Utility of Bottom-up and Top-down O&G Emission Inventory estimates for air quality management purposes

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WRAP/WESTAR

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The Clean Air Act (CAA)

- 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"
  - 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

Air Quality Planning in Eastern Utah

2006 Oil and Gas Production

BLM proposed leasing for oil shale development

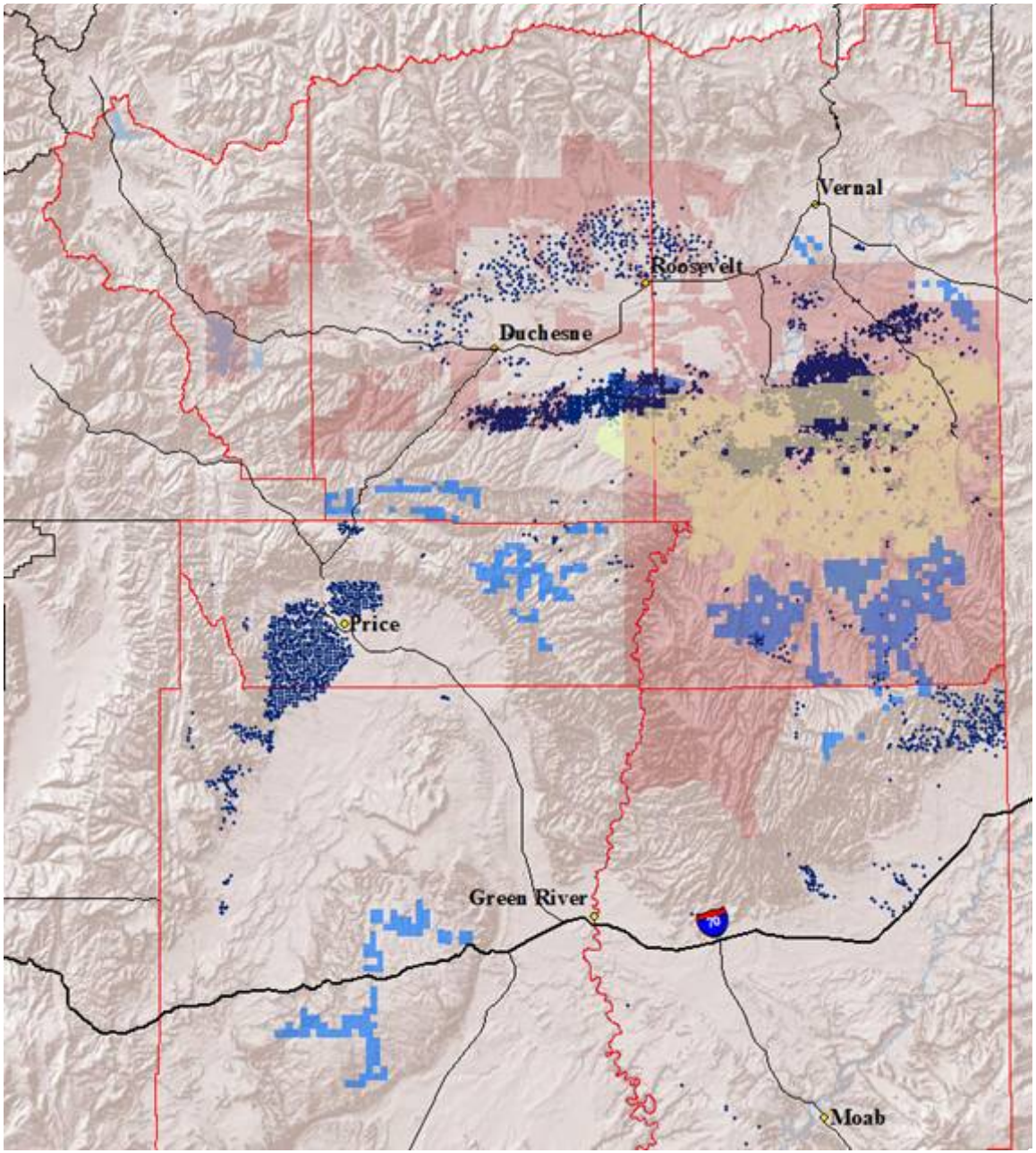
BLM proposed leasing for tar sands development

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

Oil Shale Leasing

Tar Sands Leasing

"Indian Country"



CAA 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

Regulatory-grade emissions inventories - permits

Permitted "point" sources - what are they?

- States, Tribes and EPA issue permits with emission limits
- Regulation of point sources varies by jurisdiction
  - Permitting thresholds
  - Actual emissions are less
  - Inventories tally up tons of emissions from source types
- Periodic testing and inspections are also done to verify compliance with permit conditions
- *Best-understood emissions are from permitted sources*

Permit Thresholds

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

Wide variation among states in permitting/ reporting thresholds

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

Regulatory-grade emissions inventories - Non-Point (Area) Sources

Area sources - what are they?

- Sources too small and numerous to have individual permits with emission limits
- Determination of "which are area sources" varies by jurisdiction
  - Related to permitting thresholds
  - Counted and then emissions are estimated at the <u>county</u> and <u>tribal reservation</u> levels
  - Inventories tally up tons of emissions from source types
- *Less well-understood emissions are from area sources*

Oil & Gas Basins in the Intermountain West

WRAP 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
- Fracking Engines
- Lateral compressor engines
- Workover Rigs
- Salt-Water Disposal Engines
- Artificial Lift Engines (Pumpjacks)
- Vapor Recovery Units (VRUs)
- Miscellaneous or Exempt Engines
- Flaring
- Fugitive Emissions
- Well Blowdowns
- Truck Loading
- Amine Units (acid gas removal)
- Water Tanks

Calculating basin or sub-basin regulatory emissions inventories for upstream oil and gas point and area sources

[activity count * production] * emission factor = annual emissions

- Activity characteristics affected by
  - Age
  - Controls
  - Quality and frequency of operations and maintenance
  - Throughput of liquids and gases
- Emission factors
  - One or more field tests of specific equipment at specific locations
  - Assigned by Source Classification Code
  - Representativeness assignment in EI is professional judgment
- Annual emissions are tons/year of released emissions (VOCs, NOx, CO, etc.)
  - CH_4 and C_2H_6 are not VOCs
  - Emissions inventories are flat, 2-dimensional, summed over time
- All chemical speciation, and further temporal and spatial refinements are handled in photochemical grid modeling

