

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

Amnon Bar-Ilan, Ron Friesen, John Grant, Alison Pollack  
ENVIRON International Corporation

Doug Henderer, Daniel Pring  
Buys & Associates

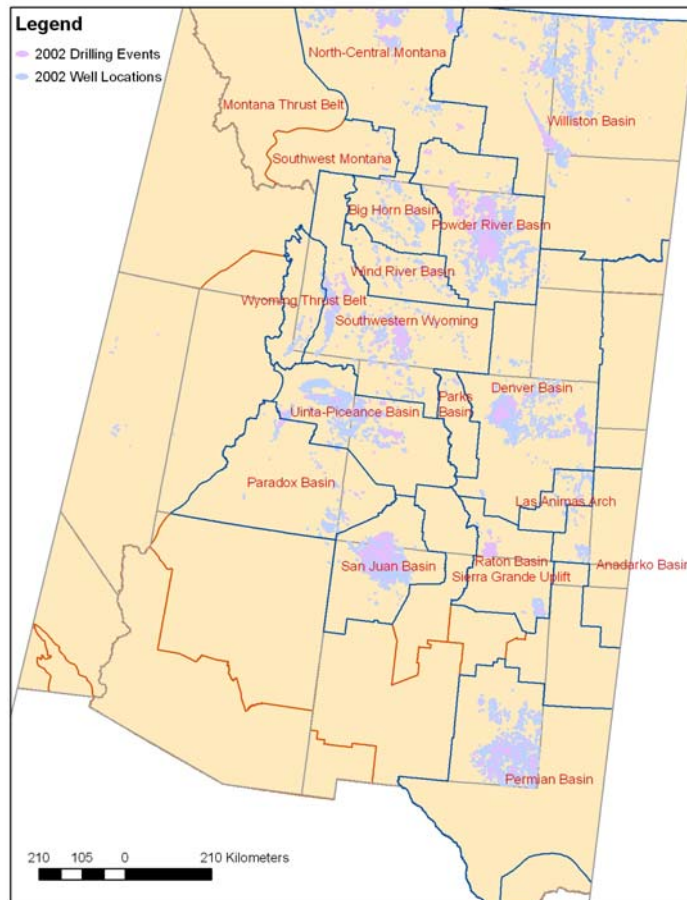
Kathleen Sgamma  
Independent Petroleum Association of Mountain States (IPAMS)

Tom Moore  
Western Regional Air Partnership (WRAP)

# 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 NO<sub>x</sub> and SO<sub>x</sub> 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 NO<sub>x</sub> 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 NO<sub>x</sub> 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: NO<sub>x</sub>, VOC, CO, PM, SO<sub>x</sub>**
- **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**

