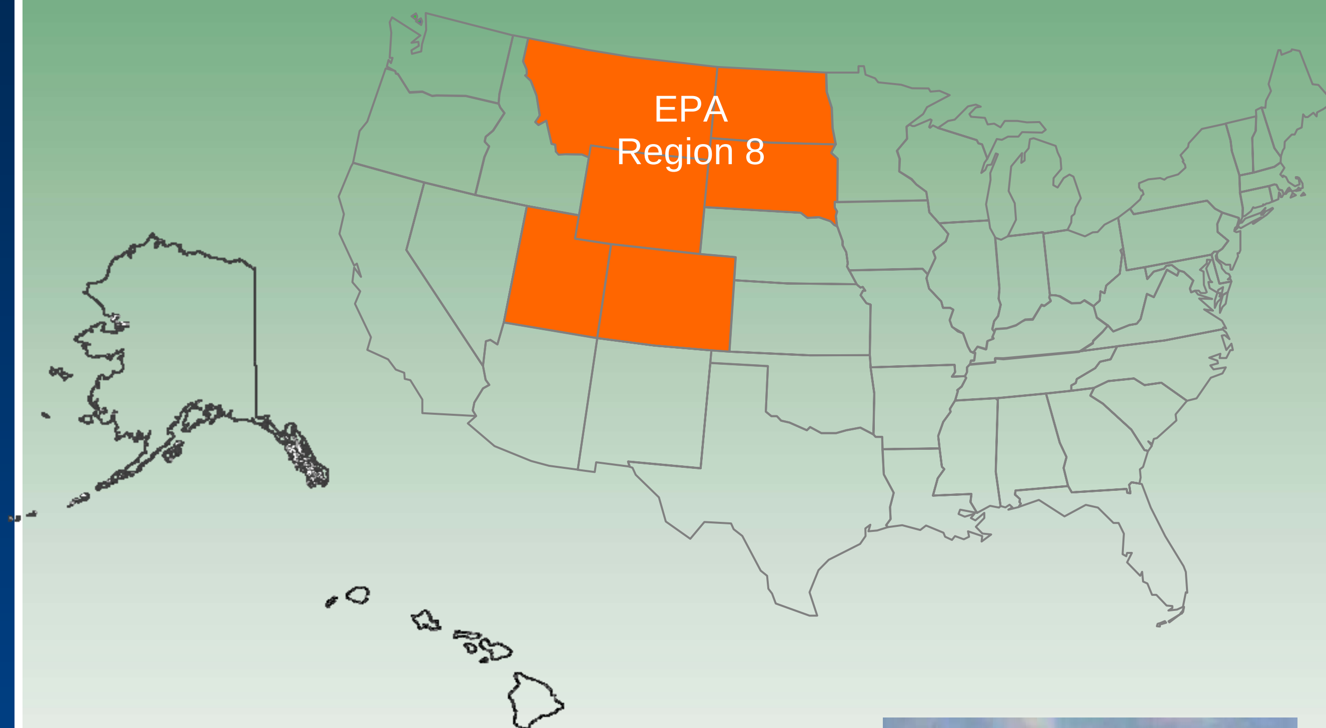
An Assessment of the Environmental Implications of Oil and Gas Production:

A Regional Case Study



September 2008

Working Draft

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

SectorStrategies

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Acronyms

ACEC	Areas of critical environmental concern
ANL	Argonne National Laboratory (DOE)
APEN	Air Pollution Emission Notice
API	American Petroleum Institute
Bbl	Billion barrels
Bcf	Billion cubic feet
BLM	Bureau of Land Management within the U.S. Department of Interior
BMP	Best management practice
CAA	Clean Air Act
CBM	Coal bed methane
CEM	Continuous emissions monitor
CERR	Consolidated Emissions Reporting Rule
CH_4	Methane
CI	Chemical injection
CO	Colorado
CO	Carbon monoxide
CO_2	Carbon dioxide
COSTIS	Colorado Storage Tank Information System
CWA	Clean Water Act
DART	Days Away Restricted or Transferred
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
DOL	U.S. Department of Labor
E&P	Exploration and production
EAC	Early action compact
EDMS	Emissions Data Management System
EIA	U.S. Energy Information Administration (DOE)
ELG	Effluent limitations guideline
EOR	Enhanced oil recovery
EPA	U.S. Environmental Protection Agency
EPAct	Energy Policy Act of 2005
FERC	U.S. Federal Energy Regulatory Commission
FRB	U.S. Federal Reserve Board
FWS	U.S. Fish and Wildlife Service (DOI)
Gal	Gallon
GHG	Greenhouse gas
GPM	Gallons per minute
GWP	Global warming potential
HAP	Hazardous air pollutant
H_2S	Hydrogen sulfide
HR	U.S. House of Representatives
HSM	Hydrocarbon Supply Model
IC	Internal combustion

ICE	Internal combustion engine
IHS	IHS Inc.
Lb	Pound
LDAR	Leak detection and repair
Mcf	Thousand cubic feet
MMscfd	Million standard cubic feet per day
MMcf	Million cubic feet
MT	Montana
NAAQS	National Ambient Air Quality Standards
NAICS	North American Industry Classification System
ND	North Dakota
NPDES	National Pollutant Discharge Elimination System
NEI	National Emission Inventory
NESHAP	National Emission Standards for Hazardous Air Pollutants
NETL	National Energy Technology Laboratory (DOE)
NFA	No further action
NGL	Natural gas liquids
NGO	Non-governmental organization
NH_3	Ammonia
NO_x	Nitrogen oxides
NRDC	Natural Resources Defense Council
NSPS	New Source Performance Standard
NWF	National Wildlife Federation
O&G	Oil and gas
OCS	Outer Continental Shelf
OECA	Office of Enforcement and Compliance Assurance (EPA)
OGAP	Oil & Gas Accountability Project
OPEI	Office of Policy, Economics, and Innovation (EPA)
OSHA	Occupational Safety and Health Adminstration (DOL)
OW	Office of Water (EPA)
PAH	Polyaromatic hydrocarbon
Pb	Lead
PM	Particulate matter
$PM_{2.5}$	PM with an aerodynamic diameter less than or equal to a nominal 2.5 micrometers
PM_{10}	PM with an aerodynamic diameter less than or equal to a nominal 10 micrometers
PM10_PRI	Primary PM_{10}
PTRCB	Petroleum Tank Release Compensation Board
QA	Quality assurance
RAPP	Refuges Annual Performance Plan
RAQC	Regional Air Quality Council
RCRA	Resource Conservation and Recovery Act
RHR	Regional Haze Rule
RICE	Reciprocating internal combustion engine
RMP	Resource Management Plan

ROD	Record of Decision
RRC	Railroad Commission of Texas
SAR	Sodium adsorption rate
SCC	Source classification code
SD	South Dakota
SDWA	Safe Drinking Water Act
SGE	Special Government Employee
SIC	Standard Industrial Classification
SIP	State Implementation Plan
SO_2	Sulfur dioxide
SO_x	Sulfur oxide
Tcf	Trillion cubic feet
TDS	Total dissolved solids
TIP	Tribal Implementation Plan
UIC	Underground injection control
U.S.	United States
USACE	U.S. Army Corps of Engineers
USDW	Underground source of drinking water
USGS	U.S. Geological Survey (DOI)
UT	Utah
VISTAS	Voluntary Innovative Strategies for Today's Air Standards
VOC	Volatile organic compound
VPP	Voluntary Protection Programs
VRP	Voluntary Remediation Program
WCI	Western Climate Initiative
WGA	Western Governors' Association
WDEQ	Wyoming Department of Environmental Quality
WESTAR	Western States Air Resources Council
WRAP	Western Regional Air Partnership
WY	Wyoming
Yr	Year

Executive Summary

Oil and gas exploration and production within the Rocky Mountain region is experiencing rapid growth. The environmental implications of these and other energy production activities are a major area of focus for the U.S. Environmental Protection Agency (EPA). Headquartered in Denver, Colorado, the EPA regional office (Region 8) partners with other federal agencies, state agencies, and Tribal governments to provide primary environmental oversight of oil and gas activities in Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming. In addition, EPA's national partnership with the Interstate Oil and Gas Compact Commission (IOGCC) is integral to continued communications, coordination, and collaboration regarding environmental oversight of oil and gas production.

The dramatic upsurge in regional oil and gas production in recent years is expected to continue. Indeed, various studies predict that the Rocky Mountain region - which includes major coal bed methane (CBM), tight gas sands, and shale gas production areas - will remain vital to U.S. natural gas production in the decades to come. At the same time, many of the region's oil and gas reserves are located in ecologically sensitive areas, raising concerns about the environmental impacts of production. These concerns continue to emerge and expand.

This report is intended to serve as a technical resource for policy makers, environmental managers, and other stakeholders focused on oil and gas production. In taking an in-depth look at available data on environmental releases from multiple sources, the report investigates a number of relevant environmental performance trends and management challenges; analyzes current and projected production impact data; offers policy insights into current initiatives; and offers examples of environmental stewardship.

Objectives Summarized

This report was produced to assist the EPA Office of Policy, Economics, and Innovation (OPEI) in assessing environmental impacts associated with oil and gas production in Region 8. The report discusses several state, regional, and national policy initiatives designed to effect environmentally responsible oil and gas production. In addition, the report's findings are intended to inform current and future agency deliberations regarding oil and gas production nationally.

Through this analysis, the EPA Sector Strategies Program seeks to provide new knowledge and insights regarding the environmental releases associated with oil and gas production. The report also identifies some of the challenges associated with acquiring and analyzing relevant environmental impact data. By focusing on key energy development issues and associated production impacts in a strategically important and resource-rich region, one that is experiencing unprecedented growth in oil and gas activities, we hope to provide valuable environmental management insights and share them broadly with policy makers, environmental managers, and other key stakeholders.

Region 8's Distinctive Oil and Gas Industry Characteristics

The oil and natural gas resources in Region 8 are distinct from other reserves located in the United States. Rich in unconventional natural gas reserves, production in Region 8 is increasingly focused on tight gas sands in Colorado and Wyoming (e.g., Washakie Basin); large oil shale reserves in western Colorado, northeastern Utah, and southwestern Wyoming; shale gas in Montana and North Dakota (e.g., the Bakken Shale); and CBM formations such as the Powder River basin in Wyoming and Montana and the Raton Basin that stretches from Colorado to New Mexico.[1] Significant natural gas resources are steadily gaining increased focus within the region. Representative examples include the tight gas sand formations in the Green River Basin of northwestern Wyoming and the Piceance Basin of northwestern Colorado. Regional increases in oil and gas production are demonstrated by the following statistics:

- In recent years, gas production has increased the most in Colorado and Wyoming; in 2005, these two states made up 54 percent of total production in the west and comprised 15 percent of total U.S. production.[2] The largest expected growth in gas production in the United States is expected to occur within these two states.[3]
- Oil production does not play as large a role in overall fuel production in Region 8. The Rockies represent only about 6 percent of total U.S. oil production,[4] and this fraction has not changed significantly in recent years. This stagnant crude oil production rate can be observed in Chapter 2, Figure 2-4.
- In terms of new oil wells, the Rockies represent about 13 percent of national activity. This fraction has increased from 5 percent in 2000 due to expanding exploration and production in Colorado's Denver Basin and the Uinta Basin of Utah.
- Potential recoverable resources in Rocky Mountain tight sands are estimated to be several hundred trillion cubic feet (TCF) of natural gas, compared to current proved reserves of about 190 Tcf for the United States as a whole. The vast size of the tight gas sands resource base within the region suggests that extraction activities are likely to expand and continue on for decades to come.
- The Powder River Basin in eastern Wyoming started CBM production in the 1980s, gained prominence in the late 1990s, and currently produces about 1 billion cubic feet (Bcf) of CBM gas per day (an amount that is greater than 50% of all U.S. CBM production).
- Shale gas exploration and production activities are increasing across the nation, including the Bakken shale in Montana and North Dakota.

[1] "Tight gas" refers to natural gas found in usually impermeable and nonporous formations, such as limestone or sandstone, which require advanced well stimulation efforts, such as fracturing or acidizing, to optimize resource extraction. "Coal bed methane" refers to natural gas trapped in underground coal seams that can be extracted before mining the coal (in some cases, the coal seams are very deep or of low quality, in which case CBM is the only hydrocarbon extracted from the seam).
[2] U.S. Federal Energy Regulatory Commission (FERC), *Natural Gas Markets: Western*, http://www.ferc.gov/market-oversight/mkt-gas/western.asp#prod.
[3] U.S. Department of Energy (DOE), Energy Information Administration (EIA), *Natural Gas Pipelines in the Central Region*, http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/central.html.
[4] Based on 2006 data.

- A recent report by the Rand Corporation estimated that between 500 billion and 1.1 trillion barrels of oil are technically recoverable from high-grade oil shale deposits located in the Green River formation in Colorado, Utah, and Wyoming. Although these deposits have yet to be commercially developed. EPA and other government agencies are investigating and addressing the relevant environmental and natural resource implications of potential oil shale production in Region 8.

Technical Approach

Unconventional oil and gas resources generally require more wells, greater energy and water consumption, and more extensive production operations per unit of gas recovered than conventional oil and gas resources, due to factors such as closer well spacing and greater well service traffic. Thus, they have the potential for greater environmental impacts. Due to these resource characteristics, oil and gas extraction in the Rocky Mountain region has a somewhat different environmental footprint than oil and gas production in other regions, providing an additional reason for focusing this analysis on Region 8. Section 2.2 and Appendix A provide further details on the unique characteristics of Region 8 and Section 2.3.2 provides details on produced water from CBM.

- The primary environmental impacts associated with oil and gas production detailed in this report are related to three main releases: air emissions, produced water, and drilling waste. Concerns about potential groundwater impacts have surfaced with respect to individual projects in Region 8; however, reported incidents have not proven to be a region-wide trend. Nevertheless, these groundwater incidents and the environmental issues they raise may warrant further investigation by EPA and others. Using predominantly 2002 baseline data, we estimated 2006 emissions for air and water as well as drilling wastes from oil and gas production activities in Region 8.
- [5]The primary air pollutants of interest are nitrogen oxides (NO_x), sulfur dioxide (SO_2), and particulate matter (PM) as precursors of regional haze, and NO_x and volatile organic compounds (VOCs) as precursors of ground level ozone. NO_x emissions are primarily from production operations and equipment such as engines (both stationary and mobile), turbines, and process heaters. VOCs constitute the largest absolute component of regulated emissions, primarily fugitive emissions including some hazardous air pollutants (HAPs) such as benzene, toluene, ethyl benzenes, and xylenes. SO_2 emissions are primarily related to combustion in the oil production sector. For more information about these air pollutants, please refer to Section 3.2. As for the production processes mentioned here, additional details are provided in Appendix A, Section A.1.
- For VOC and HAPs emissions, we found that smaller sources (“area sources,” in the data set we relied on) collectively contributed more emissions than larger, “point sources”.

[5] Oil spills, although they occur from time to time in oil and gas production, are not addressed in the context of this report due to data and other analytical limitations. This report focuses mainly on production impacts that occur within the course of normal drilling and resource recovery operations.

- In addition to CAA-regulated air pollutants, oil and gas production produces greenhouse gas (GHG) emissions. Fugitive methane (CH_4) emissions constitute the largest source of global warming potential-weighted (GWP-weighted) GHG emissions. CO_2 emissions from process heaters were about 206,000 tons and from internal combustion (IC) engines (such as compressors) were about 6.4 million tons in 2006 per our report's estimate.
- CBM formations in the Rocky Mountain region initially release large volumes of produced water as natural gas is being extracted, which, depending on the water quality, can be released to the surface, treated in place, or reinjected. The amount of produced water by state is discussed in Section 3.3.1.
- Unconventional gas extraction tends to produce greater surface disturbances and drilling waste in comparison to conventional gas extraction because of tighter well spacing and the need for fracturing. The amount of drilling waste by state is discussed in Section 3.3.2.

Key Environmental Impact Findings

This analysis produced the following overarching insights:

- This analysis showed that emissions from oil and gas production in Region 8 constitute a sizable share of total U.S. emissions from this sector (ranging from 6 percent for PM to 30 percent for HAPs; see Chapter 4, Table 4-1), reflecting the significance of Region 8 production nationally. As shown in Chapter 3, Table 3-2, within the region**, oil and gas air emissions are the largest for VOCs, comprising over 40 percent of the regional total in 2002**. Emissions of NO_x, CO, and SO_2 contribute approximately 15 percent, 9 percent, and 4 percent to the regional totals, respectively.
- The report (see Chapter 3, Table 3-7) presents air emissions by major source category—point and area—by state. VOCs, NO_x, SO_2, CO, and HAPs are the only pollutants shown, since data are available by type of major source. For VOCs and HAPs, the table reveals **area sources are a much greater contributor to emissions than point sources in Region 8**. For NO_x and CO emissions, point and area sources both contribute significantly to total emissions. The area source fraction is slightly larger for NO_x and the point source component is larger for CO. NO_x and CO emissions are primarily from large combustors (point sources) as well as small combustors and mobile sources (area sources).
- PM emissions from the oil and gas industry in Region 8 are negligible, with some data indicating they are less than 0.1 percent of the regional total. Despite the inconsistencies in available particulate data sets, it's clear that with certain areas not meeting current air quality standards and oil and gas production on the rise, these and other air quality impacts are growing areas of concern within Region 8 (and nationally).
- Per the report's estimating methodology for produced water, almost 3 billion barrels of water were produced in Region 8 in 2006, with Wyoming contributing approximately

71 percent of total produced water (for both oil and gas) from the region (see Chapter 3, Table 3-9). Produced water may require water management and treatment or may sometimes be clean enough to be used for irrigation and agricultural purposes without prior treatment.

- Developing unconventional natural gas fields often requires fracturing, or "fracing," the target resource by injecting water and chemicals into the formation, which can potentially affect groundwater sources.
- Region 8 also produced more than 46 million barrels of drilling waste in 2006 (see Chapter 3, Table 3-13). Directly related to increased rig activity, the largest amount of drilling waste was generated in Wyoming, followed by Colorado and Utah. Reuse or disposal of drilling waste, along with further disturbance of surface areas due to oil and gas production (e.g., through construction of roads and operation of drilling rigs in wilderness and undeveloped areas), are highly visible issues involving industry stewardship and regulatory oversight.
- Non-governmental organizations (NGOs), Congressional oversight bodies, and other stakeholder groups and citizens have issued studies or scrutinized the environmental implications and potential risks of expanding oil and gas production on public lands and in general. For example, the Natural Resources Defense Council (NRDC), National Wildlife Federation (NWF), and Oil & Gas Accountability Project (OGAP) have been leading critics of environmental stewardship within the oil and gas industry. Each of these organizations has released reports questioning various oil and gas production practices and environmental implications. Section 2.3 provides additional details regarding some of these critiques and the issues being raised.
- The combined, incremental effects of oil and gas production – in combination with other human activities – can pose threats to human health and the environment. Under the National Environmental Policy Act (NEPA) and associated guidance documents, these collective human activities are referred to as cumulative impacts.
- The oil and gas industry faces a number of issues and operational constraints that make it difficult to completely eliminate its environmental footprint. For instance, drilling and resource extraction create a number of wastes, such as produced water and drilling waste. Wastes that cannot be reused or recycled must be stored or disposed of in some manner, increasing the land area affected by oil and gas extraction and raising concerns over potential leakage of drilling fluids and other wastes from storage sites. In addition, a large increase in production in the oil and gas industry (or any industry) is likely to increase air emissions significantly. Installing new technologies and controls can reduce the quantity of air emissions per amount of fuel produced but cannot eliminate relevant environmental impacts altogether.
- Although many oil and gas companies have taken steps to reduce the environmental, safety, and health impacts of their operations, there are still environmental concerns that need to be better understood and addressed. To respond to these concerns, it's important that government, industry, and stakeholders develop a better understanding of where current policy and technology mechanisms are inadequate and where further controls, commitments, and innovations are needed.

- The environmental management issues raised in this report are magnified by estimates that approximately 85 percent of all oil wells and 70 percent of all gas wells nationally are marginal wells. Marginal wells are generally defined as those producing at the margin of profitability. In addition, they are often owned and operated by smaller producers that may lack the technical expertise or resources to maximize potential pollution prevention and environmental management opportunities. As noted in Section 2.3, these wells are located in mostly rural settings (although urban drilling is an emerging trend in some areas of the country). Moreover, the wells are typically spread across thousands of operations, with several distinct sources of emissions and discharges. Nevertheless, the findings in this report demonstrate that on an aggregate basis, the environmental footprint of oil and gas production in Region 8 and other producing regions across the United States is growing and deserving of increased focus and attention.

Environmental Policy Issues

- A number of initiatives have been implemented to address air, water, and land use impacts associated with oil and gas production nationally and in Region 8. These policies range from the implementation of mandatory emissions limits on oil and gas operations (e.g., under the Clean Air Act (CAA), Clean Water Act (CWA), and Safe Drinking Water Act (SDWA), state regulations, etc.), to other federal initiatives (e.g., Bureau of Land Management (BLM) activities in Region 8 and nationally), to voluntary programs and actions. Some of these activities encompass best management practices (BMPs) used by industry to reduce environmental releases.

The following examples highlight just a few of the relevant environmental policy decisions and ongoing initiatives shaping oil and gas development in Region 8 and elsewhere:

- The 2004 *Pennaco* decision compelled BLM to revise Resource Management Plans (RMPs) to address cumulative environmental impacts stemming from new CBM development proposals and other pending energy projects in the region.[6]
- BLM and states have been working with western surface land owners to resolve differences tied to the stewardship of federal mineral rights (e.g., split estate issues).
- EPA is conducting a detailed review of the CBM extraction sector to determine if it would be appropriate for the agency to initiate a rulemaking to revise, as necessary, the effluent limitations guidelines for the Oil and Gas Extraction Point Source Category (40 CFR 435) to control pollutants discharged in CBM-produced water.[7]
- EPA has reviewed and approved innovative CBM waste water treatment residual disposal options that allow injection into Class II wells, creating better economic scenarios for creating cleaner water for surface discharge or aquifer storage.

[6] *Energy, Public Lands, and the Environment*, Professor Robert B. Keiter, University of Utah S.J. Quinney College of Law, September 2008
[7] *EPA, Agency Information Collection Activities: Proposed Collection; Comment Request; Coalbed Methane Extraction Sector Questionnaire (New), EPA ICR Number 2291.01, OMB Control No. 2040-NEW* *http://www.epa.gov/fedrgstr/EPA-WATER/2008/January/Day-25/w1344.htm*

- Colorado has implemented more stringent VOC emissions standards in response to the state's rapid increase in oil and gas production-related emissions.
- Several regional initiatives focusing mainly on air quality have been established in the past decade, including the Western Regional Air Partnership (WRAP), Western States Air Resources Council (WESTAR), and Western Climate Initiative (WCI).

There are a number of additional voluntary initiatives underway that can continue to grow or be used as models for developing collaborative environmental stewardship programs in Region 8. A representative sample includes the following programs:

- EPA's Natural Gas STAR program;
- The Occupational Safety and Health Administration's (OSHA) Voluntary Protection Programs (VPP);
- The San Juan Voluntary Innovative Strategies for Today's Air Standards (VISTAS) program;
- The Wyoming Voluntary Remediation Program (VRP); and
- The Four Corners Air Quality Task Force.

Each of these programs provides meaningful incentives to program participants, ranging from the implicit (such as reduced emissions, increased product sales and profitability) to the explicit (such as operational leeway, e.g., reduced monitoring). Voluntary approaches such as these encourage improved resource stewardship, environmental protection and health and human safety. A summary of these voluntary programs is provided in Chapter 4, Table 4-2.

Potential Next Steps

In spite of the many policy initiatives, program developments, and industry practices that are now addressing oil and gas environmental implications, significant environmental concerns persist. Such challenges won't be effectively resolved without enhanced communications and the active involvement of government (federal, state, and tribal), industry, and stakeholder representatives. Moreover, since production levels are expected to continue their rapid ascent across Region 8, EPA continues to investigate and pursue a range of policy options in consultation with state partners, Tribal and industry representatives, and other key stakeholders. Although a discussion of potential next steps are not the focus of this report, specific actions and responses will continue to be investigated and pursued by EPA, partner agencies, industry leaders, and other stakeholder representatives, as appropriate.

EPA, state and other government agencies are challenged to keep pace with rapidly expanding oil and gas production as well as associated regulatory activities (e.g., rulemakings, permitting and inspections). In addition, the high volume of oil and gas projects poses unique technical and regulatory challenges for federal and state agencies alike. As such, effective regulatory oversight requires open communications, collaborative partnerships, and constant coordination. Improved environmental measurement, stakeholder involvement, and environmental management are integral to successful oil and gas production.

At a national and regional level, EPA is actively reaching out to oil and gas organizations to improve understanding, identify drivers and barriers, increase performance, and address the environmental implications of oil and gas production. In summary, EPA is well positioned to provide greater regulatory certainty and consistency in oil and gas oversight through enhanced data collection and analysis, improved information sharing and partnerships, and focused compliance assistance and enforcement.

1.0 Introduction

1.1 Objective

EPA's Sector Strategies Program, within the Office of Policy, Economics, and Innovation (OPEI), commissioned this analysis to meet the following objectives:

- Facilitate a general understanding of oil and gas production, related environmental releases, and associated environmental implications in EPA Region 8;
- Identify policy issues, program initiatives, and stewardship opportunities related to regional oil and gas production, focusing on air, water, and land issues;
- Assess environmental releases to air, water, and land resulting from current and projected oil and gas production in the region; and
- Lay the groundwork for future action to reduce environmental impacts associated with current and projected production in Region 8 and nationally.

It is important to note that this report is an analytical document and does not convey Agency decisions. The report's findings are based on the best available production data.

1.2 Approach

1.2.1 Framing the Study: Oil and Gas Production in Region 8

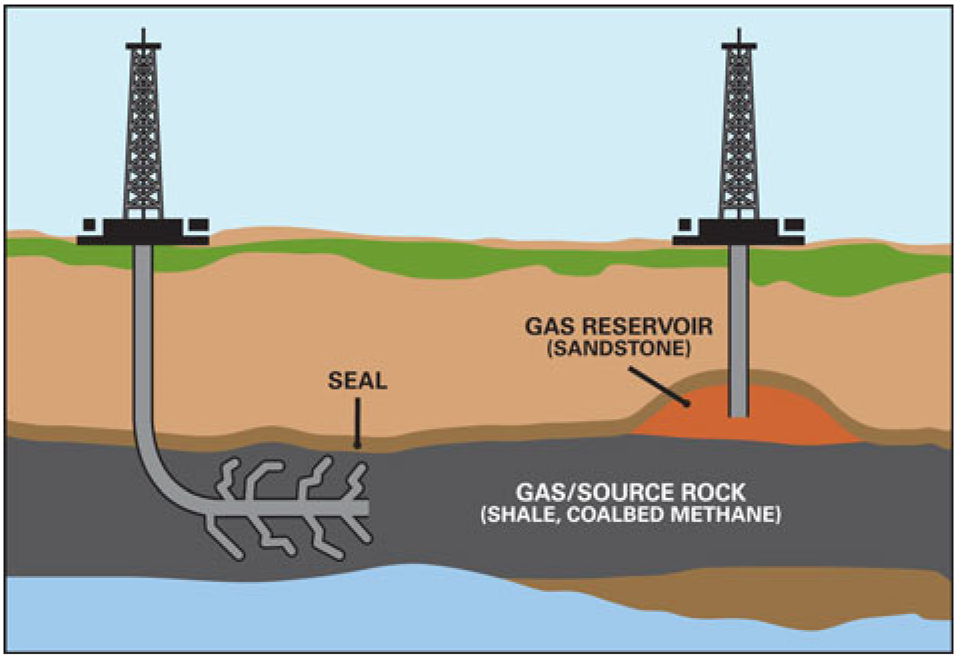
As mentioned previously, Region 8 includes Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming, and 27 sovereign tribal nations. The region is rich in natural resources, natural gas in particular, but is distinct from traditional U.S. gas producing regions, such as the Gulf Coast, in a number of ways. Specifically, Region 8 features extensive unconventional natural gas resources including tight gas sands, shale gas, and CBM.

Unconventional oil and gas resources are loosely defined as resources that are generally deeper and / or more difficult to recover than traditional oil and gas resources that have historically been produced in the United States and elsewhere. In particular, unconventional resources include geologic formations that contain oil and gas but require advanced recovery techniques due to technical challenges posed by the physical properties of the reservoir (see figure 1-1).

For example, tight gas formations require the gas-bearing formation to be artificially fractured and stimulated to allow the gas to flow freely to the wellhead. Unconventional resources may also require that extracted material be upgraded to meet relevant fuel specifications. For example, oil shale must be heated to release petroleum-like liquids that can be turned into fuel. Presently, there are a host of water and energy use, as well as associated environmental protection issues, that must be resolved in the years ahead if oil shale is going to become a viable energy source. Industry is currently investing in new technologies and approaches to test and ultimately ensure the commercial viability of these unconventional resources.

In terms of the potential size of the oil shale resource residing in Region 8, the Department of Interior (DOI) estimates subsurface deposits in Colorado, Utah, and Wyoming may be nearly three times the amount of proven petroleum reserves in Saudi Arabia. Specifically, according to BLM Director Jim Caswell, oil shale deposits "may hold the equivalent of 800 billion barrels of oil – enough to meet U.S. demand for imported oil at current levels for 110 years."[8]

Figure 1-1, Unconventional vs. Conventional Gas Production[9]



Developing, producing, and upgrading oil and gas from unconventional resources tends to be more capital-intensive than conventional operations. In general, unconventional oil and gas production tends to involve more surface disturbances and wells (due to increases in roads and servicing traffic as well as tighter well spacing, even when advanced drilling techniques are employed). Additionally, unconventional oil and gas production tends to involve considerably more energy and water use than conventional extraction operations.[10]

Growing U.S. demand for oil and gas, changing economic conditions, and emerging exploration and production expertise have combined to bring more of these resources to market. Environmental technology improvements that are reshaping oil and gas production in Region 8 and nationally include green well completions, vapor recovery

[8] Rocky Mountain News, Salazar Presses Fight on Oil Shale, September 5, 2008, www.rockymountainnews.com

[9] DTE Energy, *Conventional vs. Unconventional Gas Production,* http://www.dteenergy.com/businesses/unconventionalGas.html,.

