Examination and Critique of ARI Report: Undiscovered Natural Gas and Petroleum Resources Beneath Inventoried Roadless and Special Designated Areas on Forest Service Lands Analysis and Results,
with
Additional Discussion of U.S. Geological Survey and National Petroleum Council Reports

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I. Objectives

Certain roadless areas administered by the U.S. Forest Service (USFS) are under a moratorium for building new roads. Two reports examined below assert that whatever oil and gas resource may exist beneath the roadless areas would be unavailable for extraction without road access. This Lookout Mountain Analysis (LMA) study critically examines the issue.

The primary purpose of this report is to critique two reports from Advanced Resources International (ARI); (1) *Undiscovered Natural Gas and Petroleum Resources Beneath Inventoried Roadless and Special Designated Areas on Forest Service Lands Analysis and Results*; and (2) *Economically Recoverable Natural Gas Resources Beneath Inventoried Roadless Areas on Forest Service Lands, Analysis and Results.*

Comprehensive descriptions, methodologies, and results of the ARI studies were not available for review. The only sources available are summaries of the reports cited above. As a result, LMA was forced to infer some details concerning individual land tracts, ARI study results, assumptions, and methodologies.

The three additional "building-block" analyses used by ARI that are discussed in this LMA report are; (1) USGS's *1995 National Assessment of United States Oil and Gas Resources*, (2) *Economics and Undiscovered Conventional Oil and Gas Accumulations in the 1995 National Assessment of U.S. Oil and Gas Resources: Conterminous United States,* also published by the USGS; and (3) *Natural Gas: Meeting the Challenges of the Nation's Growing Natural Gas Demand*, published by the National Petroleum Council. Additional ancillary reports to the two USGS reports were also examined in the preparation of this LMA analysis.

Although ARI reports some amounts of oil resource likely exist underneath the lands examined in their study areas, natural gas resources are the most prominent energy commodities discussed by them. This LMA examination of the ARI reports focuses on natural gas resources.

II. Subsequent Structure of this Paper

Section III presents analysis of two USGS papers. These papers give estimates of the amounts of *undiscovered* U.S. natural gas and general discussions of natural gas resources.

Section IV describes the most pertinent aspects of a NPC report examining the adequacy of future U.S. natural gas supply and the natural gas industry's likely response to increasing demands for the energy commodity.

Section V examines the ARI studies. Included in this scrutiny of the USFS roadless area resource estimates are analyses of ARI's assumptions, methodology, and conclusions. Relevant portions of

USGS analyses and the NPC report that relate to the ARI study region or vicinity are reported here.

Section VI presents major conclusions that are drawn from the preceding sections.

III. Review of USGS Papers Estimating Undiscovered Oil and Natural Gas Resources

The USGS has published several papers presenting estimates of oil and gas resources that may be discovered in the United States. Two of these studies investigate both the amounts of likely undiscovered petroleum resources and the general locations where they may exist. In addition, the USGS provides estimates of the costs of extracting various fractions of total national undiscovered energy resources. These two reports from the U.S. Geological Survey collectively present (1) the total amount of undiscovered oil and gas in the U.S., and (2) the fraction of (1) above that might be economically recovered at (a) $18 per barrel of oil and $2 per thousand cubic feet of gas, and (b) $30 per barrel of oil and $3.34 per thousand cubic feet of gas.

Numbers cited in this report generally are the mean, or average value, of a broader probability distribution of resources. These reports give estimates of the quantities of ***undiscovered*** resources of petroleum and natural gas in onshore and immediate offshore areas in the United States. States have some claims to oil and gas resources onshore, as well as in nearshore areas ranging from the coastline out to 3 miles from shore. The Federal Government lays claim to all resources from the three-mile limit out to the 200-mile national territorial limit. The appendix to one of the USGS reports also gives the average total estimates of undiscovered oil and gas likely to be discovered in the offshore areas--the regions beyond the three-mile state-land border.

Conceptually, it is important to understand the distinction between energy resources and reserves. Resources refer to accumulations of energy commodities that may or may not be economically extractible. Reserves are the subset of resources that are known to be economically producible under likely future energy prices. For example, exploration drilling may reveal the presence of 100 million barrels of oil in place at a depth of 35,000 feet. If oil prices are $20 per barrel the costs of extracting even one barrel of oil may exceed $20. If oil prices increased to $30 per barrel, conventional petroleum production technology may allow economic recovery of 20 million barrels of oil. An oil price increase to $40 per barrel may allow the use of secondary or tertiary recovery methods that squeeze an additional 12 million barrels out of the reservoir. In the preceding example, the reserves of the hypothetical field are 32 million barrels with an oil price of $40 per barrel, 20 million barrels with an oil price of $30, and 0 barrels with an oil price of $20 or below.

The preceding example quantified economically recoverable resources at various oil prices. Technically recoverable oil or gas is the total amount of the commodity that could be extracted from the reservoir, regardless of cost.

One can think of energy resources as a series of sets. The largest set is the amount of resource that is in-place beneath the ground. This is the total quantity of oil or gas physically present in the reservoir. Oil quantities are usually expressed as the number of barrels (42 gallons per barrel), and natural gas is expressed as a number of thousand cubic feet (Mcf) or trillion cubic feet (Tcf). The technically recoverable resource subset is the amount of the energy commodity that could be pumped to the surface with an unlimited budget, using current technology. As the preceding example shows, the economically recoverable subset of the technically recoverable resource is dependent on the future commodity price. In general, the most relevant subset for policy purposes

is the economically recoverable resource because one assumes that no oil company would willingly produce energy resources at a loss.

Intellectually it may be difficult to understand how one could estimate amounts of a resource that one does not know where or if it exists. In reality no one can say with assurance how much oil and gas resources and reserves may yet remain to be discovered in this country, or where they may be. However, geologists have long recognized patterns in the distributions and amounts of energy commodities in this country. By extrapolating these recognized patterns into areas that may contain similar geological and other physical characteristics, resource experts from the USGS have put forth a series of educated guesses of the amount and costs of extraction of the likely remaining oil and gas resources yet to be discovered in this country. As our knowledge of these unexplored areas increases, these educated guesses about the volumes and locations of heretofore-undiscovered energy commodities becomes more comprehensive and more refined.

U.S. Natural Gas Resources

Technically Recoverable Resources

Table 1 graphically depicts the amounts of technically recoverable natural gas resources and natural gas reserves that might ultimately be found in the United States.

