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A New Approach to Assessing Gas and Oil Resources in the Intermountain West

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A New Approach to Assessing Gas and Oil Resources in the Intermountain West

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The availability of gas and oil resources in the Intermountain Western United States has become the subject of increased debate in recent years. Several studies have concluded that substantial amounts of gas and oil resources in the region are inaccessible because of legally restricted access to federal lands (e.g., National Petroleum Council, 1999; Advanced Resources International, 2001). Some stakeholders have reacted to the studies by calling for reduced access restrictions, while others have called the studies flawed and support continued restrictions. The debate has sparked renewed interest in the process of assessing hydrocarbon fuel resources.

This paper is part of an energy initiative by the Hewlett Foundation. In this effort the Foundation asked RAND to:

- review existing resource assessment methodologies and results
- evaluate recent studies of federal lands access restrictions in the Intermountain West
- consider a set of criteria that can be used to define the "viable" hydrocarbon resource, with particular attention to issues relevant to the Intermountain West
- develop a more comprehensive assessment methodology for the viable resource
- employ this methodology to assess the viable resource in Intermountain West basins.

This issue paper is a part of an interim report that focuses on the first three points. The full interim report is published separately (LaTourrette et al., 2001).

TRADITIONAL ASSESSMENTS ARE AN INSUFFICIENT BASIS FOR POLICY

The goal of traditional resource assessments is to estimate the potential supply of natural gas and oil resources, which, combined with estimates of the proved reserves, make it possible to appraise the nation's long-range gas and oil supply. In this report, we examine four recent assessments (U.S. Geological Survey National Oil and Gas Resource Assessment Team, 1995; Minerals Management Service, 2000; National Petroleum Council, 1999; Potential Gas Committee, 2001). Although the assessments vary, they each indicate that the Intermountain West contains substantial natural gas and oil resources. However, traditional resource assessments estimate the "technically recoverable"[1] resource, which does not reflect the amount of resource that can viably be produced. For example, in the Potential Gas Committee assessment, "No consideration is given whether or not this resource will be developed; rather, the estimates are of resources that could be developed if the need and economic incentive exist." Similarly, the U.S. Geological Survey assessment "makes no attempt to predict at what time or what part of potential additions will be added to reserves. For the National Assessment, resources and potential reserve additions are evaluated regardless of political,

[1] The technically recoverable resource refers to the amount that is estimated to be recoverable given certain assumptions about technical capabilities. In practice, the definition of the term "technically recoverable" is unclear and is inconsistently applied among the different assessments. A large part of the difference between existing resource assessments results from differing assumptions as to what constitutes a technically recoverable resource.

economic, and other considerations." The distinction between the technically recoverable resource and that which is likely to actually be produced is important when confronting questions about the potential benefits and impacts of increased natural gas and oil exploration and production.

The amount of resources that are likely to be produced depends on a number of considerations. The criterion that a resource be technically recoverable is only one of several criteria that are relevant to determining if that resource is, in fact, recoverable. Legal access restrictions, as it turns out, may not be the pivotal factor for actual resource development, because other factors play much greater roles in determining if a resource is recoverable. Three key factors are:

- exploration and production costs (those incurred in getting the resource to the wellhead)
- infrastructure and transportation costs (those incurred in getting the resource to the market)
- environmental impacts.

The wellhead and infrastructure costs are relevant, because, when compared to the revenue expected from the resource being considered for development, they determine whether it is economically feasible to proceed. Environmental impact can be treated in a similar manner by characterizing different levels of impact, allowing policymakers to choose an acceptable level, and then extracting only those resources that can likely be extracted within this acceptable level. It is important that these three factors be included as criteria in resource assessments. The resource that satisfies this more complete set of criteria has a reasonable likelihood of actually being developed and produced. We call such a resource the "viable" resource.

The cumulative effect of these additional factors on the available resource is shown conceptually in Figure 1. The application of each additional criterion—wellhead economic viability, infrastructure economic viability, and environmental acceptability —successively reduces the amount of a resource that is available at a given market price. The axes in Figure 1 are purposely reversed relative to conventional economic supply curves. This choice of using supply as the dependent variable emphasizes the fact that the amount of resource available depends on economic considerations and acceptable environmental impact. Note that the curve for environmental acceptability is conceptual only—we do not propose to calculate environmental costs. Rather, we intend to calculate the amount of the economically viable resource that can be extracted within an acceptable level of environmental impact.