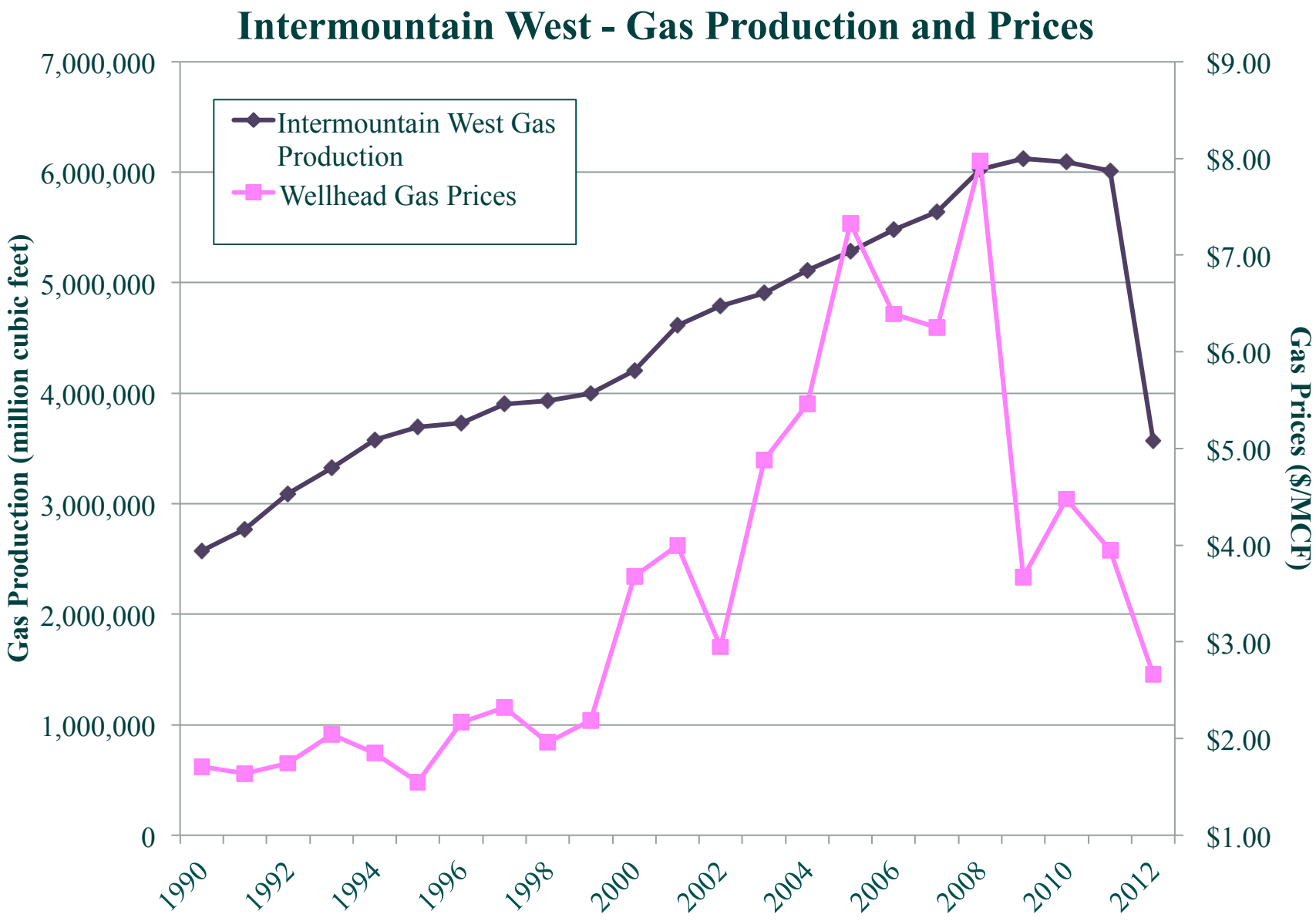
Basin Inventories

2008 Emission Inventories

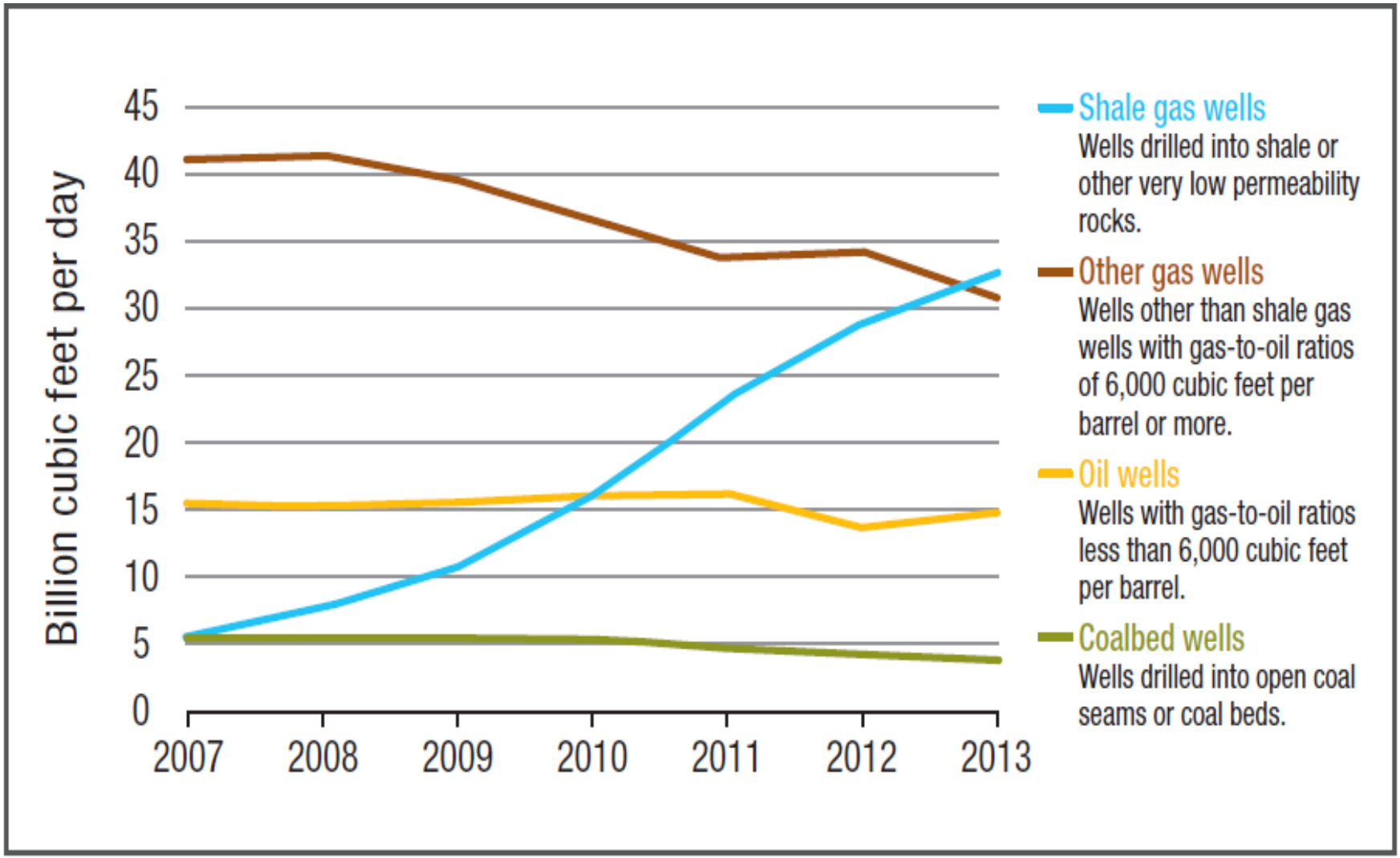
Basin	Emissions (tons/yr)				
	NOx	VOC	CO	SOx	PM
Denver-Julesburg Basin	22,165	100,622	14,367	115	717
Uinta Basin	15,508	97,302	11,569	431	716
Piceance Basin	20,113	45,714	11,520	519	1,812
North San Juan Basin	5,917	2,187	6,456	30	72
South San Juan Basin	42,233	54,469	23,602	273	557
Wind River Basin	1,335	10,993	2,062	1,276	31
Powder River Basin	20,980	14,787	15,445	596	666
Greater Green River 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**