Table 1 – Sources of Current and Future U.S. Natural Gas Supply

Gas Supply Category	U.S Gas Supply (Tcf)
Current Discovered Reserves	135.1
Current Discovered Reserve Growth	322.0
Undiscovered Conventional	258.9
Undiscovered Unconventional Continuous-Type Accumulations	308.1
Undiscovered Unconventional Coalbed Gas	49.9
Total	1,074.1

Source: U.S. Geological Survey, 1996, *1995 National Assessment of United States Oil and Gas Resources—Results, Methodology, and Supporting Data.*

Current discovered reserves, in Table 1 above, represent the amounts of *discovered* technically recoverable natural gas. The bottom four categories represent different types of *undiscovered* natural gas resources. Quantities of economically recoverable natural gas will of course be less than technically recoverable resources.

Undiscovered reserve growth refers to natural gas that is likely to be discovered within the boundaries of known oil and gas fields. Conventional resources are defined as energy deposits having physical characteristics that allow the use of traditional drilling and production techniques. A conventional gas resource might include a deposit of petroleum contained at the top of an upward-arching series of sandstone beds. A typical petroleum reservoir geometry might contain an impermeable bed of an overlying rock formation keeping the lighter oil and gas from migrating up the rock layers. In Table 1, undiscovered conventional natural gas resources refer to accumulations that might be found in new oil and gas fields, beyond the boundaries of currently known oil producing areas.

In contrast, unconventional oil and gas accumulations are a series of oil and natural gas deposit types that historically have not been developed using traditional techniques. Continuous-type natural gas deposits are ones that display an unconventional geometry. E.g., where the natural gas is not found as a gas cap trapped immediately below an impermeable layer, but might be found apparently randomly distributed within a reservoir rock.

Another unconventional resource, coal-bed gas, is found within and above beds of coal. Chemical reactions within the coal beds produce natural gas that then is either trapped amongst the faces of coal at depth, or the gas can migrate upwards from the coal beds to overlying strata or the surface.

The most notable characteristic of Table 1 is the large quantity of technically recoverable natural gas that is yet to be discovered in the U.S. The roughly 940 Tcf of undiscovered gas is seven times larger than currently known reserves. (Current U.S. annual gas consumption is about 22.2 Tcf, Source: US DOE/EIA, 2000,Country Analysis Briefs, United States).

Economically Recoverable Resources

To be considered economically recoverable the market costs of natural gas recovery must be less than or equal to the gas price. The costs that the USGS uses in assessing the costs of natural gas production include items such as the direct costs of exploration, development and production of natural gas. Not included in the USGS calculation are items such as off-site ecological costs and cumulative negative environmental impacts that might result on a public resource such as a watershed. Due to the global scope of USGS cost analyses, the agency uses generic types of cost estimation that are largely dependent on characteristics such as region, rock type, and depth of natural gas resource. This type of analysis does not allow for many adjustments for site-specific or large-area public resource impacts.

Table 2 gives regional estimates of natural gas that would be economically producible with natural gas prices of $2 per Mcf. Table 3 gives the larger amounts producible under $3.34 per Mcf. Approximately 113.5 Tcf of conventional and unconventional natural gas resource would likely be produced with a gas price of $2 per Mcf. This represents approximately 18 percent of the total technically recoverable undiscovered natural gas resource of 616.9 Tcf, derived from Table 1. As shown in Table 3, a natural gas price of $3.34 per Mcf yields a likely production of 196.2 —jumping to approximately 32 percent of the technically recoverable resource.

With a gas price of $2 per Mcf, the Gulf Coast and the Colorado Plateau and Basin and Range regions contain the greatest quantities of undiscovered economically recoverable natural gas, representing about 40 percent and 22 percent of the total projected natural gas production from these resources, respectively. In addition to the two regions named above the Rocky Mountains and Northern Great Plains would contribute about 16 percent of the production total.

Table 2 – Undiscovered *Conventional and Unconventional* Economically Recoverable U.S. Natural Gas at $2 per Mcf

Region	Conventional $2/Mcf Gas (Tcf)	Unconventional $2/Mcf Gas (Tcf)
Alaska	0.9	0.1
Pacific Coast	2.2	1.2
Colorado Plateau and Basin and Range	1.9	22.5
Rocky Mountains and Northern Great Plains	2.9	15.4
West Texas and Eastern New Mexico	3.0	6.1
Gulf Coast	3.5	42.3
Midcontinent	1.1	6.6
Eastern	0.3	3.5
TOTAL-United States	15.9	97.6

Source: U.S. Geological Survey, 1998, *Economics and the 1995 National Assessment of United States Oil and Gas Resources.*

Table 3 – Undiscovered *Conventional and Unconventional* Economically Recoverable U.S. Natural Gas at $3.34 per Mcf

Region	Conventional $3.34/Mcf Gas (Tcf)	Unconventional $3.34/Mcf Gas (Tcf)
Alaska	3.3	0.3
Pacific Coast	3.4	3.1
Colorado Plateau and Basin and Range	2.5	32.7
Rocky Mountains and Northern Great Plains	4.4	24.6
West Texas and Eastern New Mexico	4.0	9.0
Gulf Coast	7.8	62.7
Midcontinent	2.1	12.1
Eastern	0.6	23.6
TOTAL-United States	28.2	168.0

Source: U.S. Geological Survey, 1998, *Economics and the 1995 National Assessment of United States Oil and Gas Resources.*

A gas price of $3.34 per Mcf yields roughly the same relative regional contributions—36 percent for Gulf Coast, 18 percent for Colorado Plateau and Basin and Range, and 15 percent for Rocky Mountains and Northern Great Plains. One notable regional newcomer with the higher gas price is the Eastern region. This area would produce about 12 percent of undiscovered conventional and unconventional gas in this scenario, compared with a relative production of only 3 percent with a gas price of $2 per Mcf. Clearly the Eastern region still contains a relatively high amount of undiscovered natural gas, but most of the resource apparently has a relatively high cost of production.

IV. National Petroleum Council Report-- *Natural Gas: Meeting the Challenges of the Nation's Growing Natural Gas Demand*

Primary Findings

ARI also referenced in their study the National Petroleum Council Report--*Natural Gas: Meeting the Challenges of the Nation's Growing Natural Gas Demand.* The National Petroleum Council (NPC) is an organization whose members are appointed by the Secretary of Energy and represent all segments of the oil and gas industries and related interests. It is important to note that the NPC is dominated by members whose interests are best served by maximizing energy production. There are very few organizations representing purely environmental viewpoints in the NPC.

