# 1. Executive Summary

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Declining domestic reserves of natural gas and a widening gap between domestic production and demand has led to new interest in several unconventional or exotic sources of the fuel. These include the geopressurized zones off the gulf coast, the tight sands of the Western Basin, coal seams of the Eastern United States, and Devonian shales of the Appalachian Basin.

This report examines the potential for producing gas from one of these sources—the Devonian shales—Using existing technology under a variety of economic assumptions.

## Findings

A major finding of the analysis is that Devonian shale, unlike the other exotic sources, can be tapped for natural gas without the development of completely new production equipment or techniques.

A second finding is that the so-called "Brown" Devonian shales of the Basin could yield between 15 trillion cubic feet* (Tcf) and 25 Tcf of natural gas during the first 15 to 20 years of production. Over an additional 10 to 30 years of production, the Brown shale could yield half again as much, for a total production of about 23 Tcf to about 38 Tcf.

A third finding is that because Brown shale deposits are distributed over extensive areas, it may take as many as 20 years to drill all of the wells and complete the pipeline system that would be required to produce as much as 1.0 Tcf of natural gas per year.

The findings are based on the following assumptions:

- there will be no significant changes in real costs of drilling, stimulating the flow of gas or production;
- the economic and production characteristics of three regions analyzed in the assessment represent the more promising sources of natural gas from Devonian shale;
- wellhead prices for natural gas will be in the range of $2.00 to $3.00 per thousand cubic feet (Mcf);
- current tax treatment of income from natural gas production will be continued; and
- approximately 10 percent of the Brown shale resource is of high enough quality to permit commercial development.

## The Resource

The darker layers of shale of Devonian age, which are referred to throughout this report as Brown shale, are found below ground throughout the Appalachian Basin. The Brown shale can be reached by drill in southwestern Pennsylvania, southern New York, eastern Ohio, most of West Virginia, and eastern Kentucky. It also is exposed at the ground surface along the northern and western sides of the Basin.

The Brown shale is thickest and therefore more likely to yield commercial quantities of natural gas in the west-central region of the Basin. In that area, it comprises between 30 and 40 percent of

*Natural gas is measured in cubic feet: Mcf = thousand cubic feet, MMcf = million cubic feet, Bcf = billion cubic feet, Tcf = trillion cubic feet, the total mass of Devonian shale. To the west, the Brown shale becomes thinner and to the east it splits into separate beds that eventually disappear in a thick mass of coarser sediments. The Brown shale originally formed as a black mud, rich in organic matter, on the floor of a Devonian sea. Individual beds of Brown shale are up to 1,200 feet thick; maximum depth is about 12,000 feet.

The Brown shale consists of alternating paper-thin laminations of inorganic and organic matter. The inorganic layer consists of clay, quartz, and other common sedimentary minerals. The organic layer consists of extremely fine particles of coal-like material and of minute shreds of coalified woody matter. Thus the Brown shale is not an "oil shale" like the shales of Colorado and Wyoming but rather, it is coal-like.

Gas production from the shale is greatest from highly fractured zones. Evidence suggests that the gas that moves most readily in the Brown shale is in these fractures, and possibly in some of the coarser-grained laminations. The vast bulk of the gas is held in the shale mass itself, the "matrix," from which it will move into fractures and well bores at very slow rates, Initial production from Brown shale wells is relatively high, as free gas in fractures moves to the well bore, but the flow decreases steadily to that determined by the rate at which the gas in the shale matrix is released. Estimates of the total amount of gas in the Brown shale of the Appalachian Basin range up to many hundreds of Tcf.

## Gas Potential

It appears that under plausible economic, geologic, and technological assumptions the Brown shale of the Appalachian Basin contains at least 15 to 25 Tcf of readily recoverable gas.[1] This is gas that would be producible in the first 15 to 20 years of life of typical Brown shale wells. Shale gas production has a slow flow rate over a long period of time, so ultimate recoverable reserves over the 30- to 50-year expected life of production could be 40 to 50 percent greater than the 15 to 25 Tcf estimate. The recoverable gas potential of the Brown shale depends on the (1) wellhead price and production costs, (2) extent of the Brown shale resource, and (3) the relative amounts of high-, medium-, and low-grade gas-producing brown shales.

The $1.42 to $3.00 per Mcf price assumptions (equivalent to oil at $6.90 to $14.50 per barrel) used in this study are consistent with general market conditions for both interstate and intrastate gas sales. The drilling, well completion, stimulation, and production cost estimates are based on actual operating experience in 1976. All cost and price calculations are in constant 1976 dollars.

There is a good deal of evidence that in a large oil and gas area the discovery wells tend to be drilled into the better structures and subsequent drilling defines the geologic and economic limits of the resource base. In a marginal resource base such as the Brown shale (where the extensive geologic existence of gas-bearing reservoirs is not in doubt), the definition of "the better structures" includes the location relative to existing production and pipelines. Except in southeastern Kentucky, the Brown shale has only recently become a primary target of drilling operations. Even if the current areas of Brown shale development activity were initially byproducts of other activity, the "better" Brown shale prospects are probably already developed. But "better" as used here includes the factor of location relative to existing gathering lines.