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

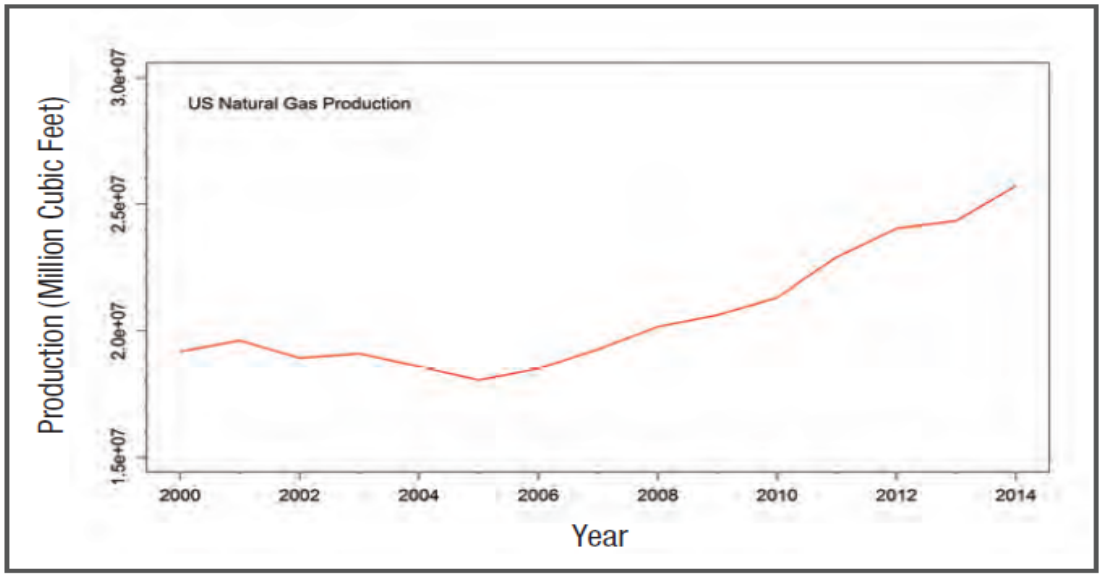
U.S. natural gas gross withdrawals by well type (2007-13)*



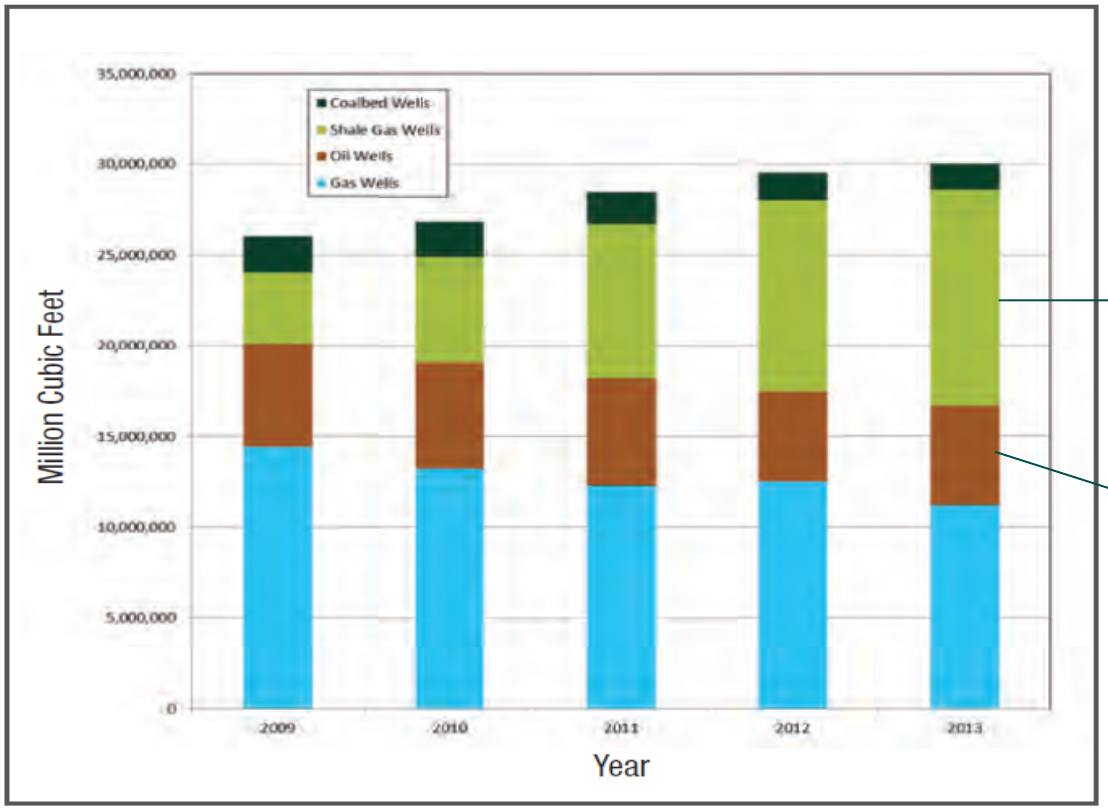
~ half of Natural Gas wells are (still) conventional/CBM

~ 25% of gas is from Oil wells

* - AWMA Environmental Manager, Aug. 2015



U.S. Natural Gas Production



Sources for Natural Gas production past 15 years

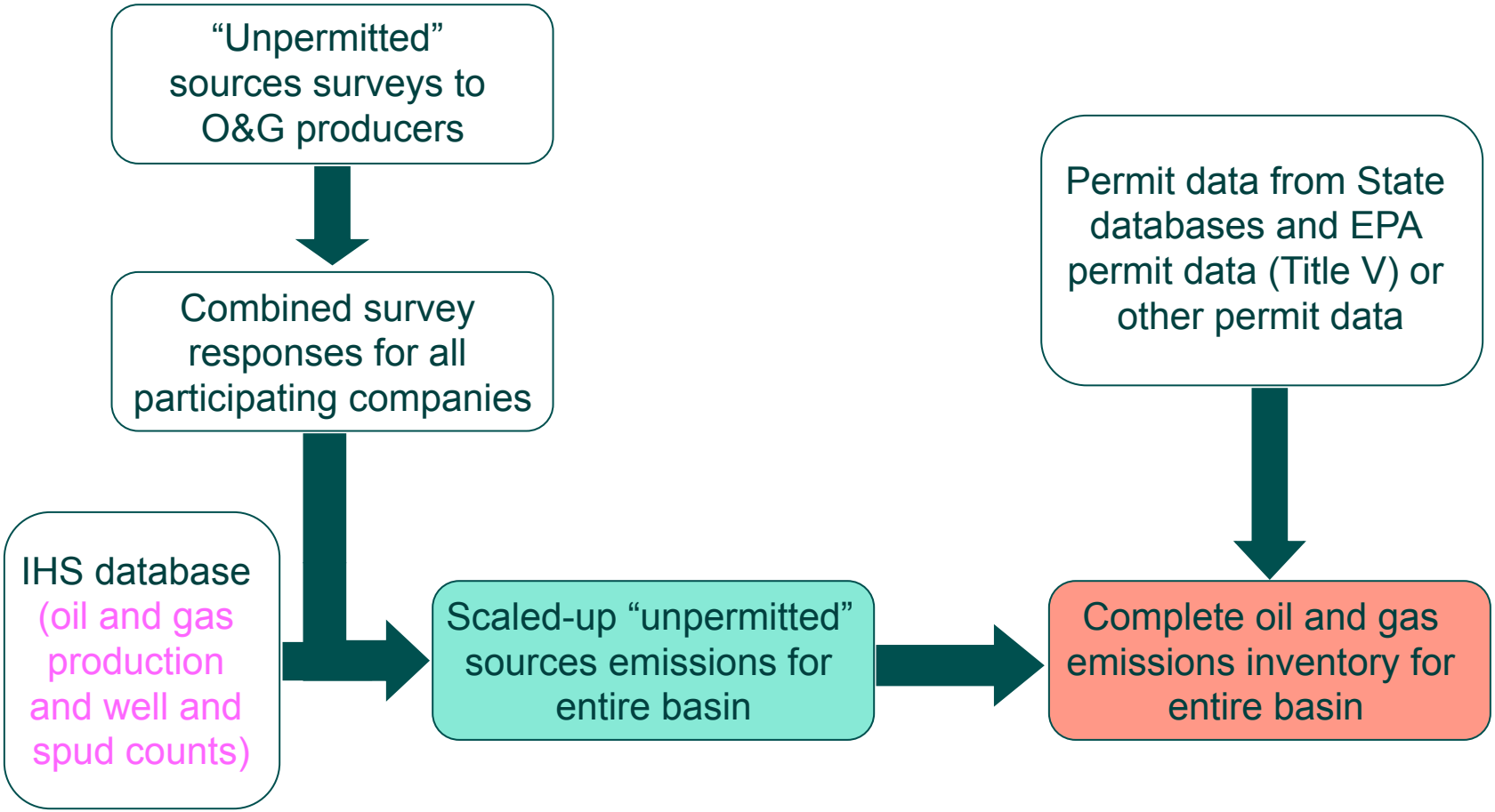
→ increasingly directly affected by current, recent EPA NSPS / NESHAP regulations

AWMA Environmental Manager, Aug. 2015

Mass Balance and (near or far) Remote Sensing – emissions from which piece of equipment or SCC process level are being represented in those data?