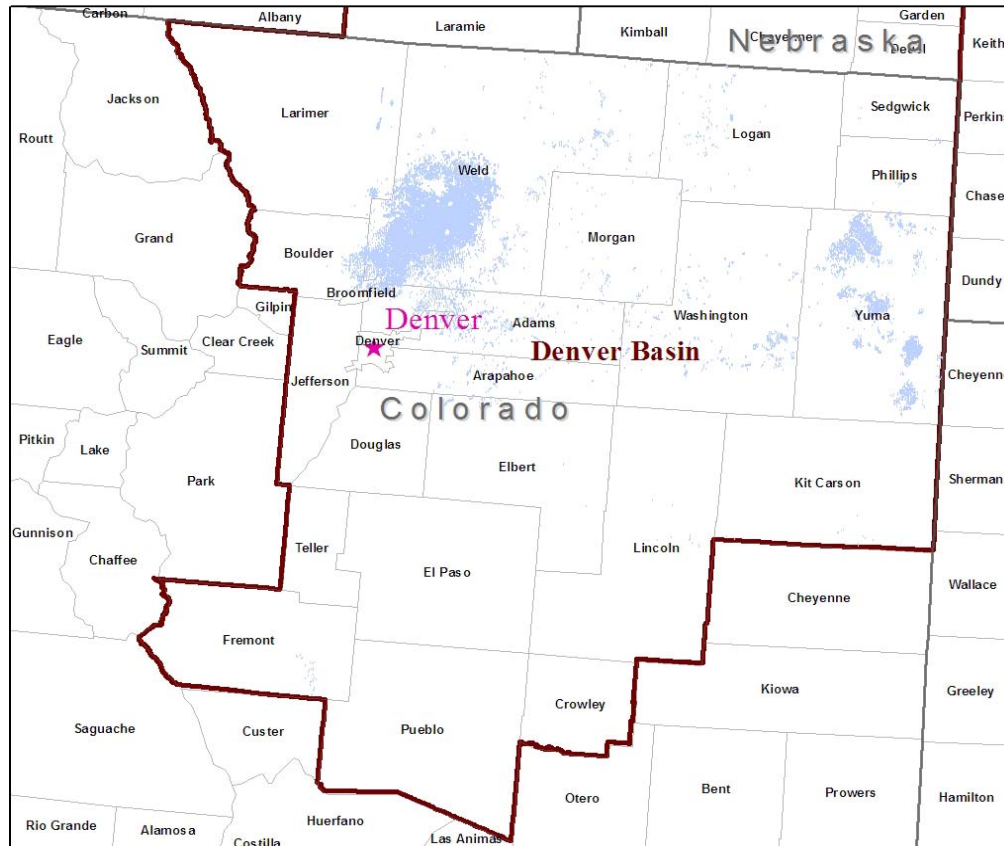
## Phase III – Source Categories

- 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

## D-J Basin



- 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

### Legend

2006 Well Locations

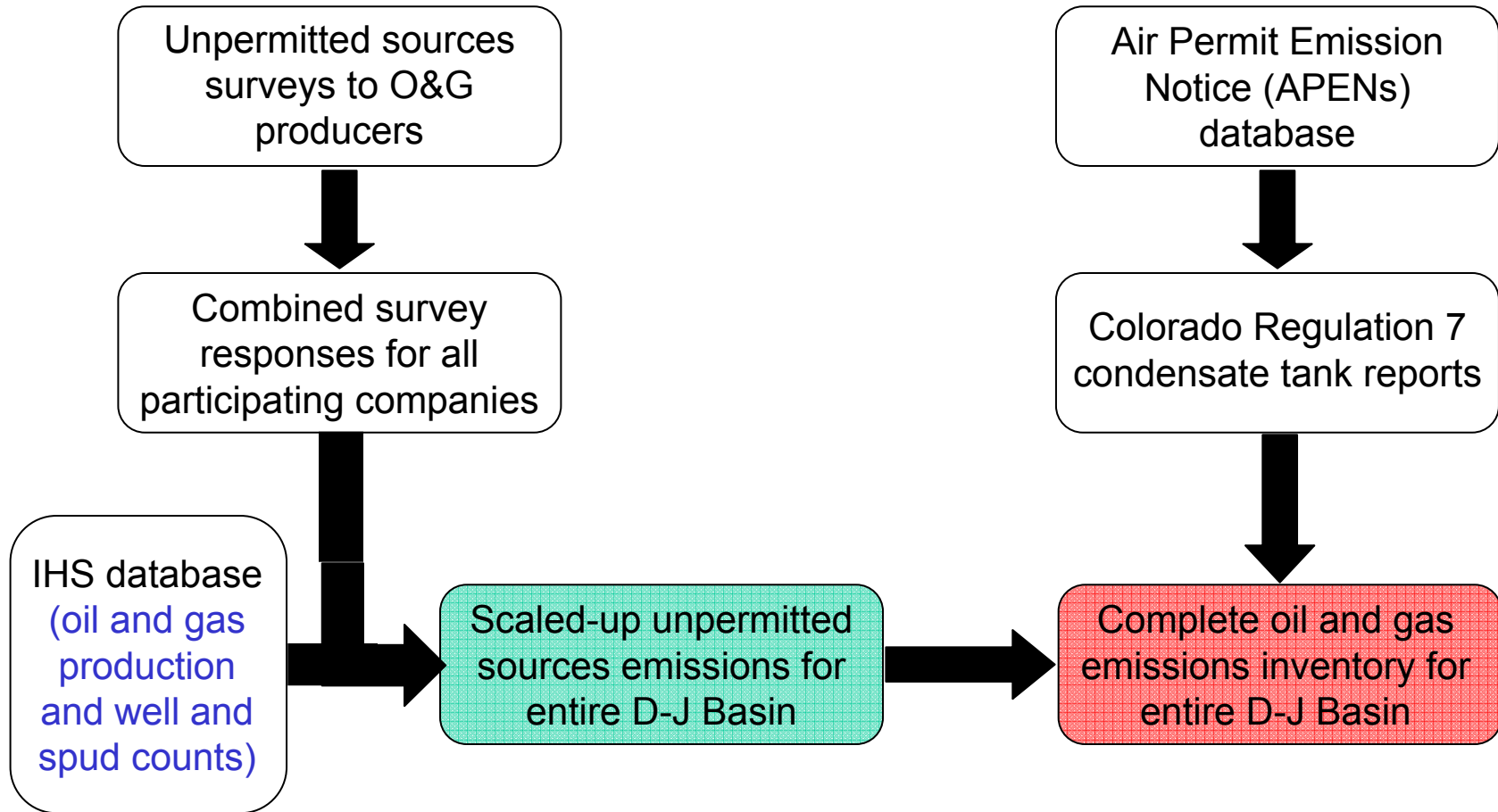


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## D-J Basin Oil and Gas Statistics

County	Well Count	Spud Count	Gas Production [MCF]	Oil Production [bbl]	Water Production [bbl]
Adams	889	7	6,738,398	406,823	628,171
Arapahoe	103	3	376,623	56,018	179,392
Boulder	232	9	2,373,186	132,523	62,787
Broomfield	14	0	635,433	31,798	14,664
Crowley	0	0	0	0	0
Denver	34	7	242,598	14,674	1,189
Elbert	60	1	196,974	38,296	155,302
Fremont	37	2	0	50,074	0
Jefferson	0	0	0	0	0
Kit Carson	12	2	344,013	21,227	201,133
Larimer	135	0	212,406	116,755	3,854,032
Lincoln	12	1	27,203	78,112	729,088
Logan	112	9	260,466	207,829	6,081,895
Morgan	66	1	290,210	92,186	2,821,974
Phillips	19	3	555,029	0	127,347
Sedgwick	3	0	50,202	1,295	48,177
Washington	457	23	2,220,766	660,357	21,455,978
Weld	11,861	877	182,996,149	12,334,121	7,022,304
Yuma	2,684	555	37,111,123	0	3,375,324