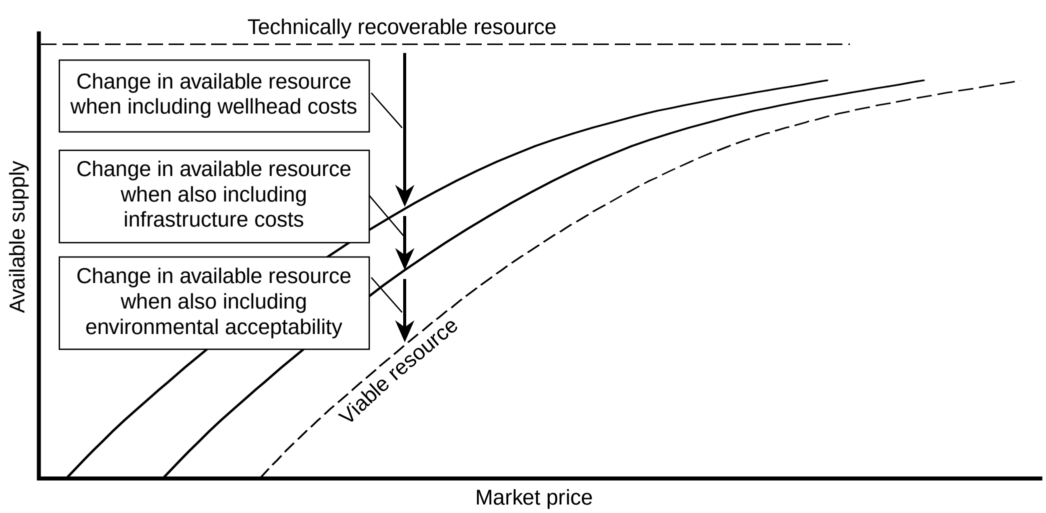

Figure 1—Effect of Viability Criteria on the Available Resource

These three factors reflect well-known and often cited issues that determine the availability of gas and oil resources. Although aspects of these issues have been addressed to varying degrees (e.g., Vidas et al., 1993; Attansi et al., 1998; National Petroleum Council, 1999), no attempt has been made to incorporate them all into a viable resource assessment. Below, we first evaluate existing studies of access restrictions. We then outline our approach to estimating the viable gas and oil resource in the Intermountain West.

LIMITATIONS OF EXISTING ACCESS RESTRICTION STUDIES

Rather than attempting to estimate the viable resource, existing approaches to understanding resource availability have focused on legal access restrictions on federal lands. Recent efforts have been spurred largely by the Energy Protection and Conservation Act of 2000, which directs federal land management agencies to assess the energy potential of public lands and identify impediments to its development. As a result, considerable effort has been and continues to be expended on quantifying the amount of gas and oil resources underlying federal lands that is subject to various forms of access restrictions.

The recent debates over access to natural gas in the Intermountain West have centered largely on the conclusions made in two recent studies. The first one, conducted as part of the recent National Petroleum Council study (National Petroleum Council, 1999), addresses the entire Rocky Mountain Region; the second, prepared for the U.S. Department of Energy (Advanced Resources International, 2001), focuses on the Greater Green River Basin in southwestern Wyoming and northwestern Colorado. In their effort to identify impediments to energy development, these studies make some important assumptions that lead them to overstate the impact of access restrictions on the available gas resource. These assumptions, some of which have also been noted in other analyses (e.g., Morton, 2001), deal with economics, the resource base considered, restriction enforcement, technology, infrastructure, and drilling schedules. As calculation of access restrictions continues to be a component of policy guidance (studies of additional basins are underway), these assumptions should be modified as described below.

- The studies should consider the restricted portion of only the economically viable resource. It is the viable resource that is relevant to understanding the amount of a resource that would be produced in the absence of access restrictions.
- Access restrictions should be evaluated in the context of all resources available to industry. Both studies fail to include proved reserves in the resource base; these reserves are substantial and not subject to access restrictions. In addition, the Greater Green River Basin study includes only federal lands in the resource base, despite the fact that over 25 percent of the gas in the basin lies under non-federal lands, which are not subject to access restrictions.
- The studies should account for the fact that access restrictions are sometimes waived. The studies themselves find that three common lease stipulations are waived in 20 to 30 percent of cases, but the studies fail to account for this finding in the primary analysis.
- The studies should account for the fact that alternative technologies, such as slant drilling, can increase access to resources within the constraints of many land use restrictions.
- The studies should account for access restrictions that could restrict pipeline and road development outside the potential drilling areas. These may preclude development even in areas where drilling is otherwise permitted.
- The studies should factor in that restrictions on timing apply to drilling only (i.e., drilling permitted only in certain months). Once a well is drilled, there are no restrictions on production or maintenance. Thus, nominally inaccessible resources can be developed via multiple-season drilling and then produced year-round.

