Science and Technology

Assessing Natural Gas and Oil Resources

An Example of a New Approach in the Greater Green River Basin

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PREFACE

This report presents a new approach to assessing natural gas and crude oil resources and the results of applying that approach to the Greater Green River Basin in southwestern Wyoming. The methodology builds upon existing assessments of technically recoverable resources by evaluating economic and environmental considerations and including these into the assessment as additional resource attributes. The primary objectives of this effort are to inform government officials and other stakeholders involved in land use planning, development of energy policies, and energy development and utilization planning. The approach aims to guide strategic (i.e., large-scale and long-term) planning, and is not intended to replace existing project-specific economic or land use planning processes. The initial framework for this approach was presented in two earlier reports:

- *Assessing Gas and Oil Resources in the Intermountain West: Review of Methods and Framework for a New Approach,* RAND MR-1553-WFHF (2002).
- *A New Approach to Assessing Gas and Oil Resources in the Intermountain West,* RAND IP-225-WFHF (2002).

This report should be of interest to federal, state, and local government land managers; and it is also expected to be useful to producers and the associated investment community, electric and natural gas utilities, and state planning agencies to help guide strategic business planning, improve long-term forecasting, and foster dialog among stakeholders. The study was funded by the William and Flora Hewlett Foundation.

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SUMMARY

Natural gas demand in the United States has been increasing for the last 15 years and is projected to grow substantially in the next 20 years. Meeting this growing demand will require an accompanying increase in supply, which is expected to come mostly from additional production in the United States. The prospect of increased U.S. production has led to ongoing efforts both to better assess our nation's natural gas resources and to develop policies for identifying and developing available resources.

Such efforts are drawing attention to the intermountain areas of the Rocky Mountains, which are relatively rich in hydrocarbon resources, particularly natural gas. National resource assessments indicate that the Rockies contain approximately 15 percent of the nation's technically recoverable (resources plus reserves) future natural gas supply. Although production in the region currently accounts for only about 9 percent of the natural gas produced in the United States, this figure is increasing rapidly as demand increases and resources in more established regions—such as Texas and the Gulf Coast—are depleted.

In the Rockies, 60 percent of the potential gas underlies federal land, compared to just 2 percent in the onshore areas of Texas and the Gulf Coast states. Thus, growth in production in the Rockies means that energy-related land use decisions will increasingly become the responsibility of federal land managers from such agencies as the Bureau of Land Management and the Forest Service. Given the rapid increase in natural gas production in the Rocky Mountains, it is increasingly important for these agencies to take a strategic view of federal land use decisionmaking—one that allows them to understand the differences between resources in different areas and thus to prioritize lands under consideration for development.

ASSESSING NATURAL GAS AND OIL RESOURCES

Federal land use planning is the process by which priorities for various land uses are established. This process incorporates a variety of considerations and attempts to weigh the merits of multiple resources (commodities or uses that the land may provide), including energy resource development and other consumptive uses, environmental management and conservation, and protection of recreational and cultural resources. The values of various resources are determined in a variety ways and documented in resource assessments. Such resource assessments play an important role in the land use planning process.

In the case of natural gas and oil, resource assessments historically focus on the amount of resource. However, additional attributes of energy resources affect the energy resource value of an area. A comprehensive assessment would include as much information about the resource as possible to help distinguish among resources in different areas. Attributes of energy resources that influence their value include the following:

- How much resource might be recoverable,
- How much resource might be available at different costs, and
- How much resource is associated with lands having different values of key environmental measures.

In this report, we present a new approach for assessing natural gas and oil resources that incorporates these elements. This methodology provides a more complete understanding of energy resource characteristics than conventional assessments do, by accounting for the economics, or real dollar costs, associated with production and by moving some of the environmental protection considerations, or social costs, upstream in the decisionmaking process. The key steps in our approach are shown in Figure S.1.