There may be additional areas which are as geologically promising as the localities examined in this study. These other areas, although more remote relative to existing pipelines, probably

[1] Readily recoverable reserves" is not a category in either the American Gas Association or U.S. Geological Survey nomenclature. In the present context, "readily recoverable reserves" are resources which can be converted to proved reserves and actually produced in a 15- to 20-year time frame.

become economically feasible at the $2.00 to $3.00 per Mcf price levels.

if higher-quality, gas-productive Brown shale accounts for as much as 10 percent of the total estimated extent of the shale (the currently producing area is less than 5 percent of the 163,000-square-mile extent of the Appalachian Basin), then a conservative estimate of the readily recoverable gas is approximately 15 to 25 Tcf. If there are 15 to 25 Tcf of readily recoverable gas, then it is possible that shale gas production in Ohio, West Virginia, New York, Kentucky, Tennessee, and Pennsylvania could account for as much as 1.0 Tcf per year in the future.

The estimates presented in this report are based on the analysis of 490 producing wells in three localities. These 490 wells were drilled by a large number of operators with different financial situations and technical capabilities. Data from a smaller number of wells drilled by a single operator exhibit higher production than the 490 wells. If the production from these single-operator wells is representative of a significant portion of the Brown shale of the Appalachian Basin, the Brown shale might contain more than 15 to 25 Tcf of readily recoverable gas and a production capability of greater than 1.0 Tcf per year. This greater potential could result from either or both (1) greater average productivity per well, or (2) a larger resource base which would permit a greater number of wells of average productivity. However, even under an optimal combination of circumstances (1 5-percent higher average production per well and a 50-percent increase in the areal extent of the quality shale resource), only about 30 to 35 Tcf of readily recoverable reserves would be producible over *15* to 20 years. Under these optimal conditions, annual shale gas production from the Appalachian Basin might approach 1.5 to 2.0 Tcf.

production of gas from the Brown shale is likely to be scattered over extensive areas, thus resulting in a relatively slow pace of development because of the need to build a pipeline gathering system. This suggests that the economically feasible expansion of the gas pipeline network required to collect new gas production will be on an incremental basis. The location of individual wells relative to potential pipeline connections (in addition to geologic promise) will continue to be an important determinant of the economic quality of Brown shale drilling prospects. Since Brown shale gas production is relatively well intensive and is likely to be scattered over an extensive area, it is prudent to presume that Brown shale gas development will proceed at a gradual pace, probably requiring at least 20 years to reach a 1.0 Tcf annual production level (about 69,000 wells in the Brown shale will be needed to produce 1.0 Tcf per year). If improvements in drilling or stimulation technology are achieved and economic incentives provided, the time necessary for the development of the gas potential of the Brown shale might be reduced. Therefore, the Congress may wish to consider the desirability of some publicly supported research and development activity directed toward improvements in Brown shale drilling and stimulation technology.

The potential impact of either (1) dramatically better technology, or (2) improvements in economic incentives beyond those examined here must be considered with caution. If economic incentives were twice as good as those considered in this study, or if drilling and stimulation technology were to improve so that these operations would cost only half as much as they now do, it is unlikely that twice as great a quantity of reserves would become economically feasible. This is because additional development efforts, which such economic or technological improvements would induce, would be pressing further and further into the poorer sites and geologic prospects.

# Policy Options To Encourage Shale Gas Production

Policy options available to encourage production of gas from the Brown shale fall into four generic categories. These categories are:

- price incentives,
- tax policies,
- research and development funding, and
- information collection and dissemination.

## Price Policies

Brown shale natural gas resource development is sensitive to price. The price of Brown shale gas sold in interstate commerce is currently restricted by Federal Power Commission (FPC) ceiling price regulations. There are three basic price strategies with respect to shale gas which could be pursued. These are:

- exempt shale gas from FPC price control or establish higher prices for gas from the Brown shale;
- deregulate the wellhead price of all new natural gas supplies; or
- take no action.

A policy which permits higher prices or exempts Brown shale ‘gas from FPC control would be analogous to a proposed policy that would permit the free market price for oil produced by enhanced recovery techniques. The qualification for gas from the Brown shale might be based on (1) geologic identification of the Brown shale as the source of gas, (2) regional specification, (3) production rate limitations, or (4) some combination of these factors.

Brown shale gas production is often commingled with production from other geologic zones. Therefore, a precise identification of gas production from the Brown shale could be extremely difficult.

