

Preliminary Assessment of the Availability of U.S. Natural Gas Resources to Meet U.S. Transportation Energy Demand

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Abstract

Recent studies have indicated that substitutes for conventional petroleum resources will be needed to meet U.S. transportation energy demand in the first half of this century. One possible substitute is natural gas which can be used as a transportation fuel directly in compressed natural gas or liquefied natural gas vehicles or as resource fuel for the production of hydrogen for fuel cell vehicles. This paper contains a preliminary assessment of the availability of U.S. natural gas resources to meet future U.S. transportation fuel demand. Several scenarios of natural gas demand, including transportation demand, in the U.S. to 2050 are developed. Natural gas resource estimates for the U. S. are discussed. Potential Canadian and Mexican exports to the U.S. are estimated. Two scenarios of potential imports from outside North America are also developed. Considering all these potential imports, U.S. natural gas production requirements to 2050 to meet the demand scenarios are developed and compared with the estimates of U.S. natural gas resources. The comparison results in a conclusion that 1) given the assumptions made, there are likely to be supply constraints on the availability of U.S. natural gas supply post-2020 and 2) if natural gas use in transportation grows substantially, it will have to compete with other sectors of the economy for that supply-constrained natural gas.

Introduction

Recent analyses have indicated that substitutes for conventional petroleum resources will be needed to meet U.S. transportation liquid fuels demand in the first half of this century. For example, in one study for the U.S. Department of Energy (DOE), Birky, et. al., indicate that a turn down in petroleum production can be anticipated in the 2015 to 2025 time span (1). In a related study, Patterson, et. al., suggest that natural gas is a promising energy resource to

supplement petroleum as it can be used in many forms: compressed or liquefied in natural gas vehicles (NGVs) or as a feedstock to convert gas to liquid products such as Fischer-Tropsch (F-T) diesel fuel or to produce hydrogen for fuel cell vehicles (FCVs) (2). The future role for natural gas looks especially prominent if technologies to recover methane hydrates can be developed that are cost-effective and environmentally benign.

This paper contains results of a preliminary assessment of the availability of U.S. natural gas resources to meet future transportation fuel demand in the U.S. The purpose of the assessment was to determine, given available information, whether it is worthwhile for government to pursue a strategy to promote the large-scale use in the U.S. of vehicles whose resource fuel is natural gas when this large scale use might face domestic supply and import problems similar to those now inherent in transportation's reliance on oil. More in-depth analysis of this issue is being conducted at DOE in study that addresses a range of alternative North American transportation energy options and futures (3).

Methodology

This analysis is focused on evaluating the potential availability of significant volumes of natural gas for use in highway transportation through 2050. Because of the uncertainty associated with developing projections for such a long-term time frame, we have developed several scenarios of the potential demand for natural gas from all sectors of the economy. We focus first on the non-transportation sectors since natural gas is not currently used in the transportation sector in any significant amount and the transportation sector would be a new market.

Some of the non-transportation demand will be met by imports of natural gas, but the rest must be met by using U.S. natural gas resources. We have reviewed various estimates of resources and focused on two in our evaluation. We have compared the cumulative natural gas production pathways required to meet U.S. non-transportation natural gas demand through 2050 to our estimate of U.S. natural gas resources to determine whether or not there may be any problems in meeting these estimates of demand for natural gas. We then have evaluated the effect of adding a substantial new market for natural gas: transportation.

Non-transportation Natural Gas Demand to 2050

Few projections of U.S. natural gas demand and supply to 2050 exist. The Energy Information Administration (EIA) has developed projections of supply and demand to 2020 (4). We use EIA's "Reference Case" projections to 2020 and develop several non-transportation natural gas demand scenarios to 2050 based on those projections. Figure 1 presents EIA's estimates to 2020 with our three scenarios to 2050.

