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A Comprehensive Emissions Inventory of Upstream Oil and Gas Activities in the Rocky Mountain States

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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**

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History of Oil and Gas EIs – WRAP Phases I & II

- **Represented the first regional inventories 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, with focus on compressor engines and drilling rigs**

History of Oil and Gas EIs – 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

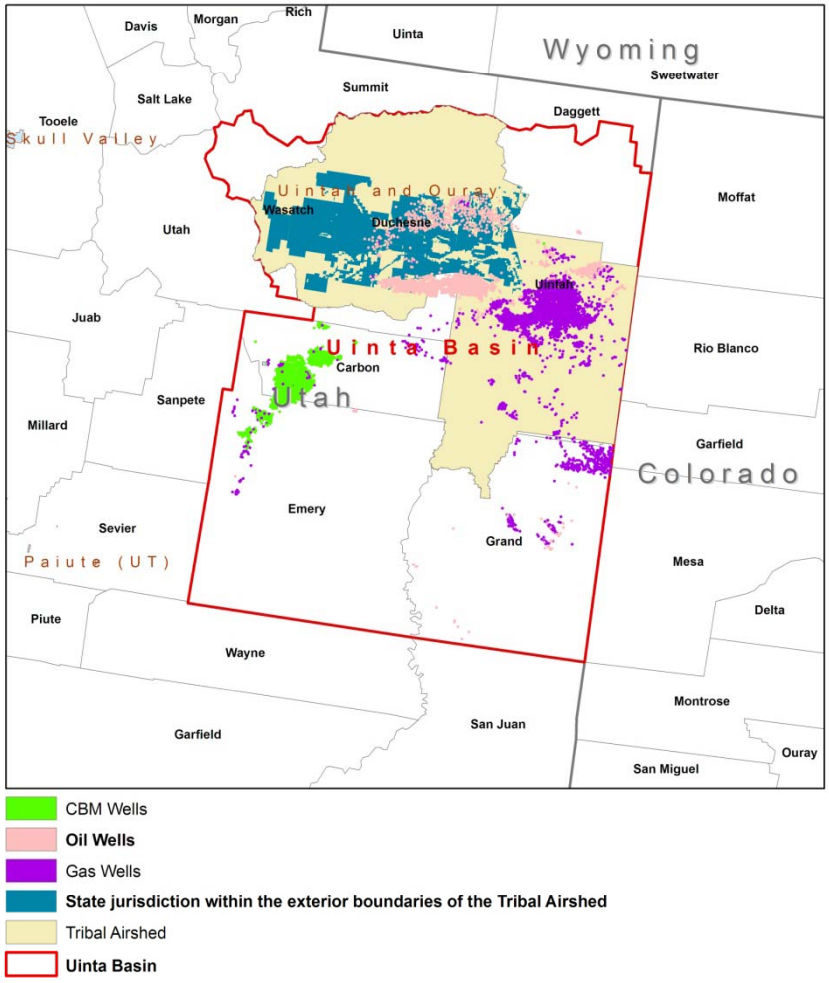
- **Considers every major oil and gas production basin in the Rocky Mountain states, including New Mexico, Utah, Colorado, Wyoming, Montana and North Dakota**
- **Considers all major oil and gas source categories and all major criteria pollutants: NOx, VOC, CO, PM, SOx**
- **Updated, regionally consistent 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 (acid gas removal)**
- **Water Tanks**

Geographic and Temporal Scope

Uinta Basin - 2006 Well Location



- **Scope of study includes the South San Juan (NM), North San Juan (CO), Denver-Julesburg (CO), Piceance (CO), Uinta (UT), Southwest Wyoming (WY), Wind River (WY), Powder River (WY), Great Plains (MT) and Williston (MT & ND) Basins**
- **To date 6 basin inventories have been completed – remaining basins are the Williston, Powder River and Southwest Wyoming**
- **For all basins the boundaries of the basins have been aligned with county boundaries**
- **All basins are analyzed for tribal and non-tribal inventories (where applicable)**
- **Baseline inventories developed for 2006 with midterm projections to 2012 (for D-J Basin projections to 2010)**

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Basin Oil and Gas Statistics

Basin	Well Count			Oil Production (bbl)			Gas Production (MCF)			Spud Counts
	total	CONV	CBM	Total	Oil Well Oil	Gas Well Condensate	Total	CONV	CBM	Total
D-J Basin	16,774	16,774	0	14,242,088	0	14,242,088	234,630,779	234,630,779	0	1500
Uinta Basin	6,881	6,018	863	11,528,121	9,758,247	1,769,874	331,844,336	254,219,432	77,624,904	1069
Piceance Basin	6,315	6,255	60	7,158,305	5,755,076	1,403,229	421,358,666	420,165,237	1,193,429	1186
North San Juan Basin	2,676	1,009	1,667	32,529	27,962	4,567	443,828,500	28,642,418	415,186,082	127
South San Juan Basin	20,649	16,486	4,163	2,636,811	1,002,060	1,634,751	1,020,014,851	520,060,869	499,953,982	919
Wind River Basin	1,350	1,330	20	3,043,459	2,563,912	479,547	198,190,024	197,166,868	1,023,156	98

Red figures are greatest value in each column, showing spatial variation in O&G E&P operations

- **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 – oil production is in historic decline**
- **Spud counts are surrogates for where greatest exploration and production activity was occurring in 2006**