In summary, the results of these access restriction studies overlook some important considerations and, in so doing, appear to be biased towards maximizing the amount of resources that are perceived to be precluded from development as a result of federal access restrictions.

BUILDING COMPREHENSIVE RESOURCE ASSESSMENTS

While one of the important purposes of access restrictions is to protect environmentally vulnerable areas, the scope of issues addressed by the current access restriction studies falls far short of that in our viable resource criteria. First of all, assessments of access restrictions do not consider economics. In addition, they are subject to inconsistent objectives, interpretations, and capabilities of several different federal lands management agencies . Further, the studies address federal lands only, and so neglect all considerations, including environmental, on non-federal land. Thus, even if the shortcomings outlined above are addressed, the approach of measuring access restrictions does not encompass several important aspects of the viable resource.

For making informed decisions, policymakers need to know how much resource is there, at what cost, and with what impact. Therefore, rather than focus on the amount of resource that is unavailable as a result of land access restrictions, we propose an approach of determining the viable resource: that which is available when considering wellhead costs, infrastructure costs, and acceptable environmental impact.

Wellhead Costs

Wellhead costs vary depending a deposit's geologic characteristics, depth, location, production profiles, and by-products. Estimating economic viability involves balancing these costs with resource revenues to determine if it would be economically logical to proceed with production (e.g., Vidas et al., 1993; Attanasi, 1998). The standard costs that need to be included when considering economic viability are:

- exploration and development drilling
- well completion
- lease equipment
- operations and maintenance
- taxes and royalties
- return on investment.

Incorporating these costs can significantly reduce the amount of gas and oil resources that is realistically viable for production in the foreseeable future. For example, based on the U.S. Geological Survey results, adding this economic criterion alone rules out, in the near term, the recovery of a very large fraction of the gas resource that would otherwise be deemed technically recoverable from the Green River Basin (Attanasi, 1998). It is important to note that technological improvements and changing economic conditions will alter these estimates over time.

Several improvements should also be made to the standard economic models to account for the unique costs of gas and oil exploration and production in the Intermountain West. The following recommendations help tailor our proposed approach to account for some of the characteristics of the Intermountain West and to improve the accuracy of economic modeling of resource development:

- Use data that reflect the region of interest.

Significant costs of gas and oil development in the Rockies can vary considerably depending on the location and characteristics of each basin. However, cost data are generally presented either by state or by a larger region. This practice impairs the accuracy of the cost data and may underestimate the costs of extracting gas and oil from many of the basins in the Rocky Mountain Region.

- Account for the high abundance of nonconventional gas in the Rockies.

One of the primary distinctions of the Rocky Mountain Region is the very high fraction of undiscovered gas that is contained in various nonconventional formations.[2] This distinction is expected to have a substantial impact on several of the cost categories. For example, well completion, lease equipment, and operating costs can be higher for low permeability (tight) sandstone and coalbed methane deposits. While existing efforts attempt to account for these higher costs by including nominal correction factors, the aggregate cost estimates may still

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[2] Nonconventional resources include low permeability (tight) sandstone, shale, chalk, and coalbed methane.

underestimate the real costs of developing Rocky Mountain gas and oil.

- Use local drilling success ratios.

The drilling success ratio is the ratio of productive wells to dry holes in a drilling increment. This ratio influences the total expected number of wells that must be drilled. The ratios used in existing assessments reflect regional averages of existing wells; thus, historical assessments are biased towards conventional deposits. A meaningful economic viability assessment should be based upon the best estimates for drilling success ratios for the specific basins and specific types of deposits being considered.

- Address other costs specific to the Rockies.

Other unique aspects of the Rocky Mountain Region that may further influence the costs of resource extraction include the steep and rugged terrain, remote locations, low quality gas, and shallow formations.

Infrastructure Costs

Much of the economically viable resources in the Intermountain West cannot be developed without constructing additional pipeline and road infrastructure. The economic models discussed above focus strictly on the costs of extracting a resource at its source (wellhead), thus ignoring the potentially large costs of building a transportation infrastructure to deliver the resource from the well to the market. The availability of infrastructure thus represents a distinctly important criterion for defining a resource as viable.

Typically, resource assessments do not consider infrastructure requirements. Capital expenditures and operating costs for infrastructure are thought to be comparatively high in the Rocky Mountain Region, given a lack of infrastructure relative to other regions. If new infrastructure (excluding transmission pipelines) is required, the additional costs could be more than 50 percent of the wellhead costs, making the gas much more expensive than the wellhead cost alone.