[10] Petroleum Technology Alliance Canada, *Filling the Gap: Unconventional Gas Technology Roadmap,* June 2006.

units, engine upgrades for non-road vehicles, and closed loop drilling fluid systems. Many of these technologies and approaches are promoted by initiatives such as the EPA Natural Gas STAR Program. A more detailed list of voluntary programs is included in Table 4-2.

In addition to stimulation techniques mentioned previously, the successful extraction of natural gas from unconventional resources requires specialized drilling and completion techniques. Such approaches tend to generate greater environmental releases than those associated with conventional gas producing techniques. For example, unconventional gas extraction tends to produce greater surface disturbances as well as large volumes of produced water. In the development of tight gas, typically from impermeable and nonporous formations, significantly more wells are required to produce the same unit of gas that could be produced from conventional formations with less energy use and surface disturbances (e.g., fewer wells)[11]. Although horizontal drilling techniques have emerged to connect more reservoir surface to the wellbore, unconventional gas development on a cumulative basis appears to be expanding the oil and gas industry's environmental footprint in Region 8. Nevertheless, technology advances are slowing the rate of environmental degradation and will be integral to future remedies and control strategies.

In recent years, as natural gas supplies from historic production areas have continued to shrink, industry's focus has shifted toward largely Region 8 and frontier areas (e.g., offshore). Oil and gas reserves in Region 8 are often located in environmentally sensitive areas, with diverse species, wildlife habitat, forests, and other natural resources. Production has increased significantly, especially over the past 5 to 10 years. In the future, major contributions to domestic gas supplies are expected to come from unconventional sources, resulting in extensive growth in natural gas exploration and production. Without the necessary control strategies and stewardship approaches, this trend could significantly expand the oil and gas industry's regional footprint. To assess the policy implications of increased oil and gas production in Region 8, this report analyzes the sector's current environmental footprint, identifies environmental issues associated with increased oil and gas production, and provides insights about government and industry efforts to measure and improve the sector's environmental performance.

1.2.2 Focus of the Report

Sectors Addressed in This Analysis

This report focuses on oil and gas production, specifically the upstream operations associated with the extraction of crude oil and natural gas from wells. It does not include, for example, discussions about pipelines or petroleum refineries, and the environmental issues and management challenges associated with these energy development activities (**NOTE**: An exception includes the air emissions quantities associated with compressor drives that are included in Sections 2.3.1 and 3.1.1.). The report also does not address electricity production associated with oil and gas production.

[11] National Energy Board, Canada et al *Analysis of Horizontal Gas Well in British Columbia,* October 2000.

Policy Issues

Several federal, regional, state, and industry initiatives designed to address environmental issues in oil and gas production are identified and discussed within the body of this report. We reviewed government publications that discuss policies and programs, and we collected and analyzed information from non-governmental organizations (NGOs), the oil and gas industry, and other stakeholders to augment our discussion of major oil and gas production concerns and initiatives. We grouped our findings into three primary environmental policy areas—air, water, and land use issues (including waste management, e.g., drilling waste)—related to increased production.

Baseline Environmental Impacts

We completed a comprehensive review of readily available data to characterize the environmental impacts associated with oil and gas production, both on a national basis and for Region 8 specifically. Appendix C summarizes our assessment of available data sources, data limitations, and data gaps.

Using the best available industry production and environmental data, which were primarily for 2002, we developed estimates for air emissions and non-air releases associated with oil and gas extraction in Region 8 for 2006. More detailed information is provided in Appendix B.

- The report addresses the following air emissions: volatile organic compounds (VOCs), nitrogen oxides (NO_x), carbon monoxide (CO), sulfur dioxide (SO_2), carbon dioxide (CO_2), hazardous air pollutants (HAPs, such as benzene, toluene, ethyl benzenes, and xylenes), particulate matter (PM), and methane (CH_4).
- After air emissions, major environmental issues associated with oil and gas extraction include produced water—primarily water that occurs naturally in the formation and must be disposed of after extraction—and waste from drilling processes, such as drilling muds and well-bore cuttings. (**NOTE**: Data characterizing groundwater impacts, specific contaminants and their respective concentrations was not available and therefore not in the report.)

Chapter 3 provides information on these pollutants, including our methodology for projecting 2002 and other environmental data to 2006.

Future Environmental Releases

To assess the environmental impacts associated with expected future growth in oil and gas production in Region 8, we researched and compiled projections for air emissions, produced water, and drilling waste in 2018 consistent with WRAP's 2018 emission projection. We describe these projections in some detail in Section C.5 of Appendix C.

Next Steps: Opportunities for Environmental Improvement

This study identifies options for reducing emissions, wastes, and other environmental impacts from oil and gas production. We identified these potential steps by reviewing current regulatory and voluntary initiatives and placing them within the context of emerging supply (e.g., unconventional resources) and environmental control issues.

1.3 Organization of the Report

The major remaining sections of this report are organized as follows:

- Chapter 2, *Background*, provides an overview of the issues that explain why Region 8 is vitally important to current and future domestic oil and gas supplies; highlights the unique characteristics of Region 8, such as its geology and potential for oil and gas production; and introduces relevant policy issues related to increased production.
- Chapter 3, *Environmental Releases*, characterizes the environmental releases associated with oil and gas production in 2002 and 2006, including air emissions, the amount of produced water in the region, and waste impacts and implications.
- Chapter 4, *Conclusions*, addresses the sector's environmental footprint and summarizes key environmental issues and related implications of increased oil and gas production. This chapter also highlights a number of current policies/programs that are helping to reduce the environmental impacts of oil and gas production in Region 8 and elsewhere.
- Appendix A, *Industry Characterization*, describes the industry in greater detail and regional oil and gas production trends.
- Appendix B, *Pollution Sources in the Oil and Gas Industry*, characterizes sources of air emissions, including greenhouse gases (GHGs), as well as sources of other environmental releases.
- Appendix C, *Data Availability and Sources*, identifies sources of industry baseline data (specifically well and production data, energy use data, and equipment and process data) as well as sources of air emissions and other releases. This appendix also describes data and methodologies used to provide future projections of air emissions and other environmental releases.
- Appendix D, *Air Emissions Sources by Source Category and Equipment Type*, describes the primary sources of air emissions for each major source category identified in Section B.1 of Appendix B.
- Appendix E, *References*, lists references used in this report.

2.0 Background

2.1 Importance of Region 8 to Domestic Oil and Gas Production

Oil and gas production has historically been concentrated in a few regions of the United States. The Appalachian region was the first oil and gas producing area in the country; other early production areas included the Michigan-Illinois Basin and the Mid-Continent Oil region, which extends from Nebraska to Texas. Over the years, U.S. production has predominantly occurred in the Texas-Louisiana region (including the San Juan and Permian Basins), along the Alaskan North Slope, and in the Gulf of Mexico.

Over the past several years, long-standing reserves have gradually been depleted as domestic demand has risen. While conventional production in traditional areas remain flat or are in decline, new production has shifted to other areas rich in unconventional resources, particularly the Rocky Mountain region (EPA Region 8). In a recent presentation by Professor Robert Keiter of the University of Utah's School of Law, relevant policy issues and trends associated with energy development in the Intermountain West were captured as follows:

- "The Western states contain abundant energy resources: coal, natural gas, oil, uranium, and hydropower, as well as geothermal, wind, and solar. We have enough coal—a 250 year supply—to meet our domestic demands, but coal does not address our transportation fuel needs and it raises serious greenhouse gas issues. We have substantial natural gas reserves and produce annually about 19 trillion cubic feet, leaving a 4 trillion cubic feet annual deficit that is being met primarily by Canada. About 11% of our domestic natural gas needs are met from the public lands, and another 25% are met from OCS lands. The biggest shortfall is with oil, where we import 58% of our needs, and that figure is projected to hit 70% by 2025. We presently produce about 5% of our domestic oil needs from the public lands, and another 30% from OCS lands. Given the current policy focus on increasing supply, the public lands have been targeted for accelerated development. This is reflected both in the federal acreage under lease and in the huge jump in wells permitted in recent years. About 47.5 million acres of federal land are currently under lease for oil and gas development, while exploratory wells are being permitted at a record pace: From 2000-2007, the number of drilling permits issued increased more than 250%, jumping from 3000 to over 7600 annually. Today, the BLM is rushing to complete (RMPs) for each of its energy-rich resource management areas, and the priority in each instance has been to [essentially] maximize leasing and exploration."[12]

Region 8 has become a major gas-producing area and, as mentioned previously, will be an increasingly important source of future domestic gas production. In recent years, gas production in Colorado and Wyoming has increased rapidly; in 2005 these two states accounted for 54 percent of total production in the west and comprised 15 percent of total

[12] *Energy, Public Lands, and the Environment*, Professor Robert B. Keiter, University of Utah S.J. Quinney College of Law, September 2008

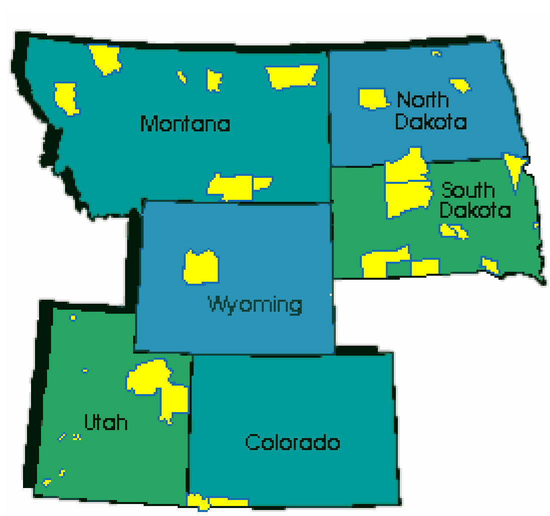
U.S. production.[13] The largest expected growth in domestic gas production is expected to occur within these two states.[14]The strategic importance of the resource base within Region 8 lies not only in its large, mostly untapped supply of oil and natural gas, but also in its abundance of other attributes –vast expanses of forests, abundant and diverse wildlife, and several national parks. The region's natural diversity and large protected areas, where many unconventional reserves are located, often produces conflicts as energy production continues to expand. Oil and gas regulators play an important role in addressing these conflicts and are charged with managing cumulative production impacts across the region.

2.2 Unique Characteristics of Region 8

2.2.1 Oil and Gas Production

As shown in Figure 2-1, Region 8 includes Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming, and 27 sovereign tribal nations. Region 8 encompasses the area generally referred to as the Rocky Mountain oil and gas province. Environmental characteristics are discussed further in section 2.2.2 and 2.2.3[3]. In addition, some definitions of the Rocky Mountain region also include northwestern New Mexico, which is the primary location of the San Juan Basin (**<u>NOTE</u>**: Although most of the San Juan Basin resides outside of Region 8, parts of it extend into Colorado and Utah as well as Arizona which is in Region 9).[15] Montana and the Dakotas are part of Region 8 as well, these states have some distinct features. Most of Montana has characteristics of the Rockies, but the eastern areas of both Montana and North Dakota are part of a separate province called the Williston Basin.

Figure 2-1. EPA Region 8 with Tribal Lands[16]



[13] U.S. Federal Energy Regulatory Commission (FERC), *Natural Gas Markets: Western*,. http://www.ferc.gov/market-oversight/mkt-gas/western.asp#prod
[14] U.S. Department of Energy (DOE), Energy Information Administration (EIA), *Natural Gas Pipelines in the Central Region*, http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/central.html.
[15] U.S. Department of the Interior (DOI), United States Geological Survey (USGS) considers the San Juan and Raton Basins, located partially in northern New Mexico, as part of the Rocky Mountain region; see http://pubs.usgs.gov/fs/fs-158-02/FS-158-02.pdf
[16] U.S. Environmental Protection Agency, Region 8, Mountains and Plains, *http://www.epa.gov/region8/tribes/*

Most Rocky Mountain oil and gas production is found in Colorado, Utah, and Wyoming, and to a lesser extent in Montana, North Dakota, and South Dakota. Although oil production is widespread across the region, the Rockies are currently dominated by natural gas production activities. Whereas Figure 2-2 shows increasing gas production in the Rockies from 1998 to 2005, Figure 2-3 shows increased rig activity in Region 8 from 2000 to 2006, a fairly reasonable indicator of expanding natural gas production within the region.

Figure 2-2. Total Dry Gas Production in the Lower 48 by Region, 1998—2005

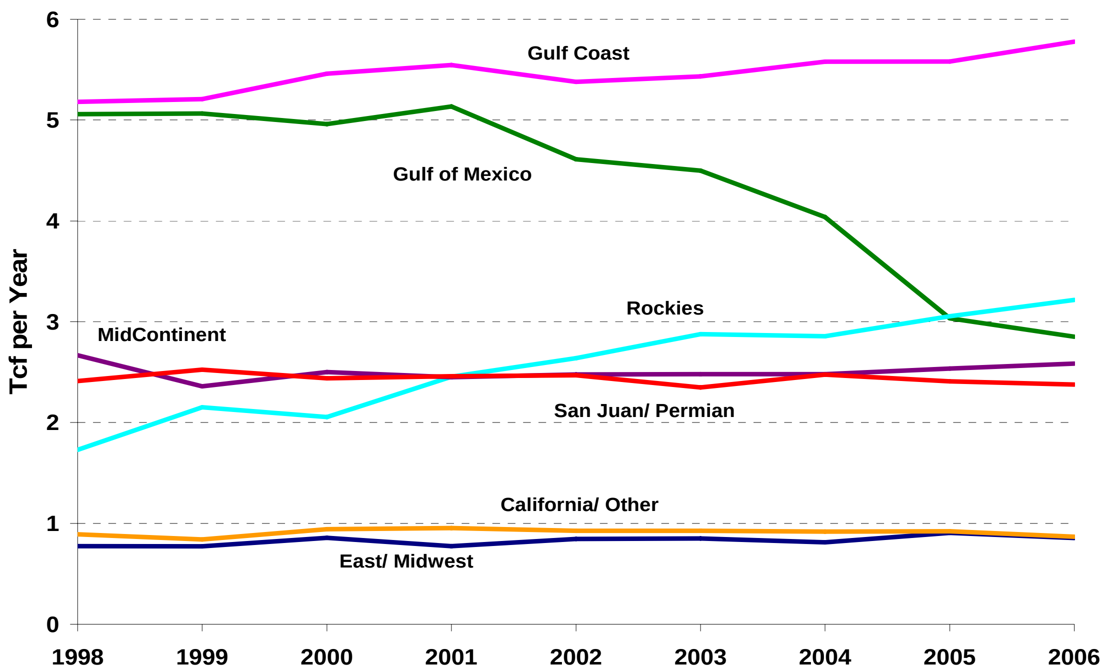
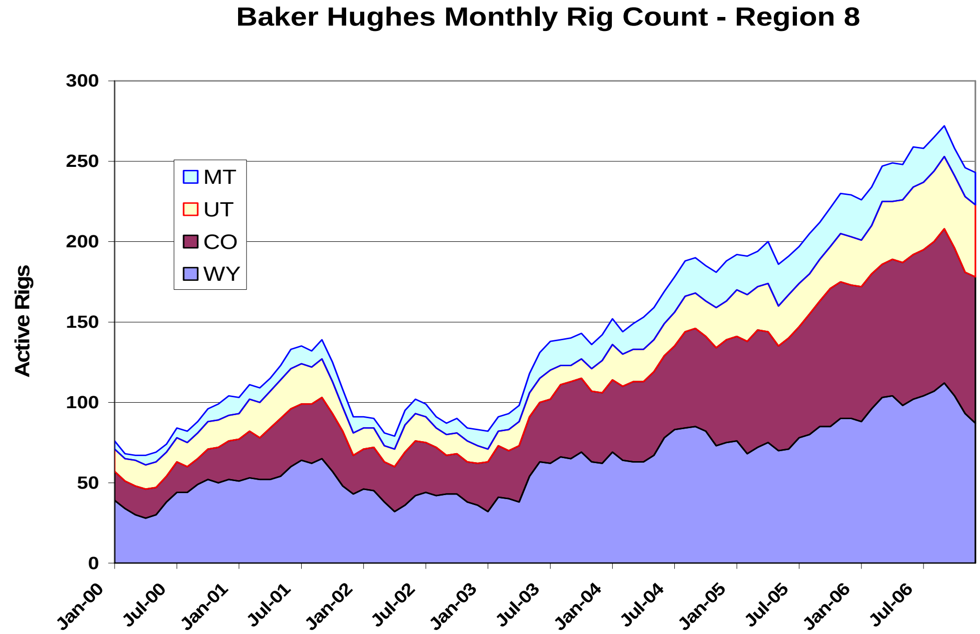
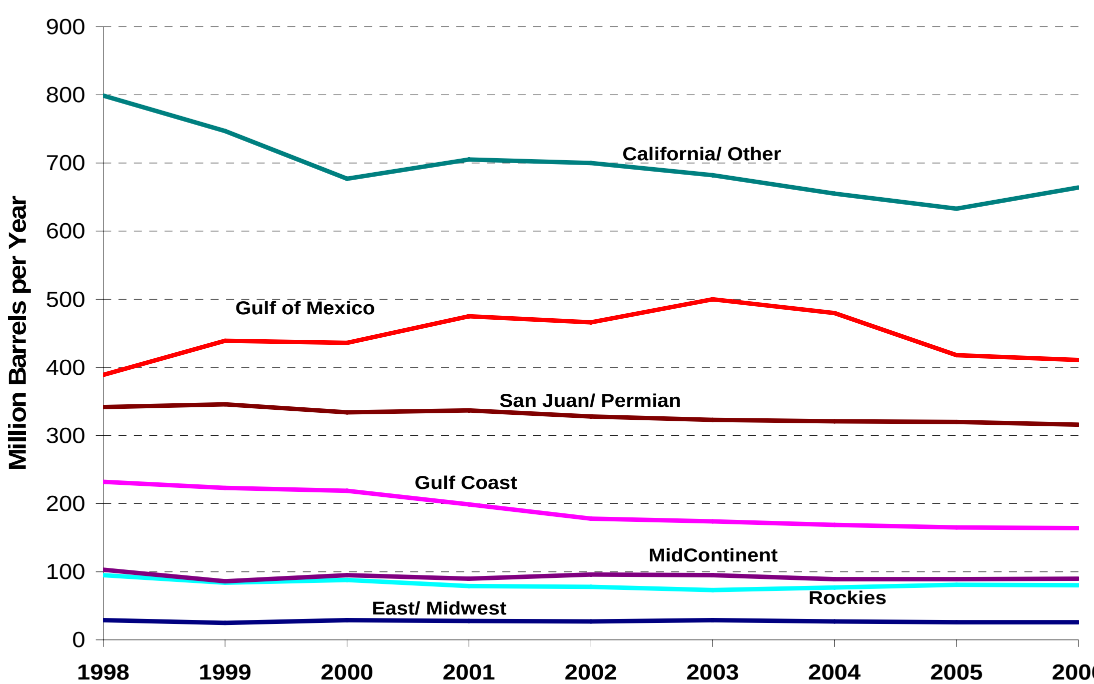


Figure 2-3. Active Oil and Gas Rigs in Region 8, 2000—2006



Conventional oil production has declined nationally, and current oil production in Region 8 is modest when compared to regional natural gas production. Figure 2-4 shows oil production levels (in million barrels per year) in the Rockies as essentially constant from 1998 to 2005.

Figure 2-4. Total Crude Oil Production in the Lower 48 by Region, 1998—2005



Production activity is concentrated in the Denver Basin of eastern Colorado and the Uinta Basin of northeastern Utah. Large oil shale deposits are present in western Colorado, northeastern Utah, and southwestern Wyoming, and may be developed in coming decades. These deposits were a focal point of earlier industry technology development efforts in the 1970s and 1980s. Although energy companies are once again conducting oil shale technology research and development (R&D) within the region, the only production of note is currently taking place on a pilot scale. Commercial production of oil shale appears to be a decade or more away, and various technical, natural resource, and environmental issues will need to be addressed in the interim.

2.2.2 Geological Characteristics

The Rocky Mountain region's geological characteristics make it very different from other oil and gas producing regions. Some of these differences are described below:

- The Gulf Coast and Gulf of Mexico generally produce oil and gas from high-porosity and high-permeability conventional oil and gas reservoirs. The high porosity and permeability of these formations generally allow oil and gas to flow freely to production wells. In addition, such operations typically involve a relatively small number of wells.
- In contrast, natural gas resources within the Rockies are found primarily in unconventional formations. For example, tight gas sands are widely distributed in areas such as the Green River Basin of southwestern Wyoming and the Piceance Basin of northwestern Colorado. This is natural gas that is now being produced and where future extraction operations are likely to be concentrated. Recoverable resources in Rocky Mountain tight sands have been assessed to be in multiple hundreds of trillion cubic feet (Tcf) of gas, compared to current proved reserves of about 190 Tcf for the United States as a whole. The magnitude of the resource means that the current expansion in extraction activities is likely to continue for decades.

The Rocky Mountain region is also the location of two of the most prolific coal bed methane (CBM) basins in the world: the San Juan Basin in southwestern Colorado and Northwestern New Mexico, and the Powder River Basin in eastern Wyoming. These CBM production areas are detailed below:

- The San Juan Basin produces from the Fruitland coal formation. This formation was the initial major area of CBM production in the Rockies. Presently, this CBM production area is characterized by large volumes of water that are produced as natural gas is extracted (i.e., produced water). Produced water is subsequently re-injected for disposal or discharged into surface water, generally after some prior treatment (although some produced water from CBM formations can be directly discharged into surface water).
- The Powder River Basin in eastern Wyoming initiated CBM production in the 1980s, gained prominence in the late 1990s, and currently produces about 1 billion cubic feet (Bcf) of natural gas per day. Surface discharge, where permissible, is a much less expensive option compared to injection; however, surface water discharge can impact

surface water quality, contribute to streambed erosion, and / or render agricultural soils nonproductive due to high sodium levels. In some instances across Region 8, produced water from natural gas extraction (e.g., CBM wells) is clean enough to be used for irrigation or watering livestock without treatment; however, it is also common to find chemicals in produced water with concentrations that can harm aquatic life and crops when discharged. As mentioned previously, EPA is actively investigating these issues along with other agency and industry representatives.

- Efforts to develop CBM natural gas resources elsewhere in the Rockies, including central Utah and southwestern Wyoming, are underway and have thus far experienced varying degrees of success.

In 2007, there were approximately 17,000 total producing CBM wells in the Powder River Basin and about 150 in southwestern Wyoming. In general, Powder River Basin coal bed production is shallower than in other areas, necessitating either conventional drilling techniques, which require large numbers of vertical wells across a large surface area, or horizontal drilling operations, which enable development of multiple wells from a single well pad. The number of wells needed to develop CBM is typically a function of depth, water characteristics, number of seams, and other technical factors.

The unconventional gas resources described in this section all have the following in common: a requirement for a greater number of wells (closer, or tighter, well spacing) to efficiently recover the gas resource. In spite of advanced drilling techniques that enable multiple wells to be drilled from a single well pad, tighter well spacing is the norm with unconventional natural gas recovery operations. For example, common practices associated with unconventional gas production can result in 8 to 16 times as many wells per area of land than would be required for conventional gas recovery[17]. The impact of this greater well density is being mitigated by the use of advanced drilling techniques, which allow multiple wells to be drilled from one well pad. However, the net result is still a greater number of well sites and surface disturbances than would have occurred in conjunction with natural gas production from conventional resources. As a result, the growth in CBM and other forms of unconventional gas production are expanding the industry's environmental footprint in Region 8 and in select areas of the country.

2.2.3 Other Natural Characteristics

Region 8 is rich in natural resources outside of the vast array of fossil fuels found there. The region contains vastly different landscapes—from mountains to plains, canyons, and deserts—that are home to a variety of plant and animal species and diverse wildlife habitat. More than a third of the acreage in Region 8 is public land owned and managed by the U.S. government, including several of the most popular national parks (e.g., Yellowstone, Glacier, Badlands, etc.). However, the region is quite arid, and the availability and quality of water has historically been limited. Protection of these natural assets substantively contributes to many of the policy issues surrounding oil and gas production in the region.

[17] National Energy Board of Canada, *Analysis of Horizontal Gas Well Performance in British Columbia*, October, 2000.

2.3 Key Policy Issues Associated With Oil and Gas Production

Natural gas development across Region 8 has been the focus of an intense environmental debate, and the complex and contentious issues underlying the conflict are likely to continue for the foreseeable future. To develop the region's oil and gas reserves, thousands of new wells must be drilled in areas that have not previously seen much drilling activity. Region 8 public lands with oil and gas production and potential are administered by the BLM. Conflicts often involve energy companies, ranchers, residents, and environmentalists; the issues being debated include air and water quality, pollution prevention and controls, land management and water rights, wildlife protection, and so forth. Increases in population and workforce issues have also fueled concerns over the impacts of oil and gas development in areas such as the Roan Plateau in Colorado[18], and Pinedale, Wyoming[19].

The combined, incremental effects of oil and gas production – in combination with other human activities – can pose threats to human health and the environment. Under the NEPA statute and associated guidance documents, these collective human activities are referred to as cumulative impacts. The following text from an EPA guidance document provides additional clarification:

- "While they may be insignificant by themselves, cumulative impacts accumulate over time, from one or more sources, and can result in the degradation of important resources. Because federal projects cause or are affected by cumulative impacts, this type of impact must be assessed in documents prepared under [NEPA] … the assessment of cumulative impacts in NEPA documents is required by Council on Environmental Quality (CEQ) regulations (CEQ, 1987). Cumulative impacts, however, are not often fully addressed in NEPA documents due to the difficulty in understanding the complexities of these impacts, a lack of available information on their consequences, and the desire to limit the scope of environmental analysis."[20]

BLM has a statutory obligation under NEPA to accurately assess and address reasonably foreseeable developments, including current or prospective energy projects that may occur within the next several decades (e.g., oil shale development) as the agency monitors and oversees such activities in Region 8 and elsewhere. With respect to current oil and gas projects, regulators and developers are considering additional mitigation measures (e.g., phased development) that are – or may soon be – needed to reduce emissions and other environmental impacts consistent with federal and state regulations.

When oil and gas production occurs, there are other industries and human activities producing environmental impacts within a common area. In reviewing proposed oil and gas development activities and projected schedules, EPA and other government agencies

[18] Environmental Working Group, *Who Owns the West? http://www.ewg.org/oil_and_gas/part6.php,* accessed August 21, 2008.
[19] U.S. Environmental Protection Agency, Region 8, *Final EPA Comments on Pinedale Anticline,* February 2008
[20] 'Consideration of Cumulative Impacts in EPA Review of NEPA Documents.' U.S. Environmental Protection Agency, Office of Federal Activities (2252A) - EPA 315-R-99-002/May 1999 (http://www.epa.gov/compliance/resources/policies/nepa/cumulative.pdf)

with oversight responsibilities must consider the cumulative impacts of human activities – from energy projects such as coal mining to other forms of development. In addition, policy makers must weigh potential mitigation strategies, adaptive management approaches (e.g., environmental monitoring, control measures, etc.), or other measures to reduce uncertainty and lessen current or potential environmental impacts over time.

The following discussion summarizes primary policy issues related to oil and gas production in the following three categories: air, water, and land use. In addition, we summarize industry actions to address environmental issues related to their respective oil and gas operations.

2.3.1 Air Issues

Under the Clean Air Act (CAA) states have the primary responsibility to address air-related impacts from energy development. States are required under the Act to maintain - or come into attainment with - National Ambient Air Quality Standards (NAAQS) through State Implementation Plans (SIPs) or other state mechanisms. Although states have the lead, EPA works closely with the states to find solutions to improving air quality. The CAA requires EPA to set NAAQS for six common air pollutants (also known as "criteria pollutants") which are found all over the United States. They are particle pollution (often referred to as particulate matter), ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead. These pollutants can cause harm to human health and the environment and can lead to property damage. Of the six pollutants, particle pollution and ground-level ozone are the most widespread health threats. EPA refers to these six as “criteria pollutants” because they are regulated with respect to human health-based and/or environmentally-based criteria (i.e., science-based guidelines) the agency develops in setting permissible levels. Primary standards are limits based on human health criteria whereas secondary standards are thresholds intended to prevent environmental and property damage.

Air emissions associated with oil and gas production can significantly impact air quality and impair visibility. Concerns regarding these impacts have expanded in recent years as oil and gas production in Region 8 has grown. Air emissions generated during oil and gas production, along with emissions from other sources, are regulated by the Clean Air Act (CAA) and can be grouped into three categories:

- Criteria air pollutants (ozone, CO, SO_2, PM, and their precursors, including NO_x and VOCs);
- Hazardous air pollutants[21] (HAPs, primarily fugitive VOC emissions from oil and gas production);
- Haze precursors (which include ozone, NO_x, SO_2, and particulates); and

In addition, greenhouse gases (GHGs, which include CO_2 and CH_4) are generated during oil and gas development. EPA issued an advance notice of proposed rulemaking (ANPRM) in July 2008 considering possible GHG emission regulation under the Clean

[21] EPA is currently required to control 187 HAPs.

Air Act. Several Rocky Mountain states have developed or are considering mandatory GHG emission limits.

Region 8 has initiated several actions to curb emissions from a number of industrial sectors and sources, and oil and gas operations have been at the forefront of these regional efforts. Most air policy-related activities relevant to the oil and gas industry in Region 8 fall into one of three areas:

- Regulation of industrial emissions under federal law and implementation of new, more stringent state-level programs;
- Participation in voluntary regional initiatives to reduce emissions; and
- Industry initiatives to address energy and environmental issues in the region.

Federal and State Regulation of Air Emissions

The Clean Air Act is a complex and comprehensive federal law that regulates air emissions from all sources, including area, stationary, and mobile sources. Most air policy issues related to oil and gas production are determined by the way associated operations are regulated under the CAA. Air regulations are implemented and enforced by individual states through their State Implementation Plans (SIPs) and through permitting activities that draw directly on EPA implementation of the CAA. In addition, the BLM is responsible for management and conservation of federal surface lands and mineral rights within its purview and controls air emissions from federal lands working in cooperation with EPA and other government agencies.

