ENVIRON

Oil and Gas Emission Inventories

An introduction to the 2002 and 2018 WRAP inventories

March 6, 2006

ENVIRON

Today's Presentation

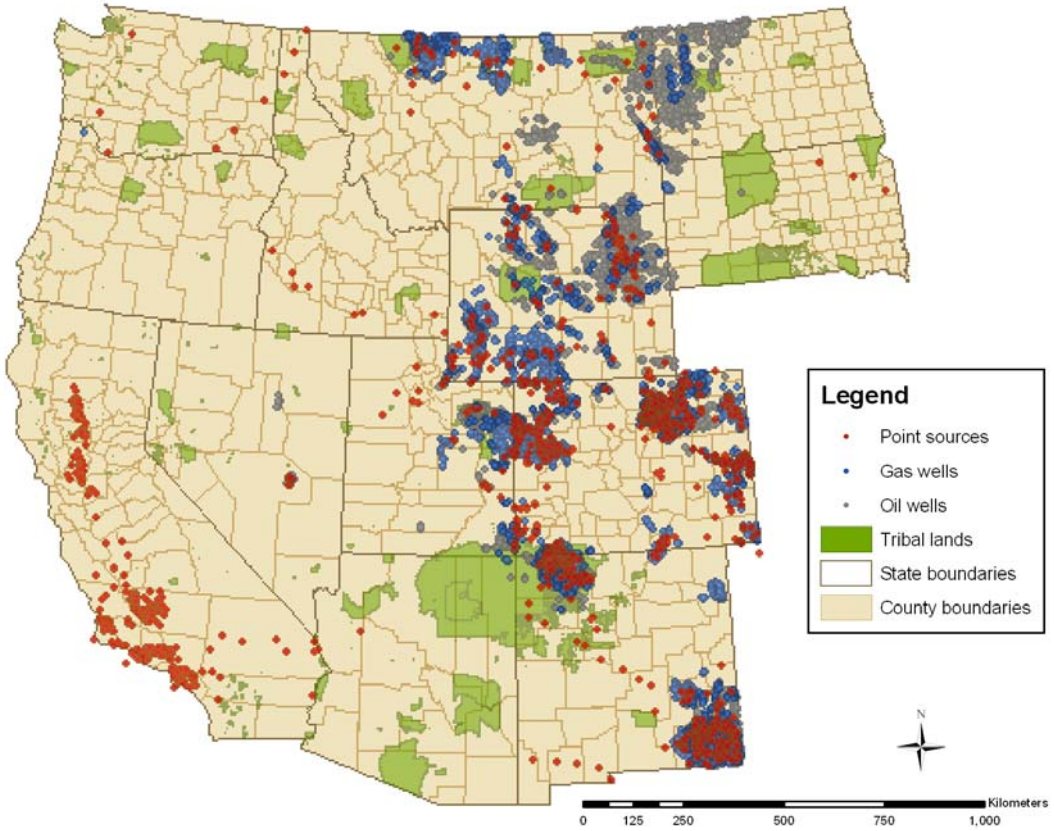
- Background
- 2002 Inventory Methodology
- 2018 Inventory Methodology
- Four Corners' Inventories
- Oil and Gas Controls
- Additional Projects

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

$$EF_A = EF_J \times (D_A / D_J) \times (T_A / T_J)$$

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
- Dj = 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
  - Colorado 2002 point source inventory (2004)
  - New Mexico Oil and Gas Association inventory (2003)
  - BLM environmental impact statements
  - 2002 East Texas inventory (2005)

Natural Gas Compressor Engines
Emissions Calculation

- Emission factor: 2.3x10-5 tons NOx/MCF, derived from NMOGA inventory
- Activity data: Gas production obtained from oil and gas commissions

Emission Calculation

E = P x EF

Where:
E = 2002 NOx emission
P = 2002 gas production (MCF)
EF = Emission factor, $2.3x10^{-5}$ tons NOx / MCF