The NPC paper was written in response to a request from the Secretary of Energy to provide advice on the potential contribution of natural gas in meeting the nation's future economic, energy, and environmental goals.

The report's primary conclusion is that *the estimated natural gas resource base is adequate to meet an increasing demand* (italics added). And, advances in technology have continued to increase the size of economically recoverable natural gas resources. The NPC panel further stated that these conclusions were based on several assumptions including, adequate access to resources, continued technological advancement, ability to finance new infrastructure and supply, availability of skilled workers, and the need for additional drilling rigs. Examples of technological advances are a discussion of extended-reach drilling that allows access to resources located 5 to 6 miles laterally from the drilling site, and deeper drilling in offshore areas to depths of greater than 8,000 feet.

The NPC report made several important observations; (1) natural gas demand has been growing faster than even the fastest growth rate projected in a early 1990s study; (2) the domestic natural gas reserve base in the lower 48 states is about 1466 Tcf (with the most significant new resources coming from new discoveries in the Gulf of Mexico); (3) the primary source of natural gas imports is from Canada—technically recoverable resource base of about 670 Tcf; and (4) Liquified Natural Gas (LNG) imports will likely increase to about 0.9 Tcf.

To reach the conclusions in the NPC report, the organization scrutinized the known and undiscovered natural gas resource base and then estimated the likely sources of supply and matched it to the future domestic natural gas demand.

Additional infrastructure requirements, as noted in the study, include new pipelines to reach frontier-region gas, expansion of existing pipelines, new "laterals" to feed the rapidly growing electricity-demand for gas, and new construction and expansion of existing gas storage areas to meet peak and seasonal demands. The report estimates an aggregate need of 38,000 miles of new gas transmission lines, 263,000 miles of distribution mains, and approximately 0.8 Tcf of new gas storage capacity by 2015.

V. ARI Reports

ARI Reports: USGS Data in ARI Study Areas

USGS Conventional Resources

Table 4 shows the undiscovered economically and technically recoverable conventional natural gas resources of the U.S. and ARI study area. The ARI study region comprises about 11.5 percent of total undiscovered U.S. conventional technically recoverable natural gas resources (29.8 Tcf out of 258.9 Tcf). Nationally, at $2 per Mcf, approximately 30 percent of undiscovered technically recoverable conventional natural gas can be produced. Within the ARI study area the economically recoverable fraction of undiscovered conventional resources is about 49 percent. A major reason for the smaller recovery ratio nationally is because of the low recovery assigned to the large Alaskan gas resources. At $3.34 per Mcf national recovery of undiscovered conventional technically recoverable natural gas resources climbs to approximately 47 percent, compared to a 67 percent recovery rate in the ARI study area.

Federal Lands' Share of Conventional Resources

Given the very large proportions of federal lands in the Western U.S., one might expect that virtually all of the conventional natural gas resource might be located on federal lands. But, as shown in Table 5, almost 38 percent of the undiscovered conventional natural gas is likely to be found beneath private and state lands in the ARI study area. The federal land proportion of the undiscovered conventional natural gas ranges from a low of 1.3 percent in the Denver Basin, to a high of 83.3 percent in the Montana Thrust Belt.

Table 4 – Undiscovered *Conventional* Technically and Economically Recoverable Natural Gas Resources in ARI Study Area

USGS Province	Conventional Technically Recoverable Gas (Tcf)	Conventional Recoverable @ $2/Mcf Gas (Tcf)	$2/Mcf Fraction of Tech. rec.	Conventional Recoverable @ $3.34/Mcf Gas (Tcf)	$3.34/Mcf Fraction of Tech. rec.
Western Great Basin	0.0	0.0	0.0%	0.0	0.0%
Eastern Great Basin	0.3	0.1	23.6%	0.1	41.9%
Uinta-Piceance Basin	4.5	2.5	55.4%	3.5	77.5%
Paradox Basin	2.0	0.4	22.2%	0.9	47.1%
San Juan Basin	1.0	0.4	47.0%	0.7	74.6%
Albuquerque-Santa Fe Rift	0.4	0.0	0.0%	0.0	6.5%
Northern Arizona	0.2	0.0	0.0%	0.0	9.8%
Montana Thrust Belt	1.9	0.9	47.5%	1.3	65.3%
North-Central Montana	0.8	0.1	12.3%	0.4	49.2%
Southwest Montana	0.4	0.0	0.0%	0.0	0.0%
Williston Basin	1.7	0.4	24.1%	0.9	54.8%
Powder River Basin	1.6	0.4	24.7%	0.8	51.4%
Big Horn Basin	0.6	0.1	21.9%	0.3	54.0%
Wind River Basin	1.2	0.3	21.5%	0.5	43.9%
Wyoming Thrust Belt	10.7	8.6	80.8%	9.5	88.9%
Southwestern Wyoming	1.6	0.2	10.0%	0.6	37.3%
Park Basins	0.0	0.0	0.0%	0.0	0.0%

USGS Province	Conventional Technically Recoverable Gas (Tcf)	Conventional Recoverable @ $2/Mcf Gas (Tcf)	$2/Mcf Fraction of Tech. rec.	Conventional Recoverable @ $3.34/Mcf Gas (Tcf)	$3.34/Mcf Fraction of Tech. rec.
Denver Basin	0.8	0.0	0.7%	0.2	24.8%
Raton Basin-SG Uplift	0.0	0.0	0.0%	0.0	0.0%
Total Region	29.8	14.5	48.7%	19.9	66.9%
Total U.S.	258.9	77.5	29.9%	121.8	47.1%

Source: U.S. Geological Survey, 1998, OF-95-75-N and OF-95-75-H, *1995 National Oil and Gas Assessment and Onshore Federal Lands, and Economics and Undiscovered Conventional Oil* and *Gas Accumulations in the 1995 National Assessment of U.S. Oil and Gas Resources: Conterminous United States.*

USGS Unconventional Natural Gas Resources

The preceding discussions of natural gas resources have concentrated on conventional resources. But, the ARI study area also contains a large quantity of *unconventional* resources. Table 6 depicts the federal lands' share of undiscovered unconventional technically recoverable natural gas resources within the study region. At least two characteristics of the study area's undiscovered unconventional resource are notable; (1) the majority of the unconventional gas resources is concentrated in Rocky Mountain/Great Plains region (100 Tcf out of 120 Tcf), and (2) the economically recoverable fraction of the total unconventional resource is much greater for the lesser-endowed Colorado Plateau/Basin and Range province than the Rocky Mountain/Great Plains region (88 percent recovery vs. 5 percent recovery at $3.34 per Mcf).