<b>Totals</b>	<b>16,774</b>	<b>1,500</b>	<b>234,630,779</b>	<b>14,242,088</b>	<b>46,758,757</b>

## Phase III Methodology Diagram for D-J Basin



# Sample Unpermitted Source Survey – Completion Venting

3a. 2006 Re Completions

		Total Re Completions Conducted in 2006
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2b. Re completion Details if provided for a representative well(s).

Completions							Controls				
Survey ID	Representative Well	Representative Well ID	No. Wells Represented	Count(ies)	Field	Basin	Volume of Gas Vented (MCF) uncontrolled	Controls Used (Y/N)	Type of Control (Flaring / Green Completion)	Green Completion Control Efficiency	Volume Flared (MCF)
<i>Ex. Well 1</i>	<i>representative</i>	<i>abc-1</i>		<i>Logan</i>		<i>Denver-Julesburg</i>					
Well 1	representative					Denver-Julesburg					
Well 2	representative					Denver-Julesburg					
Well 3	representative					Denver-Julesburg					

- **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

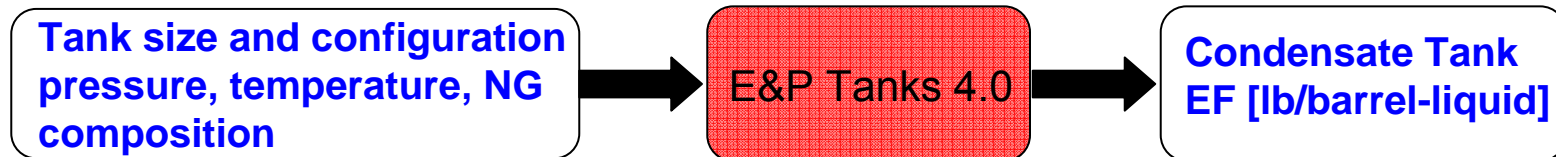
$$E_{drilling,rig} = \sum \frac{EF_i \times HP \times LF \times t_{drilling}}{907,185}$$