Similar-appearing, gas-productive brown and black shales of differing geologic ages extend throughout many portions of the United States in addition to the Appalachian Plateaus, and a regional specification restricted to the Appalachian Plateaus might therefore omit substantial shale gas resource potential. Production rate limitations for eligibility for exemption from price regulation might be more manageable, and also would apply to gas production from tight formations in other parts of the country. Definition and administration of a multitiered pricing system for gas from the Brown shale could become arbitrary, complex, and cumbersome.

Deregulation of the wellhead price of all new gas supplies would include prospective additions to the U.S. natural gas supply from the Brown shale of the Appalachian Basin. Such a strategy would create price incentives in the range of $2.00 to $3.00 per Mcf, on which conclusions presented in this report are based. Such price incentives might provide the stimulus necessary for an extensive testing of the economic feasibility of Brown shale gas production. If 10 percent of the 163,000-square-mile extent of the Brown shale is medium- to high-quality gas-productive shale, an expansion in drilling efforts could result in production of approximately 1.0 Tcf per year of gas from the Brown shale of the Appalachian Basin within the next 20 years.

If Congress takes no action on prices, existing prices would be the only incentive to encourage gas production from the Brown shale. Current maximum interstate gas prices encourage gas production with existing technology from only the high-quality Brown shale areas. Therefore, continuation of present gas pricing policy could result in foregoing substantial additions to the U.S. natural gas supply which may be available from the Brown shale of the Appalachian Basin.

## Tax Policies

The tax policies available to Congress to encourage Brown shale gas production include:

- restoration of the general 22-percent depletion allowance;
- definition of Brown shale gas production as enhanced recovery so as to maintain the depletion allowance for small producers;
- retention of expensing of intangible drilling costs as a tax option; and

- creation of a 1 O-percent investment tax credit for gas production from the Brown shale.

The analysis reported here indicates that a 10-percent investment tax credit has little effect on shale gas production. Areas of lower resource quality did not become economically feasible for shale gas production when a 10-percent investment tax credit was incorporated into the analysis. However, the addition of a 22-percent depletion allowance increased the after-tax, net-present value of shale wells and made certain production methods economically feasible in shales of lower quality. Basically, a 22-percent depletion allowance has about the same positive effect on the economics of shale gas production as a $.50 per Mcf increase in the wellhead price of shale gas.

## Research and Development

There are several areas in which research and development with special relevance to the Brown shale of the Appalachian Basin might be fruitfully pursued. These include:

- defining resource characteristics,
- development of drilling techniques and equipment, and
- improvement of logging and stimulation techniques.

Even though about 10,000 wells already produce gas from the Brown shale of the Appalachian Basin, few quantitative data are available to adequately characterize the resource potential of the entire 163,000-square-mile Appalachian Plateaus. Until the Brown shale resource is adequately characterized, specific targets for technology development are not possible. A systematic coordinated inventory of Brown shale should be one of the first steps in developing the gas potential of the Brown shale sequence.

The most common techniques used to characterize the Brown shale are those developed for use in traditional oil and gas reservoirs, Development of special drilling techniques and equipment specifically for use in the Brown shale could expedite the development of its gas potential. Because of the importance of well stimulation in the production of gas from the Brown shale, improvement in the effectiveness and reductions in costs of stimulation techniques could make gas production from Brown shale more economically attractive. Price incentives can be expected to induce some private activity in these research and development areas. However, because much drilling, well stimulation, and production will be done by operators who do not control large shares of Brown shale resources, it is unlikely that those operators will invest large amounts in aggressive research and development programs. Therefore, it may be prudent to commit public funds for research and development activity directed specifically toward improvements in shale drilling and stimulation technology.

## Information Collection and Dissemination

Although the Devonian shale sequence is distributed over a wide geographic area, only a small portion of it has potential as a commercial source of gas. If the gas potential of the Brown shale is exploited, a large number of independent operators are likely to be drilling a large number of wells in many different locations on the Appalachian Plateaus. Under these conditions, particularly in the early years of the development effort, it might be desirable to fund publicly the collection, coordination, and dissemination of information and analyses detailing the results of actual operating experiences. This activity should be undertaken by a creditable public group so that the results are available to the public and private sectors alike. The information collection and dissemination efforts might initially include the public funding of conferences where research and development results and improved drilling and stimulation technologies are reported. If the Brown shale has a potential to produce 1.0 Tcf of gas per year, and economic incentives are provided, it is likely that private enterprise will assume necessary research and development efforts within a comparatively short period of time.

## Conclusions

There are a number of policy options available which could encourage production of gas from the Brown shale of the Appalachian Basin. A significant and substantial policy option is to permit free-market prices for gas from Brown shale formations. Restoration of the 22-percent depletion allowance would have about the same effect as increasing the well head price of shale gas by $.50 per Mcf. Research and development efforts which characterize the Brown shale resource, decrease the cost of drilling and stimulation of wells, and increase the gas production from wells, could increase the economic attractiveness of producing gas from the Brown shale of the Appalachian Basin.