Table 5 – Federal Lands and Undiscovered *Conventional* Technically Recoverable Natural Gas Within the ARI Study Area

USGS Province	Federal and Nonfederal Lands Conventional Gas Tcf (mean)	Federal Lands Conventional Gas Tcf (mean)	Federal Onshore lands Fraction of Total Conventional Gas
CO Plateau/Basin & Range			
Eastern Great Basin	0.34	0.20	58.8%
Western Great Basin	0.00	0.00	N/A
Uinta-Piceance Basin	4.53	3.23	71.3%
Paradox Basin	1.98	1.18	59.6%
San Juan Basin	0.95	0.35	36.8%
Albuquerque-Santa Fe Rift	0.35	0.07	20.0%
Northern Arizona	0.17	0.09	52.9%
Subtotal-CO Plat/B & R	8.32	5.12	61.5%
Rky Mtn/N. Great Plains			
Montana Thrust Belt	1.92	1.60	83.3%
North-Central Montana	0.85	0.08	9.4%
Southwest Montana	0.41	0.04	9.8%
Williston Basin	1.72	0.26	15.1%

USGS Province	Federal and Nonfederal Lands Conventional Gas Tcf (mean)	Federal Lands Conventional Gas Tcf (mean)	Federal Onshore lands Fraction of Total Conventional Gas
Powder River Basin	1.62	0.91	56.2%
Big Horn Basin	0.62	0.49	79.0%
Wind River Basin	1.24	0.95	76.6%
Wyoming Thrust Belt	10.68	7.97	74.6%
Southwestern Wyoming	1.57	1.17	74.5%
Park Basins	0.02	0.01	50.0%
Denver Basin	0.76	0.01	1.3%
Raton Basin-SG Uplift	0.04	0.01	25.0%
Subtotal-Rky Mtn/N Gr Pl	21.45	13.50	62.9%
Total Study Region	29.77	18.62	62.5%
Total Onshore U.S.	258.9	57.9	22.4%

Source: U.S. Geological Survey, 1998, OF-95-75-N, *1995 National Oil and Gas Assessment and Onshore Federal Lands*.

Table 6 – Undiscovered Total *Unconventional* Natural Gas Resources on Federal Lands in the ARI Study Area (Includes Coalbed- and Continuous-Type Resources).

USGS Province	Onshore Federal Lands Unconventional Gas Tcf (mean)	$2/Mcf Unconventional Gas Tcf (mean)	Economically Producible Fraction @ $2/Mcf	$3.34/Mcf Unconventional Gas Tcf (mean)	Economically Producible Fraction @ $3.34/Mcf
CO Plateau/Basin & Range					
Eastern Great Basin	0.59	0.00	0.0%	0.00	0.0%
Western Great Basin	0.00	0.00	0.0%	0.00	0.0%
Uinta-Piceance Basin	10.43	4.86	46.6%	8.06	77.3%
Paradox Basin	0.73	0.00	0.0%	0.12	16.5%
San Juan Basin	8.83	6.71	76.0%	8.38	94.9%
Albuquerque-Santa Fe Rift	0.20	0.00	0.0%	0.00	0.0%
Northern Arizona	0.53	0.00	0.0%	0.00	0.0%
Subtotal-CO Plat/B & R	18.93	11.57	61.1%	16.56	87.5%
Rky Mtn/N. Great Plains	0.00	0.00	0.0%	0.00	0.0%
Montana Thrust Belt	0.83	0.00	0.0%	0.00	0.0%
North-Central Montana	3.87	1.00	25.8%	1.05	27.1%
Southwest Montana	0.10	0.00	0.0%	0.00	0.0%
Williston Basin	3.93	0.00	0.0%	0.00	0.0%
Powder River Basin	0.56	0.00	0.0%	0.51	90.8%
Big Horn Basin	0.79	0.00	0.0%	0.00	0.0%
Wind River Basin	0.77	0.00	0.0%	0.16	20.9%
Wyoming Thrust Belt	0.75	0.00	0.0%	0.00	0.0%
Southwestern Wyoming	93.21	0.27	0.3%	3.31	3.6%
Park Basins	0.50	0.00	0.0%	0.00	0.0%
Denver Basin	0.05	0.00	0.0%	0.03	56.4%
Raton Basin-SG Uplift	0.25	0.00	0.0%	0.09	36.0%

USGS Province	Onshore Federal Lands Unconventional Gas Tcf (mean)	$2/Mcf Unconventional Gas Tcf (mean)	Economically Producible Fraction @ $2/Mcf	$3.34/Mcf Unconventional Gas Tcf (mean)	Economically Producible Fraction @ $3.34/Mcf
Subtotal-Rky Mtn/N Gr Pl	100.68	1.27	1.3%	5.15	5.1%
Total Study Area	119.60	12.84	10.7%	21.71	18.2%
Total Onshore Fed. Land	143.16	13.10	9.2%	23.26	16.3%

Source: U.S. Geological Survey, 1998, OF-95-75-N, 1995 *National Oil and Gas Assessment and Onshore Federal Lands.*

This unbalanced nature of the regions is shown by the fact that the Rocky Mountain/Great Plains region is heavily endowed with a large supply of unconventional natural gas (100 Tcf) but the economic recovery rate for that gas is only 5 percent at the higher gas price. On the other hand, the smaller natural gas resource in the Colorado Plateau/Basin and Range province (19 Tcf) has an 88 percent recovery rate at $3.34 per Mcf.

Coalbed-Type vs. Continuous-Type Unconventional Resources

In the preceding discussion the two major components of unconventional natural gas resources were lumped together to judge their collective contribution to the regional natural gas endowment. There are actually significant differences in regional distribution and economic recovery between the two primary constituents of unconventional natural gas; (1) coalbed gas, and (2) continuous-type gas. As mentioned previously, coalbed gas is natural gas that is attributed to and is usually in or nearby existing coal deposits. Continuous-type gas occurrences as used by the USGS is more of an "other" type of resource category in that the agency tends to lump together various types of non-traditional natural gas occurrences not related to coal.

Tables 7 and 8 depict coalbed- and continuous-type gas resources in the ARI study region, respectively. The USGS provinces within the ARI study are have modest-to-significant amounts of technically recoverable coalbed gas—12 Mcf in the CO Plateau/Basin and Range region and 3 Mcf in the Rocky Mtn/N. Great Plains area. Most of the region's resources are concentrated within a few of the plays. The CO Plateau/Basin and Range Province contains almost 80 percent of the resource in the ARI study area, with the Uinta-Piceance Basin holding the largest technically recoverable resource of almost 8 Tcf.