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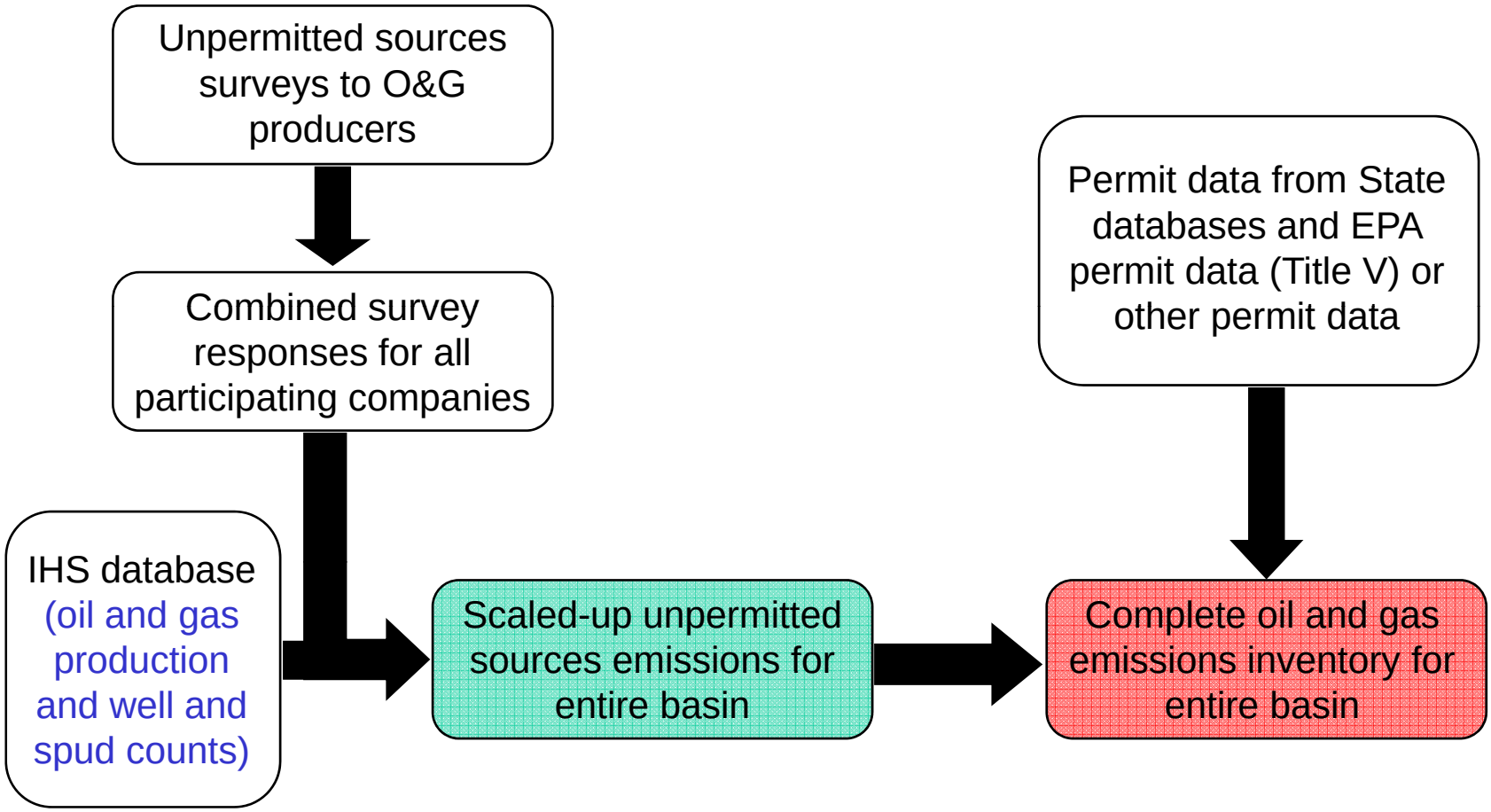
Phase III Methodology Diagram



State Permitting Thresholds

State	Emissions Thresholds (tons/yr)	Comments
New Mexico	Notice of Intent Required for Facilities with Emissions > 10tpy Criteria Pollutants; Permits Required for Facilities > 25 tpy	Due to technical issues with the permit data, only major source facility permits (> 100 tpy) were used in New Mexico
Colorado	Permits Required for All Sources with Emissions > 2 tpy Criteria Pollutants	Air Permit Emission Notices (APENs) used for all sources with emissions > 2 tpy
Utah	Permits Required for All Sources with Potential to Emit (PTE) > 100 tpy	Sources subject to NSPS or with HAPs emissions at 10 tpy for one pollutant or 25 tpy for combination of HAPs must be issued permits
Wyoming	Combustion Sources: Engines with HP < 200 (Equivalent to Approx. 1 tpy NOx) Permit Not Required; Oil and Gas Process Sources (Tanks and Dehydration): 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)	Wyoming permit data treated separately depending on the development region: the Jonah-Pinedale Anticline Development (JPAD) area; the "concentrated" development area including seven Counties in SW WY; and state-wide development areas.
Montana	Permits Required for All Sources with Potential to Emit (PTE) > 25 tpy	
North Dakota	Permits Required for All Sources with Potential to Emit (PTE) > 100 tpy	Permit data available on facilities with actual emissions > 25 tpy

- **Wide variation in permitting thresholds from state to state, in source categories permitted, and regional variations in state permit requirements within states**

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 – 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)

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Results – Criteria Pollutant Emissions

- **Oil and gas production a significant source of NOx, VOC, CO emissions, particularly in rural counties**
- **NOx emissions primarily result from wellhead and centralized compression**
- **VOC emissions contributions from many different processes including tank flashing, dehydration and pneumatics**
- **SOx and PM emissions minor in most basins and primarily driven by drill/workover rigs (sour gas production in some basins)**