CBM Pump Engines
Data Collection

- Generator databases
  - Wyoming database of diesel generators
  - Wyoming list of permitted natural gas generators
- 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

$$z_1 + \frac{P_1}{\gamma} + \frac{v_1^2}{2g} + H_P - H_L = z_2 + \frac{P_2}{\gamma} + \frac{v_2^2}{2g}$$

Modified Bernoulli

$$H_P = d + H_L$$

2. Calculate Frictional Losses

$$H_L = f \times \frac{L}{D} \frac{V^2}{2g}$$

Darcy-Weisbach

or

$$H_L = \frac{V^{1.85} L}{(1.318 \times C_H)^{1.85} \times R^{1.17}}$$

Hazen-Williams equation

3. Calculate Pump Power

$$P = H_P \times Q \times \gamma / 550$$

4. Calculate Engine Power

$$P_E = P / \varepsilon_P / \varepsilon_G$$

CBM Pump Engines
2: Estimate Engine Emissions

$$E = \sum_w EF * (A_w * H_A + 0.1 * A_w * H_I)$$

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)

State	Engine EF (g/hp-hr)	Source
Colorado	12	NONROAD 2004
New Mexico	12	NONROAD 2004
Wyoming	6.1*	WY DEQ

*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

$E = SUM_i(P_g \times EF_{g,i}) + SUM_j(Pc \times EF_{c,j}) + SUM(EF_w)$

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

$E = SUM_i(P_o \times EF_{g,i}) + SUM(EF_w)$

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

State	Point Source Inventory Threshold	Reconciliation
Arizona	PTE 40 TPY	Oil and gas emissions occur on tribal lands => no reconciliation required
Colorado	2 TPY actual emissions	Removed compressor, condensate tank and glycol dehydrator emissions from area source inventory
New Mexico	PTE 25 TPY	
Utah	PTE 100 TPY	Created scaling factor based on NM point inventory and gas production

2002 Oil and Gas Emissions

VOC Emissions (tpy)

	Oil Wells	Gas Wells	Condensate Tanks	Area Source Total	Point Source Total	Total
WRAP Total	36,550	215,662	103,792	374,715	93,371	468,087

NOx Emissions (tpy)

	Compressor Engines	Drill Rigs	Wellhead	CBM Pump Engines	Area Source Total	Point Source Total	Total
WRAP Total	54,828	21,536	42,800	3,141	130,376	181,191	311,566

