State Policy Opportunities for Management of Unconventional Oil & Gas

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Methodology

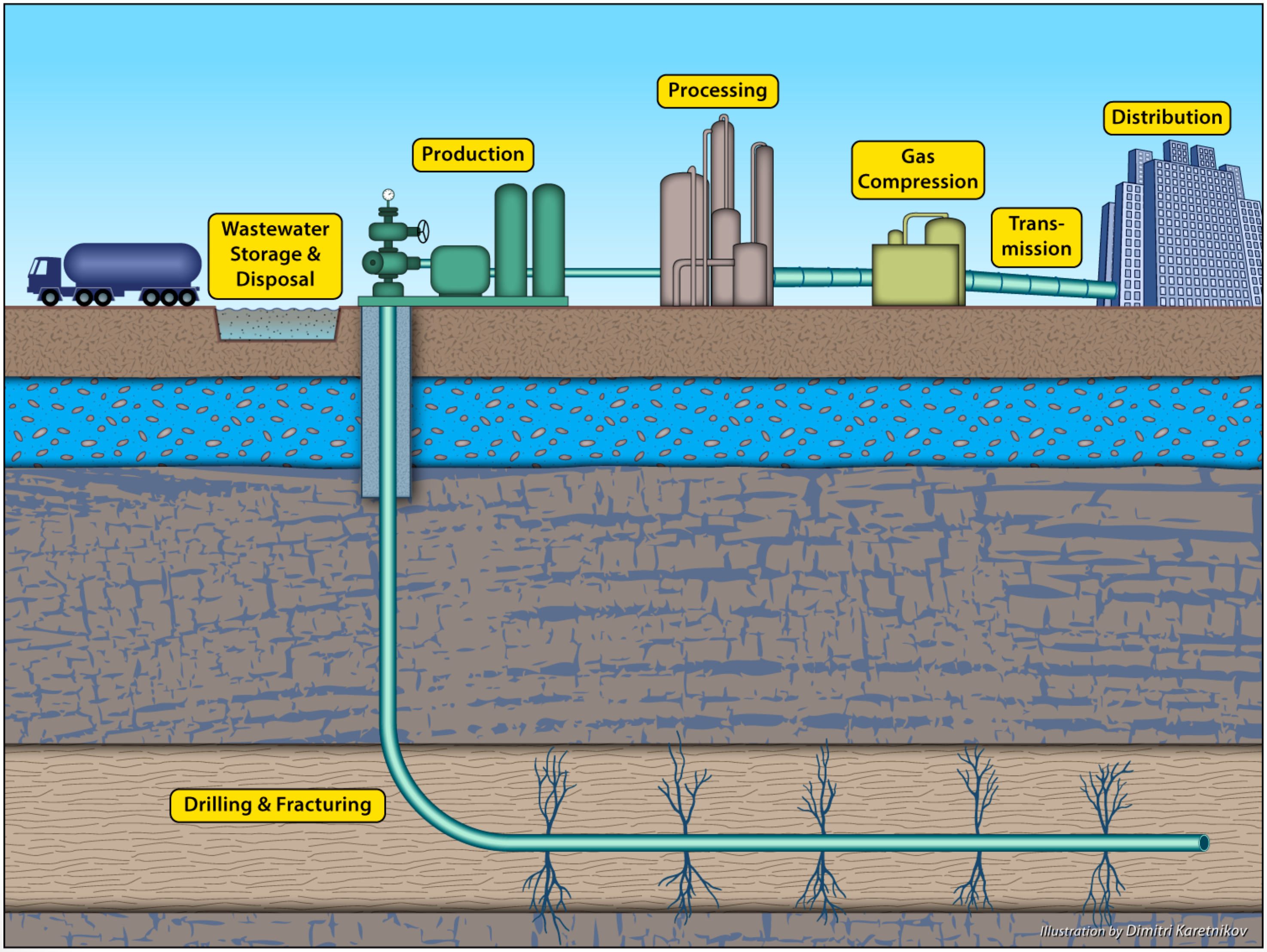
- Extensive literature review of most recent research available
  - Peer-reviewed publications
  - Government reports
- October 2014 traveled to Colorado, Texas, Pennsylvania, and Maryland
- Over 45 interviews
  - Public officials and staff (local, state, and federal government)
  - Oil & gas operators, industry support service providers, trade associations
  - Environmental and advocacy groups
  - Journalists, economists, scientists, and other scholars

Roadmap of Presentation

- Background
- Water Quantity & Quality Impacts
- Air & Climate Impacts
- Summary of Policy Recommendations

Background

Process Overview



Where does drilling occur?

7 regions accounted for 95% of domestic oil production growth & all of domestic natural gas production growth during 2011-2013

(EIA *Drilling Productivity Report.* October 2014)

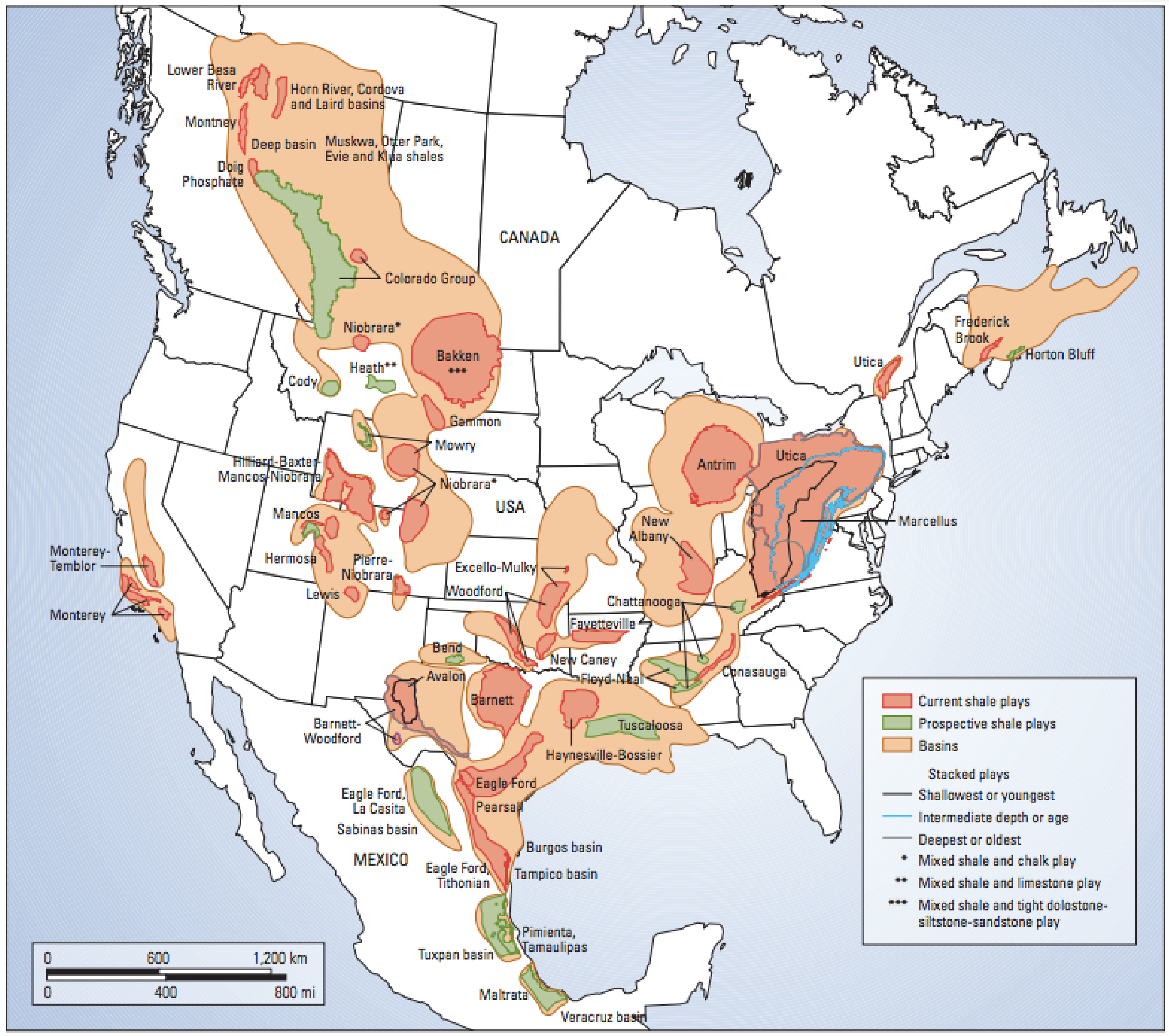


Image adapted from Kuuskraa et al. in Boyer et. al., Shale Gas: A Global Resource, Oilfield Autumn Review, 23, No. 3, 2011.

Exemptions Create Regulatory Gaps

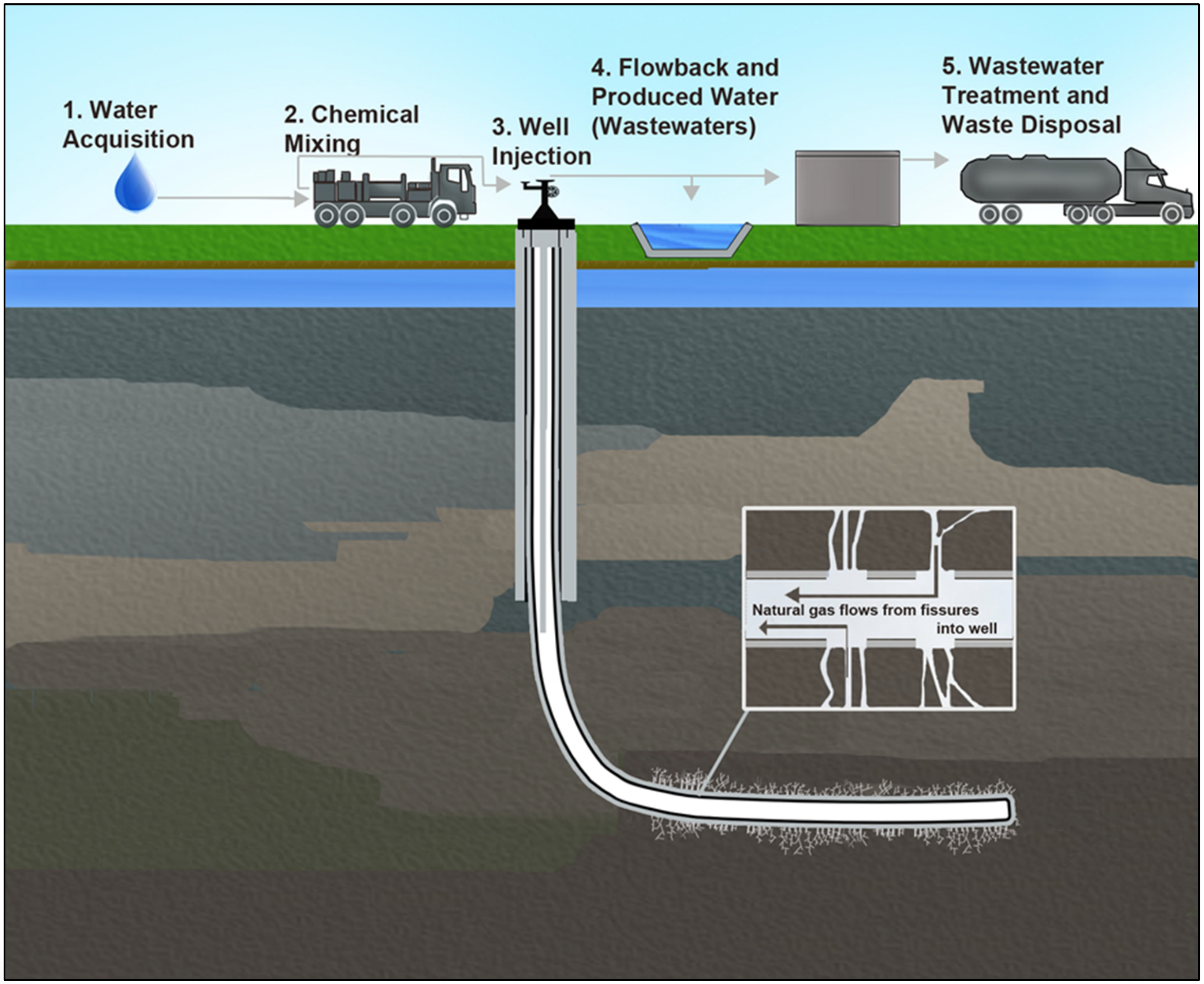
Federal Regulations with Exemptions for Unconventional Oil & Gas
Clean Water Act
Safe Drinking Water Act
Resource Conservation and Recovery Act
Emergency Planning and Community Right-To-Know Act
Clean Air Act
Comprehensive Environmental Response, Compensation, and Liability Act
National Environmental Policy Act

Source: U.S. EIA, October 2014

Water Quantity & Quality Impacts

- Water Sourcing
- Subsurface Water
- Surface Water
- Overall Recommendations

Protecting Water Resources



Source: United States Geological Survey, 2014

Water Quantity & Quality Impacts

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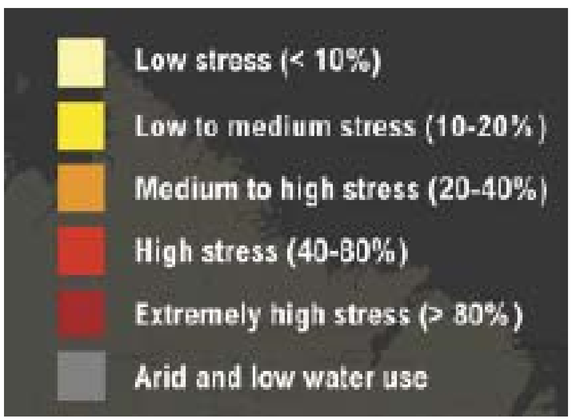
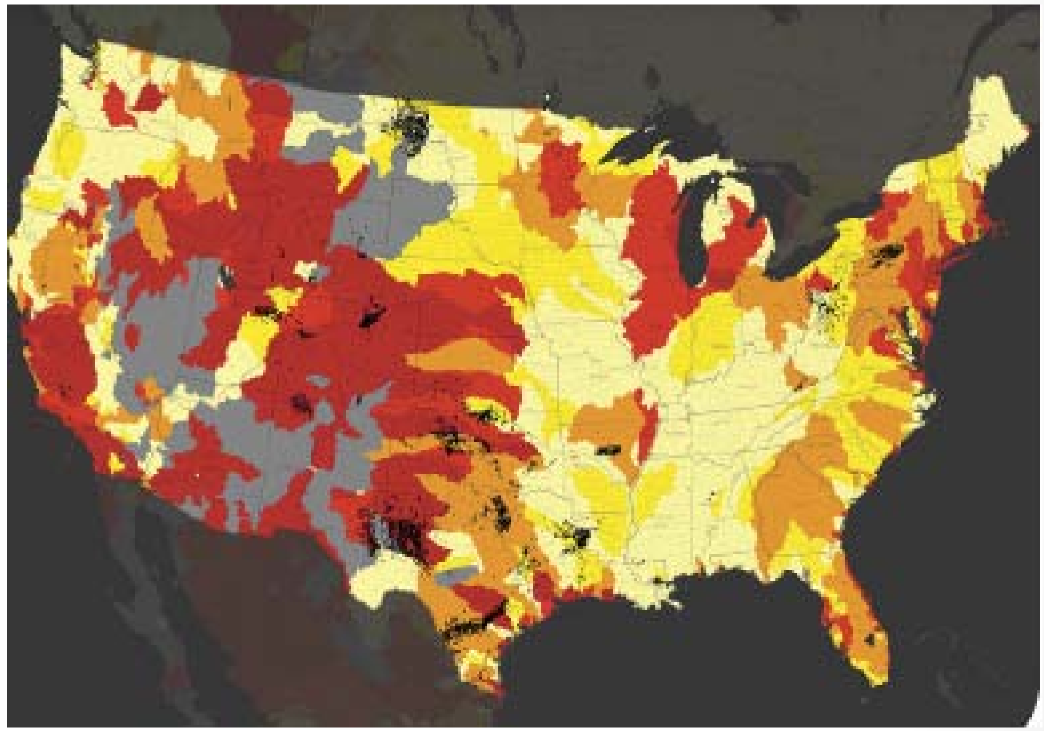
Water Sourcing Risks

Nearly half of wells using hydraulic fracturing are in regions with high or extremely high water stress





Source: Ceres. “Hydraulic Fracturing & Water Stress: Water Demand by the Numbers.” 2014

Water Sourcing Risks

- Resources for the Future study found 26 of 30 states surveyed required some type of permitting for water withdrawals
  - Of those 26 states, only half require permits for all withdrawals
  - Several states do not require permits at all, but only require disclosure of water use over a certain threshold
  - Some states exempt the oil & gas industry from permitting requirements for water withdrawals
    - ***Kentucky***: exempts from both surface and groundwater reporting
    - ***Texas***: requires for surface water, but generally not groundwater

Water Sourcing Leading Practices & Examples

- Water Withdrawal Tracking
  - ***Michigan***'s GIS-based tool
  - ***Louisiana***'s network of groundwater monitors & baseline data
- Coordination of regional water withdrawal management
  - ***Susquehanna River Basin Commission***
- Groundwater Source Identification
  - ***Ohio*** requires operators to identify ground & surface water
- Improved Wastewater Reuse & Recycling
  - ***Texas*** loosened restrictions in order to encourage recycling

