# Upstream Oil and Gas Emission Inventories: Regulatory and Technical Considerations

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**Air Quality and Oil & Gas Development in the Rocky Mountain Region**
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# Overview

- Emission inventories – background
- O&G development in the Intermountain West
- History of O&G emission inventory development
- WRAP Phase III inventories
- Technical methodology
- Results for an example basin
- Cross-basin comparisons
- Regulatory requirements
- Emission inventory issues – improvements and new concepts
- Current and future work

# The Clean Air Act

- Federal Clean Air Act - major revisions 1970, 1977, 1990
  - Establishes regulatory authorities and structures to manage air pollution for the entire U.S.
  - Series of Titles in CAA lay out specific and broad authorities
    - Complex requirements for EPA and states have evolved with more than 20 years of interpretation since last major update
  - Clearly establishes federal–state partnership to regulate and manage air pollution
    - Local air quality control agencies (county or district) and tribes can be “treated as states”

# The Clean Air Act

- Directs EPA to set and periodically review (and revise as needed)
  - National Ambient Air Quality Standards (NAAQS) to protect public health and welfare for six criteria air pollutants: O3, NO2, SO2, CO, PM10/2.5, Lead
  - Technology-based standards for major sources and some area sources of air toxics
  - 1990 Amendments established and/or revised
    - Specific requirements to correct NAAQS nonattainment
    - Permitting programs for major and minor stationary sources
    - New Source Review (NSR) in NAAQS nonattainment areas
    - Prevention of Significant Deterioration (PSD) in other areas
    - Additional protection for Class I areas

# National Environmental Policy Act (NEPA)

- NEPA requires federal agencies to consider the environmental impacts of their proposed actions and reasonable alternatives to those actions
- Federal agencies prepare an Environmental Impact Statement (EIS) or Environmental Assessment (EA) for oil and gas development on federal lands
- Vast majority of O&G NEPA actions are by U.S. Bureau of Land Management, a lesser number by the US. Forest Service
  - BLM controls much of the mineral estate in the West, separate from surface ownership
  - Once development is authorized by the federal agency through the NEPA process, air emissions become the responsibility of the states, or the EPA regional office in the case of tribal lands

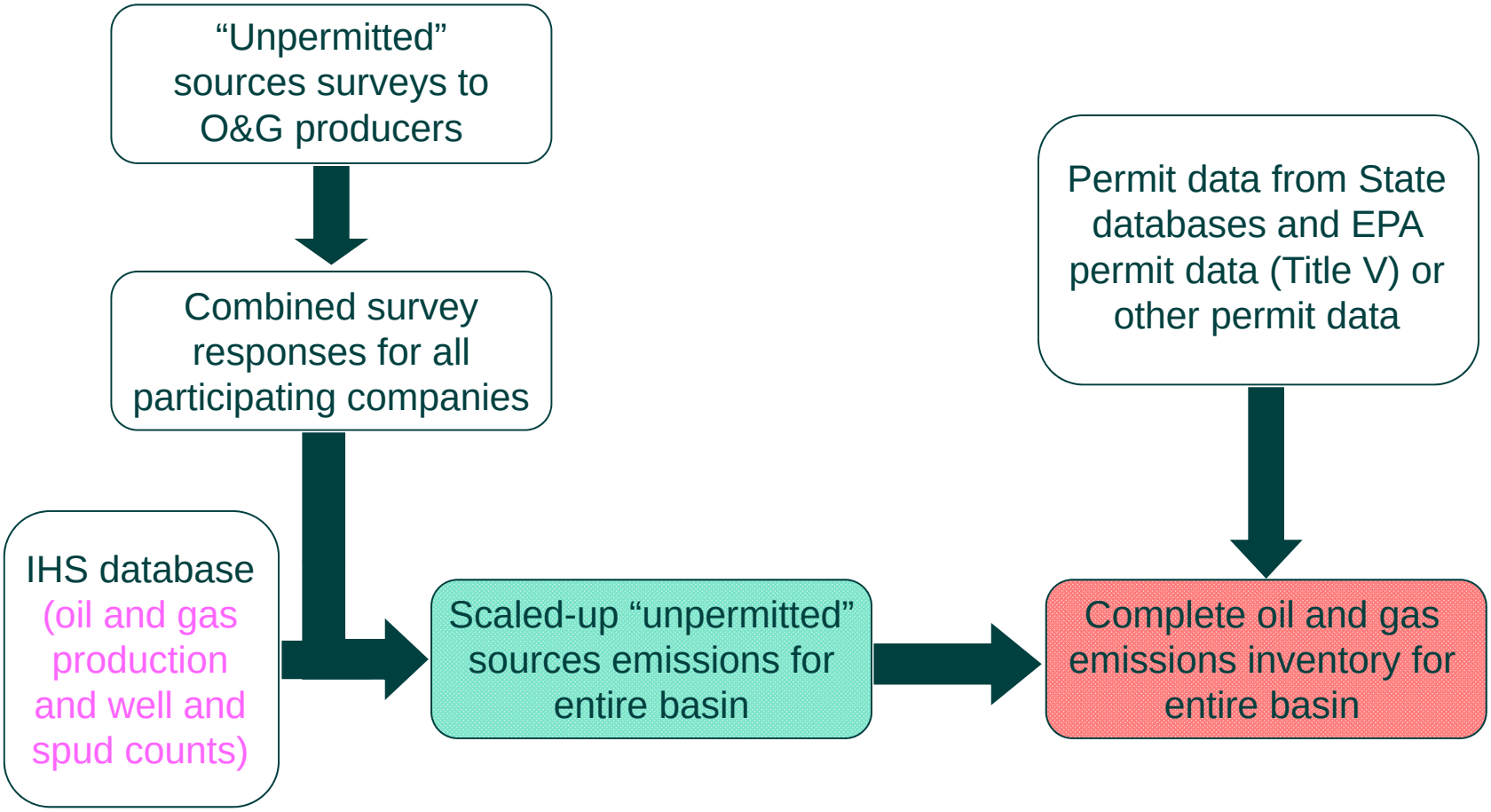
# Emissions Inventories

- 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
    - 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
- 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 | County(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"**

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# 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**

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# Phase III Methodology

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

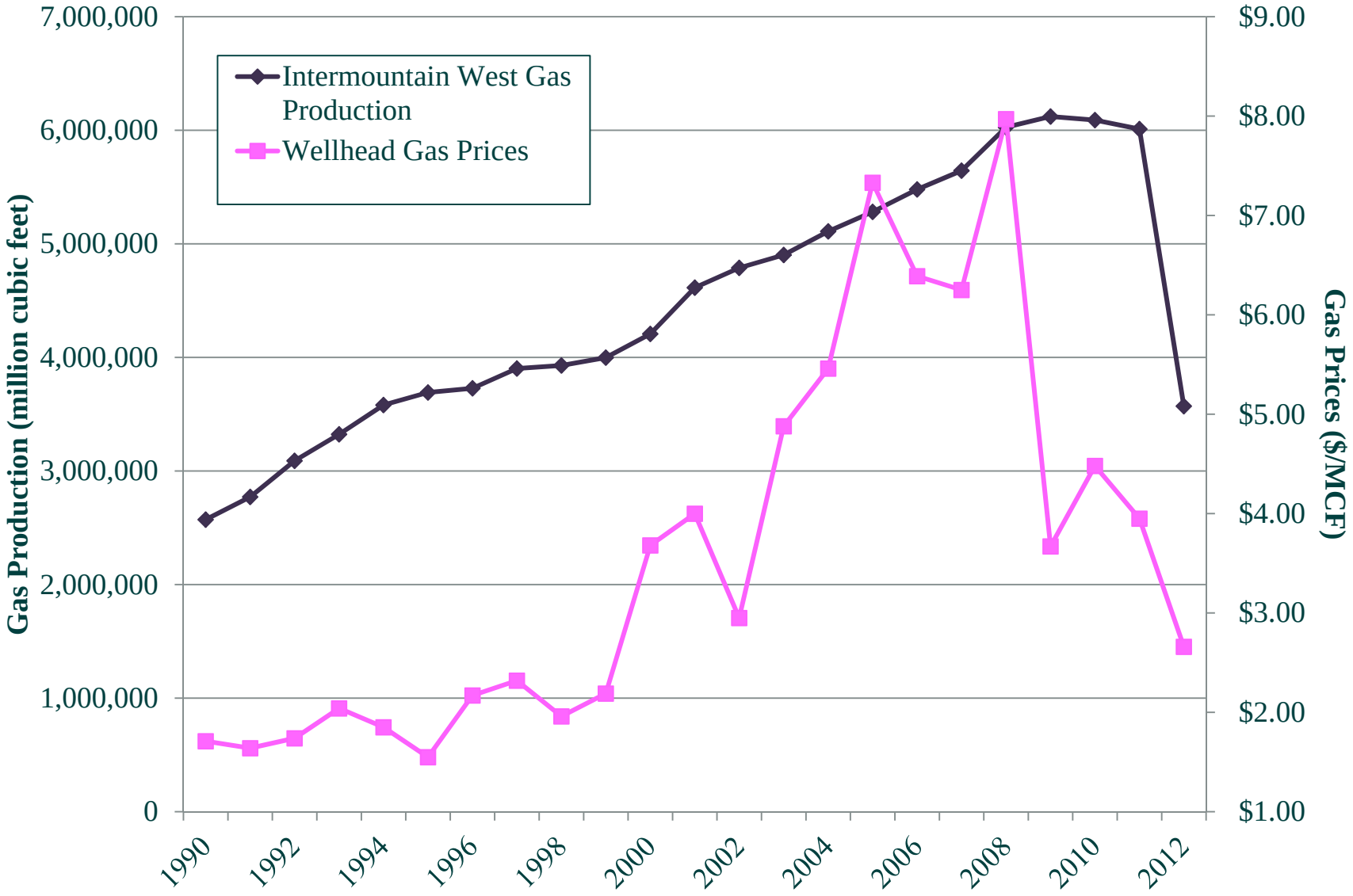
| State | Emissions Thresholds (tons/yr) |
|---|---|
| New Mexico | Notice of Intent Required for Facilities with Emissions > 10tpy Criteria Pollutants; Permits Required for Facilities > 25 tpy |
| Colorado | Permits Required for All Sources with Emissions > 2 tpy Criteria Pollutants |
| Utah | Permits 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**