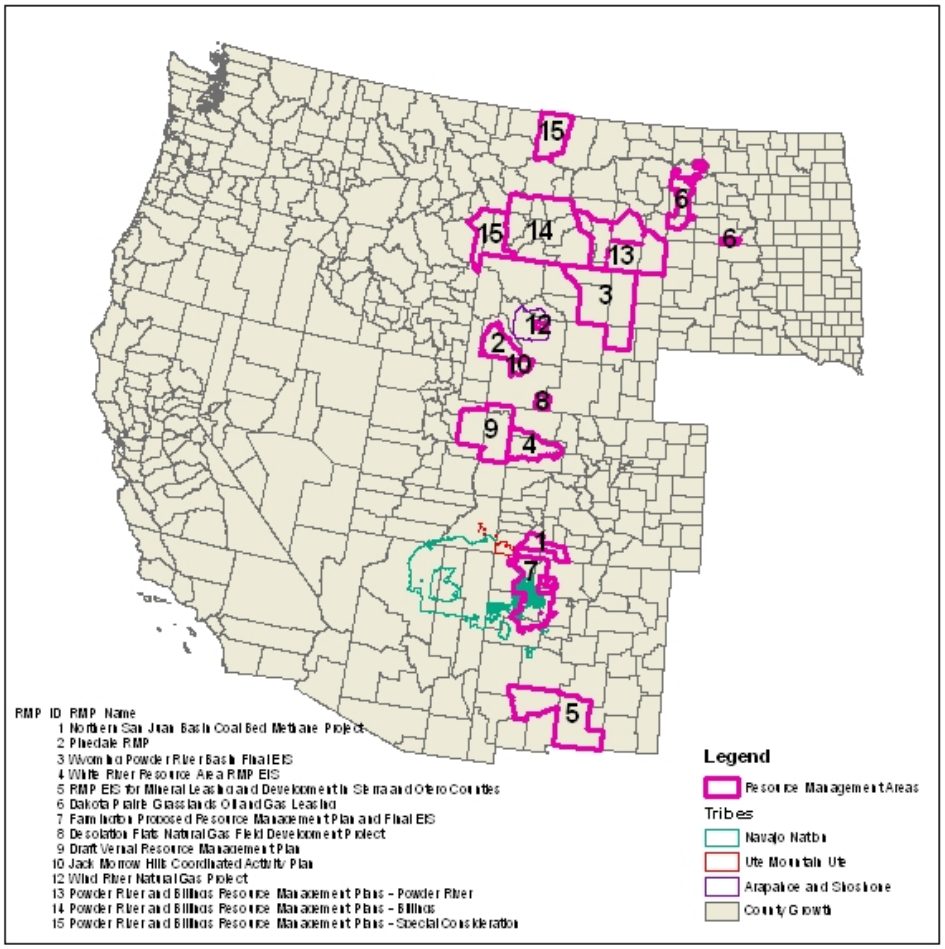
Change in 2002 Oil and Gas Emissions

	WRAP Oil and Gas Inventory			Oil and Gas in Previous Inventory			Change in Oil and Gas Emissions	
	Area	Point	Total	Area	Point	Total	Total	Percent
WRAP Total	130,376	181,191	311,566	14,479	181,191	195,670	115,897	59%

Future Year (2018) Inventory Procedure

- Grow county and tribal level emissions based on estimated growth in oil and gas production
- Sources of data
  - Local
    - Resource management plans (BLM)
    - Alaska Department of Natural Resources
  - Regional, Energy Information Administration
    - Oil production growth = 1.334
    - Gas production growth = 1.458
- Adjust for post-2002 on-the-books controls
- Special cases
  - Sierra and Otero, NM
  - CBM development in Montana, North Dakota and Utah