- Drilling rig engine emissions factors assumed to be Tier 0 and fully deteriorated
- Engine-specific average load factor used throughout drilling event
- Typical rig composed of 3-6 engines, each with horsepower ranging from 300-1500 HP
- 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]
- Typical small condensate tank EF derived by defining average tank characteristics

$$E_{exempt,tanks,outside} = \frac{P_{exempt,tanks} \times EF_{exempt,tanks}}{2000}$$

- 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

## Estimation Methodology – Vented Sources

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

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

$$E_{venting,BASIN} = E_{venting,TOTAL} \frac{W_{TOTAL}}{W}$$

- 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)

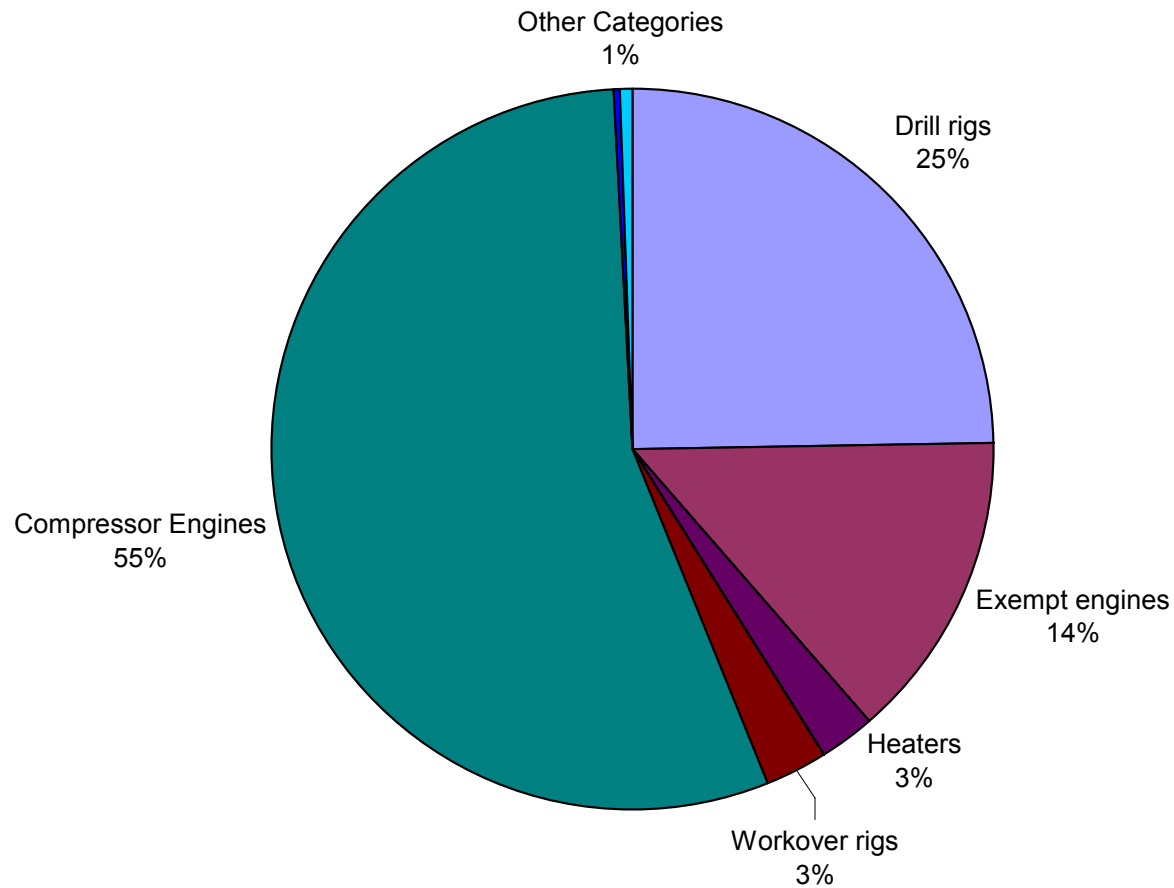
## Results – Criteria Pollutant Emissions

- Oil and gas production a significant source of NO<sub>x</sub>, VOC, CO emissions
- SO<sub>x</sub> 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