Basin	Emissions (tons/yr)				
	NOx	VOC	CO	SOx	PM
D-J Basin	20,783	81,758	12,941	226	636
Uinta Basin	13,093	71,546	8,727	396	623
Piceance Basin	12,390	27,464	7,921	314	992
North San Juan Basin	5,700	2,147	6,450	15	52
South San Juan Basin	42,075	60,697	23,471	305	574
Wind River Basin	1,814	11,981	2,840	1,792	37

Red figures are greatest value, showing spatial variation in O&G E&P emissions

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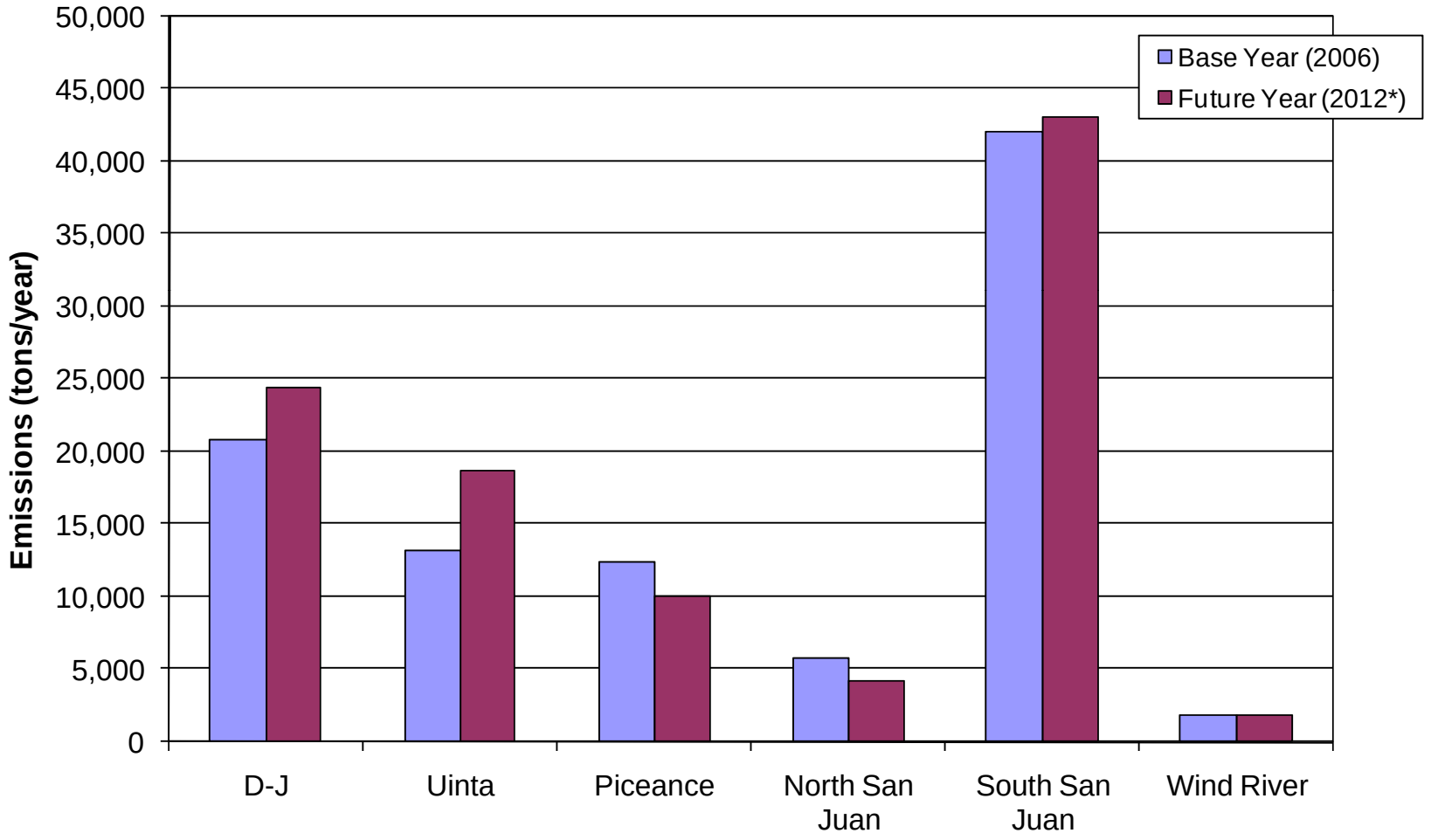
Results – NOx Emissions