Resource Management Areas

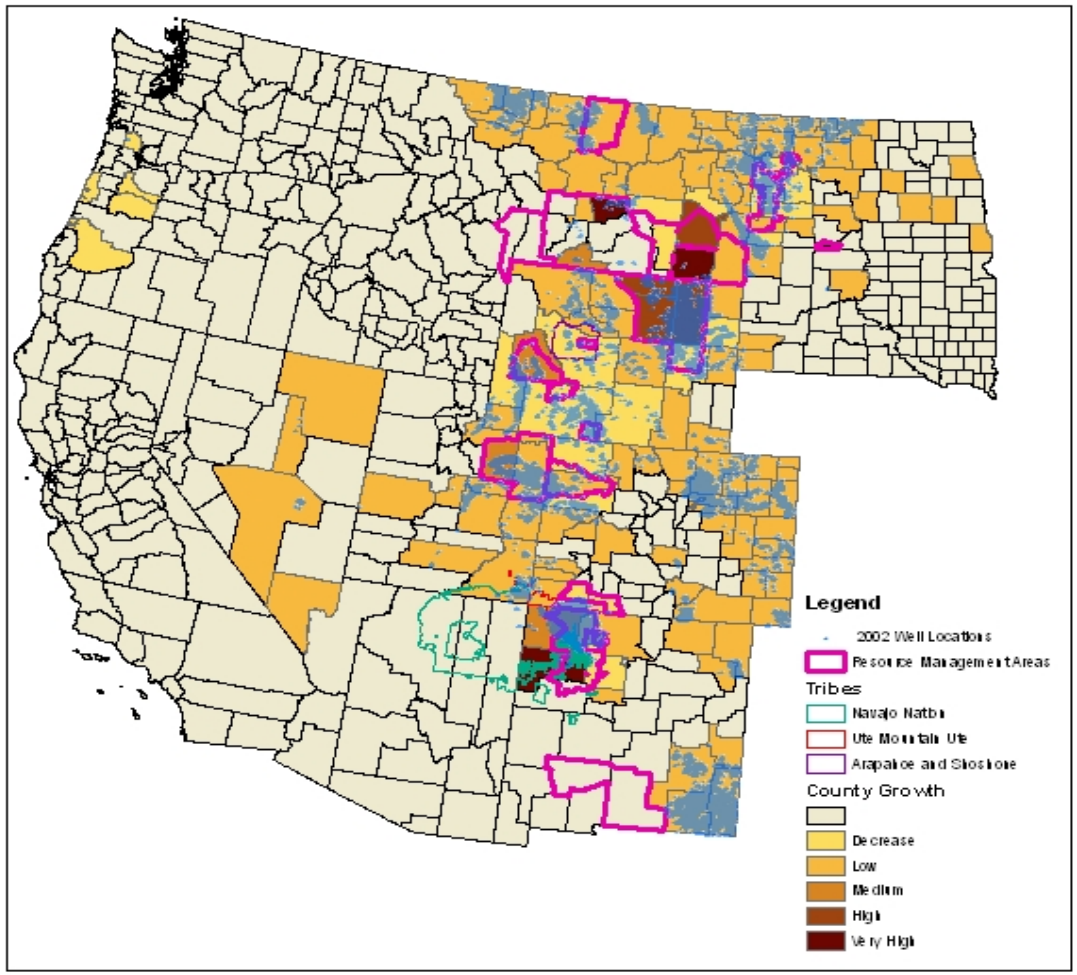


$$G = \frac{(W_{02} + W_f - W_P)}{W_{02}}$$

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



2018 Oil and Gas Emissions

VOC Emissions (tpy)

	Oil Wells	Gas Wells	Condensate Tanks	Area Source Total	Point Source Total	Total
WRAP Total	43,248	648,762	194,895	886,904	100,811	987,715

Change in VOC Emissions, 2002 to 2018

	Oil Wells	Gas Wells	Condensate Tanks	Area Source Total	Point Source Total	Total
WRAP Total	18%	201%	88%	137%	8%	111%

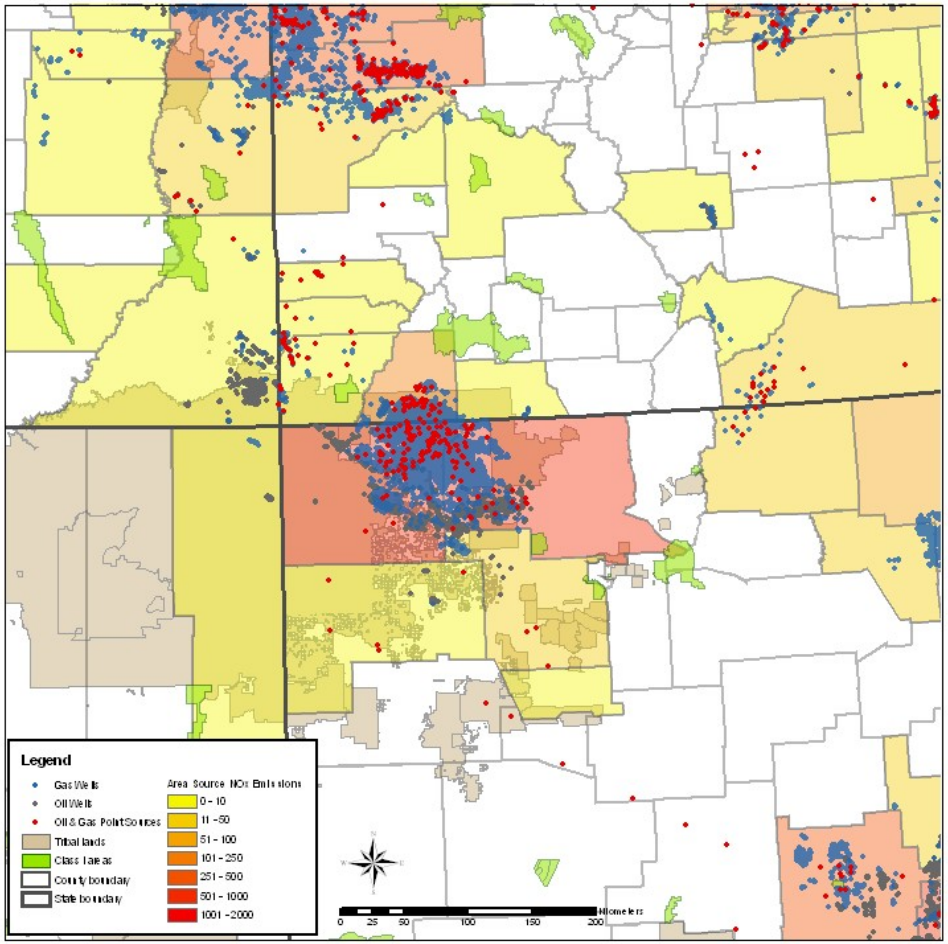
NOx Emissions (tpy)