County	NO <sub>x</sub> [tons/yr]	VOC [tons/yr]	CO [tons/yr]	SO <sub>x</sub> [tons/yr]	PM [tons/yr]
Adams	2,286	3,005	939	13	19
Arapahoe	742	408	253	0	4
Boulder	129	803	76	1	4
Broomfield	14	193	10	0	0
Crowley	63	1	85	0	1
Denver	32	103	19	0	2
Elbert	43	363	27	0	1
Fremont	16	329	9	0	1
Jefferson	6	0	10	0	0
Kit Carson	10	139	6	0	1
Larimer	37	651	23	0	1
Lincoln	14	462	11	0	0
Logan	491	1,382	183	2	9
Morgan	672	883	672	132	4
Phillips	40	47	26	0	1
Sedgwick	1	11	0	0	0
Washington	284	4,509	207	1	9
Weld	12,310	64,111	8,393	51	421
Yuma	3,592	4,359	1,993	24	158
<b>Totals</b>	<b>20,783</b>	<b>81,758</b>	<b>12,941</b>	<b>226</b>	<b>636</b>

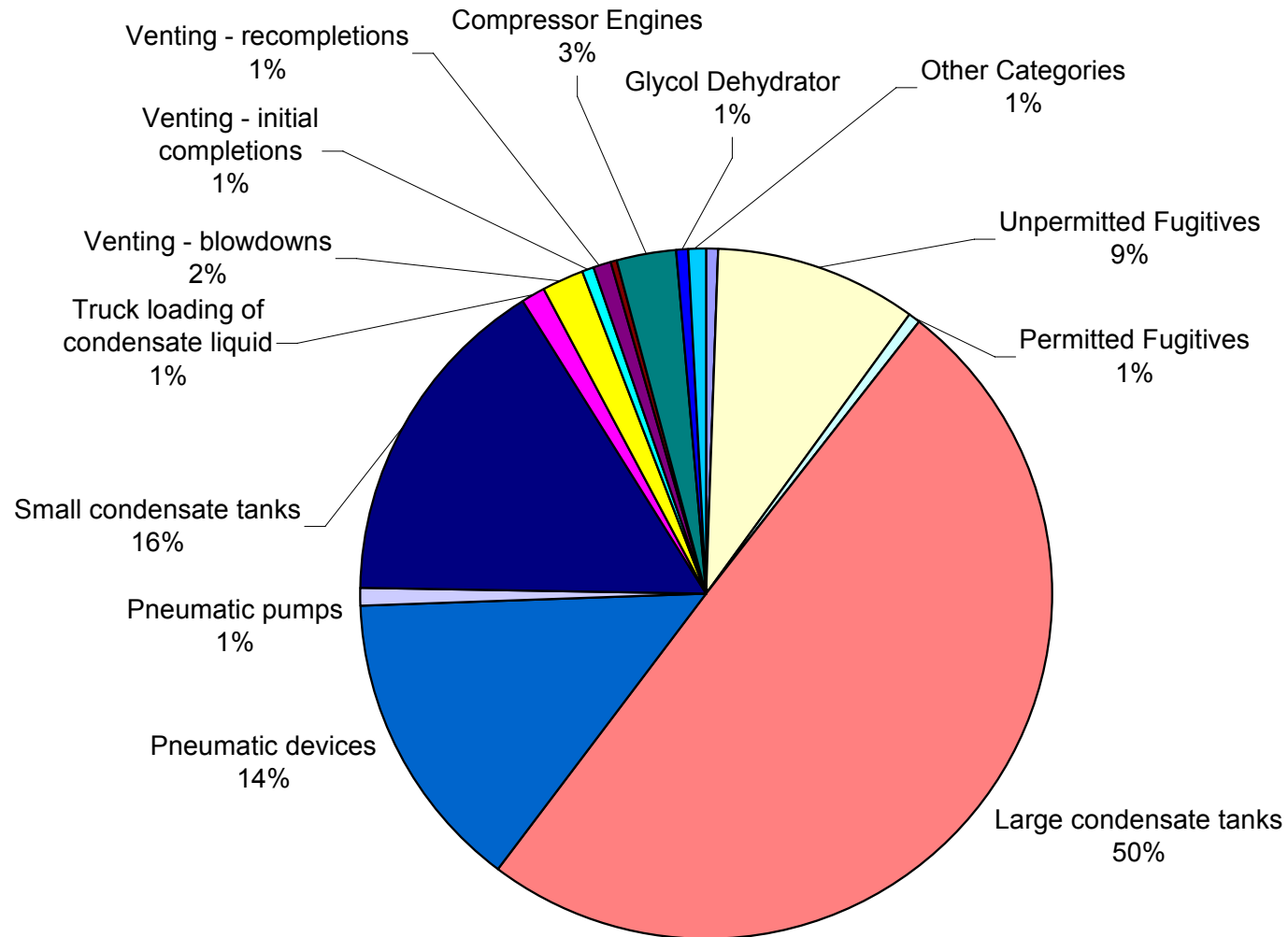


# Results – NOx Emissions By Source Category



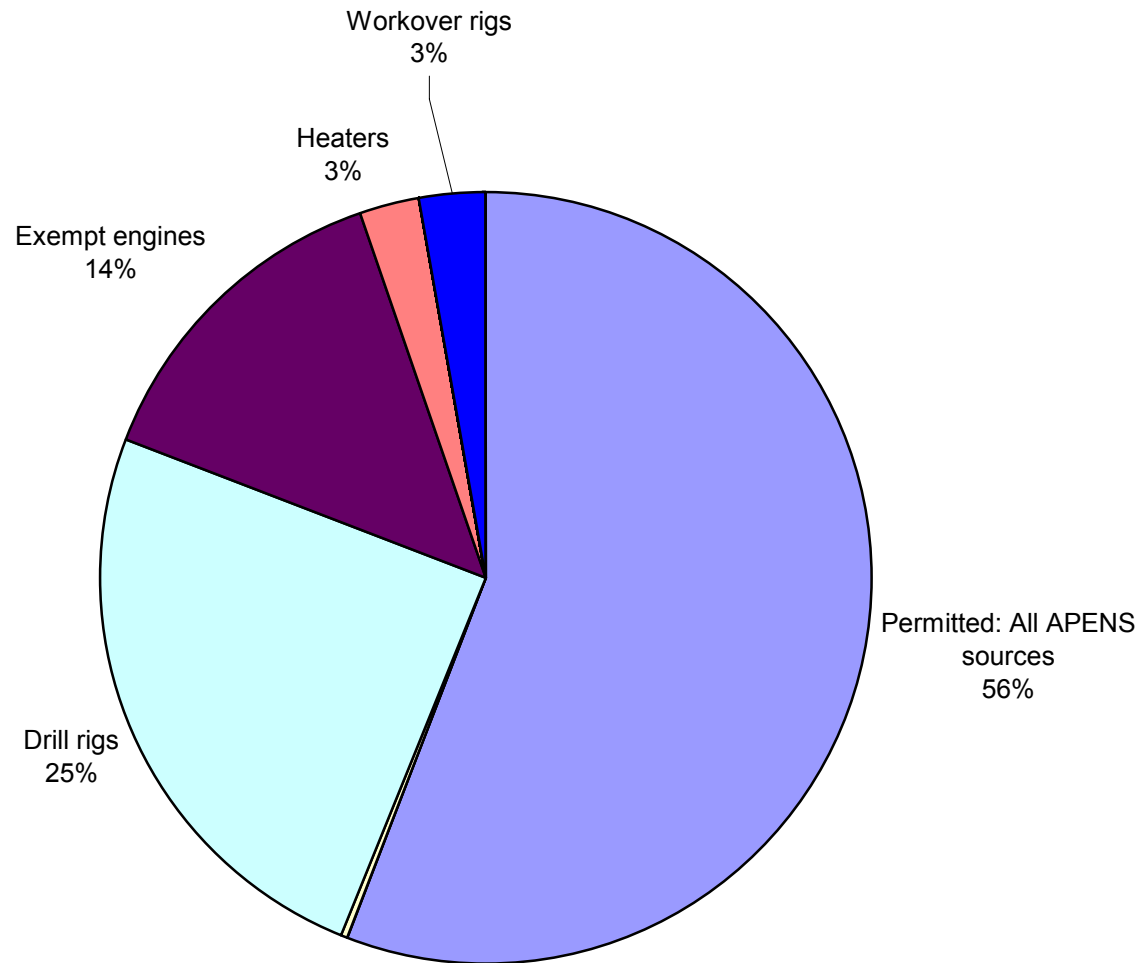
- NOx emissions dominated by compressor engines (central and wellhead) and drill rigs