# 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



# Eastern Utah

2006 Oil and Gas Production

BLM proposed leasing for oil shale development

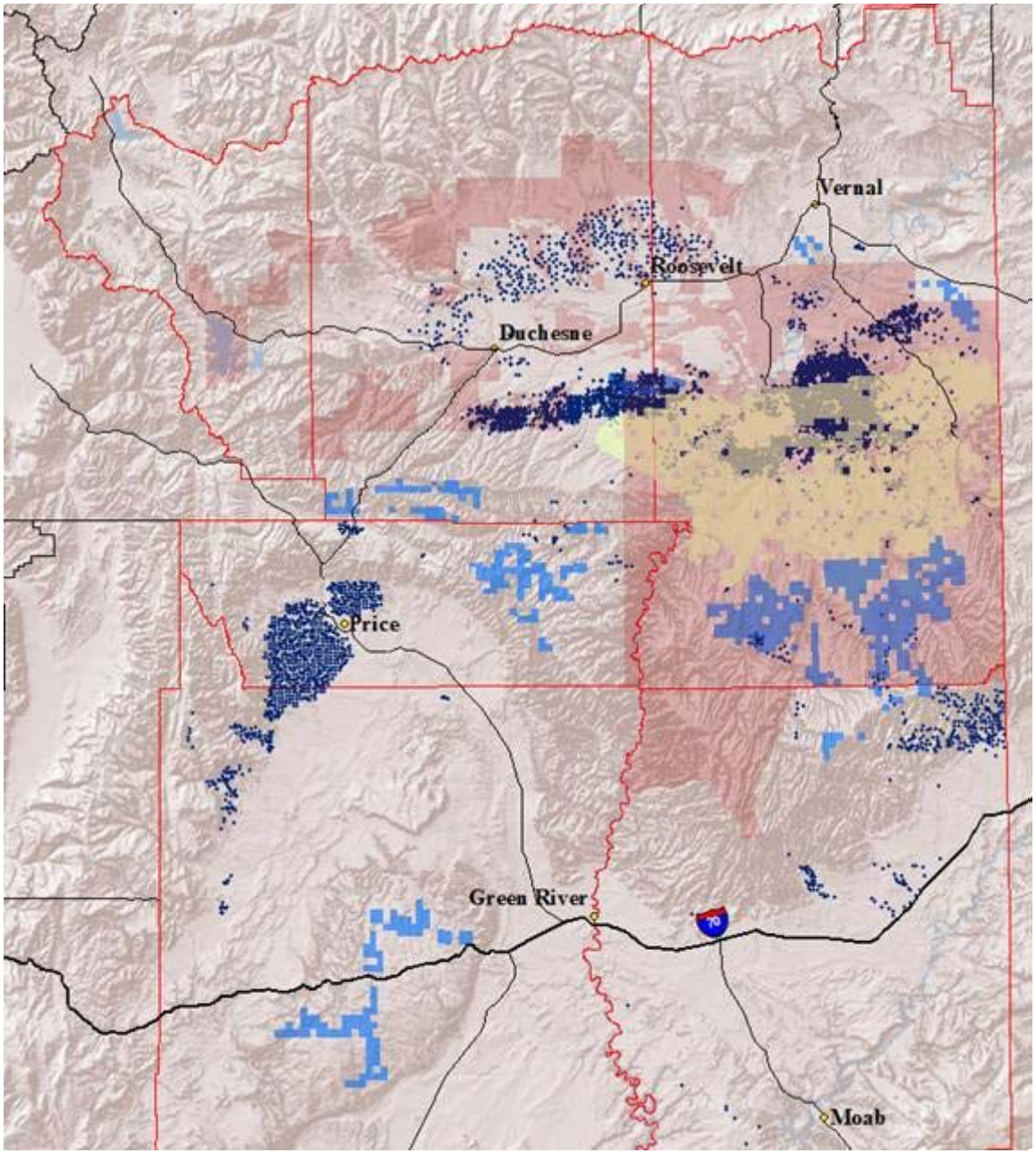
BLM proposed leasing for tar sands development

"Indian Country" – Regulatory authority controlled by the Tribes and EPA

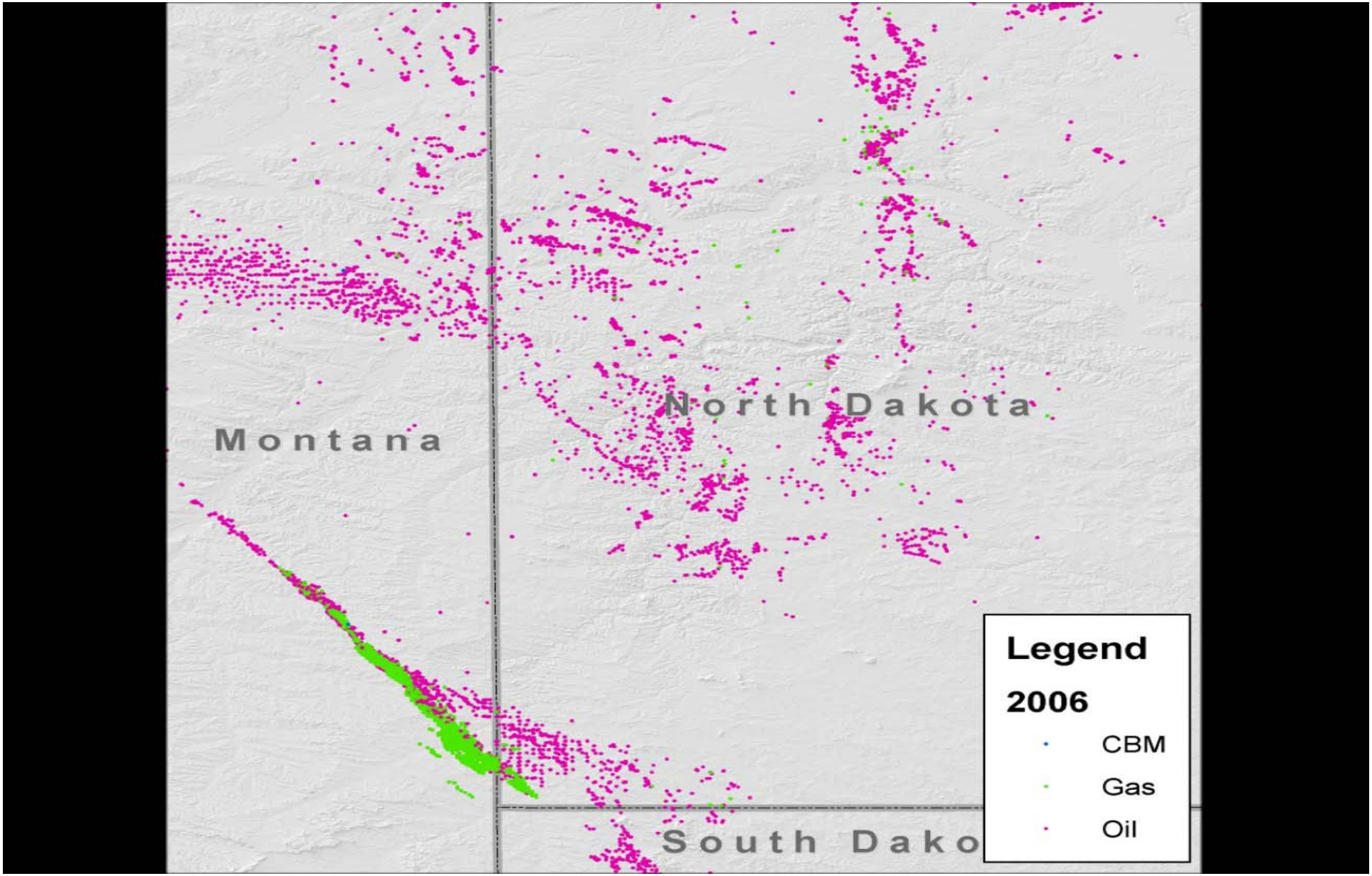
Oil Shale Leasing

Tar Sands Leasing

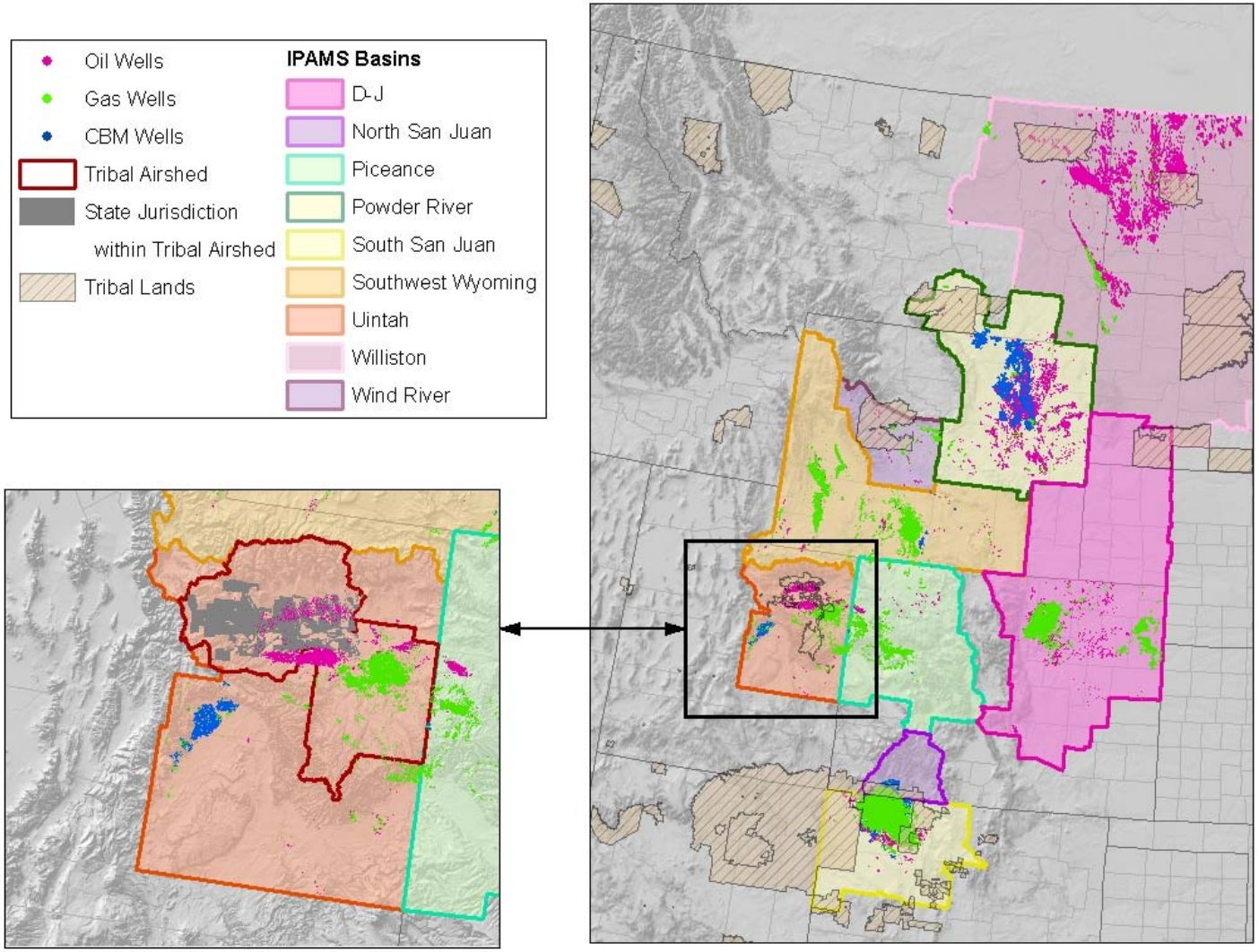
"Indian Country"