	Compressor Engines	Drill Rigs	Wellhead	CBM Pump Engines	Area Source Total	Point Source Total	Total
WRAP Total	166,009	27,082	84,932	1,348	279,370	126,536	405,907

Change in NOx Emissions, 2002 to 2018

	Compressor Engines	Drill Rigs	Wellhead	CBM Pump Engines	Area Source Total	Point Source Total	Total
WRAP Total	203%	26%	98%	-57%	114%	-30%	30%

2002 NOx Emissions in the Four Corners



Four Corners, 2002 Area Source Oil & Gas Emissions

State/Tribal Portion	2002 Annual Emissions (tons)		
	NOx	SO2	VOC
Arizona	-	-	-
Colorado	10,139	162	7,542
New Mexico	48,064	1,010	107,857
Utah	4,821	147	30,269
Ute Mt. Ute	540	0	793
Navajo Nation	1,167	2	2,344
4 Corners Total	**64,730**	**1,321**	**148,805**

Notes:

-These totals represent only the portion of the states/tribes in the four corners region

-All emissions in the State of Arizona occur on tribal lands

-SO2 emissions have only been estimated for drill rigs

Four Corners, 2018 Area Source Oil & Gas Emissions

State/Tribal Portion	2018 Annual Emissions (tons)		
	NOx	SO2	VOC
Arizona	-	-	-
Colorado	10,412	5	11,073
New Mexico	123,168	14	250,902
Utah	12,617	5	88,701
Ute Mt. Ute	785	0	1,156
Navajo Nation	2,810	0	4,540
4 Corners Total	**149,792**	**24**	**356,371**

State/Tribal Portion	Percent Difference 2002 to 2018		
	NOx	SO2	VOC
Colorado	3%	-97%	47%
New Mexico	156%	-99%	133%
Utah	162%	-97%	193%
Ute Mt. Ute	45%	-99%	46%
Navajo Nation	141%	-93%	94%
4 Corners Total	**131%**	**-98%**	**139%**