Water Sourcing Leading Practices & Examples

- Operator Reporting Use
  - ***Pennsylvania*** requires daily monitoring and compliance data
- Cradle-to-Grave Water Lifecycle Analysis
  - ***Pennsylvania*** requires a water management plan for shale gas production that covers full lifecycle of water, including identification of water source, amount wanting to withdrawal, and an analysis of withdrawal impact on the source
- Public Transparency
  - ***Susquehanna River Basin Commission***'s Water Resource Portal: to disclose water permits and data on amounts and location of withdrawals to public
  - ***Louisiana***: communities receive advance notice of future development

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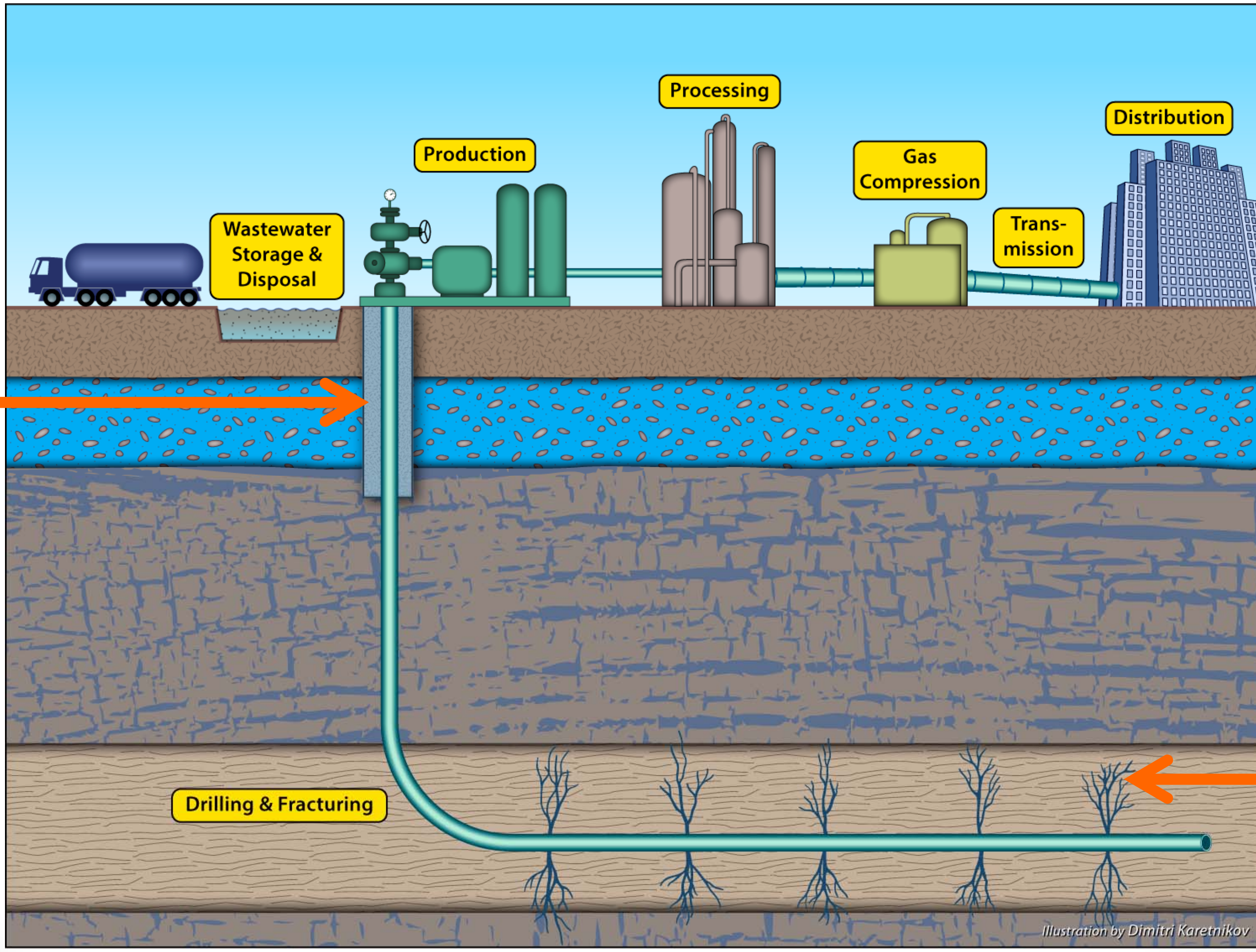
Subsurface Water Contamination Risks

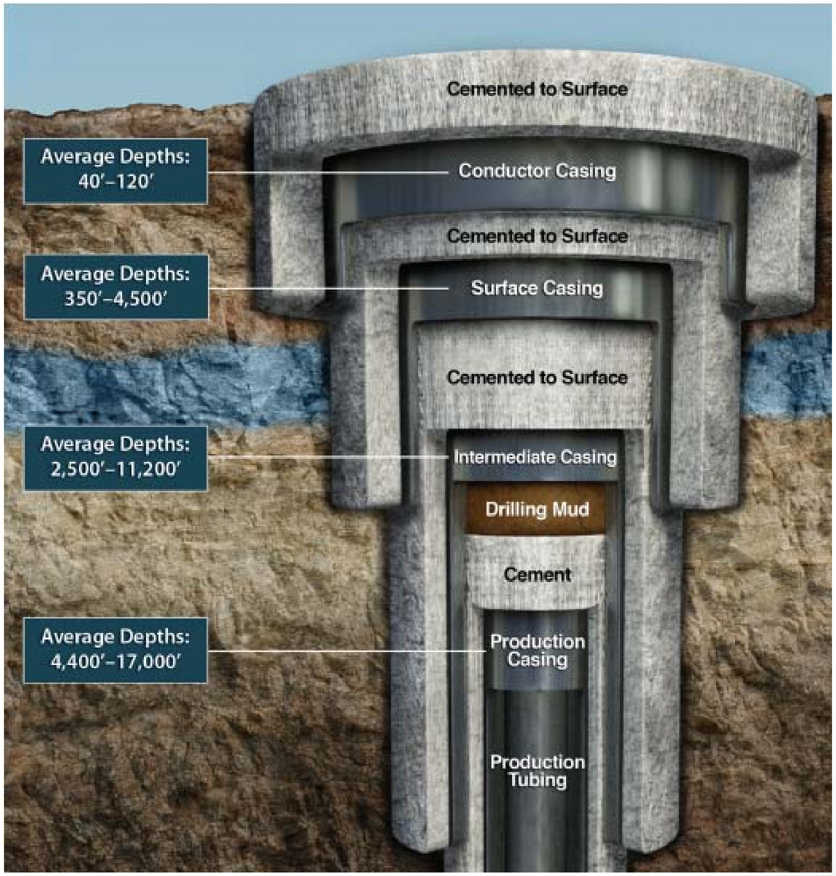
Well Integrity



Hydraulic Fracturing

Well Integrity Risks to Subsurface Water

- Cement is most critical factor
- Significant percentage of unconventional gas wells have integrity issues
  - 3.4%-6.3% for Marcellus in PA, up to 9.8%
- Natural gas contamination correlated with gas wells, wellbore is likely migration pathway
- Contamination difficult to pinpoint and not evident in all unconventional plays



Source: NPC, 2011

Well Integrity Leading Example

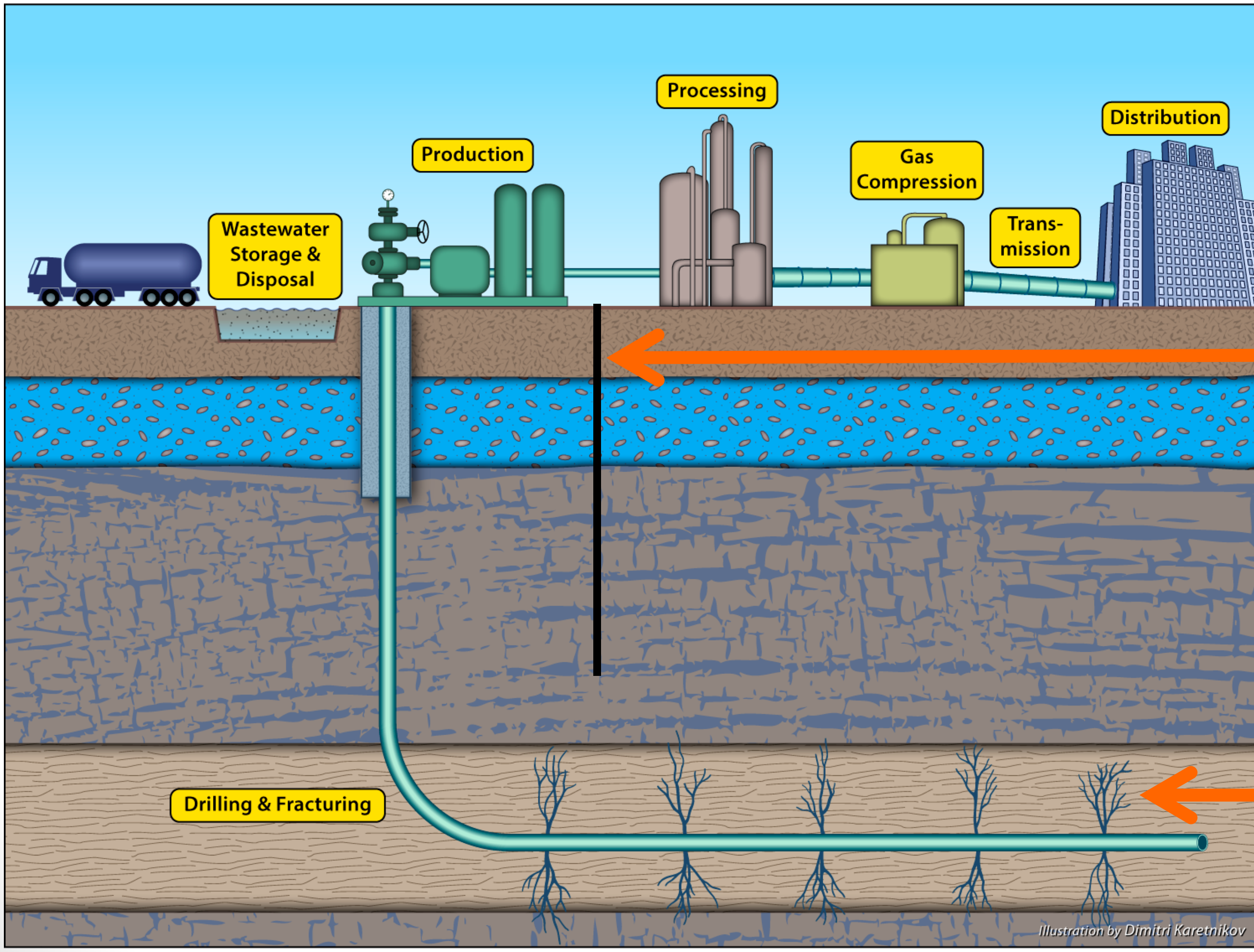
Ohio

- ***Casing and Cementing***
  - Adherence to American Petroleum Institute (API) standards required
  - Plans approved by regulator prior to drilling
  - Notification of inspector prior to casing and cementing
  - Cementing reports submitted upon completion of cementing
- ***Well evaluation and remediation***
  - Casing integrity tests for each casing and formation integrity tests under certain conditions
  - Monitoring and inspection of well integrity required throughout well life
  - Notification and remediation required if deficiency detected

Well Integrity Leading Practices/Recommendations

- Ensure adherence to highest standards of casing and cementing
- Require evaluation and remediation of well integrity during drilling and casing, and throughout well life
  - Casing and formation integrity tests
  - Cement evaluation logs
- Enhanced approvals and disclosure
  - Approval of casing and cementing plans
  - Notification of inspectors prior to critical stages

Hydraulic Fracturing Risks to Subsurface Water



Adjacent well (active or abandoned)

Fractures well below aquifers in major shale plays

Unconventional Development Risk: Pavillion, Wyoming

Known

- Hydrocarbons and hydraulic fracturing chemicals contaminated primary aquifer
- Geology is atypical of most plays: gas extracted from lower unit of same formation as primary aquifer, with no confining lithological barrier between
- Surface casings of gas production wells do not extend below deepest water wells; many production wells do not have casing and cement that adequately isolate wells from aquifer formation

Unknown

- Whether contamination resulted directly from hydraulic fractures, through well pathways (compromised well integrity), or from surface

Summary & Lessons

- Contamination likely resulted from gas development
- Comprehensive characterization of local geology and adjacent wells required to assess risk of hydraulic fracturing and to design production wells to adequately protect aquifers

Hydraulic Fracturing Leading Example

Illinois

- ***Dedicated Hydraulic Fracturing Regulatory Act***
- ***Water Testing***
  - Pre and post-drill required
- ***Fracturing Fluid Disclosure***
  - Mandatory; chemical family names required for ‘trade secret’ chemicals
  - Disclosure of ‘trade secret’ chemicals to healthcare professionals when required
- ***Approvals and disclosure***
  - Separate permitting for hydraulic fracturing
  - Notification and approval required before each fracture treatment

Hydraulic Fracturing Leading Practices/Recommendations

- Mandatory pre and post-drill water testing
- Mandatory fracturing fluid disclosure
  - Require relevant chemical family names for trade secret ingredients
- Enhanced approvals and disclosure
  - Additional approval for hydraulic fracturing
  - Notification of regulators and/or public
- Require comprehensive risk assessment prior to fracturing, 'Area of Review'
  - Characterization of geology, adjacent wells, risk assessment and addressing of identified risks

Water Quantity & Quality Impacts

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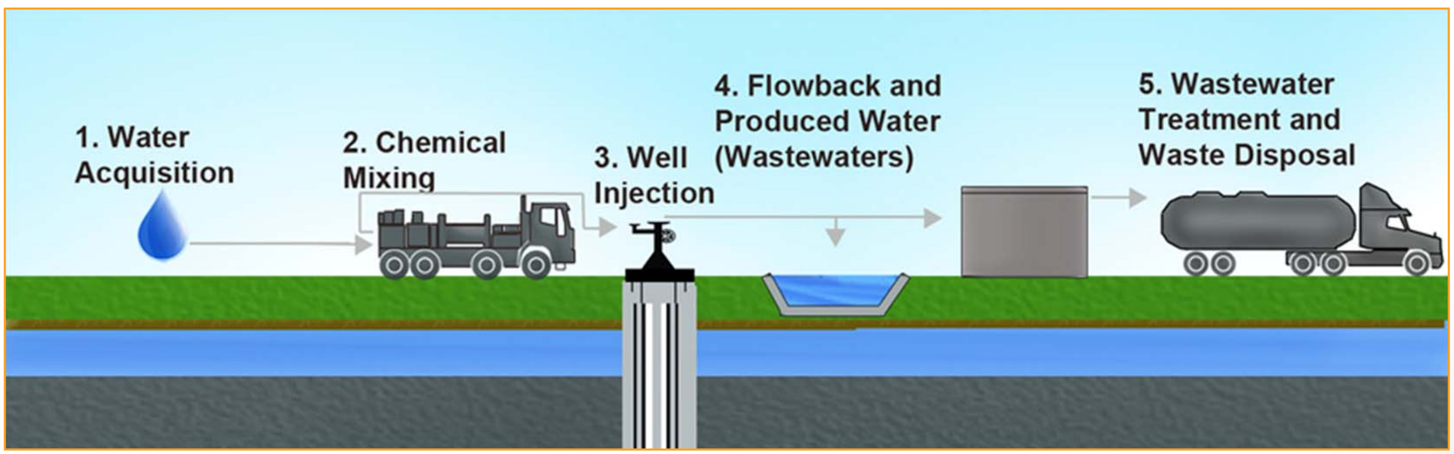
- Overall Recommendations

Surface Water Risks

- Large volume of wastewater from hydraulic fracturing
- Risks from leaks, spills, and inadequate treatment
- Potentially occur during storage, treatment, and disposal
- Impacts drinking water quality and ecosystem function



Contaminants of Concern

- ***High total dissolved solids (TDS):*** Can negatively impact drinking water quality and ecosystem function
- ***Industrial additives containing benzene, toluene, ethylbenzene, and xylenes (BTEX):*** Toxic volatile organic compounds (VOCs) found in diesel-based additives (regulated) and non-diesel additives (currently unregulated)
- ***Radionuclides (NORMs):*** Naturally occurring radioactive materials in the subsurface. Risks to drinking water, river sediments, and treatment workers
- ***Disinfection Byproducts (DBPs):*** Toxic byproducts produced when inorganic species combine with organic matter during drinking water disinfection process

Surface Water Recommendations

Maximize recycling and reuse

- Leverage on-site treatment technologies
  - Example: Aquatech's MoVap Shale Gas Wastewater Mobile Distillation Unit used in ***Pennsylvania***
  - Example: High-salinity friction reducers as fracturing fluid additives
- Implement regulations that foster recycling and reuse
  - Example: ***Texas*** allows operators to recycle wastewater on their land or transfer to another operator's land, without a permit *(Groundwater Protection Council (GWPC), 2014)*