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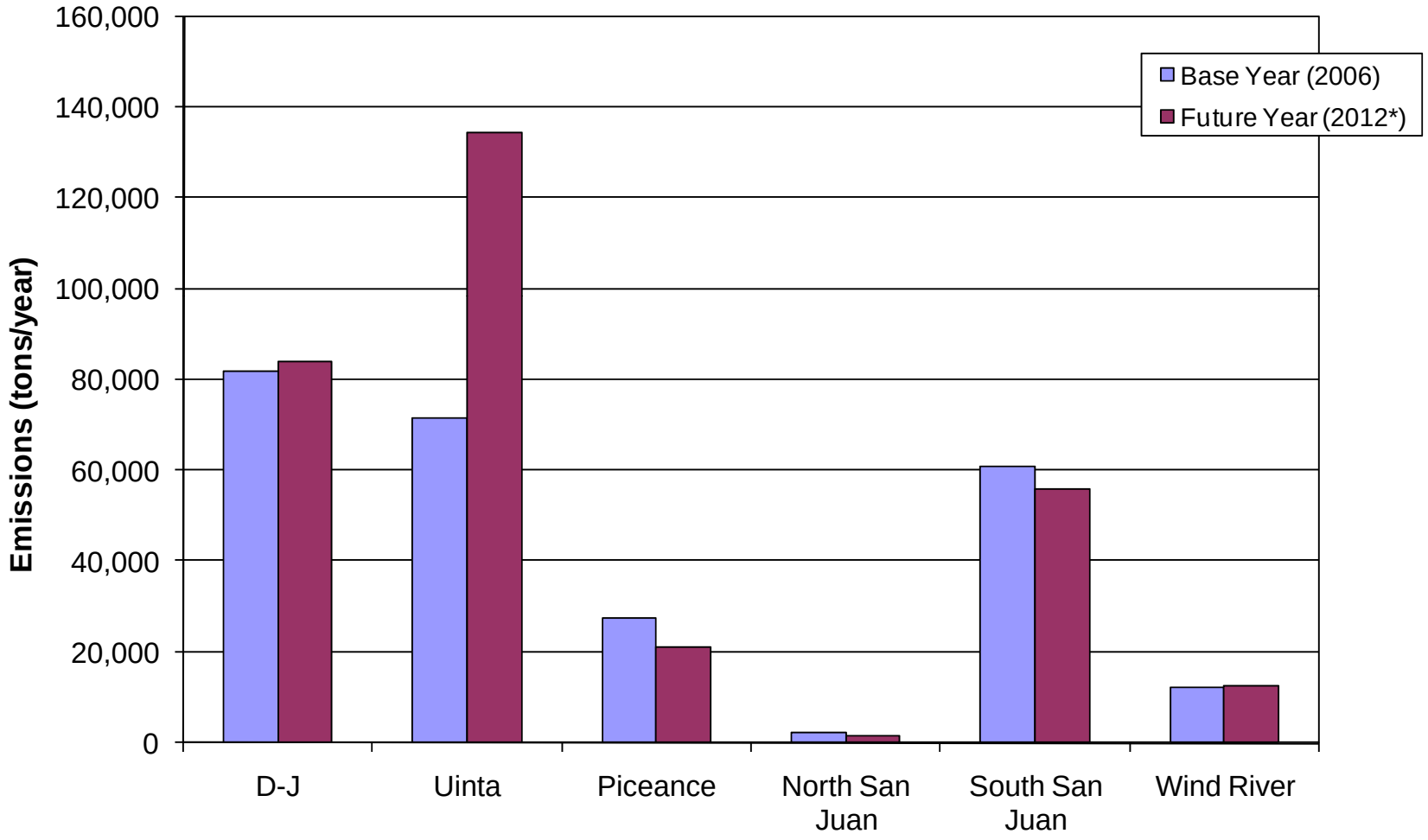
Results – VOC Emissions



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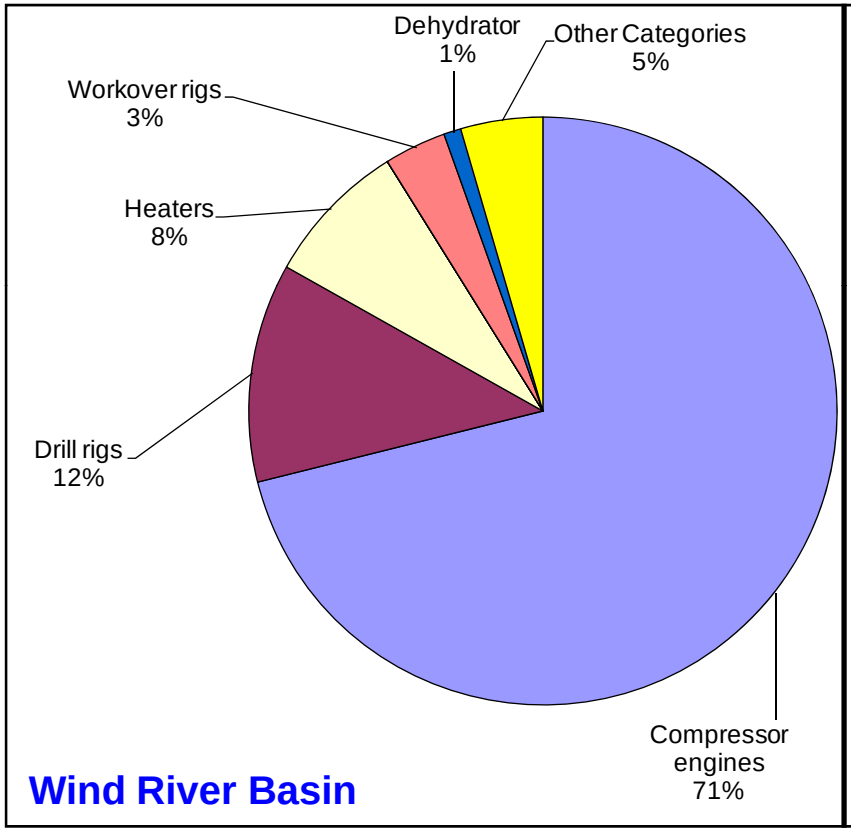
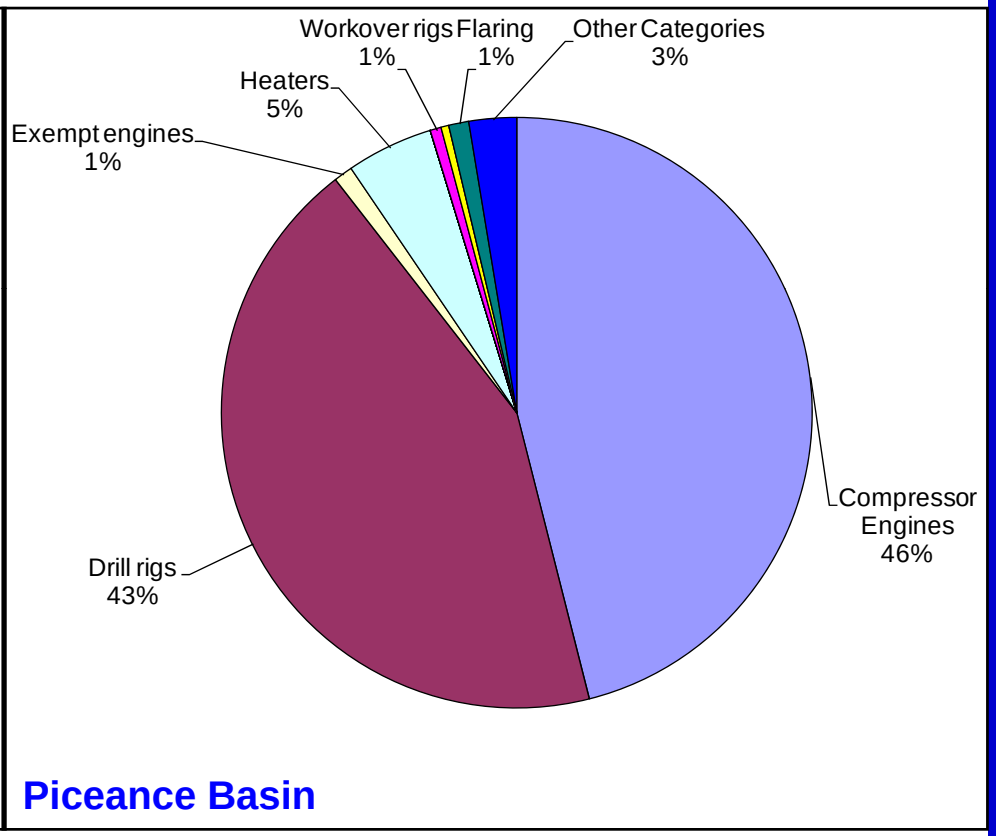
Results – Example NOx Emissions Breakdown By Source Category