Controls Included in WRAP Inventory

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

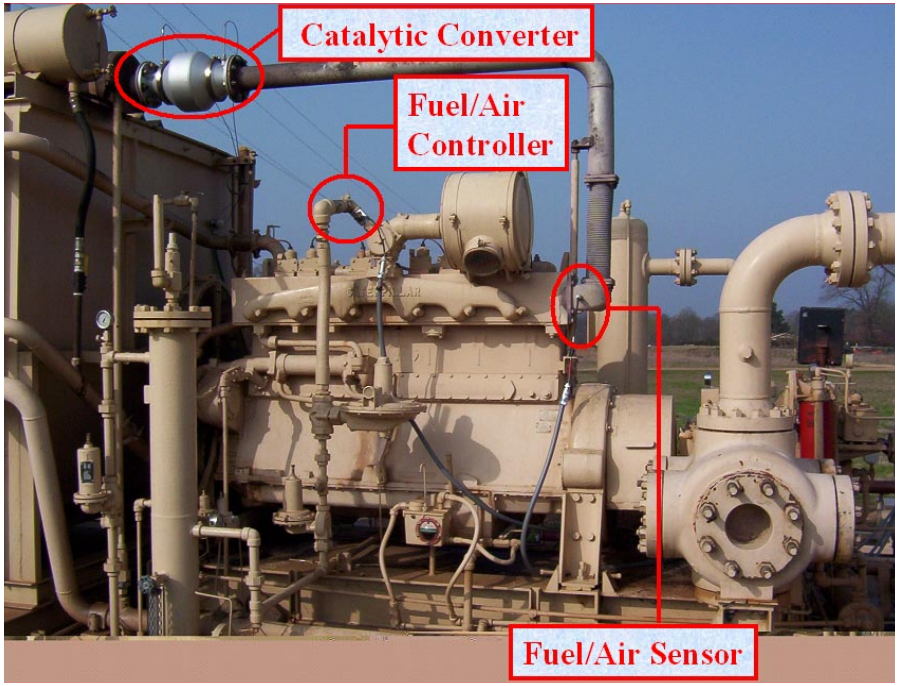
*Will apply only in nonattainment areas

Additional Control Information

- Controls under development
  - Montana, proposed 25 tpy site cap
  - Utah, reporting and control 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

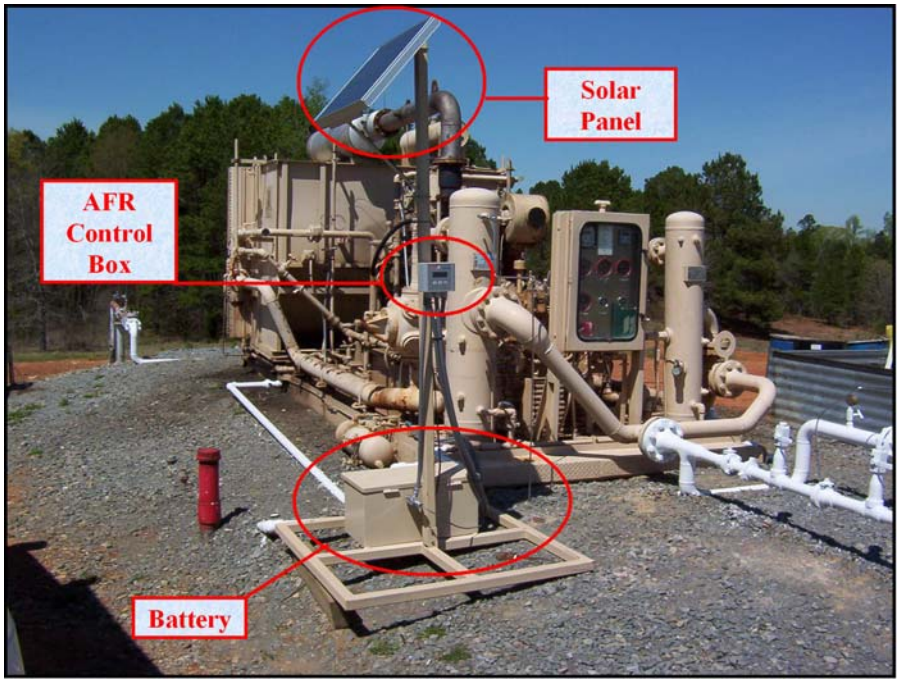
Compressor Engine Control Option

System Design



Control System

Power Supply



Compressor Engine Control Option

Cost Effectiveness

Emissions Reductions Achieved

Engine	70640	74236	70024	75558	72386
Before (g NOx/hp-hr)	11.6	13.0	13.3	12.7	12.4
After (g NOx/hp-hr)	0.3	0.5	0.5	0.4	0.5
NOx Control Efficiency	97%	96%	96%	97%	96%

- 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**

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