Upstream Oil and Gas Emission Inventories in the Inter-Mountain West

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National Tribal Forum on Air Quality
Swinomish Indian Tribal Community, Anacortes, WA
May 14, 2014

Overview

- Emission inventories – background
- History of O&G emission inventory development
- WRAP Phase III inventories
- Technical methodology
- Results for an example basin
- Cross-basin comparisons
- Regulatory approach
- Emission inventory issues – improvements and new concepts

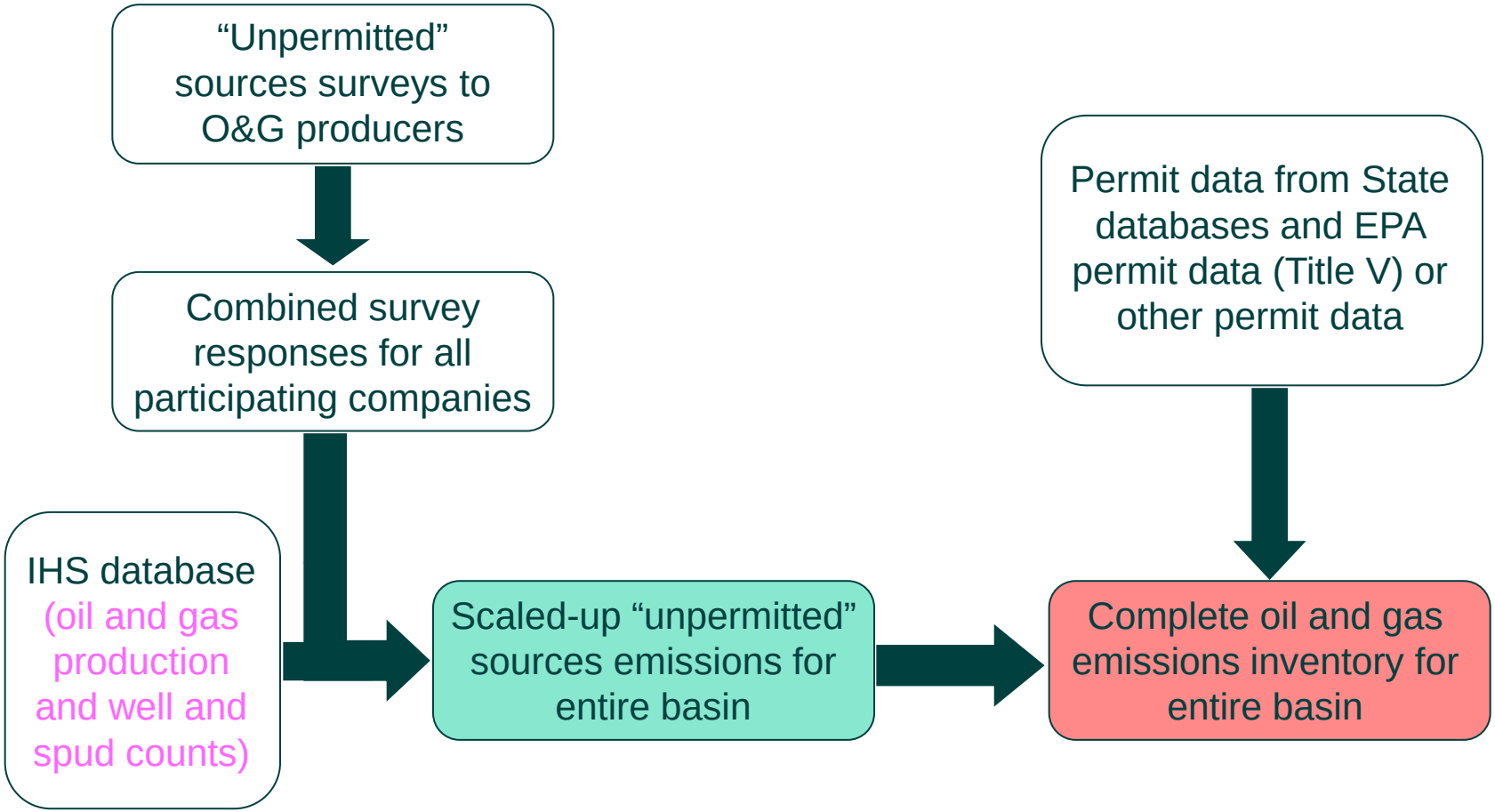
Emissions Inventories

- Emissions are what is regulated, not ambient air quality - through:
  - Limits on permitted sources and tracking of actual emissions
    - Strategies that address group or types of sources by specifying technology for operations (fuels, turnover of technology) or controls (specified emissions limits)
    - Fees for permitted sources allow regulators to recover costs to issue, inspect, and monitor impacts
  - Reporting and analysis of inventory data allows trend and compliance tracking – done for multiple purposes
    - A heightened effort is required to build and understand a baseline historical period inventory for a modeling study
    - Modeling studies also require projections of future emissions to assess control programs to efficient emissions reduction strategies

WRAP Phase III Inventories

- First regionally-consistent O&G inventory study in the Intermountain West
  - First inventory to cover all criteria pollutants (NOx, VOC, SOx, CO, PM)
- Scope of study includes 9 major basins: South San Juan (NM), North San Juan (CO), Denver-Julesburg (CO), Piceance (CO), Uinta (UT), Southwest Wyoming (WY), Wind River (WY), Powder River (WY), and Williston (MT & ND) Basins
  - All 9 basins completed as of June 2013
  - Production on tribal lands in 5 of 9 Basins
- Baseline inventories developed for 2006 with midterm projections to 2012 or 2015
- Baseline updates to 2008 for WestJump AQMS – more updates planned

Phase III Methodology Diagram



Phase III Methodology

Unpermitted sources surveys to O&G producers

3a. 2006 Recompletions

	Total Recompletions Conducted in 2006

2b. Recompletion 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)
Ex. Well 1	*representative*	*abc-1*		*Logan*		*Denver-Julesburg*					
Well 1	representative					Denver-Julesburg					
Well 2	representative					Denver-Julesburg					
Well 3	representative					Denver-Julesburg					

- **Detailed spreadsheet-based surveys sent to major operators in each basin**
- **Not all sources surveyed are “unpermitted”**

Phase III Methodology

Scaled-up "unpermitted" sources emissions for entire basin

Basin	Percentage Ownership in Phase III		
	Gas	Liquid	Wells
D-J	63%	58%	50%
Piceance	84%	91%	75%
Uinta	82%	78%	71%
North San Juan	85%	93%	87%
South San Juan	82%	48%	67%
Wind River	97%	23%	54%
Southwest Wyoming	77%	64%	54%
Powder River	46%	24%	30%
Williston	30%	33%	20%

- **Survey respondents in Phase III do not represent all production in a basin**
- **Scale-up of survey data necessary to capture all activity**

Phase III Methodology

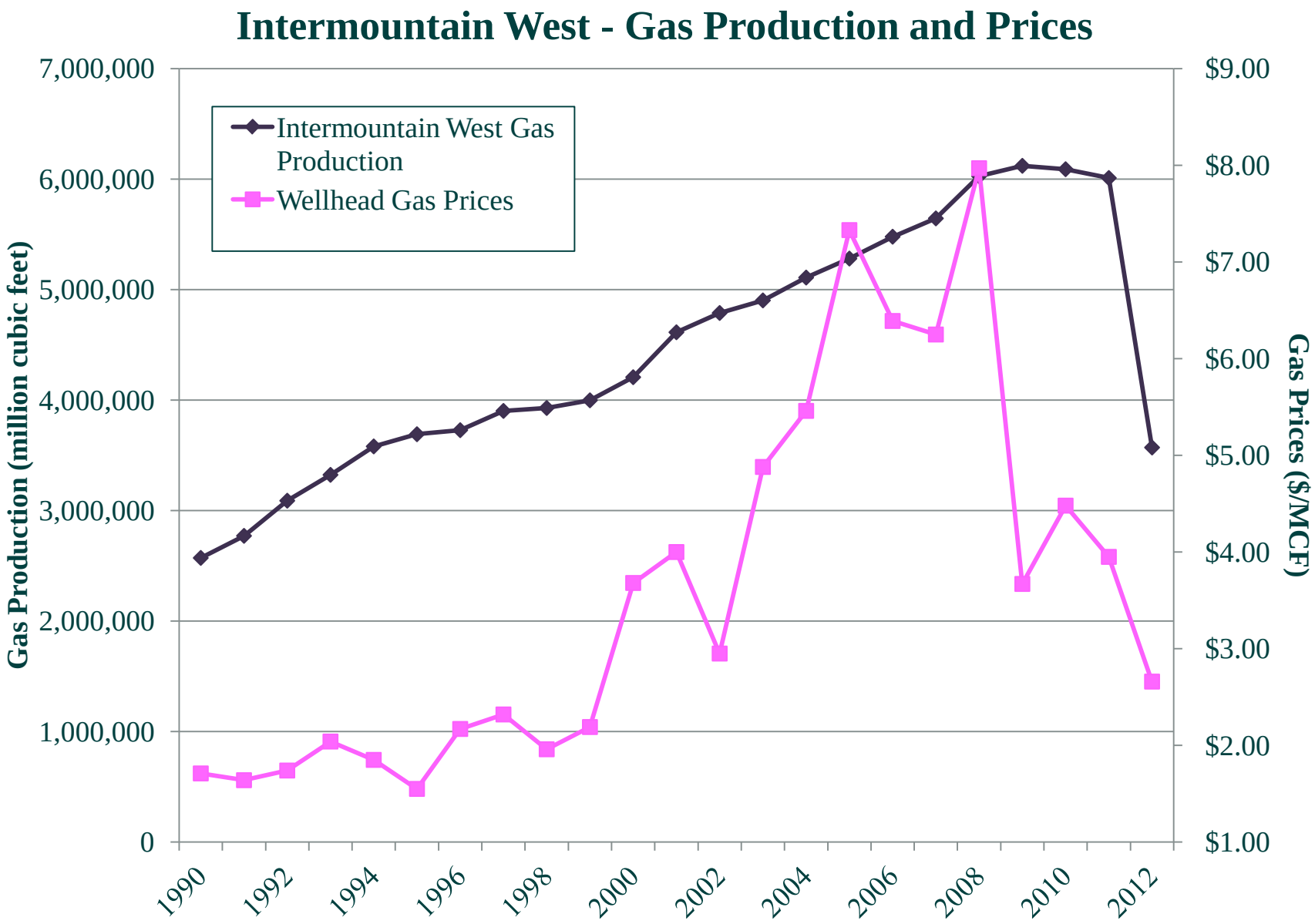
Permit data from State databases and EPA permit data (Title V) or other permit data

State	Emissions Thresholds (tons/yr)
New Mexico	Notice of Intent Required for Facilities with Emissions > 10tpy Criteria Pollutants; Permits Required for Facilities > 25 tpy
Colorado	Permits Required for All Sources with Emissions > 2 tpy Criteria Pollutants
Utah	Permits Required for All Sources with Potential to Emit (PTE) > 100 tpy
Wyoming	Combustion Sources: All Compressor Engines Require Permit; Oil and Gas Process Sources : 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 or CDA)
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