More methodology,
Data if there’s time and interest

WRAP Methodology Diagram



WRAP 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"**

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
  - and produced and leaked methane…..
- 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

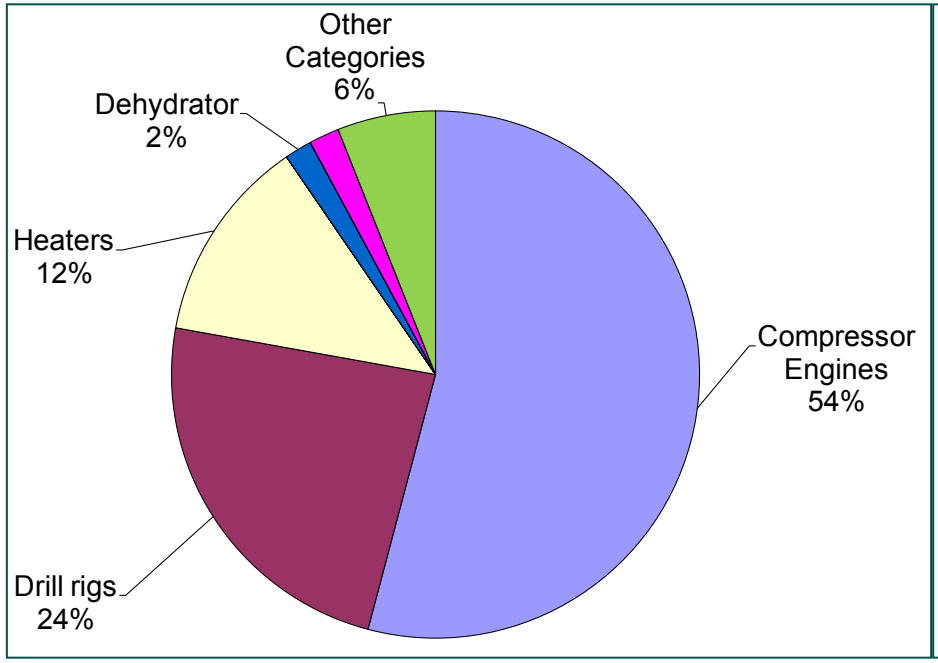
WRAP Methodology

Response rates from operator surveys of "unpermitted" sources emissions for entire basin

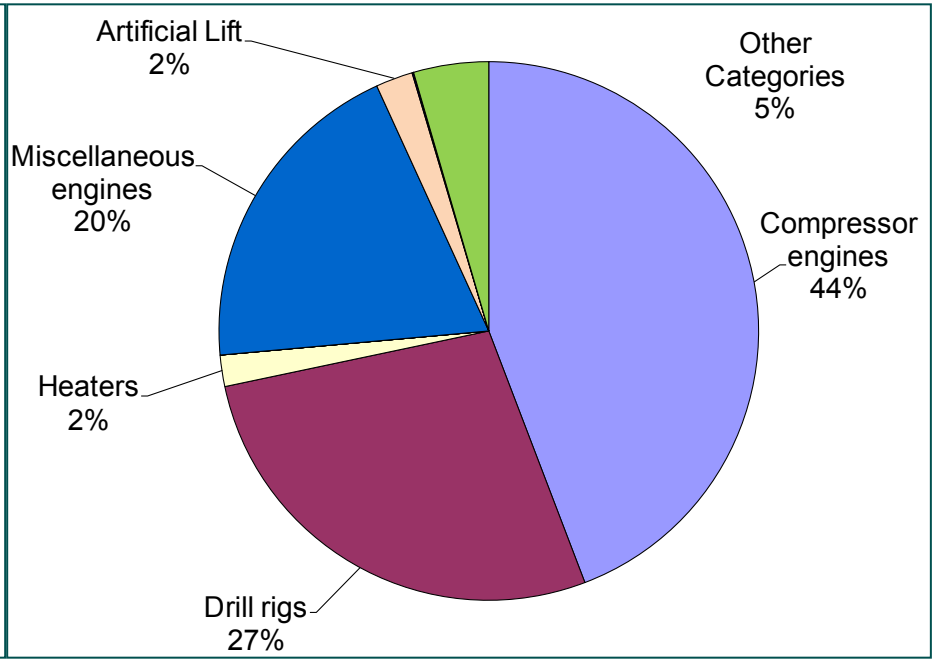
Basin	Percentage Ownership in Phase III		
	Gas	Liquid	Wells
Denver-Julesburg	63%	58%	50%
Piceance	84%	91%	75%
Uinta	82%	78%	71%
North San Juan	85%	93%	87%
South San Juan	82%	48%	67%
Wind River	97%	23%	54%
Greater Green River	77%	64%	54%
Powder River	46%	24%	30%
Williston	30%	33%	20%