As is the case with air pollution regulation throughout the rest of the U.S., states within Region 8 develop and implement regulatory controls to address oil and gas production emissions. Various environmental groups have been critical of the oil and gas industry and governmental policy to control air emissions and other forms of pollution from these sources.[22] Several groups have recommended that the federal government should establish more stringent controls on oil and gas production. For example, environmental groups have called for emissions limits and other national standards that states can build upon and even exceed should additional controls be deemed necessary.

This section examines regulation and enforcement concerns under three federally-based standards: the National Ambient Air Quality Standards (NAAQS), National Emissions Standards for Hazardous Air Pollutants (NESHAP), and New Source Performance Standards (NSPS). In addition, state air permitting programs and BLM standards implemented in cooperation with EPA programs are also discussed.

<u>National Ambient Air Quality Standards (NAAQS)</u>. Under the CAA, NAAQS establish health-based ambient standards for regulating criteria pollutants. States are responsible for demonstrating how they will meet the NAAQS through their SIPs. Although most of

[22] Environmental groups have questioned government efforts to adequately regulate the oil and gas industry. The Natural Resources Defense Council report, *Drilling Down: Protecting Western Communities from the Health and Environmental Effects of Oil and Gas Production*, October 2007, http://www.nrdc.org/land/use/down/down.pdf, presents many of these concerns.

Region 8 is in attainment with these standards, a primary concern involves ground level ozone in the Denver Front Range—where substantial oil and gas development is underway and nonattainment issues exist (i.e., exceedences of 8-hour ozone standards). In addition, NO_x and VOCs from regional oil and gas operations are suspected to be substantive precursors to ozone nonattainment in Colorado. As part of its response to this growing concern, Colorado has taken a number of steps to reduce emissions associated with oil and gas production, specifically VOC emissions. In 2004, the Denver metro area entered into an early action compact (EAC) with EPA to reduce ozone levels and avoid classification of the area as a high-pollution area.[23] However, the Denver Front Range area was designated as nonattainment for the 8-hour ozone standard in November 2007, and at the time of publication the area was expected to submit a new plan to reduce ground level ozone.

Other states in Region 8 that have met attainment standards for ozone, but until recently were in nonattainment for other pollutants, are now meeting the NAAQS standards for ozone and are waiting to be redesignated:

- Montana had 10 areas in moderate nonattainment for PM standards and a couple of areas in nonattainment for SO_2. Montana has released several State Implementation Plans (SIPs) to control fine particulates in certain areas of the state and is waiting to be redesignated.
- Utah had two areas in nonattainment for SO_2 emissions which are now meeting the standards. Utah has several areas still in moderate nonattainment for PM standards, while Wyoming has one area.

In contrast, North Dakota and South Dakota are presently in attainment with all relevant NAAQS.

On March 12, 2008, EPA significantly strengthened its NAAQS for ground-level ozone. EPA revised the 8-hour "primary" ozone standard, designed to protect public health, to a level of 0.075 parts per million (ppm). The previous standard, set in 1997, was 0.08 ppm. Several rural areas in Region 8 with high oil and gas development may well be impacted by the new ozone standard. In addition, Southwest Wyoming and the Four Corners area (a Region comprising sections of Utah, Colorado, New Mexico, and Arizona) are likely to be in nonattainment with the new ozone standard.

Due to expanding demand for access to Region 8's extensive fossil fuel and natural resources, states in the region collaborated with EPA to develop a Draft Energy Strategy (2004), which outlines a number of key goals and objectives that help address air, water, and land management issues. Four principal goals underpin the Draft Energy Strategy:

1. Ensure efficient and timely EPA decisions about energy projects;
2. Continue to meet federal environmental requirements and maintain or improve environmental quality with respect to energy projects;
3. Promote energy efficiency and renewable energy; and

[23] VOCs are regulated as precursors to ozone.

4. Strengthen environmental and energy partnerships with co-regulators and other stakeholders.

Air-related tasks in the Draft Energy Strategy primarily relate to meeting EPA's health-based NAAQS or helping nonattainment areas reach compliance.

New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants (NESHAP). Federal New Source Performance Standards (NSPS) are technology-based standards that limit criteria pollutant emissions from specific types of equipment. HAPs are also regulated through technology-based limits on specific hazardous pollutants. These limits are developed on a process-by-process basis. EPA has taken recent actions to control emissions from oil and gas activities by finalizing regulations that apply to engines used in oil and gas production: NSPS for Stationary Spark Ignition Internal Combustion Engines (ICE), and National Emission Standards for Hazardous Air Pollutants (NESHAP) for Reciprocating Internal Combustion Engines (RICE). Categories of activities that use these types of engines and may be subject to regulation include natural gas transmission, crude petroleum and natural gas production, and natural gas liquids producers. Recently promulgated NSPS rules will regulate NO_x, CO, and VOC emissions, whereas the NESHAP regulations will control formaldehyde, CO, or VOC emissions, depending on which emissions are considered appropriate from certain engine types. These final rules became effective March 18, 2008.

State Air Permitting. Major sources of air emissions, such as large compressor stations and gas plants, must obtain construction and operating permits from the appropriate permitting authority, usually the state air agency. Permits to construct are issued under New Source Review (NSR) for air emissions sources located in NAAQS nonattainment areas, and under Prevention of Significant Deterioration (PSD) in NAAQS attainment areas (the program is often collectively referred to as PSD/NSR or simply NSR). These air permits ensure that sources of criteria air pollutants do not cause or contribute to violations of the NAAQS. Smaller, "minor" sources of air emissions must usually obtain an air permit under a state minor source permitting program. In addition, these permits implement site-specific conditions to enable enforcement of the NSPS and NESHAP requirements. For tribal lands in Region 8, EPA is presently the permitting authority, rather than the individual states. In addition, Region 8 is working on finalizing a federal minor source permitting program for tribal lands. Given the large growth in oil and gas production and associated oil and gas air emission sources – some of which are located on tribal lands – operating these air permitting programs is a significant resource impact for both EPA Region 8 and the individual states' environmental programs.

Bureau of Land Management (BLM). Following enactment of the Energy Policy Act of 2005 (EPAct), EPA entered into a Memorandum of Understanding (MOU) with DOI-BLM, the U.S. Department of Agriculture (USDA), and the U.S. Department of the Army. This MOU seeks to focus agency efforts to effectively streamline federal permits. The underlying goal is to enhance efforts to process oil and gas use authorizations while maintaining environmentally responsible management of federal lands where oil and gas resources are located.

Since the MOU was established in October 2005, EPA has effectively collaborated with BLM and other signatories on various oil and gas permitting and related issues. Presently, the BLM field office in Vernal, Utah, is investigating oil and gas industry violations of air quality standards and seeking to project future emissions from energy development. The study is paying close attention to oil and gas production within the Uinta Basin,[24] and BLM plans to use the data to determine the best ways of reducing emissions from wells, compressors, storage tanks, and other equipment. For example, BLM may consider incorporating certain technology controls and other permit requirements that would decrease certain air pollutants, such as NO_x and PM, commonly associated with production operations.

EPA is also successfully implementing an MOU with the Interstate Oil and Gas Compact Commission (IOGCC). The IOGCC is a congressionally chartered organization of 37 oil and natural gas producing states responsible for protecting and developing the states' oil and gas resources. Through IOGCC, participating state governors and the agencies, programs, and staff within their purview seek to develop, conserve, and protect oil and gas resources in efficient, cost-effective, and environmentally responsible ways. In some instances, states and EPA have concurrent jurisdiction relating to a host of oil and gas regulatory efforts. In other instances, the states and EPA have independent authorities that may be complementary when effectively coordinated. The EPA-IOGCC MOU focuses federal and state environmental oversight and regulatory activities on oil and natural gas exploration and production. In addition, the MOU improves regulatory cooperation among the states and the agency by promoting cost-effective environmental protection, minimizing duplication, increasing efficiencies and communication, and enabling the exchange of information and expertise. Lastly, the MOU identifies mutual issues of concern as well as mutually beneficial joint activities, and creates a permanent means of consultation between EPA and the IOGCC.

Voluntary Regional Initiatives

To improve air quality beyond federal requirements, a number of regional organizations have been formed in the western states to address air pollution concerns. These organizations include the Western Regional Air Partnership (WRAP), Western States Air Resources Council (WESTAR), and Western Climate Initiative (WCI). Brief descriptions of each are provided below.

Western Regional Air Partnership. Formed in 1997, WRAP[25] is a collaborative and essentially voluntary effort involving state and federal agencies for the purpose of providing regional planning, etc. for SIPs seeking to improve visibility in western areas, primarily by providing the technical expertise and policy tools needed by states and tribes to implement the federal Regional Haze Rule (RHR), designed to protect visibility in federal Class I areas. The Rule requires states to set periodic goals for improving visibility in these areas. WRAP is the successor to the Grand Canyon Visibility Transport

[24] Oil and gas development is expected almost to double in Uinta County in the next few years. About 10,000 new wells are either planned or already being developed in the county; almost 6,000 wells are currently in production. See Red Lodge Clearinghouse, *BLM moves to reduce air emissions from energy development in Uinta Basin*, February 2008, http://rlch.org/content/view/344/62/.

[25] For more information on WRAP, see http://www.wrapair.org/.

Commission, formed to improve visibility in the Grand Canyon and other park and wilderness areas around the Colorado Plateau.[26] All Region 8 states and tribes participate in WRAP. One of the organization's key contributions is the Emissions Forum, which oversees a comprehensive tracking and forecasting system, called the Emissions Data Management System (EDMS). Policy makers use EDMS to assess and address air quality issues. For example, EDMS data are used for air quality modeling and help policy makers comply with the requirements of EPA's RHR. In addition, WRAP data are used extensively within this report to help EPA, states, and other stakeholders effectively characterize current and future air emissions trends associated with oil and gas production.

Western States Air Resources Council. Another voluntary group similar to WRAP is WESTAR, which was formed in 1998.[27] Fifteen western states participate in WESTAR, including all Region 8 states. Although WESTAR does not track emissions like WRAP does, the organization provides a forum to discuss air quality issues in the west. For example, in September 2007, WESTAR hosted a conference focused on oil and gas development issues that highlighted several BMPs to reduce oil and gas production emissions.[28] Representative BMPs discussed during the conference included installing vapor recovery units on storage tanks, installing fuel recovery systems and static packs to reduce venting at compressor stations, testing for fugitive emissions through leak detection and repair (LDAR), and repairing or replacing pressure safety valves and other equipment or piping where fugitive emissions tend to originate.

Western Climate Initiative. The purpose of the WCI is to help participating organizations reduce GHG emissions in the west. WCI[29] was formed in February 2007, when the governors of Arizona, California, New Mexico, Oregon, Washington, and the Canadian provinces of British Columbia and Manitoba forged an agreement establishing the initiative. Since that time, Montana and Utah have also signed on as participants, and Alaska, Colorado, Idaho, Nevada, and Wyoming are presently observers of the WCI process. In August 2007, WCI set a regional target of reducing GHG emissions to 15 percent below 2005 levels by 2020. WCI presently features a number of working groups and is holding meetings to seek stakeholder comments about the potential design and implementation of a regional cap-and-trade program focused on reducing GHG emissions.

2.3.2 Water Issues

Another major policy challenge related to oil and gas production involves water sources, competing uses and demands, and associated conflicts. Unconventional natural gas resources (e.g., tight sands, shale gas, etc.) generally require higher water use than conventional gas extraction. In addition, CBM formations in the Rocky Mountain region

[26] The RHR seeks to improve visibility in 156 national parks and wilderness areas throughout the United States, but located primarily in the west. See http://www.epa.gov/oar/visibility/program.html for additional information on EPA's Regional Haze Program.
[27] For more information on WESTAR, see http://www.westar.org/index.html.
[28] An agenda and presentation materials from the September 2007 WESTAR conference can be accessed at http://www.westar.org/Docs/Tech%20Confs/Oil-Gas%2007/agenda.doc.
[29] For more information on WCI, see http://www.westernclimateinitiative.org/.

release large amounts of produced water, which is released to the surface, treated in place, or reinjected into the subsurface depending on a number of variables, including water quality, permit limits, availability of injection wells, and so forth. Competing energy and agricultural needs, as well as other industrial requirements and population growth, are increasing pressure on scarce regional water resources.

The Powder River Basin produces natural gas from younger, shallower coal beds than those in the San Juan Basin. To date, almost all of the produced water has been surface discharged rather than injected. The Powder River Basin is located in a predominantly arid area, and clean water is a valuable resource. Hence, any suitable produced water is used for irrigation and livestock. In addition, several factors have hindered deep injection within the basin thus far. For example, if suitable injection zones are too deep or are limited in their capacity to accept fluid relative to the volume of water produced by CBM development, producers must find other options. In addition, although deep injection protects surface waters, potential beneficial uses of CBM produced water are sacrificed. The high costs associated with drilling and operating injection wells as dedicated facilities tend to impose barriers as well. Nevertheless, there are some shallow zones available that could be used for injection purposes if the water from the center of the basin is not suitable for surface discharge without prior treatment. Operators may choose injection in the future if the cost-benefit calculations and other tradeoffs associated with surface discharge without prior treatment are not sufficient.

In addition, the interplay of states' rights and water usage in the region, as well as evolving federal water policy, only add to the complexity of the underlying issues and inevitable conflicts that arise. The following discussion addresses these main water issues:

- Water discharges governed by regulations promulgated under the Clean Water Act (CWA) and Safe Water Drinking Act (SDWA);
- State limits on produced water and associated issues (e.g., state water rights); and
- Water contamination from storm water runoff and oil spills.

Federal Water Regulations

Produced water from oil and gas operations is, by volume, the largest waste stream associated with oil and gas production. The content of produced water typically varies depending on the geographic location of the field, the type of hydrocarbons being produced, and other features associated with the geology and extraction techniques used. In some instances across Region 8, produced water from natural gas extraction (e.g., CBM wells) is clean enough to be used for irrigation or watering livestock without prior treatment; however, it is also common to find chemicals in produced water with concentrations that can harm aquatic life and crops when they are discharged or used for irrigation, respectively. Thus, produced water discharged from oil and gas production is subject to various water permitting guidelines under CWA and SDWA, and these issues are discussed in more detail below.

Clean Water Act. CWA requires EPA to establish national, technology-based regulations, known as effluent limitations guidelines (ELGs), designed to reduce pollutant discharges from categories of industry discharging directly to U.S. waters. These guidelines are implemented through National Pollutant Discharge Elimination System (NPDES) permits. Effluent guidelines apply to facilities engaged in field exploration, drilling, and well production in offshore, coastal, and onshore areas. There are effluent guidelines for petroleum refining discharges as well, but these matters are not examined in this report, which focuses on upstream oil and gas production issues.

Produced water from CBM wells is not currently regulated under federal effluent limitations guidelines developed to address the potentially unique characteristics of these production operations. With the rapid growth of CBM production within Region 8 and other producing regions across the nation, environmental concerns have begun to emerge, and EPA is currently studying these issues in depth[30]. In 2003, the U.S. Court of Appeals for the Ninth Circuit ruled that water discharges from CBM wells are a pollutant under CWA. However, in a recent court ruling related to the lawsuit Natural Resources Defense Council vs. EPA, the Ninth Circuit Court of Appeals remanded to the agency its 2006 rulemaking responding to language in the Energy Policy Act of 2005. Specifically, through this action, the Ninth Circuit Court of Appeals has raised questions and uncertainty regarding the extent to which oil and gas exploration and production will be exempted from Clean Water Act (CWA) NPDES reporting requirements.[31] EPA has petitioned the court to rehear the case and the final outcome of these and had yet to be determined at the time of this report's publication.

In 2007, EPA's Office of Water (OW) initiated the aforementioned study of CBM operations. Once the agency's industry survey and study process is complete, EPA may choose to conduct further analyses, take no further action, or initiate a rulemaking to develop new or revise existing effluent guidelines to include water discharges from these operations. EPA is expected to complete its CBM study by the end of 2009 or 2010.

Safe Drinking Water Act. The SDWA was established to protect the quality of drinking water in the United States; therefore, it focuses on all waters actually or potentially designated for drinking. Environmentalists, health advocates, and the public have called attention to exemptions for the oil and gas industry, including those related to the SDWA.[32] Nevertheless, with respect to oil and gas production, EPAct significantly amended SDWA in the following fundamental ways:

- First, hydraulic fracturing operations, also referred to as "fracing" or "fracking," are used to improve gas flow for unconventional resources and exempted from regulation under SDWA.[33]

[30] U.S. Environmental Protection Agency, *EPA's Clean Water Act Review of the Coalbed Methane Industrial Sector,* June 2007, http://www.epa.gov/guide/304m/2008/cmb-slides.pdf, accessed 08.19.08.
[31] The Ninth Circuit Court of Appeals Decision in NRDC v. EPA and its Impact on Storm Water Permitting of Oil & Gas Activities in Pennsylvania *Oil & Gas Alert,* by Kenneth S. Komoroski, Michael J.R. Schalk. June 30, 2008, http://www.klgates.com/newsstand/Detail.aspx?publication=4661,
[32] Oil and Gas Accountability Project, *Our Drinking Water at Risk: What EPA and the Oil and Gas Industry Don't Want Us to Know About Hydraulic Fracturing*, April 2005, http://www.earthworksaction.org/pubs/DrinkingWaterAtRisk.pdf.
[33] Fracking fluids may contribute to water contamination since they contain hazardous materials such as gels, polymers, biocides, fluid loss agents, thickeners, enzyme breakers, acid breakers, oxidizing agents, friction reducers, and surfactants.

- Second, EPAct calls for voluntary discontinuance of diesel fuel used in fracking operations instead of disallowing such use.
- Last, underground injection in oil and gas operations is defined so EPA has the authority to regulate fracking fluids as a possible contaminant to the water supply only if diesel fuel additives were used.

Critics of these statutory provisions have stated that they contribute to drinking water contamination. Some environmentalists and legislators are calling for the exemption to be removed because of suspected groundwater contamination that may stem from hydraulic fracturing. In a recent letter to the Governor of New York, in anticipation of expanding shale gas production in the Marcellus shale rock formation, the Environmental Working Group and the Endocrine Disruption Exchange (TEDX) made the following assertion:

> "In Colorado, at least 65 chemicals used by natural gas producers are listed as hazardous under six (6) major federal laws designed to protect Americans from toxic substances. Some of these chemicals may be injected underground or spilled during drilling and / or 'hydrofracing' operations … If any of these 65 chemicals were emitted or discharged from an industrial facility, reporting to [EPA] would be mandatory, and in most cases permits would require strict pollution limits and companies would be subject to specific cleanup standards."

Presently, per informal communications with EPA regional staff, minimal ground-water monitoring activities are being funded to investigate these issues. However, other stakeholders are raising questions about potential groundwater and human health impacts stemming from hydraulic fracturing practices. Clearly, precise data is needed to allow regulators and operators alike to properly assess these issues as they work to prevent environmental harm and protect human health and safety.[34] Prior to enactment of this legislation, EPA assessed the potential for contamination of underground sources of drinking water (USDW) by reviewing existing literature on water quality incidents that were potentially linked to hydraulic fracturing. EPA released its findings in 2004, concluding there were no confirmed cases of drinking water contamination resulting from fracturing fluid injection into CBM wells or subsequent underground movement of such fracturing fluids.[35]

State Limits

Some Region 8 states, such as Colorado, Montana, and Wyoming, have been delegated the authority to issue discharge permits to control produced water, and differing state policies have resulted in some disputes. CBM operations that surface discharge produced water in Colorado typically have to apply for discharge permits. Wyoming and Montana have implemented stringent effluent limits. Wyoming's discharge limits for CBM produced water are determined by the ecological attributes of the drainage area receiving such discharges and by the designated use for each drainage. In addition, Wyoming is

[34] 'East Coast Gas Boom Renews Activists' Bid To Kill Drinking Water Act Waiver,' Inside EPA, 8/14/08
[35] EPA, *Evaluation of Impacts of Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs*, EPA 816-R-04-003, 2004, http://www.epa.gov/safewater/uic/pdfs/cbmstudy_attach_uic_exec_summ.pdf.

developing general permits that establish limits for the entire watershed. Historically, differences between western states regarding discharge limits, permitting, water rights, and how these issues are mitigated have produced varying degrees of conflict within Region 8. For example, in 2006, Montana adopted water quality standards setting new limits on CBM water discharges into several water bodies, including the Tongue River, Powder River, and their tributaries. The rivers originate in northern Wyoming, where extensive CBM development has occurred, but flow into agricultural areas of Montana.

While some farmers and conservation groups in Montana and Wyoming support the 2006 standards because of concerns regarding potential impacts to water quality and flow rates, the state of Wyoming joined with several companies and filed lawsuits in state and federal court challenging Montana's new regulatory standards for CBM produced water discharges. At the time of publication, the state court had ruled in Montana's favor and that decision is being appealed. Additionally, in early 2008, the U.S. Supreme Court agreed to consider a lawsuit between Montana and Wyoming over the shared waters of the Tongue, Powder, and Little Powder Rivers, and that litigation is ongoing.

Tribal Limits

Region 8 has approved four tribes to implement Clean Water Act water quality standards. The confederated Salish and Kootenai Tribes of the Flathead Reservation in Montana and the Assiniboine and Sioux Tribes of the Fort Peck Indian Reservation in Montana have federally-approved water quality standards. Where EPA has not approved a state or tribe to implement federal environmental programs including the CWA, EPA directly implements the programs in the tribal lands.

Stormwater Runoff and Fuel Spills

- Stormwater Runoff. Inconsistency in the treatment of stormwater runoff at oil and gas production operations has raised concerns about the environmental impacts of discharges. Although EPA had begun to regulate certain stormwater discharges containing sediment from oil and gas construction sites in the 1990s, EPAct resulted in a policy shift. In 2006, EPA responded to the new statutory mandate and published a rule that exempts construction activities at oil and gas sites from the requirement to obtain an NPDES permit for stormwater discharges except in very limited instances. EPA's rulemaking is consistent with EPAct and encourages voluntary application of BMPs for construction activities associated with oil and gas field activities. The EPA rulemaking also encourages oil and gas production operations to minimize erosion and control sediment to protect surface water quality. However, as mentioned previously, a federal appellate court decided to remand EPA's rulemaking exempting construction activities at oil and gas facilities from CWA stormwater permitting requirements. The final outcome of these court proceedings remains in question.
- Fuel Spills and Modifications to Regulations. When they occur, fuel spills contribute to water contamination, habitat loss, and other undesirable consequences if they are not contained and subsequently migrate from flowlines, gathering lines, and / or storage vessels. Various studies validate that the amount of spills related to fossil fuel production is significant. For example, one report found there were approximately 924

oil and gas industry spills in Colorado over a 4-year period (2002—2006).[36] In addition, over that same period, 20 percent of all oil and gas industry spills contaminated water to some degree. Spilled products include crude oil/condensate, produced water, and “other products” such as hydraulic fracturing fluids, diesel fuel, glycol, drilling muds, and other chemicals that can have a deleterious environmental impact. Although this report, as previously mentioned, does not present data and findings relevant to fuel spill impacts, concentrations, and volumes, they are important issues and a focal point for oil and gas regulatory oversight.

2.3.3 Land Use Issues

Oil and gas production in Region 8 contributes to a number of land use issues[37]. Most land use-related activities and criticisms of production operations revolve around:

- Surface disturbances due to drilling, and certain drilling techniques used to reduce these impacts;
- Impact of oil and gas operations on wildlife due to surface disturbances, noise, and other industrial activities;
- Treatment of drilling waste; and
- Separation of surface and mineral rights.

Surface Disturbance. Extraction of unconventional resources such as tight gas and shale gas, which are abundant in Region 8, can cause a greater surface disturbance than production of conventional gas resources. As previously stated, more wells are required to produce unconventional natural gas due primarily to the lower porosity of the formations where the resources reside. However, certain extraction techniques have been

Co-Regulator Efforts Around Land Use: Oil and Gas Environmental Assessment

In1996, Region 8 and U.S. Fish and Wildlife Service (FWS) Region 6 formed a partnership to assess oil and gas waste management issues impacting production and related sites. Originally referred to as the Problem Oil Pit (POP) effort, the name was changed to Oil and Gas Environmental Assessment (OGEA). Co-regulators participating in the effort included state oil and gas agencies and environmental agencies, tribal energy and environmental agencies, BLM, and the U.S. Bureau of Indian Affairs (BIA). Participants focused on threats posed by these facilities to surface and ground water resources, as well as wetlands. In addition, participants focused attention and resources to determine where oily waste in open pits posed threats to migratory birds and other wildlife and to correct problems as they found them. EPA OGEA team participants and other Federal, State, and Tribal co-regulators pursued several activities intended to improve compliance and environmental conditions at production sites, including commercial waste management facilities. As a result of these efforts, in 2003 EPA developed a report that reviewed the work of the team in Region 8, made recommendations for future action, and examined how co-regulators and the regulated community can ensure lasting environmental benefits from this effort.

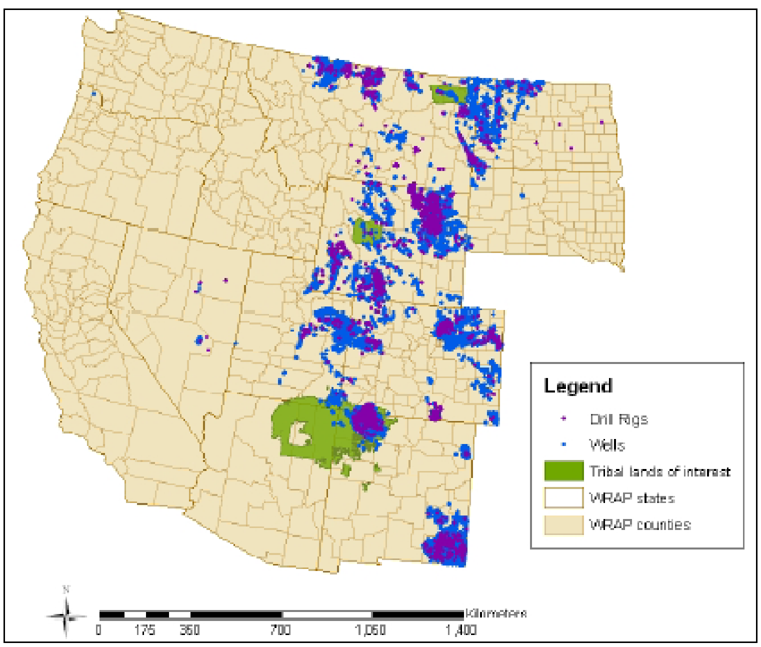
[36] Oil and Gas Accountability Project, *Colorado Oil and Gas Industry Spills: A Review of COGCC data (June 2002-June 2006)*, http://www.earthworksaction.org/pubs/Spills.pdf.
[37] U.S. Environmental Protection Agency, *Report of the Oil and Gas Environmental Assessment (OGEA) Effort 1996-2002,* January 2003.

developed to reduce the total area of surface disturbance and partially offset this requirement.

For example, horizontal drilling techniques are widely used to access and produce natural gas from such low permeability formations in Region 8 and elsewhere (e.g., shale gas production operations such as those common to the Barnett Shale in Region 6). In addition, horizontal drilling techniques are now being extensively employed in CBM natural gas production.

Horizontal drilling is used to enable multiple wells to be established from a single well pad, thus reducing the overall surface area used for drilling (i.e., well-pad acreage). Hydraulic fracturing and disposal of fluids used for this practice is another environmental concern. In addition, although not the focus in Region 8, oil and natural gas production can contribute to land subsidence over time as evidenced by operations within the Gulf Coast and other areas. Figure 2-5 shows the western states' oil and gas footprint by indicating drill rig concentrations and well locations in Region 8 – Montana, North Dakota, South Dakota, Wyoming, Utah, Colorado, and 27 tribal nations (**NOTE**: The Western Regional Air Partnership (WRAP) consists of the six states of Region 8 plus Washington, Oregon, California, Idaho, New Mexico, Arizona, Nevada, and Alaska.)

Figure 2-5. Rocky Mountain States' Oil and Gas Producing Regions



Impacts on Wildlife. Wilderness areas across Region 8 increasingly must coexist with oil and gas production. Heavy-duty trucks and roadways used for fuel production and transportation contribute to noise and air pollution in undeveloped areas. In addition, drilling activities are reportedly impacting wildlife habitat and some animal species that reside within these public lands. For example, the Rocky Mountain Front Range ranks in the top 1 percent of U.S. wildlife habitat and has a number of native big game animals that need a large home range to thrive.[38] Studies have raised concerns that new roadways and expanding drilling operations disrupt migration, habitat, and wintering grounds for certain species. Heavy-duty trucks and roadways used for fuel production and transportation contribute to noise and air pollution. Some environmentalists, residents, wildlife experts, and others resist further oil and gas exploration in Region 8, and surface disturbance and wildlife impacts caused by road development and drilling operations are among the leading issues cited.

Treatment of Drilling Waste. Drilling waste is another key issue, and environmental groups and other stakeholders have raised concerns regarding the treatment, storage, and disposal or reuse of such production byproducts. Oil and gas production generally produces drilling waste that contains mud, rock fragments and cuttings from the wellbore, and chemicals added to improve the properties and performance of drilling muds and fluids. Such drilling waste accounts for the second largest amount of waste derived from oil and gas production (second to produced water). Certain methods have been adopted in recent years to reuse and/or reduce drilling waste as well as to diminish the toxicity of various drilling waste; nevertheless, benefits have often not been realized.

To reduce their drilling footprints, some producers have developed methods to reuse nontoxic drilling waste or treat toxic waste compounds. For example, certain drilling waste is being processed and converted into a low-cost substitute for construction aggregate. Another method involves the substitution of nontoxic fluid additives to reduce or eliminate the toxicity of such wastes. In addition, some companies have begun to implement closed-loop drilling fluid systems that eliminate the dumping of waste byproducts into an open pit. This approach can be expensive but has proven effective in reducing drilling waste, associated water use, and truck traffic for shipping wastes offsite to a treatment facility.