- **Wide variation among states in permitting/reporting thresholds**
- **Now adding well-level data from EPA Tribal Minor Source reporting requirements**

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


Intermountain West - Gas Production and Prices
Intermountain West Gas Production
Wellhead Gas Prices
Gas Production (million cubic feet)
Gas Prices ($/MCF)
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
$9.00
$8.00
$7.00
$6.00
$5.00
$4.00
$3.00
$2.00
$1.00
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012

Eastern Utah

2006 Oil and Gas Production

BLM proposed leasing for oil shale development

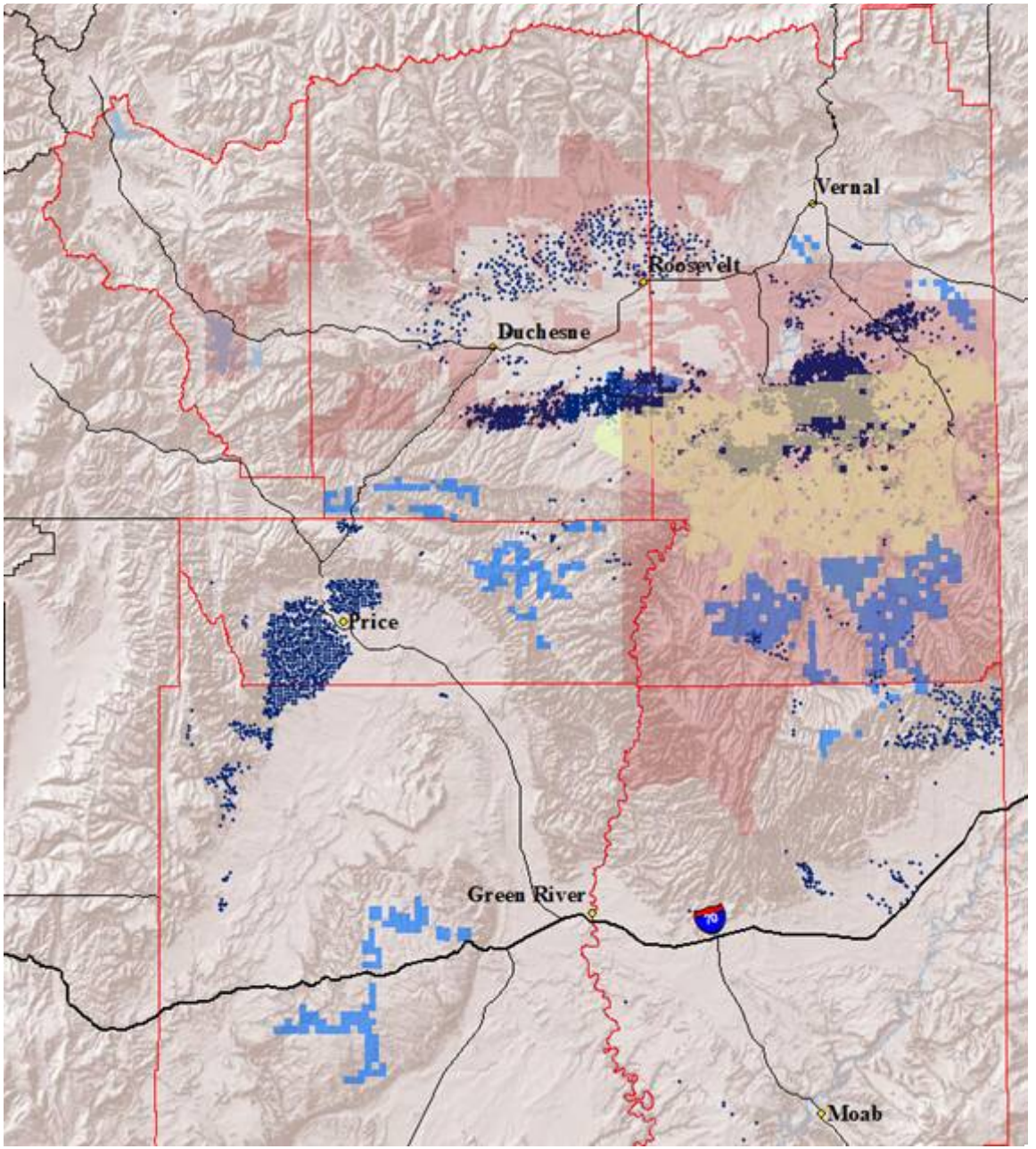
BLM proposed leasing for tar sands development

“Indian Country” – Regulatory authority controlled by the Tribes and EPA

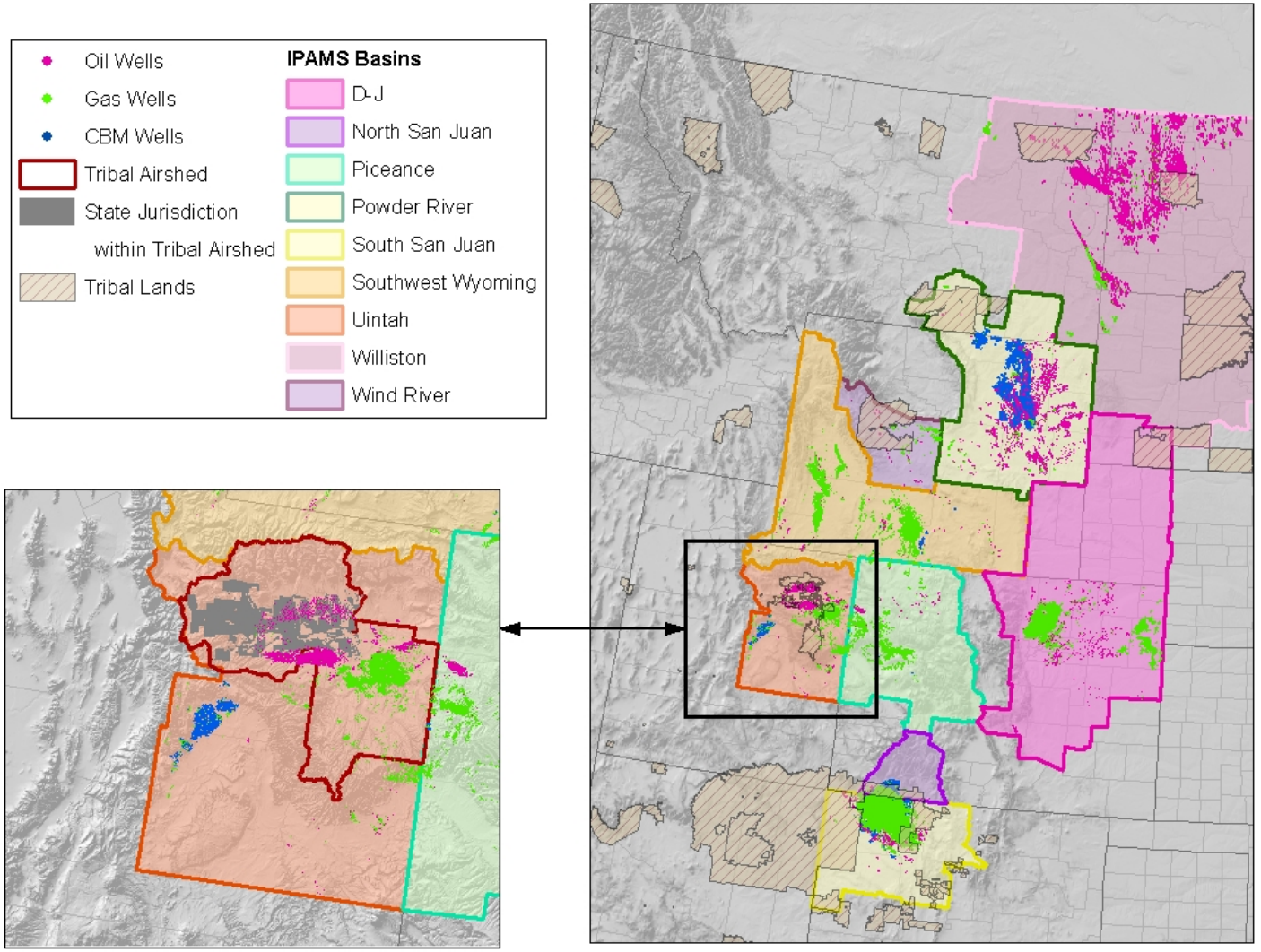
Oil Shale Leasing

Tar Sands Leasing

“Indian Country”



Geographic Extent



Basin Oil and Gas Statistics

2008 Production Statistics

Basin	Well Count				Oil Production (bbl)			Gas Production (MCF)			Spud Counts
	Total	Oil	Non-CBM Gas	CBM	Total	Oil Well Oil	Gas Well Condensate	Total	Non-CBM	CBM	Total
D-J Basin	20,054	3,620	16,434	0	19,363,429	3,428,383	15,935,046	266,919,382	266,919,382	0	1,777
Uinta Basin	8,405	2,658	4,869	878	15,458,217	12,165,460	3,292,757	415,443,288	346,793,180	68,650,108	1,149
Piceance Basin	9,300	644	8,569	87	7,785,316	5,424,924	2,360,392	659,065,078	657,495,707	1,569,371	2,121
North San Juan Basin	2,969	97	1,003	1,869	39,462	31,491	7,971	432,276,612	33,749,342	398,527,270	226
South San Juan Basin	21,776	1,670	15,421	4,685	2,549,679	957,056	1,592,623	951,832,297	499,085,236	452,747,061	585
Wind River Basin	1,389	566	805	18	3,010,316	2,565,847	444,469	141,577,755	137,709,512	3,868,243	53
Powder River Basin	27,256	7,177	544	19,535	18,857,799	18,378,654	479,145	607,467,975	53,887,969	553,580,006	2,086
Southwest Wyoming Basin	11,072	1,143	9,616	313	17,334,716	5,548,836	11,785,880	1,735,260,915	1,718,031,661	17,229,254	1,418
Williston Basin*	8,144	6,623	1,518	3	105,868,409	101,729,112	4,139,297	150,025,060	149,979,559	45,501	716

Red figures are greatest value in each column, showing spatial variation in O&G E&P operations
* Williston Basin production statistics are for 2009

- **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 except the Williston Basin**
- **Spud counts are surrogates for where greatest exploration and production activity was occurring in 2008**