Surface Water Recommendations

Implement best management practices for storage

- Tanks increasingly used, but pits are much more common
- ***Recommendations for pits:*** pit liners (required by ***23 states***), freeboard (required by ***20 states***), inspections (pre-operation inspections required by ***10 states***), and encourage transition to tanks
- ***Recommendations for tanks:*** secondary containment (required by ***22 states***), tank design requirements based on stored fluids (specified by ***5 states***), and routine maintenance (required by ***14 states***)

Source: Groundwater Protection Council (GWPC), 2014

Surface Water Recommendations

Implement wastewater treatment best management practices

- Ban disposal to publicly owned treatment works (POTWs) (banned by ***3 states***, informally by ***5 states***)
- Focus on centralized waste treatment facilities (CWTs) to provide centralized oversight of treatment and surface water disposal, after appropriate NPDES re-permitting, addition of specific state regulations for contaminants of concern, and treatment upgrades
- ***Few CWTs*** have been re-permitted to accept hydraulic fracturing wastewater and dispose to surface waters, but this approach holds great potential
- Proper residuals handling after treatment

Source: Groundwater Protection Council (GWPC), 2014

Water Quantity & Quality Impacts

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Protecting Water Resources: Policy Opportunities

Water Sourcing

- Water withdrawal tracking and management
- Operator reporting use
- Improved incentives for wastewater reuse and recycling

Well Integrity

- Adherence to highest standards of casing and cementing
- Casing and cementing plans approved by regulator prior to drilling
- Evaluation and remediation of well integrity throughout well life

Hydraulic Fracturing

- Comprehensive area-of-review-type risk assessment before fracturing
- Mandatory pre-drill water testing and post-completion monitoring
- Mandatory disclosure of chemical family names of fracturing fluids

Wastewater Management

- Promote recycling and reuse to reduce/eliminate wastewater volumes
- Implement best management practices for storage
- Ban discharge to POTWs
- Focus on CWTs to provide centralized oversight of treatment and disposal
- Proper treatment residuals management

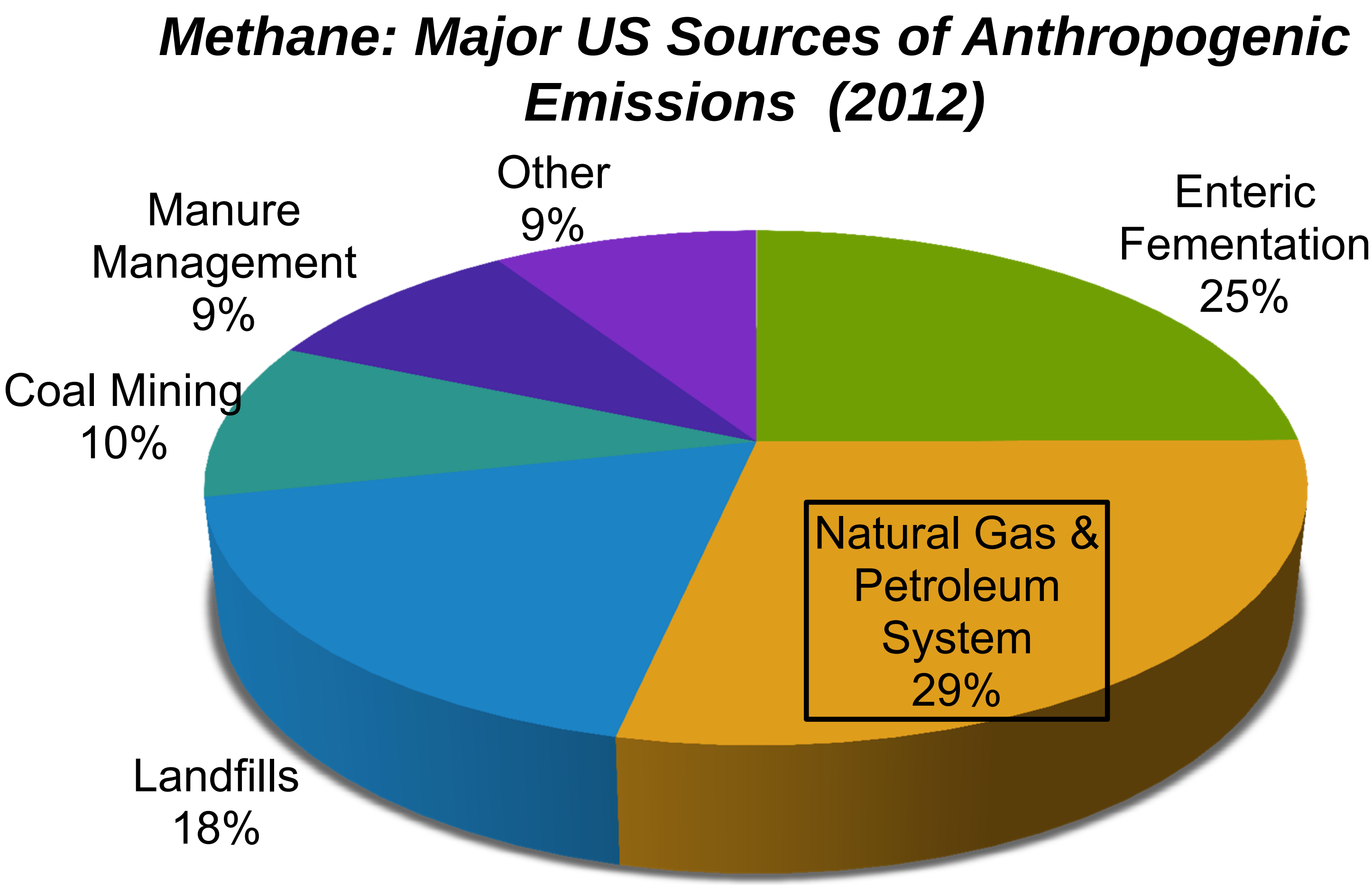
Air & Climate Impacts

- Air Emissions
- Overall Recommendations

Air & Climate Impacts

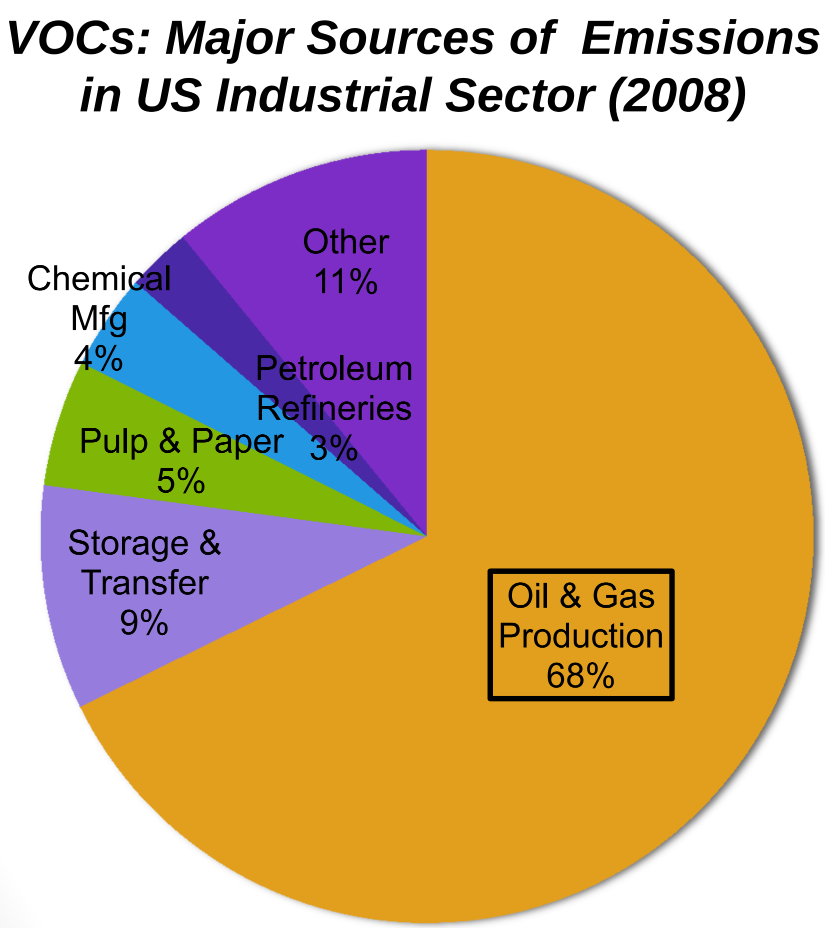
- **Air Emissions**
- Overall Recommendations

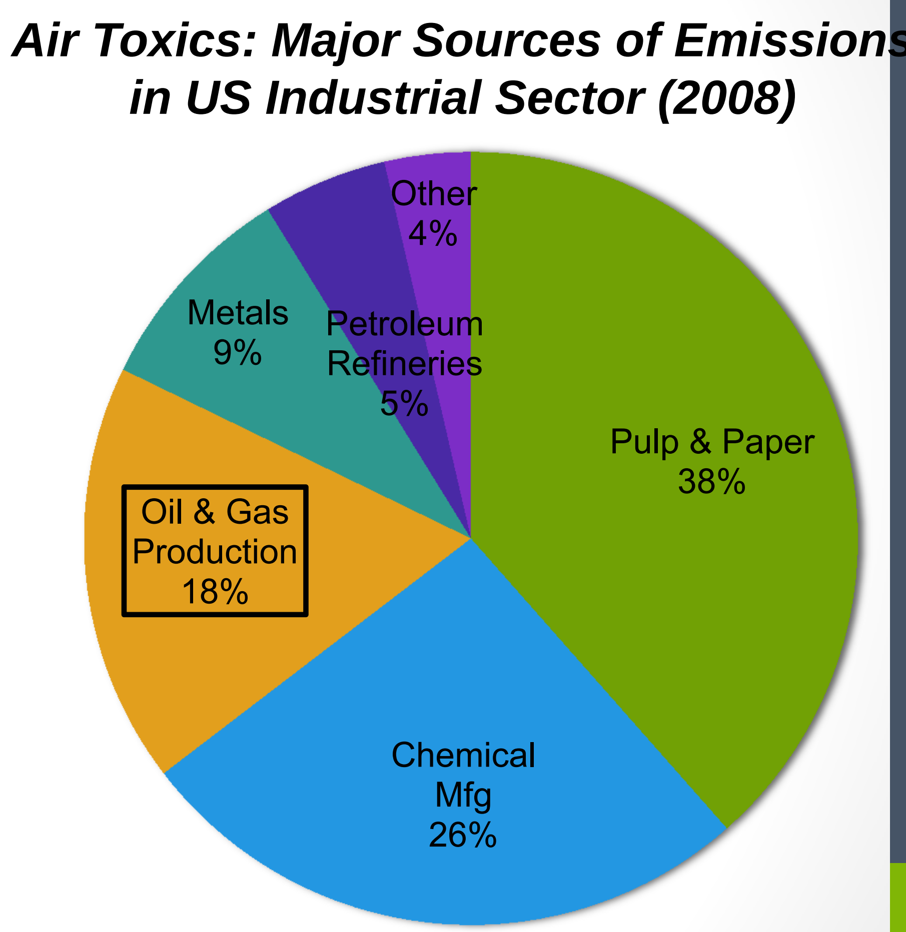
Air Emissions



Data Source: EPA, 2014

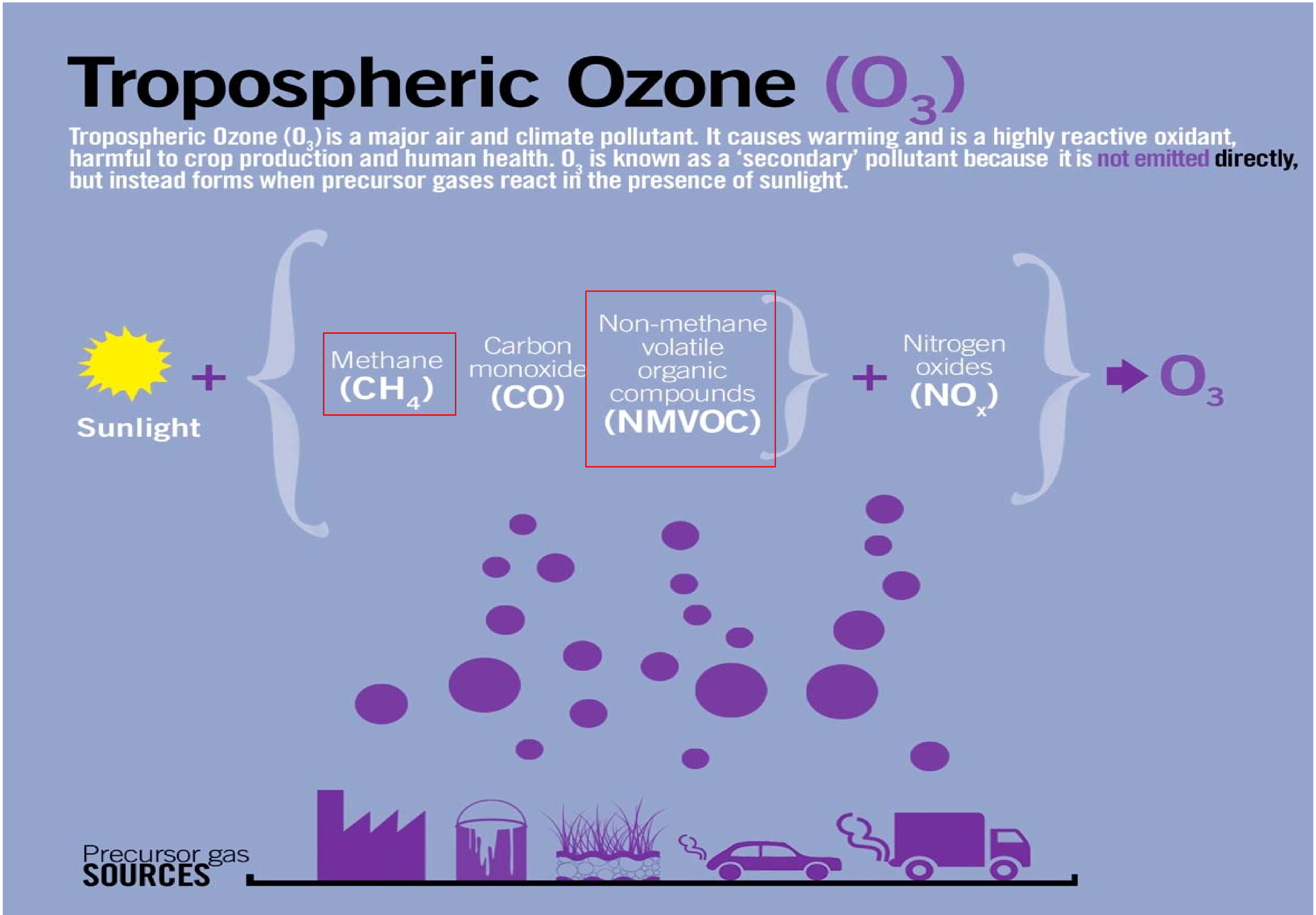
Air Emissions





Oil & Gas Industry accounts for 12% of total VOC Emissions in U.S.