Overall, these practices seek to reduce the environmental footprint of fossil fuel production; however, they also have drawbacks. For example, EPA estimates that only 10 percent of total drilling waste volumes are either reused or recycled (e.g., as levee fill in construction and infrastructure projects), and that current demand for such byproducts in other manufacturing sectors is not significant.[39]

Land Use Rights. Another issue related to land use deals with how surface and mineral rights are distributed under split estate lands. Split estate lands refer to those lands on which private parties own the surface and the federal government owns subsurface minerals. Under U.S. law, the government's mineral rights supersede those of private parties. Problems have surfaced with these split estate issues, especially as the government has increasingly used its rights to advance oil and gas production on public lands to meet domestic energy needs and to generate royalties (for the U.S. Treasury as well as states).

[38] Joel Connelly, National Wildlife Federation, *Frontal Assault*, Aug/Sep 2004, vol. 42 no. 5, http://www.nwf.org/nationalwildlife/article.cfm?issueID=69&articleID=959.
[39] EPA Region 8, *Oil & Gas Beneficial Reuse Summary, Region 8 E&P Report*.

BLM is the principal government agency responsible for management and conservation of federal surface lands and mineral rights. Most of the land managed by BLM is located in the western United States, where there are abundant fossil fuel resources. The job of balancing resources and uses is challenging, and BLM has been criticized for advancing agency priorities that support increased domestic fuel production without adequately addressing competing needs. Public disapproval has involved claims of decreased efforts in inspection and enforcement, thus harming public lands as well as privately owned surface rights. Opponents of oil and gas production claim that BLM has supported rapid industry development, thereby enabling erosion, adverse impacts to water quality and wildlife habitat, and a wide range of surface disturbances.

In response to public concerns, BLM has been working diligently with surface owners to try to resolve issues involving split estate lands. Suggestions compiled by BLM include educating surface owners and operators of their rights, involving surface owners in the land use planning process, and notifying surface owners of surface-related compliance issues that could affect their property value.

Industry has also acted to address public concerns regarding environmental issues related to its oil and gas operations. For example, Shell Oil sponsored a "national dialogue on energy security" and held a number of events around the country in the past few years to solicit public opinion on energy issues and potential future directions.[40] Rocky Mountain residents provided mixed responses regarding new energy production, and much feedback focused on current and potential uses of environmentally friendly technologies that provide efficient access to the region's vast oil and gas resources.

As oil and gas production continues to expand within Region 8, so too do the number of public health concerns surfaced by local residents who feel adversely impacted by development activities. Some residents in Garfield County, CO have contacted local public health officials about respiratory problems to be investigated and acted upon. Similarly, citizen groups in Pinedale, WY have articulated concerns about exposure to unhealthy ozone levels that have been recorded in the Green River Valley. Although public health impacts of oil and gas activities are outside the scope of this report, these issues merit added consideration. EPA and other agencies continue to investigate and, as appropriate, respond to these issues in Region 8 and other producing states where similar concerns have surfaced.

2.3.4 Summary of Policy Issues

Section 2.3 of this report highlights only some of the major policy issues surrounding oil and gas operations in Region 8. The issues are too numerous and complicated by conflicting interests of the oil and gas industry, impacted residents, and other stakeholders to be comprehensively addressed within the context of this report. In short, with a growing worldwide economy that requires vast amounts of energy, U.S. and global demand for hydrocarbons is not expected to abate any time soon. This finding is

[40] Shell Oil Company, *A National Dialogue on Energy Security: The Shell Final Report*, http://www.shell.com/static//usa/downloads/energy_security/pdf/shell_final_report.pdf

consistent with ones articulated in the 2007 National Petroleum Council report[41]. Clearly, regional efforts to control fossil fuel emissions more effectively—ranging from GHG cap-and-trade programs to carbon capture and sequestration—will be necessary as production and other fossil fuel activities continue to expand. In addition, the genuine concerns of affected residents will need to be addressed to resolve current claims, avoid increased confrontation between the affected parties, and prevent adverse environmental, human health and safety impacts.

To satisfy domestic demand for energy and with a major push to access and tap into reliable energy sources domestically, growth in natural gas production and other forms of natural resource extraction within the Rocky Mountain region is occurring. In addition to oil and gas, other fossil fuels, and nuclear power, increased development of renewable energy sources - such as hydropower, solar, and wind resources – in Region 8 is likely. Coupled with an increased focus on energy efficiency and resource conservation, the successful development of diverse sources of energy is absolutely essential to U.S. energy security. As such, an open and collaborative effort will be required between all parties to provide for better stewardship of oil and gas resources—across Region 8 and the nation as a whole.

[41] National Petroleum Council, *Facing the Hard Truths About Energy*, http://www.npchardtruthsreport.org.

3.0 Environmental Releases

3.1 Data Sources and Assumptions

As noted in Section 1.2.2, we characterized the environmental releases associated with oil and gas production in 2002 and 2006, focusing on air emissions as well as produced water and drilling waste. Development of the 2002 data set is documented in Appendix C; these data were then used with other sources to estimate the same set of environmental impacts (i.e., air emissions, produced water, and drilling waste) for 2006.

In addition, the methodological approach used to estimate 2006 environmental impacts helps provide a more current view of the dynamic growth in oil and gas production in Region 8 since 2002 (the baseline year for much of the data currently available and featured in this report). Sections 3.1.1 and 3.1.2 below summarize key 2002 data sources and 2006 extrapolation assumptions.

3.1.1 2002 Data Sources and Assumptions

Air Emissions

Oil and gas production facilities focused on drilling and resource extraction are exempt from EPA's Toxic Release Inventory (TRI) reporting requirements. As such, data resources for air emissions (and other environmental impacts) stemming from oil and gas production are limited. After researching and evaluating various information sources, the EPA Sector Strategies Program decided to profile and analyze the WRAP air emissions data. Indeed, the WRAP data set is the principal information source underpinning our analytical assessment of air emissions associated with oil and gas production in Region 8. The WRAP estimates of air emissions for 2002[42] are well documented and appear to be the best available given the oil and gas production environmental impact data limitations previously referenced. Specifically, air emissions data obtained from WRAP include estimates of NO_x, SO_2, VOCs, CO, particulates, ammonia (NH_3), and hydrogen sulfide (H_2S).

The WRAP defines air emissions sources in a slightly different way than CAA programs do. In WRAP terminology, a point source is "a specific source of air pollution" and an area source is "many small sources of air pollution in which the contribution of each source is relatively small, but combined may be a significant source of air pollution." The CAA categorizes stationary sources as "major" or "minor" for pollutants, based on the potential or permitted air emissions, and it defines "area source" as a stationary source of air pollution that is not major. WRAP's categorization of point sources most closely correlates to major sources of air pollution, but could potentially include minor sources as well. Note that WRAP's categorization of area sources could include certain mobile sources that effectively function as stationary sources, such as drilling rigs.

[42] A 2005 update of this data is available in the WRAP document *WRAP Area Source Emissions Inventory Projection and Control Strategy Evaluation – Phase II*, September 2007.

Other main assumptions for the WRAP 2002 inventory are described below:

- ***For point sources:***
  - Original estimates of point source air emissions are based on data collected from states and local agencies (through the National Emissions Inventory (NEI), other EPA data sets, and other data sources maintained by organizations outside the agency). These original estimates of point source air emissions were reviewed and revised by WRAP.
  - Point source emissions data used in this analysis account for installed control device reductions. Control devices accounted for in the WRAP inventory include NO_x controls, VOC reduction measures, LDAR systems, and others.
  - The classification of a point source differs from state to state. For example, in Colorado, a threshold of 2 tons per year of NO_x is used for point sources; in other states, the threshold is greater than 2 tons.[43]
  - The WRAP database is the region's most comprehensive source for criteria pollutant emissions data; however, data for some of the important fields, specifically those pertaining to production and throughput, are not available.
  - Not every well or producing facility will have enough emissions to be classified as a point source. Therefore, the WRAP emissions estimates from smaller stationary sources are grouped together in the area source category.
  - Another limitation of our analysis is that production within tribal lands is not captured. Although there were data in the WRAP database, the relevant state locations were not identified. Due to the relatively modest contribution of these sources to total projected emissions from regional production operations, the additional time and resources needed to account for them accurately were not expended.[44]
- ***For area sources:***
  - WRAP area source estimates include only NO_x, VOC, and SO_2 emissions from larger sources. As such, not all air pollutants from oil and gas sources are included.
  - For NO_x and SO_2 estimates, sources were limited to compressor engines, drill rigs, and CBM pump engines.
  - For VOC estimates, sources were limited to oil well tanks and pneumatic devices, gas well pneumatic devices, gas well dehydrators, gas well completion flaring and venting, and controlled as well as uncontrolled condensate tanks.

[43] For example, Colorado has by far the greatest number of point sources, most of which are in the natural gas liquid extraction facility category. Although Wyoming has large gas production, the sources are defined differently than in Colorado, resulting in fewer listed point sources, though the emissions are still captured as area sources.
[44] EPA is presently engaged in a rulemaking process focused on New Source Review Minor Permits for air sources on tribal lands.

- Due to limitations associated with environmental data from tribal lands previously referenced, area source emissions for production are excluded. Although it is possible that state data would include tribal data, there is no confirmation available.
- Regarding CO_2 emissions, the U.S. Census of Mining (a subset of the U.S. Economic Census data set) reports fuel consumption from oil and gas extraction establishments in 2002. In addition, the U.S. Department of Energy (DOE) Energy Information Administration (EIA) reports natural gas lease and plant consumption data, which help to quantify CO_2 emissions. Specifically, natural gas lease and plant is recovered natural gas used as fuel for various oil and gas extraction operations and natural gas processing equipment. CO_2 emissions were then calculated by applying standard emissions factors to the fuel consumption estimates from the Census and EIA data sets, respectively.

Produced Water

Although water discharges from oil and gas extraction facilities are reported to EPA, this data is not readily available to the public. Primary sources for water data presented in this report originate from proprietary industry information sources, Lasser, Inc. and IHS, Inc., respectively. Lasser is the oldest U.S. source of oil and gas production data. Similarly, IHS is a global provider of information products and services, providing critical insights into oil and gas production, energy, and other key industries since 1959. These are privately managed databases, and their information is largely based on data reported by industry to the states for taxation and royalty purposes. They are widely used by industry and government to characterize oil and gas exploration and production activity. The Lasser data provide information on the number of wells drilled and amount of oil, gas, and water produced. Data extracted from these sources were used to estimate well counts and volumes of produced water resulting from production. We used the IHS database to identify the CBM wells and to help disaggregate the well data, including produced water, by well type.

Drilling Activities

Estimates of drilling waste profiled in this report were calculated by using the American Petroleum Institute's (API) *Overview of Exploration and Production Waste Volumes and Waste Management Practices in the United States*. This resource provides emission factors that help analysts capture volumes of drilling waste associated with production.[45] We used those emission factors in combination with operating data to provide annual estimates for 2002 and 2006, respectively.

3.1.2 2006 Data Development Assumptions

In developing estimates of environmental impacts of regional oil and gas production in 2006, we first assembled, developed, and analyzed the 2002 data set. Using the 2002 baseline, we then extrapolated data and carried the estimates forward to 2006 using production-related variables tied to oil and gas drilling activities. Regional estimates for

[45] Note: API emission factors from the reference guide mentioned above are generally believed to be the best available.

2006 are based on this extrapolation and augmented by production-related trends data as well as relevant EIA data sources. However, due to data limitations regarding individual production operations within Region 8, no specific assumptions or calculations were made to capture possible operator adjustments to oil and gas processes (e.g., installation of emissions control devices) between 2002 and 2006. In addition, no adjustments were made to incorporate changes in federal and state laws and implementing regulations affecting air emissions and non-air releases from oil and gas production. We did not perform these adjustments, because relevant emissions data, as well as the time and staffing resources to investigate and analyze them, were limited.

In spite of the limitations, the 2006 estimates help to illustrate the potential breadth of environmental impacts associated with rapid growth of oil and gas production in the past five years. Table 3-1 summarizes how we developed the 2006 data, by pollutant. The choice of variables selected depended on the relevance of the source data as well as the availability of 2006 state data. For example, state oil and gas production data as well as EIA natural gas processing figures were used to calculate all air emissions except CO_2. To develop the CO_2 emissions projections (out to 2006), we used industrial production indices (or growth factors) provided by the Federal Reserve Board (FRB) by relevant North American Industry Classification System (NAICS) codes. In addition, we augmented these projections with EIA statistics reflecting natural gas lease and plant consumption for 2006.

For produced water, we used the 2006 Lasser and IHS data. For drilling waste, we used 2006 API drilling data to estimate growth in drilling waste from 2002 to 2006.

Table 3-1. Methodology to Develop 2006 Data, by Pollutant

Pollutant	Methodology
Air Emissions: VOCs, HAPs, NO_x, CO, SO_2, NH_3, H_2S, all PMs	Extrapolated 2002 to 2006 using oil and gas production by state. *Data source:* EIA
Air Emissions: CH_4	Extrapolated 2005 to 2006 using oil and gas production and gas processing data by state. *Data source:* EIA
Air Emissions: CO_2	Extrapolated 2002 fuel (except natural gas lease and plant) consumption to 2006 using FRB Industrial Production Indices for the following NAICS: NAICS 211111 (Crude Petroleum and Natural Gas Extraction), NAICS 211112 (Natural Gas Liquids Extraction), NAICS 213111 (Drilling Oil and Gas Wells), and NAICS 213112 (Support Activities for Oil and Gas Extraction Operations). Note that FRB data are only at the national level. For natural gas lease and plant, extrapolated 2002 to 2006 using the EIA national estimate of natural gas lease and plant. *Data sources:* FRB, EIA
Produced Water	Used Lasser and IHS produced water estimates for 2006.
Drilling Waste	Extrapolated 2002 to 2006 using API drilling activity data by state. *Data source:* API

3.2 Estimated Air Emissions: Comparing 2002 Baseline to 2006 Estimates

Section 3.2 presents air emissions estimates for 2002 and 2006, respectively, providing insights into the growing significance of oil and gas production activities in Region 8.[46] Table 3-2 compares 2002 criteria pollutant emissions from production as reported by WRAP to the total emissions from all industrial categories and sources within Region 8. From these data, one can see that VOCs[47] from oil and gas production account for nearly 40 percent of total emissions in Region 8. NO_x is another significant challenge, as production-related emissions represent almost 15 percent of the regional total.

From 2002 to 2006, regional oil and gas production increased by about 25 percent, and drilling activity expanded by 27 percent (as reflected by regional increases in production wells). Given the rapid growth during this period, various stakeholders are voicing concerns that increasing VOC and NO_x emissions from production operations will substantively contribute to expanding ground-level ozone and regional haze issues. These concerns have resulted in new regulations to limit NO_x and other emissions from oil and gas production sources (e.g., Federal NSPS regulations, Colorado's new NO_x, CO, and VOC regulations for the oil and gas industry).

Table 3-2. Oil and Gas Criteria Pollutant Emissions Compared to Total Region 8 Criteria Pollutant Emissions, 2002 (tons)

Pollutant	Emissions From Oil and Gas Sector	Total Region 8 Emissions	Oil and Gas Emissions as Percentage of Regional Emissions
VOCs	262,953	651,580	40.4%
NO_x	87,130	587,942	14.8%
CO	37,880	413,990	9.2%
SO_2	18,385	503,041	3.7%
PM	834	2,172,255	<0.1%

Table 3-3 shows total criteria pollutant emissions from oil and gas production in 2002 grouped by state and pollutant. Wyoming has the greatest air emissions, followed closely by Colorado. These two states encompass the most oil and gas production in the region. Conversely, South Dakota has the lowest criteria pollutant emissions and the least oil and gas production compared to other Region 8 states. The table also shows that VOC emissions represent the largest regulated pollutant, followed by NO_x, CO, and SO_2. The PM emission estimates are not very reliable due to limited data and variable definitions of the different kinds of PM; however, they are relatively insignificant compared to other criteria pollutants common to oil and gas production.

Particulate emissions available from WRAP are "PM10_PRI" (PM10 primary emissions, the sum of filterable and condensable particulates). Note that particulate emissions were not available for three states: Montana, North Dakota, and South Dakota. As discussed in Appendix C, Sections C.2.2 and C.2.3, emissions from sources in these states may be

[46] Note: Numbers in associated tables in this section may not add due to rounding.
[47] Although EPA does not list VOCs as one of the six criteria pollutants, they are referenced in this section due to their role as a precursor to ozone, a listed criteria pollutant.

too small on an individual basis to be included in the point source category. In addition, the WRAP data collection project initiated in 2005 to expand the criteria pollutant inventory did not include particulates, leaving data gaps for those states.

Table 3-3. Criteria Pollutant Emissions by Pollutant, by State, 2002 (tons)

Pollutant	CO	MT	ND	SD	UT	WY	Total
VOCs	90,683	5,502	7,805	288	36,537	122,138	262,953
NO_x	45,960	7,761	7,571	361	5,108	20,369	87,130
CO	20,720	1,183	798	11	2,443	12,725	37,880
SO_2	220	227	2,882	6	1,590	13,460	18,385
PM10_PRI	384	0	0	0	16	9	408

Table 3-4 shows total criteria pollutant emissions from production in 2006 increased by 24 percent from the 2002 baseline. Production emissions in Montana increased by almost 75 percent, while emissions in Colorado increased by almost 28 percent. The fastest growing criteria pollutants are NO_x and PM10_PRI, which are projected to increase by 28 percent and 27 percent, respectively, over this 4-year period.

Table 3-4. Criteria Pollutant Emissions by Pollutant, by State, 2006 (tons)

Pollutant	CO	MT	ND	SD	UT	WY	Total
VOCs	115,517	9,596	9,596	302	45,472	142,383	322,865
NO_x	58,546	13,536	9,307	378	6,358	23,745	111,870
CO	26,395	2,064	980	12	3,041	14,834	47,326
SO_2	281	396	3,544	6	1,978	15,691	21,895
PM10_PRI	489	0	0	0	20	10	519

Table 3-5 shows non-criteria pollutant pollutants, GHGs, and HAPs by state in 2002. When methane emissions are weighted by their global warming potential (GWP),[48] CO_2 equivalent methane emissions represent the largest non-criteria pollutant emissions (at over 10 million tons). While these emissions are not currently regulated, GHG regulations are being developed within the region, from individual states to the WCI, and some industry companies are taking proactive measures to find ways of reducing GHG emissions. In fact, BP America received the 2007 IOGCC National Environmental Stewardship Award for their project to reduce GHG emissions by challenging the conventional wisdom of standard practices associated with well venting.[49] By comparison, HAP emissions are much smaller and are primarily VOCs.

Table 3-6 shows non-criteria pollutant pollutants, GHGs, and HAPs by state for 2006. From 2002 to 2006, CO_2 emissions increased an estimated 32 percent, HAP emissions grew by 19 percent, and CH_4 increased by almost 13 percent. Whereas Utah and Wyoming reported the fastest growth in non-criteria pollutant emissions, South Dakota exhibited a decline in emissions, the only state in Region 8 to do so.

[48] GWP is a measure of how much a GHG is expected to contribute to global warming. In the case of methane, GWP is approximately 21 times the global warming contribution of CO_2 (whose GWP is, by definition, 1) measured over a 100-year timeframe.
[49] http://www.iogcc.state.ok.us/iogccs-2007-chairmans-stewardship-award-winners-are

Table 3-5. Non-Criteria Pollutant Air Emissions by Pollutant, by State, 2002 (tons)

Pollutant	CO	MT	ND	SD	UT	WY	Total
CH_4 (CO_2 equivalent)	3,216,621	410,513	591,147	37,543	893,226	5,217,392	10,366,442
CH_4	153,172	19,548	28,150	1,788	42,535	248,447	493,640
CO_2	1,644,066	622,154	265,536	15,767	403,571	2,240,802	5,191,897
HAPs	3,781	130	431	15	3,932	25,450	33,738

Table 3-6. Non-Criteria Pollutant Air Emissions by Pollutant, by State, 2006 (tons)

Pollutant	CO	MT	ND	SD	UT	WY	Total
CH_4 (CO_2 equivalent)	3,645,531	773,105	773,699	39,252	1,044,258	5,404,241	11,680,085
CH_4	173,597	36,815	36,843	1,869	49,727	257,345	556,195
CO_2	2,130,662	762,281	273,938	13,565	566,341	3,120,791	6,867,579
HAPs	4,817	226	529	15	4,893	29,668	40,149

Table 3-7 presents air emissions by major source category—point and area—by state. VOCs, NO_x, SO_2, CO, and HAPs are the only pollutants shown, since data are available by type of major source.

Table 3-7. Total Point and Area Emissions of VOCs, NO_x, SO_2, CO, and HAPs, by State, 2002 (tons)

Pollutant/Source	CO	MT	ND	SD	UT	WY	Total
VOCs							
Point	*63,423*	*58*	*66*	*0*	*576*	*2,691*	*66,814*
Area	*27,259*	*5,444*	*7,740*	*288*	*35,961*	*119,447*	*196,139*
Total	*90,683*	*5,502*	*7,805*	*288*	*36,537*	*122,138*	*262,953*
NO_x							
Point	*22,442*	*204*	*2,940*	*0*	*1,774*	*5,644*	*33,003*
Area	*23,518*	*7,557*	*4,631*	*361*	*3,335*	*14,725*	*54,126*
Total	*45,960*	*7,761*	*7,571*	*361*	*5,108*	*20,369*	*87,130*
SO_2							
Point	*102*	*2*	*2,524*	*0*	*1,573*	*13,309*	*17,510*
Area	*118*	*225*	*358*	*6*	*17*	*150*	*874*
Total	*220*	*227*	*2,882*	*6*	*1,590*	*13,460*	*18,385*
HAPs							
Point	*2,777*	*1*	*0*	*0*	*52*	*220*	*3,050*
Area	*1,004*	*128*	*430*	*15*	*3,880*	*25,230*	*30,688*
Total	*3,781*	*130*	*431*	*15*	*3,932*	*25,450*	*33,738*
CO							
Point	*13,874*	*165*	*761*	*0*	*1,883*	*9,179*	*25,862*
Area	*6,847*	*1,018*	*36*	*11*	*560*	*3,546*	*12,018*
Total	*20,720*	*1,183*	*798*	*11*	*2,443*	*12,725*	*37,880*

For VOCs and HAPs, the table reveals **area sources are a much greater contributor to emissions than point sources in Region 8**. For NO_x and CO emissions, point and area sources contribute significantly to total emissions. The area source fraction is slightly larger for NO_x and the point source component is larger for CO. NO_x and CO emissions are primarily from large combustors (point sources) as well as small combustors and mobile sources (area sources). On the other hand, SO_2 emissions are dominated by large point source combustors. Methane emissions are not shown in Table 3-7, primarily because the exact split between area and point sources is not known. However, it is generally believed that methane releases are primarily from area sources and are considered fugitive emissions.[50]

Table 3-8 projects the point and area source emissions for 2006. For VOCs and HAPs, we estimate point source emissions have grown faster than area source emissions over the 4-year period. For NO_x, SO_2, and CO, area source emissions increased more than point source emissions.

Table 3-8. Total Point and Area Emissions of VOCs, NO_x, SO_2, CO, and HAPs, by State, 2006 (tons)

Pollutant/Source	CO	MT	ND	SD	UT	WY	Total
VOCs							
Point	*80,793*	*101*	*81*	*0*	*717*	*3,137*	*84,829*
Area	*34,725*	*9,494*	*9,515*	*302*	*44,755*	*139,246*	*238,036*
Total	*115,517*	*9,596*	*9,596*	*302*	*45,472*	*142,383*	*322,865*
NO_x							
Point	*28,588*	*356*	*3,614*	*0*	*2,207*	*6,579*	*41,344*
Area	*29,958*	*13,180*	*5,693*	*378*	*4,150*	*17,166*	*70,526*
Total	*58,546*	*13,536*	*9,307*	*378*	*6,358*	*23,745*	*111,870*
SO_2							
Point	*130*	*3*	*3,103*	*0*	*1,958*	*15,515*	*20,710*
Area	*151*	*393*	*441*	*6*	*21*	*175*	*1,186*
Total	*281*	*396*	*3,544*	*6*	*1,978*	*15,691*	*21,895*
HAPs							
Point	*3,538*	*2*	*0*	*0*	*65*	*256*	*3,861*
Area	*1,279*	*224*	*529*	*15*	*4,828*	*29,412*	*36,288*
Total	*4,817*	*226*	*529*	*15*	*4,893*	*29,668*	*40,149*
CO							
Point	*17,673*	*288*	*936*	*0*	*2,344*	*10,700*	*31,941*
Area	*8,722*	*1,776*	*45*	*12*	*697*	*4,134*	*15,385*
Total	*26,395*	*2,064*	*980*	*12*	*3,041*	*14,834*	*47,326*

3.3 Estimated Non-Air Releases (Produced Water and Drilling Waste), 2002 and 2006

Non-air releases mainly refers to produced water (from oil and gas resource extraction) and drilling waste (i.e., drilling muds and fluids as well as drill cuttings). Sections 3.3.1 and 3.3.2 present the data and implications for produced water from 2002 to 2006, while Sections 3.3.3 and 3.3.4 present the data and implications regarding drilling waste.[51]

[50] Fugitive emissions are those stemming from unanticipated releases or leaks in production equipment and associated processes.
[51] Note: Numbers in associated tables in these sections may not add due to rounding.

3.3.1 Produced Water Summary

Proper management of produced waters is a high priority topic in Region 8. Tables 3-9, 3-10, and 3-11 show estimates of produced water for Region 8, categorized by state and type of producing well. Table 3-9 shows the amount of produced water from oil and gas extraction activities in the region by state, for 2002 and 2006, from data provided by an industry data aggregation company, Lasser Inc. (Note that data provided on the Wyoming Oil and Gas Conservation Commission website differs from the Lasser data, indicating a 7.5 % increase in produced water in Wyoming from 2002 to 2006. [52])

In 2002, almost 3 billion barrels of produced water were extracted in Region 8, with Wyoming contributing almost 75 percent of total produced water. There was only a slight increase of total produced water in the region projected from 2002 to 2006 (1.7 percent). Whereas South Dakota, Utah, and Wyoming showed reductions in produced water, Colorado, Montana, and North Dakota showed increases. The largest percentage increases in production (from 2002 to 2006) appear to have been in North Dakota and Montana.

Table 3-9. Produced Water by State, 2002 and 2006 (barrels)

State	2002	2006	Percent Change
WY	2,091,105,179	2,025,898,781	-3%
CO	348,255,005	405,507,349	16%
UT	136,296,362	128,669,683	-6%
MT	123,397,156	158,186,310	28%
ND	98,537,154	127,383,733	29%
SD	8,108,174	8,015,208	-1%
Total	2,805,699,030	2,853,661,064	2%

The category “oil with gas wells” (where “associated gas” is produced) was the largest contributor of produced water in Region 8, as shown in Table 3-10.[53] Oil-only wells released the second largest amount of produced water. Combined, these two well types account for 69 percent of total produced water in the region. These results are not unexpected, since oil wells typically release more produced water than gas wells (particularly as they mature and produce fewer and fewer barrels of oil over time). Wyoming is the primary source of produced water in the region for both well types, providing further indication of the broad scope of production activities within the state. From coal to oil and gas production and other forms of energy development, Wyoming is one of the nation’s leading providers of domestic fuels. Most of the water produced from oil wells is re-injected underground. Oil wells often use water injection to stimulate oil production[54] (e.g., “water flooding”), and produced water from these operations is often recycled and re-injected to stimulate further production. In addition, in terms of disposal

[52] http://wogcc.state.wy.us/StatisticsMenu.cfm?Skip='Y'&oops=49
[53] Natural gas is found in two basic forms: associated gas and non-associated gas. Associated gas occurs in crude oil reservoirs either as free gas (associated) or as gas in solution with crude oil (dissolved gas). Non-associated gas is not in contact with significant quantities of crude oil in the reservoir.
[54] Some wells inject steam or water into the producing formation to promote oil recovery from wells where production has slowed. Steam and water flooding are two common approaches to enhanced oil recovery (EOR).

options, produced water is re-injected into deep formations via underground injection control (UIC) wells.[55]

Table 3-10. Produced Water by Well Type, 2002 (barrels)

State	Oil-Only Wells	Gas-Only Wells	Oil With Gas Wells	Gas With Oil Wells	Total
WY	601,234,810	569,061,152	853,631,461	67,177,756	2,091,105,179
CO	81,962,976	158,856,545	102,323,995	5,111,489	348,255,005
UT	21,684,832	31,145,993	79,283,960	4,181,577	136,296,362
MT	50,775,321	16,847,685	55,708,537	65,613	123,397,156
ND	20,953,673	3,521	74,617,442	2,962,518	98,537,154
SD	915,122	614	5,121,998	2,070,440	8,108,174
Total	777,526,734	775,915,510	1,170,687,393	81,569,393	2,805,699,030

Table 3-11 shows produced water by well type, including CBM, for 2006. We estimate that produced water coming from oil wells (oil-only wells and oil with gas wells) declined slightly from 2002 to 2006. During the same period, produced water associated with gas wells (gas-only wells, including CBM wells, and gas with oil wells) appears to have increased, with the largest projected increase coming from gas with oil wells.

Table 3-11. Produced Water by Well Type, 2006 (barrels)

State	Oil-Only Wells	Gas-Only Wells	Oil With Gas Wells	Gas With Oil Wells	Total
CO	47,185,142	217,006,510	127,734,624	13,581,073	405,507,349
MT	56,283,830	28,076,898	73,443,690	381,892	158,186,310
ND	26,358,334	17,382	92,659,049	8,348,968	127,383,733
SD	616,231	953	5,597,759	1,800,265	8,015,208
UT	28,124,959	23,725,241	65,148,166	11,671,317	128,669,683
WY	615,254,891	566,049,418	782,635,991	61,958,481	2,025,898,781
Total	773,823,387	834,876,402	1,147,219,279	97,741,996	2,853,661,064

Gas-only wells also release produced water, but CBM wells release substantially more produced water than non-CBM wells. The quality and composition of produced CBM water varies widely, as shown in Table 3-12. Nevertheless, there is significant interest in CBM produced water in Region 8. The main reason behind the increased attention is that these CBM gas wells often yield high quality, and high volumes of, produced water that supports agricultural, ranching, and other uses[56] (**NOTE**: Specific data on produced water usage in agricultural purposes (e.g., center-pivot irrigation) is not available and thus could not be analyzed for purposes of this report).