Basin Inventories

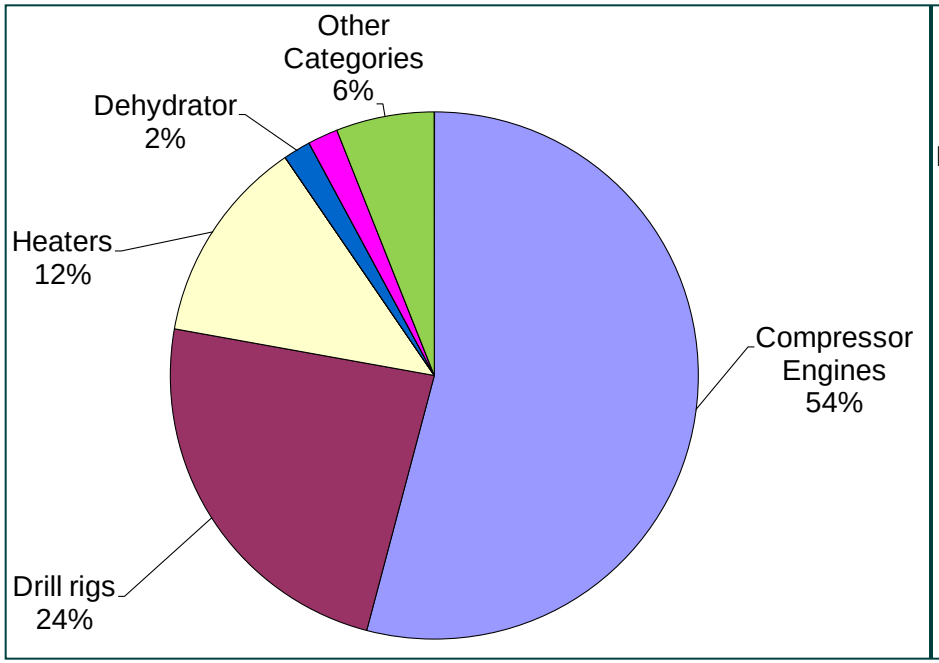
2008 Emission Inventories

Basin	Emissions (tons/yr)				
	NOx	VOC	CO	SOx	PM
D-J Basin	22,165	100,622	14,367	115	717
Uinta Basin	15,508	97,302	11,569	431	716
Piceance Basin	20,113	45,714	11,520	519	1,812
North San Juan Basin	5,917	2,187	6,456	30	72
South San Juan Basin	42,233	54,469	23,602	273	557
Wind River Basin	1,335	10,993	2,062	1,276	31
Powder River Basin	20,980	14,787	15,445	596	666
Southwest Wyoming Basin	23,824	87,374	16,024	6,030	679
Williston Basin*	14,387	357,798	18,765	2,081	1,045

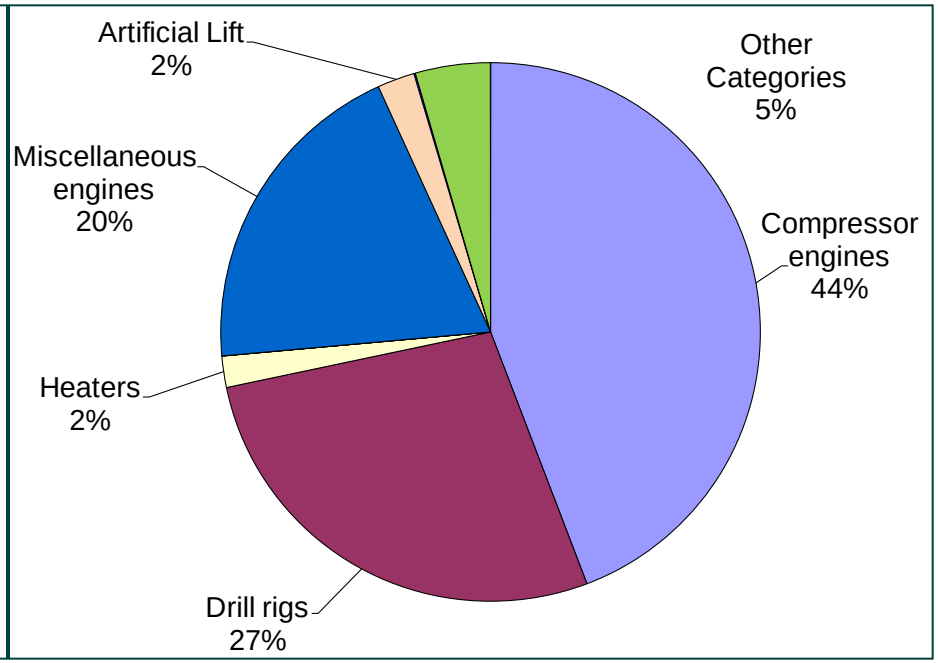
* Williston Basin emissions are for 2009

- **Wide variation in inventories among basins**
- **Drivers for variations include production types (liquid vs. gas, CBM vs. non-CBM, sour vs. sweet gas), regulatory control levels, intensity of activity**