Including all federal lands contained in the ARI study area, the USGS has calculated that the maximum economically recoverable fraction of continuous-type of natural gas is 36 percent on the Colorado Plateau/Basin and Range and 4 percent in the Rocky Mountain/Northern Great Plains regions (at $3.34 per Mcf). Much greater recoveries are projected for coalbed gas however, 86 percent of the technically recoverable resources in the Colorado Plateau/Basin and Range, and 44 percent in the Rocky Mountain/Northern Great Plains region (again with a price of $3.34 per Mcf).

Table 7 – Undiscovered Unconventional Coalbed Natural Gas Resources and Recoveries on Federal Lands at Various Natural Gas Prices

	Federal Lands				
	Coalbed-Type Gas	Coalbed-Type Gas	Coalbed-Type Gas	Coalbed-Type Gas	Coalbed-Type Gas
	Technically Recoverable	Recoverable @ $2/Mcf	Producible Fraction	Recoverable @ $3.34/Mcf	Producible Fraction
USGS Province	**Tcf (mean)**	**Tcf (mean)**	**@ $2/Mcf**	**Tcf (mean)**	**@ $3.34/Mcf**
CO Plateau/Basin & Range					
Eastern Great Basin	0.0	0.0	N/A	0.0	N/A
Western Great Basin	0.0	0.0	N/A	0.0	N/A
Uinta-Piceance Basin	7.9	3.4	43.0%	6.4	81.0%
Paradox Basin	0.0	0.0	N/A	0.0	N/A
San Juan Basin	3.8	3.2	84.2%	3.7	97.4%
Albuquerque-Santa Fe Rift	0.0	0.0	N/A	0.0	N/A
Northern Arizona	0.0	0.0	N/A	0.0	N/A
Subtotal-CO Plat/B & R	11.7	6.6	56.4%	10.0	85.5%
Rky Mtn/N. Great Plains					
Montana Thrust Belt	0.0	0.0	N/A	0.0	N/A
North-Central Montana	0.0	0.0	N/A	0.0	N/A
Southwest Montana	0.0	0.0	N/A	0.0	N/A
Williston Basin	0.0	0.0	N/A	0.0	N/A
Powder River Basin	1.0	0.0	0.0%	0.5	50.0%
Big Horn Basin	0.0	0.0	N/A	0.0	N/A
Wind River Basin	0.2	0.0	0.0%	0.2	94.1%
Wyoming Thrust Belt	0.0	0.0	N/A	0.0	N/A
Southwestern Wyoming	1.9	0.3	16.0%	0.7	36.8%
Park Basins	0.0	0.0	N/A	0.0	N/A
Denver Basin	0.0	0.0	N/A	0.0	N/A
Raton Basin-SG Uplift	0.1	0.0	0.0%	0.1	81.8%
Subtotal-Rky Mtn/N Gr Pl	3.2	0.3	9.4%	1.4	43.8%
Total Study Area	14.9	6.8	45.8%	11.5	77.2%
Total Onshore U.S.	16.1	7.0	43.5%	11.8	73.3%

Source: U.S. Geological Survey Circular 1145, 1998, *Economics and the 1995 National Assessment of United States Oil and Gas Resources.*

Table 8 –Undiscovered Unconventional Continuous-Type Natural Gas Resources on Federal Lands and Recoveries at Various Natural Gas Prices

	Federal Lands				
	Continuous-Type Gas	Continuous-Type Gas	Continuous-Type Gas	Continuous-Type Gas	Continuous-Type Gas
	Technically Recoverable	Recoverable @ $2/Mcf	Producible Fraction	Recoverable @ $3.34/Mcf	Producible Fraction
USGS Province	Tcf (mean)	Tcf (mean)	@ $2/Mcf	Tcf (mean)	@ $3.34/Mcf
CO Plateau/Basin & Range					
Eastern Great Basin	0.0	0.0	N/A	0.0	N/A
Western Great Basin	0.0	0.0	N/A	0.0	N/A
Uinta-Piceance Basin	9.7	1.5	15.5%	1.7	17.5%
Paradox Basin	0.1	0.0	0.0%	0.1	92.3%
San Juan Basin	8.5	3.5	41.5%	4.7	55.3%
Albuquerque-Santa Fe Rift	0.0	0.0	N/A	0.0	N/A
Northern Arizona	0.0	0.0	N/A	0.0	N/A
Subtotal-CO Plat/B & R	18.3	5.0	28.0%	6.5	35.5%
Rky Mtn/N. Great Plains				0.0	
Montana Thrust Belt	0.0	0.0	N/A	0.0	N/A
North-Central Montana	3.8	1.0	26.3%	1.1	29.0%
Southwest Montana	0.0	0.0	N/A	0.0	N/A
Williston Basin	3.8	0.0	0.0%	0.0	0.0%
Powder River Basin	0.0	0.0	N/A	0.0	N/A
Big Horn Basin	0.0	0.0	N/A	0.0	N/A
Wind River Basin	0.0	0.0	N/A	0.0	N/A
Wyoming Thrust Belt	0.0	0.0	N/A	0.0	N/A
Southwestern Wyoming	92.5	0.0	0.0%	2.6	2.8%
Park Basins	0.0	0.0	N/A	0.0	N/A
Denver Basin	0.0	0.0	N/A	0.0	30.0%
Raton Basin-SG Uplift	0.0	0.0	N/A	0.0	N/A
Subtotal-Rky Mtn/N Gr Pl	100.1	1.0	1.0%	3.7	3.7%
Total Study Area	118.4	6.0	5.1%	10.2	8.6%
Total Federal U.S.	127.1	6.4	5.0%	11.4	9.0%

Source: U.S. Geological Survey Circular 1145, 1998, *Economics and the1995 National Assessment of United States Oil and Gas Resources.*

Of particular importance is the high economic recovery rates seen in the coalbed gas production. Almost one-half of the technically recoverable resource can be economically extracted at $2 per Mcf, and more than three-quarters at $3.34 per Mcf, when considering all lands in the regions. Some of the plays in both regions have an economically recoverable fraction of near 95 percent of the technically recoverable natural gas resources.

There are moderate-to-substantial technically recoverable resources of continuous-type natural gas resources, but the economic recovery rates are usually much lower. Largest resources are concentrated in the Southwestern Wyoming area of the Rocky Mountain/Northern Great Plains region, with a technically recoverable gas content of about 93 Tcf. By contrast, the collective amount found in the Colorado Plateau/Basin and Range Province is about 18 Tcf.