Wind River Basin



Piceance Basin

- **NOx emissions primarily comprised of compressor engines (central and wellhead) and drill rigs for basins in which active drilling was occurring in 2006**

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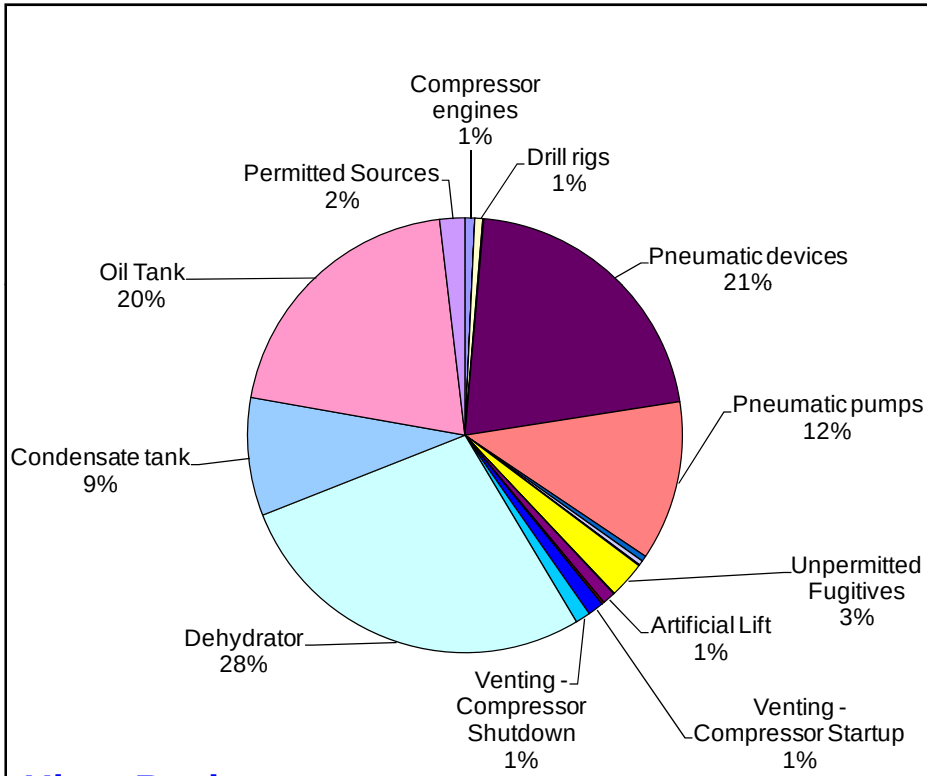
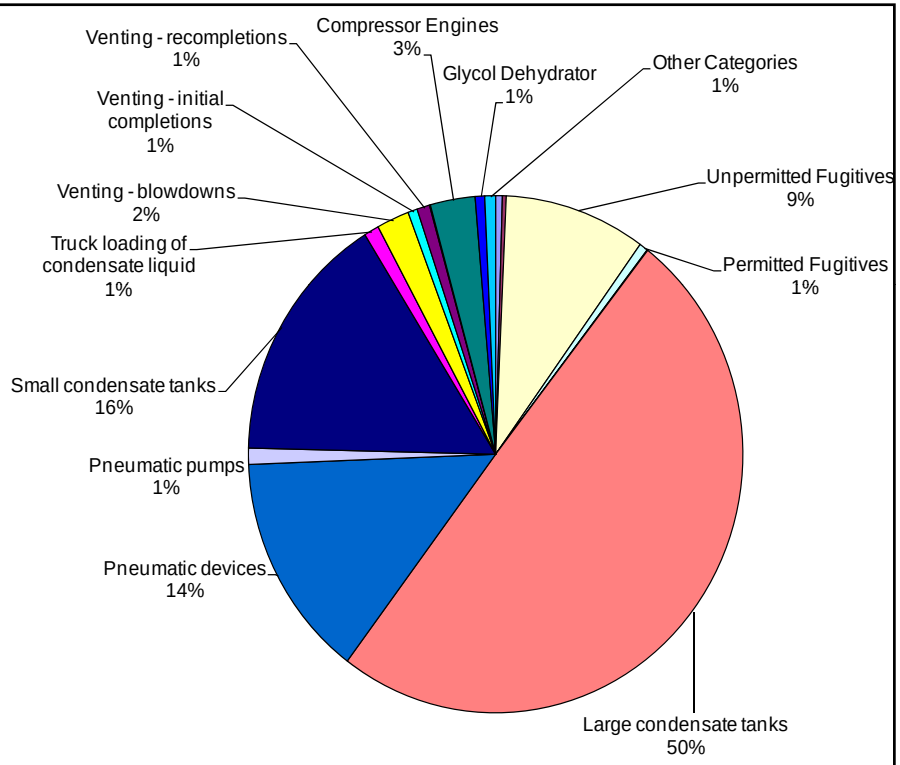
Results – Example VOC Emissions Breakdown By Source Category