Results – Example NOx Emissions Breakdown By Source Category



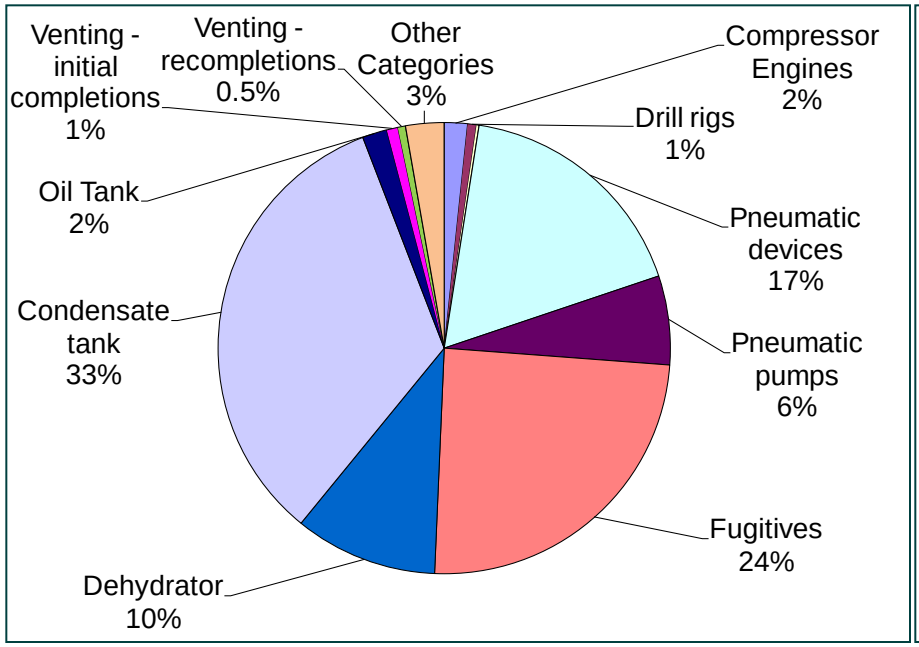
Southwest Wyoming Basin



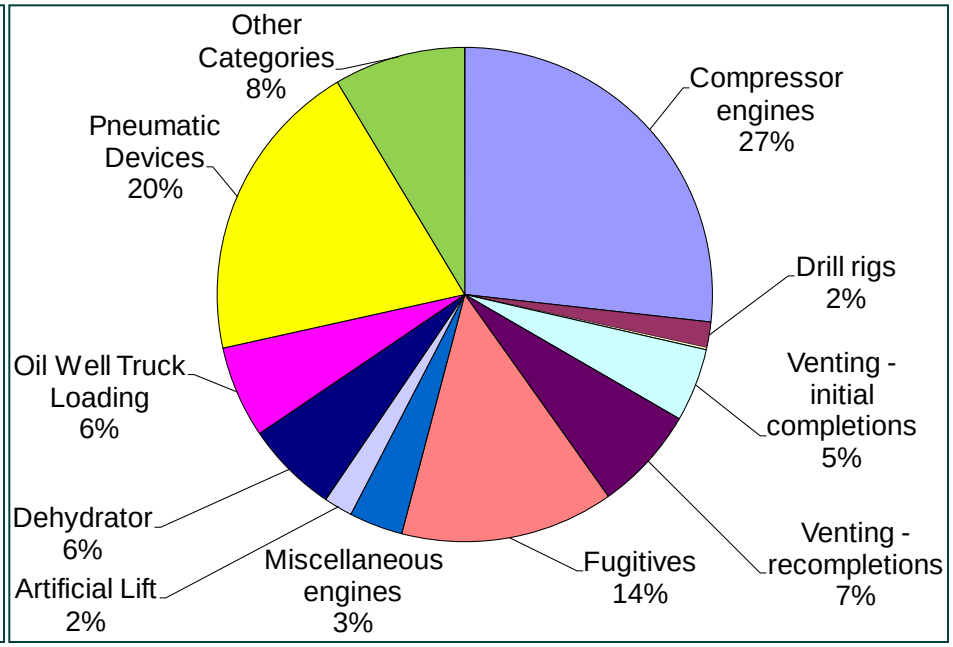
Powder River Basin

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

Results – Example VOC Emissions Breakdown By Source Category



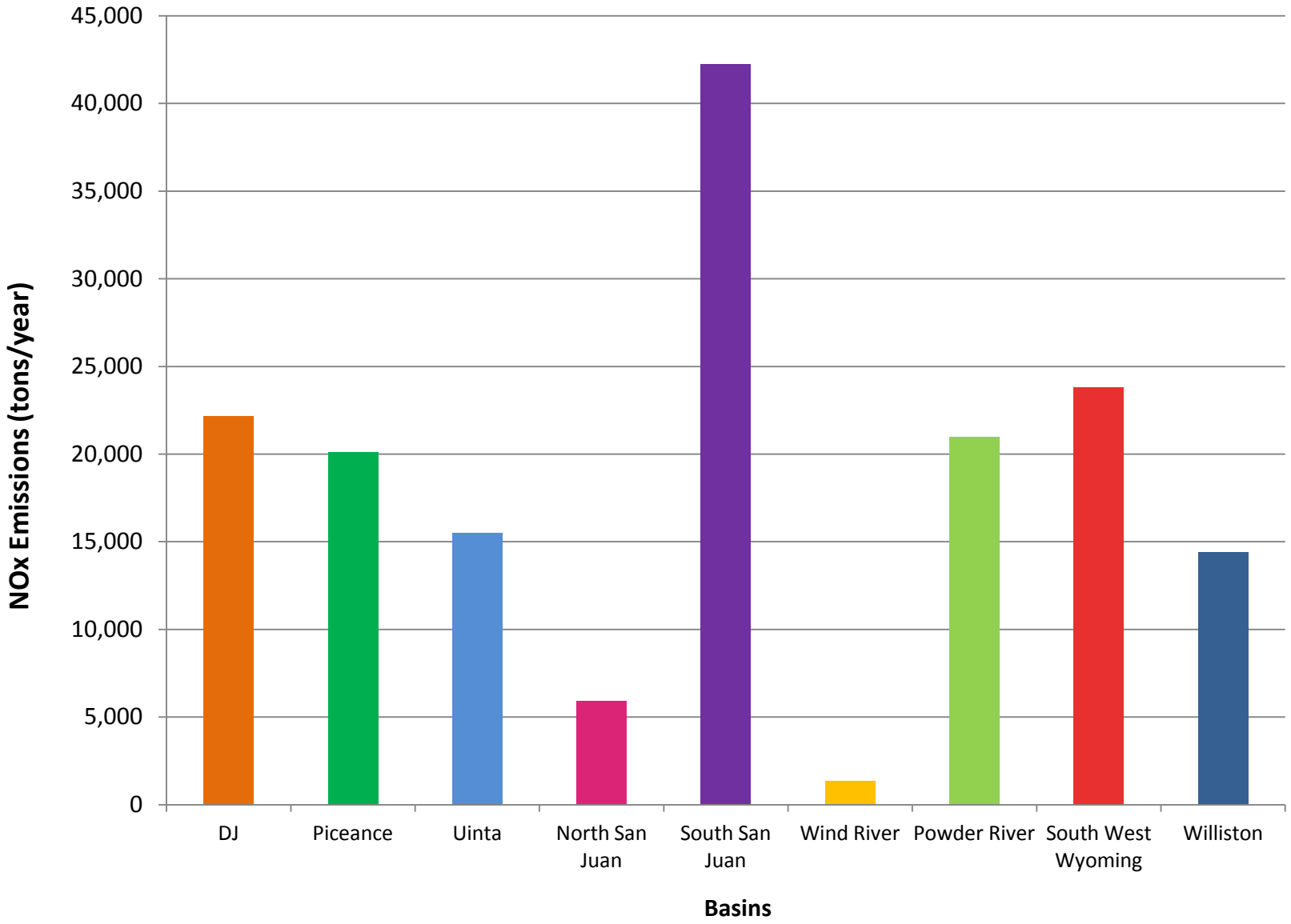
Southwest Wyoming Basin



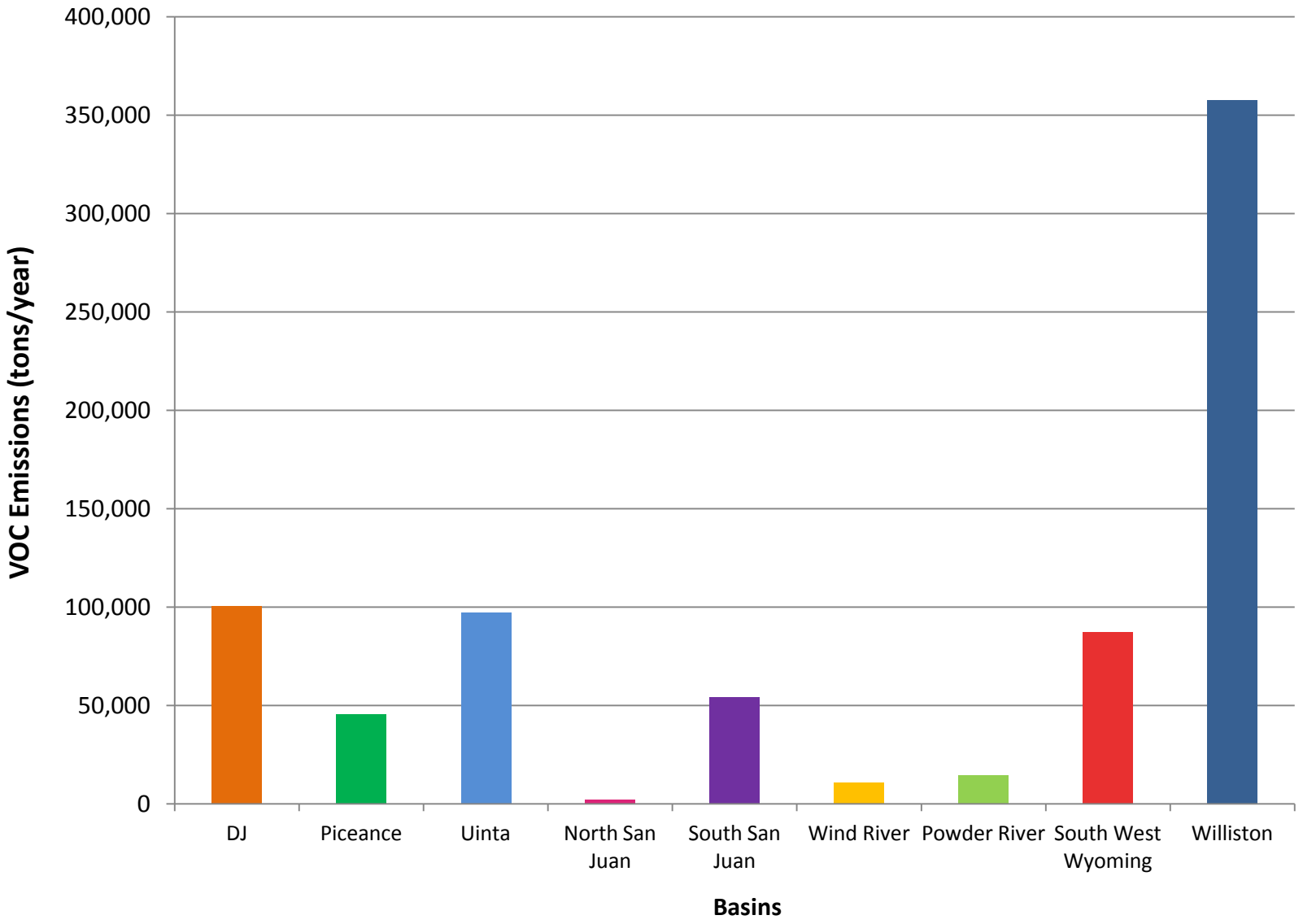
Powder River Basin

VOC emissions sources vary significantly from basin to basin – tank flashing, dehydration and pneumatic devices are consistently large source categories in most basins, but for CBM dominant basins other categories are significant

