<td>115,897</td>
</tr>
<tr>
<td>Area</td>
<td>130,376</td>
<td>14,479</td>
</tr>
<tr>
<td>Point</td>
<td>181,191</td>
<td>195,670</td>
</tr>
<tr>
<td>Total</td>
<td>311,566</td>
<td>115,897</td>
</tr>
</tbody>
</table>

**Background**

2002 Inventory Methodology

2018 Inventory Methodology

Oil and Gas Controls

Additional Projects
Future Year (2018) Inventory Procedure

• Grow county and tribal level emissions based on estimated growth in oil and gas production
• Sources of data
  – Local, Bureau of Land Management
  – Regional, Energy Information Administration
• Adjust for post-2002 on-the-books controls
• Special cases
Resource Management Areas

\[ G = \frac{(W_{02} + W_f - W_p)}{W_{02}} \]

where:

- \( G \) = the 2002 to 2018 growth factor
- \( W_{02} \) = the wells (oil/gas/CBM) active in 2002
- \( W_f \) = the wells (oil/gas/CBM) forecast to be added by 2018
- \( W_p \) = the wells (oil/gas/CBM) estimated to be plugged and abandoned by 2018
Resulting Areas of Growth

Legend
- 2002 Well Locations
- Resource Management Areas
- Tribes
- State authorizations
- Appalachian and Eastern
- County Growth
  - Low
  - Medium
  - High
  - Very High

Background  2002 Inventory Methodology  2018 Inventory Methodology  Oil and Gas Controls  Additional Projects
# 2018 Oil and Gas Emissions

## VOC Emissions (tpy)

<table>
<thead>
<tr>
<th>Source Type</th>
<th>Oil Wells</th>
<th>Gas Wells</th>
<th>Condensate Tanks</th>
<th>Area Source Total</th>
<th>Point Source Total</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRAP Total</td>
<td>43,248</td>
<td>648,762</td>
<td>194,895</td>
<td>886,904</td>
<td>100,811</td>
<td>987,715</td>
</tr>
</tbody>
</table>

## Change in VOC Emissions, 2002 to 2018

<table>
<thead>
<tr>
<th>Source Type</th>
<th>Oil Wells</th>
<th>Gas Wells</th>
<th>Condensate Tanks</th>
<th>Area Source Total</th>
<th>Point Source Total</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRAP Total</td>
<td>18%</td>
<td>201%</td>
<td>88%</td>
<td>137%</td>
<td>8%</td>
<td>111%</td>
</tr>
</tbody>
</table>

## NOx Emissions (tpy)

<table>
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<tr>
<th>Source Type</th>
<th>Compressor Engines</th>
<th>Drill Rigs</th>
<th>Wellhead</th>
<th>CBM Pump Engines</th>
<th>Area Source Total</th>
<th>Point Source Total</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRAP Total</td>
<td>166,009</td>
<td>27,082</td>
<td>84,932</td>
<td>1,348</td>
<td>279,370</td>
<td>126,536</td>
<td>405,907</td>
</tr>
</tbody>
</table>

## Change in NOx Emissions, 2002 to 2018

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<thead>
<tr>
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<th>Wellhead</th>
<th>CBM Pump Engines</th>
<th>Area Source Total</th>
<th>Point Source Total</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRAP Total</td>
<td>203%</td>
<td>26%</td>
<td>98%</td>
<td>-57%</td>
<td>114%</td>
<td>-30%</td>
<td>30%</td>
</tr>
</tbody>
</table>
# Controls Included in WRAP Inventory

<table>
<thead>
<tr>
<th>Process</th>
<th>Control</th>
<th>2002</th>
<th>Post 2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressors</td>
<td>emission limits of 1-2 g/bhp-hr</td>
<td>Wyoming, Utah</td>
<td>Federal emission standards, Colorado*</td>
</tr>
<tr>
<td>Drill rigs</td>
<td></td>
<td></td>
<td>Federal emission standards</td>
</tr>
<tr>
<td>Pump Engines</td>
<td>emission limits on gas engines of 1-2 g/bhp-hr</td>
<td>Wyoming</td>
<td>Federal emission standards</td>
</tr>
<tr>
<td></td>
<td>use line power</td>
<td>Montana, Utah</td>
<td></td>
</tr>
<tr>
<td>Condensate Tanks</td>
<td>control with 98% efficiency using combustion, vapor recovery, etc...</td>
<td>Montana, North Dakota, Wyoming</td>
<td>Colorado*</td>
</tr>
<tr>
<td>Glycol Dehydrators</td>
<td>control with 90% efficiency</td>
<td></td>
<td>Colorado*</td>
</tr>
<tr>
<td>Completion:</td>
<td>control with flare or vapor recovery (50 – 90% effective)</td>
<td>All states</td>
<td></td>
</tr>
<tr>
<td>Flaring &amp; Venting</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Will apply only in nonattainment areas*
Additional Control Information

• Controls under development
  – Montana, proposed 25 tpy site cap
  – Utah, reporting and control requirements
  – Wyoming considering drill rig requirements

• EPA Natural Gas Star Program
  – Industry developed strategies to control emissions from many oil and gas processes
  – http://www.epa.gov/gasstar/index.htm

• Northeast Texas compressor control demonstration
Compressor Engine Control Option
System Design

Control System

Power Supply

Catalytic Converter
Fuel/Air Controller
Fuel/Air Sensor

Solar Panel
AFR Control Box
Battery

Background  2002 Inventory Methodology  2018 Inventory Methodology  Oil and Gas Controls  Additional Projects
**Compressor Engine Control Option**

**Cost Effectiveness**

<table>
<thead>
<tr>
<th>Emissions Reductions Achieved</th>
<th>Engine</th>
<th>70640</th>
<th>74236</th>
<th>70024</th>
<th>75558</th>
<th>72386</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before (g NOx/hp-hr)</td>
<td>11.6</td>
<td>13.0</td>
<td>13.3</td>
<td>12.7</td>
<td>12.4</td>
<td></td>
</tr>
<tr>
<td>After (g NOx/hp-hr)</td>
<td>0.3</td>
<td>0.5</td>
<td>0.5</td>
<td>0.4</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>NOx Control Efficiency</td>
<td>97%</td>
<td>96%</td>
<td>96%</td>
<td>97%</td>
<td>96%</td>
<td></td>
</tr>
</tbody>
</table>

- Annual emission reduction = 12.3 tons NOx
- Annualized costs = $2,250
- $2,250 / 12.3 tons NOx = $183 / ton NOx*

*Assumes 3% discount rate and five year project life

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| Background | 2002 Inventory Methodology | 2018 Inventory Methodology | Oil and Gas Controls | Additional Projects |
Additional Projects

• Northwest New Mexico area source inventory
  – Cover additional processes
  – Obtain improved activity data and emission factors
  – Estimate SO2 emissions from additional sources

• Upcoming four corners PSD increment analysis expected to establish historical inventories
Additional Information

- WRAP oil and gas inventory documentation: http://www.wrapair.org/forums/ssjf/documents/eictts/oilgas.html
- WRAP emissions database: http://www.wrapedms.org
- Contacts: jrussell@environcorp.com or apollack@environcorp.com