Uinta Basin



Denver-Julesburg Basin

- **VOC emissions sources vary significantly from basin to basin – tank flashing, dehydration and pneumatic devices are consistently large source categories in most basins**

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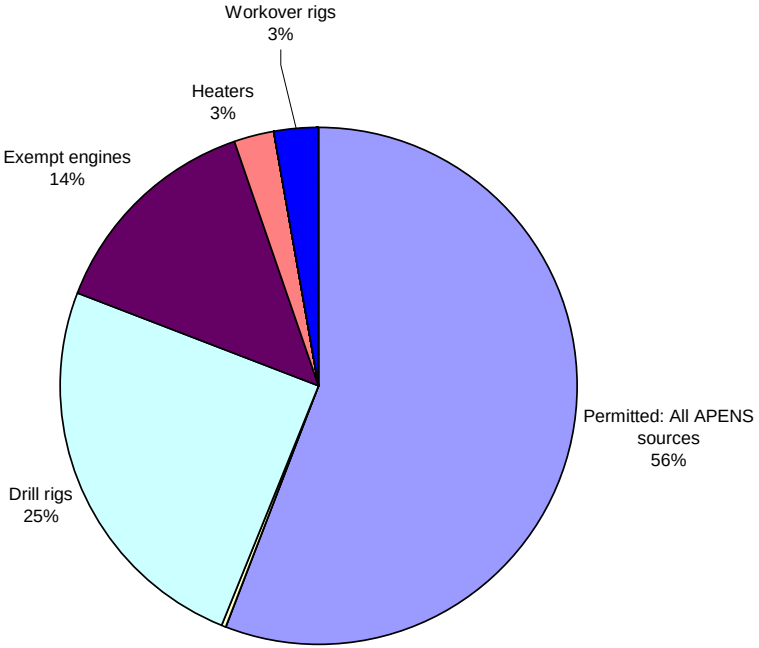
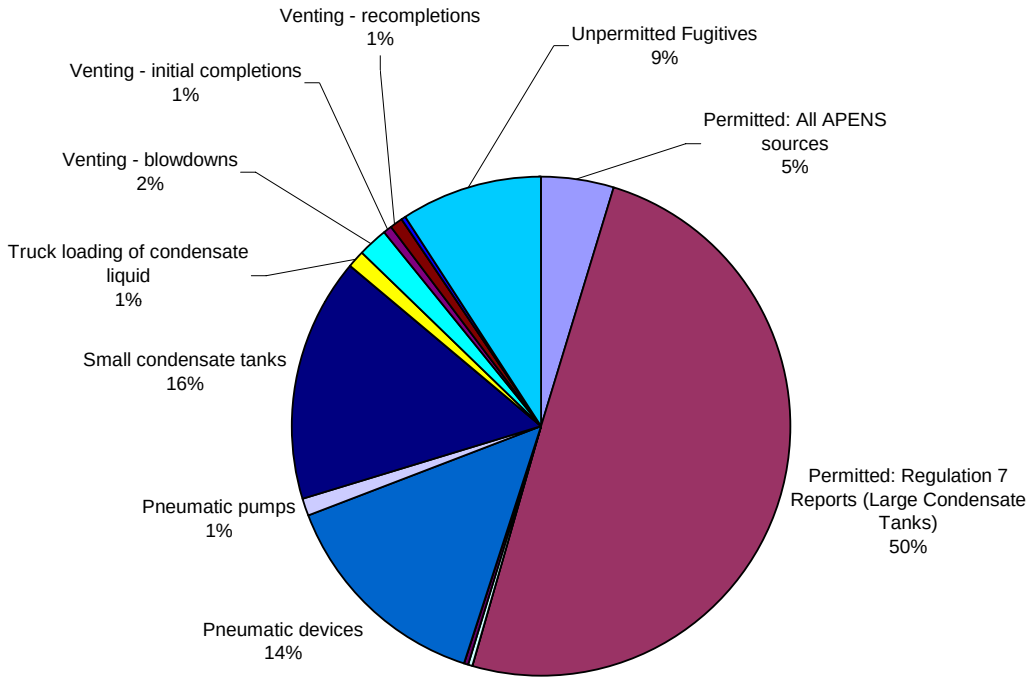
Results – Example Permitted vs. Unpermitted NOx and VOC Emissions