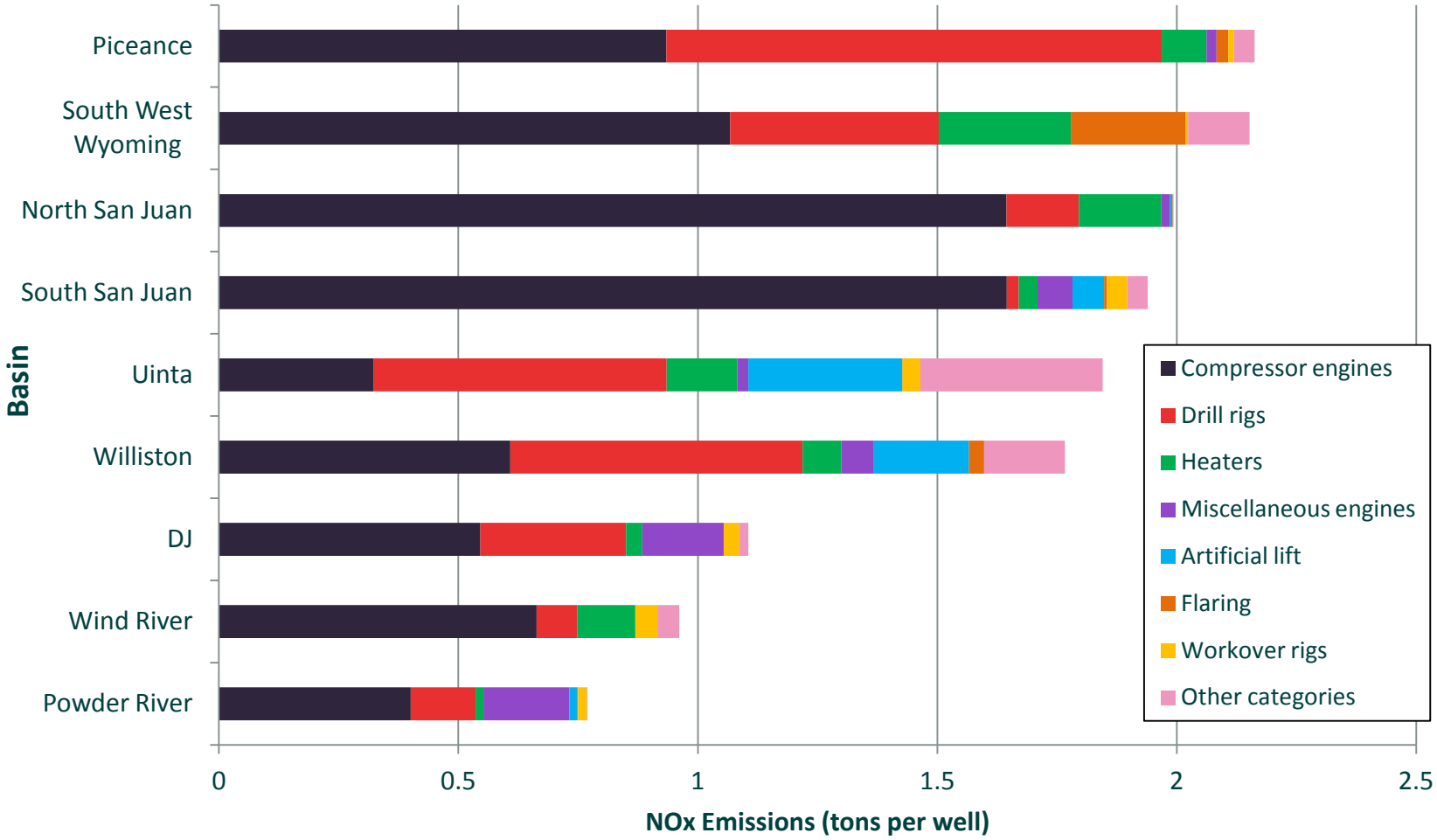
Cross-Basin – NOx Emissions



Cross-Basin – VOC Emissions

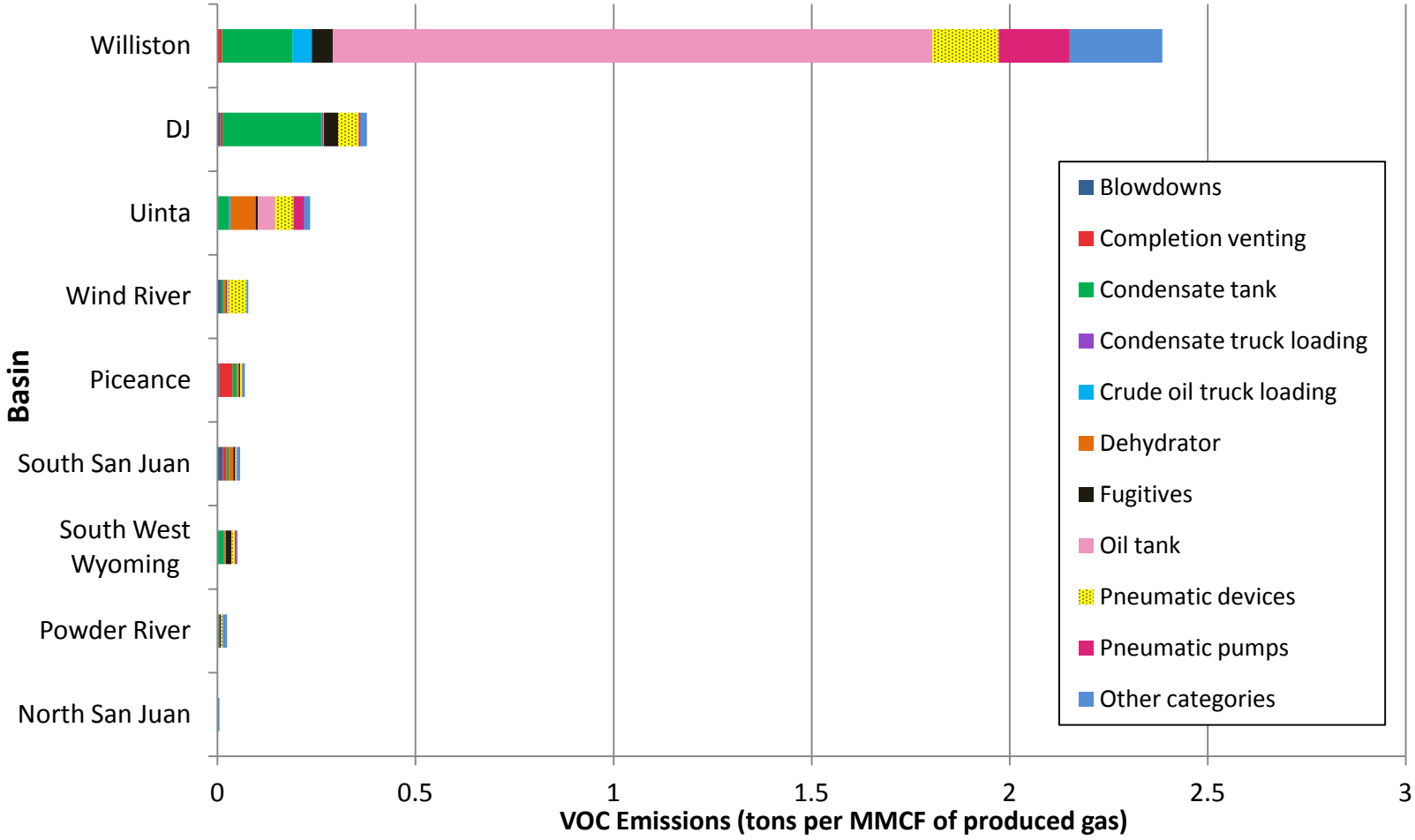


Cross-Basin – Per-Well NOx Emissions



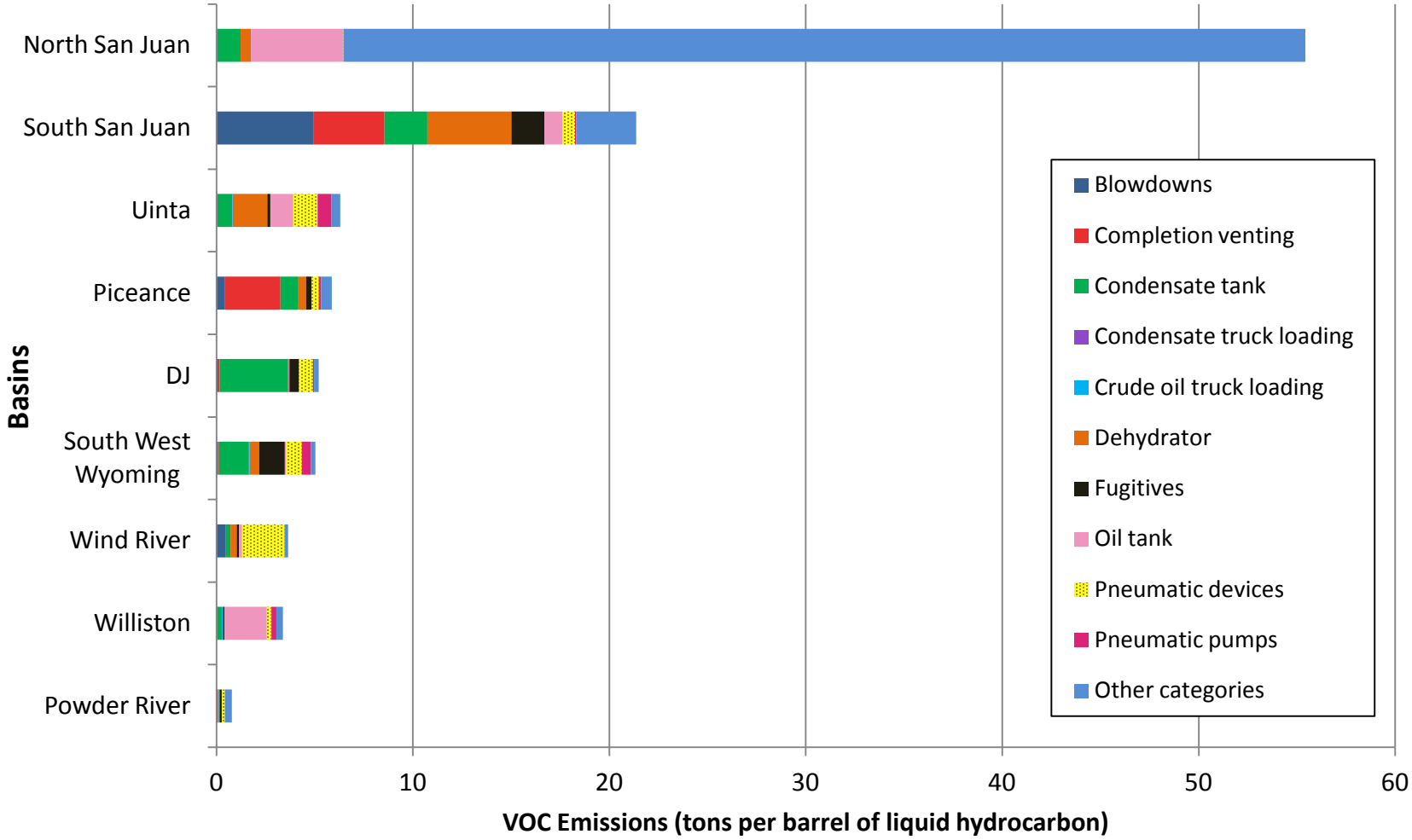
Per well NOx emissions relatively consistent across basins – differences mainly due to usage of compression and centralized vs. wellhead compression

Cross-Basin – Per-Unit-Gas-Production VOC Emissions



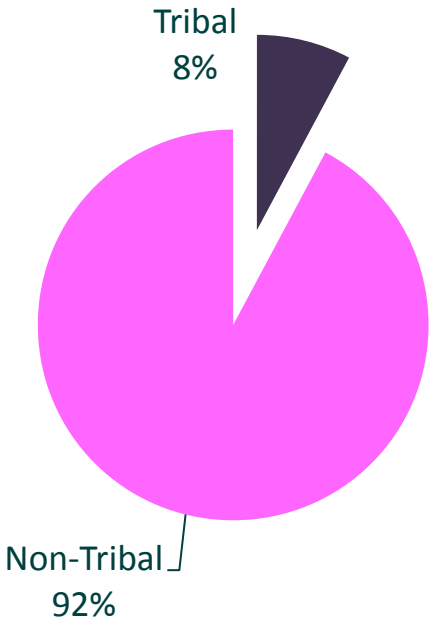
Per unit gas production VOC emissions vary widely across basins – differences due to levels of liquid hydrocarbon production (oil and condensate) and VOC content of produced gas

Cross-Basin – Per-Unit-Liquid-Production VOC Emissions



Per unit gas production VOC emissions vary widely across basins – differences due to levels of liquid hydrocarbon production (oil and condensate) and VOC content of produced gas

South San Juan Basin – 2006 NOx Emissions Contribution by Designation

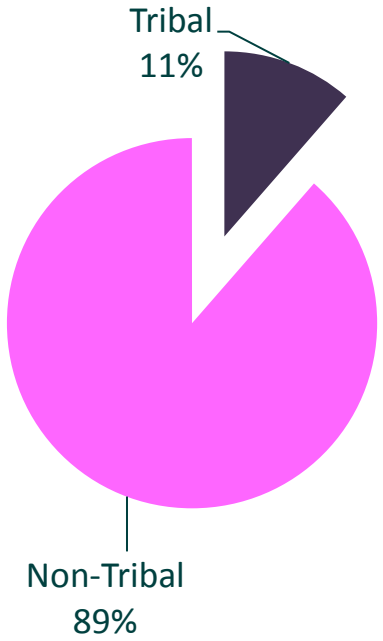


Basin-wide NOx Emissions (tons/yr)- 42,075

Tribal NOx Emissions (tons/yr) - 3,287
Permitted Emissions - 1,341
Non-permitted Emissions - 1,946

Non-Tribal NOx Emissions (tons/yr) - 38,788
Permitted Emissions - 11,054
Non-permitted Emissions - 27,734

South San Juan Basin – 2006 VOC Emissions Contribution by Designation

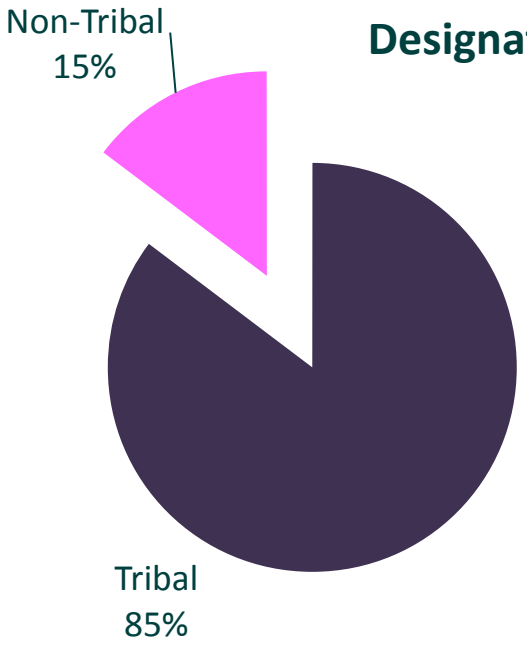


Basin-wide VOC Emissions (tons/yr)- 60,697

Tribal VOC Emissions (tons/yr) - 6,923
Permitted Emissions - 427
Non-permitted Emissions -6,496

Non-Tribal VOC Emissions (tons/yr) - 53,774
Permitted Emissions - 4,969
Non-permitted Emissions - 48,805

North San Juan Basin – 2006 NOx Emissions Contribution by Designation

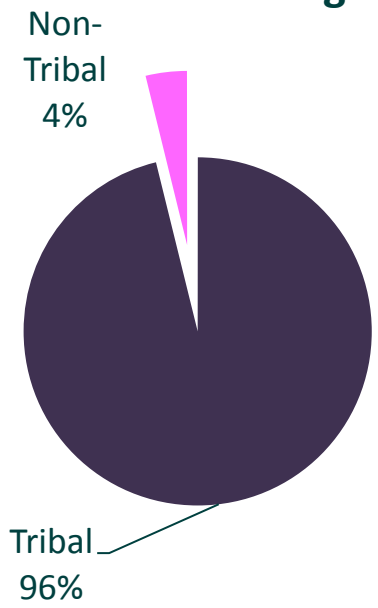


Basin-wide NOx Emissions (tons/yr)- 5,700

Tribal NOx Emissions (tons/yr) - 4,862
Permitted Emissions - 0
Non-permitted Emissions - 4,862

Non-Tribal NOx Emissions (tons/yr) - 838
Permitted Emissions - 757
Non-permitted Emissions - 81

North San Juan Basin – 2006 VOC Emissions Contribution by Designation



Basin-wide VOC Emissions (tons/yr)- 2,147

Tribal VOC Emissions (tons/yr) - 2,064
Permitted Emissions - 0
Non-permitted Emissions - 2,064

Non-Tribal VOC Emissions (tons/yr) - 83
Permitted Emissions - 61
Non-permitted Emissions - 22