As noted in Section 2.3.2, EPA's Office of Water is conducting an in-depth study of the CBM sector. The agency is presently surveying oil and gas companies to assess current issues and impacts, leadership practices, economic considerations, and other issues

[55] Oil and gas UIC wells are classified as Class II wells. In these wells, produced water and other fluids associated with oil and gas extraction (produced water) are reinjected into the same formation. The fluids are mostly salt water (brine).

[56] Additional information on GHG emissions and produced water issues can be found at: http://www.beneficialusesummit.com/2008/2008presentations.html

influencing industrial operations and associated environmental management practices in Region 8 and other U.S. locations with CBM production.

Table 3-12. Characteristics of CBM-Produced Water[57]

Pollutant	Pollutant Concentration by Basin (mg/L)									
	San Juan Basin		Black Warrior Basin		Powder River Basin		Raton Basin		Uinta Basin	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Barium	0.7	63	ND	ND	0.06	2	ND	ND	ND	ND
Calcium	0	228	ND	ND	5	200	4	24	ND	ND
Chloride	0	2,350	40	36,000	3	119	15	719	2,300	14,000
Iron	0	228	0.1	400	0.03	11	0.1	23	ND	ND
Magnesium	0	90	ND	ND	1	52	1	8	ND	ND
Potassium	0.6	770	ND	ND	2	20	1	17	ND	ND
Sodium	19	7,130	60	21,500	89	800	210	991	ND	ND
Sulfate	0	2,300	1	1,350	0.01	1,170	1	204	ND	ND

Source: Analysis of Discharge Data for Six Industry Categories (Bartram, 2003).
Min – Minimum.
Max – Maximum.
ND – No data available.

Primary pollutants commonly found in produced water from CBM operations include mineral salts, sodium, and metals such as iron. While produced water extracted from oil wells often cannot be safely discharged and is typically re-injected, CBM produced water can often have beneficial uses in agriculture (e.g., water for irrigation purposes), ranching (e.g., drinking water for livestock), and other applications. Given the fairly high quality of some CBM produced water, operators are permitted to discharge produced water into streams and rivers, provided this water is of sufficient quality to meet the designated uses of the receiving water body or is treated to meet those uses. However, in cases where the pollutant concentrations are too high for surface discharge, the produced water may be treated, re-injected, or impounded for evaporation and infiltration. These impoundments may have hydrologic connections to surface waters. Some operators are able to use CBM produced waters containing high concentrations of dissolved inorganics for livestock watering or irrigation with proper soil amendments and monitoring.

In addition, some produced water from CBM operations may be re-injected into deep geological formations (where injection zones are available). This is a common practice in some CBM basins (e.g. San Juan Basin in Colorado and New Mexico). Other basins have geologic conditions that present technical challenges to re-injection of CBM produced water. For example, the Wyoming Oil and Gas Conservation Commission estimates that across the Powder River Basin, nearly half of the wells drilled for injection cannot accept produced water and that half of the wells that can initially accept produced

[57] U.S. Environmental Protection Agency, *Technical Support Document for the 2006 Effluent Guidelines Program Plan,* http://www.epa.gov/guide/304m/2006-TSD-whole.pdf

water quickly become impaired (from plugging) and thus not a viable option for further injection[58].

3.3.2 Produced Water Management and Implications

Oil and gas production activities have various implications for water management, from storm water management (as construction sites are prepared for eventual exploration and production) to management of produced water. Nevertheless, produced water is, by volume, the largest waste stream associated with production. Effective management of produced water—and operator preparations to ensure spill prevention, countermeasures, and control—can present technical challenges and impose costs on producers, particularly small businesses. Environmental issues identified with produced water management range from potential harm to aquatic life and crops from pollutants or chemical constituents that flow into these areas to streambed erosion from produced water discharges. A DOE report prepared by the Argonne National Laboratory provides the following issue summary:

> "[Produced water] is not a single commodity. The physical and chemical properties of produced water vary considerably depending on the geographic location of the field, the geological formation with which the produced water has been in contact for thousands of years, and the type of hydrocarbon product being produced. Produced water properties and volume can even vary throughout the lifetime of a reservoir. If water flooding operations are conducted [to enhance resource recovery], these properties and volumes may vary even more dramatically as additional water is injected into the formation."[59]

3.3.3 Drilling Waste Summary

Oil and gas production yields drilling waste that contains mud, rock fragments, and cuttings from the wellbore, as well as chemicals added to improve mud properties. Such drilling waste accounts for the second largest amount of waste resulting from oil and gas production (second only to produced water). Drilling fluids include drill cuttings (i.e., rock removed from the formation during drilling) and drilling muds (i.e., water or oil-based fluids with additives that are pumped down the drilling pipe to offset formation pressure, provide lubrication, and seal off the wellbore to avoid contamination and remove cuttings). Other associated wastes include oily soil, tank bottoms, workover fluids, produced sand, pit and sump waste, pigging waste, iron sponge, dehydration condensate water, molecular sieve waste, and oily cuttings.

Table 3-13 shows the volume of drilling waste (in barrels) by state for 2002 and 2006. Whereas Wyoming produced the largest amount of drilling waste, followed by Colorado and Utah, South Dakota produced the least amount among Region 8 states.

[58] EPA-HQ-OW-2006-0771-0970.
[59] Argonne National Laboratory, *A White Paper Describing Produced Water from Production of Crude Oil, Natural Gas, and Coal Bed Methane*, prepared for DOE's National Energy Technology Laboratory (NETL), January 2004.

Table 3-13. Drilling Waste by State, 2002 and 2006 (barrels)

State	2002	2006	Percent Change
WY	10,834,600	17,668,762	63%
CO	6,138,174	10,098,340	65%
UT	4,533,724	9,222,269	103%
MT	2,741,195	5,965,305	118%
ND	1,484,341	3,370,840	127%
SD	37,451	123,756	230%
Total	25,769,484	46,449,272	80%

In 2002, almost 26 million barrels of drilling waste were generated across Region 8. We estimate that drilling waste increased by approximately 80 percent from 2002 to 2006. Although South Dakota is not a major source of drilling waste, it still reported the largest percentage increase of any state in the region, as the 2006 projection has more than tripled the 2002 baseline. In Montana, North Dakota, and Utah, drilling waste more than doubled. Significant growth is projected in Colorado and Wyoming for 2006, as drilling waste increased by more than 60 percent relative to the 2002 baseline.

3.3.4 Drilling Waste Management and Implications

Oil and gas companies have sought to minimize drilling waste and associated environmental impacts in the following ways: recycling and reuse of certain drilling byproducts, employing nontoxic drilling fluids, and using closed-loop drilling fluid systems to more effectively manage associated wastes. Nevertheless, various environmental groups and other stakeholders continue to express concern over potential groundwater contamination from drilling fluids as well as the amount of surface area used to treat, store, and dispose of such wastes.

Drill cuttings have been used for road spreading to mitigate some of the industry truck traffic damage, but concerns persist regarding associated environmental impacts due to the hydrocarbon content of these byproducts. In many situations, road-spreading applications involving drill cuttings are prohibited by regulatory agencies. Before drill cuttings can be beneficially reused, their salinity and hydrocarbon moisture and clay content must be assessed. Even after separation from other byproducts, cuttings are still coated with mud and, therefore, difficult to use for construction. Treatment options and combining drill cuttings with other materials can mitigate some of the barriers to reuse.

Regulatory agencies have initiated efforts to encourage the eventual reuse of drilling wastes. At the federal level, drill cuttings are typically exempt from Resource Conservation and Recovery Act (RCRA) hazardous waste regulations, and this policy does enhance the potential for beneficial reuse[60]. In addition, DOE has funded several projects to test the feasibility of reusing cuttings. It has been 20 years since the RCRA exemption for oil and gas exploration and production was implemented, and many

[60] US Environmental Protection Agency, *Exemption of Oil and Gas Exploration and Production Wastes from Federal Hazardous Wastes Regulations,* October 2002,. http://www.epa.gov/epaoswer/other/oil/oil-gas.pdf

practices and chemicals used have changed during that time. EPA may need to revisit the continued validity of the exemption in light of the advancements in practices. For example, more information about ground water contamination as a result of advancements developed in the RCRA program may be pertinent. In addition, better technology such as synthetic liners and leak detection systems may have become more reliable and less costly for operators to install and maintain over the past two decades.

Outside Region 8, some states are addressing liability and other concerns that can inhibit beneficial reuse of drill cuttings. For example, in December 2006, the Railroad Commission of Texas (RRC) revised Texas Administrative Code Title 16, Part 1, Chapter 4 and Subchapter B to specify that “a recyclable product is not a waste.” The rule was proposed to mitigate liability concerns of potential end users considering reuse options.[61]

[61] ICF International. *Beneficial Reuse of Industrial Byproducts in the Gulf Coast Region*, prepared for EPA’s Sector Strategies Program, February 2008.

4.0 Summary

4.1 Summary of Data Findings

As detailed in Chapter 3, air emissions, produced water, and drilling waste are the leading environmental concerns associated with oil and gas exploration and production in Region 8 and elsewhere. Land use conflicts also can create adversity, delays, and lawsuits. As an example, cultural resource protection and recreational opportunities on federal lands may overlap or compete with private-sector interest in areas of high development potential – from oil and gas production to other industrial operations. Environmental impacts can arise due to improper management of produced water and drilling waste; accidental hydrocarbon and produced water releases; abandoned or orphaned wells; and emissions from oil and gas exploration, production, and storage units. Impacts to ground-surface also result from related activities, such as site clearing; construction of roads, tank batteries, brine pits, and pipelines; and other necessary land modifications that produce surface disturbances. As oil and gas companies steadily continue to increase industry's investment in exploration and production in Region 8 and nationally, the need for effective environmental management and protection has never been greater.

With conventional oil and gas production in decline throughout the United States and domestic fuel consumption costs on the rise, unconventional oil and gas resources are becoming increasingly attractive and profitable to U.S. producers. Representative unconventional oil and gas resources found in Region 8 states include CBM, heavy oil, oil sands, gas stored in ultra-tight formations (i.e., tight gas or shale gas), and oil shale. Converting these fossil fuel resources into energy for consumers via oil and gas production has environmental consequences, including increased water use, air emissions, drilling waste, surface disturbances, and land and habitat impacts.

Unconventional natural gas operations such as tight gas and CBM require more wells to produce the same volume of gas than conventional wells, resulting in more drilling and greater surface disturbances. In addition, extracting natural gas from CBM wells produces significant volumes of produced water. Due to these resource characteristics and their associated production, oil and gas extraction in the Rocky Mountain region has a somewhat different—and likely greater—environmental footprint than production from conventional operations in other regions. The rapid expansion of oil and gas production activities in recent years, coupled with abundant proven and projected reserves, suggest that Region 8 will remain strategically important from an energy security perspective for years to come. Although growth in oil and gas production is expected to continue, natural gas extraction will dominate the region—primarily from tight gas and CBM formations—given its vast resource base. Moreover, despite improvements in drilling technology that shrink the environmental impacts of unconventional reserves per unit of production, such operations still involve a greater degree of surface disturbance and more water production than conventional gas extraction.

Such environmental impacts stem from the higher total volume of production in the region brought on by tighter well spacing and other operational characteristics of unconventional resource development. Although horizontal drilling does reduce the number of well pad locations relative to conventional extraction techniques, these and other operational advances are not sufficient to offset the range of environmental impacts associated with unconventional gas production. However, horizontal drilling technology can mitigate some of the negative environmental impacts. The following quote from one industry executive overseeing oil and gas operations in the Rockies succinctly captures some of the tradeoffs associated with unconventional gas production:

> "There are vast volumes of gas in the Rockies. The gas is there. The difficulty is that, as we drill these poorer and poorer quality reservoirs, it takes three or four wells today to deliver the same volume of gas that one conventional well would've yielded 10 or 15 or 20 years ago."[62]

In summary, the environmental footprint associated with oil and gas production continues to expand, fueling stakeholder concerns and regulatory deliberations regarding the potential pathway forward. As reflected in Table 4-1, this report shows that environmental impacts from oil and gas production in Region 8 are significant, with air emissions from regional oil and gas production estimated to comprise 6 percent of PM to 30 percent of HAPs of total U.S. emissions for this sector in 2006.

Table 4-1. Region 8 Versus National Oil and Gas Air Emissions/ Produced Water/Drilling Waste, 2006 (tons/barrels)

Pollutant	Region 8	U.S. Total	Region 8 as Percentage of U.S. Total
Emissions in Tons			
VOCs	322,865	1,111,445	29%
NO_x	111,870	839,803	13%
CO	47,326	273,051	17%
SO_2	21,895	105,227	21%
PM	1,060	19,200	6%
HAPs	40,149	134,508	30%
CH_4	556,195	3,841,447	14%
CO_2	6,867,579	49,706,996	14%
Water and Waste in Barrels			
Produced Water	2,853,661,064	19,445,269,921	15%
Drilling Waste	46,449,272	233,887,586	20%

Air pollutants of interest are NO_x, SO_2, and PM as precursors of regional haze, and NO_x and VOCs as precursors of ground level ozone. VOC emissions are the largest sources in Region 8, and these pollutants account for nearly two-thirds (64 percent) of total regional emissions (all sources, not just oil and gas) per the study's 2006 projections. NO_x emissions are primarily from engines (both stationary and mobile), turbines, and process heaters. VOCs are primarily fugitive emissions and include some HAPs such as benzene, toluene, ethyl benzenes, and xylenes. SO_2 emissions are primarily related to combustion in the oil production sector.

[62] "Tapping Into Energy's Fringe: As Companies Drill for 'Unconventional' Natural Gas, Environmental Impacts Mount," High Country News, 12/12/05.

Lastly, fugitive CH_4 emissions constitute the largest source of GWP-weighted GHG emissions. Due to its unique unconventional resource base and emerging production characteristics, Region 8 contributes about 15 percent and 20 percent of the total produced water and drilling waste, respectively, to the national total.

Outside of air emissions, produced water from gas wells is perhaps the most contentious environmental management issue confronting regulators and operators alike. Almost 3 billion barrels of produced water were extracted in Region 8 in 2002 and 2006, with Wyoming contributing nearly 70 percent of total produced water (from both oil and gas production).[63] Although gas production appears to have increased significantly from 2002 to 2006, produced water volumes have not experienced a similar increase due to changes in the mix of producing formations (e.g., CBM formations that yield high volumes of produced water versus CBM and tight sand formations that do not). Although produced water often has beneficial uses, water management and treatment, when necessary, can have negative impacts as well, such as streambed erosion brought on by produced water discharges.

In terms of wastes generated during production, Region 8 produced more than 46 million barrels of estimated drilling waste in 2006, an 80 percent increase compared to 2002. Wyoming produced the largest amount of estimated drilling waste, followed by Colorado and Utah. Construction of roads and operation of drilling rigs in wilderness and undeveloped areas are other highly visible and often controversial aspects of oil and gas production, particularly in pristine areas. In response to these concerns, regulators are attempting to find substantive ways to lessen potential impacts and reduce the industry's footprint in these areas.

As an example, in 2007, BLM proposed to manage 21,034 acres on top of the Roan Plateau in northwestern Colorado as Areas of Critical Environmental Concern (ACECs). According to BLM, the second of the agency's two proposed Records of Decision (RODs) governing industry development of the plateau entails the following land use requirements:

> "[V]irtually all of the acres of ACECs would be managed under no surface occupancy stipulations, which means no surface disturbance is allowed. When the proposed ACECs are taken with the additional 17,336 acres stipulated no surface occupancy in the first ROD, more than 50 percent of the planning area would be stipulated no surface occupancy."[64]

4.2 Summary of Initiatives to Address Oil and Gas Demand and Environmental Footprint Issues

A number of environmental management initiatives and industry leadership practices have been developed to try to balance the increasing demand for domestic fuel production with the need to reduce the potential environmental and safety impacts of oil

[63] Based on 2006 data.
[64] U.S. Bureau of Land Management, *First Record of Decision on Roan Plateau Plan*, June 8, 200, http://www.blm.gov/rmp/co/roanplateau/.

and gas production. BLM is in the process of focusing the development by requiring federal lease unitization, making operators achieve interim reclamation standards before further surface disturbance is authorized, and use of appropriate timing limitations in the lease stipulations based on wildlife disturbance thresholds.

Examples of such activities include, but are not limited to, studies that investigate the impacts of certain oil and gas activities and then suggest mitigation practices and voluntary approaches for achieving such reductions (e.g., regional working groups convened with the goal of reducing air emissions). These policies and practices are discussed briefly in the sections below and are grouped according to federal, state, and regional initiatives;[65] other ongoing analyses; and voluntary programs. Lastly, as previously mentioned, concerns regarding actual and potential public health impacts of oil and gas production have been raised but are beyond the purview of this study.

4.2.1 Federal Initiatives

The federal government has sponsored a number of initiatives related to the oil and gas industry. The following listing is a representative sampling of these efforts (some of which were previously referenced in this report):

- EPA has recently conducted a number of investigations into the impacts of oil and gas activities on domestic water supplies. As previously mentioned, one such study is part of OW's ongoing investigation into the CBM sector, which resulted in MOUs with hydraulic fracturing service companies[66]. Published in 2004, this study focused on whether the injection of certain hydraulic fracturing fluids into CBM wells can contaminate USDWs.[67]
- EPA is conducting a detailed review of the CBM extraction sector to determine if it would be appropriate to conduct a rulemaking to revise the effluent guidelines for the Oil and Gas Extraction Point Source Category (40 CFR 435) to control pollutants discharged in CBM-produced water.[68]
- To raise awareness and provide guidance for managing drilling wastes and other environmental impacts from oil and gas production, EPA's Office of Enforcement and Compliance Assurance (OECA) issued *Profile of the Oil and Gas Extraction Industry Sector Notebook*, an important guide that recommends a number of leadership practices for oil and gas exploration and production operations.[69] Examples of suggested practices include using a closed-loop drilling fluid system, which replaces a reserve pit with storage tanks; reusing drilling fluids; reducing storm water runoff impacts through the use of sediment traps, containment dikes, and other methods; and reusing or recycling drilling waste.

[65] Further details on these programs and policies can be found in Chapter 2 of the report.
[6666] U.S. Environmental Protection Agency, *EPA's Clean Water Act Review of the Coalbed Methane Industrial Sector,* June 2007, http://www.epa.gov/guide/304m/2008/cmb-slides.pdf, accessed 08.19.08.
[67] EPA, *Evaluation of Impacts of Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs*, EPA 816-R-04-003, 2004, http://www.epa.gov/safewater/uic/pdfs/cbmstudy_attach_uic_exec_summ.pdf.
[68] http://www.epa.gov/fedrgstr/EPA-WATER/2008/January/Day-25/w1344.htm.
[69] EPA, OECA, *Profile of the Oil and Gas Extraction Industry Sector Notebook, Chapter 5, Pollution Prevention Opportunities*, http://www.epa.gov/oecaerth/resources/publications/assistance/sectors/notebooks/oilgaspt2.pdf.

- BLM has been working with western surface land owners to resolve numerous issues related to federal mineral rights. Such split estate issues remain contentious and are a major focal point within BLM and other agencies overseeing production. The BLM Colorado State Office is working to improve its interim reclamation standards that would reduce the time needed to restore the surface disturbance to minimally "healthy" rangeland condition.
- FWS, through its Refuges Annual Performance Plan (RAPP), is working to protect wildlife in Region 8 from various activities, including oil and gas production.

4.2.2 State Initiatives

In addition to federal activities, there are numerous state initiatives related to curbing the environmental footprint from the oil and gas industry. The following represents only a partial list of some of the more noteworthy state efforts:

- States such as Colorado, Montana, and Wyoming have implemented CBM discharge standards to control and reduce produced water impacts.
- Colorado has implemented more stringent VOC standards, primarily in response to the rapid increase in oil and gas production depicted in this report.
- As noted in Section 2.3.1 and summarized in Section 4.2.3 below, many western states participate in a variety of regional air quality and climate initiatives. Colorado, Utah, and Montana have all developed Climate Action Plans, and Utah and Montana have joined the Western Climate Initiative, a regional effort to reduce GHG emissions.

4.2.3 Regional Initiatives

As noted previously, most policy activity concerning air emissions revolves around voluntary regional organizations such as the following:

- WRAP, which tracks emissions to help meet regional haze requirements;
- WESTAR, which has issued a number of BMPs for oil and gas operations; and
- WCI, which seeks to reduce GHG emissions in the western United States.

4.2.4 Other Ongoing Analyses and Policy Initiatives

Although this report mentions various federal, state, and regional programs designed to reduce the environmental footprint of oil and gas production (in Region 8 and nationally), Congress, NGOs, and other "watchdog" organizations are scrutinizing industry operations as well as tax and regulatory exemptions being proposed or currently in place. Regulators are being pressured to implement incremental leasing approaches to reduce both the impacts and pace of expanding oil and gas development (in Region 8 and elsewhere) without sacrificing potential oil and gas royalties, state revenue streams, employment, and other relevant socio-economic considerations. There is increased focus on wildlife protection zones, and BLM is designating select areas as ACECs in its efforts to manage valuable and often vulnerable natural resources more effectively.

4.2.5 Voluntary Programs

Many of the aforementioned policies and studies have sought to identify and mitigate the effects of oil and gas production on the environment. Expansion of compliance monitoring and enforcement action is ongoing, but there are also many opportunities for voluntary activities to mitigate environmental impacts for the industry. As conventional resources continue to be depleted and market considerations for unconventional development remain favorable, regulators are moving to develop and implement policies and programs that will lessen and potentially prevent future environmental impacts. The following voluntary programs are especially noteworthy and are already having a positive influence on industry's environmental management and approaches:

- EPA's Natural Gas STAR program;
- Occupational Safety and Health Administration's (OSHA) Voluntary Protection Programs (VPP);
- The San Juan VISTAS program;
- The Wyoming Voluntary Remediation Program (VRP); and
- The Four Corners Air Quality Task Force.

Each of these programs provides incentives, either implicitly as reduced emissions and increased product sales or explicitly as operational leeway such as reduced monitoring, to program participants. Such voluntary approaches encourage stewardship of the resources available to the oil and gas industry, while contributing to environmental protection and have been an effective complement to regulatory compliance and enforcement. Table 4-2 provides additional information on each of these programs.

Table 4-2. Summary of Voluntary Environmental Programs Available to the Oil and Gas Sector

Program Attributes	Natural Gas STAR	OSHA VPP	San Juan VISTAS	Wyoming VRP	Four Corners Air Quality Task Force
Objectives	Identify and promote the implementation of cost-effective technologies and practices to reduce methane emissions	• Promote effective workplace health and safety (in many cases, this translates into reduced environmental impact as well) • Enable companies to be better stewards of their operations by prioritizing government enforcement resources for oversight of higher risk establishments	Identify, promote, and implement cost-effective technologies and practices to reduce air pollution affecting northwestern New Mexico	Set up a process for owners or potential developers of contaminated sites • To determine actions required for remediation quickly • To put contaminated sites back into productive reuse	Address air quality issues in the Four Corners region, increase air pollution awareness, and consider options for mitigating air pollution
Pollutants Under Purview	Methane (CH_4)	Focuses on health and safety	VOCs, CO, NO_x, SO_2, all gases that affect ozone and haze, and GHGs	All types of land and water contamination	VOCs, CO, NOx, SO_2, all gases that affect ozone and haze, and GHGs
Partners	110+ partners across the four sectors of the oil and gas industry (production, processing, transmission, and distribution); 8 international partners; and 19 endorser organizations	All groups covered by OSHA, including federal agencies	Private and public entities: industries, businesses, municipalities, organizations and community groups	Not applicable—there are no partners, *per se*, but the program is designed to support owners, operators, and purchasers of contaminated sites	100+ members (private citizens, public interest groups, universities, industry, and federal, state, local and tribal governments) and 150 interested parties
States	All states, including Region 8 states	All states, including Region 8 states	New Mexico (but lessons learned are presumably applicable to Region 8 and other oil and gas producing states)	Wyoming	Arizona, Colorado, New Mexico, and Utah (i.e., the Four Corners region)
Partner Benefits	• Efficient and new technologies save partners operational costs • Reduction in methane emissions (primarily fugitives) • Additional revenues from saved methane emissions • Recognition as environmentally sensitive institution	• "Star demonstration" sites evaluated every 12 to 18 months • "Merit" sites evaluated every 18 to 24 months • "Star" sites evaluated every 3 to 5 years	• Lower production costs due to efficient technology use • Pollution reduction • Capture more product for market sale • Recognition from the VISTAS program as Clean Air Partner (press release, advertisements, articles, and awards)	• Provides three types of liability assurances: 1. Covenants not to sue 2. Certificate of completion 3. No further action (NFA) letters • Brownfield assessment assistance	Reduction in air pollution
Program Outreach/ Resources	• Technology transfer workshops for all sectors of the oil and gas industry • Annual implementation workshop • Technical documents • Feasibility studies • Partner challenge study, identifying opportunities	• "Special Government Employee" (SGE) program to extend government resources and expertise • Mentoring • Safety and health management course	• Technology transfer workshops • Outreach materials • Assist partners with technology and practice implementation by analyzing opportunities, where applicable	Various fact sheets	• Quarterly meetings • Workgroup participation • Outreach material

Program Attributes	Natural Gas STAR	OSHA VPP	San Juan VISTAS	Wyoming VRP	Four Corners Air Quality Task Force
Achievements	• Partners have eliminated over 575 Bcf of methane emissions since the program's establishment • Methane emissions reductions of approximately 86 Bcf were achieved by partners in 2006 • Additional revenue of more than $600 million in natural gas sales was generated	The Days Away Restricted or Transferred (DART) case rate is 52% below industry average for average participant worksite	Not ascertained	Over 90 sites have registered with the program so far	• 125 mitigation options developed by members in 2 years • Increased air pollution awareness • Provided resources to agencies responsible for air quality management in the Four Corners area

Appendix A: Industry Characterization

A.1 Industry Description

As shown in Table A-1, the following North American Industrial Classification System (NAICS) codes were included in this analysis of oil and gas production issues and associated environmental impacts:

Table A-1. NAICS Codes Addressed in This Analysis

NAICS	Description
2111	Oil and Gas Extraction
211111	Crude Petroleum and Natural Gas Extraction
211112	Natural Gas Liquid Extraction
213111	Oil and Gas Drilling
213112	Support Activities for Oil and Gas Operations

In addition, as shown in Table A-2, the following Standard Industrial Classification (SIC) codes were included in this analysis:

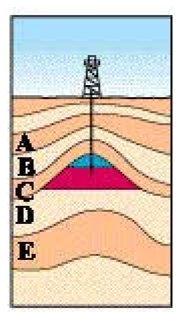
Table A-2. SIC Codes Addressed in This Analysis

NAICS	Description
1311	Crude Petroleum and Natural Gas
1321	Natural Gas Liquids
1381	Drilling Oil and Gas Wells
1382	Oil and Gas Field Exploration Services
1389	Oil and Gas Field Services, not elsewhere classified

In general, upstream oil and gas industry activities include seismic and geological data acquisition and interpretation, leasing and permitting, drilling activities, workovers and recompletions, and production operations. Workovers and recompletions are operations that work to increase or improve recovery of oil and natural gas from existing wells. As defined here, production operations encompass an array of activities that are needed to gather and process the oil and gas prior to transport and sale.

Oil is found and extracted from geological formations in which the hydrocarbons are trapped in a porous formation below an impermeable cap rock (Figure A-1). These conventional formations have high permeability, which allows the oil and gas to flow freely to the wellhead. Generally, one or a small number of wells are adequate to recover oil and gas from subsurface formations.

Figure A-1. Conventional Oil Formation



Conventional wells typically range from 3,500 to 10,000 feet deep, and some are even deeper. In Wyoming, for example, some conventional wells are as much as 24,000 feet deep. Natural gas and water are typically trapped in the same formation and are produced along with the oil. Natural gas produced from an oil reservoir is known as "associated gas" and is typically separated from the oil and subsequently processed and then transferred to pipelines for sales and distribution. Water from the formation is known as "produced water" and is disposed of during production, recycled, or reused. Water from conventional oil formations often contains concentrations of hydrocarbons as well as chemicals associated with drilling processes. Produced water can be a valuable resource; beneficial uses include irrigation applications (e.g., water for center pivot irrigation), drinking water for livestock, and so forth.

Non-associated gas, representing the majority of domestic gas production, is natural gas that is extracted independently from oil production. There are several categories of non-associated gas:

- **Conventional gas** is natural gas found in high-permeability formations that allow the hydrocarbons to flow freely to the wellhead (similar to formations containing conventional oil).
- **Tight gas** is defined as natural gas production from low-permeability, or tight, reservoirs. Such reservoirs have very small pore spaces between the sandstone grains, and these characteristics prevent the gas from flowing freely to the wellbore. It is generally necessary to stimulate the pore spaces artificially, enabling the gas to flow from the formation to the wellhead.
- **Coal bed methane (CBM)** is natural gas produced from coal seams and represents a substantial—and ever growing—percentage of domestic gas production, especially in Region 8. In general, CBM wells are typically only 1,000 to 4,000 feet deep and require artificial stimulation to free up and direct the gas to the wellhead.
- **Shale gas** is another form of natural gas experiencing rapid growth in production across Region 8 and in other gas producing regions (e.g., the Barnett Shale in Region 6). Shale is also a low-permeability formation, and natural gas production requires artificial stimulation (discussed in greater detail in Section A.1.1 below).

Relevant oil and gas development activities that tend to generate the most substantive environmental impacts include field development drilling and subsequent production (including gas processing). Development drilling generally involves completion of numerous wells, while production operations can impact an area for many years as oil and gas continue to be extracted from the subsurface and processed above ground. These activities are described below in Sections A.1.1 through A.1.3.