Data Source: Lattanzio, 2013

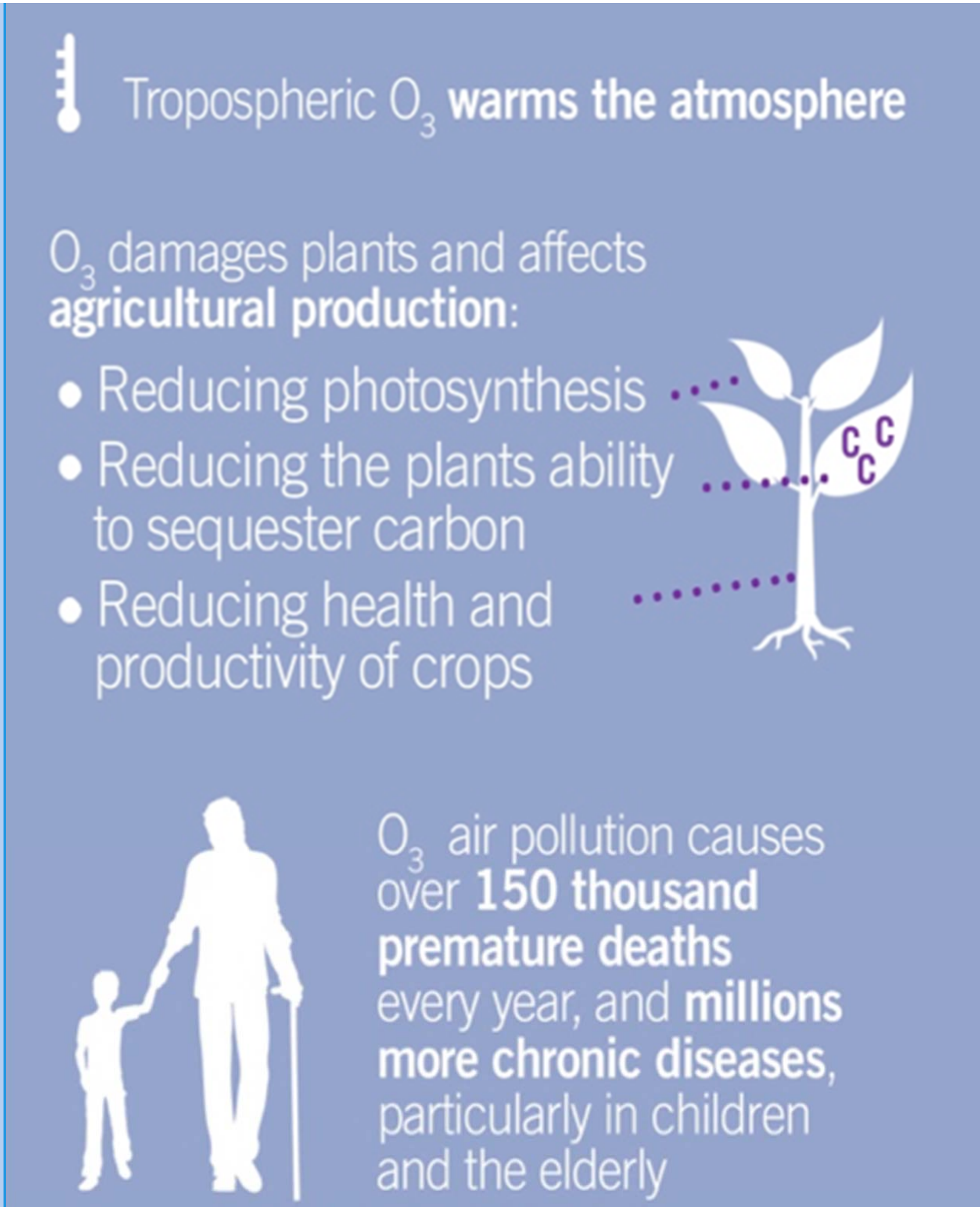


Source: http://www.grida.no/graphicslib/detail/tropospheric-ozone-o3_402d

Climate Change

Agriculture

Human Health



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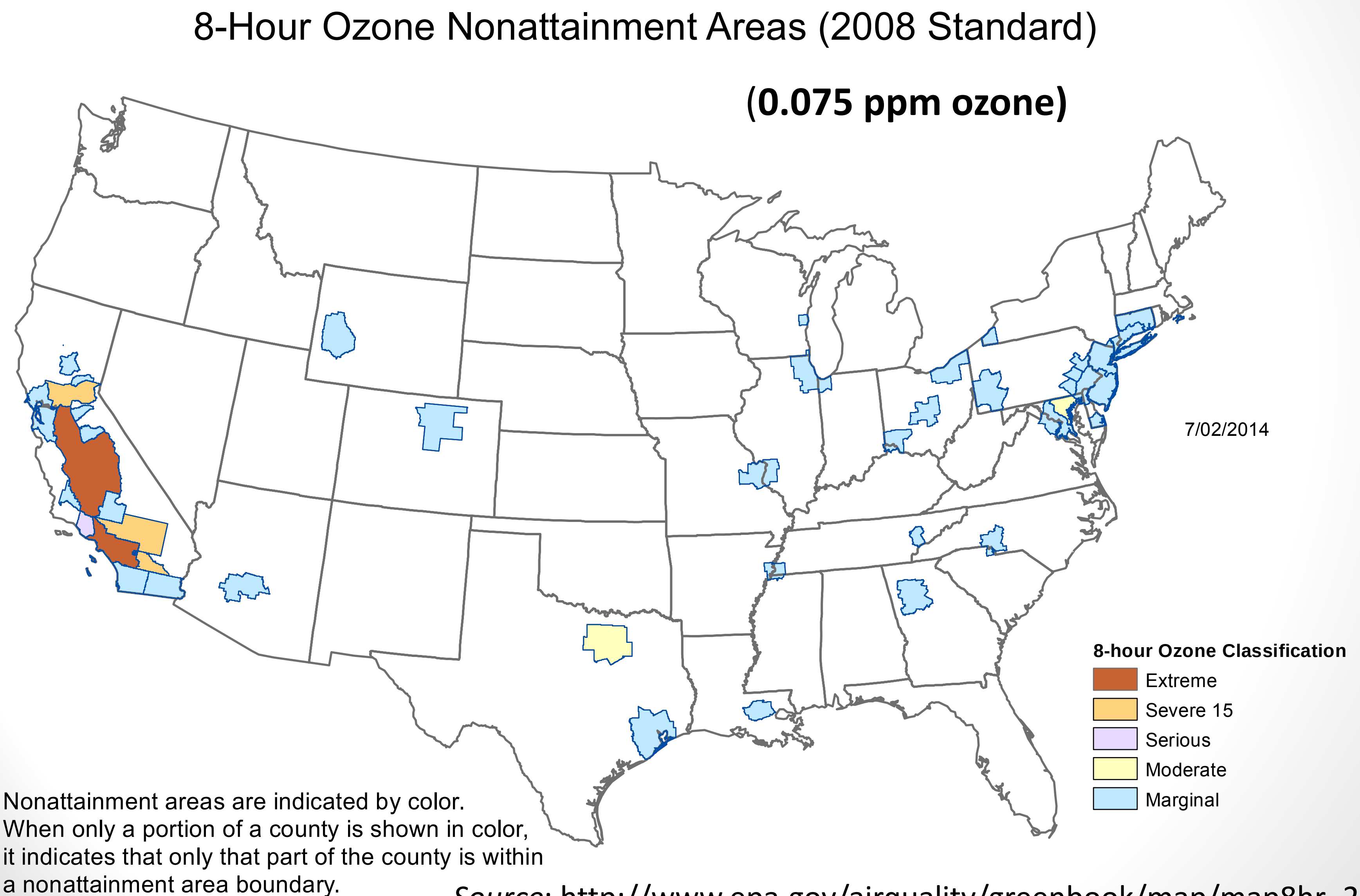
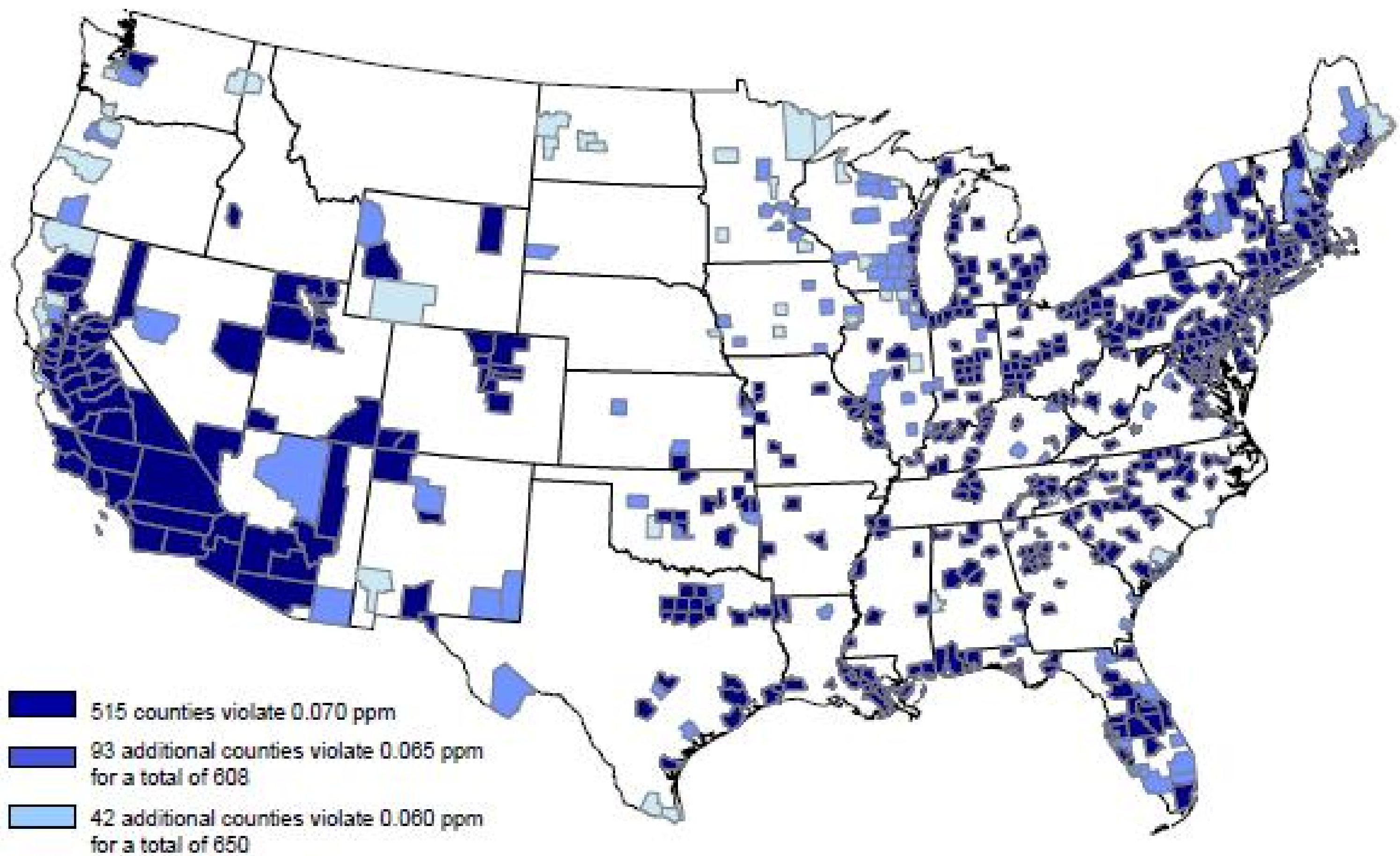
Current Ozone Nonattainment



Source: http://www.epa.gov/airquality/greenbook/map/map8hr_2008.pdf

Potential Future Ozone Nonattainment

Counties With Monitors Violating Proposed Primary 8-hour Ground-level Ozone Standards
0.060 - 0.070 parts per million
(Based on 2006 – 2008 Air Quality Data)
EPA will not designate areas as nonattainment on these data, but likely on 2008 – 2010 data which are expected to show improved air quality.

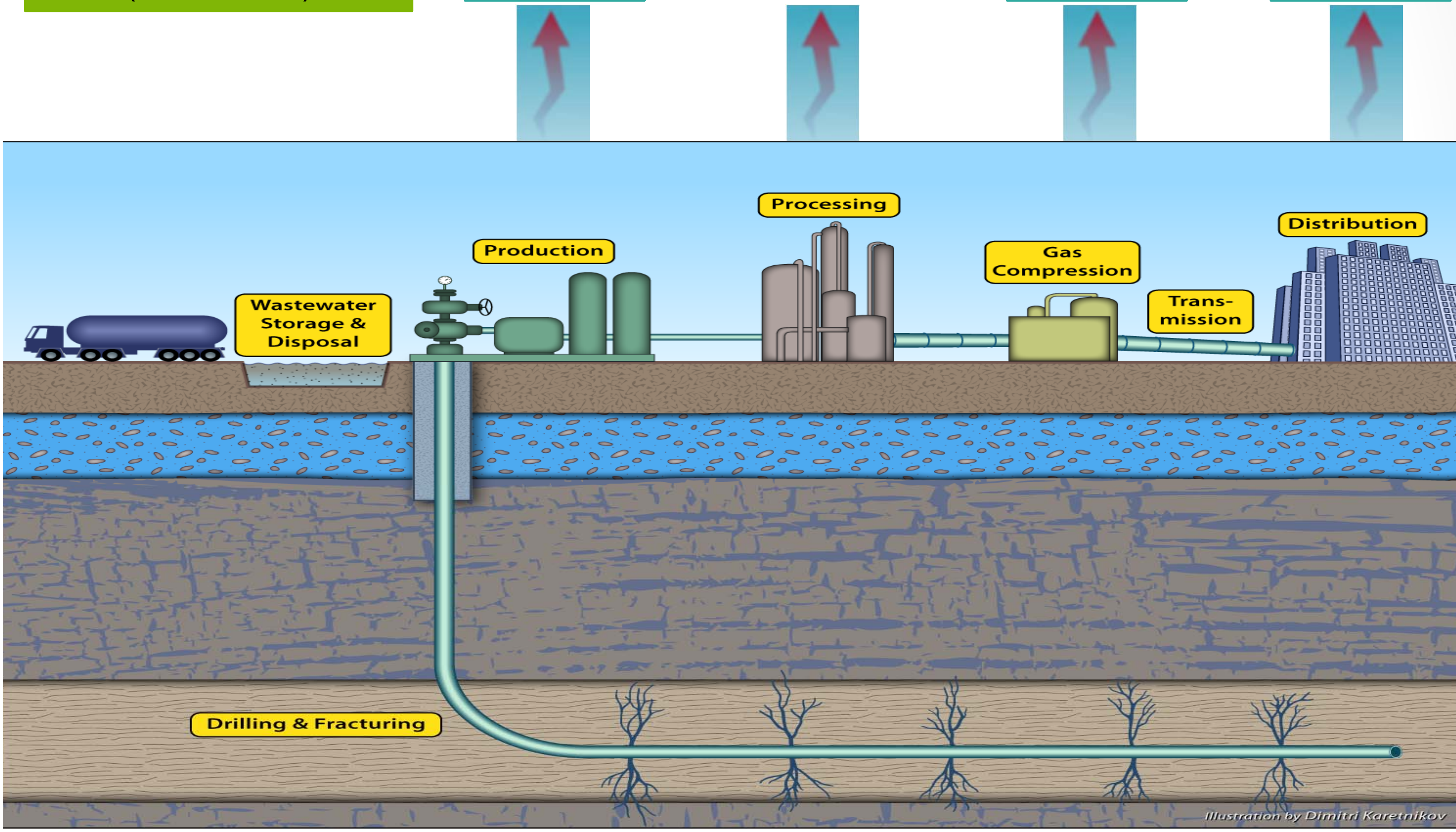


Source: http://www.epa.gov/

Major Sources of Methane Emissions

EPA Inventory in 2012
(EPA, 2014)

2000 Gg (32%)	900 Gg (14%)	2100 Gg (33%)	1200 Gg (20%)



Mitigation Approach Depends on Type of Emission

Fugitive Emissions

(Unintentional Leaks)

- Address through Leak Detection & Repair Programs (LDAR)

Vented Emissions

(Intentional Leaks)

- Equipment performance or technology standards
- Change operational practices

Fugitive Emissions

Leak Detection And Repair (LDAR) Programs

- Periodically identify & repair
- Comprehensive, documented & reported
- Cost effective or low cost if broadly applied

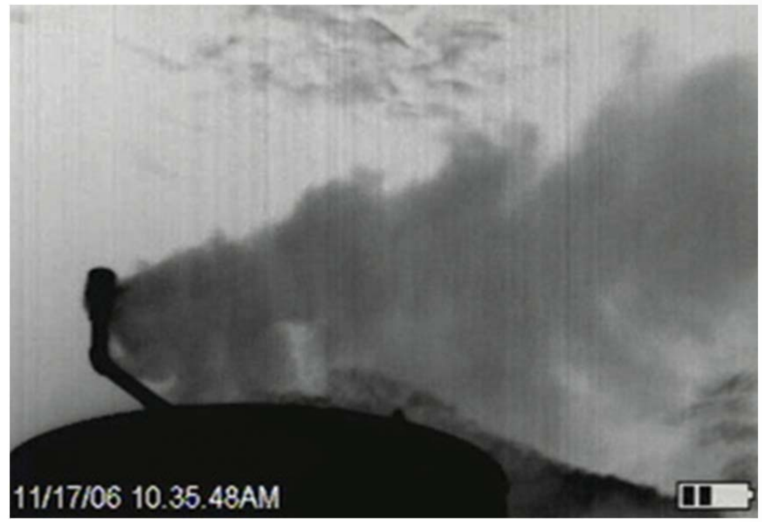
State Examples

- WY, CO, OH & CA
- Details vary

Vented Emissions

Eliminate unnecessary venting where possible

- Well completions/flowback: Extend REC and/or no venting requirements to oil & gas wells
- Liquids unloading/well maintenance: Require best management practices



State examples:

- CO, WY: gas and oil wells – no difference

Vented Emissions

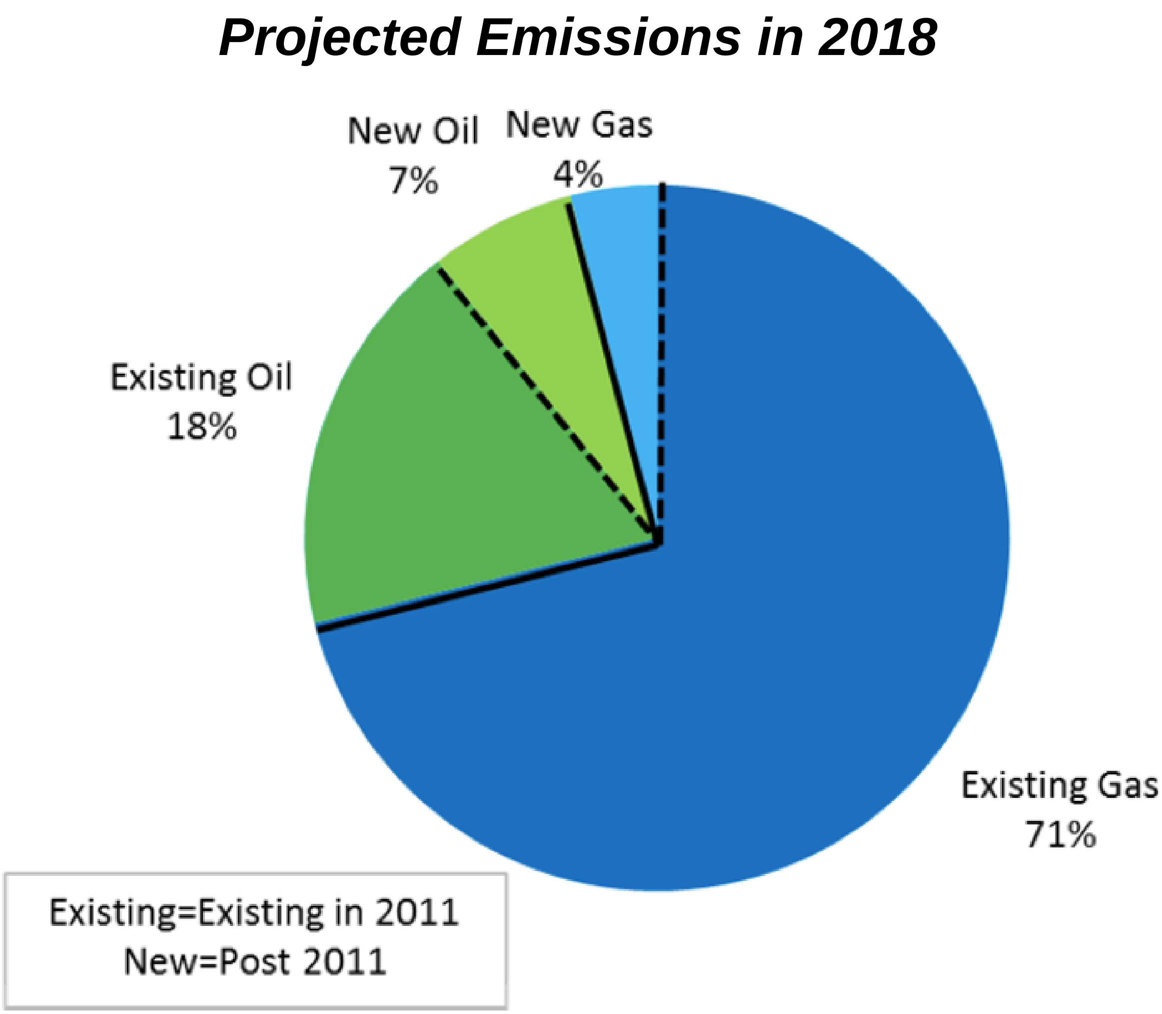
Variety of technology and performance approaches to minimize emissions from major sources

- Compressor rod packing replacement
- Low-bleed (< 6scfh) or no-bleed pneumatic actuators
- Pneumatic pump replacement (not currently required but often highly cost effective)
- Storage tanks: "Operate without venting" or emissions controls

State examples:

- CO: Controls applied to existing infrastructure
- Effective example: Pneumatic actuators

New vs Existing Sources



EDF/ICF, "Economic Analysis of Methane Emission Reduction Opportunities in US Onshore Oil Oil & Natural Gas Industries", 2014.

Recommendations to Address Distribution and Transmission Leakage

Often no incentive for companies to reduce leakage

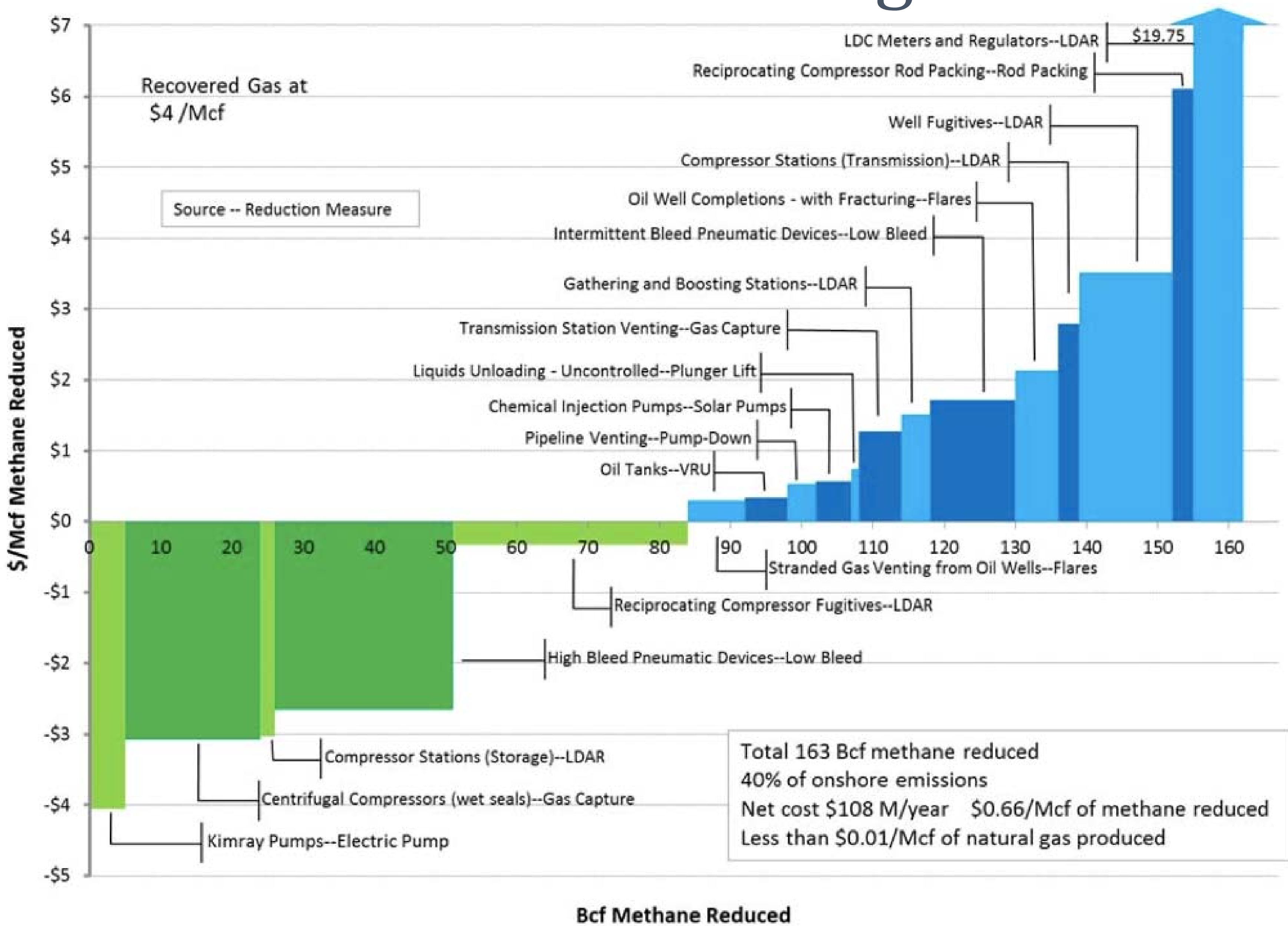
- Introduce financial incentives to reduce leakage rates
- Shorten cost recovery time horizons on infrastructure projects

State examples

- MA & NY introduced incentives to reduce leak rates
- CA requires LDAR programs

Sources: Howarth et al, 2011; Cleveland, 2014

Cost effectiveness of regulations



EDF/ICF, "Economic Analysis of Methane Emission Reduction Opportunities in US Onshore Oil Oil & Natural Gas Industries", 2014.

Air Emission Recommendations

Fugitive emissions

- Implement broad, risk-based leak detection and repair program without equipment exemptions

Vented emissions

- Phase in regulation to existing facilities/equipment
- Close gaps in oil well regulation
- Leverage off industry best practice
- Aim for a no emissions approach where demonstrated technology exists
- Broaden and strengthen existing federal requirements across all segments

Air & Climate Impacts

- Air Emissions
- **Overall Recommendations**

Air Policy Opportunities

- Existing regulations allow states to control for methane indirectly by using another VOC or odor/pollution standard
- Given the proposed EPA rule to strengthen the O3 NAAQS, released November 2014, regions of O_3 non-attainment will likely expand
- Stricter O_3 regulations will require states in O_3 non-attainment areas to reduce emissions of all hydrocarbons including methane
- Establish baseline air monitoring protocols that:
  - Require frequent mandatory monitoring of O&G production facilities especially of pumps, compressors and pneumatic devices
  - Consider pipeline monitoring of leaks
  - Increase fines associated with known violations

Air Policy Opportunities

- Existing federal regulation provides some framework for states to expand upon:
  - Leak detection and repair (LDAR)
  - Reduced emission completion (REC)
- Meanwhile, states may be able to use existing regulations to regulate hydrocarbons including methane. Examples include:
  - California AB 32 (California Global Warming Solutions Act)
  - Colorado – regulate hydrocarbons

Summary of Policy Recommendations

Water Recommendations	Leading states	Economic Costs to Business	Role of Government
Maximize recycling and reuse of hydraulic fracturing wastewater	TX	Varies depending on fresh water, transport and disposal costs	Examine restrictions on current recycle allowances
Implement wastewater treatment best management practices	Open opportunity	Varies depending on treatment upgrades necessary	Permitting and upgrading CWTs
Require area-of-review assessment before fracturing	IL	Low	Create rules and consolidate into formal process
Require high standards for well integrity	OH, IL	Low relative to total well costs (0.2%)	Legislation and rulemaking; reporting requirements

Source for Well Integrity Costs: US Bureau of Land Management, 2012

Air Recommendations	Leading States	Methane Reduction	Pure Economic Cost to Business	Role of Government
Require LDAR Programs	CA, CO, OH, WY	59.5 Bcf (14%)	-$1.50 to $20 per Mcf, depending on stage of process	Create regulation
Extend Flaring Requirement to All Wells	CO, WY, ND, OH, SD, UT, NE	8.2 Bcf (2%)	$2 per Mcf methane reduced	Create regulation
Require Installation of Low or No-Bleed Pneumatic Equipment	CO	43.3 Bcf (10%)	-$4 to $1.50 per Mcf reduced	Create regulation
Reciprocating Compressor Rod Packing		3.6 (0.8%)	$6 per Mcf reduced	Create regulation
Introduce Financial Incentives for LDCs	NY, MA	NA	Negative or zero	Negotiate rates with LDCs

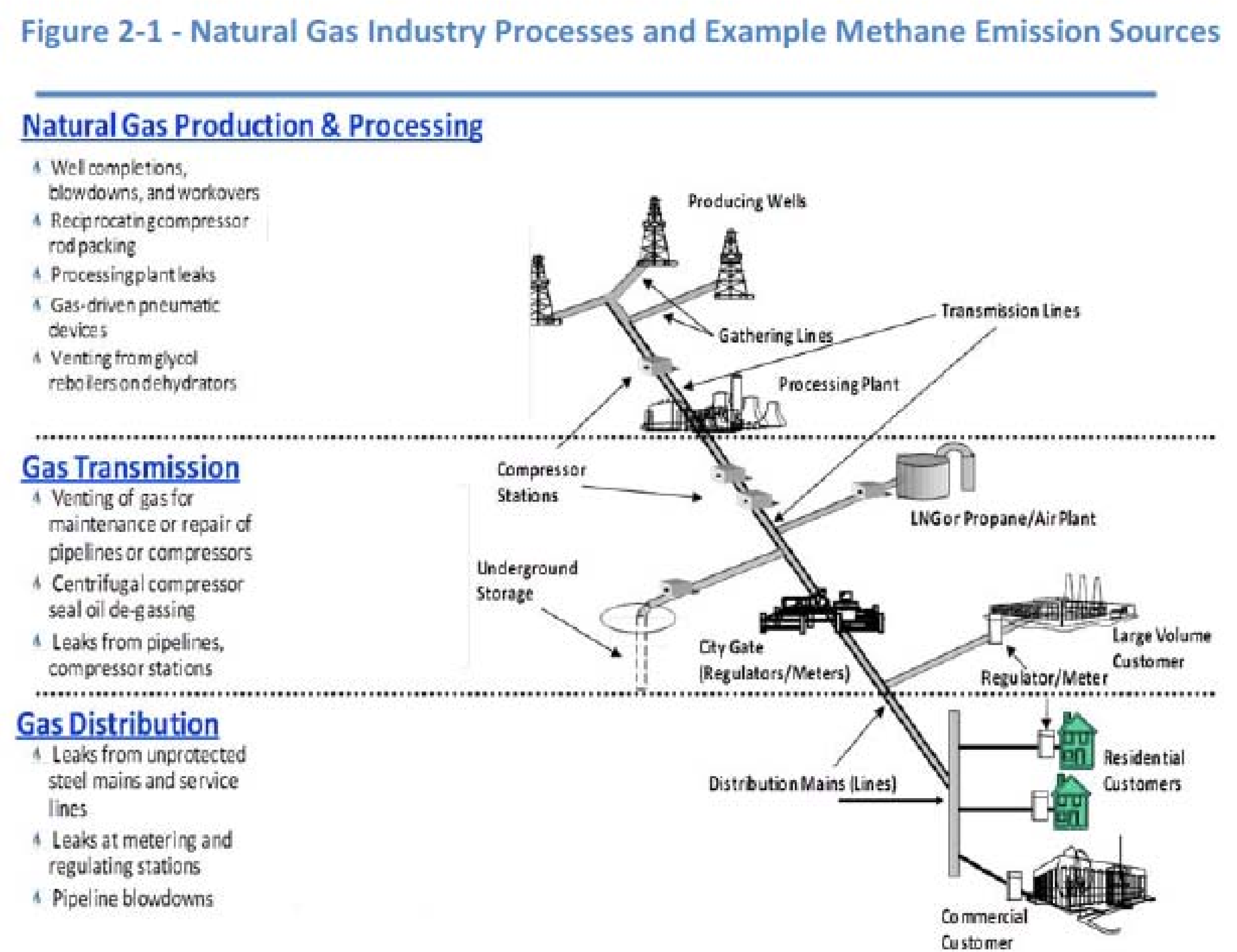
Source for Costs: ICF, 2014

Questions?

Thank you for your attention

Appendix

APPENDIX



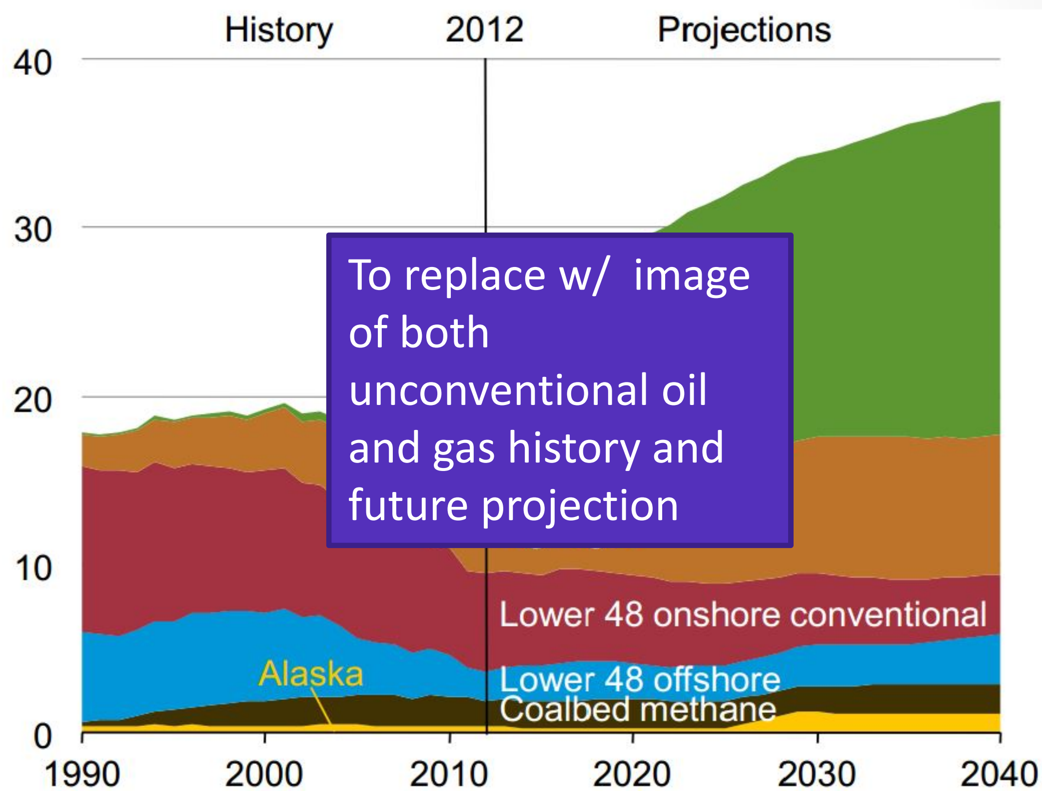
Source: ICF/EDF Economic Analysis of Methane Emission Reduction Opportunities in the U.S. Onshore Oil and Natural Gas Industries. March 2014

U.S. Unconventional Energy Boom

56% increase
in U.S. natural gas production
by 2040, unconventional
drilling will drive 75% of this
increase

By 2020, oil production from
unconventional sources will
account for over 50% of total
US oil production

U.S. Production (billion cubic feet per day)

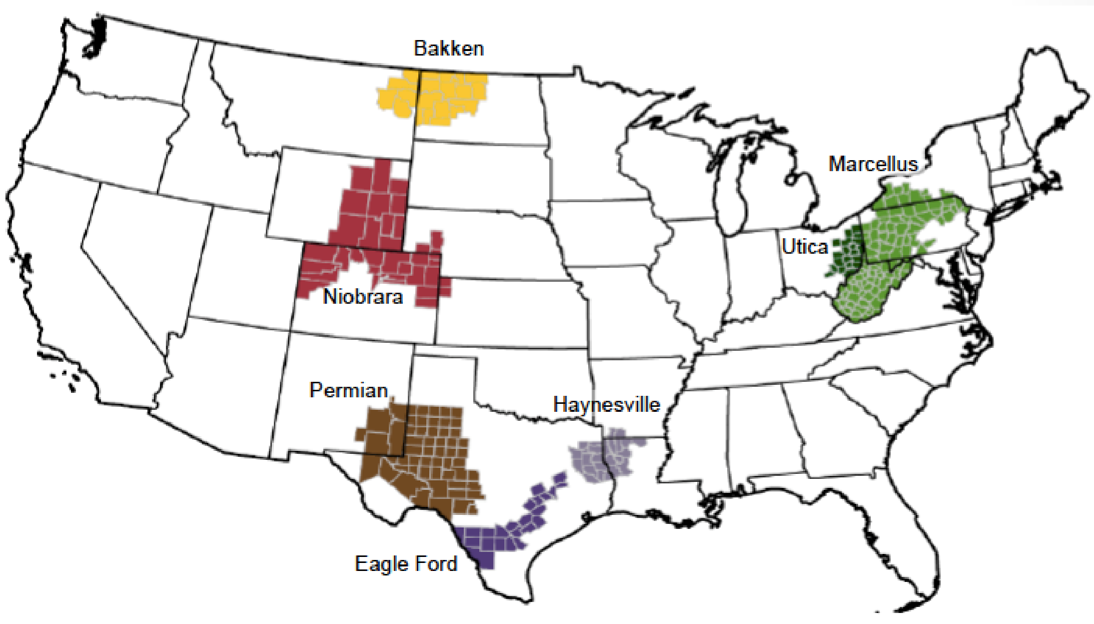


To replace w/ image of both unconventional oil and gas history and future projection

- Source: DOE.Annual Energy Outlook 2014 with projections to 2040. DOE/EIA-0383 (2014). April 2014

Where does drilling occur?