Primary infrastructure components include gathering systems, which connect wells to gas processing plants; gas processing plants, the number of which depends on the size and type of deposit; and long-haul transmission lines. The infrastructure requirements and costs depend on the location, number, and characteristics of the wells that are needed to extract gas and oil resources from individual deposits in the region. The costs also depend on drilling depths, well spacings, well pressures, flow rates per well, recovery rates per well, and type of geological formations, all of which can be highly variable.

Several complicating factors in the Rocky Mountain Region increase infrastructure requirements and costs. These factors include:

- the remoteness of existing pipeline infrastructure, particularly transmission pipelines
- the rough terrain, unstable soil, and icing in colder climates
- the extensive water disposal requirements associated with coalbed methane deposits
- the need for extensive compressor capability to transport the very low-pressure gas from nonconventional deposits.

In addition, produced water and other wastes may need to be removed from the site in some cases, potentially requiring additional pipeline capacity.

Infrastructure costs can be assessed for different locations and ultimately parameterized in terms of a few key variables. Based on these variables, the costs can be scaled for varying distances from transmission pipelines. Beyond specific distances, development will no longer be viable.

Environmental Impact

Finally, it is important to evaluate the potential environmental impacts of exploration and production. This evaluation would describe how much of a resource is on lands that are highly vulnerable to ecological disruption versus lands where production activity could have a lower impact. Such an assessment would provide policymakers with a framework with which to determine what constitutes an environmentally acceptable resource.

The environmental impacts of oil and gas extraction begin with the transformation of the landscape to accommodate the drilling apparatus, service roads, and pipelines. Solid waste, hazardous waste, and large volumes of wastewater are then generated during construction, operation, and abandonment of the project, with potential implications for regional air and water quality. There are also the rare but potentially serious effects of accidental spills and blowouts. Such disruptions could adversely affect complex ecosystems, with implications for the health of various species. Ecosystems in the Rocky Mountain area include a rich array of plant and animal species that face increasing stresses due to a number of ongoing human processes, such as agriculture, grazing, urbanization, and mineral extraction.

Environmental impacts may also extend beyond ecological resources to include impacts on historical, anthropological, paleontological, and societal resources. One of the more difficult impacts to consider, but often one with the greatest public interest in scenic areas such as the Rocky Mountains, is the aesthetic impact on landscapes. Introduction of machinery, development of roads, and the denuding of vegetated landscapes to support extraction often carry aesthetic implications.

Oil and gas extraction activities are regulated to guard against environmental impacts associated with air, water, solid waste, and hazardous waste. Regulation, however, does not necessarily prohibit projects with significant environmental impacts. The appropriate federal agency oversees the process and determines environmental thresholds for specific projects. In weighing whether to grant a permit, these agencies temper their consideration of environmental issues with considerations of the social benefits of exploration and development.

For policy purposes, a broader assessment of the environmental impacts of resource development on vulnerable lands is important. Individual indicators could track a spectrum of impacts, including air quality, water quality, soil conditions, hazardous materials, protected species, migration patterns, vegetation habitats, and land use changes. These impacts can be summarized in vulnerability indices, and parcels of land can then be assigned to spatially oriented (mapped) vulnerability categories. The indices and maps can help policymakers (a) understand the spatial distribution of vulnerable environmental areas within a total resource area and (b) given some acceptable level of environmental impact, select which areas are best suited to development.

The indices can help policymakers designate an environmentally viable resource by incorporating various environmental measures, project-specific actions, and available mitigation options.

COMPREHENSIVE ASSESSMENTS WILL HAVE MAJOR IMPLICATIONS

To reiterate, the viable resource is a subset of the technically recoverable resource. In other words, the viable resource is the fraction of the technically recoverable resource that is also economically feasible for production, sufficiently supported by infrastructure, and environmentally acceptable. For the purposes of making decisions regarding gas and oil development, it is the viable resource that matters.

There are two immediate implications. First, the current debate over access to federal lands needs to be refocused. There continues to be much debate about the amount of gas and oil resources in the Intermountain West that is subject to various access restrictions. Given that this debate focuses on the technically recoverable resource and addresses only federal lands, the debate is unduly narrow and does not adequately address the full implications of resource development. The debate needs to focus instead on the resource that is viable to produce. A debate about access restrictions alone does not illuminate the discussion.

Second, it would be prudent to have a better understanding of the economic costs, infrastructure requirements, and environmental impacts of increased production before determining whether to change the status of federal lands available for exploration.