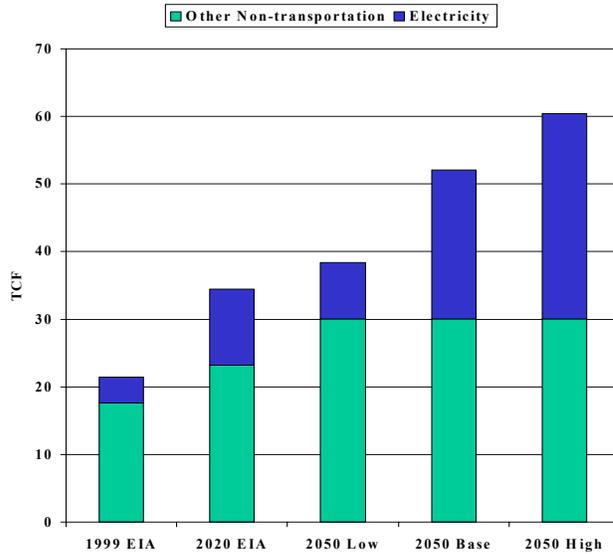


Figure 1: Non-transportation Natural Gas Demand Projections and Scenarios

EIA projects that non-transportation demand for natural gas will grow from 21 trillion cubic feet (TCF)/year now to 35 TCF in 2020. (1 TCF/year is approximately 1 quadrillion Btu/year or 0.5 mmb/day crude oil daily). For our scenarios to 2050, we assume continued growth in demand for natural gas. Our estimate of natural gas demand for all but the electricity sector is the same for each of the three scenarios: 30 TCF/year in 2050 vs EIA's projection of 23 TCF in 2020. This represents a slightly lower growth rate post-2020 than EIA had assumed pre-2020.

The key difference among our three scenarios is in our assumptions with respect to the use of natural gas to generate electricity and the total demand for electricity. There is great uncertainty concerning the role that natural gas will play in the generation of electricity in the future. In its Reference Case, EIA projects that natural gas will generate 25% of all electricity in 2020, up from about 11% in 1999 and that total energy to generate electricity will increase from 35 Quads (or 34 TCF-equivalent) in 1999 to 46 Quads (or 45 TCF-equivalent) in 2020. Therefore, total natural gas use in electricity generation will grow from 3.8 TCF/year to 11.3 TCF/year. Alternatively, to meet the Kyoto accord to reduce greenhouse gas emissions, EIA estimates that total electricity demand would have to be lower than today's total, but that natural gas would provide 45% of that demand in 2020 or 14 TCF (5). Another study, the Clean Energy Futures study, projects that natural gas demand for electricity could range from about 5.5 TCF to 9 TCF/year in 2020 (6).

To address this uncertainty regarding the role of natural gas, we developed a number of scenarios with a broad range of natural gas demand for electricity. The three selected for analysis assume that total electricity use in 2050 requires 56.5 Quads (55 TCF-equivalent), which is below a simple extension of EIA's 1999-2020 growth rate in electricity demand. The share of electricity demand met by natural gas varies from 15% (Low) to 40% (Base) to 55% (High) in the three scenarios, or from 8 to 30 TCF/year in 2050.

In sum, we evaluate the implications of three scenarios to 2050 in which non-transportation natural gas demand ranges from 38 TCF to 60 TCF/year. The demand in the Low scenario for 2050 is essentially the same as EIA's projection for 2020, while the demand in the High scenario is 75% higher.

U.S. Natural Gas Resources

Natural gas resource assessments vary substantially. Differences exist in methodology, assumptions (e.g., what advances in exploration technologies are assumed) and, sometimes, the types of resources that are included. Figure 2 presents a comparison of four recent assessments (7). The resource estimates vary from 1258 TCF for the Potential Gas Committee (PGC) to 2225 TCF for the Gas Technology Institute (GTI) Advanced technology case. The resource estimates include 167 TCF of proved reserves (those resources which have been demonstrated with reasonable certainty to be recoverable) and other potentially recoverable resources.

The assessments of the PGC (a committee with representatives from the oil and gas industry, government and universities and which has published biennial estimates since 1968) and the U.S. Geological Survey (U.S.GS) are based on geological analysis. In such analyses, the physical volumes of reservoir rock are estimated as is the percentage with which the reservoirs are filled. The National Petroleum Council (NPC) and GTI use an econometric model which relates its results to industry operational experience and explicitly treats the effects of advances in technology on gas production and price.