7 regions accounted for 95% of domestic oil production growth and all of domestic natural gas production growth during 2011-2013



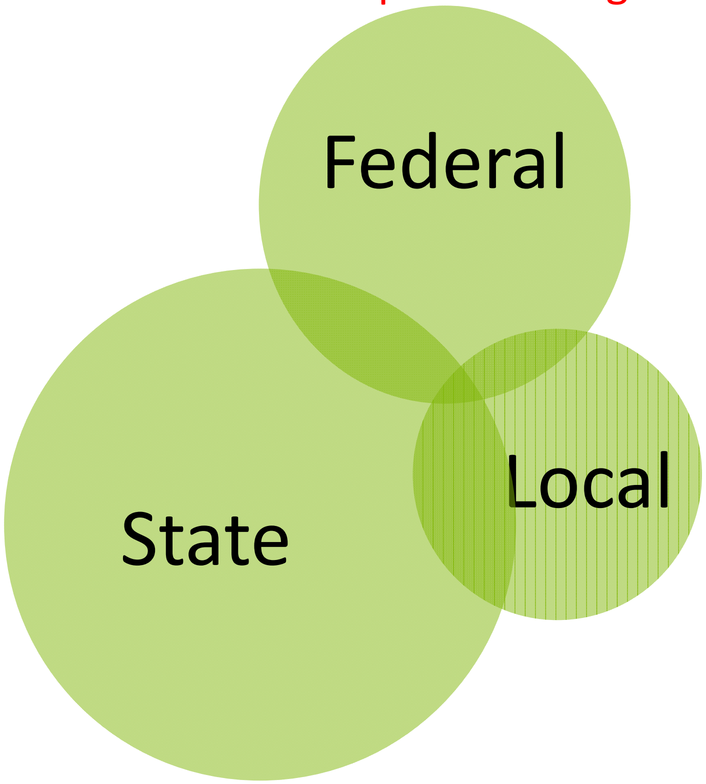
Include point/make the image show all locations where drilling occur…somehow show the increase, point is impacts many states. Also point is distribution and transmission impacts all.

Rapidly growing to more areas….and in more

Source: U.S. EIA. Drilling Productivity Report. October 2014.

A *Fractured* Regulatory Framework

I will include arrows with where major water and air impacts are regulated.



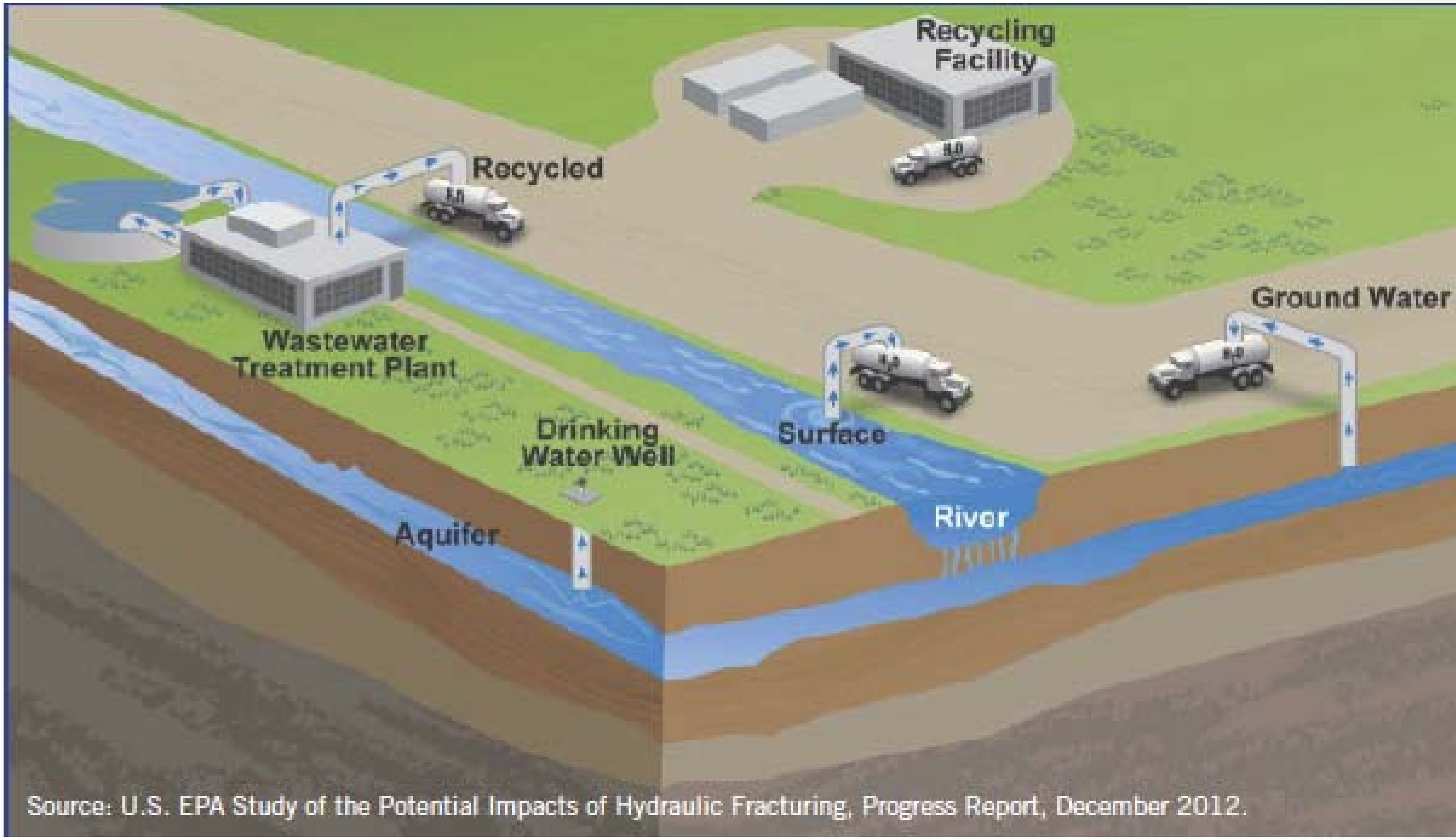
- Air quality regulated by…..
- Water mainly regulated by….
- In the United States, regulation of oil and gas development historically falls to the state.
- For most other industries - typically land use is regulated at the most local level

Exemptions Cause Regulatory Gaps

Federal Regulations with Exemptions for Unconventional Oil and Gas
Clean Air Act (state gaps include hydrocarbon regulation e.g. Colorado)
Clean Water Act
Safe Drinking Water Act
Resource Conservation and Recovery Act
Emergency Planning and Community Right-To-Know Act
Comprehensive Environmental Response, Compensation, and Liability Act
National Environmental Policy Act

Source: U.S. EIA. Drilling Productivity Report. October 2014.

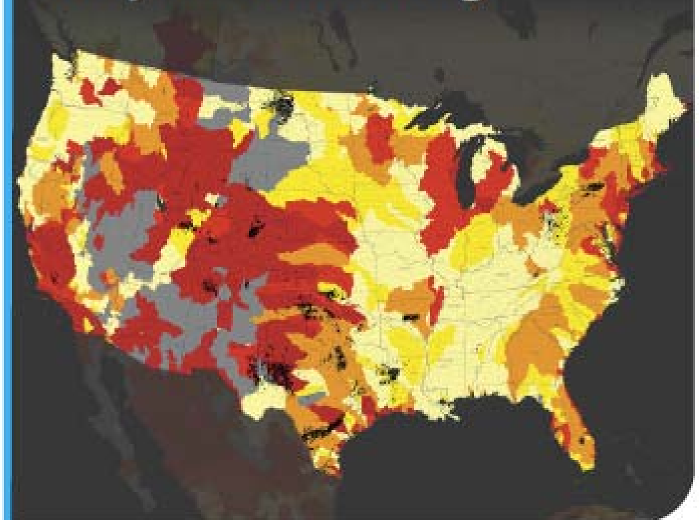
Water



Recycling Facility
Recycled
Wastewater Treatment Plant
Drinking Water Well
Surface
Ground Water
Aquifer
River
Source: U.S. EPA Study of the Potential Impacts of Hydraulic Fracturing, Progress Report, December 2012.

United States

Water Use Trends for Hydraulic Fracturing



U.S. Data Summary (January 1, 2011 - May 31, 2013) as reported by FracFocus

WATER USE TRENDS

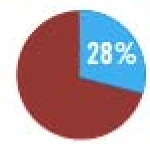
Number of Wells Used to Calculate Water Volume Data:	39,294
Total Water Use *(gallons)*:	97.5 billion
Average Water Use *(gallons/well)*:	2.5 million

EXPOSURE TO WATER RISKS

Proportion of Wells in **High or Extreme Water Stress:**	48%
Proportion of Wells in **Medium or Higher Water Stress:**	73%
Proportion of Wells in **Drought Regions** (as of Jan. 7, 2014):	56%

LOCAL WATER USE IMPACTS

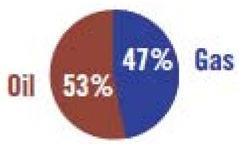
Water Use in Top 10 Counties as Proportion of Water Use Nationally



Number of Counties with Hydraulic Fracturing Activity:	402
Highest Water Use by a County *(gallons)*: Dimmit County, Texas	4 billion

OPERATING TRENDS

Type of Wells Reported:



Number of Operators Reporting to FracFocus (1st Quarter 2013)

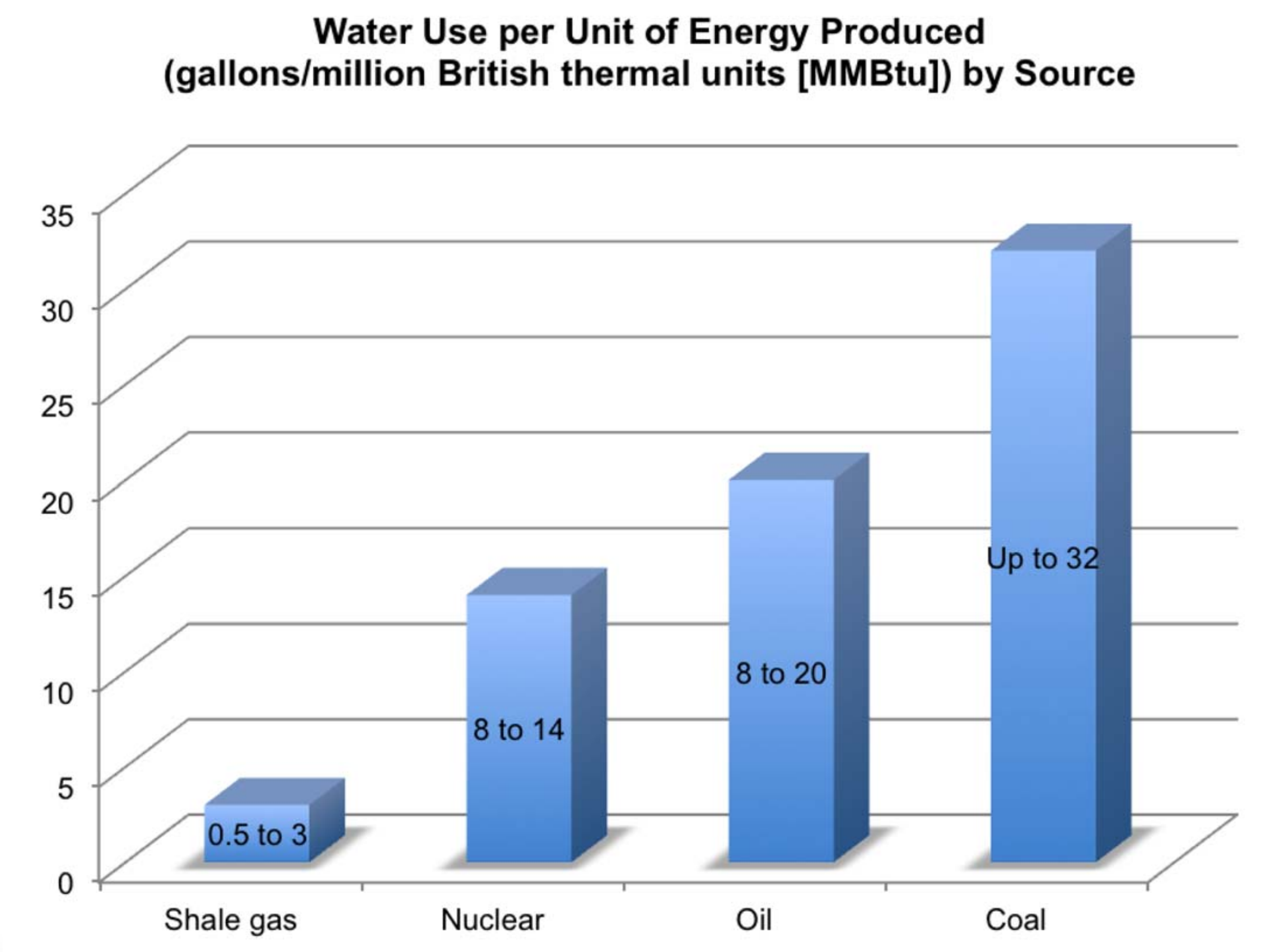
253

OPERATORS
Top Three in U.S. by Water Use:
- Chesapeake
- EOG
- XTO

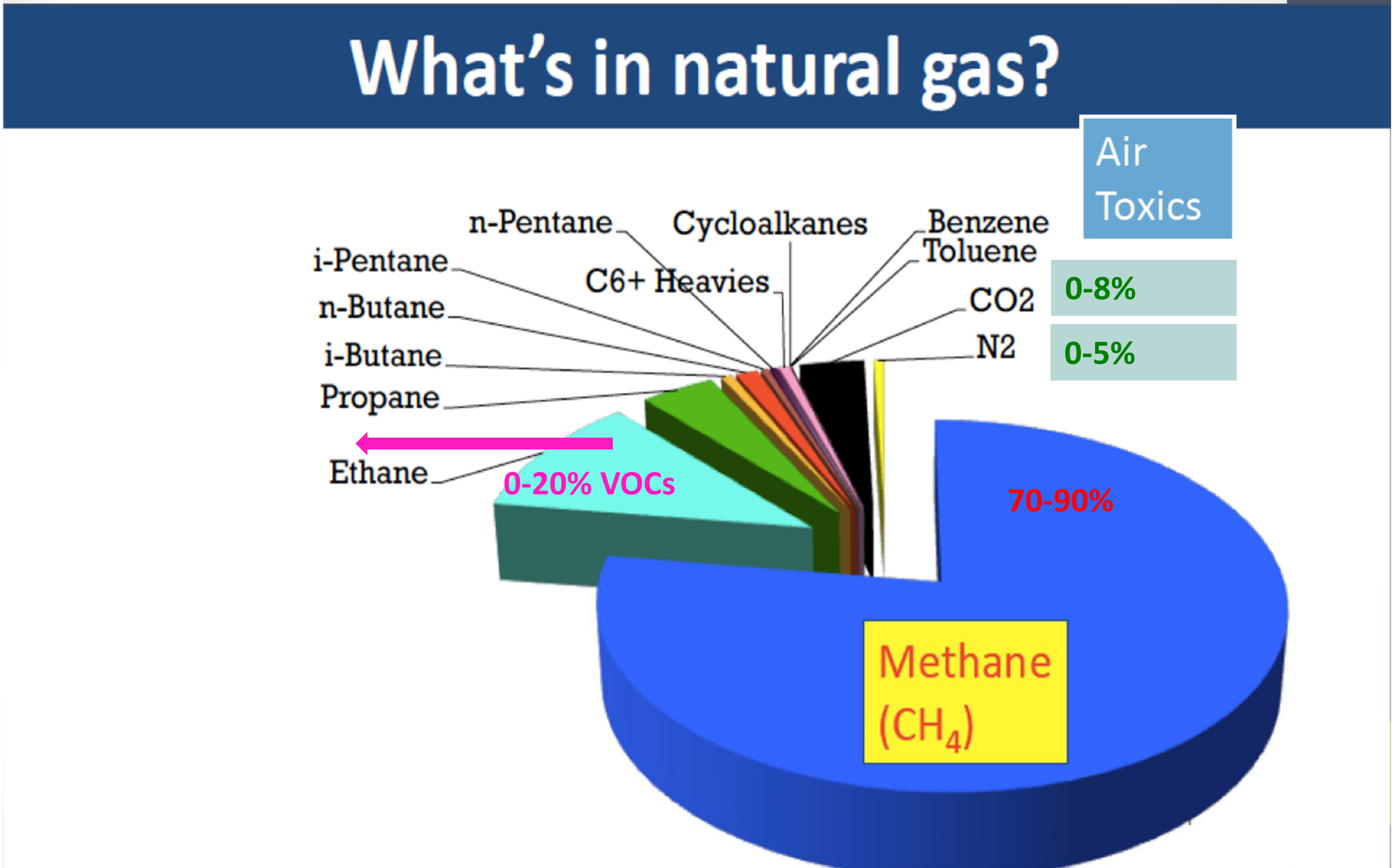
SERVICE PROVIDERS
Top Three in U.S. by Water Use:
- Halliburton
- Schlumberger
- Baker Hughes