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

Results – Example NOx Emissions Breakdown By Source Category



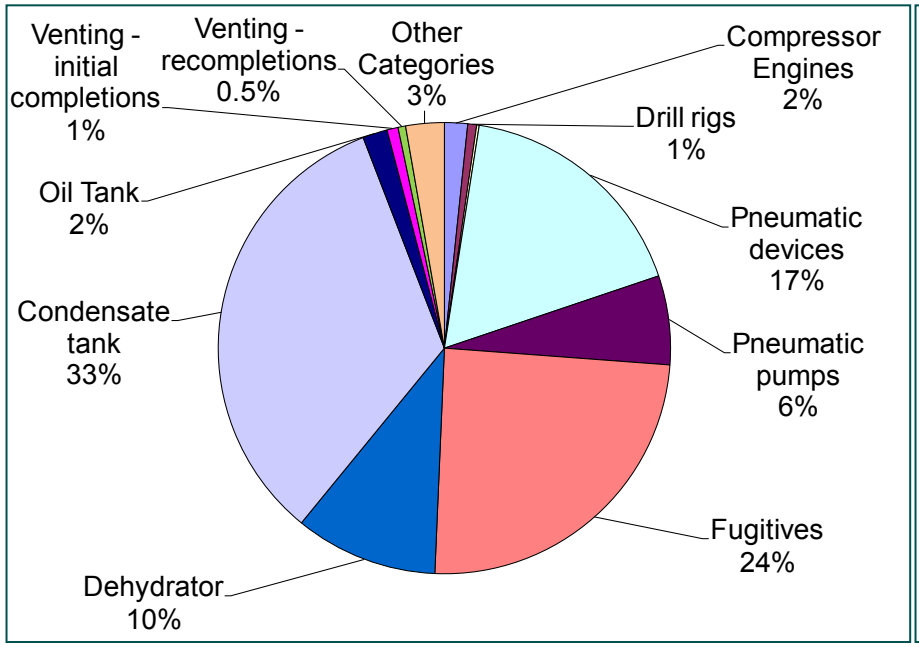
Southwest Wyoming Basin



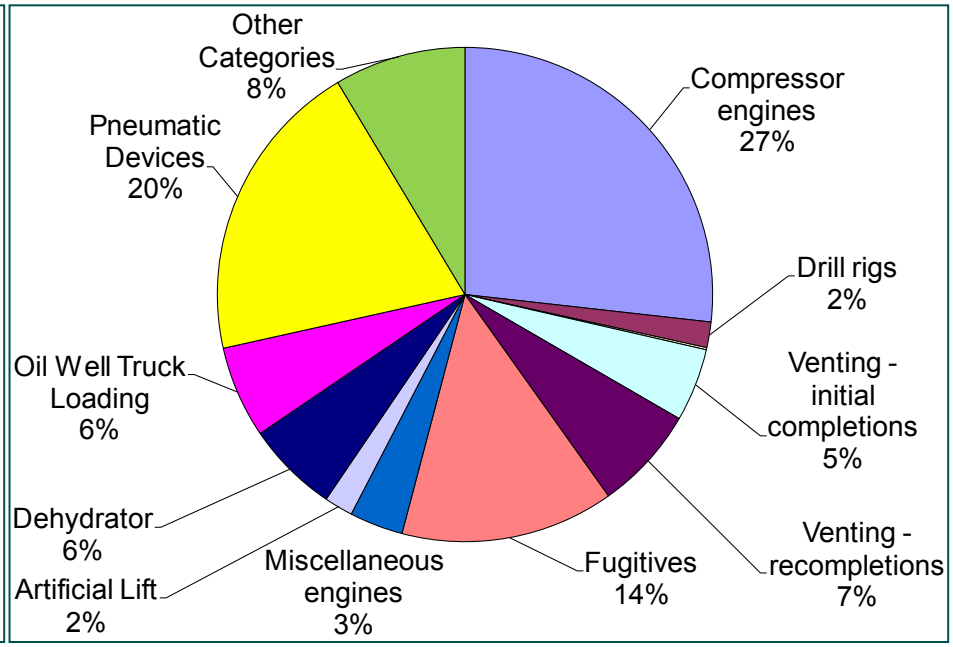
Powder River Basin

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