# Bakken Field Well Activity 2006-11



# 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

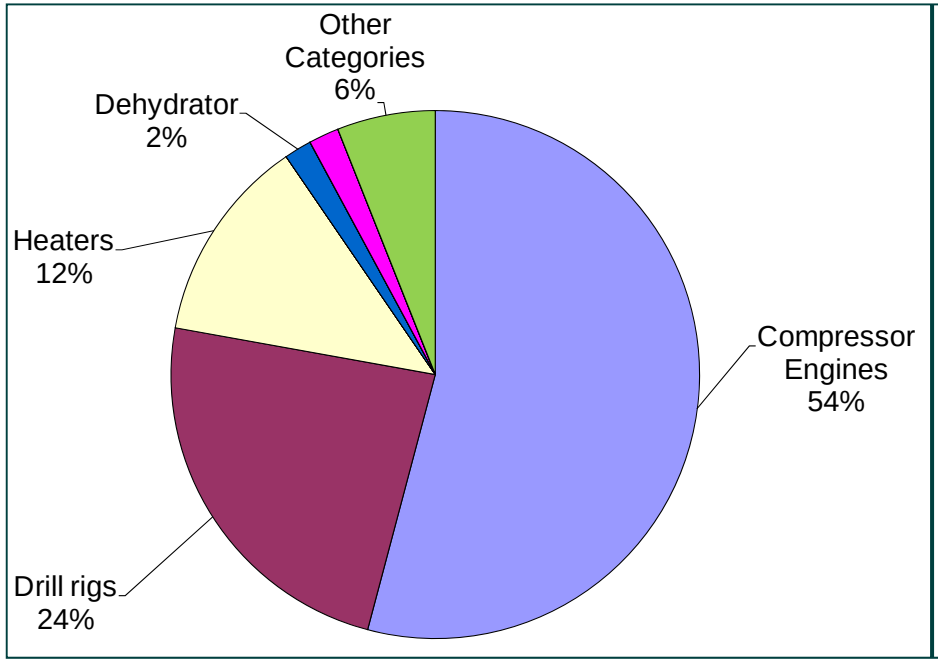
## 2008 Emission Inventories

| 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 |

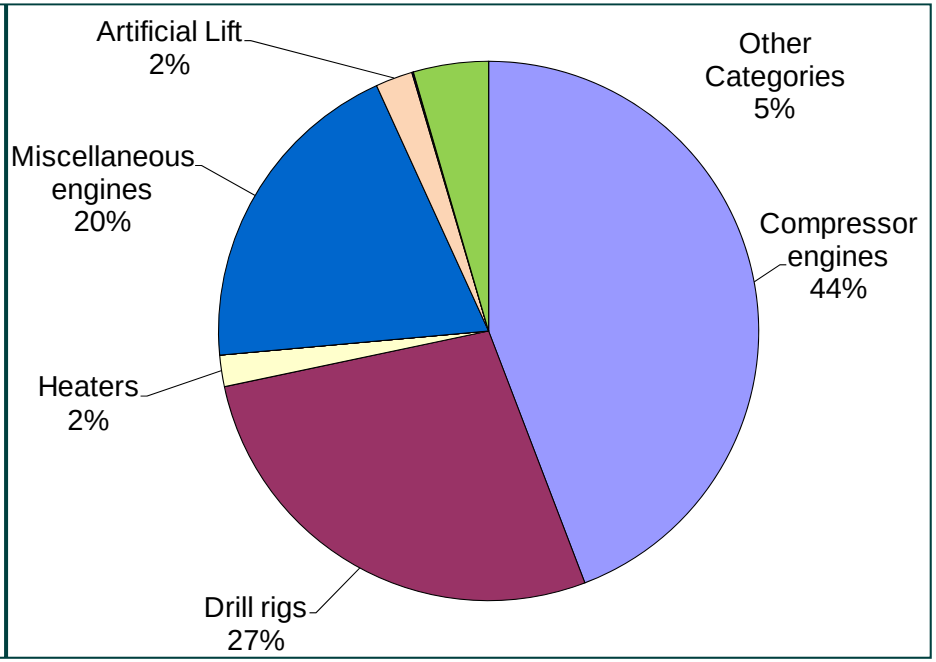
* Williston Basin emissions are for 2009