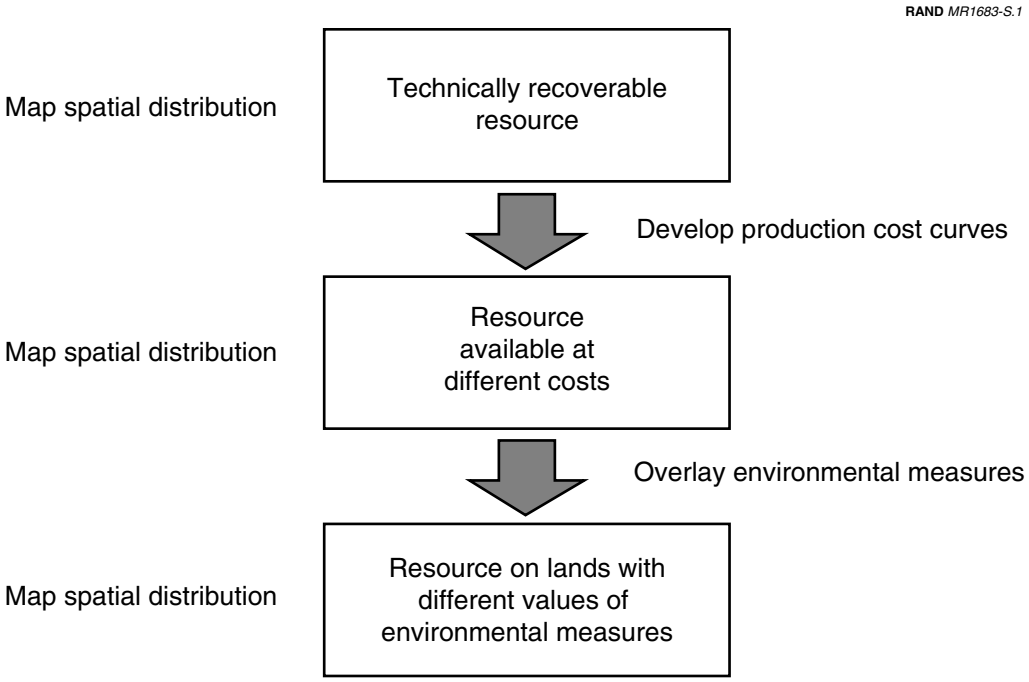

Figure S.1—Summary of Approach

In addition to helping inform the federal land use planning process, the comprehensive resource assessment proposed in this study is intended to improve decisionmaking in a number of other arenas. Potential benefits of this approach in these different areas are summarized below.

Federal Land Use Planning

The proposed assessment approach could help distinguish among lands with similar amounts of natural gas or oil. Areas with similar amounts of technically recoverable resources may have very different amounts of economically recoverable resource. Similarly, areas can be classified according to how much of the resource is on lands that are potentially more vulnerable to negative environmental impacts. Together, this information would further characterize energy resources and could help inform the process of setting priorities for energy-related land use decisions.

National Energy Planning

Assessing the merits of different policy options, such as increasing energy efficiency standards, investing in energy technologies, or pursuing expanded production would be facilitated with an understanding of the costs associated with each. Assessing the economically recoverable resources would help constrain costs and returns associated with production, which are currently unclear.

Production costs also exert a strong influence on fuel choices and amounts of fuel imports. Planning for future energy supplies thus strongly depends on estimates of energy resource production costs.

States, Utilities, and Producers

As states become more dependent on natural gas for electricity generation, state planners need to understand the resource potential. Prices from various potential sources are influenced by the amount of resource at different production costs. Similarly, utilities, many of which are making long-term investments in gas-fired power plants, could make better investment decisions with this type of information.

Economic Effects of Resource Extraction

An understanding of the economically recoverable resource as well as the potential environmental concerns associated with its production may also help define the effect that energy resource production might have on the local, regional, and national economies. A realistic understanding of the economic impacts at all scales depends on the amount of development and production activity that will actually occur.

ADVANTAGES AND LIMITATIONS

The proposed assessment approach can help federal and state land managers and policymakers at all levels set priorities and strategically plan for long-term resource use. Several aspects of this methodology are new and offer supplementary benefits to decisionmakers. Our approach

- Treats economic costs and environmental characteristics as integral attributes of energy resources that affect their value,
- Links the economic analysis with the spatial analysis, enabling decisionmakers to consider relative priorities for development based on the economic viability of the resource,
- Overlays the distribution of resources under various economic assumptions with distributions of environmental characteristics of lands associated with energy resources,
- Is intended to be applicable to other areas of the Rocky Mountains as well as to other regions of the nation, and
- Offers an additional tool for energy forecasters to provide further spatial and temporal refinements to their long-term resource estimates.

At the same time, this approach is preliminary in several aspects and has limitations and uncertainties. It is designed to enhance and supplement the regional assessment of gas and oil resources for the purposes of strategic (long-term and large-scale) planning of energy resource development on public lands. The method is not intended to be used to replace detailed economic or environmental analyses on specific leases. Also, this approach is intended to be part of a broader set of information sources used by decisionmakers in guiding land use and other energy development–related policy. We do not intend to define particular areas where drilling may be inappropriate. Rather, our intent is to provide a framework for assessing the value of energy resources.

Several assumptions are embedded in the spatial distribution of resources, production cost functions, and overlay analyses. Sensitivity of the results to these assumptions is an important consideration in interpreting the results. Also, uncertainties about the effect of gas or oil development on environmental measures mean that these overlays should be used to signal the need for further study and analysis of likely impacts and opportunities for mitigation.