# Results – VOC Emissions By Source Category



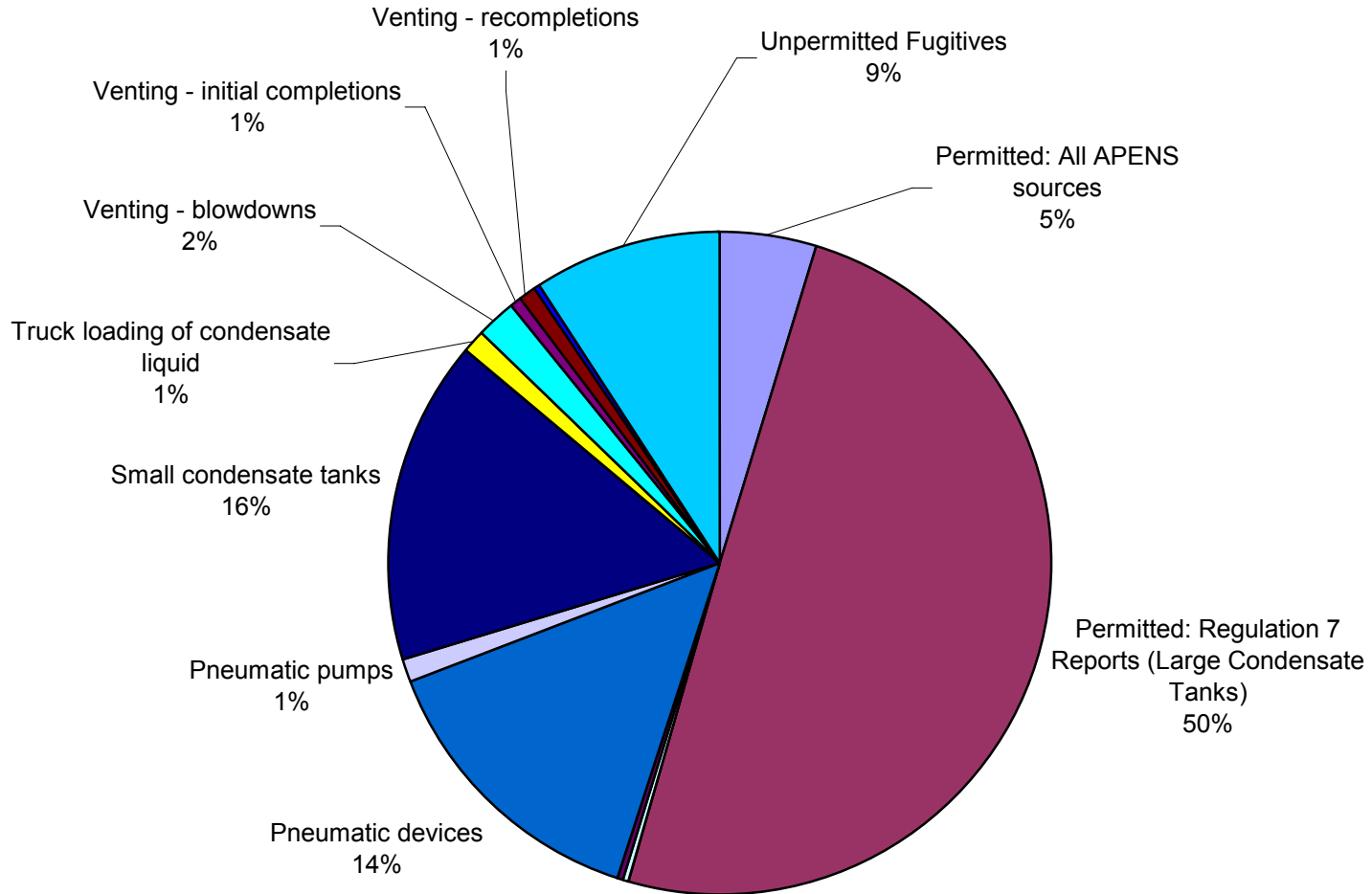
• Top VOC source categories include condensate tanks, pneumatic devices and fugitives

## 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 uninventoried unpermitted sources

## 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**
- Next steps – generation of mid-term (2010) and far-term (2018, 2020) emissions projections for D-J Basin

## Acknowledgements

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## 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 rates corrected for local variations in heat content of gas
- Heater firing rate in [BTU/hr] provided for various heater types by survey respondents
- 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

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

- 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

$$E_{engine,TOTAL} = E_{engine} \frac{W_{TOTAL}}{W}$$

- 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