The USGS data show large variance in regional recovery rates. The huge resources in the Southwestern Wyoming play are assigned about a 4 percent recovery rate, compared with a regional average for the Colorado Plateau/Basin and Range Province of about 36 percent at a price of $3.34 per Mcf.

ARI Reports: NPC Study

The NPC discussed access to natural gas resource various regions. According to their report, the Rocky Mountains (defined broadly) has "significant access restrictions". They claim that 40 percent of the region's resource on federal lands, 137 Tcf, is either closed to exploration or is open under "restrictive" provisions. Some of the causes of access restrictions cited in the reported are environmental or multiple-use conflicts

Few details of specific cases in the NPC study were available for review. However, one Rocky-Mountain-area case calculated the impact of simultaneously (1) tightening access restrictions in the Rocky Mountains and (2) eliminating a key offshore lease sale. The collective result of these actions in the NPC models was to increase gas price by $0.16 by 2010 and decrease U.S. production by 0.5 Tcf in that year. The mirror-image of this model case—relaxing Rocky Mountain access conditions and making additional offshore areas available, had the effect of decreasing gas price by $0.45 and increasing domestic production (mostly in the Rockies and eastern Gulf of Mexico) by 1.6 Tcf in 2015.

ARI Reports: Methodology

ARI overlaid boundaries of Inventoried Roadless Areas (IRA) and Special Designated Areas (SDA) over the USGS boundaries of the various "plays" that collectively comprise the undiscovered technically recoverable conventional and unconventional natural gas resources of the region.

As stated by the USGS "a play is 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." In laymen's terms it is a body of rock with similar characteristics that tend to favor the presence of oil or gas.

Homogeneous Distribution

ARI assumed a homogeneous distribution of petroleum throughout each play. A homogeneous distribution of a play implies that the thickness and oil or gas content or a rock-unit is the same throughout its entire distribution on the map. Using this assumption, if a play extended from Colorado to Montana, any given acreage in Colorado would have an equal chance of containing a barrel of oil or Mcf of gas underneath it as an equal acreage in Montana.

In the absence of specific knowledge about plays, an assumption of homogeneous distribution within the plays may be a reasonable approximation. But, if only a small part of a play is sampled it may lead to misleading results. For example, if a play of 100 million acres is judged to hold 10 Tcf of gas, an IRA that is one percent (1 million acres) would be assumed to have 0.1 Tcf of gas. In reality the regional variation in gas content of the plays may mean that the 1 million acres may have contain much less or much more than one percent of the play's total gas content. As the IRA becomes a larger and larger fraction of the play area, the less likely it is that the homogeneous distribution will result in misleading results.

One other potential concern is the ARI's implicit assumption that any oil or gas directly underneath an IRA is producible only with a well directly above the resource. As reported in a previous section, the NPC report states that current technology now allows a single well to produce resources from a 12 mile-diameter circle. This means that the only resources within an IRA that would not be producible from an outside well would have to be more than 6 miles from any IRA boundary. Because ARI apparently did not consider this factor their resource estimates very likely overstate the total resource that would be "locked-up" within each IRA without building access roads.

Slope Analysis

Another feature included in the ARI analysis is slope analysis. ARI initiates each play analysis with a range of values for technically recoverable gas derived from USGS data. If a play was assumed by ARI to be relatively rich in oil or gas resources ("high") and the IRA region within the play was judged to have slopes less than 30 percent (shallow), ARI assigned the USGS' 95th percentile values for the region. IRAs with slopes greater than 30 percent (steep) in "high" oil or gas plays were assigned the mean value (or "average", or "expected value") from USGS data. Plays that ARI judged to have a "mean" amount of oil or gas resource and containing steep slopes in the IRA area were assigned the USGS mean value for the play. Steep slopes in the same "mean" resource value IRA were assigned the 5th percentile of the USGS resource value. In a similar fashion, plays containing relatively small amounts of oil or gas resource ("low") and containing IRAs with shallow slopes received a resource value from the 5th percentile of the USGS distribution--while the steep slopes in the "low" resource areas received a zero resource value.

For example, assume that the USGS reported the following values for the technically recoverable gas resources in Play A: 95 percent chance that play A contains at least 0.1 Tcf of gas, a mean ("average' or "expected value") chance that Play A contains at least 0.4 Tcf of gas, and a 5 percent chance that Play A contains at least 9 Tcf of gas. There are 19 chances in twenty (5th percentile) that the play contains at least 0.1 Tcf, the mean, or most representative assumption, is that the play holds at least 0.4 Tcf, and there is one chance in twenty (95th percentile) that the play holds 9 Tcf or more.

Discussions of "one chance in twenty" and 5th percentile can be confusing. Sometimes it is easier to consider the converse concept. Using the previous example, the 5th percentile can also be expressed by saying that there is a 5 percent chance (or one chance in twenty) that a play contains no *more* than 0.1 Tcf. Likewise the 95th percentile can be described by saying that there is a 95 percent chance (nineteen chances in twenty) that the play has no more than 9 Tcf.

Resuming the previous example, assume that the acreage of an IRA within play A equals 10 percent of the total play. And, ARI identifies the play as a "high" resource play. If ARI determines that the slopes in the IRA are shallow, ARI assigns the 95th percentile resource value of 9 Tcf to the whole play and therefore 0.9 Tcf to the IRA (10 percent). Conversely, "low" resource plays and high slopes are assigned a resource value of zero.

There seems to be at least one major bias inherent in ARI's slope analysis that has the effect of greatly overstating likely technically recoverable resources. One might think that rounding up on the rich resource plays and rounding down on the poorer resource plays might cancel out the errors—much like rounding every digit above 5 upwards and below 5 downwards. But, the errors definitely do not cancel.

Values reported by the USGS on technically recoverable oil and gas resources are almost always very "positively skewed." The consequence of this is evident in the preceding example; the 5th percentile value is 0.1 Tcf, the mean value is 0.4 Tcf, and the 95th percentile is 9 Tcf. The 5th percentile and the mean value are only 0.3 Tcf apart. Meanwhile the 95th percentile is 8.6 Tcf from the mean.

Statistical theory asserts that, if one must use only one number from a probability distribution, such as the USGS values for the oil and gas resources of each play, the "best" and "most unbiased" number to choose is the mean value. That is why a synonym for mean in statistical theory is "expected value." The net result of this methodology is that ARI has very likely overestimated the expected value of technically recoverable resources within the IRAs.