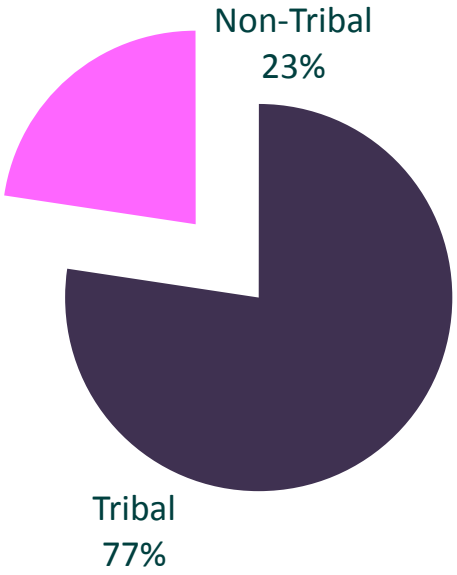
Uinta Basin – 2006 NOx Emissions Contribution by Designation

Basin-wide NOx Emissions (tons/yr)- 13,093

Tribal NOx Emissions (tons/yr) - 9,962
Permitted Emissions - 2,339
Non-permitted Emissions - 7,622

Non-Tribal NOx Emissions (tons/yr) - 3,131
Permitted Emissions - 0
Non-permitted Emissions - 3,131

Uinta Basin – 2006 VOC Emissions Contribution by Designation

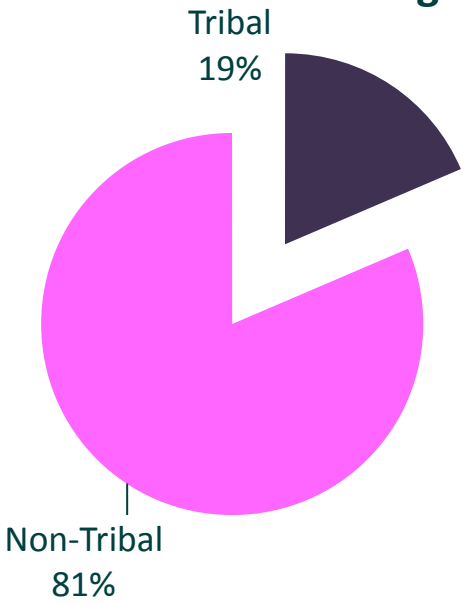


Basin-wide VOC Emissions (tons/yr)- 71,546

Tribal VOC Emissions (tons/yr) - 55,370
Permitted Emissions - 1,320
Non-permitted Emissions - 54,049

Non-Tribal VOC Emissions (tons/yr) - 16,176
Permitted Emissions - 0
Non-permitted Emissions - 16,176

Wind River Basin – 2006 NOx Emissions Contribution by Designation

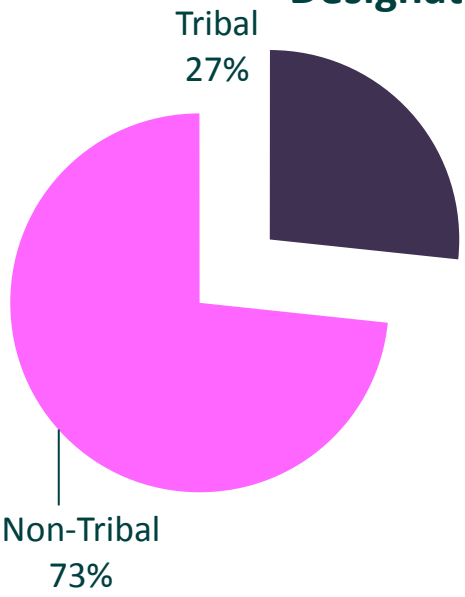


Basin-wide NOx Emissions (tons/yr)- 1,814

Tribal NOx Emissions (tons/yr) - 337
Permitted Emissions - 217
Non-permitted Emissions - 119

Non-Tribal NOx Emissions (tons/yr) - 1,478
Permitted Emissions - 550
Non-permitted Emissions - 928

Wind River Basin – 2006 VOC Emissions Contribution by Designation

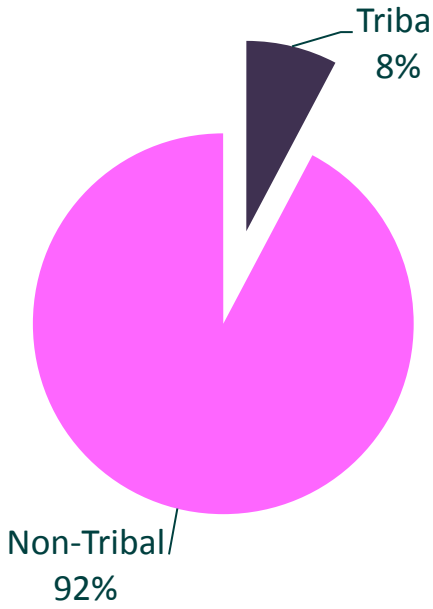


Basin-wide VOC Emissions (tons/yr)- 11,981

Tribal VOC Emissions (tons/yr) - 3,196
Permitted Emissions - 97
Non-permitted Emissions - 3,099

Non-Tribal VOC Emissions (tons/yr) - 8,786
Permitted Emissions - 421
Non-permitted Emissions - 8,364

Williston Basin – 2009 NOx Emissions Contribution by Designation

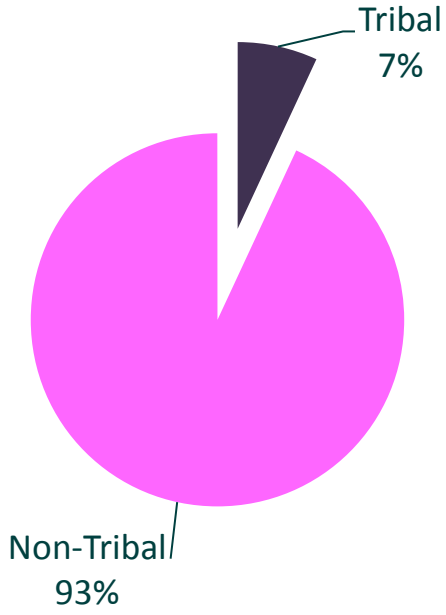


Basin-wide NOx Emissions (tons/yr)- 14,387

Tribal NOx Emissions (tons/yr) - 1,114
Permitted Emissions - 64
Non-permitted Emissions - 1,050

Non-Tribal NOx Emissions (tons/yr) - 13,273
Permitted Emissions - 4,142
Non-permitted Emissions - 9,131

Williston Basin – 2009 VOC Emissions Contribution by Designation



Basin-wide VOC Emissions (tons/yr)- 357,798

Tribal VOC Emissions (tons/yr) - 24,802
Permitted Emissions - 18
Non-permitted Emissions - 24,784

Non-Tribal VOC Emissions (tons/yr) - 332,996
Permitted Emissions - 1,815
Non-permitted Emissions - 331,180

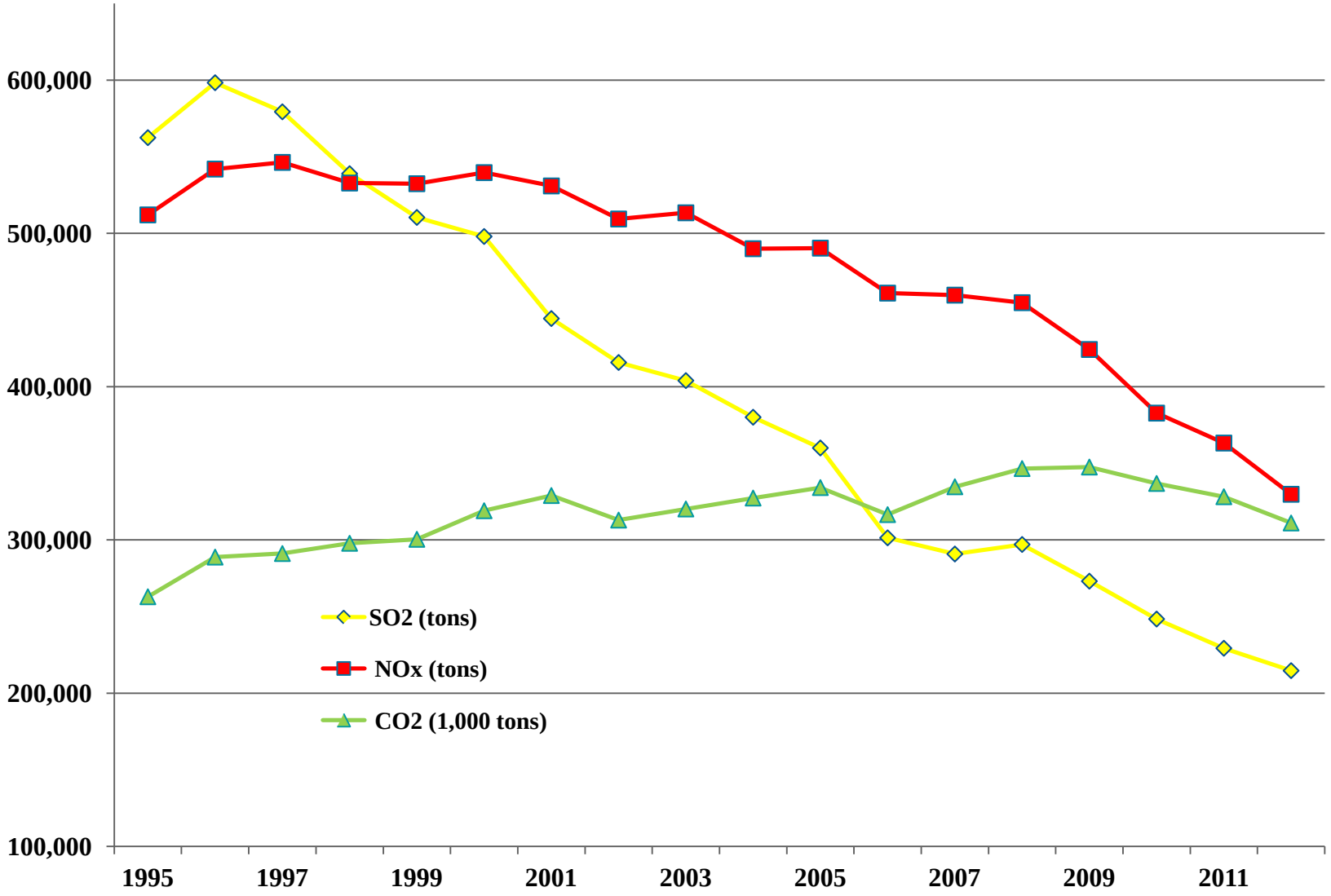
Projections of Future Emissions – Background

- Need
  - Air quality planning to correct violations of health and welfare standards
  - To prevent violations of standards and to reduce exposure
  - Account for state and federal regulations “on the books and on the way”
  - Effectively consider “known future” to estimate additional costs and benefits of additional control options
- Scope
  - Change across all source categories from baseline actual emissions into the future
  - Anthropogenic sources affected by
    - Economic factors
    - Changes in technology
    - Emerging standards
  - Biogenic or natural sources
    - Not as well understood
    - Affected by climate change and other factors
    - Usual practice is hold future projections constant