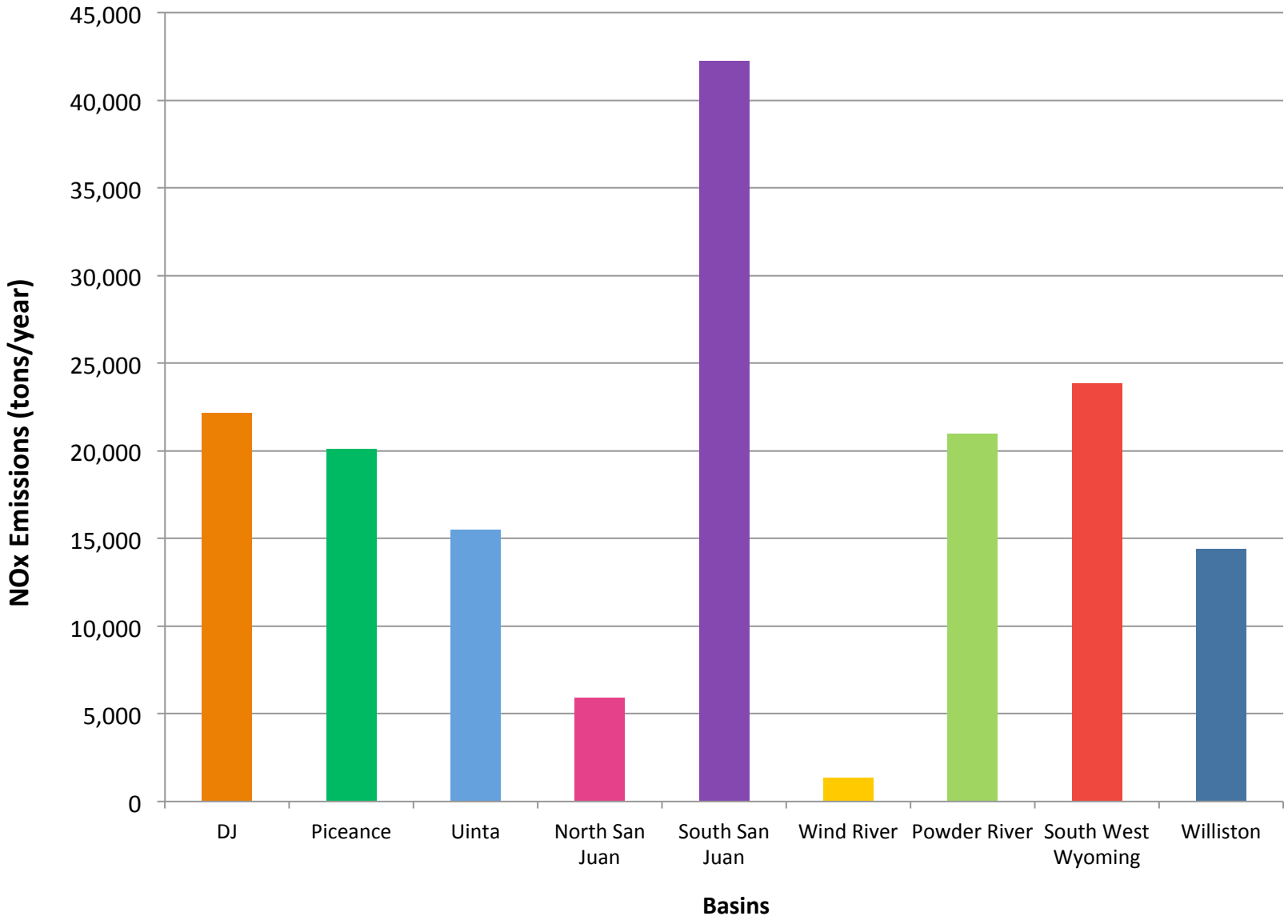
Southwest Wyoming Basin



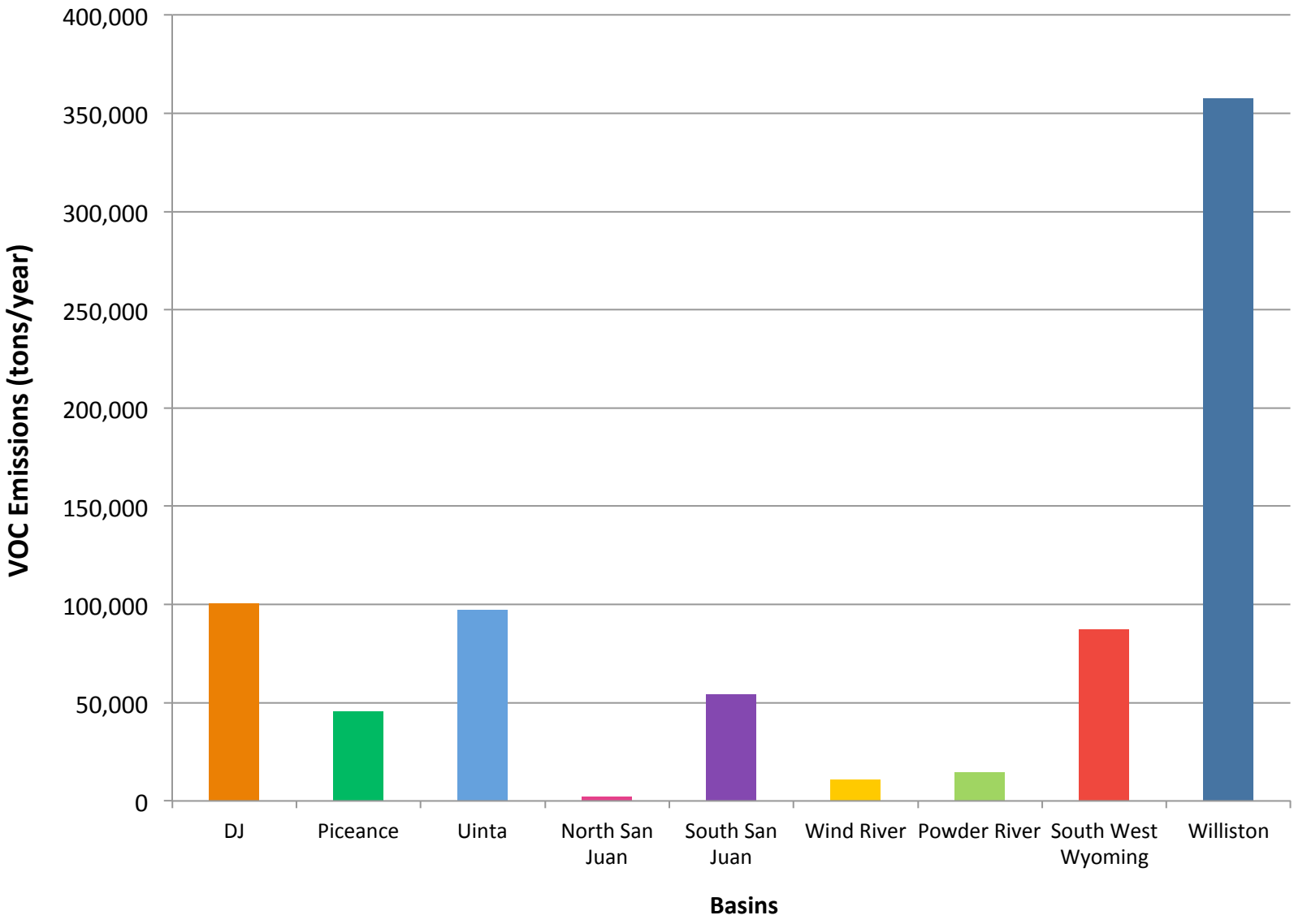
Powder River Basin

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

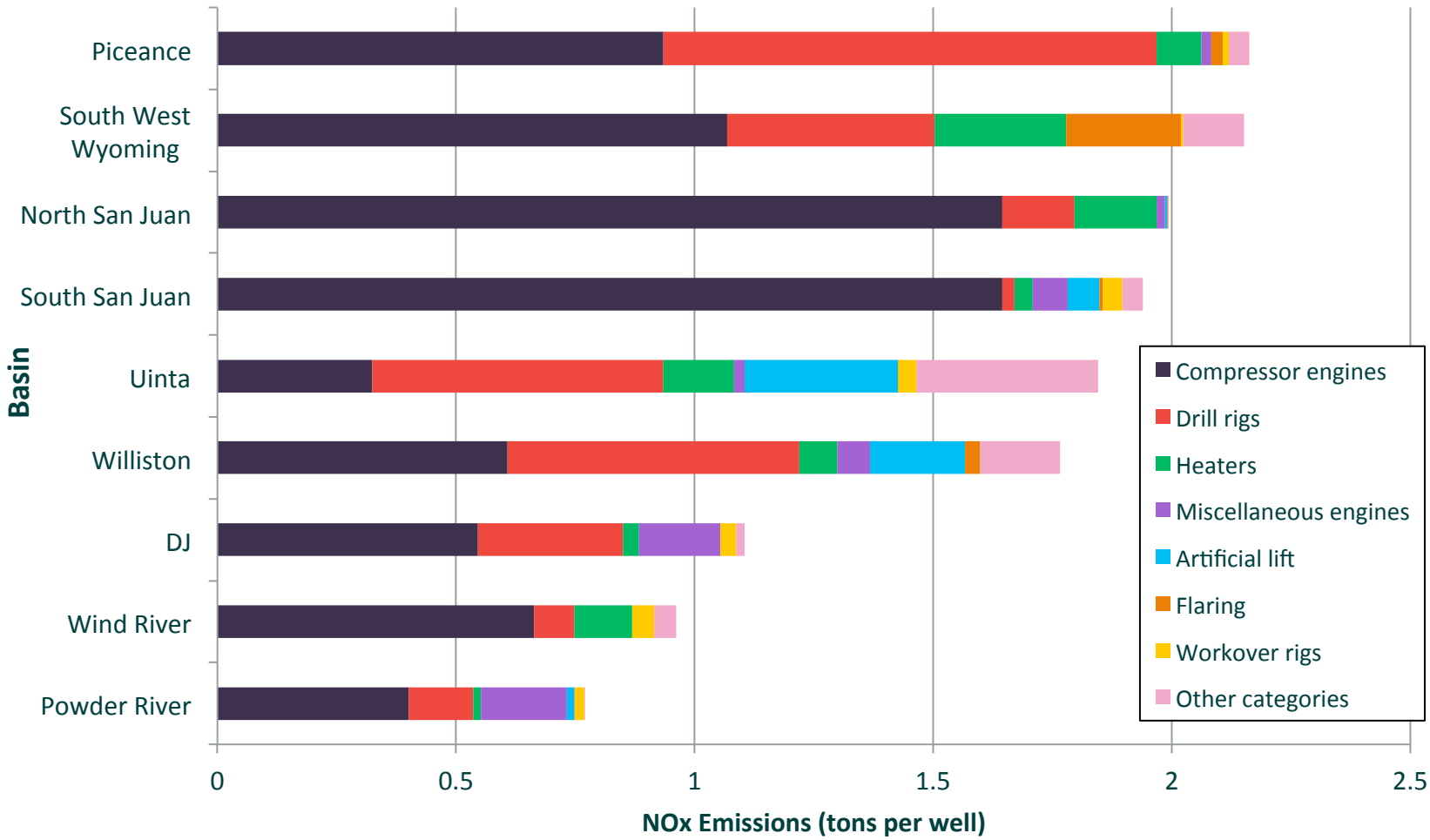
Cross-Basin – NOx Emissions



Cross-Basin – VOC Emissions