A.1.1 Drilling and Well Operations

The major activities involved in drilling and completing an oil or gas well include: (1) site preparation, (2) casing and cementing, (3) drilling, and (4) stimulation and completion.

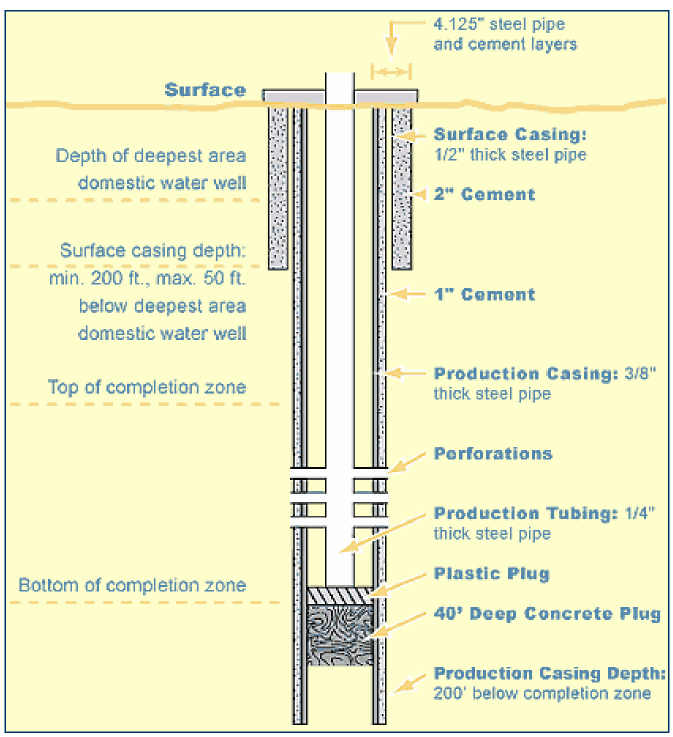
Site Preparation

Site preparation involves surveying and permitting, road and well pad construction, and reserve pit excavation. Surveying is carried out to ensure the proper location and boundaries of the well site. Road and pad construction involves construction of an access road to the well site as well as grading and leveling of the well pad. A well pad must be large enough to accommodate various construction and service company equipment (typically several acres), and adjacent reserve pits hold fluids that are used and extracted during drilling operations. Unlike conventional gas extraction, the low permeability of unconventional formations requires more wells and tighter well spacing to recover resident natural gas reserves. Horizontal drilling techniques tend to offset associated surface disturbances to some degree by enabling multiple wells to be drilled from a single well pad. New road construction and subsequent vehicular traffic (often in ecologically sensitive wilderness areas) are perhaps the most visible surface disturbances associated with natural gas production in Region 8.

Casing and Cementing

Prior to initiating drilling operations, surface conductor casing is constructed. Casing is similar to drill pipe, but larger. In addition, casing is designed to be cemented into the well to preserve well integrity and protect underground sources of drinking water (USDWs) (Figure A-2). Conductor casing of about 20 inches in diameter is first set, and as the well is drilled toward its ultimate depth, progressively smaller strings of casing are cemented inside the earlier strings. In this manner, portions of the well that have already been drilled are sealed off for safety, wellbore integrity, and protection of USDWs.

Figure A-2. Wellbore and Casing



Drilling

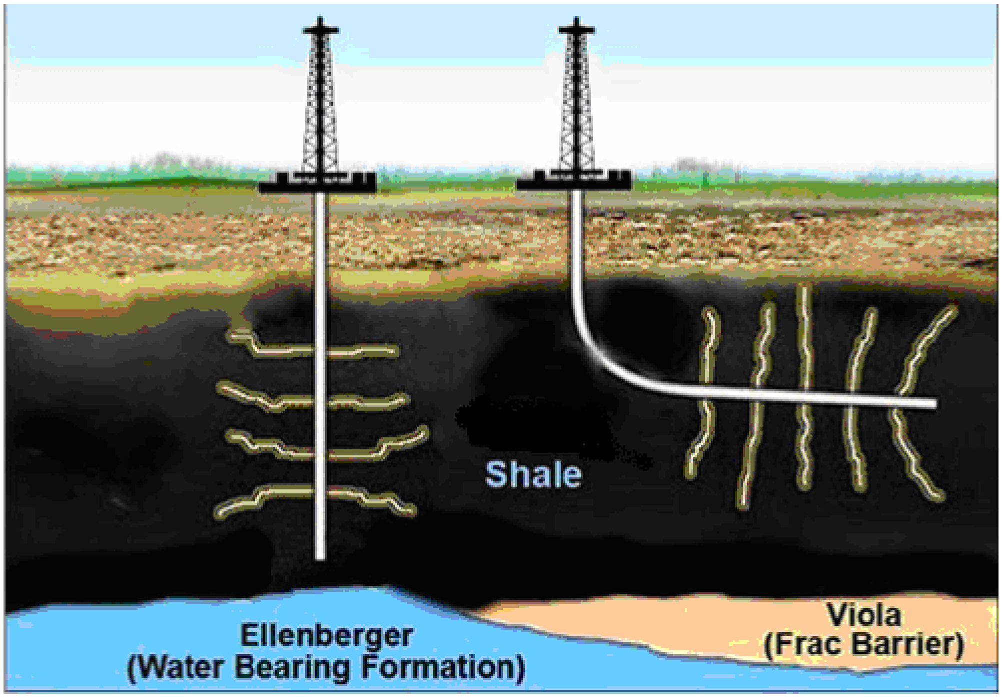
Historically, domestic drilling has been dominated by rotary rigs that create vertical wellbores. Rotary rigs are powered by diesel engines and use a rotating string of drill pipe to turn a drill bit against the rock interface. Drilling fluids or muds are pumped downward via the drill pipe and circulated back to the surface to remove rock cuttings. In addition, drilling fluids and muds help to control pressure ratios from within the wellbore, and the amount of fluid system pressure is typically adjusted by varying their relative density. Various types of fluid systems can be used, including water-based and oil-based muds. The density of the drilling fluid depends on the pressure gradient and other characteristics of the formation being targeted. In some cases, drilling is carried out in a slightly underbalanced, or lower pressure, condition to minimize formation damage and improve production flow. Drilling muds and well cuttings are gathered in lined surface pits during drilling operations. When they are no longer useful, these drilling byproducts are removed from the production site and either disposed of (e.g., landfilled) or converted for one or more beneficial uses. For example, drill cuttings have been used as an alternative to gravel in construction or cement manufacturing.

In the last 15 years or so, onshore directional and horizontal drilling have represented a growing percentage of oil and gas exploration and production activities. Directional drilling allows the operator to use a small surface well pad and drill outward to access a large portion of the reservoir. Such directional techniques reduce surface disturbances and in many cases improve overall project economics. Directional drilling is used extensively in areas such as the Jonah-Pinedale tight gas field in Wyoming and is planned for future tight gas development in other locations (e.g., northwestern Colorado's Piceance Basin, the Bakken shale fields in Montana and North Dakota; etc.).

In addition, increased targeting of unconventional reservoirs in Region 8 has resulted in more horizontal drilling activities. Horizontal drilling features techniques that shift the wellbore from a vertical to a horizontal orientation within the target reservoir (Figure A-3). The horizontal drilling allows wellbore contact with thousands of feet of reservoir and is generally done in conjunction with well stimulation along the horizontal borehole. Such drilling methods are being used extensively in shale gas as well as CBM production operations. Horizontal drilling is also used in certain oil production operations (e.g., in the Williston Basin of North Dakota).

In recent years, variants of horizontal drilling have been developed, and elaborate subsurface drilling patterns are used to more efficiently tap CBM. These methods, including "pinnate drilling," drill numerous subsurface wellbores parallel to the coal seam. Initial pinnate drilling applications have focused on the Appalachian Basin, although they have potential in the Rocky Mountain region as well. Attractive features of these approaches include the potential to improve project economics and to reduce greatly surface disturbances and associated environmental impacts.

Figure A-3. Horizontal Drilling



Stimulation and Completion

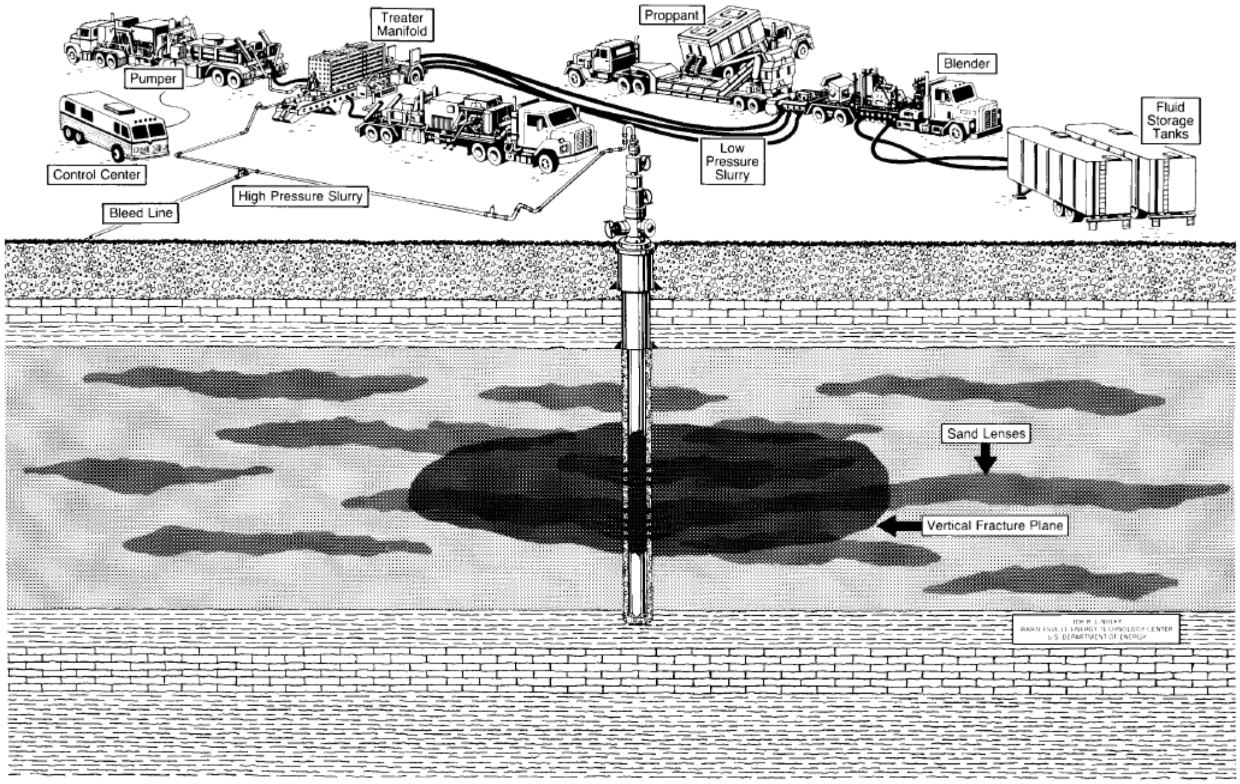
After the well has been drilled to total depth, a string of production casing is cemented in. This allows the hydrocarbons to be produced while protecting USDWs. The production casing also enables the well to be sealed off from the surface if there is a problem.

Most unconventional gas reservoirs are subject to stimulation operations to improve flow to the wellbore. Hydraulic fracturing is the most commonly used method of gas well stimulation (Figure A-4). The first aspect of hydraulic fracturing is to perforate the production casing with projectiles and subsequently pump a water-based solution into the formation through the perforated areas. Water is pumped into the reservoir at pressures up to 10,000 pounds per square inch, inducing fractures in the formation. In addition, materials such as silica sand are pumped in to prop the fractures open, allowing natural gas to flow more freely to the wellbore.

Tight sand fracturing in the Rocky Mountain region typically involves stimulation of many zones in a well with spacing intervals of up to thousands of feet between them. In shale formations such as the Barnett Shale in northern Texas, several separate fractures are carried out within the horizontal portion of the well. Fracturing is typically accomplished with large truck-mounted pumps that are powered by diesel engines.

Figure A-4. Hydraulic Fracturing[1]

Hydraulic fracturing is a means of creating fractures emanating from the well bore in a producing formation to provide increased flow channels for production. A viscous fluid containing a proppant such as sand is injected under high pressure until the desired fracturing is achieved. The pressure is then released allowing the fluid to return to the well. The proppant, however, remains in the fractures preventing them from closing.



A.1.2 Gas Production and Processing

Once a well has been stimulated and completed, natural gas operations move into the production phase. Initial production of gas generally begins as natural flow from the wellhead into the gathering system. As a field matures, there is a decline in reservoir pressure. Natural gas wells flow gas to the surface until abandonment, but in some cases gas compression equipment is required to reduce backpressure and increase flow rates.

In most cases, raw gas streams must be treated prior to introduction into the pipeline system. Heavy liquids such as butane are removed near the well site as lease condensate. Gas may also contain non-hydrocarbons such as carbon dioxide (CO_2), hydrogen sulfide (H_2S), or nitrogen. Nitrogen and CO_2 are inert gases and have the undesirable effect of reducing the heating content of the gas. These non-hydrocarbons are removed if they are present in sufficient concentrations to degrade the quality of natural gas being processed. Natural gas is gathered and sent to processing plants for removal of these constituents. Gas processing plants include combustion units (internal combustion (IC) engines and turbines) and chemical process units that produce nitrogen oxides (NO_x), volatile organic compounds

[1] U.S. Department of Energy (DOE), Enhanced Oil Recovery (EOR) Research Program.

(VOCs), and particulates. Storage facilities for oil and other liquid hydrocarbons may also release fugitive VOC and methane (CH_4) emissions.

Region 8 is an arid region, typically subject to drought. CBM gas production produces large volumes of water from the coal bed formation that must generally be pumped out, treated, reused, and/or disposed of in some manner. Disposal of produced water is one of the other major visible impacts of gas production in Region 8. Water disposal may consist of surface discharge with or without treatment, or injection into a porous formation via injection well. Salts are among the most common produced water impurities, and the high sodium content of the brine presents environmental management challenges. Such water quality characteristics determine whether the water can be discharged into local rivers and streams, used for irrigation, or must be treated or specially disposed of.

In addition, treatment can include evaporation ponds or processing that reduces the salinity of produced water prior to further disposition. For example, with surface discharges throughout the Powder River Basin of northeastern Wyoming, operators and permitting authorities alike need to ensure recipient streams and rivers are able to accommodate variable chemical characteristics and concentrations of produced waters. These issues are complex, and considerations include assessing the volume of water being produced, the flow rate of streams (i.e., ephemeral or perennial), and the compositional characteristics of the water. In some cases, the key environmental issue is simply the large volume of produced water that must be effectively managed to prevent runoff or erosion problems.

Generally, tight gas and shale gas development are not challenged by significant water volumes and production that originate in the subsurface (as is generally the norm with CBM gas production); however, water used in hydraulic fracturing processes must be provided for (often transported in and out of production sites by truck) and subsequently treated, recycled, or disposed of. Such process water is typically in much smaller quantities than produced water from conventional oil and gas formations or natural gas production from CBM wells.

A.1.3 Oil Production and Processing

Crude oil either flows to the wellhead under natural reservoir pressure or is pumped to the surface with a pumping unit. At the surface, production activities yield variable quantities of crude oil as well as associated natural gas and formation water. The water is generally saline and may also contain hydrocarbons. Oil and gas are separated near the wellhead by separator units (i.e., horizontal or vertical cylindrical vessels with baffles that provide filtration). The associated gas may be further processed following separation to remove liquids and moved offsite by gas pipeline, or some or all of the gas may be used on location to power production equipment. In addition, associated gas may be re-injected into the formation to maintain reservoir pressure.[2]

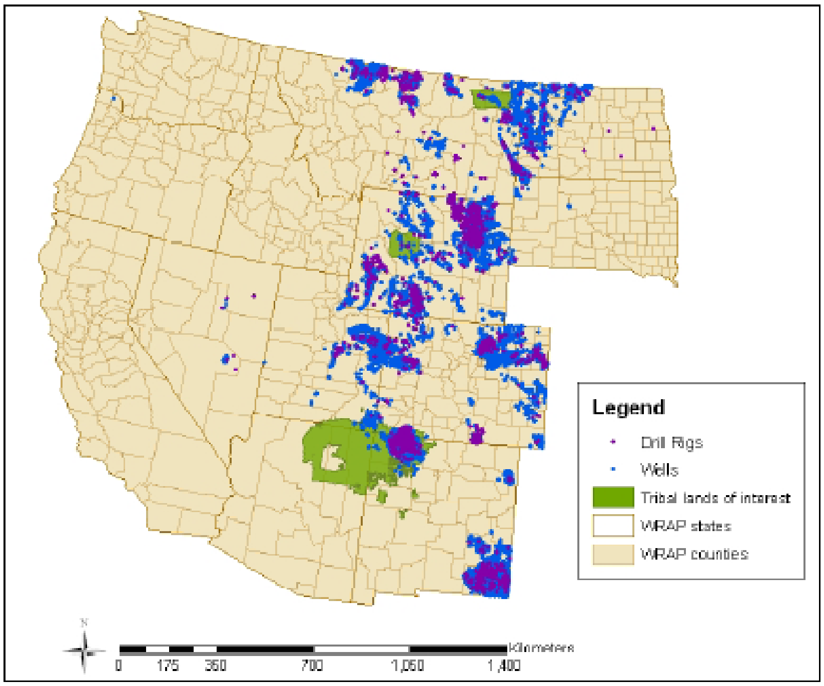
[2] Note: Prudhoe Bay, Alaska, production operations often employ these approaches to maintain reservoir pressure and augment hydrocarbon flow rates.

Produced water from formations yielding crude oil is generally corrosive and therefore removed prior to product transportation and storage. Water is drained at gathering stations and at oil storage tanks in the field area. Prior to pipeline transport, a glycol dehydration unit is used to remove the remaining water from the oil. After on-site processing, crude oil may be temporarily stored in tanks near the field or transported to a bulk storage terminal within the area. The oil is then transported to a refinery by pipeline or in some cases by trucking if a suitable pipeline is not available.

A.2 Regional Oil and Gas Production Trends

Oil and gas production has historically been concentrated in a few regions of the United States based on the location of the geological resource. The Appalachian region was the first oil and gas producing area in the country. Other early producing areas included the Michigan-Illinois Basin and the Mid-Continent. For many years the predominant producing regions have been the Texas-Louisiana region (including the San Juan and Permian Basins) and the Gulf of Mexico. However, recent years have seen substantial growth in the Rocky Mountains (Figure A-5).

Figure A-5. Rocky Mountain States Oil and Gas Producing Regions



Region 8 comprises much of what is generally called the Rocky Mountain oil and gas province. Some of the Rocky Mountain region resides outside Region 8, primarily the San Juan Basin in northwestern New Mexico. Region 8 also includes Montana and the Dakotas. Most of Montana has geological characteristics of the Rocky Mountain oil and gas province, but eastern Montana and North Dakota are part of a separate geological province called the Williston Basin.

Presently, oil and gas production is underway in Colorado, Utah, and Wyoming, as well as Montana, North Dakota, and South Dakota. However, Region 8 is dominated by natural gas production, and oil production is secondary at the moment. The Rocky Mountain region is a major gas producing province and is forecast to be even more important for future domestic gas production through 2030 and beyond. Conventional oil production has actually been in decline, and oil production is concentrated in the Denver Basin of eastern Colorado, the Uinta Basin of northeastern Utah, and the Bakken shale field of Montana and South Dakota.

Given the commercial potential of shale oil in the region, oil production has vast energy supply implications for the future. Large oil shale deposits are present in western Colorado, northeastern Utah, and southwestern Wyoming, and may be developed in coming decades. The oil shale deposits were the focus of a previous industry technology development and pilot project in the 1970s and 1980s, but for various technical and other reasons, commercial production never materialized.

The Rocky Mountain region has geological characteristics that make it very different from other oil and gas producing regions, such as the Gulf Coast. The Gulf Coast and Gulf of Mexico generally produce oil and gas from conventional high-porosity, high-permeability oil and gas reservoirs. High porosity and permeability mean that the oil and gas in the formation can easily flow into the production well. Conventional reservoirs are generally defined as high-porosity formations that contain well-defined contacts between oil, gas, and water and can be produced using standard methods. In contrast, current activity in Region 8 is focused on unconventional natural gas formations, and extracting these resources has significant water use implications. To extract the resource from tight gas or shale gas formations successfully, fractures are opened with pressurized water, requiring water use (which must be recycled, reused, and/or disposed of) as well as greater surface disturbance from heavy trucks and other specialized equipment. As fracturing only releases gas within a certain distance of the drill bore, multiple horizontal bores must be drilled into the formation. Although improvements in drilling technology mean that multiple bores can be drilled from a single well site, unconventional resource extraction is generally associated with a higher number of well sites per acre than conventional extraction. However, as tight gas and shale gas formations do not contain large volumes of water, product extraction from these formations does not create significant produced water issues.

Table A-3 shows oil and gas production in Region 8; note that numbers may not add due to rounding. In 2002, the region produced nearly 3.3 trillion cubic feet (Tcf) of natural gas and 137 million barrels of oil, compared to total U.S. production of almost 19 Tcf of gas and 2 billion barrels (Bbls) of oil. Most natural gas production occurred in Wyoming and Colorado, as these two states represent 86 percent of total gas produced in the region in 2002. Wyoming produced slightly more than Colorado during this year. Gas production in Wyoming and Colorado is increasing rapidly, and these states are expected to be the location of most future growth in gas production in the United States. Oil production is dominated by Wyoming and North Dakota. Wyoming accounts for approximately one-third of the total oil production in the region, while North Dakota is next in line at about 19 percent. South Dakota produced the least amount of gas and oil among Region 8 states.

Table A-3. Total Oil and Gas Production in Region 8, 2002

State	Gas (million cf)	Oil (1,000 Bbls)
WY	1,776,311	54,872
CO	1,045,365	18,696
UT	292,752	13,767
MT	86,304	16,860
ND	57,783	29,670
SD	32,072	3,061
Region 8 Total	3,290,588	136,928
U.S. Total	18,927,788	2,097,124

Figures A-6 and A-7 illustrate regional gas and oil production trends in the lower 48 states from 1998 to 2005. In recent years, natural gas production has grown by approximately 50 percent in the Rocky Mountain region, while it has been flat or declining in most other regions. Oil production in the Rocky Mountain region is small compared with other regions and shows no significant growth trend.

Figure A-6. Total Dry Gas Production in the Lower 48 by Region, 1998—2005

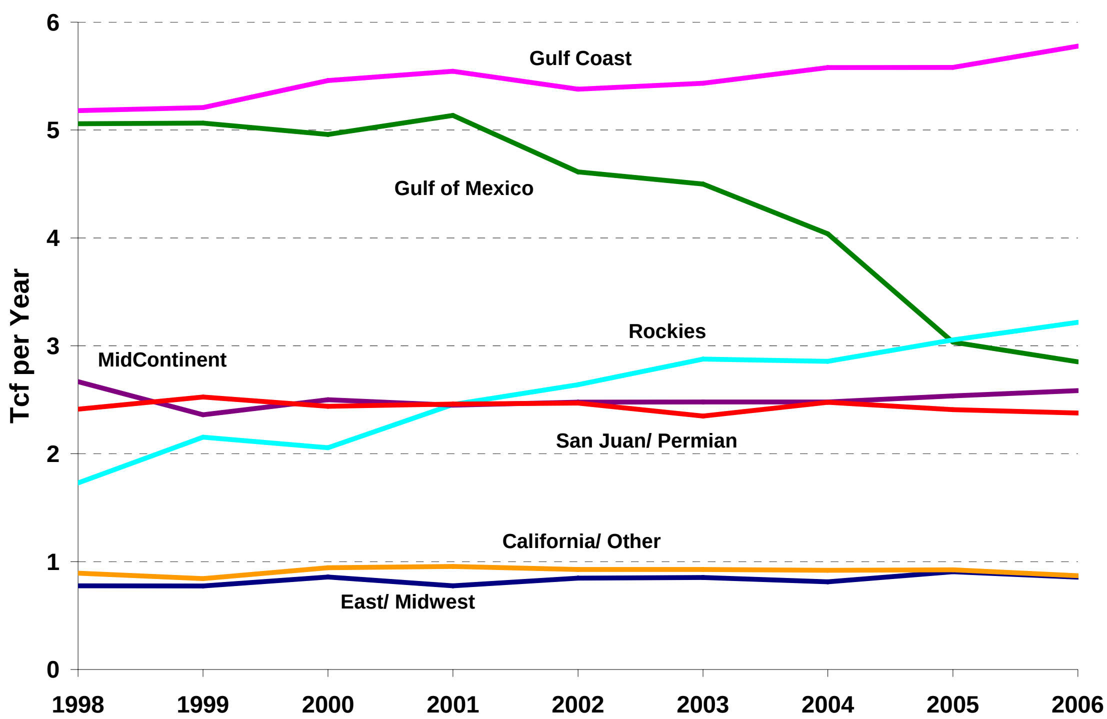
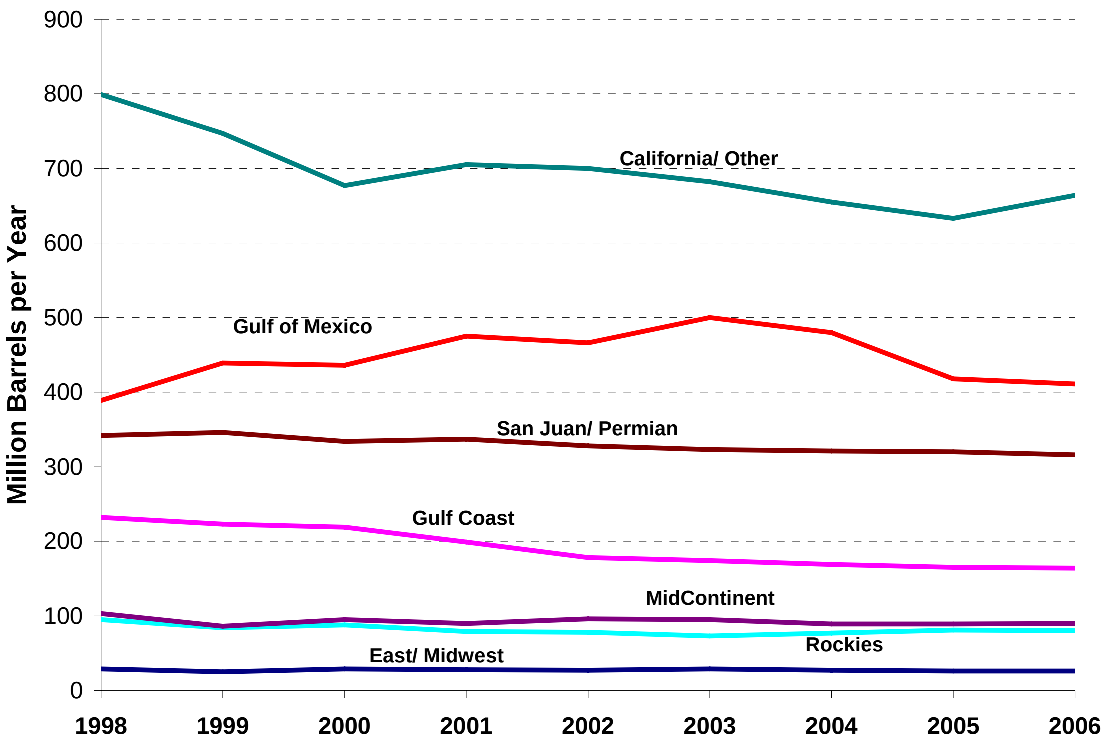


Figure A-7. Total Crude Oil Production in the Lower 48 by Region, 1998—2005



Undeveloped natural gas resources in the Rockies are found primarily in tight gas sands. These sands are widely distributed as basin center deposits, and accumulations are found in areas such as the Green River Basin of southwestern Wyoming and the Piceance Basin of northwestern Colorado. They are characterized by enormous amounts of in-place gas resources distributed across a depth of thousands of feet and present throughout the central portion of major basins. It is this gas that is now being drilled and will be the focus of future production. Recoverable resources in Rocky Mountain tight sands have been assessed to be in the hundreds of Tcf of gas, compared to current proved reserves of about 190 Tcf for the United States as a whole. The magnitude of the resource means that the current expansion in extraction activities is likely to continue for decades.

The Rocky Mountain region is also the location of two of the most prolific CBM basins in the world: the San Juan Basin in southwestern Colorado and northwestern New Mexico, and the Powder River Basin in eastern Wyoming. The San Juan Basin produces from the Fruitland coal formation. This formation was the initial major area of CBM production in the Rockies and is characterized by large volumes of water that are produced with the gas (produced water), most or all of which is typically re-injected for disposal. The Powder River Basin gained prominence for CBM production in the 1980s and produces about 1 billion cubic feet (Bcf) per day. This basin produces from younger, shallower coal beds than those in the San Juan Basin. To date, almost all of the produced water has been surface discharged, rather than injected, which can impact surface water quality and contribute to streambed erosion.[3] Efforts to develop significant CBM elsewhere in the Rockies, including central Utah and southwestern Wyoming, have had variable success.

In a recent accounting, there were approximately 17,000 producing coal bed wells in the Powder River Basin and about 150 in southwestern Wyoming. Powder River Basin coal beds are shallower than in other areas, necessitating drilling a large number of vertical wells across a large area. As mentioned previously, the number of wells needed to develop CBM is a function of depth, water characteristics, number of seams, and other factors.

Natural gas resource development in the region has been the focus of an environmental debate, because in order to develop the reserves, thousands of new gas wells must be drilled in areas that have not seen much drilling activity. Much of the land is administered by the U.S. Bureau of Land Management (BLM) and is subject to federal control. This has created conflicts between energy development interests and environmentalists over resource access, water rights, wildlife, and other issues. The growing population of the region has also been a factor, and oil and gas development has become a focus of debate.

A.2.1 Recent Trends in Rocky Mountain Oil and Gas Production

Figures A-8 through A-9 and Table A-4 summarize recent trends in Rocky Mountain oil and gas industry activity and compare regional activity with total activity across the United States; note that numbers in Table A-4 may not add due to rounding. These figures and data show trends in total oil and gas production from 2000 to 2005 for new oil and gas well completions, as well as the total number of producing oil and gas wells in 2006. These data highlight the region's rapid growth in extraction activity, particularly for natural gas.