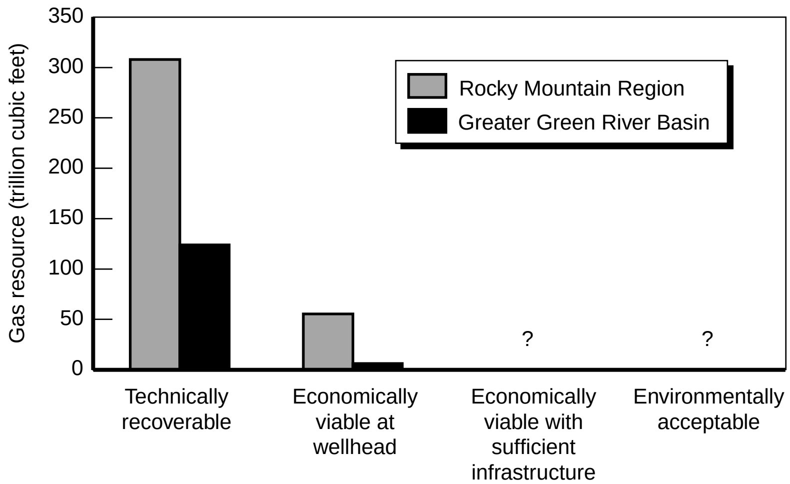

Figure 2—Potential Effect of Viability Criteria on Gas Resource

At present, it is possible to make only a first-order estimate of the effect of some of these viability criteria on the amount of gas that could be viable in the Rocky Mountain Region. Figure 2, based data from the U.S. Geological Survey economic analysis (Attanasi, 1998), shows that the economic viability criterion alone can dramatically reduce the amount of gas that is viable for extraction. At a wellhead price of $3.34 per thousand cubic feet of gas (equivalent to $30 per barrel of oil), less than 20 percent of the technically recoverable gas in the total Rocky Mountain Region is economically viable, and only 5 percent of the technically recoverable gas in the Greater Green River Basin is economically viable. Note that these results do not necessarily reflect RAND's analysis. The costs of exploring and developing gas and oil deposits in the Rocky Mountain Region are decreasing with technological advances. Our economic analysis will use different data and assumptions and may produce different results.

This report lays the foundation for determining the viable gas and oil resource. The next step will be to apply this methodology to estimate the viable resource in individual basins. RAND will begin this effort by analyzing the Green River Basin. The analysis will specify the relationships among gas and oil deposits, technological options, economic costs, infrastructure requirements, environmental sensitivities, and other variables to allow for a comprehensive assessment of the viable gas and oil resource.

Outputs will be presented both numerically and spatially (in the form of Geographic Information System maps that show the amount and location of resources that satisfy the various viability criteria). Such an output will provide a useful way to characterize the viable resource in the context of many important variables, such as deposit types, well locations, existing and needed infrastructure, environmental sensitivities, topography, and other relevant spatial attributes. This method of conducting and presenting resource assessments would be a significant improvement over present practice.

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REFERENCES

Advanced Resources International, Inc., *Federal Lands Analysis Natural Gas Assessment Southern Wyoming And Northwestern Colorado Study Methodology and Results*, http://fossil.energy.gov/oil_gas/reports/fla/, 2001.

Attanasi, Emil D., *Economics and the 1995 Assessment of United States Oil and Gas Resources*, U.S. Geological Survey Circular 1145, 1998.

LaTourrette, Tom, Mark Bernstein, Paul Holtberg, Chris Pernin, Ben Vollaard, Mark Hanson, Kathryn Anderson, Debra Knopman, *Assessing gas and oil* *resources in the Intermountain West: Review of Methods and Framework for a New Approach*, RAND MR-1553-WFHF, Santa Monica, 2002.

Minerals Management Service, *Outer Continental Shelf Petroleum Assessment, 2000*, U.S. Minerals Management Service, 2000.

Morton, Peter, *The Department of Energy's "Federal Lands Analysis Natural Gas Assessment:" A Case of Expediency Over Science*, The Wilderness Society, 2001.

National Petroleum Council, *Natural Gas: Meeting the Challenges of the Nation's Growing Natural Gas Demand*, National Petroleum Council, 1999.

Potential Gas Committee, *Potential Supply of Natural Gas in the United States,* Potential Gas Agency, Golden, CO, 2001.

U.S. Geological Survey National Oil and Gas Resource Assessment Team, *1995 National Assessment of United States Oil and Gas Resources,* U.S. Geological Survey Circular 1118, 1995.

Vidas, E. Harry, Robert H. Hugman, and David S. Haverkamp, Guide to the Hydrocarbon Supply Model: 1993 Update, Gas Research Institute, Report GRI-93/0454, 1993.

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