Western ozone and PM precursors - key emissions sources

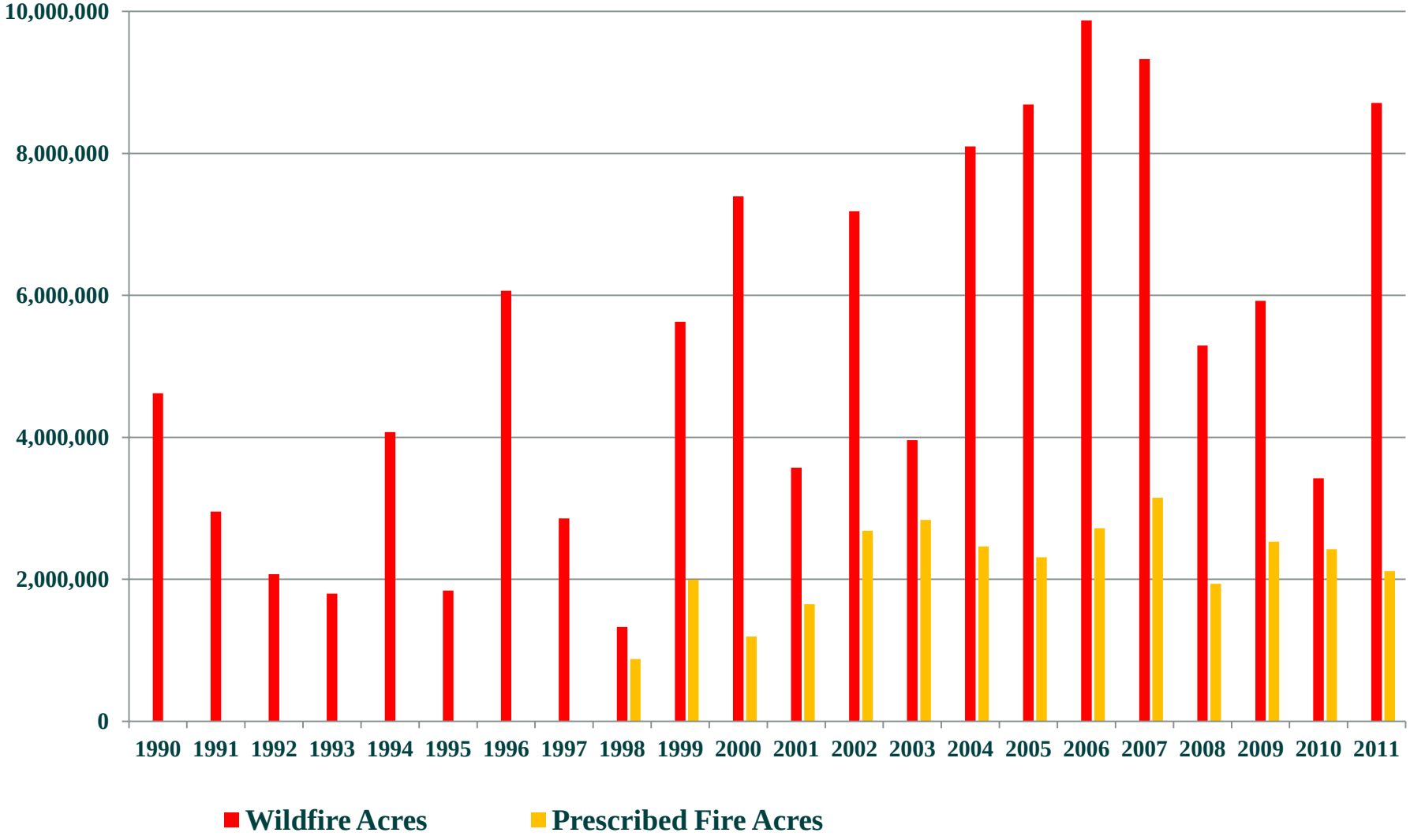
- Power plants decreasing markedly
- Mobile sources controlled and emission rates decreasing markedly through federal rules and state testing programs
- Fire activity and effects are huge (among the largest air pollution sources in the West), receiving intensive study
  - Deterministic & Empirical Assessment of Smoke's Contribution to Ozone (DEASCO$_3$)
  - Prescribed and Other Fire Emissions: Particulate Matter Deterministic & Empirical Tagging & Assessment of Impacts on Levels (PMDETAIL)
  - Others….
- Biogenics (natural plant sources)
- Oil and gas……..
  - Phase III study
  - Emissions Inventories for Williston and MT North Central (Great Plains) Basins

Power Plant Emissions Trends – Western Interconnect



Data Source: EPA Clean Air Markets Division

U.S. Wildfire and Prescribed Fires Acres Burned - 1990 through 2011



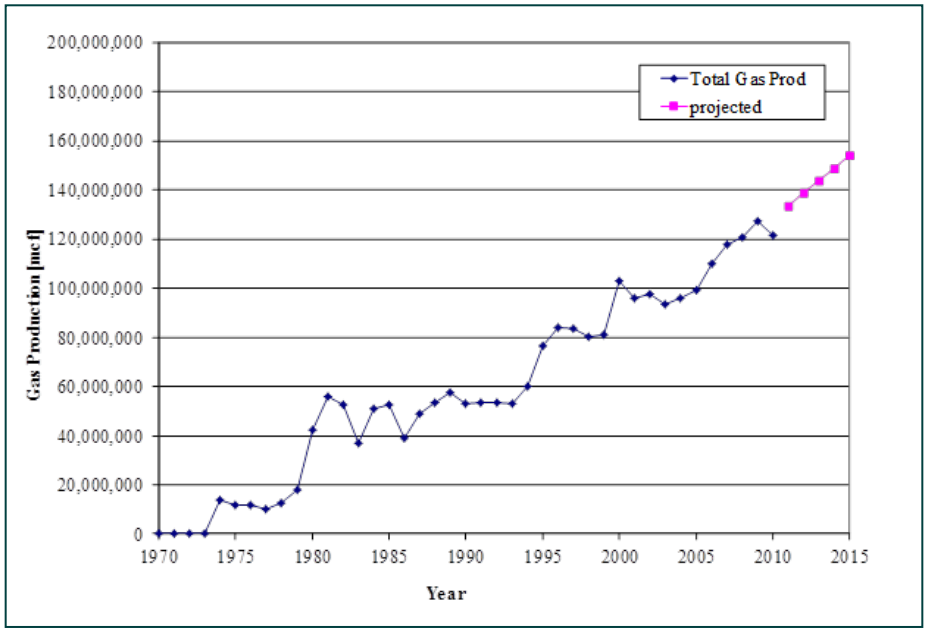
2012 and 2013 right behind 2006 in wildfire acres burned

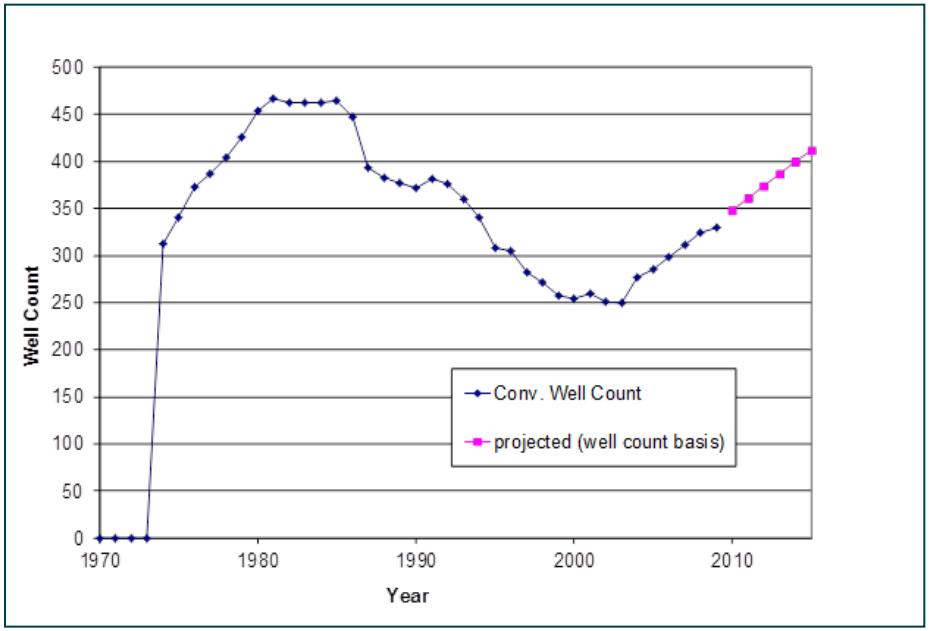
Projections - Methodology

- No standardized methodology for conducting projections – each inventory study has used different approaches (RMPs, NEPA projects, regional inventories)
- Phase III inventories use a three-step approach:
  1. Activity scaling factors
  2. “Uncontrolled” projections
  3. State and federal regulatory control requirements
- Activity scaling requires input from operators on planned activities and/or analyzes trends and/or relies on industry studies
- State and federal regulatory control requirements complex