Figure A-8 shows that the Rockies represented about 17 percent of total U.S. gas production in 2005, up from 11 percent in 2000. Almost all of the production increase has been in Colorado and Wyoming, where it is primarily due to development of tight gas and CBM. The Rockies represent only about 6 percent of total U.S. oil production, and this fraction has not changed significantly in recent years. However, this percentage could increase in coming years with the increased use of enhanced oil recovery.

[3] Not all CBM is associated with large amounts of co-produced water. In Alberta, for example, a coal bed formation that does not produce significant water with the gas is being extensively developed.

Figure A-8. Comparison of U.S. and Rockies Gas Production, 2000—2005

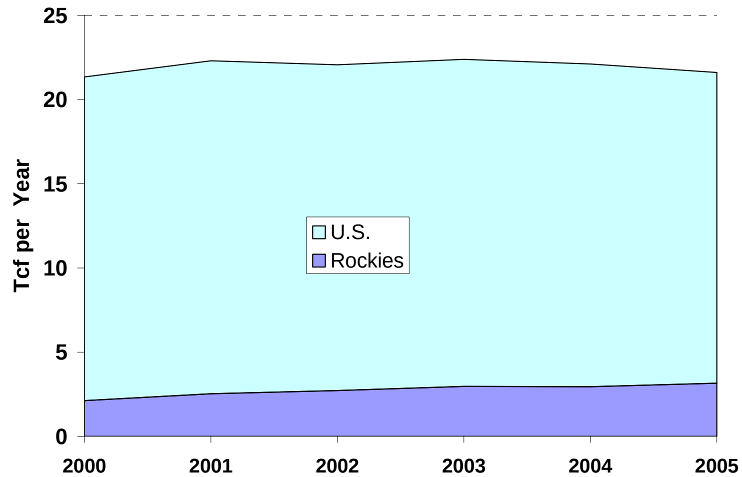


Figure A-9 shows that there were approximately 7,900 gas wells completed in the Rockies in 2005, representing 29 percent of total U.S. completions. In recent years this percentage has declined, from 38 percent in 2000. However, this is somewhat of a statistical aberration caused by the dominance of CBM drilling in Wyoming's Powder River Basin, which has declined slightly since peaking several years ago. The growth in Rockies activity would be more apparent if viewed over a longer period.

In terms of new oil wells, the Rockies represent about 13 percent of national activity. This fraction has increased from 5 percent in 2000 due to increased activity, e.g., in Colorado's Denver Basin and the Uinta Basin of Utah.

Figure A-9. Comparison of U.S. and Rockies Gas Well Completion, 2000—2005

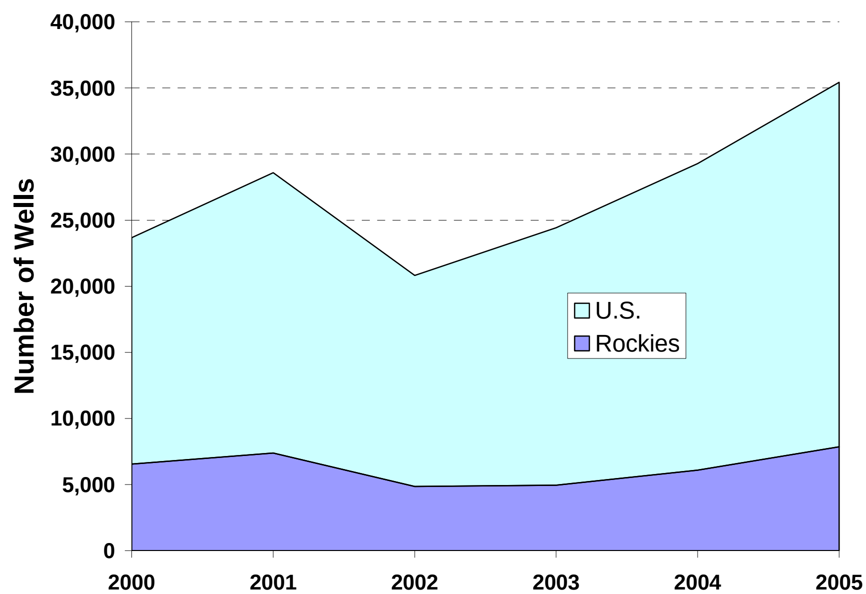


Table A-4. Oil and Gas Production and Drilling Activity in the Rockies

Rockies and U.S. Dry Gas Production

Billion Cubic Feet per Year

	CO	UT	WY	MT	Rockies Total	U.S. Total	Rockies Percent of U.S.
2000	759	226	1,070	67	2,122	19,219	11%
2001	882	288	1,286	73	2,529	19,779	13%
2002	964	286	1,388	77	2,715	19,353	14%
2003	1,142	278	1,456	86	2,962	19,425	15%
2004	1,050	282	1,524	95	2,951	19,168	15%
2005	1,104	308	1,642	100	3,154	18,458	17%

Rockies and U.S. Crude Oil Production

Million Barrels per Year

	CO	UT	WY	MT	Rockies Total	U.S. Total	Rockies Percent of U.S.
2000	17	14	54	15	100	1,880	5%
2001	16	13	48	16	93	1,915	5%
2002	17	12	46	18	93	1,875	5%
2003	16	12	42	19	89	1,877	5%
2004	18	13	43	22	96	1,819	5%
2005	19	15	45	30	109	1,733	6%

Rockies and U.S. Annual Completed Gas Wells

	CO	UT	WY	MT	Rockies Total	U.S. Total	Rockies Percent of U.S.
2000	920	365	4,888	384	6,557	17,126	38%
2001	1,344	484	5,249	318	7,395	21,202	35%
2002	1,270	351	2,942	296	4,859	15,970	30%
2003	1,490	274	2,679	508	4,951	19,482	25%
2004	1,736	301	3,617	435	6,089	23,193	26%
2005	2,496	438	4,356	578	7,868	27,562	29%

Rockies and U.S. Annual Completed Oil Wells

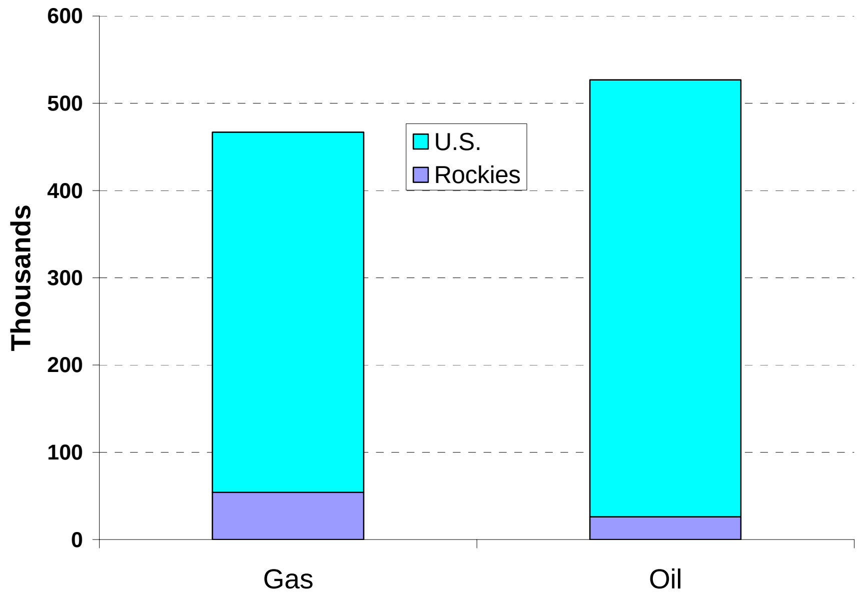
	CO	UT	WY	MT	Rockies Total	U.S. Total	Rockies Percent of U.S.
2000	73	84	145	75	377	8,209	5%
2001	34	106	127	163	430	8,934	5%
2002	21	40	90	144	295	6,929	4%
2003	36	117	154	225	532	8,135	7%
2004	312	299	413	287	1,311	11,170	12%
2005	406	355	518	361	1,640	12,734	13%

2006 Producing Oil and Gas Wells

	CO	UT	WY	MT	Rockies Total	U.S. Total	Rockies Percent of U.S.
Gas	19,993	5,012	25,052	4,078	54,135	413,174	13%
Oil	7,567	2,401	10,205	5,862	26,035	500,785	5%
Total	27,560	7,413	35,257	9,940	80,170	913,959	9%

In 2006, the Rockies had a total of 54,100 producing gas wells and 26,000 producing oil wells, shown in Figure A-10. This represents 13 percent and 5 percent of the U.S. totals, respectively.

Figure A-10. Total U.S. and Rockies Oil and Gas Producing Wells, 2006



In 2002, a total of almost 22 million feet of wells was drilled in Region 8. Table A-5 shows total footage of wells drilled by state; note that numbers may not add due to rounding. Wyoming reported the largest drilling footage at 8.5 million feet, followed by Colorado, with slightly over 7 million feet.

In 2002, there were over 72,000 gas and oil wells in Region 8. Table A-6 presents data on the total number of wells and the average well depth by state; note that numbers may not add due to rounding. The number of wells is an indicator of the drilling activity and related emissions. Deeper wells require longer drilling times and produce more drilling waste. Wyoming has the greatest number of wells, followed by Colorado. South Dakota reports the fewest number of wells. On average, the deepest wells are in North Dakota, while Montana has the shallowest wells. Overall, the region has an average well depth of 5,848 feet.

Table A-5. Footage Drilled by State in Region 8, 2002

State	Feet
WY	8,531,181
CO	7,055,372
UT	2,698,645
MT	1,803,418
ND	1,413,658
SD	36,360
Total	21,538,634

Table A-6. Well Data by State for Region 8, 2002

State	Total # of Wells	Average Well Depth (ft)
WY	31,600	6,020
CO	22,342	5,856
MT	8,707	3,420
UT	5,572	6,558
ND	3,591	9,013
SD	248	6,660
Total	72,060	5,848

In Region 8, the majority of wells are gas wells. As shown in Table A-7, over 28,400 wells are gas-only wells, accounting for almost 40 percent of total wells in the region; note that numbers may not add due to rounding. Wyoming accounts for the majority of gas-only wells. Table A-7 also presents the number of wells producing both oil and gas. The "Oil With Gas Wells" data refer to wells that produce more oil than gas using a predefined ratio between oil and gas production. The "Gas With Oil Wells" data refer to wells producing more gas than oil, using the same predefined ratio.[4] In 2002, there were 15,693 oil with gas wells, and 15,762 gas with oil wells. The remaining wells in the region are oil-only wells, totaling 12,183.

Table A-7. Well Data by Type and State for Region 8, 2002

State	Total # of Wells	Oil-Only Wells	Gas-Only Wells	Oil With Gas Wells	Gas With Oil Wells
WY	31,600	6,276	13,731	5,225	6,368
CO	22,342	1,763	8,135	4,788	7,656
MT	8,707	2,694	4,633	1,355	25
UT	5,572	467	1,784	1,809	1,512
ND	3,591	914	77	2,452	148
SD	248	69	62	64	53
Total	72,060	12,183	28,422	15,693	15,762

Region 8 also has a substantial number of CBM wells. These are gas-only wells and are, therefore, a subset of the gas-only wells presented above. Table A-8 presents the number of CBM wells in Region 8 by state; note that numbers may not add due to rounding.

Table A-8. CBM Wells by State for Region 8, 2002

State	Gas-Only Wells	# of CBM Wells	Percent CBM
WY	13,731	11,628	85%
CO	8,135	3,680	45%
MT	4,633	236	5%
UT	1,784	758	42%
ND	77	0	0%
SD	62	0	0%
Total	28,422	16,302	57%

CBM wells can be found in all Region 8 states except for North Dakota and South Dakota. Nevertheless, most CBM wells are currently found in Wyoming, representing 71 percent of total CBM wells in Region 8. In addition, 57 percent of the gas-only wells in the region are CBM wells. In Wyoming, the percentage is much higher, 85 percent.

Table A-9 presents 2004 data on natural gas processing plants in Region 8 (2002 data are not available); note that numbers may not add due to rounding. According to these data, Wyoming represents more than half of total natural gas processing capacity in the region,

[4] For this study, the predefined ratio is 12.5 gas/oil (Mcf/Bbls). If a well has a ratio less than 12.5, it is classified as "oil with gas well." Otherwise, it is a "gas with oil well."

although it has fewer than half the number of plants. Colorado represents the second largest capacity and number of plants. These results are consistent with the production results identifying Colorado and Wyoming as having the largest volume of gas production in Region 8.

Table A-9. Total Number and Capacity of Natural Gas Processing Plants in Region 8, 2004

State	Capacity (Mcf)	Number of Plants
WY	6,920	45
CO	2,093	43
UT	970	16
ND	222	8
MT	133	3
SD	0	0
Total	10,338	115

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Appendix B: Pollution Sources in the Oil and Gas Industry

The analysis of emissions from oil and gas exploration and production begins with an inventory and characterization of the sources of these emissions by medium and type. This report addresses several categories of emissions from oil and gas production activities. Air emissions include:

- **Criteria air pollutants:** These are pollutants that are regulated by National Ambient Air Quality Standards (NAAQS), including ground level ozone (the primary component of smog), carbon monoxide (CO), sulfur dioxide (SO_2), and particulate matter (PM). Ozone is not a direct emission but is formed in the atmosphere from nitrogen oxide (NO_x) and volatile organic compounds (VOCs). NO_x and VOCs are, therefore, regulated as precursors to ozone. VOCs are either hydrocarbon fugitive emissions or products of fossil fuel combustion. Most of the other emissions are the result of fossil fuel combustion in engines, turbines, and process heaters.
- **Hazardous air pollutants (HAPs):** These primarily include fugitive VOC emissions that are classified as HAPs.
- **Haze precursors:** Visibility and regional haze are important factors in the Rocky Mountains. Regulators, environmental groups, and other affected stakeholders are very concerned about pollutants that reduce visibility, including NO_x, SO_2, and particulates.
- **Greenhouse gases (GHGs):** These are gases, including CO_2 and methane (CH_4), have climatic warming effects. CO_2 includes CO_2 from combustion of fossil fuels and CO_2 that is removed from raw natural gas and vented. CH_4 emissions are primarily fugitive emissions from gas system operations. CH_4 has a global warming potential (GWP) 21 times higher than CO_2. There is increasing interest in measuring GHG emissions and their impacts in the western states. Arizona, California, Montana, New Mexico, Oregon, Utah, and Washington and have formed the Western Climate Initiative (WCI) to establish and meet GHG reduction targets. Colorado is establishing its own targets, and other states may follow suit. In addition, legislative proposals have been introduced in Congress to regulate GHG emissions in the future. EPA issued an advance notice of proposed rulemaking (ANPRM) in July 2008 considering possible GHG emission regulation under the Clean Air Act.

The non-air emissions include produced water and drilling waste. Produced water is one of the most significant environmental issues associated with gas production in Region 8.

B.1 Sources of Air Emissions

After researching and evaluating various information sources, the EPA Sector Strategies Program decided to feature the WRAP air emissions data. As such, it is important to note that WRAP defines air emissions sources in a slightly different way than CAA programs do. In WRAP terminology, a point source is "a specific source of air pollution" and an area source is “many small sources of air pollution in which the contribution of each source is relatively small, but combined may be a significant source of air pollution.” The CAA categorizes stationary sources as “major” or “minor” for pollutants, based on the potential or permitted air emissions, and it defines “area source” as a stationary source of air pollution that is not major. WRAP’s categorization of point sources most closely correlates to major sources of air pollution, but could potentially include minor sources as well. Note that WRAP’s categorization of area sources also includes certain mobile sources that effectively function as stationary sources, such as drilling rigs.

The sources of air emissions associated with oil and gas production in Region 8 can be categorized into four categories based on function and size of source. For purposes of data categorization in this report, point sources are large stationary sources that can be separately measured and tracked. Area sources include smaller stationary sources, such as small compressors, and certain mobile sources, such as drill rigs and frac units, which are tracked as a group rather than individually. The major point source categories include:

- **Large compressor stations (at least 100 million standard cubic feet per day (MMscfd) of gas:** Used to move natural gas through pipelines. Usually connected to interstate gas transmission lines, although they could also be linked with collection systems that bring gas from the wells and processing sites to the main transmission lines. These stations have very large compressors powered by reciprocating engines or combustion turbines that burn gas from the pipeline.
- **Large gas processing plants:** Responsible for a variety of processes involved in removing liquids, impurities, and inert gases from natural gas, including fractionation, sweetening, treatment, dehydration, and compression. Emissions sources include internal combustion engines (ICEs) and process heaters.
- **Standalone production sites:** Intermediate-sized natural gas processing plants that are similarly responsible for a variety of processes involved in removing liquids, impurities, and inert gases from natural gas, including fractionation, sweetening, treatment, dehydration, and compression.
- **Wellhead sites and small compressor stations:** The smallest of the source categories, most of the small compressor stations process between 10 and 100 MMscfd of natural gas. These sites are usually operated to pressurize the natural gas so it can be transported in a sale pipeline connected to a large compressor station. Wellhead sites include a wellhead and in some sites, a test separator to estimate the ratio of oil, water, and natural gas in the production stream. These sites are linked to a common production header and are routed to an intermediate site or a commingling facility to handle the fluid from multiple well sites more efficiently.

The first two source categories listed above are usually considered point sources, and the other two categories are usually included in the area sources. Across these four source categories, three basic equipment categories contribute to air emissions:

- **Internal combustion equipment:** Primarily natural gas-fired engines and combustion turbines used in compressors, generators, and pumping units, or diesel-fired engines that power generators, trucks, or mobile equipment such as drilling rigs or frac units. Emissions include NO_x, PM_{10}, $PM_{2.5}$, VOCs, SO_x, and CO.

- **External combustion equipment:** Covers a variety of equipment such as boilers, heaters, glycol and amine regenerators, separators, sulfur recovery units, and combustion flares. Emissions include NO_x, PM_{10}, $PM_{2.5}$, VOCs, SO_x, and CO.
- **Storage and separation vessels:** Includes a variety of equipment such as separators, storage tanks, pressure and level controllers, glycol dehydrator flash tanks, glycol dehydrator still columns, gas-operated and chemical injection pumps, and oil/water skimmers. These units are a primary source of fugitive VOC emissions, which leak out of tanks, pipes, valves, and fittings or evaporate from exposed liquid surfaces. Wells, gathering pipelines, dehydrators, and separators generate the majority of methane emissions, followed by transmission and storage.

B-1 identifies the emission sources and pollutants covered in this sector. Table B-2 summarizes the typical range of air pollution sources in the exploration and production sector along with the source classification codes (SCCs) used to categorize the sources and typical emission factors and control efficiency data; this list was compiled by the Michigan Department of Environmental Quality. The emission factors come from EPA’s AP-42 listing of emission factors and other standard data sources. While these sources do not provide emission rates for specific facilities, they are typical values that provide a good first estimate of standard emissions factors and control efficiencies.

Table B-1. Emission Sources and Pollutants for Oil and Gas Production

Source Category	Pollutant	Emission Unit	Large Compressor Stations	Natural Gas Processing Plants	Stand-alone Production Sites	Small Compressor Stations & Wellheads
Internal Combustion	NO_x, PM_{10}, $PM_{2.5}$, VOCs, SO_x, CO	Natural gas-fired engines	✓	✓	✓	✓
		Diesel-fired engines	✓	✓	✓	✓
External Combustion		Line heaters	✓		✓	✓
		Separators		✓	✓	
		Heat treaters			✓	
		Glycol regenerators	✓	✓	✓	✓
		Amine regenerators		✓	✓	
Storage and Separation Vessels	VOCs	Sulfur recovery units		✓		
		Combustion flares	✓	✓	✓	
		Fugitives	✓	✓	✓	✓
		Separators		✓	✓	✓
		Glycol dehydrator flash tanks	✓	✓	✓	✓
		Glycol dehydrator regenerator still columns	✓	✓	✓	✓
		Storage tanks	✓	✓	✓	
		Pressure and level controllers	✓	✓	✓	
		Gas operated pumps & chemical injection (CI) pumps	✓		✓	✓
		Oil/water skimmers			✓	

Table B-2. Air Emissions Sources for the Oil and Gas Production Industry

SCC	Description	Pollutant	Emission Factor	Control Efficiency
Natural Gas Engines				
2-02-002-53	Standard "rich burn" engines May include: Natural gas process heaters Natural gas production compressors Natural gas production flares—excluding SO_2	CO NO_x PM_{10} $PM_{2.5}$ SO_2 VOC	3.794E3 lb/mmcf 2.254E3 lb/mmcf 9.69E0 lb/mmcf 9.69E0 lb/mmcf 6.00E-1 lb/mmcf 3.02E1 lb/mmcf	3-way catalyst CO – 80% NO_x – 90% VOCs – 50%
2-02-002-54	Lean burn engines May include: Natural gas process heaters Natural gas production compressors Natural gas production flares—excluding SO_2	CO NO_x PM_{10} $PM_{2.5}$ SO_2 VOC	5.68E2 lb/mmcf 4.162E3 lb/mmcf 7.90E-2 lb/mmcf 7.90E-2 lb/mmcf 6.00E-1 lb/mmcf 1.204E2 lb/mmcf	Oxidation catalyst CO – 80% VOCs – 50%
Process Heaters (excluding engines noted above)				
3-10-004-04	Process heaters	CO NO_x PM_{10} SO_x VOC	3.50E1 lb/mmcf 1.40E2 lb/mmcf 3.00E0 lb/mmcf 6.00E-1 lb/mmcf 2.80E0 lb/mmcf	
Tank Storage				
4-04-003-01	Fixed roof tank—breathing loss	VOC	3.6E1 lb/kgal-yr-crude oil (storage capacity)	Vapor recovery system – 95% Flare – 95%
4-04-003-02	Fixed roof tank—working loss	VOC	1.1E0 lb/E3 gal crude oil (throughput)	Vapor recovery system – 95% Flare – 95%
Truck Loading				
4-06-001-32	Truck loading	VOC	2.0E0 lb/E3 gal crude oil	Vapor recovery system – 95%
Gas Dehydrators				
3-10-003-21	Glycol dehydrator—Niagaran	VOC	9.24E4 lb/yr-GPM Glycol	Tube and shell condenser with flash tank – 90% Vapor recovery system – 95% Flare – 95%
3-10-003-22	Glycol dehydrator—Prairie du Chien	VOC	1.94E4 lb/yr-GPM Glycol	Tube and shell condenser with flash tank – 90% Vapor recovery system – 95% Flare – 95%
3-10-003-23	Glycol dehydrator—Antrim	VOC	9.2E1 lb/yr-GPM Glycol	Vapor recovery system – 95% Flare – 95%
Amine Plant				
3-06-009-06	Amine plant	SO_2	3.76E3 lb/ton hydrogen sulfide	
Fugitive Emissions (excludes fugitive emissions from crude oil sumps)				
3-10-888-01	Fugitive emissions—light crude oil	VOC	1.44E1 lb/each-yr valve	
3-10-888-02	Fugitive emissions—gas production	VOC	3.60E0 lb/each-yr valve	
3-10-888-03	Fugitive emissions—gas plant	VOC	2.74E1 lb/each-yr valve	

In addition to the relatively permanent emission sources described in this section, emissions are also associated with drilling and well stimulation. These emissions are primarily from truck-mounted diesel engines used to power drilling equipment and hydraulic fracturing equipment used to stimulate gas formations. The equipment is typically in one location for days or weeks and would typically be included as part of the area source emissions.

B.2 Sources of Greenhouse Gas Emissions

The two primary GHGs emitted from oil and gas exploration and production (E&P) are CO_2 from fossil fuel combustion and CH_4 from leaks, venting, and fugitive emissions. As previously noted, methane has greater global warming effect (or GWP) than CO_2—the GWP for CH_4 is 21 times that of CO_2. The emissions data for methane in this report are for the actual tons of methane reported and should be multiplied by 21 to derive the CO_2 equivalent emissions.

B.3 Sources of Non-Air Pollution

There are three basic types of non-air pollution associated with oil and gas extraction:

- **Produced water:** Consists of water and treatment chemicals placed into and extracted from the formation containing the gas or oil, and accounts for the majority of oil and gas production wastes. Produced water is generated naturally from petroleum reservoirs or operations using primary and secondary recovery techniques. Chemical compositions of produced water can differ substantially between sources and between development and production techniques. Produced water is usually stored in tanks for surge capacity and to separate oil from water before disposal. Produced water is also a result of coal bed methane (CBM) production, and these gas operations are the primary source of produced water currently managed in Region 8. Water quality varies in producing basins in both CBM and conventional production.
- **Drilling waste:** Contains drilling mud, cuttings from the wellbore, and chemicals added to improve mud properties, and account for the second largest amount of waste resulting from oil and gas production (after produced water). Drilling fluids include drill cuttings (rock removed during drilling) and drilling muds (water or oil-based fluids with additives that are pumped down the drilling pipe to offset formation pressure, provide lubrication, and seal off the wellbore to avoid contamination and remove cuttings). This includes synthetic muds and fluids.
- **Other associated wastes:** Include oily soil, tank bottoms, workover fluids, produced sand, pit and sump waste, pigging waste, iron sponge, dehydration condensate water, molecular sieve waste, and oily cuttings.
  - *Oily soil:* Contamination of soil with oil usually results from equipment leaks and spills.
  - *Tank bottoms:* Consist of heavy hydrocarbons, sand, clay, and mineral scale that deposit in the bottom of the oil and gas separators, treating vessels, and crude oil stock tanks.

- *Workover fluids:* Produced from well control, drilling or milling operations, and stimulation and/or cleanup of an oil and gas bearing formation. The fluids coming from drilling or milling operations as well as control fluids are usually considered produced water. Stimulation or cleanup fluids are expected to contain HAPs. The waste composition data for workover fluids provided by the American Petroleum Institute (API) are mainly based on spent stimulation fluid samples since these data yield conservative HAP emissions estimates.
- *Produced sand:* Sand and other formation solids can build up in the wellbore in both producing and injection wells, and need to be removed.
- *Pit and sump waste:* Production pits are used to store production fluids. As in tank bottoms, heavy materials settle on the bottom of pits or sumps and must be removed. Composition of pit and sump wastes varies between facilities.
- *Pigging waste:* Produced when pipelines are cleaned or "pigged." The waste consists of produced water, condensed water, crude oil, and natural gas liquids. It may also contain small amounts of solids, such as paraffin, mineral scale, sand, and clay.

Appendix C: Data Availability and Sources

The initial task conducted in this analysis was to identify and assess the sources of environmental and industry data that can be used to characterize and estimate the environmental impacts associated with the oil and gas production sector. This assessment was conducted with a primary focus on Region 8 data availability, but also included a broader assessment of general data availability for the oil and gas industry.

A baseline characterization of the industry's environmental impacts requires the following information:

- Baseline and benchmarking information for a particular base year, including facility data, oil and gas production, well characteristics, geology, and depth; energy use; and equipment and process data.
- Emissions data for specific sources and source categories. Pollutants to be considered depend on what data are available.
- Oil and gas industry outlook information including:
  - Recent reports on long-term trends of industry; and
  - Expected changes in emissions performance in the industry driven by federal, state, and local regulations.

The following sections list and describe the available data sources found in our assessment; note that numbers in the tables may not add due to rounding.

C.1 Industry Baseline Data

C.1.1 Baseline Well and Production Data

All states in Region 8 maintain information on wells and gas processing facilities, existing and planned (i.e., those applying for permits). State databases of wells are maintained by:

- Colorado Oil and Gas Conservation Commission (wells and facilities related to oil and gas production);
- Montana Oil and Gas Information System;
- North Dakota Oil and Gas Division;
- South Dakota Oil and Gas Section;
- Utah Division of Oil, Gas and Mining; and
- Wyoming Oil and Gas Conservation Commission (wells and gas plants).

In addition, the states' oil and gas database contains information about wells in tribal lands. ICF International maintains a comprehensive nationwide database with information on every oil and gas well, including historical production and well depth.

The database is currently being updated. Table C-1 shows the current oil and gas well count (without updates) for each state in Region 8 for 2006.

Table C-1. ICF Oil and Gas Well Count by State, 2006

State	# of Oil Wells	# of Gas Wells	Total
CO	7,567	19,993	27,560
MT	5,862	4,078	9,940
ND	3,120	178	3,298
SD	158	71	229
UT	2,401	5,012	7,413
WY	10,205	25,052	35,257
Total	29,313	54,384	83,697

The U.S. Energy Information Administration (EIA) within the U.S. Department of Energy (DOE) also has oil and gas well data, including information from marginal wells, which was developed in connection with the Distribution of Oil and Gas Wells and Production Project, undertaken on behalf of DOE's National Energy Technology Laboratory (NETL) with support from U.S.PetroSystem.[5] The objective of this effort was to develop a database for analyses assessing the impact of technological development on marginal gas wells. Table C-2 shows EIA's 2004 data on oil and gas wells for the states in Region 8, which is generally in line with ICF data.

In other oil and gas producing regions, state governments and the Minerals Management Service within the U.S. Department of the Interior (for federal offshore areas) maintain records of oil, gas, and in most cases water production, by "property." A property is either a single gas or oil well, or in the case of oil, often an oil lease containing one or more oil wells. These production records are maintained for tax, conservation, and environmental purposes. In some instances, these data can be obtained from Web sites maintained by the state. Also, data aggregating companies, such as Lasser Inc., gather these data and offer them to the public for a fee. The Lasser data can be used to develop statistics for oil, gas, and water production for any geographic area of interest.

Table C-2. EIA Oil and Gas Well Count by State, 2004

State	# of Oil Wells	# of Gas Wells	Total
CO	4,288	23,208	27,496
MT	3,765	5,356	9,121
ND	3,122	428	3,550
SD	75	129	204
UT	2,180	3,936	6,116
WY	10,471	23,370	33,841
Total	23,901	56,427	80,328

[5] U.S. PetroSystem, formed in spring 2000, is a cooperative multi-agency program established for creation, maintenance, and sharing of data used in the study of domestic and worldwide oil and gas resources, reserves, production, production capacity, and associated technologies and economics. Agencies support this work not only for the cost effectiveness and efficiency gained from pooling their resources, but also for shared knowledge gained from cooperation. At present, U.S. PetroSystem member organizations include EIA, NETL, and the U.S. Geological Survey.