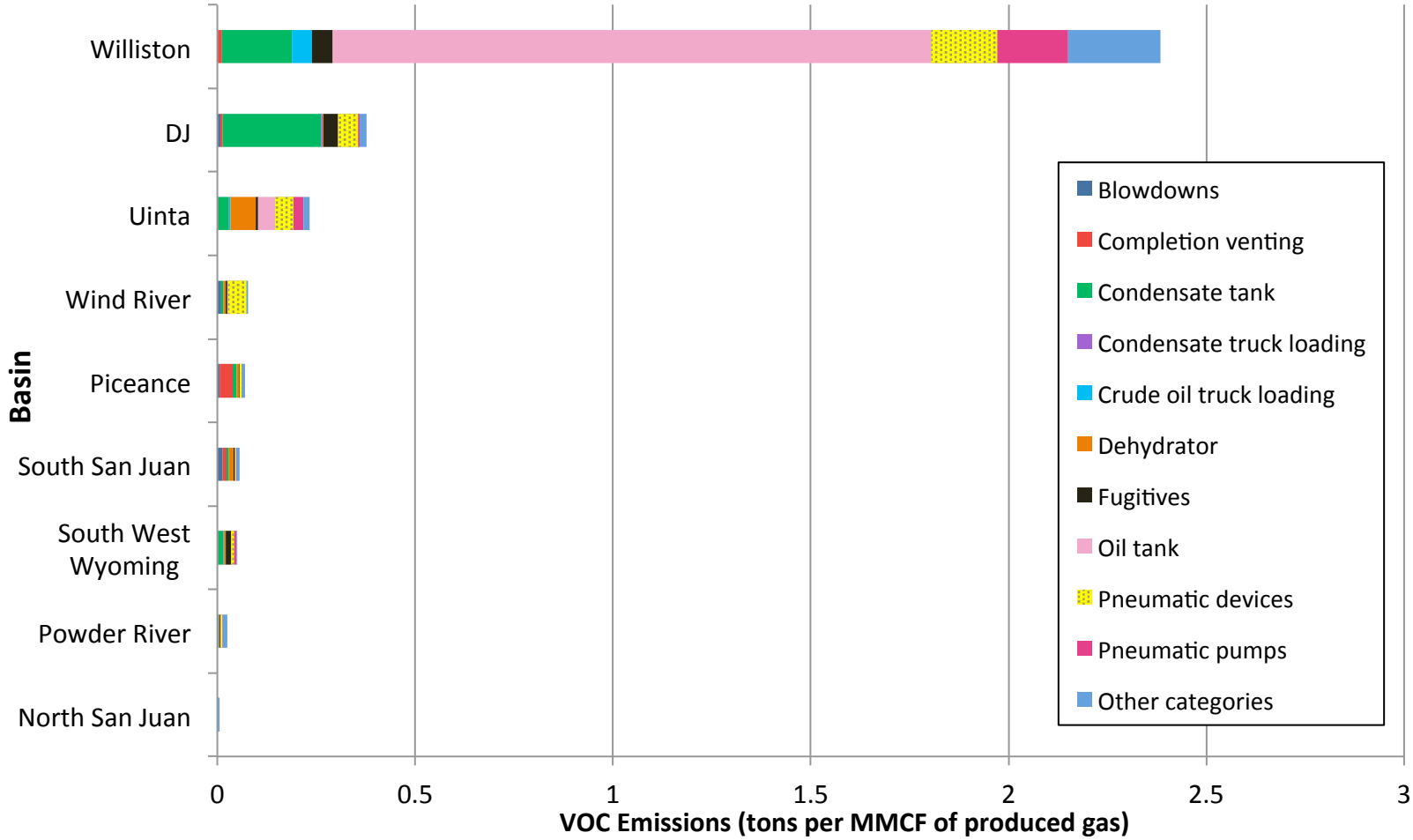


Cross-Basin – Per-Well NOx Emissions



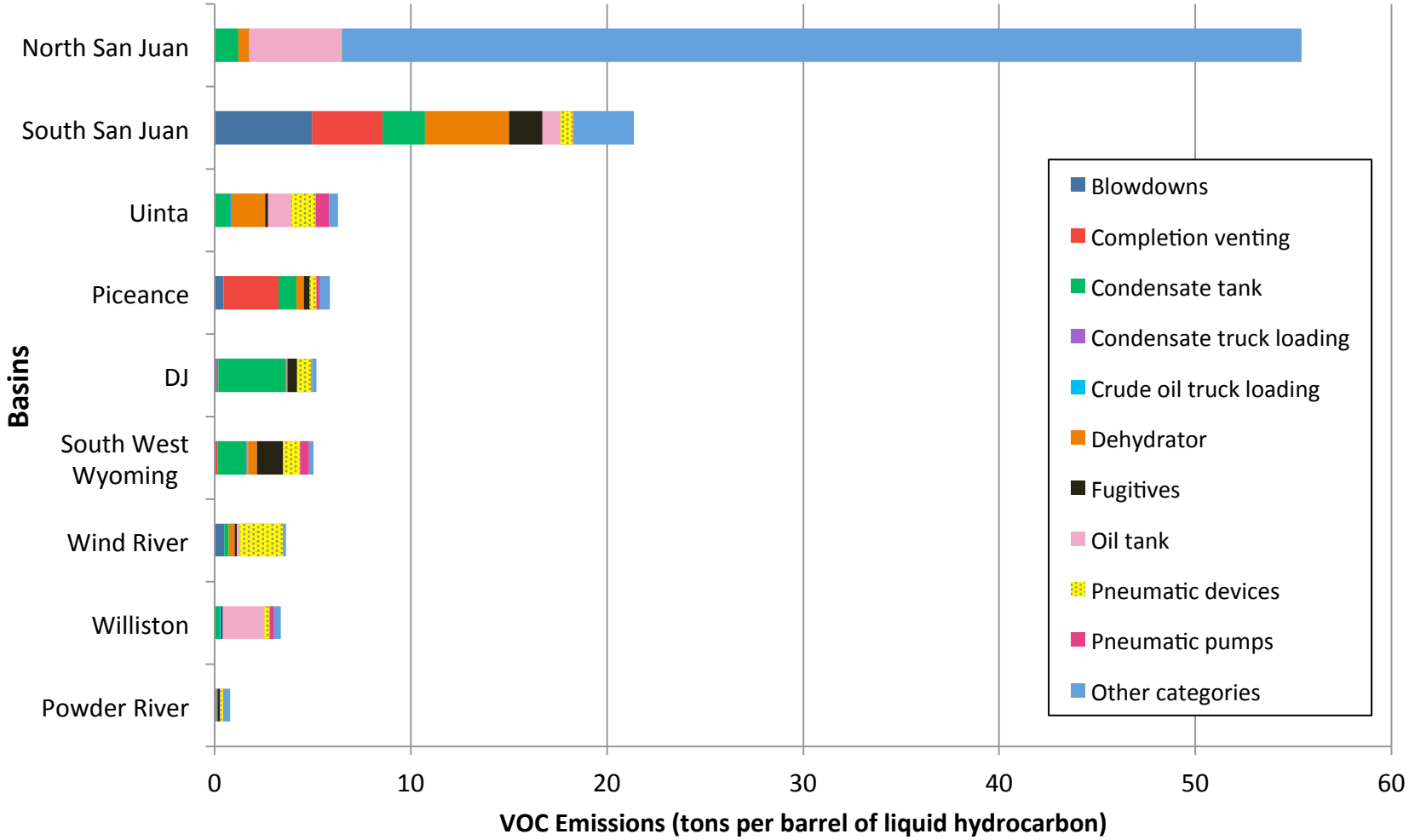
Per well NOx emissions relatively consistent across basins – differences mainly due to usage of compression and centralized vs. wellhead compression