Rate of Technological Change

A third major assumption used by ARI is that technology will continue to lower the cost of extracting natural gas a historical rate of improvement (as measured by ARI). Changes in technology tend to be discrete events, such as the development of viable lateral drilling techniques that allows each well to recover resources from a larger area. This technology results in cost savings because each well can produce a greater amount of resources. When measured over a long period of time a series of these discrete events can be "averaged"—resulting in an "average" rate of technology improvement.

ARI has apparently done this technology "averaging" analysis and applied it *only* to the oil and gas resources that they judge to fall within IRAs. For maximum validity, ARI should apply this technology to the nation's entire stock of oil and gas resources. In a nutshell, if this analysis is applied to oil and gas in IRAs to increase their resource estimates, it should be equally applied to the relevant oil and gas resource estimates outside of the IRAs. If it is not equally applied the net result of the technological change analysis is to inflate the value of the resources in the IRAs relative to those outside.

The subsequent sections show some of the discernable cumulative quantitative effects of the biases discussed in this section.

ARI Reports: Technically Recoverable Resources

With the above methodological considerations, ARI calculated that the IRAs and SDAs in the nineteen Rocky Mountain Provinces that they examined contained a mean of about 14.9 Tcf, with IRAs containing about 11.3 Tcf and SDAs about 3.6 Tcf. Distribution of technically recoverable natural gas within IRAs varied; Uinta/Piceance Basin (3.9 Tcf), Wyoming Thrust Belt (3.2 Tcf), Southwestern Wyoming (2.0 Tcf), and Montana Thrust Belt (1.6 Tcf). The SDAs with the largest natural gas resource were Uinta/Piceance Basin (2.3 Tcf) and Southwestern Wyoming (0.8 Tcf). Minimal oil resources were expected to be discovered within IRA or SDA boundaries.

ARI's Nine Largest Plays

Table 9 shows data on the nine largest plays in ARI's study. According to the firm these nine plays comprise 14 percent of total IRA acreage yet contain 83 percent of total technically recoverable gas. Although IRAs in the nine largest plays in the ARI study make up 3.4 percent of total play acreage, the gas resource estimates assigned to the IRAs is 8.4 percent of total play resource.

This real-life example can be used to illustrate the effects of bias from ARI methodologies. Using the mean values from USGS distributions and applying them proportionally to the IRAs within the plays results in a cumulative estimate for technically recoverable gas in the nine largest IRAs of 1.272 Tcf.

ARI's use of slope analysis and assumptions about continuing cost reductions from technological change results in a technically recoverable gas resource estimate for the same area of 9.345 Tcf—more than 635 percent greater than expected from using USGS regional values.

No one knows for sure what is actually in the ground unless and until it is drilled. Therefore, no one can say that one particular estimate is "right" or "wrong." But, LMA argues that policy questions such as this deserve to receive balanced treatment for all resources. The same methodology should be used for all potential resources that are both discovered and undiscovered, and both inside and outside of IRAs.

Table 9 – ARI and USGS Estimates of Technically Recoverable Gas Resources for the Nine Largest Plays in ARI Study

Play	Play Acreage	IRA Acreage	USGS Gas Mean (Tcf)	USGS IRA Gas (Tcf)	ARI Gas (Tcf)	IRA Percent of Acreage	IRA Percent of USGS Gas
Imbricate Thrust Gas	12,289,093	1,192,787	1.830	0.178	1.618	9.7%	88%
Moxa Arch Extension	6,480,218	206,303	2.905	0.049	1.568	1.7%	54%
Northern Thrusts	8,229,268	749,469	4.942	0.301	1.508	6.1%	31%
Uinta Basin-Emery	6,397,757	60,882	0.748	0.004	1.159	0.5%	155%
Greater Green River Basin-Mesaverde	11,379,223	65,322	51.708	0.275	0.950	0.5%	2%
Tight Gas Uinta Tertiary West	6,325,089	12,194	0.514	0.001	0.789	0.1%	154%
Tight Gas Piceance Mesaverde Williams Fork	7,792,607	218,522	4.870	0.087	0.642	1.8%	13%
Greater Green River Basin-Cloverly-Frontier	14,833,498	105,206	37.251	0.319	0.566	0.9%	2%
Piceance Basin-Western Basin Margin	7,503,568	113,576	6.492	0.060	0.545	0.9%	8%
Total	**81,230,321**	**2,724,261**	**111.260**	**1.272**	**9.345**	**3.4%**	**8.4%**

Sources: ARI, 2000, *Economically Recoverable Natural Gas Resources Beneath Inventoried Roadless Areas on Forest Service Lands, Analysis and Results* and U.S. Geological Survey, 1998, OF-95-75-N, 1995 *National Oil and Gas Assessment and Onshore Federal Lands* and The Wilderness Society, 2001, personal communication, estimates of acreage in various USGS plays.

ARI Report: Economically Recoverable Resources

The preceding discussion centered on technically recoverable resources. But natural gas resources are most valuable if they can be *economically* extracted. Using the assumptions discussed in this and prior sections ARI asserts that a maximum of about 78 percent of conventional natural gas could be economically extracted with a price of $4 per Mcf. Coalbed gas and "tight gas" recovery rates assumed in the ARI study are 77 percent 70 percent, respectively at the higher price of $4 per Mcf.

To estimate the economically recoverable fraction of technically recoverable resources in USFS roadless areas, ARI uses NPC's highest natural gas price scenario the "Increased Oil Price Case". This NPC case has a natural gas price that averages slightly more than $3 per Mcf. ARI then asserts that a higher average gas price of $4 per Mcf better represents the average natural gas

price over the next 30 years. The effect of higher gas prices is an increase in the economically recoverable fraction of technically recoverable natural gas resources.

Drilling "sweet-spots", or using technology to define high-grade areas within a region is yet another way in which ARI methodology assumes increases in economic recovery rates. This "sweet-spot" technique is actually used oil and gas exploration and allows an operator to target more promising areas within a region rather than drilling on a uniform grid over the entire region. Because of the enormous size of the resource area evaluated by the USGS, the agency was forced to use the more simplifying assumption that every region was drilled on a grid pattern—regardless of the localized "richness" of some areas within each play. Again, the result of this ARI assumption is an increase in economically recoverable resources. However, unlike some of the earlier assumptions, LMA believes that this one is much more defensible.

Table 10 shows estimates of economically recoverable resources with ARI recovery rates and technically recoverable resources. Also shown in Table 10 are the economically recoverable resources using average USGS recovery rates for each natural gas resource type and region (with a natural gas price of $3.34 per Mcf). Substituting average regional USGS recovery rates for ARI recovery rates results in a 38 percent decrease in recovered natural gas, from 8.5 to 5.3 Tcf.