NOx Emissions – D-J Basin



VOC Emissions – D-J Basin

- **For the D-J Basin example both NOx and VOC emissions from unpermitted sources are approximately 45% of the basin-wide total emissions**
- **Unpermitted sources represent a significant contribution to total basin emissions even in Colorado where the permitting threshold is 2 tpy**

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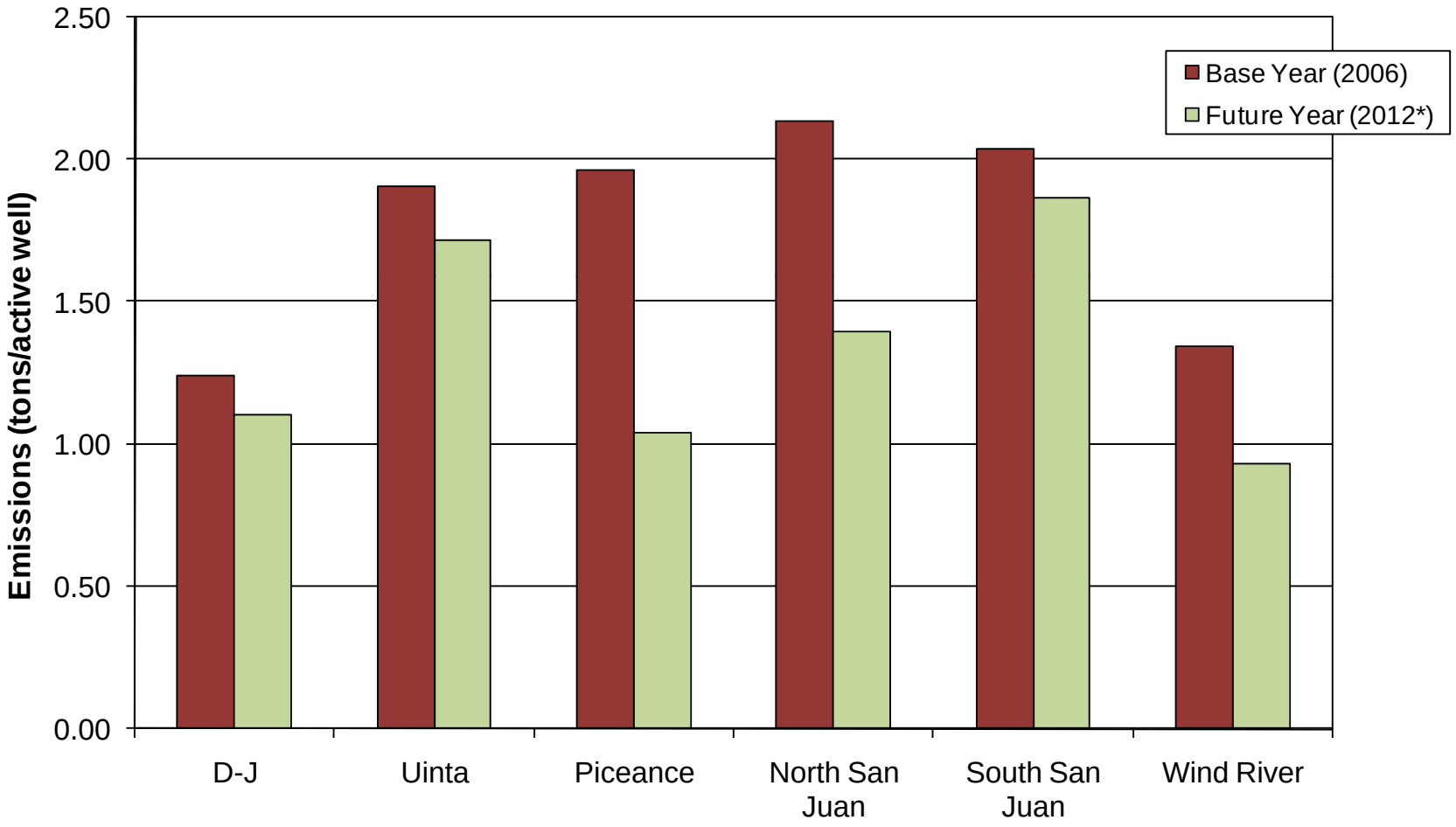
Results – Per-Well NOx Emissions