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

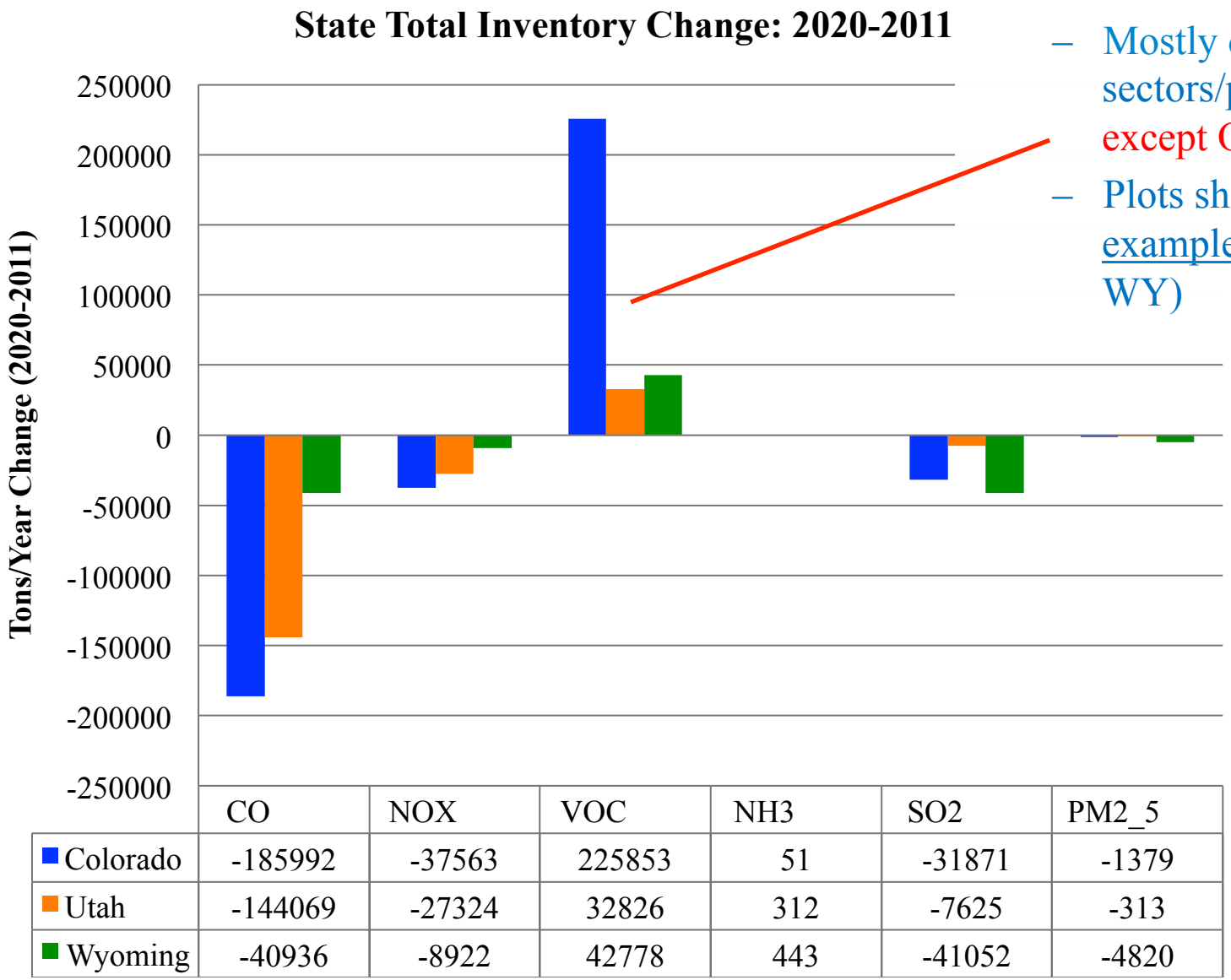


Per unit gas production VOC emissions vary widely across basins – differences due to levels of liquid hydrocarbon production (oil and condensate) and VOC content of produced gas

Oil & Gas Projections - Methodology

- No standardized methodology for conducting projections
  - Each inventory study has used different approaches (EPA methods, Resource Management Plans, NEPA air quality projects, Western States Air Quality Modeling Study regional inventories)
- WRAP O&G inventories have used 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 and continuing to evolve
  - National rules focused on new sources

Trends in projected emissions - example



- Mostly decreases for all sectors/pollutants/states except O&G VOCs
- Plots show differences for example states (CO, UT, WY)

Source: Intermountain West Data Warehouse – Western Air Quality Study

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

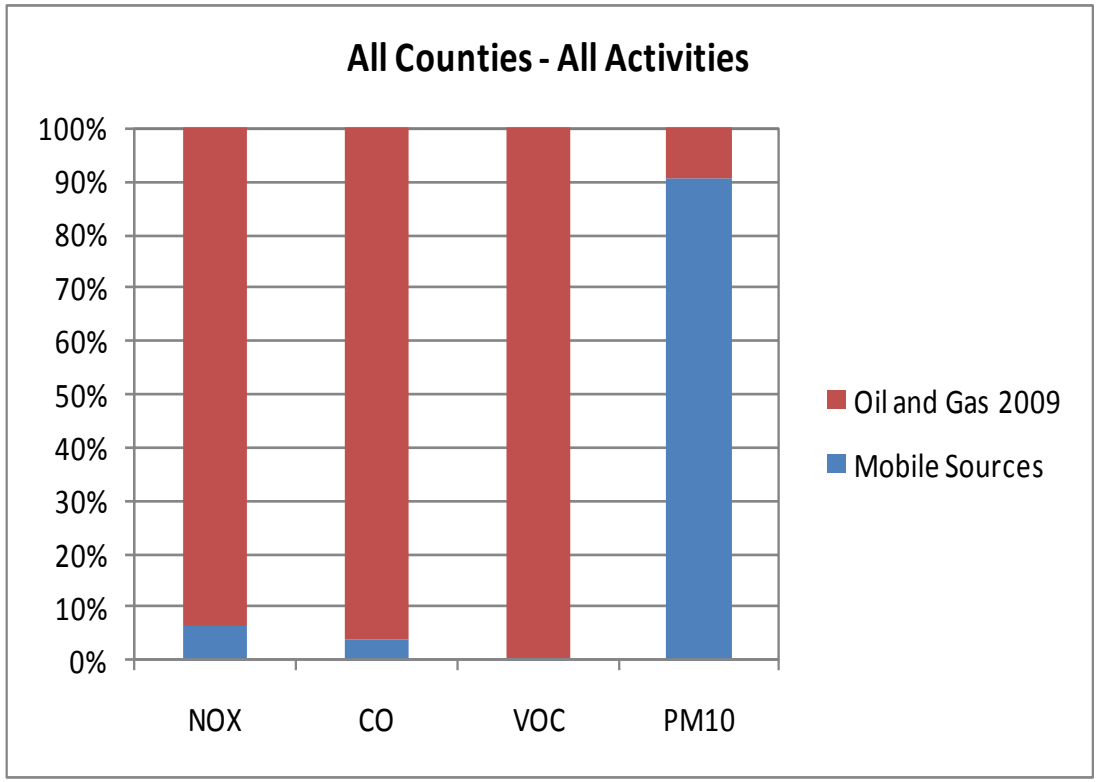
Issues and New Concepts – Missing Categories

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

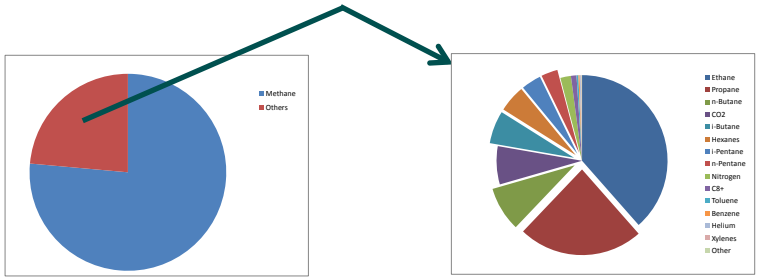
Non-routine events

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

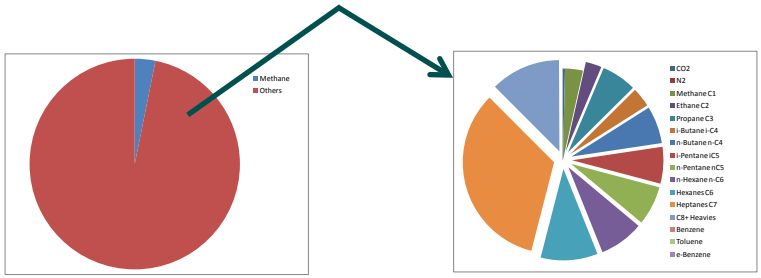
Issues and New Concepts – Skewness

- 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