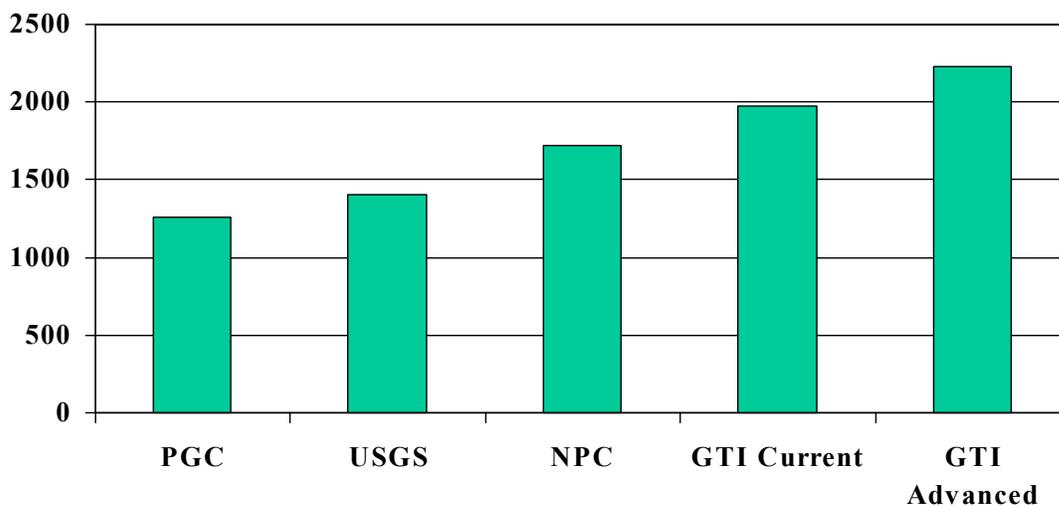


Figure 2: Recent Assessments of U.S. Natural Gas Resources (TCF)

In our analysis, we use assessments based on geological analysis: those of the PGC for the U.S. and those of the U.S.GS for the rest of the world (see the next section on imports). In 2000, the PGC estimates that the U.S. has 1258 TCF in remaining recoverable natural gas resources, both conventional and unconventional (tight gas, gas shale, and coalbed methane). Methane hydrates

are not included because "so little is known about them and their reproducibility, they are not at present included as a source of methane in estimates of the technically recoverable natural gas resource base, nor are they included as a source of methane in existing models and forecasts" (7). However, the PGC report acknowledges that, if methane hydrates could be developed, their potential is vast.

Natural Gas Imports

The U.S. currently imports natural gas, virtually all from Canada. Table 1 presents current U.S. imports, EIA's estimates for 2020, and this assessment's import scenarios for 2050. EIA projects that U.S. imports from Canada will grow from 3 TCF/year currently to over 5 TCF/year in 2020. It forecasts continued exports to, rather than imports from, Mexico. This assumption is consistent with that of the PGC which expects a 10-fold increase in our exports to Mexico to 2010. EIA projects that imports from the rest-of-the-world (ROW) via ocean tanker in the form of liquefied natural gas (LNG) will grow from virtually nothing to 0.75 TCF/year in 2020.

Table 1: U.S. Imports of Natural Gas (TCF)

	1999 EIA	2020 EIA	2050 Low Imports	2050 High Imports
Canada	3.29	5.46	4.8	4.8
Mexico	-0.01	-0.40	-0.40	-0.40
LNG	0.10	0.74	0.74	5
<i>Total</i>	<i>3.38</i>	<i>5.8</i>	<i>5.14</i>	<i>9.4</i>

Few estimates of U.S. imports of natural gas beyond 2020 are available. An assessment conducted by Canada's National Energy Board projects that Canadian exports to the U.S. will decline between 2020 and 2025 (8). In one of two cases evaluated, the decline is to 4.6 TCF/year and in another to 3.5 TCF/year in 2025.

In this assessment we assume that imports from Canada will decline post-2020. We postulate a decline to 4.8 TCF/year. We assume that we will not import any natural gas from Mexico and that in fact we will continue to export small quantities to Mexico through 2050.

Our imports from the ROW may well increase substantially post-2020. As illustrated in Figure 3, the ROW resources (which include those of Canada and Mexico) are large: more than 10 times those of the U.S. (9). However, demand for natural gas in the ROW will also increase. Figure 4 illustrates several possible growth scenarios for world demand for natural gas to 2050. The estimates to 2020 are from EIA's International Energy Outlook (IEO) and include the U.S. (10). EIA projects a doubling of demand to 2020. The two post-2020 estimates illustrate a) a level demand from 2020 onward and b) a tripling of current demand.