For our emissions estimates, we used the Lasser database to obtain well production data. Data and information on natural gas processing plants were obtained from EIA, which reports state-level data on natural gas processing every year. However, an inventory of natural gas processing plants is not reported yearly. Such an inventory was developed in 2004 and 1995. The 2004 inventory was used to obtain data on natural gas processing plant capacity and number of plants.

C.1.2 Energy Use Data

Energy use data can be used to calculate emissions related to energy use or fuel combustion. ICF maintains a cogeneration database that includes cogeneration oil and gas production facilities. Also, the U.S. Census of Mining (of the Census Bureau) reports fuel consumption for the oil and gas industry, but only at the national level.

ICF, as part of its 1998 industrial energy consumption base year work, has estimated total energy consumption for the energy mining industry (includes oil and gas production and coal mining) for the region equivalent to Region 8.

C.1.3 Equipment and Process Data

An inventory of equipment/process equipment, such as petroleum storage tanks, engines, boilers and other pressure vessels, and dehydrators, could be helpful in estimating emissions from oil and gas production equipment. These state-level data may be available in some places, but there is substantial variability in the availability and usefulness of such data for this type of analysis. The availability and applicability of such data in Region 8 is as follows:

- **Colorado:**
  - The Colorado Storage Tank Information System (COSTIS) is the state's storage tank information database. Although one can access the database for a list of facilities, only public employees are given complete access to information on the tanks. Also, facilities are not identified by type of business/industry, so extraction of oil and gas production facilities will be a time-consuming process.
  - The Regional Air Quality Council (RAQC) has developed (with guidance from Colorado's oil and gas industry) emissions factors for VOC emissions from oil and gas production storage tanks. The average emissions factors are fairly close to the EPA AP-42 emissions factors.
  - RAQC has a list of facilities with VOC emissions reductions information on control technologies.
  - RAQC has an Excel file of glycol dehydrators in the northeastern part of the state. Emissions levels and control information are included.
  - RAQC has an Excel file of compressors in the northeastern part of the state. Emission levels and control information are included.

  - RAQC has an Excel file of condensate tanks in the northeastern part of the state. Emission levels and control information are included.

- **Montana:** The Petroleum Tank Release Compensation Board (PTRCB) database tracks releases (leaks) from petroleum tanks in the state. It is not clear whether all petroleum tanks are included in the database.
- **North Dakota:** Has no database available to the public.
- **South Dakota:** Has no database available to the public.
- **Utah:**
  - Has a boiler and pressure vessel database.
  - The Department of Environmental Quality maintains files of underground storage tanks, but it is probably not useful for this type of analysis.
- **Wyoming:**
  - Has a downloadable Excel file that contains facilities with storage tanks. The database includes critical information such as type of content, size of tank, etc. Nevertheless, this facilities/tanks database does not identify the type of industry/business for the facility, thus extraction of oil and gas production facilities would be a time-consuming process.
  - The Wyoming Department of Environmental Quality (WDEQ) developed emissions factors and guidance for calculating volatile organic compound (VOC) emissions from storage tanks.
  - WDEQ developed emissions factors and guidance for calculating various emissions from oil and gas production activities as part of its permit process.

C.2 Air Emissions Data

C.2.1 Criteria Air Emissions and Data Sources Considered

Several potential sources of air emissions data were considered for use in this analysis.

National Emissions Inventory

EPA's National Emissions Inventory (NEI) is intended to be a comprehensive facility and emission unit-specific database covering all criteria air pollutants and hazardous air pollutants (HAPs) nationally. In general, NEI is used by states and EPA for air quality modeling and planning purposes, and was developed by EPA's Emission and Inventory Analysis Group in Research Triangle Park, North Carolina. The current base year for air emissions data is 2002. NEI nominally contains emission measurements and estimates for seven criteria pollutants—including those of interest for this project (VOCs, sulfur dioxide (SO_2), nitrogen oxides (NO_x), and particulate matter (PM))—and 187 HAPs. In addition, NEI addresses emissions data for all major contributors to air pollution, including point, mobile, and nonpoint sources. Emission estimates are available currently for years 1990 and 1996 through 2002 for criteria pollutants and for years 1999 through 2002 for HAPs.

The point source emissions are represented in NEI for individual processes at an industrial facility. NEI is developed using the latest data and best available estimation methods, including data from continuous emissions monitors (CEMs), data collected from all 50 states and many local and tribal air agencies, and emissions estimates from EPA's latest models, such as the MOBILE and NONROAD models. Seasonal and daily records submitted by state, local, and tribal agencies are included in NEI, although their emissions are excluded from annual emission summary totals.

Criteria pollutant emissions for NEI are collected under the Consolidated Emissions Reporting Rule (CERR) (40 CFR Part 51). Under CERR, states are required to report emissions of SO_2, VOCs, NO_x, carbon monoxide (CO), lead (Pb), PM_{10}, $PM_{2.5}$, and ammonia (NH_3). Large sources (Type A) are required to report annually, while the other sources (Type B) are required to report every three years. For the 2002 base year, both Type A and Type B were required to report.

An initial processing of the NEI database for oil and gas production facilities in Region 8 states shows there are only 65 reporting facilities. Table C-3 summarizes these data by Standard Industrial Classification (SIC) code. The overall number of sources for these states as reported in NEI is small relative to the amount of production underway (and facilities operating), as reflected in Appendix A.

Table C-3. NEI Data on Oil and Gas Production Facilities in Region 8, 2002

State	Crude Petroleum and Natural Gas Extraction (SIC 1311)	Natural Gas Liquids (SIC 1321)	Total
CO	28	6	34
MT	4	1	5
ND	0	0	0
SD	0	0	0
UT	5	3	8
WY	13	5	18
Total	50	15	65

NEI data are based on a combination of methods, including facility reporting, modeling, and estimates. There are generally inconsistencies in how sources of emissions are categorized and emissions estimates are calculated. Missing data also call into question the overall reliability of the NEI dataset with respect to oil and gas production facilities currently operating. Areas where experience with NEI has shown data unreliability include:

- A substantial number of data values are missing, especially values for emissions unit size and description (e.g., NEI yielded only 672 large boilers in the United States, which is substantially lower than the approximately 1,500 large boilers known to be operational).
- For a given emissions unit, the Source Classification Code (SCC) used to classify it may be different than the unit description.

- In some cases, the unit of measure used to report emissions is inconsistent with the reported capacity of the unit.
- One NEI equipment record may actually reflect data for multiple pieces of equipment.
- Facility address information may be missing, showing only the town or state rather than the facility address.
- Some emission units have multiple subemission units (called process units) that have inconsistent values for certain data fields.

For these reasons, NEI data may not be the most complete or accurate mechanism for determining air emissions associated with the oil and gas industry. Analysis of the data for Region 8 described in Appendix A suggested that this would be a concern for the sector of interest in this study.

State Air Emissions Data

Another possible source of information is inventory data from individual states. Some states in Region 8 maintain an air emissions inventory, and it is likely that similar inventories would be available in other oil and gas producing states. The state information sources in Region 8 include:

- **Colorado:** The Colorado Department of Public Health and Environment maintains an inventory of emissions by county and industry/source and pollutant type (CO, NO_x, PM_{10}, SO_2, VOC, benzene). The latest available data are for 2004.
- **Montana:** Montana links to EPA's inventory data (NEI, AQD) for its state data.
- **North Dakota:** The North Dakota Department of Health maintains an emissions inventory for the state. The latest available information is for 2005.
- **South Dakota:** No emissions inventory could be found.
- **Utah:** The statewide inventories of Utah are provided by the Department of Environmental Quality. The data are summarized for the following criteria pollutants, in tons per year, reporting from point, area, and mobile sources within the state: CO, NO_x, PM_{10} and $PM_{2.5}$, SO_x, and VOCs. HAP emissions are reported for each county in pounds per year, listed by chemical or chemical class. No data are specified directly for the oil and gas industry. The latest available data are for 2005.
- **Wyoming:** Wyoming links to EPA's inventory data (NEI, AQD) for its state data.
- **Native American Tribes:** There are only a handful of inventories available for tribal areas, and they are specific to one tribe. The Western Regional Air Partnership (WRAP) has initiated a data assessment for an air emissions inventory for tribes, and associated work is ongoing.

As shown above, some of the states in Region 8 maintain some emission inventories for the oil and gas sector, and others do not. There were often insufficient and inconsistent data available to rely heavily on these sources for this analysis.

Toxics Release Inventory

An additional source of information often used for HAPs and non-air wastes is EPA's Toxics Release Inventory (TRI); however, oil and gas exploration and production operations are not required to report to this inventory, and so this data source was not used for this report.

Regional Air Emissions Data

In oil and gas producing regions, regional governmental partnerships may be a source of environmental and industry data. After reviewing the various options available, the primary data source used in our assessment of air emissions in Region 8 is provided by WRAP.

Generally speaking, WRAP is a collaborative effort and voluntary organization of tribal governments, state governments, and various federal agencies. Formed in 1997, WRAP was organized to succeed and implement the Grand Canyon Visibility Transport Commission's recommendations. WRAP is also implementing regional planning processes to improve visibility in all western Class I areas by providing the technical and policy tools needed by states and tribes to implement the federal Regional Haze Rule (RHR). Other common air quality issues raised by WRAP members may also be addressed.

The WRAP Emissions Forum oversees development of a comprehensive emissions tracking and forecasting system, which can be utilized by WRAP or its member entities. It monitors the trends in actual emissions and forecasts the anticipated emissions that will result from current regulatory requirements and alternative control strategies.

As part of its air quality planning work, WRAP has developed criteria emissions data for two major categories: point or stationary sources, and area or nonpoint sources. It has also developed data for on-road mobile sources; off- or non-road mobile sources; fires; windblown dust; and biogenic sources. These data from WRAP's 2002 inventory were determined to be the most accurate and complete source of criteria air emissions data for this project, and were, therefore, used for this report. WRAP has extensive documentation on how the various emissions were calculated. The approach WRAP used could be replicated, if necessary, to estimate emissions for other regions.

WRAP provided EPA the latest version of its 2002 emissions inventory for all point and area sources through database files in December 2007. The air emissions data obtained from WRAP included estimates for NO_x, SO_2, VOCs, CO, particulates, NH_3, and hydrogen sulfide (H_2S). Details on these data sources are provided below.

C.2.2 WRAP Data on Point Sources

WRAP's point source database contains a variety of information for each stationary point source in the region, including all emission points on site; stack parameters (height, diameter, flow, velocity, temperature, type); production rates (design capacity, maximum nameplate capacity); actual throughput fuel parameters (heat content, ash content, sulfur content); SIC code; North American Industry Classification System (NAICS) code (although not available for all records); location (latitude, longitude); and emission controls. Though the database is the region's most comprehensive source for criteria emissions data, data for some of the important fields, specifically those pertaining to production and throughput, are missing.

Table C-4 shows the number of oil and gas plants/facilities included in the Point Sources Site Report database by state by SIC code. Point sources are the larger stationary emissions sources and thus include primarily larger internal combustion engines (ICEs) and turbines and processing facilities. Not every well or producing facility will have enough emissions to qualify as a point source. The smaller stationary sources are grouped together in the area source category. Colorado has by far the greatest number of point sources, and most of those are in the natural gas liquid extraction facility category. Although Wyoming has high gas production, the sources are defined differently than in Colorado, resulting in fewer listed point sources, though the emissions are still captured as area sources.

Also note that no data on tribal land are presented in this report. The tribal land data in the WRAP database is not organized or listed by state location.. Examination of a sample the tribal land emissions indicated that their contribution was small relative to the emissions for Region 8. Due to the small contribution of these sources to the total emissions relative to the time that would have been required to evaluate them, they were not included in this analysis.

Table C-4. Number of Oil and Gas Facilities in WRAP by State and SIC Code

SIC	SIC Description	CO	MT	ND	UT	SD	WY	Total
1311	Crude Petroleum and Natural Gas	3,927	149	40	199	0	354	4,669
1321	Natural Gas Liquids	3,491	18	40	93	0	182	3,824
1381	Drilling Oil and Gas Wells	0	0	0	0	0	0	0
1382	Oil and Gas Field Exploration Services	0	0	0	0	0	0	0
1389	Oil and Gas Field Services, not elsewhere classified	41	0	0	0	0	27	68
Total		7,459	167	80	292	0	563	8,561

C.2.3 WRAP Data on Area Sources

WRAP also has an inventory report on area source emissions from oil and gas production for the year 2002. The report, *An Emission Inventory of Non-Point Oil and Gas Emissions Sources in the Western Region*, was published in December 2005. It includes emissions from tanks, compressors, and engines not included in the point source emissions inventory as part of the area source emissions inventory.

In 2005, WRAP initiated a project to estimate the area source emissions from oil and gas field operations for 2002, focusing on NO_x and VOC emissions. Beginning in 2006, WRAP refined the inventory's "first cut" emissions numbers with more precise data on basin-specific activity. It also examined possible options for controlling the emissions that come from individually small but ubiquitous pieces of field production equipment, including drill rigs, gas compressors, coal bed methane (CBM) pumps, liquid hydrocarbon storage tanks, glycol dehydration units, pneumatic instrument controls, and completion flaring and well-venting procedures. The 2006 effort expanded the inventory to include SO_2 emissions. This effort was completed in fall 2007. The latest data obtained from WRAP also included CO emissions in the area source inventory. This latest set of data was used for this analysis.

As the WRAP analysis did not include data for area source emissions beyond the four pollutants discussed above (NO_x, VOCs, SO_2, and CO), other area source emissions, including PMs, are not included in this analysis. Also, WRAP did not estimate area source emissions data for Native American tribal areas, so such emissions are not included in this analysis. Based on available data, the tribal areas are a relatively small source of area source emissions, so this is probably not a large omission.

C.2.4 Hazardous Air Pollutants

WRAP data do not include HAPs, however, the primary HAPs emissions for this sector are fugitive VOCs, which are reported in the WRAP data. Since WRAP does not include HAPs data, estimates of HAP emissions were developed using emissions factors provided by WDEQ and WRAP area source assumptions. WDEQ has developed factors that relate emissions factors for HAPs and VOCs for various emissions sources in the oil and gas industry. WRAP has used these factors in its study and analysis for the industry. To be consistent with the WRAP point and area source assumptions and the estimates used for the other pollutants, the ratio of HAPs over VOC emissions factors, by type of source, was applied to the VOC area and point emissions. For point sources, HAP emissions were calculated only for glycol dehydrators, which are primary sources of HAPs in the industry. Table C-5 shows the HAP and VOC emissions factors from WDEQ that were used in the analysis.

Table C-5. HAPs and VOC Emissions Factors by Source

Source	Units	VOCs	HAPs
Gas Well Dehydrators	lbs/yr/MMCFD	27,485.6	13,695.6
Condensate Tanks Uncontrolled	lbs/yr/barrel per day	3,271.0	116.0
Oil Well Tanks	lbs/yr/barrel per day	160.00	2.66
Gas Well Completion—Flaring and Venting	tons/well	86.0	3.0
Condensate Tanks Controlled	lbs/yr/barrel per day	65.740	2.320
Gas Well Pneumatic Devices	tons/well	0.200	0.008
Oil Well Pneumatic Devices	tons/well	0.100	0.004

C.2.5 Carbon Dioxide Emissions

EPA's report, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990—2005* (April 2007), was considered as a potential data source for CO_2 emissions. However, the level of detail in the EPA inventory is not sufficient for apportioning emissions to Region 8 sources as readily as fuel consumption, which can be used to calculate CO_2 emissions directly. The fuel consumption values for 2002 were taken directly from the 2002 Census of Mining, which reports fuel consumption for the following major segments of the oil and gas industry by NAICS:

- NAICS 211111: Crude Petroleum and Natural Gas Extraction;
- NAICS 211112: Natural Gas Liquid Extraction;
- NAICS 213111: Drilling Oil and Gas Wells; and
- NAICS 213112: Support Activities for Oil and Gas Operations.

There were items in the 2002 Census data that were withheld. In these instances, we made best estimates based on available information, including previous Census information and data on similar fuels. Also, instead of using the Census estimates on natural gas lease and plant (labeled in the Census as "natural gas produced and used in the same plant as fuel" and "residue gas produced and used in the same plant as fuel"), we used annual estimates from EIA, which we deemed more consistent than the Census estimates.

The 2002 Census data were only available for the national level, and thus the national data needed to be disaggregated by region. To do the regional disaggregation, the number of wells was used for the NAICS 211111 and NAICS 213112 segments, drilling footage for NAICS 213111, and natural gas processing activity information for the NAICS 211112 segment.

To disaggregate CO_2 estimates by end use, in general we used WRAP point source estimates for SO_2 emissions, which are available by SCC. The SCC emissions data are provided by fuel type. The SO_2 emissions by SCC were used to apportion the CO_2 emissions by fuel and SO_2 content. CO_2 emissions were estimated by fuel by SCC. There were instances where the SO_2 emissions by SCC information were not available (e.g., for NAICS 213111 and NAICS 213112). For these two sub-industries, emissions from distillate oil and natural gas were assigned to ICEs. Residual oil was assigned to process heat. Emissions from motor gasoline were assigned to off-road transportation. While the allocation by process is not as detailed as for the criteria pollutants, it provides a general breakdown.

C.2.6 Methane Emissions

Methane emissions are significant in the oil and gas industry. EPA's report, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990—2005* (April 2007), was used to develop the CH_4 emissions estimates used in this analysis. The report provides national CH_4 emissions for various sources in the oil and gas production industry. These national emissions by source were then allocated by state, based on appropriate factors for each process, such as gas production, oil production, pipeline capacity, and gas processing quantities. These estimates are all considered area sources.

C.3 Non-Air Pollution Data

Other pollution data addressed in this analysis include produced water and drilling waste. A database maintained by the industry data aggregation company, Lasser Inc., was used to estimate the amount of produced water resulting from oil and gas operations in Region 8. The database also includes well-count and oil and gas production data, which were used for this study. The amount of produced water can be calculated using geological data and standard production factors in order to estimate future produced water volumes.

Another database, called the IHS database, which is another data provider of oil and gas production, was used to identify CBM wells. This information was used to help disaggregate the well data, including produced water, by well type.

Well depth data was also estimated from Lasser and IHS information to assist in estimating emissions associated with drilling. These databases are based on data reported by industry to the states for taxation and royalty purposes and are widely used by industry and government to characterize exploration and production activity.

To estimate drilling waste, we first obtained drilling activity information, specifically footage data, from the American Petroleum Institute (API). The amount of waste was calculated based on the data from API and an estimate of the drilling waste factor (barrels of waste per foot drilled) also from API. The drilling waste factors vary by state and are based on the API report, *Overview of Exploration and Production Waste Volumes and Waste Management Practices in the United States* (May 2000). Table C-6 shows the drilling waste factors used for each state.

Table C-6. Drilling Waste Factors by State

State	Bbls/ft
CO	0.87
MT	1.52
ND	1.05
SD	1.03
UT	1.68
WY	1.27

We have not found any real measured data on the other associated wastes. These can be estimated based on industry production factors and drilling data. In 2000, EPA released the analysis, *Associated Waste Report: Crude Oil Tank Bottoms and Oily Debris*. The information and other data in the report could be used to estimate current associated waste levels (crude oil tank bottoms and oily debris).

C.4 Other Emissions Information Sources

Other information and data sources that could be useful in similar analyses include:

- The Houston Advanced Research Center report, *VOC Emissions from Oil and Condensate Storage Tanks*, which provides typical data on these fugitive emissions.
- Other states (not in Region 8) have guidance on how to calculate VOC emissions from oil tanks.

- The Gas Technology Institute (formerly, Gas Research Institute) has developed emission factors for all types of pollutants from glycol dehydrators. The data were developed using a variety of sources, including equipment survey data.
- ICF has developed emission factors for many oil and gas industry operations as part of emission inventory work for EPA and private clients.

The biggest category of missing data is likely to be emissions from short-term or intermittent operations, such as drilling and well stimulation. It is not clear how significant these are with respect to the overall inventory; however, available emission factors can be used to estimate these emissions and determine how important they are.

C.5 Future Projections

C.5.1 Industry Outlook

The following data sources have been found to be potentially useful to project future emissions resulting from oil and gas production:

- States have permit data on pending drilling sites that could be used to do a short-term (1—2 year) projection of drilling activity from the base year.
- Some states (e.g., Colorado) have developed their own projections of long-term growth rates.
- EIA's *Annual Energy Outlook* also has projections of natural gas and crude oil production by region.
- ICF could develop projections of future oil and gas production using its Hydrocarbon Supply Model (HSM).

C.5.2 Emissions Projections, 2018

The primary data source for the criteria air emissions projections is WRAP, which developed a detailed forecast of regional air emissions for the year 2018 (see Appendix E references). Their projections were based on a projection of the growth of the oil and gas industry in the region (as provided in Resource Management Plans (RMPs) of the U.S. Bureau of Land Management; where RMPs were not available, EIA regional production forecasts were used); changes in applicable regulations; evaluation of the penetration of emission control technologies; and assumed retirement of facilities and wells. The projections are provided by facility and emissions unit. Documentation of the methodology to develop the forecast is provided in several reports:

- Eastern Research Group, Inc., *WRAP Point and Area Source Emissions Projections for the 2018 Base Case Inventory, Version 1* (prepared for the Western Governors' Association and WRAP, Stationary Sources Joint Forum), January 25, 2006.
- Environ International Corporation, *Final Report Oil and Gas Emission Inventories for the Western States* (prepared for the Western Governors' Association), December 27, 2005.

- Environ International Corporation, *WRAP Oil & Gas: Part 1: 2002/2005 and 2018 Area Source Emissions Inventory Improvements*, May 8, 2007.
- Environ International Corporation, *WRAP Oil & Gas: 2002/2005 and 2018 Area Source Controls Evaluation*, May 30, 2007.

WRAP's assumptions on the growth of the oil and gas industry in Region 8 were based on a variety of sources and are provided by county and type of emissions source. The data for these growth rates are presented in the Eastern Research Group report noted above. Given the detailed analysis embodied in these projections, they were determined to be the most credible projections of future criteria emissions for the sector. The two key factors are the rate of increased drilling and production and the implementation of new emission control regulations for equipment in the sector. While there is continued debate about the future growth of drilling in the region, this projection was based on permit data from federal regulators there. It also included proposed or expected new control requirements for engines and process heaters.

As noted, WRAP does not provide projections for HAP and CH_4 emissions. For this study, because of the similarity and relation of emissions sources and factors for VOCs and HAPs, the projection trend in VOC emissions was used to estimate HAP emissions, similar to the approach taken for current emissions. For methane emissions, the growth rates in oil and gas production in the Rocky Mountain region, as estimated by EIA, were used to extend the 2002 emissions of methane to 2018.

For produced water, the projected growth in NO_x emissions from drilling rigs by state from WRAP was used to extrapolate 2002 produced water levels to 2018.

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Appendix D: Air Emissions Sources by Source Category and Equipment Type

Table D-1 describes the primary sources of air emissions for each major source category identified in Section B.1: large compressor stations, natural gas processing plants, stand-alone production sites, and small compressor stations and wellhead sites.

Table D-1. Sources of Air Emissions by Equipment Type and Source Category

Major Source Categories	Internal Combustion Sources NO_x, PM_{10}, $PM_{2.5}$, VOCs, SO_x, CO		External Combustion Sources NO_x, PM_{10}, $PM_{2.5}$, VOCs, SO_x, CO			
	Natural Gas-Fired Engines	Diesel-Fired Engines	Line Heaters	Separators	Heat Treaters	Glycol Regenerator
Large compressor stations	Compressors, generators	Emergency generators not used under normal service	Maintain temperature of gas to reduce formation of natural gas hydrates in transmission lines	No	No	Used to drive off water absorbed by the glycol when the "wet" natural gas was bubbled through it in a gas dehydrator
Natural gas processing plants	Compressors (primarily reciprocating engines), generators, pumping units	Emergency generators not used under normal service	No	If no source can accept the gas, compression, or combustion flare, vessel will vent to the atmosphere to maintain flow of the liquid to other separators, treatment, and storage vessels	No	Used to drive off water absorbed by the glycol when the "wet" natural gas was bubbled through it in a dehydrator
Stand-alone production sites (intermediate-sized facilities)	Compressors (primarily reciprocating engines), generators, pumping units	Emergency generators not used under normal service	Used to heat the fluid after it takes a pressure drop through the "choke" at the wellhead	If no source is ready to accept the pressurized gas, compression, or combustion flare, vessel will vent to atmosphere to maintain flow of the liquid to other separators, treatment, and storage vessels	Used to break multiphase emulsion of oil/water/gas in the fluid	Used to drive off water absorbed by the glycol when the "wet" natural gas was bubbled through it in a dehydrator
Small compressor stations and wellheads	Compressors (reciprocating engines), pumping units	Generators and prime movers for drilling ops (mechanical pump power & power generation); generators for CBM ops (to power water pumps, especially in remote areas)	Used to heat the fluid after it takes a pressure drop through the "choke" at the wellhead	No	No	Used to drive off water absorbed by the glycol when the "wet" natural gas was bubbled through it in a dehydrator

	External Combustion Sources, *Continued*			Storage and Separation Vessels		
	NO_x, PM_{10}, $PM_{2.5}$, VOCs, SO_x, CO			VOCs		
	Amine Regenerator	Sulfur Recovery Unit	Combustion Flare	Fugitives	Separators	Glycol Dehydrator Flash Tank
Large compressor stations	No	No	Used to destroy natural gas and other hydrocarbons during emergency situations (blowdowns, vents, and uncontrolled/unscheduled VOC emissions)	Leakage of VOCs from a variety of valves, leaks, and exposed process sources	No	A portion of the natural gas is removed from the triethylene glycol (TEG) due to pressure drop
Natural gas processing plants	Used to remove the entrained pollutants (CO_2 and H_2S) from fluid used in a "sweetening unit." Pollutants may be flared, vented directly to atmosphere, or sent to a sulfur recovery unit.	Used to recover sulfur off the amine regenerator	Used to destroy natural gas and other hydrocarbons during emergency situations (blowdowns, vents, and uncontrolled/unscheduled VOC emissions)	Leakage of VOCs from a variety of valves, leaks, and exposed process sources	If there is no source ready to accept the pressurized gas, compression, or combustion flare, vessel will vent to atmosphere to maintain flow of the liquid to other separators, treatment, and storage vessels	A portion of the natural gas is removed from the TEG due to pressure drop
Stand-alone production sites (intermediate-sized facilities)	Used to remove the entrained pollutants (CO_2 and H_2S) from fluid used in a "sweetening unit." Pollutants may be flared, vented directly to atmosphere, or sent to a sulfur recovery unit.	No	Used to destroy natural gas and other hydrocarbons during emergency situations (blowdowns, vents and uncontrolled/unscheduled VOC emissions)	Leakage of VOCs from a variety of valves, leaks, and exposed process sources	If there is no source ready to accept the pressurized gas, compression, or combustion flare, vessel will vent to atmosphere to maintain flow of the liquid to other separators, treatment, and storage vessels	A portion of the natural gas is removed from the TEG due to pressure drop
Small compressor stations and wellheads	No	No	No	Leakage of VOCs from a variety of valves, leaks, and exposed process sources	If there is no source ready to accept the pressurized gas, compression, or combustion flare, vessel will vent to atmosphere to maintain flow of the liquid to other separators, treatment, and storage vessels	A portion of the natural gas is removed from the TEG due to pressure drop

	Storage and Separation Vessels, *Continued*				
	VOCs				
	Glycol Dehydrator Regenerator Still Column	Storage Tanks	Pressure and Level Controllers	Gas-Operated Pumps and Chemical Injection (CI) Pumps	Oil/Water Skimmers
Large compressor stations	Glycol will release the water and entrained hydrocarbon under the heat of the regenerator reboiler	Includes both hydrocarbon and water storage tanks. Salt water storage tanks may be hydrocarbon emissions source as some water separation techniques leave a layer of oil on top of the water.	Equipment that controls the vessel levels and pressure ranges (could be several hundred controllers at a compressor station). Certain older models vent gas continuously and at a rate of up to 1000 cubic feet per day (cfd).	Pumps move fluids from one storage vessel to another. CI pumps are used to inject corrosion, scale, and biological inhibitors into flow lines. There can be significant numbers of CI pumps at well sites at the wellhead.	No
Natural gas processing plants	Glycol will release the water and entrained hydrocarbon under the heat of the regenerator reboiler	Includes both hydrocarbon and water storage tanks. Salt-water storage tanks may be hydrocarbon emissions source as some water separation techniques leave a layer of oil on top of the water. Condensate storage usually controlled with vapor recovery units, though flares may be used as an alternative control.	Equipment that controls the vessel levels and pressure ranges (could be several hundred controllers at a compressor station). Certain older models vent gas continuously and at a rate of up to 1000 cfd.	No	No
Stand-alone production sites (intermediate-sized facilities)	Glycol will release the water and entrained hydrocarbon under the heat of the regenerator reboiler	Includes both hydrocarbon and water storage tanks. Salt water storage tanks may be hydrocarbon emissions source as some water separation techniques leave a layer of oil on top of the water.	Equipment that controls the vessel levels and pressure ranges (could be several hundred controllers at a compressor station). Certain older models vent gas continuously and at a rate of up to 1000 cfd.	Pumps move fluids from one storage vessel to another. CI pumps are used to inject corrosion, scale, and biological inhibitors into flow lines. There can be significant numbers of CI pumps at well sites at the wellhead.	Use of natural gas that is bubbled through the produced water to release additional entrained oil is common and often not accounted for in emissions inventories
Small compressor stations & wellheads	Glycol will release the water and entrained hydrocarbon under the heat of the regenerator reboiler	No	No	Pumps move fluids from one storage vessel to another. CI pumps are used to inject corrosion, scale, and biological inhibitors into flow lines. There can be significant numbers of CI pumps at well sites at the wellhead.	No

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