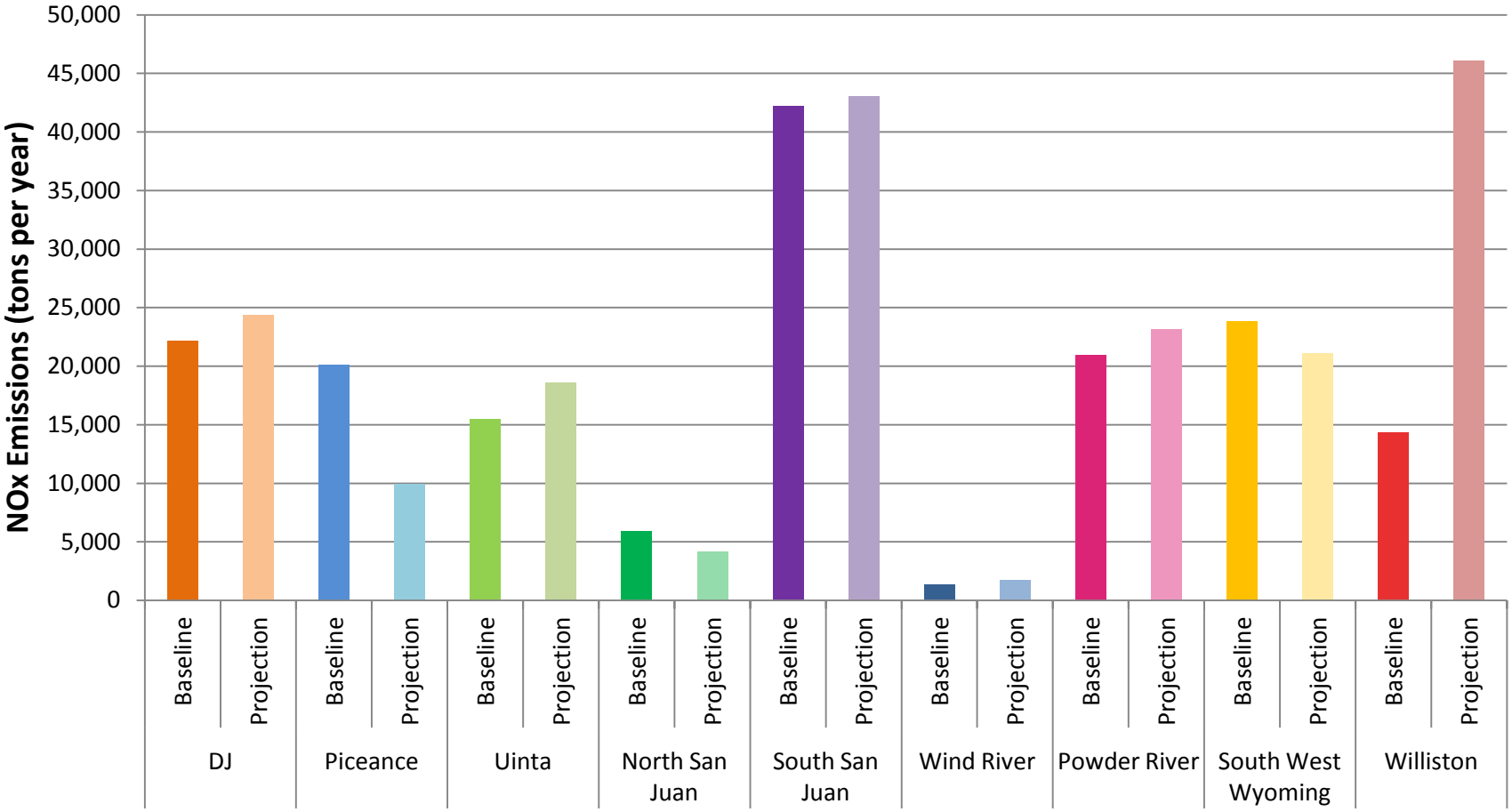
Projections - Methodology

- Operators queried for planned drilling activities
- Well decline data gathered to generate basin-average curves
- Production projections constructed from operator data/historic trends



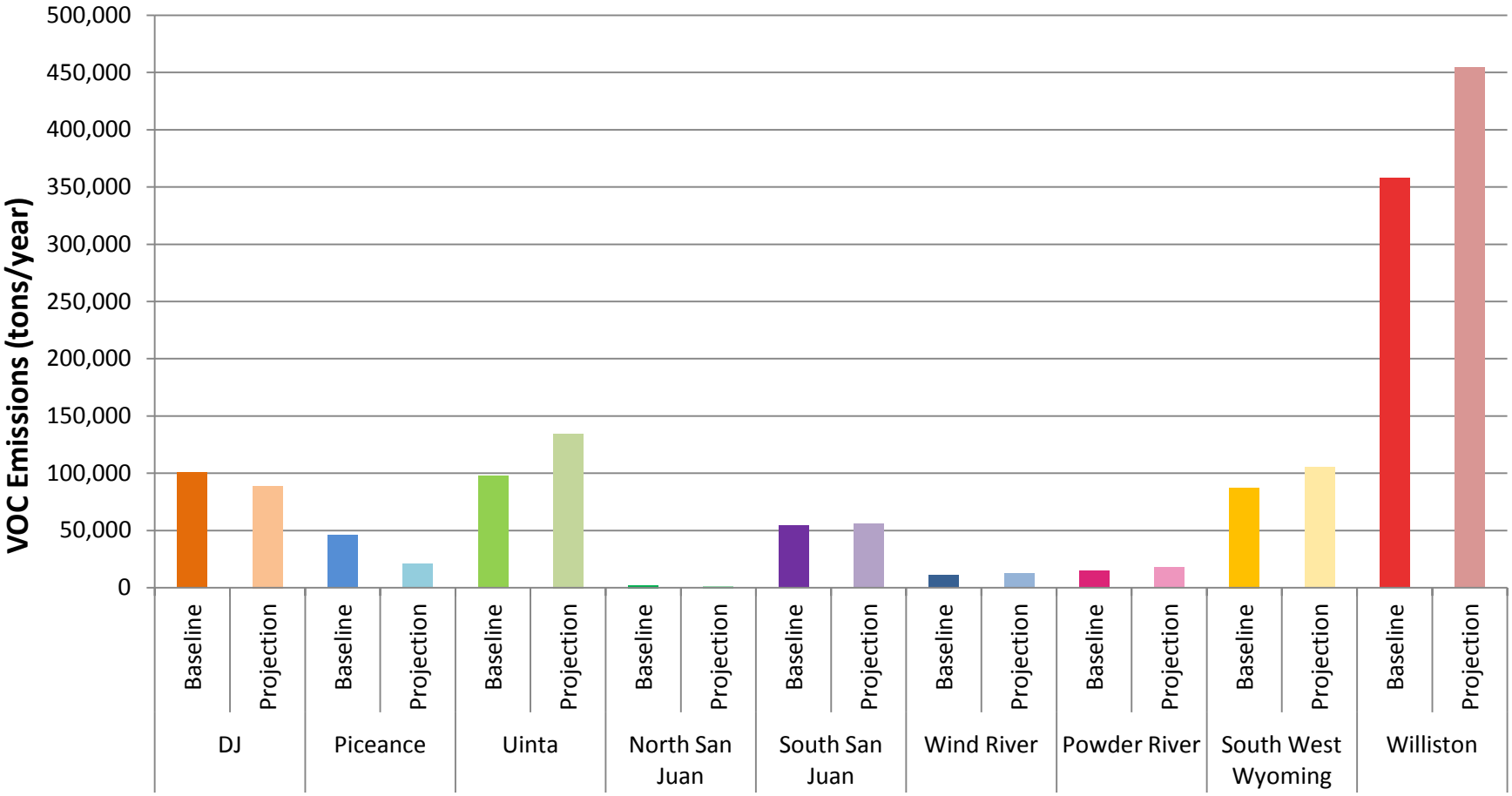


NOx Projections - Results



Emissions projections are complex mix of growth or decline factors and controls from natural equipment turnover and state/federal regulations

VOC Projections - Results



State regulations vary widely from state to state in emission source categories regulated and levels of control required

Regulatory Approaches – Point vs. Area

Point vs. Area Sources	
Pros	Cons
Better spatial resolution	Resource intensive (to states and industry)
Gather actual emissions/actual usage	Resource intensive to process
Improved accuracy of emissions	Factor approach still used for minor sources

- **Expect improvement in spatial resolution and accuracy of emissions data from point sources but significant effort to process and track**
- **Colorado (APENs) and Wyoming (site surveys) already doing this**

Issues and New Concepts – Missing Categories

Produced water (evaporation) ponds

- Emission factors uncertain and highly dependent on composition, production type
- Seasonal/diurnal variations
- See for example Utah State University work to characterize emissions in Uinta Basin

Issues and New Concepts – Missing Categories

Field gathering pipelines

- Lack of data on extent of pipeline infrastructure within fields
- Pipeline companies historically not part of the inventory process

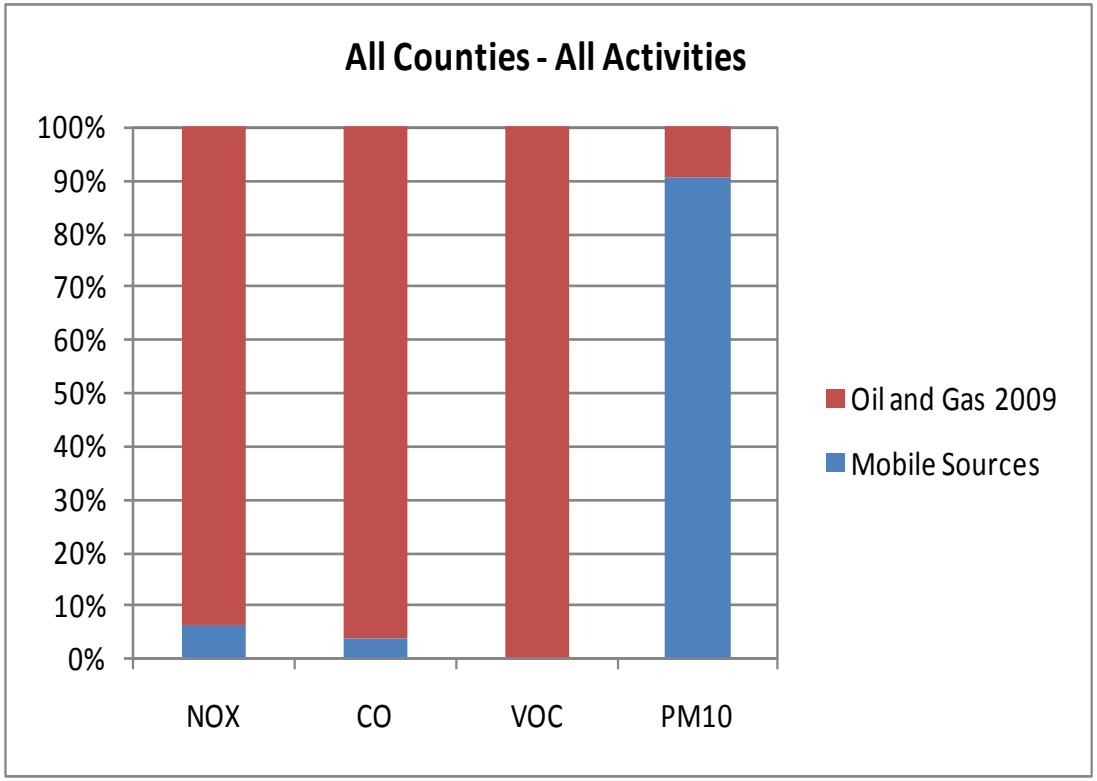
Issues and New Concepts – Missing Categories

Midstream sources

- Midstream sources not always captured in inventories – state reporting thresholds
- Midstream sources on tribal lands
- Midstream companies historically not part of the inventory process

Issues and New Concepts – Missing Categories

Mobile sources



- **Trucking and off-road equipment likely underestimated in existing mobile inventories**
- **Activities dispersed throughout basins and among basins**
- **See for example P3 study in Piceance Basin**

As operators and regulators move to other systems to produce and move products and by-products (train, pipelines and electrification) and away from trucks and diesel/field gas combustion, new data is needed

Issues and New Concepts – Skewness

- **Poorly performing and "non-average" sources could have significantly higher emissions than estimated in inventories**
- **Analogous to "smoking vehicles" in mobile source inventories**
- **Statistical sampling/monitoring of sources needed to develop methods to represent this in inventories**
- **See for example NOAA monitoring in Uinta Basin and CDPHE capture efficiency adjustments**

Closing

- Technology for exploration and production has changed
- Physical scope of production, variation in production activities
- Oil and gas cost and benefit
- Clean Air Act structure
- Existing vs. future development
- Source category efforts toward continued collaborative study

Acknowledgements

Amnon Bar-Ilan and John Grant
ENVIRON Intl. Corp.
Novato, CA

Kathleen Sgamma
Western Energy Alliance
Denver, CO

Doug Henderer
Newfield Exploration
Denver, CO

Lee Gribovicz
Airstar Consulting

Thanks –

Tom Moore, WRAP Air Quality Program Manager
Western States Air Resources Council (WESTAR)

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Western Regional Air Partnership | www.wrapair2.org