Table 10 – Economically Recoverable Resources: ARI and USGS Estimates

	Economically Recoverable Resources			
Resource Type	ARI ($4 gas) Recovery Rate	ARI Recovered Resource (Tcf)	USGS ($3.34 gas) Recovery Rate	USGS Recovered Resource (Tcf)
Conventional	78%	4.1	63%	3.3
Coalbed methane	77%	1.7	77%	1.7
Tight gas/Continuous	70%	2.7	9%	0.3
Total	75%	8.5	47%	5.3

Source: ARI, 2000, *Economically Recoverable Natural Gas Resources Beneath Inventoried Roadless Areas on Forest Service Lands, Analysis and Results* and U.S. Geological Survey Circular 1145, 1998, *Economics and the1995 National Assessment of United States Oil and Gas Resources.*

ARI Report: Economic Impacts

A final section of the ARI reports on the "economic activity" that might be derived from IRAs. This number is simply obtained by their range of estimates of economically recoverable resources of 7.7 Tcf (at $3 per Mcf) to 8.5 Tcf (at $4 per Mcf). Multiplying the amount of resources times the assumed prices results in their estimates of $23 to $34 billion of economic activity. Economic activity estimates may tend to overstate national and regional benefits from potential petroleum extraction because they do not take into account the costs of extracting the oil and gas.

VI. Conclusions

The U.S. has a number of sources of natural gas for future consumption—discovered and inferred reserves, imports from currently known and undiscovered foreign sources, and undiscovered domestic resources. No one knows with any real certainty the amounts of natural gas that might become available from the latter category. But, scientists from the U.S. Geological Survey (USGS) have systematically surveyed the nation's public and private lands to come up their best estimates about the oil and gas endowment of lands that have not been exhaustively explored.

Starting from the knowledge base created by the USGS, ARI has focused on a very small fraction of these relatively "unexplored lands." Many, if not most of the acreage under ARI's scrutiny has been open for oil and gas leasing for many years but apparently petroleum producers have found other lands more deserving of their interest.

The prior administration instituted a moratorium on constructing new roads in some U.S. Forest Service lands. ARI has looked at a small number of the USFS lands proposed for continued roadless status and given their estimates on the likely oil and gas resources that may still be undiscovered beneath them. A primary ARI assumption is that any resources underlying IRAs would not be producible without building access roads within the IRAs.

It is not possible to comprehensively evaluate the ARI study because so little documentation of it was available to this reviewer. Given the material that was available from ARI, and the much more extensive source material from the USGS and NPC, this author finds that the methodology of the ARI study seems to contain a number of items that individually and collectively have the effect of boosting the prospective oil and gas qualities of the Forest Service lands in question.

A review of USGS and other Federal Government information about natural gas resources shows that this nation probably contains about 1074 trillion cubic feet (Tcf) of known and yet-to-be-discovered sources of technically recovered natural gas. The ARI report focuses on a small subset of the undiscovered natural gas resources. According to USGS literature, the largest concentrations of future natural gas production are likely to come from many regions, including the Gulf of Mexico, the Colorado Plateau/Basin and Range area, and the Rocky Mountain/ Northern Great Plains region.

At the request of the previous administration, the National Petroleum Council (NPC) presented a report in 1999 whose major conclusion was that this nation's estimated natural gas resources base is adequate to meet an increasing demand. As might be expected from an energy-interest group, the report's wish list contained calls for more areas open for drilling and continued access to financial capital to foster development of new infrastructure and sources of natural gas supply. Also, Canadian gas sources, already a major contributor to U.S. markets, are expected to expand appreciably in the years to come. Liequified Natural Gas (LNG) imports to the U.S. are also expected to increase in the future.

NPC also reports that new lateral drilling technology allows for petroleum recoveries from areas as far as 6 miles from drill sites. ARI apparently ignores the implications of lateral drilling capabilities by assuming that all resources underlying IRAs could only be produced by allowing access roads to drill sites within IRAs.

Also, the ARI report surprisingly shows that, even with the Federal Government's predominant land holdings in the West, almost 38 percent of conventional gas resources in the West are likely located underneath non-Federal lands. ARI says that the bulk of the country's unconventional natural gas resources are located in the Rocky Mountain/Great Plains region, but the Colorado Plateau/Basin and Range areas likely contain less costly but smaller deposits of these resources.

Methodologies in the ARI report seem to contribute to an upward bias to resource estimation of the report's Inventoried Roadless Areas (IRAs). Use of slope analysis in the ARI report combined with the typical shapes of USGS resource estimation distributions apparently result in a significant upward bias in estimates of technically recoverable natural gas resources. Application of their ARI's technological change methodology was not apparently biased per se, but the fact that ARI used it only on resources within the IRAs and not outside these lands tends to exaggerate the importance of potential natural gas resources that might be found within the currently unroaded areas.

The nine largest natural gas plays in the ARI analysis purportedly contain about 83 percent of the report's total technically recoverable natural gas resources in the IRAs. Comparison of the natural gas endowment from ARI and USGS sources seems to indicate that ARI-measured technically recoverable natural gas resources in currently unroaded areas contain about 635 percent more natural gas than might be expected from proportional application of USGS data. Using Wilderness Society, USGS, and ARI data, LMA concludes that the nine largest plays in the ARI study contain about 3.4 percent of natural gas play acreage, but about 8.4 percent of the plays' natural gas resources. Presumably the upward biases apparently inherent in the ARI methodology contribute to this disproportionate result.

Economically recoverable fractions of natural gas resources from the ARI report were also greater than expected from examination of USGS sources. ARI estimates showed an average regional recovery rate of about 75 percent of technically recoverable gas in the study area, while USGS estimates showed a much lower expected extraction of about 47 percent. Most of the differences between the two sources are likely due to differential assumptions about current and future technology and expected future natural gas prices. It is important to note that if (1) costs of natural gas extraction decrease and (2) prices of gas are higher those modeled by the USGS, then increases in economically recoverable gas resources would come not only from potential sources within IRAs but from the entire national and international natural gas resource base. These additional sources of economically recoverable natural gas supplies from outside of the IRAs are not discussed in ARI reports.

Finally, the economic activity estimates in the ARI report are the product of their estimates of future natural gas prices and their economically recoverable natural gas resources. These numbers do not reflect the costs of finding, extracting, transporting, and marketing the prospective natural gas resources.