- **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



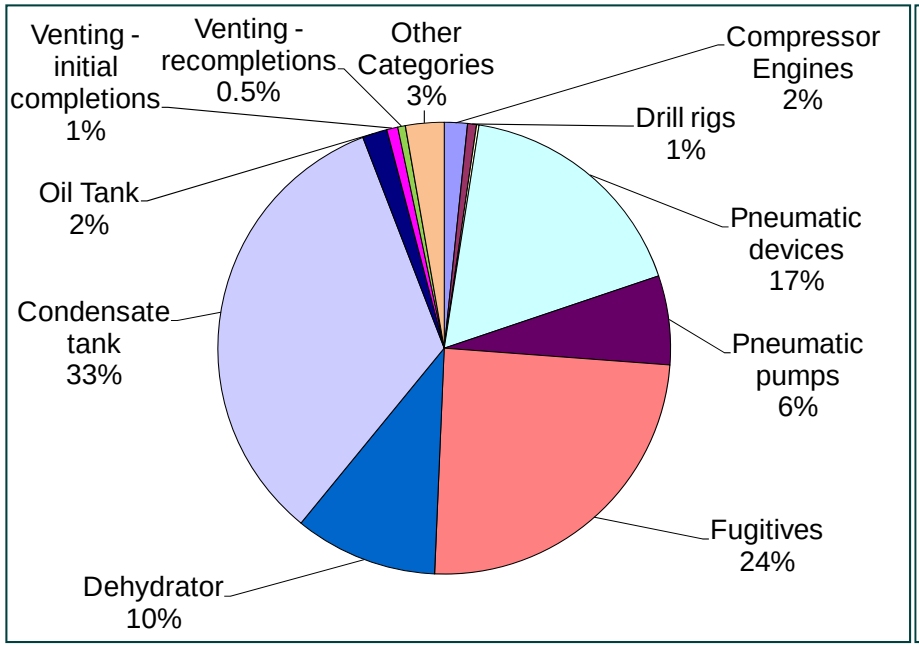

Southwest Wyoming Basin



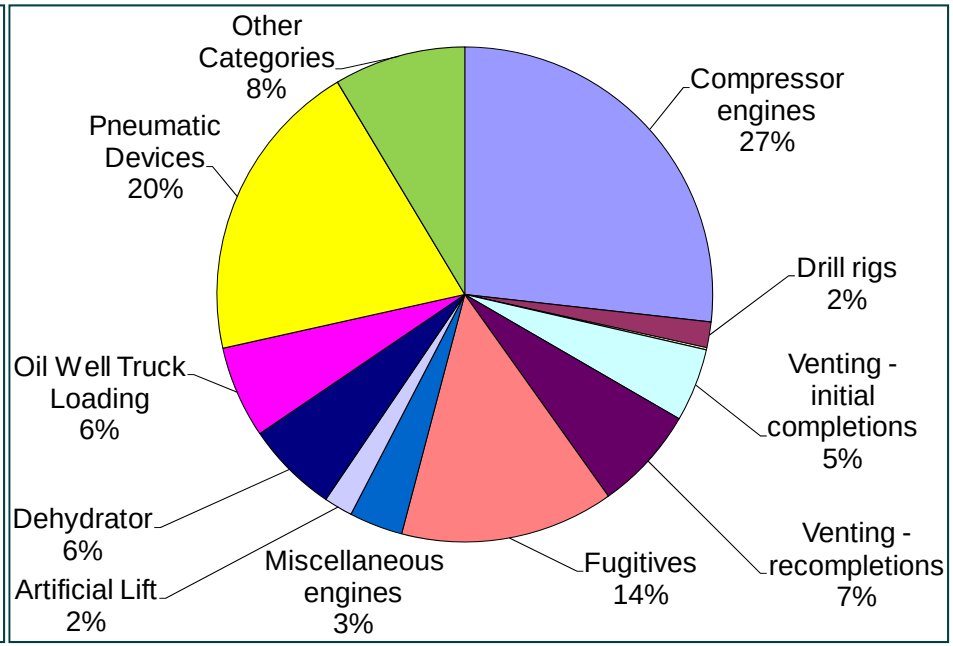

Powder River Basin

**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



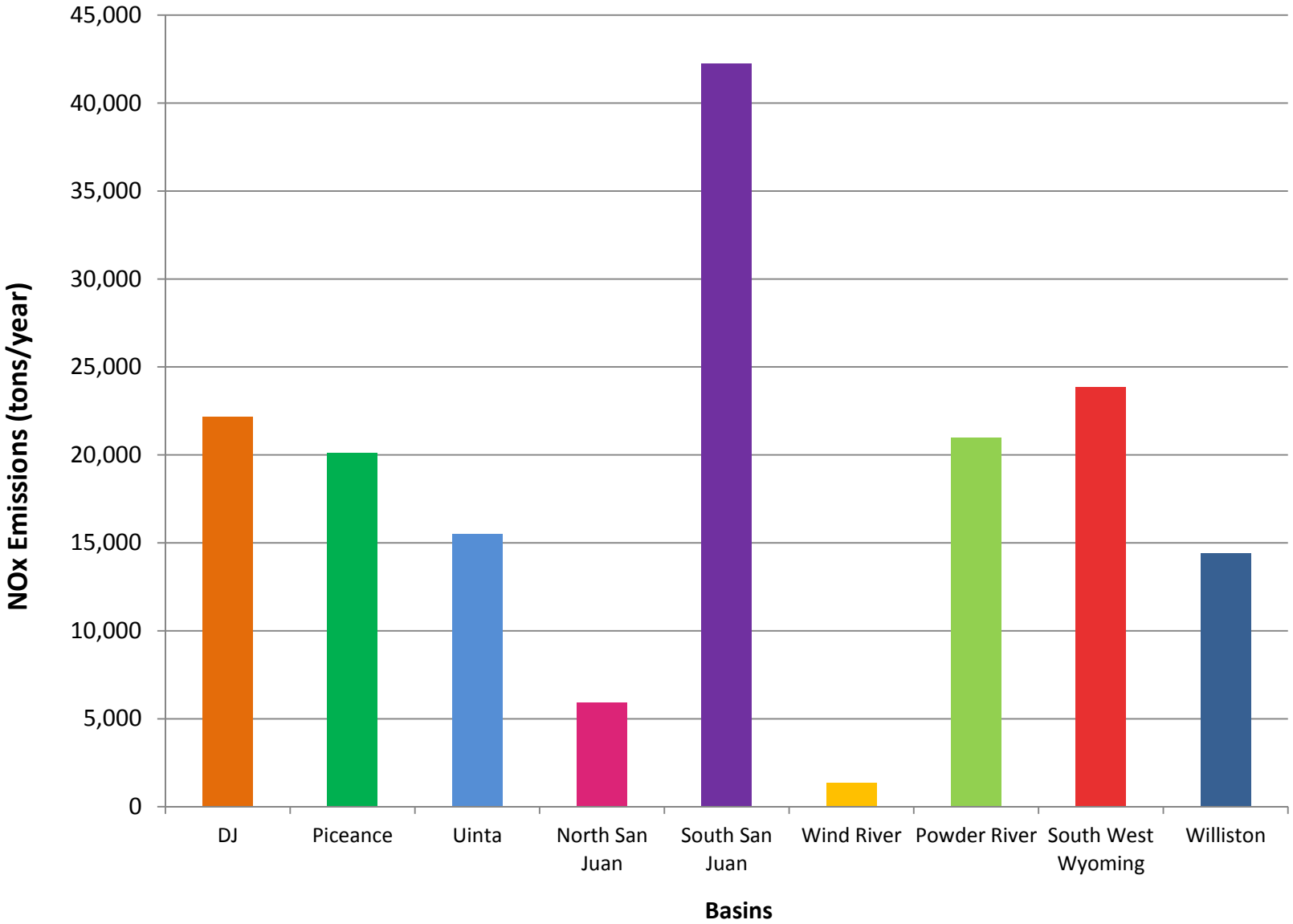

**Southwest Wyoming Basin**



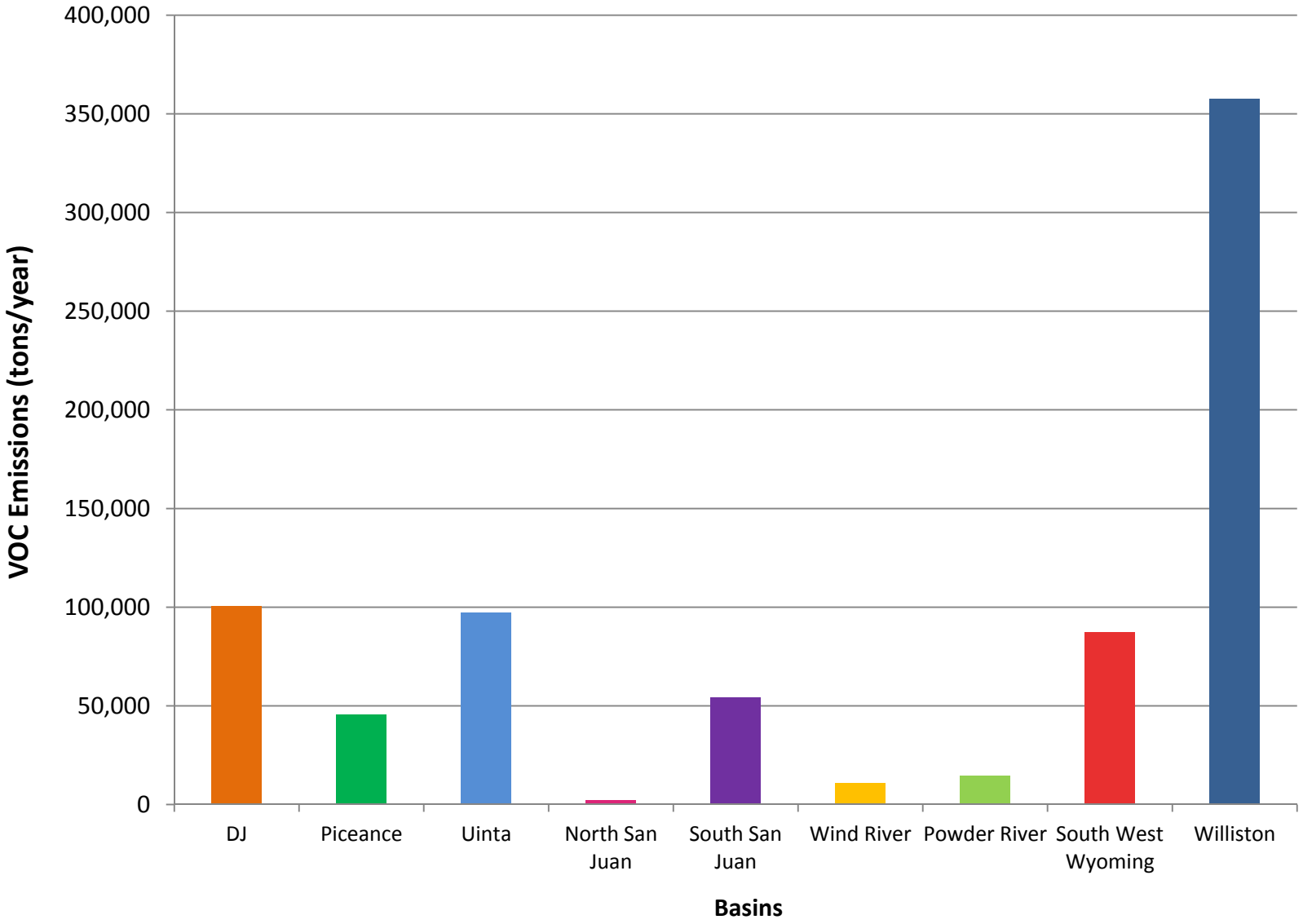

**Powder River Basin**

**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**

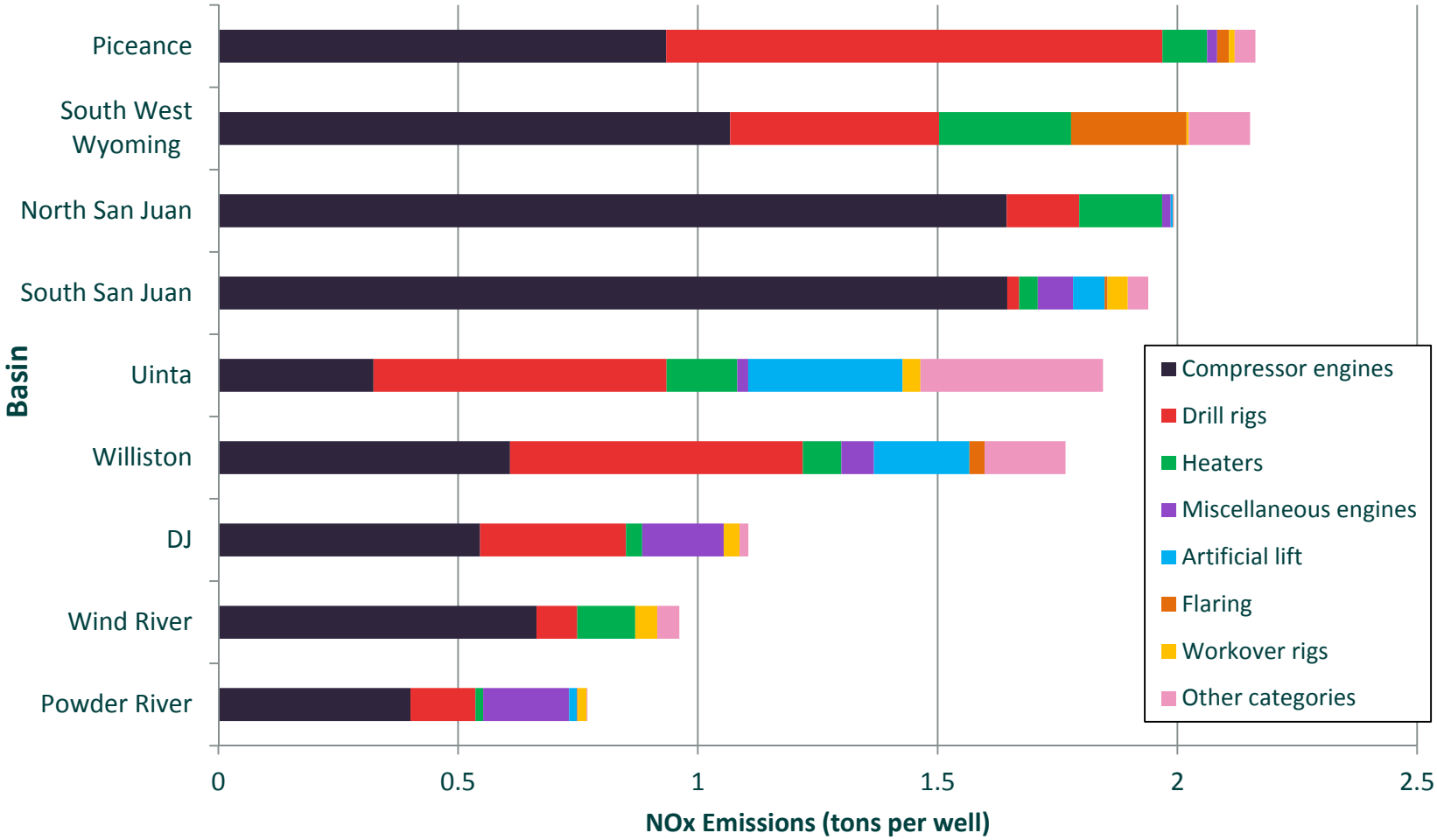
# Cross-Basin – NOx Emissions



# Cross-Basin – VOC Emissions

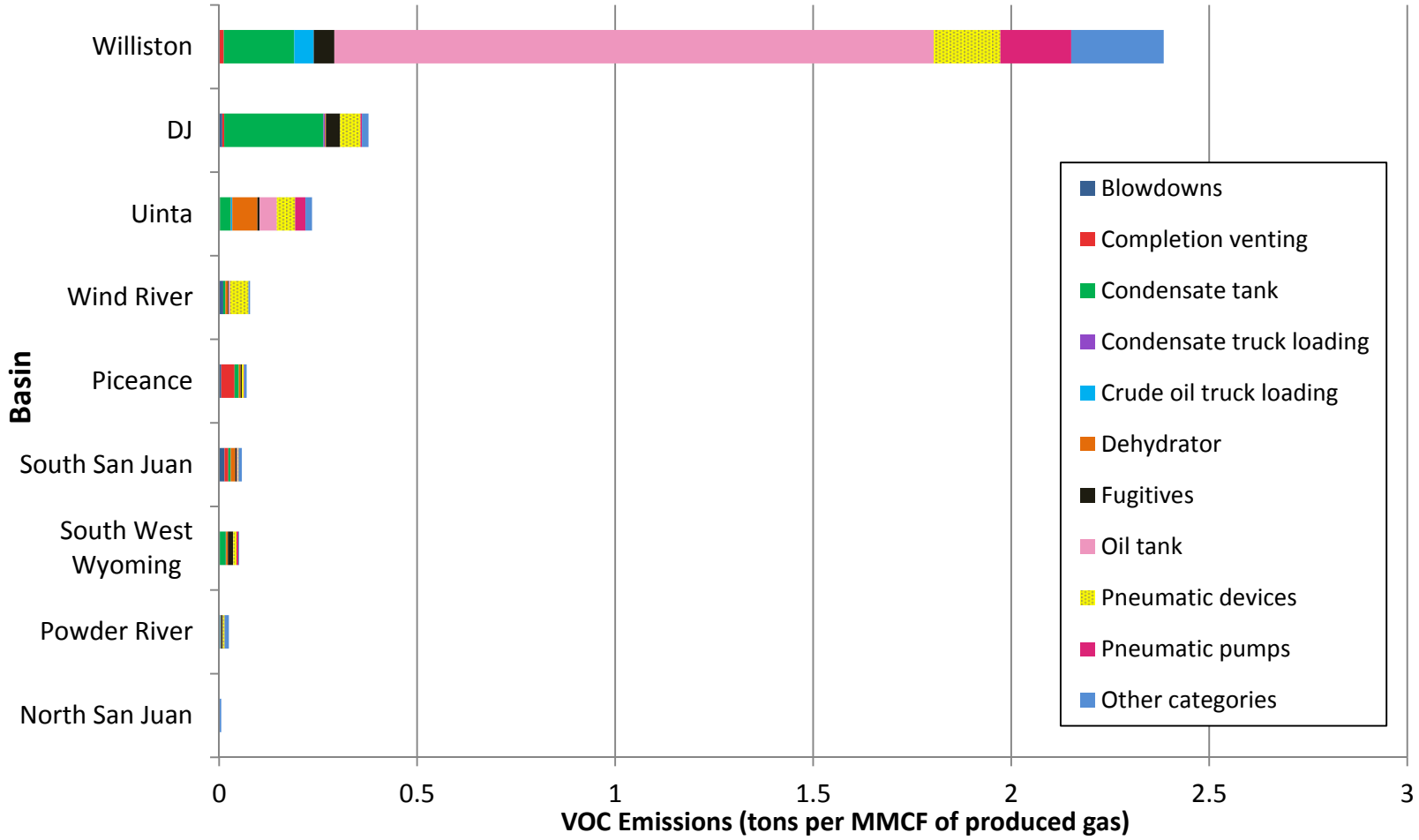


# Cross-Basin – Per-Well NOx Emissions



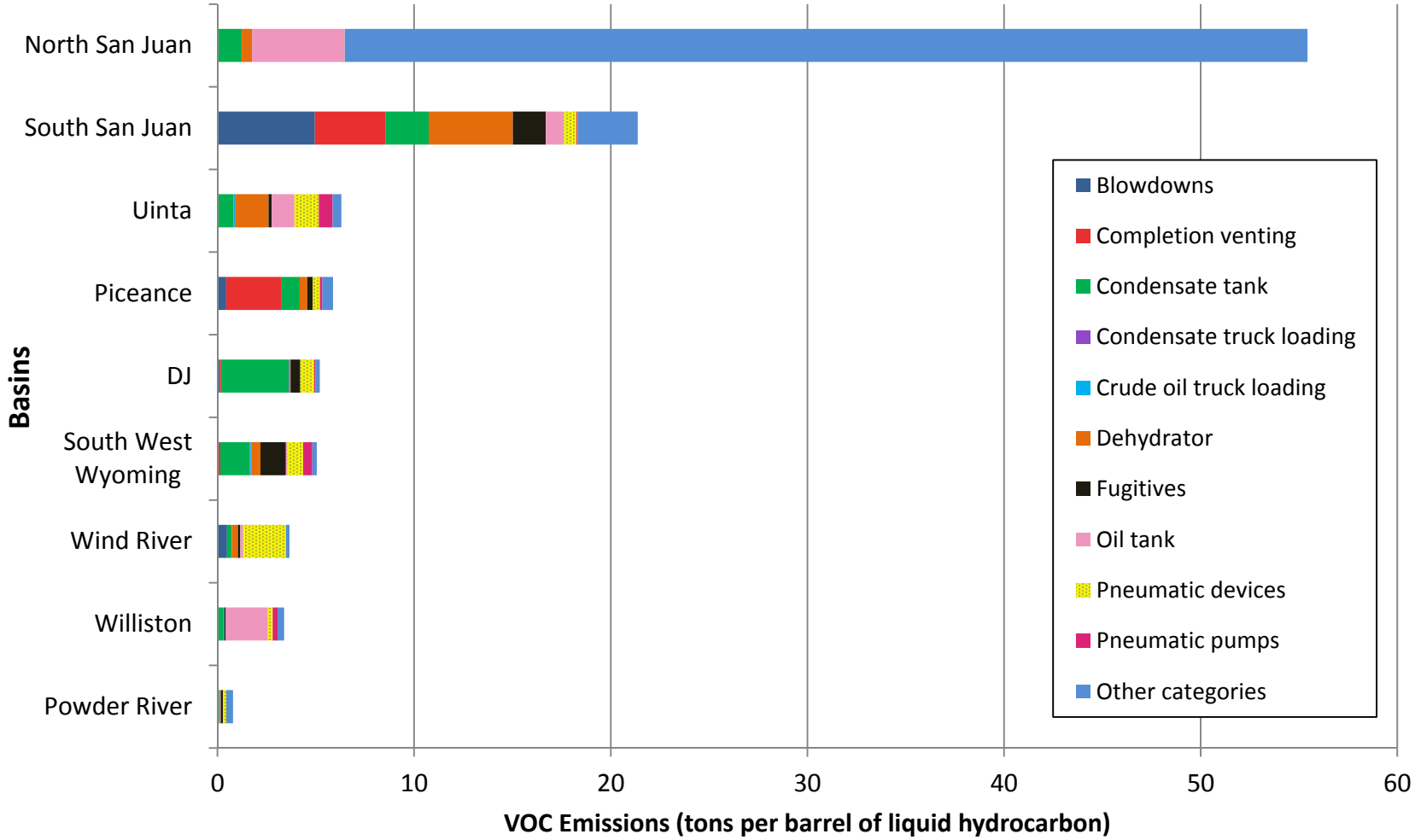