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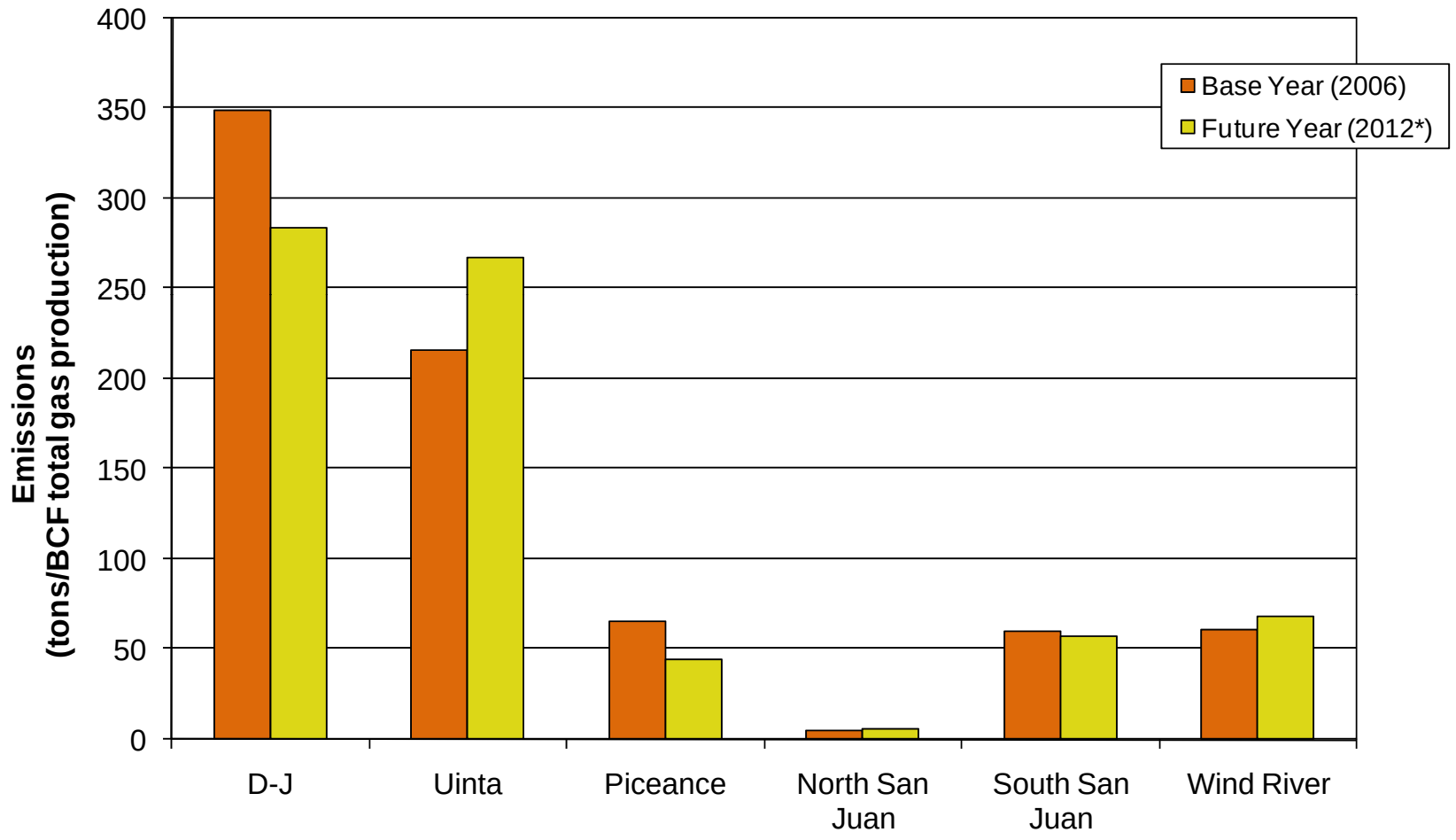
Results – Per-Unit-Gas-Production VOC Emissions



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Inventory Findings

- **Wide range of NOx, VOC emissions between basins for the six basins completed thus far – indication that basin-level inventories are necessary to capture regional differences in activity and production levels**
- **NOx emissions per well are relatively consistent among basins, driven by the number of active wells and number/size of equipment – differences in some basins are due to a combination of regulatory requirements for compressor engines and the relative level of activity of drilling rigs**
- **VOC emissions per well vary widely across basins – highest values are for the D-J and Uinta Basins which have significant oil and condensate production, indicating that tank flashing emissions are significant for these basins**
- **SOx emissions are driven primarily by off-road diesel fuel use (declining in the near future with EPA diesel fuel sulfur rules) and sour gas production – thus far only the Wind River Basin has significant sour gas production**
- **Inventories are capable of capturing significant unpermitted and unreported emissions for both NOx and VOC – even in states where the permitting threshold is low**

Related Future Work

On-road & off-road mobile sources' emissions associated with exploration & production activity, beyond drilling & workover rigs

- Piceance Pilot Project (P3) for Piceance Basin in northwest Colorado
- Tailpipe exhaust, fuel evaporative emissions and particulate from tire/brake wear and paved/ unpaved road dust generated from vehicular activity
- Activity types include employee access, management and equipment service traffic, light and heavy duty delivery vans, heavy duty construction equipment
- Piceance mobile source EI results to be compared against the point & area emissions to evaluate the significance of the mobile source emissions
- Project will provide "unit operation" factors to help improve estimates in other O&G basins in the Rocky Mountain west
- Sponsored by States of Colorado, New Mexico, Utah, and Wyoming, and funded through EPA's Energy Overtarget program

Related Future Work

- **Update Phase III data from 2006 baseline to Phase IV 2009 baseline**
  - Triennial updates to keep inventories current for emissions trends/air quality planning
- **Use of Phase III Oil & Gas inventory in regional analysis of potential control strategies for states impacted by O&G operations**
  - States will need to comply with increasingly stringent ambient air quality standards for ozone, particulate and other pollutants
- **Bureau of Land Management (BLM) does O&G development review and leasing for minerals under both public & private lands**
  - Majority of western O&G operations are on public lands
  - BLM typically conducts Environmental Assessments or Environmental Impact Statements under the National Environmental Policy Act
  - Historically EA/EIS evaluations have been conducted in isolation, using emission inventories compiled for that particular project, without full consideration of the impacts of other projects in the region
  - Use WRAP Phase III inventories and triennial updates, regionally consistent in calculation methodology and assumptions for periodic cumulative analyses of planned and leased energy development, to assist states and federal agencies with air quality planning