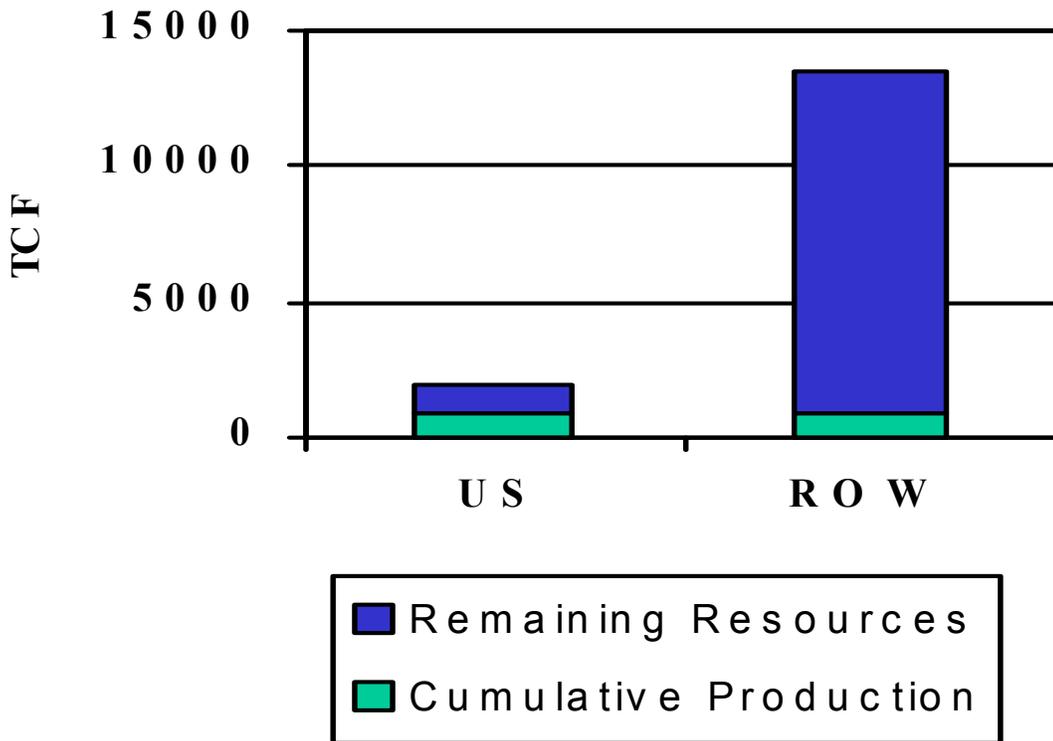


Figure 3: U.S.GS Estimates of World Natural Gas Resources

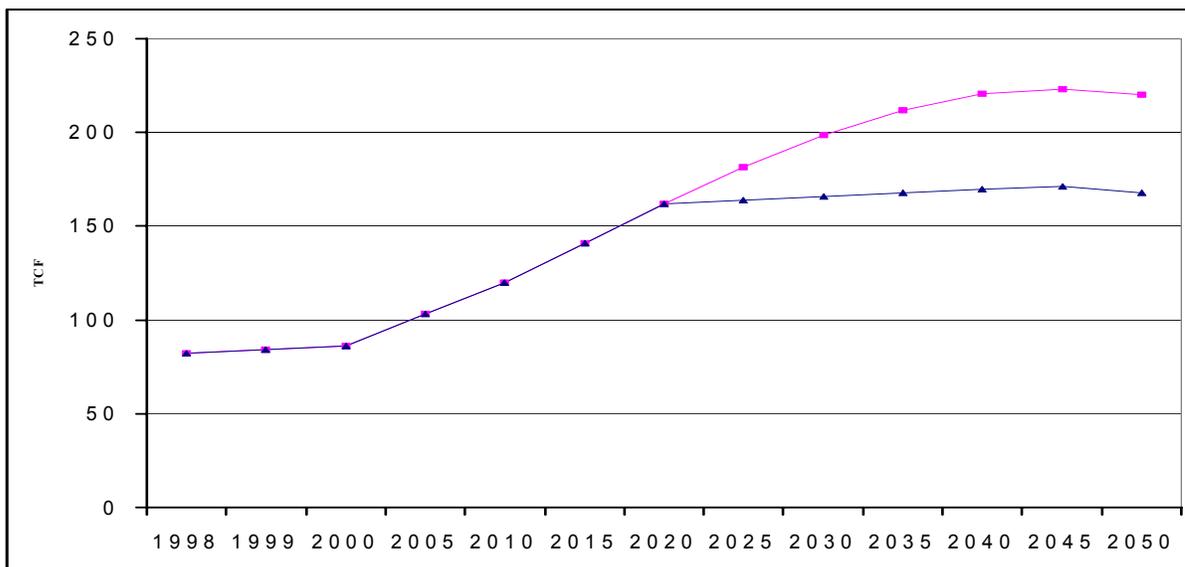


Figure 4: World Natural Gas Demand Estimates: Two Cases

We have not conducted a detailed assessment of the potential for future natural gas imports from the ROW (excluding Canada and Mexico) in the form of LNG. Instead, as presented in Table 1, we developed two LNG import scenarios. In one, assuming that world demand for natural gas grows from 2020 through 2050, then our LNG imports will be held at the same level as EIA projects for 2020 (Low Imports). In the other, assuming that world demand levels off after 2020, then our LNG imports can rise from 0.75 TCF/year to 5 TCF per year (High Imports).