**Per well NOx emissions relatively consistent across basins – differences mainly due to usage of compression and centralized vs. wellhead compression**

# 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**

# 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

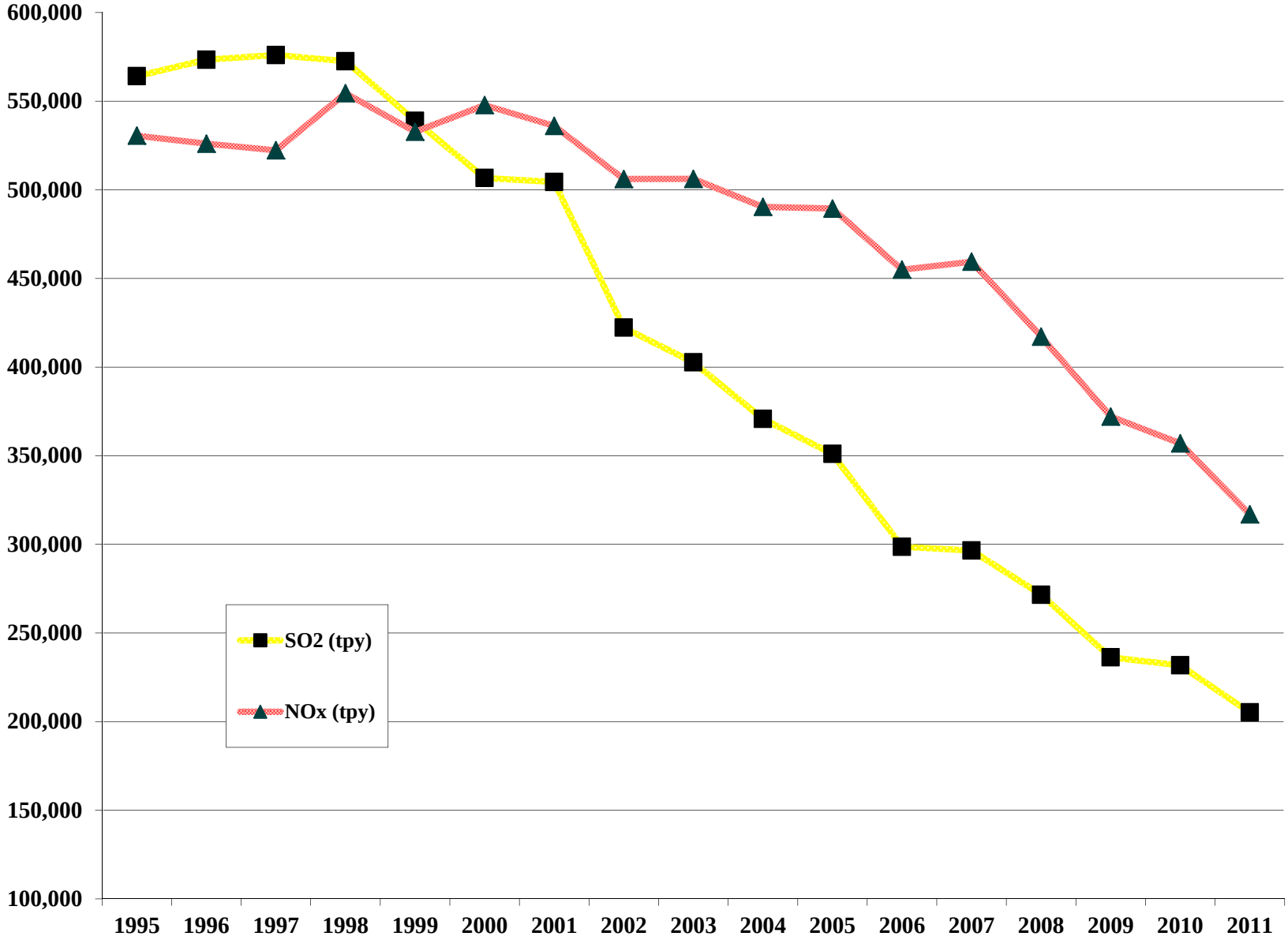
# Analysis of States' and EPA Oil & Gas Air Emissions Control Requirements for Selected Basins in the Western United States (2013 Update)

- State Control Regulations as Compared to Federal Rules (VOC & Minor Source Permits)
- State Control Regulations as Compared to Federal Rules (NOx Control Requirements)
- WRAP Phase III Oil and Natural Gas Emission Inventories
  - Qualitative analysis reviews where such changes will occur as a result of state and federal regulations, as well as which source categories are likely affected
  - Report to be published in early November