Source: Ceres. Hydraulic Fracturing & Water Stress: Water Demand by the Numbers—Shareholder, Lender & Operator Guide to Water Sourcing. 2014

Water use PER UNIT OF ENERGY



Air emissions: Risks

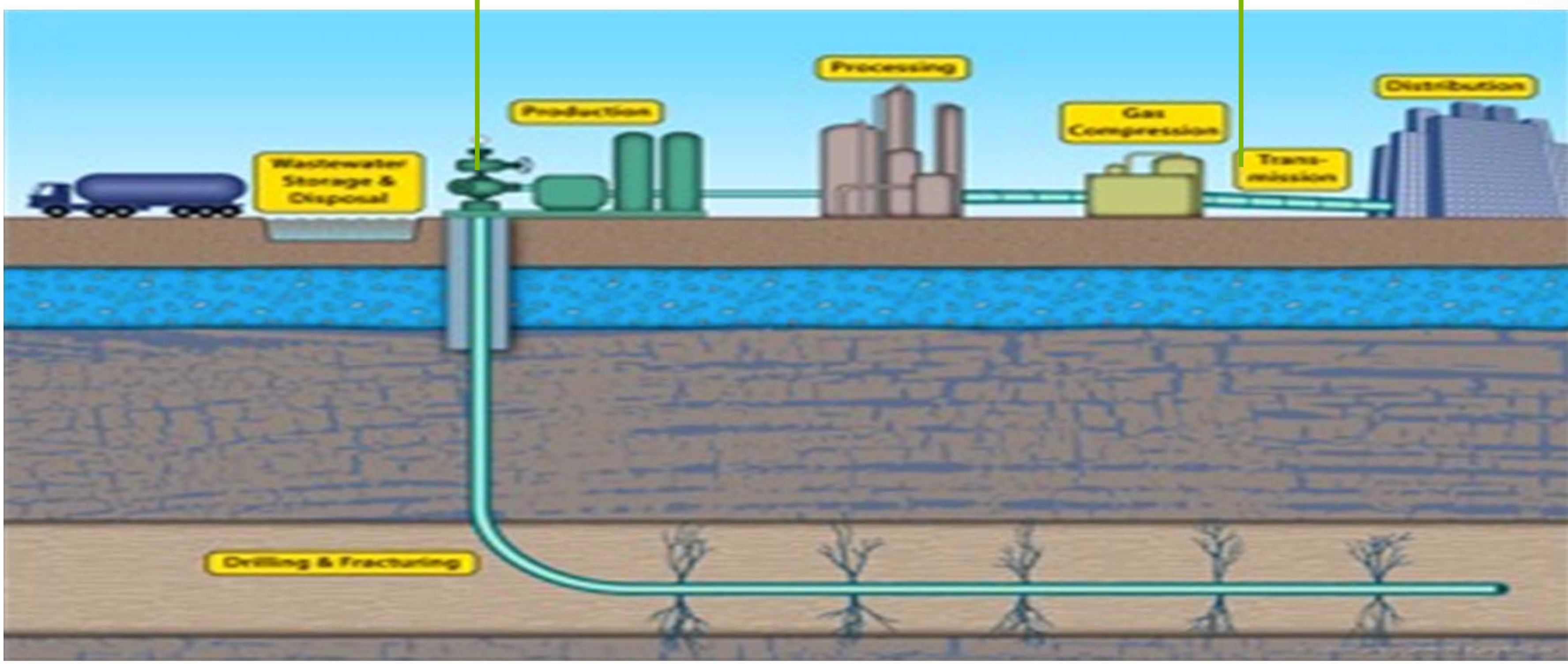


Source: EDF, 2014

Percentage of Methane in Gas Increases After Processing

Produced "raw gas"
≈ 70-90% Methane

By transmission, gas
≈ 98-99% Methane



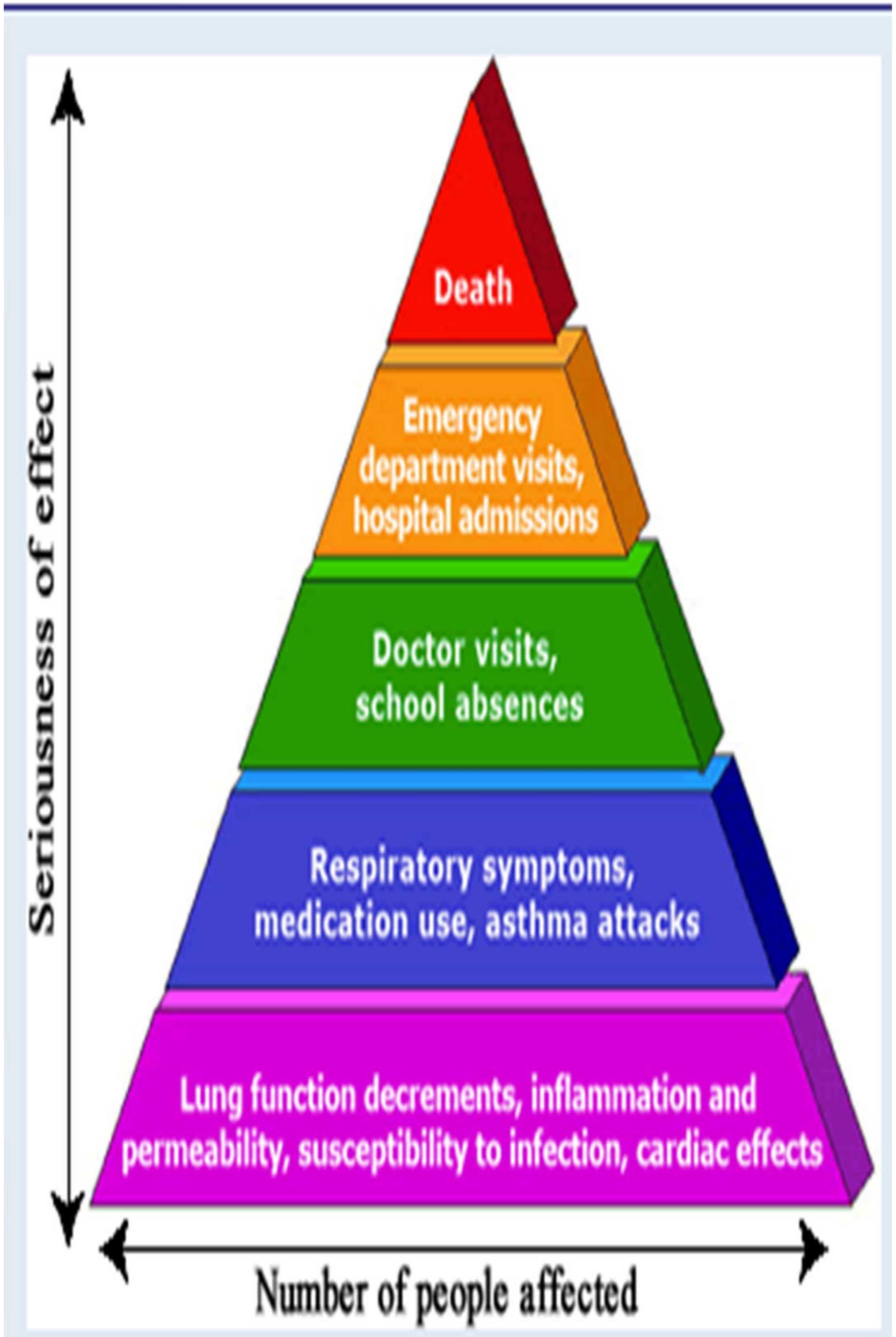


Figure 2: Pyramid of effects caused by ozone

The relationship between the severity of the effect and the proportion of the population experiencing the effect can be presented as a pyramid. Many individuals experience the least serious, most common effects shown at the bottom of the pyramid. Fewer individuals experience the more severe effects such as hospitalization or death.

Source: http://www.epa.gov/apti/ozonehealth/population.html

Fig. Major Sources of Methane Emissions from Production (Gg)

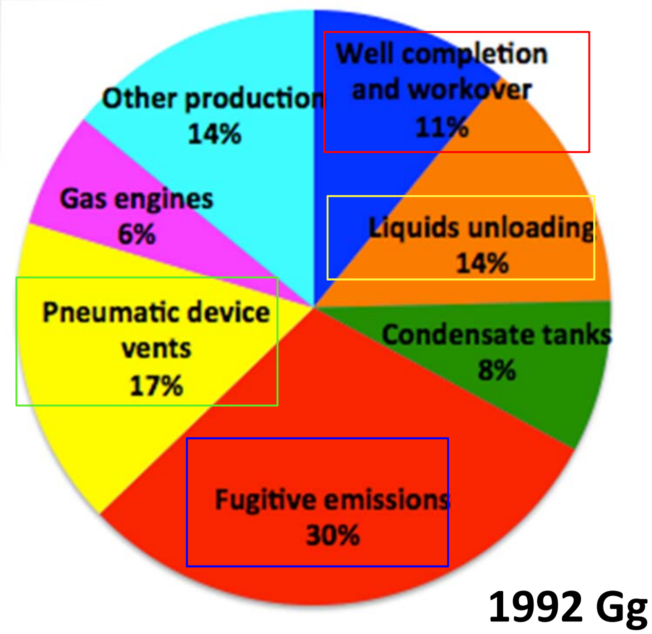


Fig. Major Sources of Methane Emissions from Processing (Gg)

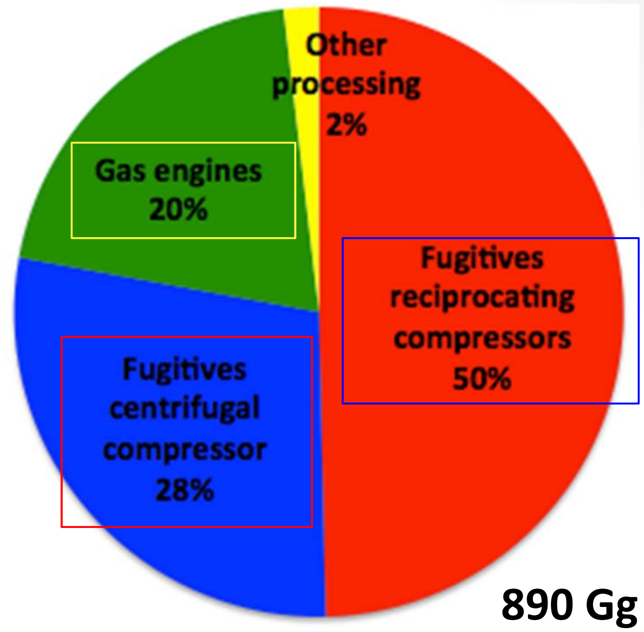
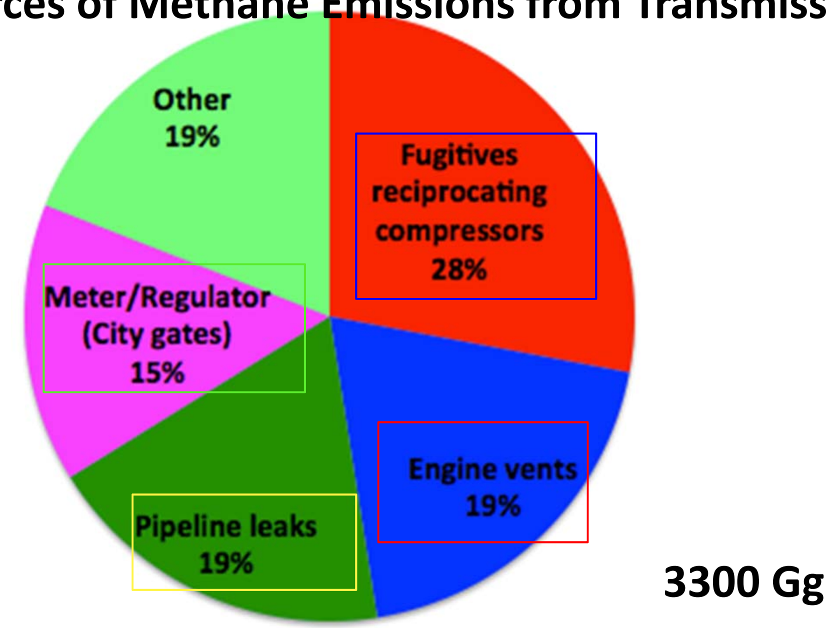


Fig. Major Sources of Methane Emissions from Transmission (Gg)



Data Source: EPA, 2014

Lifecycle GHG Emissions Conventional vs. Shale gas system

Major Sources	Conventional gas (g CO2e/MJ)	Shale gas (g CO2e/MJ)
Emissions During Well Completion	0.18 (0-0.4)	2.0 (0.1-8.6)
Routine Venting and Equipment Leaks at Well Site	2.9 (1.1-5.0)	2.9 (1.1-5.0)
Emissions During Liquid Unloading	2.9 (0.6-6.6)	---
Emissions During Workovers	---	2.5 (0-4.8)
Emissions During Gas Processing	5.2 (1.2-15.3)	5.2 (1.2-15.3)
Emissions During Transport, Storage and Distribution	2.2 (0.1-7.4)	2.2 (0.1-7.4)
Total	13.4 (3-34.7)	14.8 (2.5-41.1)

(Source: Jiang et al., 2011; Howarth et al., 2011; NETL, 2011; Stephenson et al., 2011; Burnham et al., 2011; Hultman et al., 2011; Weber and Clavin, 2012)

What is EPA's definition of Volatile Organic Compounds (VOC)?