NATURAL GAS IN THE GREATER GREEN RIVER BASIN

We have initially applied this method to the Greater Green River Basin, located primarily in southwestern Wyoming. The Greater Green River Basin contains substantial amounts of natural gas, with estimates of resources plus reserves of 135 to 160 trillion cubic feet (Tcf). This constitutes approximately 10 percent of the nation's total. Our results for this region reflect a reasonable range of assumptions regarding economic and environmental considerations. These results, which are summarized

in Table S.1, are instructive for developing the methodology further and providing insights that may help inform strategic energy resource planning in this basin.

Economic Analysis

By estimating separate costs for each resource unit ("subplay"), resource category, resource type, and depletion increment, separate costs were estimated for over 1,200 distinct analysis units throughout the basin. The analysis indicates that, depending on the economic scenario, 35 to 45 percent of the natural gas resources could be produced profitably at a market price of $3/MMBtu, which is similar to recent prices in Wyoming. Up to 65 percent could be profitably produced if the market price were $5/MMBtu.

The spatial analysis shows that the fraction of technically recoverable gas that is economically recoverable at a given price varies substantially from place to place. This result illustrates the value of the combination of economic and spatial analyses: When looking at specific areas, the concentrations of economically recoverable resources does not necessarily correlate directly with the concentrations of technically recoverable resources. This is illustrated in Maps 2.2 and 3.1 in the maps section, which show these concentrations. The circles highlight an example of an area where the difference between the concentration of technically recoverable and economically recoverable gas is considerably greater than the basinwide average, whereas the squares show an area where the concentrations of technically and economically recoverable gas are very similar.

Table S.1

Summary of Results

		Cost ($/MMBtu)	
		3	5
Economically recoverable gas	Tcf:	47–68	70–104
	% of TRR:	35–45	52–65
Percentage of economically recoverable gas on lands			
With high terrestrial vertebrate species richness[a]		17	17
Within 2,000 m of sensitive species locations		14	14
Within 6,500 m of sensitive species locations		65	65
With surface water, wetlands, or riparian habitats		9	10
Near human settlements		5	6
With high surface slope[b]		8	8
With high aquifer recharge rate[c]		9	9
With shallow groundwater[d]		9	10
Subject to no access[e]		10	10
Subject to restricted access[e]		31	30

NOTES: Ranges for economically recoverable gas reflect different economic scenarios. Results for environmental measures are for the USGS-based scenario only; percentages shown do not necessarily apply to separate areas and so are not additive.

[a]>119 species/area.

[b]>25%.

[c]>2 inches/year.

[d]<16 feet.

[e]Results are based on aggregated lease stipulations from the Department of Energy study (Advanced Resources International, Inc., 2001) and are not related to environmental measures analyzed in this study.

Environmental Considerations

The environmental measures analysis provides additional understanding of the gas resources in the Greater Green River Basin. In this analysis, we examined seven environmental measures:

- Terrestrial vertebrate species richness,
- Proximity to sensitive species observed locations,
- Surface water and riparian habitat zones,
- Proximity to human settlements,
- Surface slope,
- Aquifer recharge rate,
- Depth to groundwater.

The first three measures address primarily ecosystem quality, the fourth represents issues related to human use of the area, and the final three measures examine primarily water quality. We also considered land that is subject to existing federal land access restrictions. Measure values were grouped into bins defined primarily by the statistics of the data for the basin, as well as regulatory and scientific considerations in some cases. Maps of the spatial distribution of the lands with different measure values were then generated. Note that using statistically derived bin values does provide a relative sense of environmental concern for this specific area, and in so doing provides useful guidance. However, because these values are not based on empirically derived relationships between gas and oil development activities and potential environmental impacts, they say little about actual environmental risk and in that sense the environmental measures need to be developed further.

The relative proportion of economically recoverable gas on lands having different values of environmental measures is presented in Table S.1. For the most part, the concentrations of economically recoverable gas are in areas having relatively lower potential environmental concern with respect to the environmental measures we considered. As with the economic evaluation, however, environmental overlay results for certain areas within the basin differ from the basinwide average values shown in Table S.1. Some areas with relatively high gas concentrations coincide with riparian habitats, high terrestrial vertebrate species richness, and shallow groundwater. Such insights may be particularly useful in areas, such as north of the LaBarge Platform, that may appear quite promising judging by the economic analysis alone.

The connection between environmental measures and sensitivity to environmental impact is complex, and actual environmental impacts would not necessarily result from development in areas of nominally greater environmental concern. However, our results suggest that in some areas there may be more costs associated with mitigating potential impacts than in some other regions. This information would be useful to public land managers who may need to prioritize their efforts in permitting lands for exploration and production.

The results generated from this approach can provide decisionmakers with more information about natural resources that can help guide strategic resource planning, help prioritize difficult decisions that are being made about access to federal lands, and help understand the potential consequence of those decisions.