# Western Ozone and PM Precursors - Key Emissions Sources

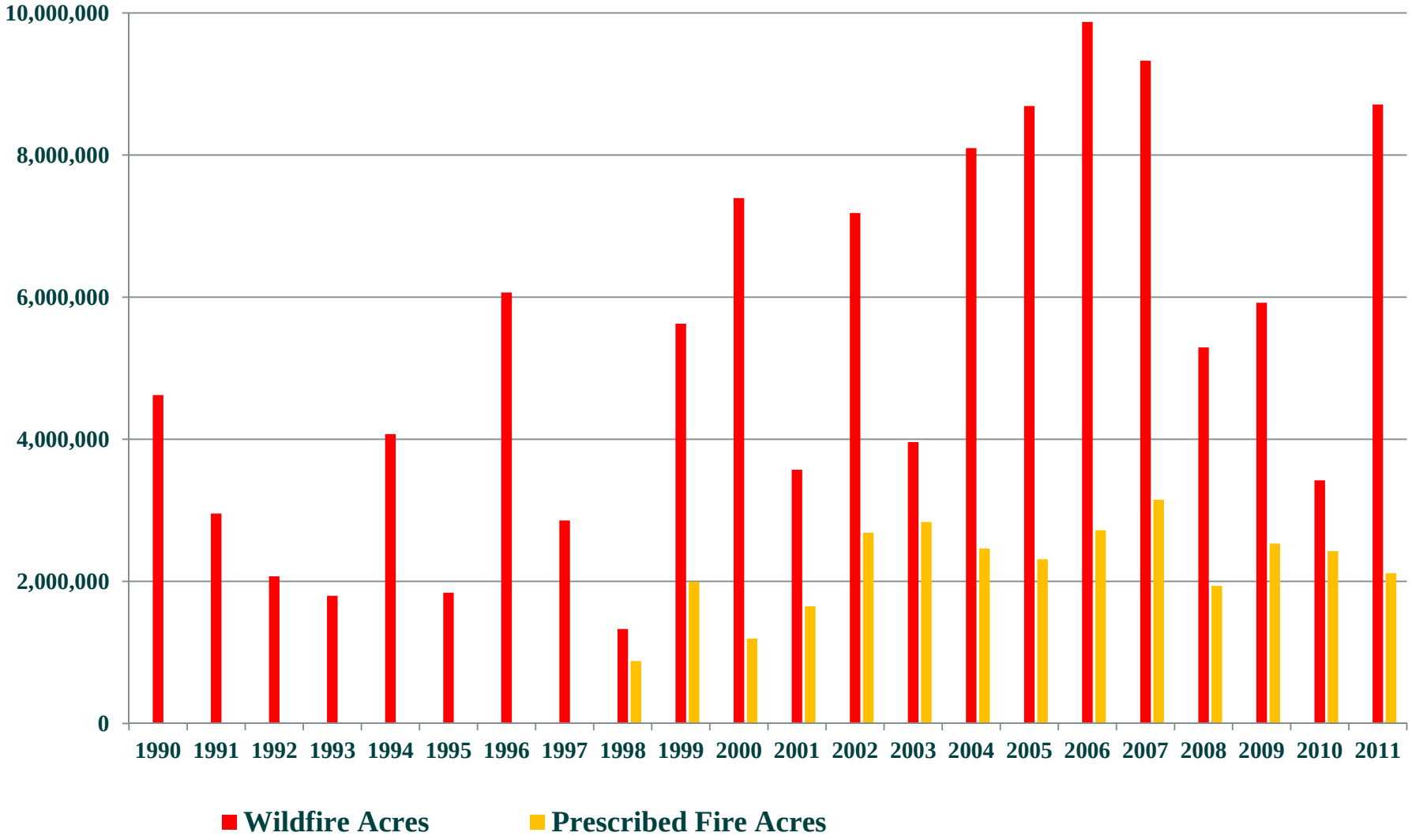
- Power plants decreasing markedly
- Mobile sources controlled and emission rates decreasing markedly through federal rules and state testing programs
- Fire activity and effects are huge (among the largest air pollution sources in the West), receiving intensive study
  - Deterministic & Empirical Assessment 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

# Western State Power Plant Emissions Trends



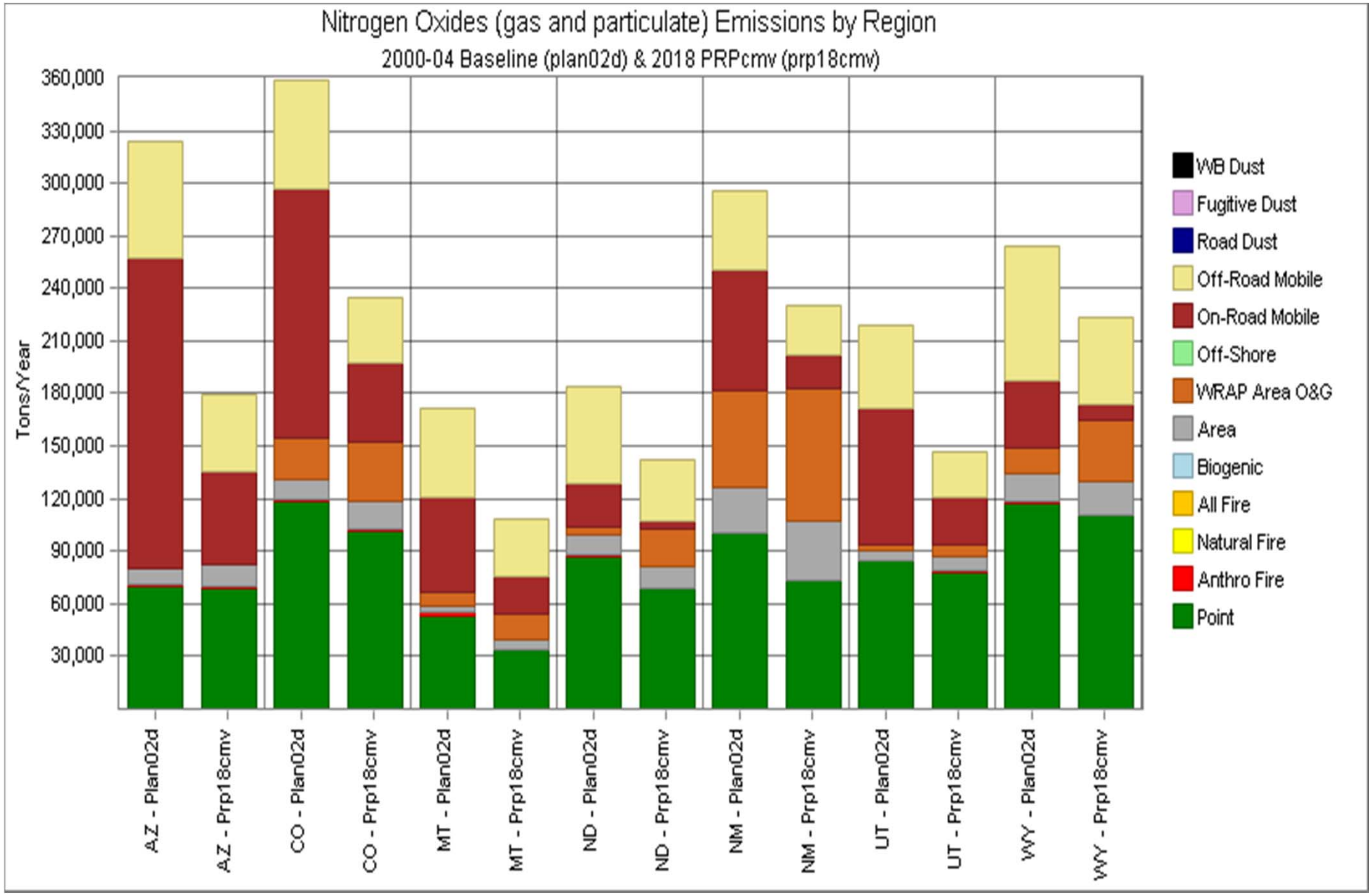

Data from EPA Clean Air Markets Division

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

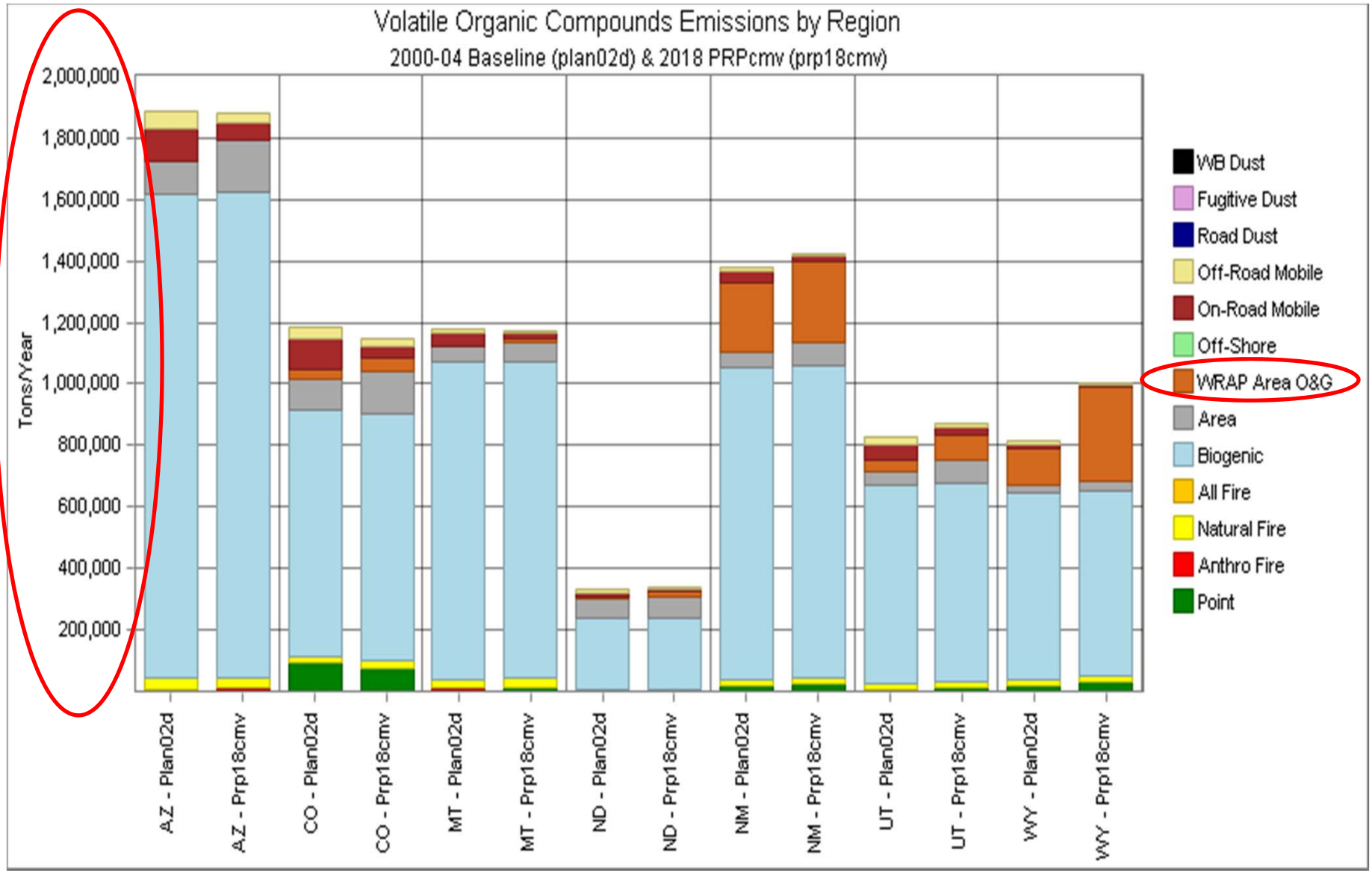



2012 is right behind 2006 in wildfire acres burned

# Projected Change for selected Western States in Anthropogenic NOx Emissions from 2002 to 2018



# Projected Change For Selected Western States in Gaseous Volatile Organic Compound Emissions From 2002 to 2018

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# EPA Guidance 2018 $O_3$ Projections Procedures