- The term "VOC - Volatile Organic Compounds" has a special regulatory meaning for EPA. It is defined in 40 CFR 51.100(s).
- The definition reads as follows: "(s) Volatile organic compounds (VOC) means any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric photochemical reactions."
- Immediately following the definition is a list of organic compounds that "have been determined to have negligible photochemical reactivity..." This list includes mostly chlorofluorocarbons. **The two most important organic compounds that are not classified as VOC are methane and ethane.**

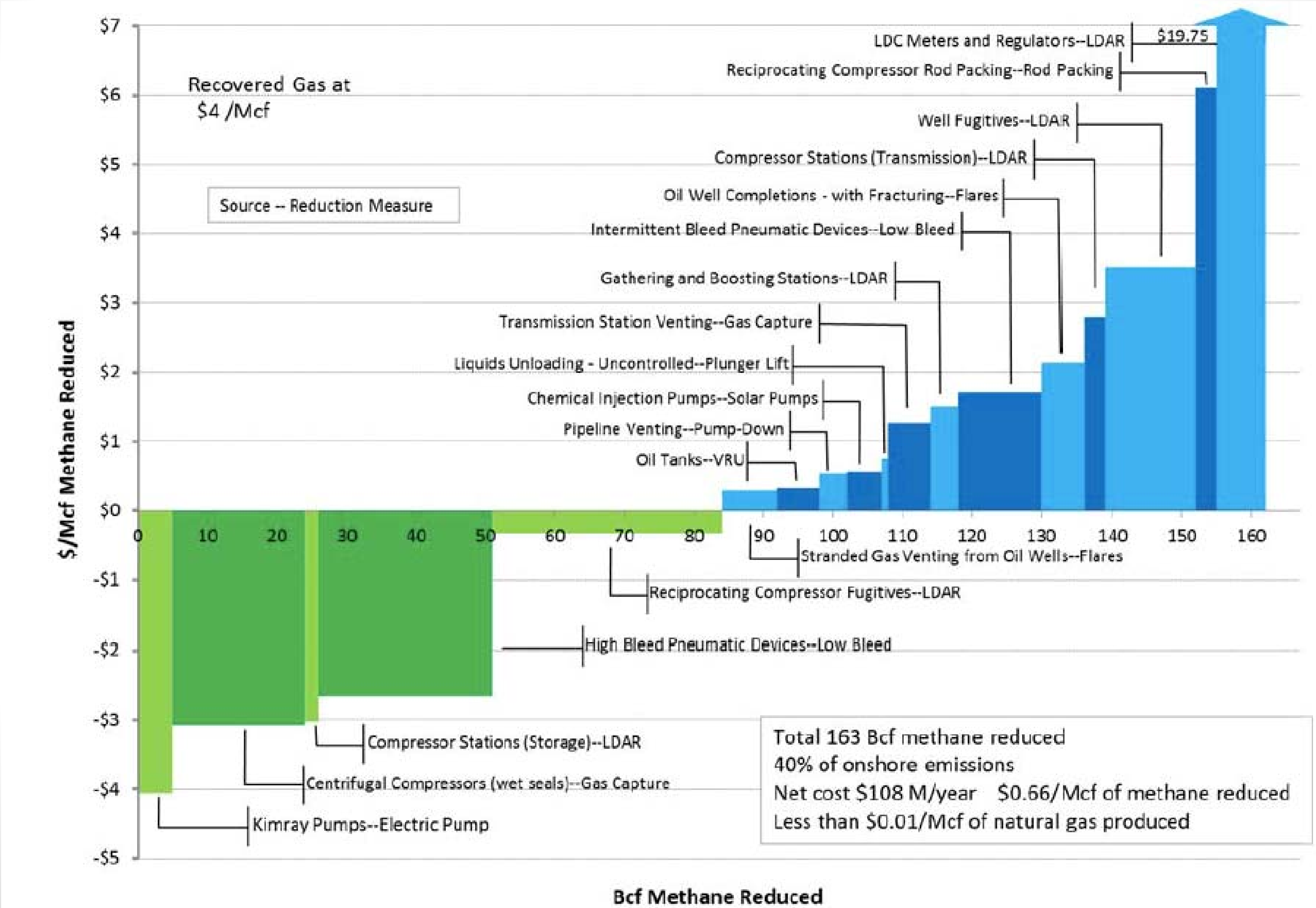
What are toxic air pollutants?

- Toxic air pollutants, also known as hazardous air pollutants, are those pollutants that are known or *suspected to cause cancer* or other serious health effects, such as *reproductive effects or birth defects*, or adverse environmental effects. EPA is working with state, local, and tribal governments to reduce air toxics releases of 187 pollutants to the environment. Examples of toxic air pollutants include benzene, which is found in gasoline; perchloroethylene, which is emitted from some dry cleaning facilities; and methylene chloride, which is used as a solvent and paint stripper by a number of industries. Examples of other listed air toxics include dioxin, asbestos, toluene, and metals such as cadmium, mercury, chromium, and lead compounds.

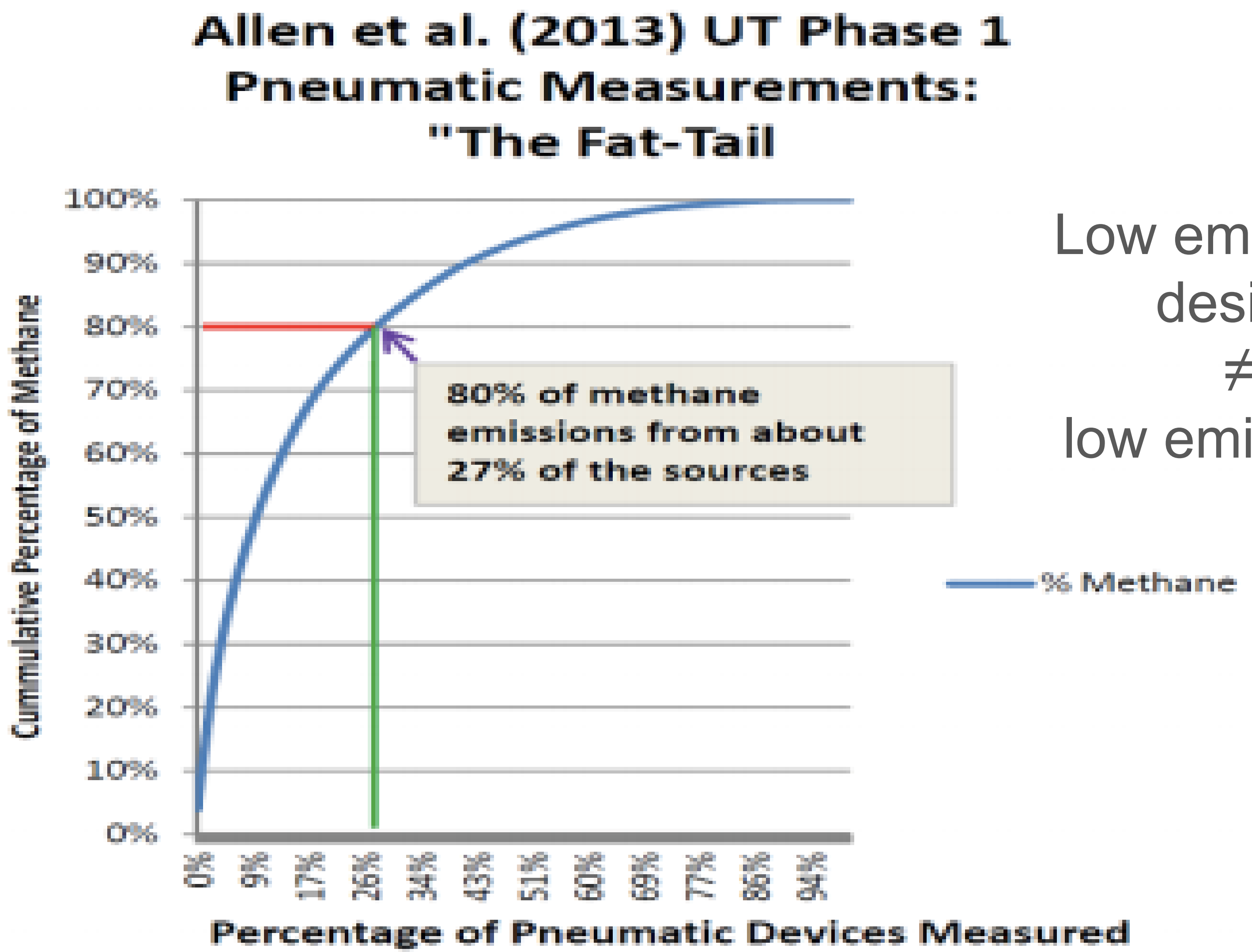
- ***What are the health and environmental effects of toxic air pollutants?***

- People exposed to toxic air pollutants at sufficient concentrations and durations may have an increased chance of getting cancer or experiencing other serious health effects. These health effects can include damage to the immune system, as well as neurological, reproductive (e.g., reduced fertility), developmental, respiratory and other health problems. In addition to exposure from breathing air toxics, some toxic air pollutants such as mercury can deposit onto soils or surface waters, where they are taken up by plants and ingested by animals and are eventually magnified up through the food chain. Like humans, animals may experience health problems if exposed to sufficient quantities of air toxics over time.

Cost effective emission technologies



Need Comprehensive Coverage



Low emissions
design
≠
low emissions

Reducing Vented Emissions to Zero

"We can achieve near zero percent leakage. No, not near zero – zero."
- Chuck Davidson, Noble Energy CEO

Should have a "Zero Tolerance" Approach to CH4 Leakage
- Governor Hickenlooper (Colorado)

- Industry leaders have shown they can limit emissions
- Leading operators and states can set example for others

Air Emission Recommendations

Fugitive emissions:

- Implement broad, risk-based leak detection and repair program without equipment exemptions.

Vented emissions:

- Leverage off industry best practice
- Aim for zero-tolerance approach where demonstrated technology exists.
- Broaden and strengthen existing federal requirements across all segments.
- Phase in regulation to existing facilities/equipment.
- Close gaps in oil well regulation.

Map of Ozone Nonattainment areas

Image source: www.epa.gov

Map of Ozone Nonattainment areas: Include New Federal

Image source: www.epa.gov

Tropospheric O_3 **warms the atmosphere**

O_3 damages plants and affects **agricultural production**:

- Reducing photosynthesis
- Reducing the plants ability to sequester carbon
- Reducing health and productivity of crops

O_3 air pollution causes over **150 thousand premature deaths** every year, and **millions more chronic diseases**, particularly in children and the elderly

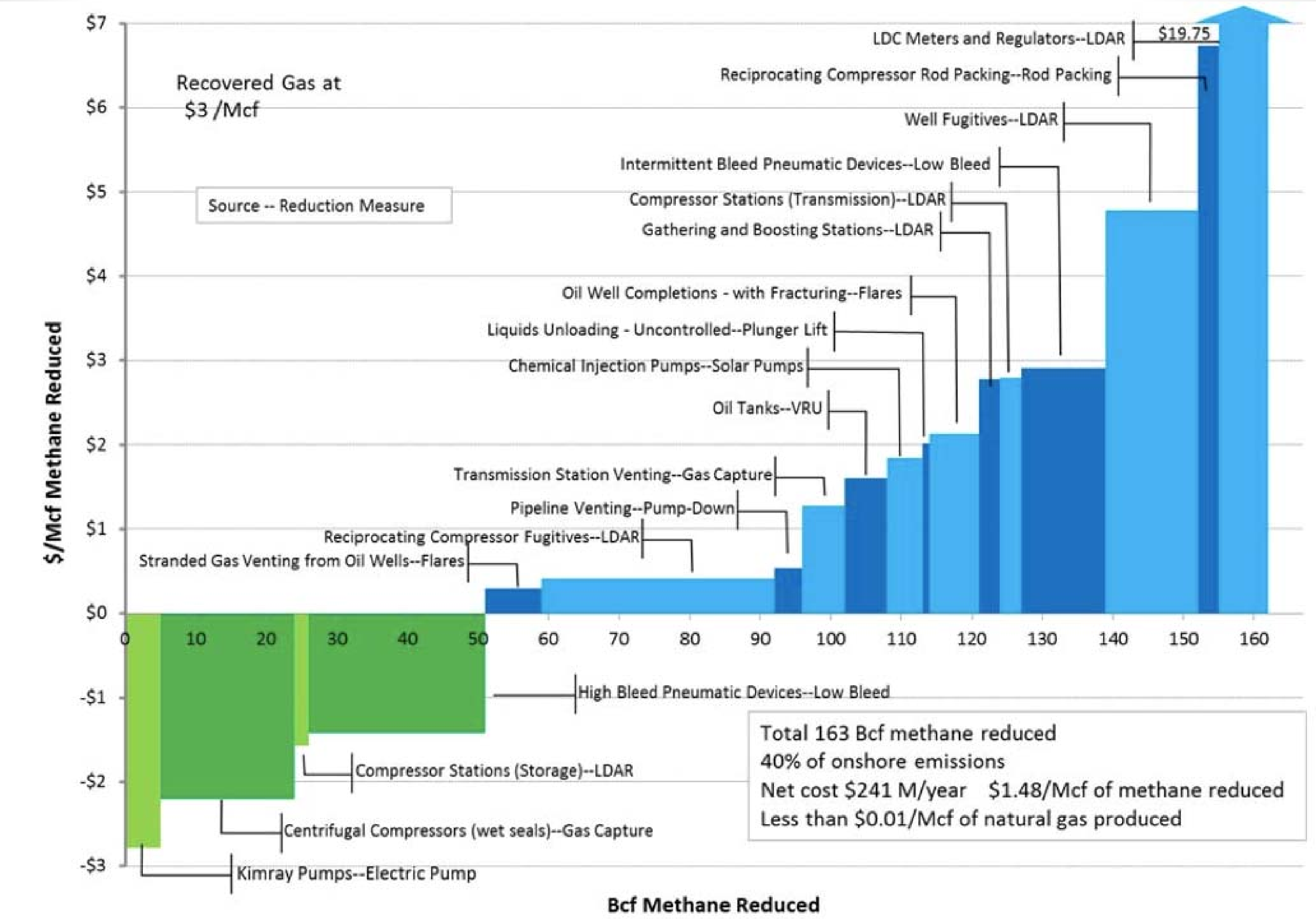
U.S. Unconventional Energy Boom

56% increase in U.S. natural gas production by 2040, unconventional drilling will drive 75% of this increase

By 2020, oil production from unconventional sources will account for over 50% of total US oil production

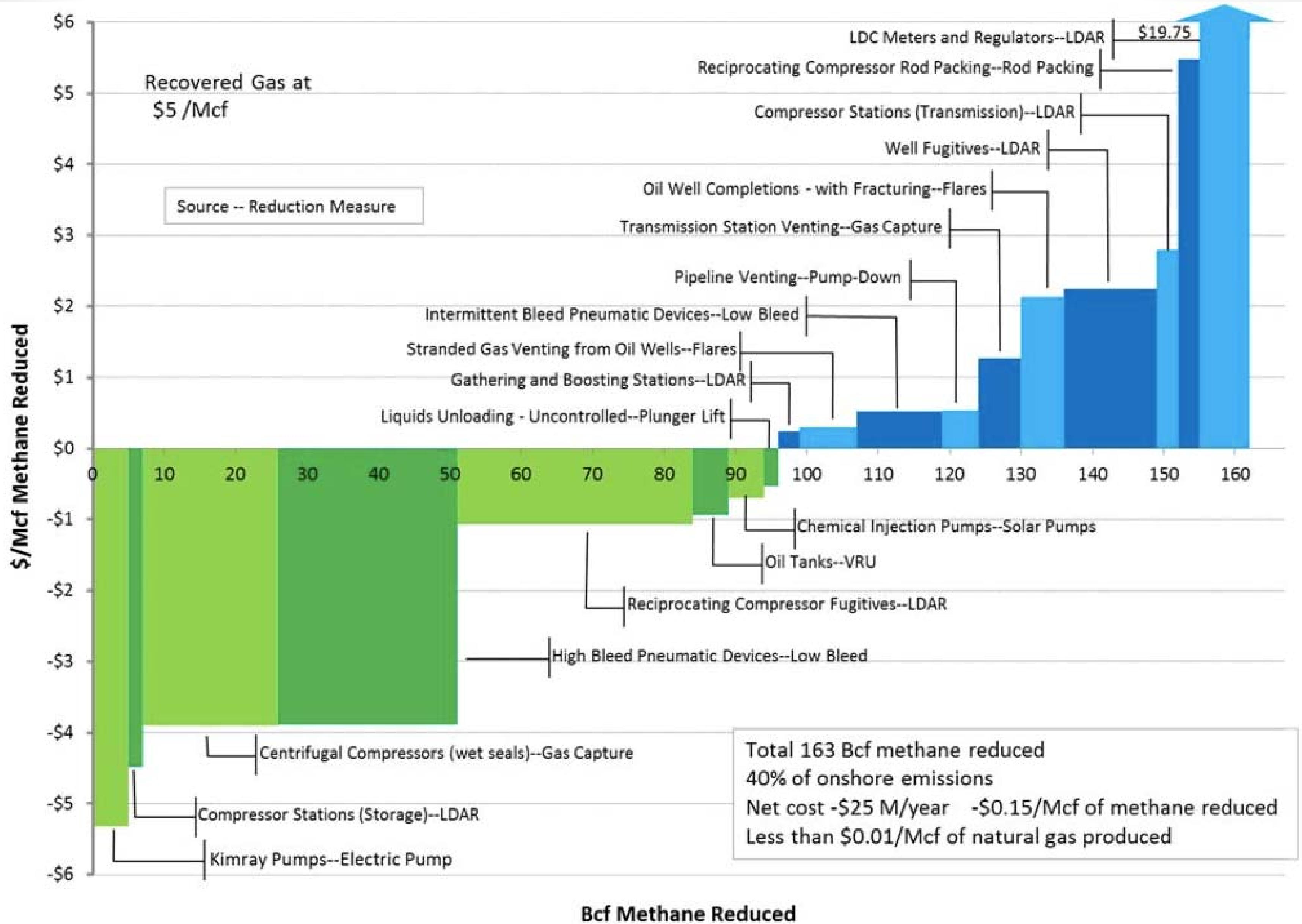
- ADD IMAGES

Cost effectiveness of regulations



EDF/ICF, "Economic Analysis of Methane Emission Reduction Opportunities in US Onshore Oil Oil & Natural Gas Industries", 2014.

Cost effectiveness of regulations



EDF/ICF, "Economic Analysis of Methane Emission Reduction Opportunities in US Onshore Oil Oil & Natural Gas Industries", 2014.