IMPLICATIONS FOR THE ROCKIES

The primary objective of this study was to develop a methodology that incorporates economic and environmental considerations into energy resource assessments. The methodology was developed with a focus on the Greater Green River Basin because of its overall high resource potential and its diverse range of deposit types and depths, which results in a large range in development and production costs. In doing so, we have highlighted some aspects of natural gas resources in the Greater Green River Basin that may not be directly evident from technically recoverable resource assessments. However, the value of this approach is expected to be even more evident when it has been applied to all the basins in the Rocky Mountains and eventually to all basins in the country. Just as a basinwide evaluation using a consistent methodology allows federal land managers to compare and prioritize areas within the Greater Green River Basin, a Rockies-wide evaluation will allow these managers to make the same type of comparisons and prioritizations among areas within different basins.

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GLOSSARY AND ABBREVIATIONS

Aquifer	A geologic unit that acts as an underground water reservoir
Aquifer recharge	The rate of infiltration of surface water into the soil and its percolation through the soil and unsaturated geologic material into the groundwater
ARI	Advanced Resources International
Associated gas	Natural gas produced from wells in which crude oil is the primary product
Bcf	Billion cubic feet
BLM	U.S. Bureau of Land Management (Department of Interior)
cf	Cubic feet
Coalbed methane	A type of natural gas resource in which the gas resides in coal deposits
Conventional	A type of natural gas resource in which deposits possess downdip water contacts and which can be extracted using traditional development practices
Depth to groundwater	Distance from the surface to the top of the initial groundwater aquifer
Drilling success rate	The ratio of successful holes to the total number of wells drilled
EIA	Energy Information Administration
EPCA	Energy Policy and Conservation Act
ERR	Economically recoverable resource
ESA	Endangered Species Act
FNAI	Florida Natural Areas Inventory

GIS	Geographic information system
Habitat	An area defined by certain ecological factors that generally supports certain associations of species
Human settlement	An area characterized by conversion of natural lands for general human use; does not include roads or agricultural use areas
Mcf	Thousand cubic feet
MMbbl	Million barrels
MMBtu	Million British thermal units
MMcf	Million cubic feet
Natural gas liquids	The heavier components of natural gas that form liquids at atmospheric pressure and temperature
NEPA	National Environmental Policy Act
Nonassociated gas	Natural gas produced from wells in which gas is the primary product
Nonconventional	Resources contained in low permeability sandstone ("tight sandstone" or "tight gas"), shale, chalk, and coalbed deposits; also referred to as continuous deposits
NPC	National Petroleum Council
Play	A set of known or postulated oil or gas accumulations sharing similar geologic, geographic, and temporal properties, such as source rock, migration pathway, timing, trapping mechanism, and hydrocarbon type
Proved reserves	Estimated quantities of a resource that are recoverable from known reservoirs under existing economic and operating conditions
psi	Pounds per square inch
Reserve appreciation	The resource expected to result from future extensions in existing pools in known producing reservoirs
Resource area	A spatial subdivision of a subplay; each subplay is divided into a producing, extension, and new field area
Resource category	A classification of resource distinguished by geological, engineering, or economic factors; primary categories are proved reserves, reserve appreciation, and undiscovered resources

Riparian habitat	An area that surrounds surface waters, with characteristic natural vegetation of such areas
Sensitive species	A plant or animal species that is identified by scientific criteria as warranting greater conservation effort or given special status under conservation law
Species richness	A measure of number of species groups expected to occur within a given habitat area
Stimulation	General term for a class of processes, including hydraulic fracturing and acidizing, used to increase porosity and increase gas or oil flow during production
Subplay	A specific portion of a play, as defined for this study
Surface slope	A ratio of vertical to horizontal change in distance above a level, horizontal axis
Surface water	Water that is apparent for significant periods of time at the earth's surface, both permanently (e.g., larger rivers and lakes) and seasonally (e.g., wetlands, ephemeral streams)
Tcf	Trillion cubic feet
Technically recoverable resource	The amount of energy resource that can potentially be recovered given current or anticipated future technology
Tight sandstone	Natural gas or oil reservoir rock with low permeability; see "nonconventional"
TRR	Technically recoverable resource
Undiscovered resources	Resources estimated to exist in new fields but which have yet to be discovered or confirmed
Upland habitat	An area beyond open water, wetland, and riparian areas, with characteristic natural vegetation of such areas
USGS	U.S. Geological Survey (Department of Interior)
Well recovery	The total amount of resource extracted from a well
Well spacing	The number of wells per unit area, usually expressed as wells per acre

Wellhead	The point at which the resource exits the ground; in the context of domestic price data, the generic term "wellhead" is used to reference the production site or lease property; in practice, the wellhead price is generally measured at the lease boundary and thus includes a fraction of the processing, compression, and gathering costs
WYGAP	Wyoming Gap Analysis Program
WYNDD	Wyoming Natural Diversity Database