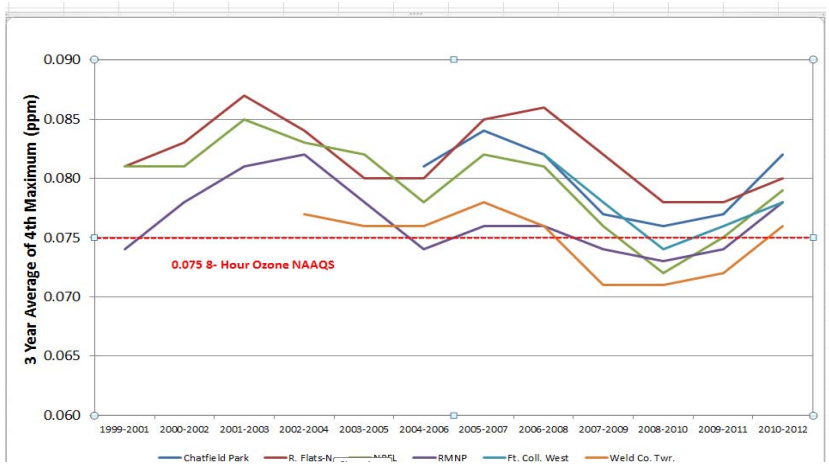
- Start with a current year observed Design Value (DVC)
  - EPA recommends average of three Design Values (DVs) centered on modeling year (2008) (5-Year DV)
    - DVC averaged of DVs from 2006-2008, 2007-2009 and 2008-2010
- Use relative changes in 2018 & 2008 modeling results to scale DVC to obtain future year Design Value (DVF)
  - Relative Response Factors (RRFs) based on ratio of 2018 to 2008 modeling results

$$DVF = DVC \times RRF$$

- Compare DVF with March 2008 0.075 ppm ozone NAAQS
  - Current study not a SIP attainment demonstration analysis

# 2018 Projections for Sensitivity Tests

- Sensitivity to current year DVC
  - 5-Year DVC based on 2006-2010 and 2008-2012 observations



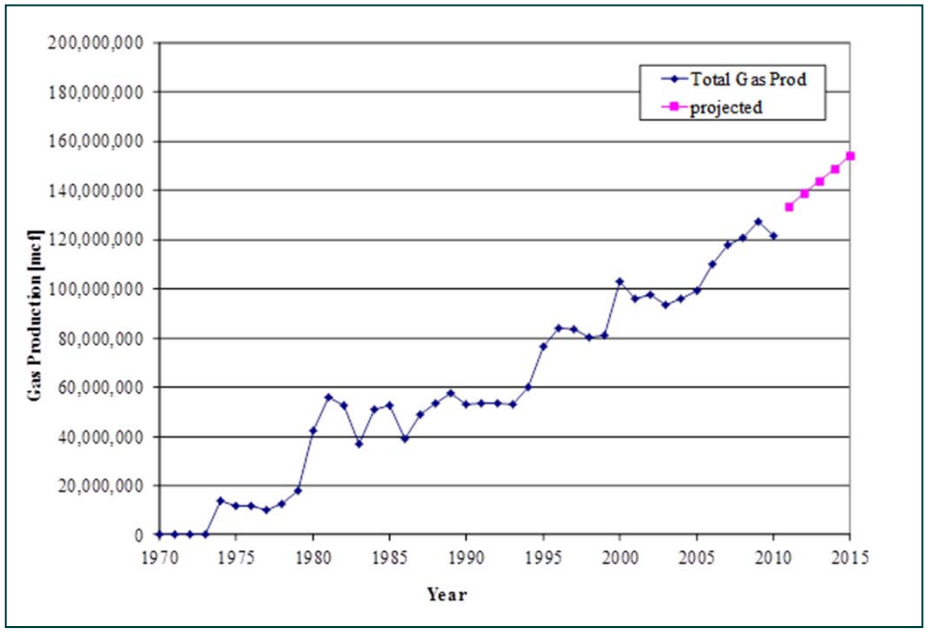

| DMA/NFR NAA Use 2018 O&G | nox08 | nox18 | % | voc08 | voc18 | % |
|---|---|---|---|---|---|---|
| Total Anthropogenic | 400.3 | 232.2 | -42.0% | 533.1 | 618.7 | 16.1% |
| Biogenic | 5.0 | 5.0 | 0.0% | 135.1 | 135.1 | 0.0% |
| Total | 405.3 | 237.2 | -41.5% | 668.2 | 753.8 | 12.8% |
| **Use 2008 O&G** | **nox08** | **nox18** | **%** | **voc08** | **voc18** | **%** |
| Total Anthropogenic | 400.3 | 243.5 | -39.2% | 533.1 | 479.1 | -10.1% |
| Biogenic | 5.0 | 5.0 | 0.0% | 135.1 | 135.1 | 0.0% |
| Total | 405.3 | 248.5 | -38.7% | 668.2 | 614.1 | -8.1% |

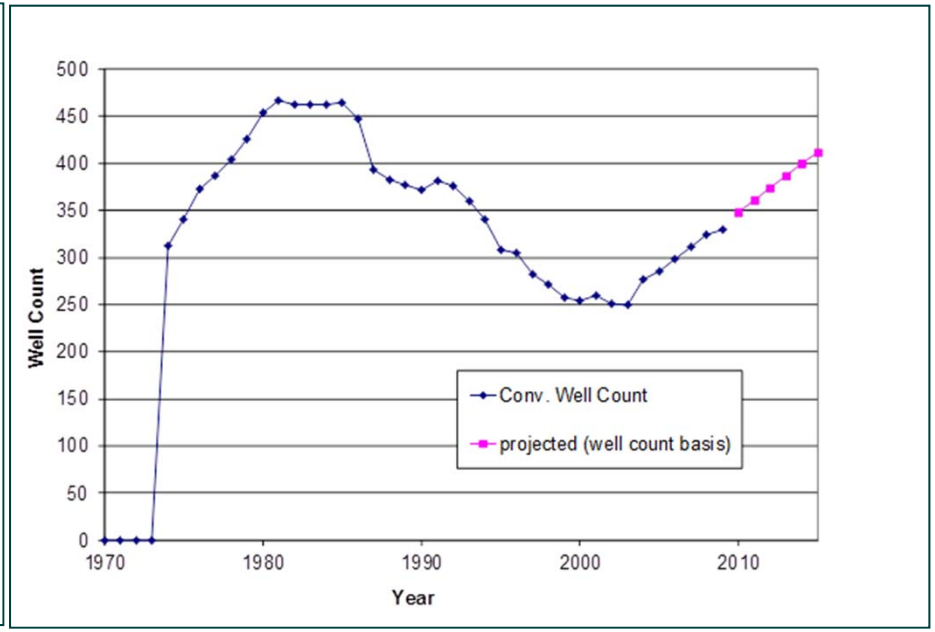
# Projections - Methodology

- 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

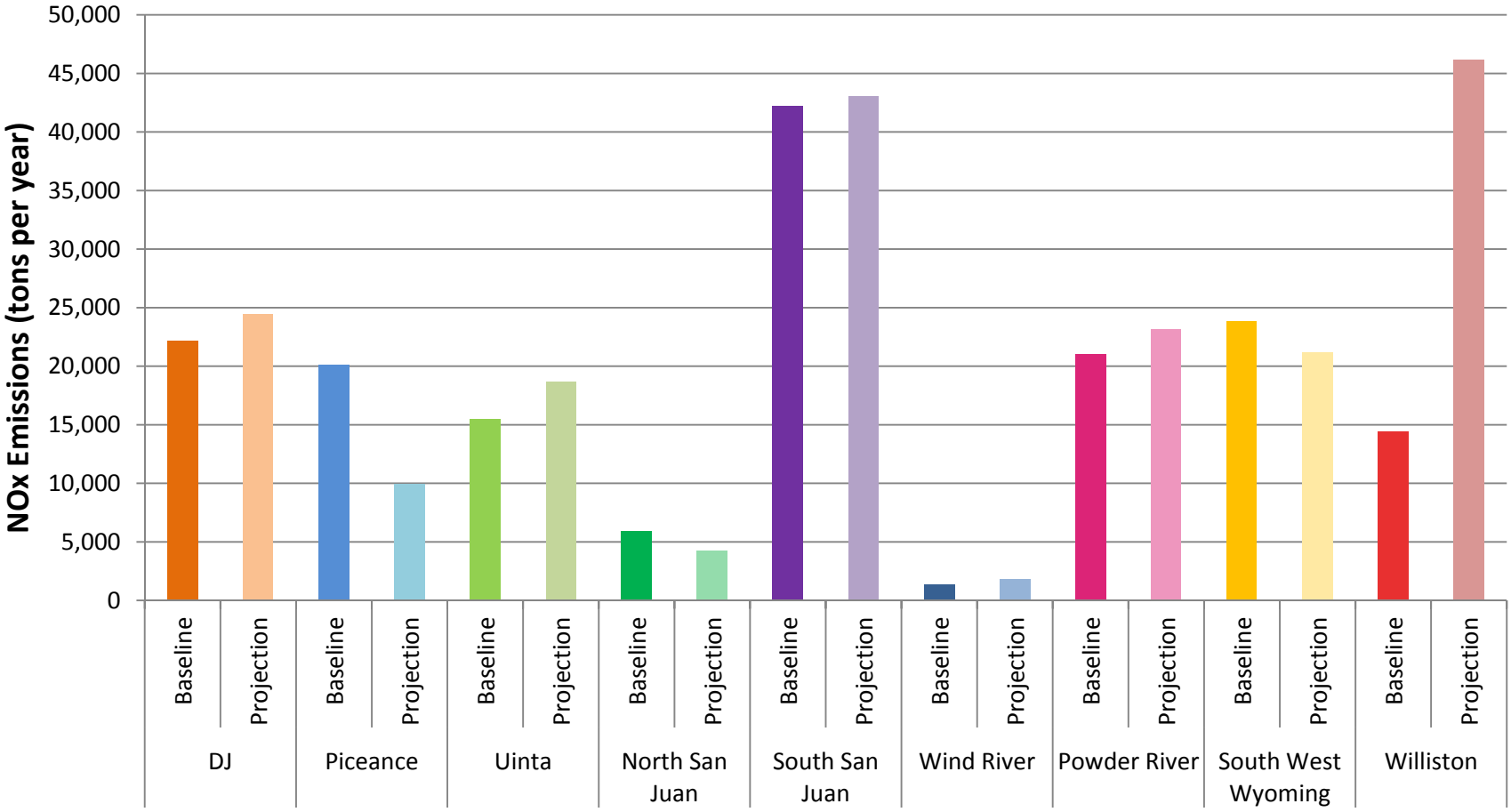
# Projections - Methodology

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



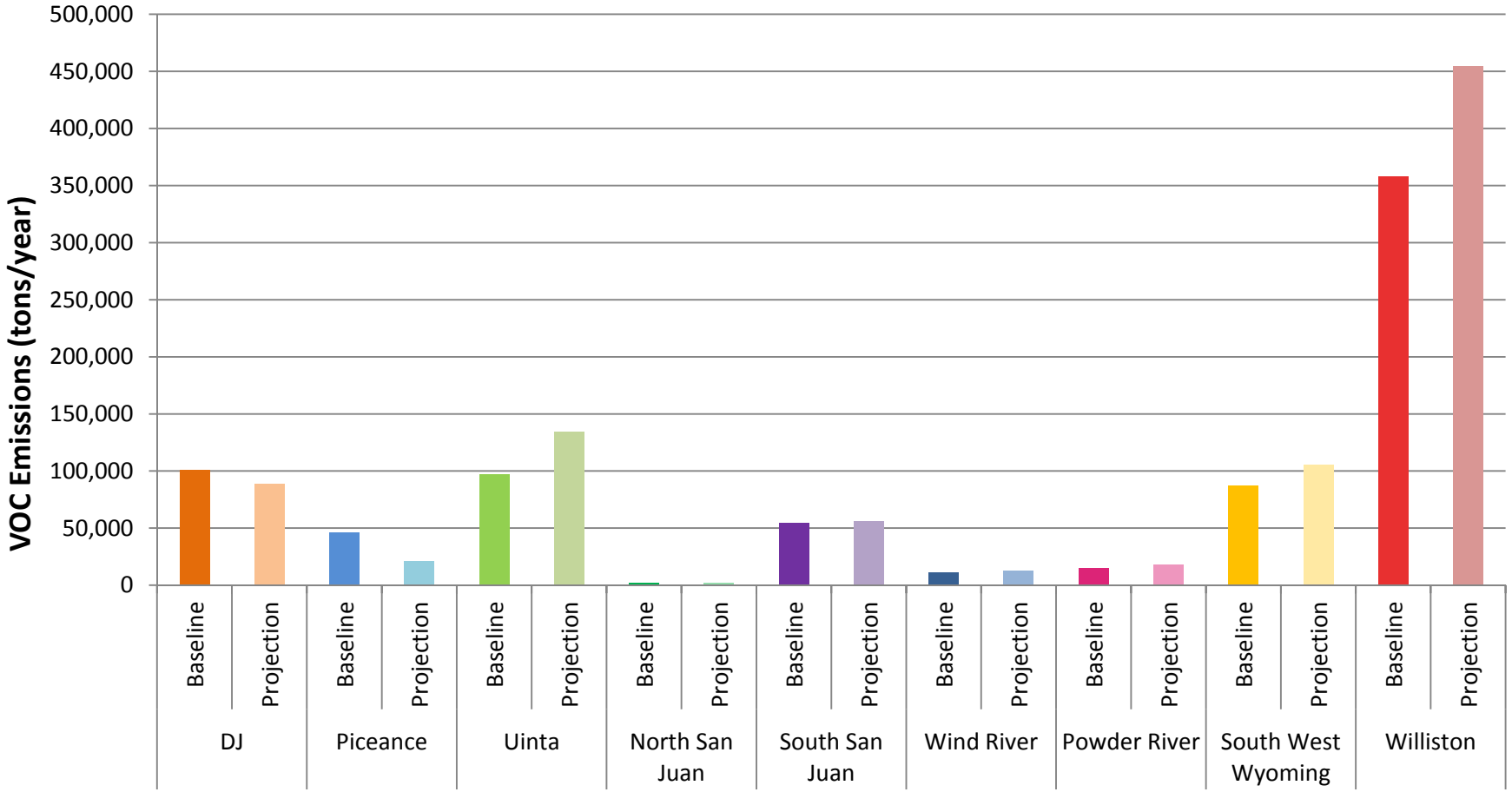



# NOx Projections - Results




**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**

# Emission Inventories – Issues and New Concepts

1. Point vs. area sources
2. Missing source categories
3. Skewness
4. Gas composition data
5. New factor data
6. Uncertainties

# Issues and New Concepts – 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

- **Phase III inventories significant improvement on past inventories**
- **Some categories could not be included due to lack of data, lack of emissions quantification approach**
- **Potential contribution to inventories – unclear**

# 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

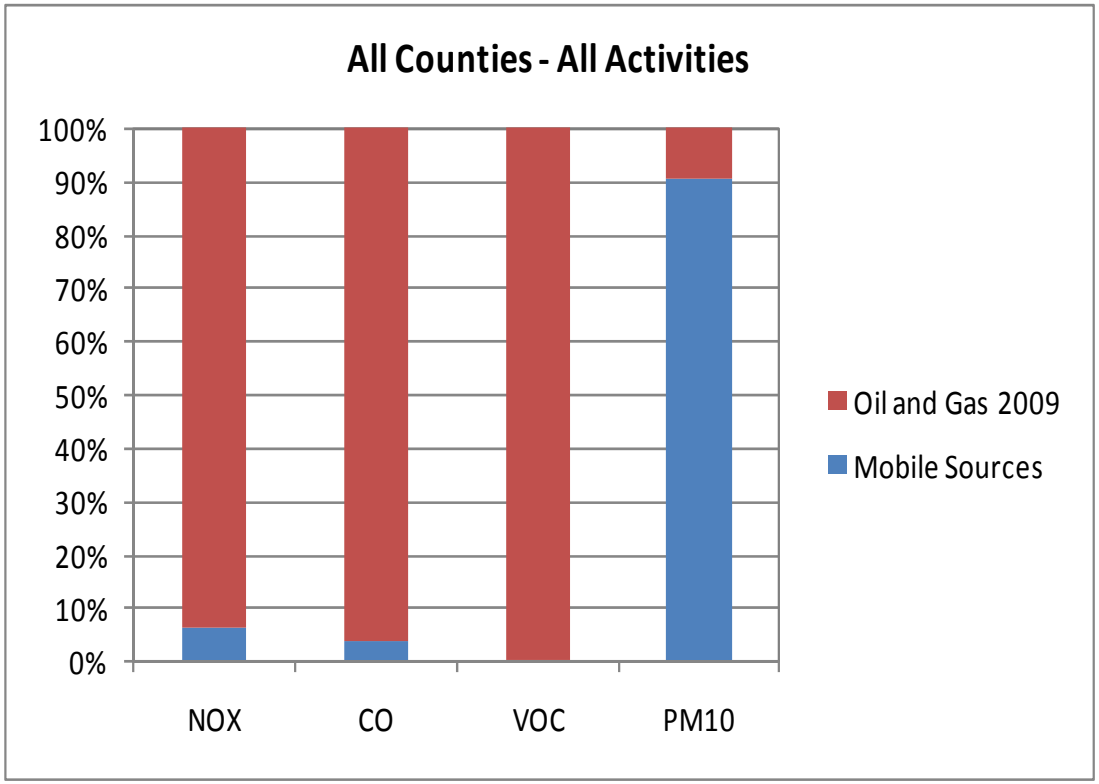
# Issues and New Concepts – Missing Categories

## 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 – Missing Categories

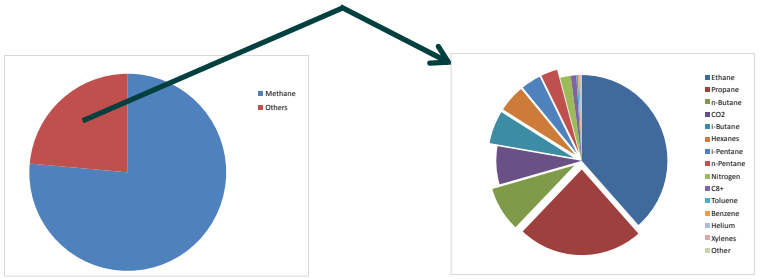
## Non-routine Events

- **Pipeline blowdowns**
- **Spills/upsets**
- **Maintenance activities**

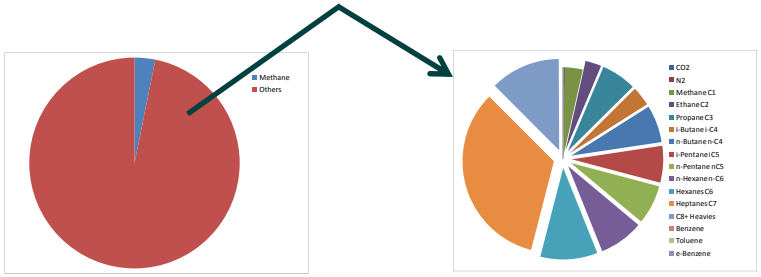
# Issues and New Concepts – Skewness

- 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

# Issues and New Concepts – Gas Compositions




**Conventional Gas**
**(Vented/Fugitive Sources)**




**Flash Gas**
**(Condensate and Oil Tanks)**

- Gas compositions in Phase III use a basin-average approach
- Variability within a basin by production type (field to field)
- Variability within the production/gathering system
- More data needed – field or formation level approach for basins?

# Issues and New Concepts – Factors and Uncertainty

## New factor data

- Fugitive emissions
- Venting from well completions
- Water tanks / evap ponds

## Uncertainty

- Uncertainties not quantitatively estimated in most inventories
- Large data sets needed to estimate uncertainty
- Helpful in identifying poorly-characterized sources, and estimating uncertainty in AQ modeling

# Related Ongoing and Future Work

- **Oil and gas mobile sources pilot project**

  http://www.wrapair2.org/Mobile.aspx

- **Update Phase III data from 2006 baseline to Phase IV 2009 baseline**

  http://www.wrapair2.org/PhaseIV.aspx

- **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

# 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

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