In sum, this assessment assumes that the U.S. will import between 5 TCF (Low Imports) and 9 TCF (High Imports) by 2050. Imports of natural gas between 2020 and 2050 are essentially linear in both scenarios.

Annual U.S. Natural Gas Production

EIA estimates that annual production of natural gas in the U.S. will grow from 19 TCF in 1999 to 29 TCF in 2020. The natural gas that would have to be produced annually in the U.S. post-2020 to meet the requirements of the three non-transportation demand scenarios is simply a calculation of the difference between the demand of the three scenarios and the two import scenarios. Therefore we have six sets of annual production estimates, named as follows: Low Demand, Low Imports; Low Demand, High Imports; Base Demand, Low Imports; Base Demand, High Imports; High Demand, Low Imports; and High Demand, High Imports.

The production requirements of each of these six scenarios are presented in Figure 5. U.S. natural gas production in 2050 could range from essentially the same level as EIA projects for 2020 (29 TCF) to nearly double that amount (55 TCF). Production of natural gas to meet any transportation demand would have to be added to these estimates.

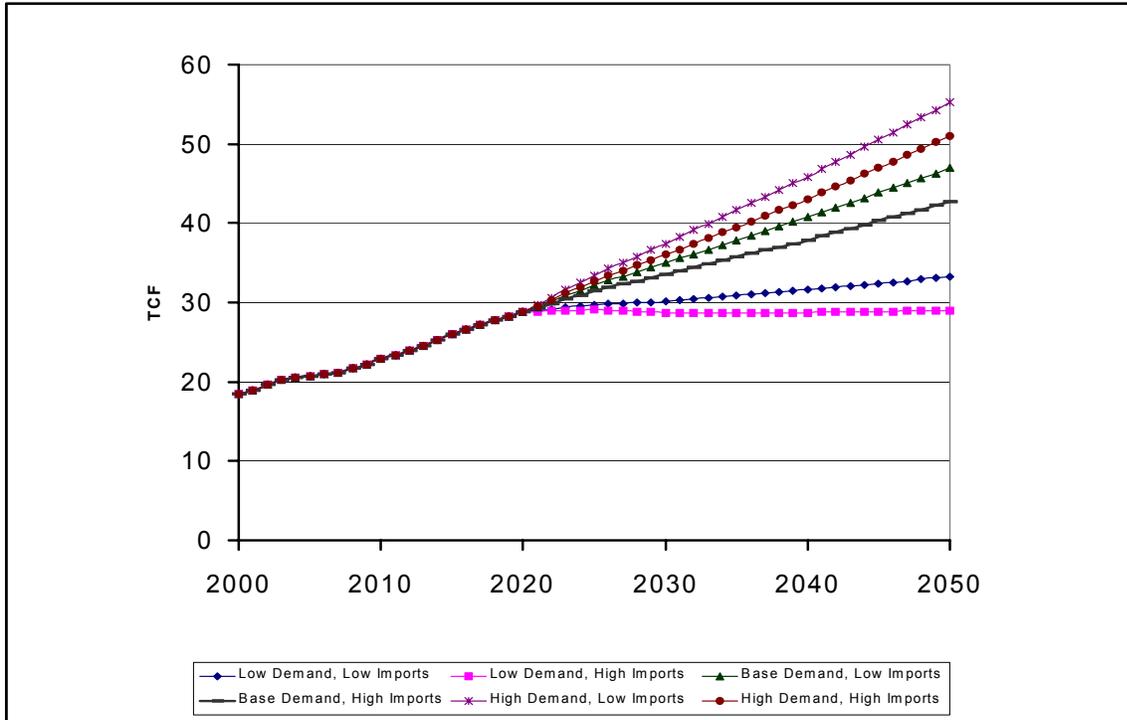


Figure 5: Annual U.S. Production to Meet Non-transportation Natural Gas Demand

Cumulative Effect of U.S. Natural Gas Production on U.S. Natural Gas Resources

The cumulative effect of the annual production requirements of the six non-transportation demand/import scenarios is presented in Figure 6 and compared with the resource estimate of the PGC. (The resource estimate of the PGC increases slightly over time consistent with the rate of increase that has occurred in the last 10 years of the PGC's biennial estimates.) All six scenarios would result in complete depletion of natural gas resources by 2050, with the earliest depletion occurring shortly after 2040. Such complete depletion is impossible. Prices will increase rapidly when natural gas resources are reduced to a low level which will encourage users to shift to less expensive alternatives and/or to use less natural gas. However, the figure illustrates that there will be supply constraints on natural gas in the U.S. within the next 50 years, assuming that the resource estimates of the PGC are reasonably accurate.

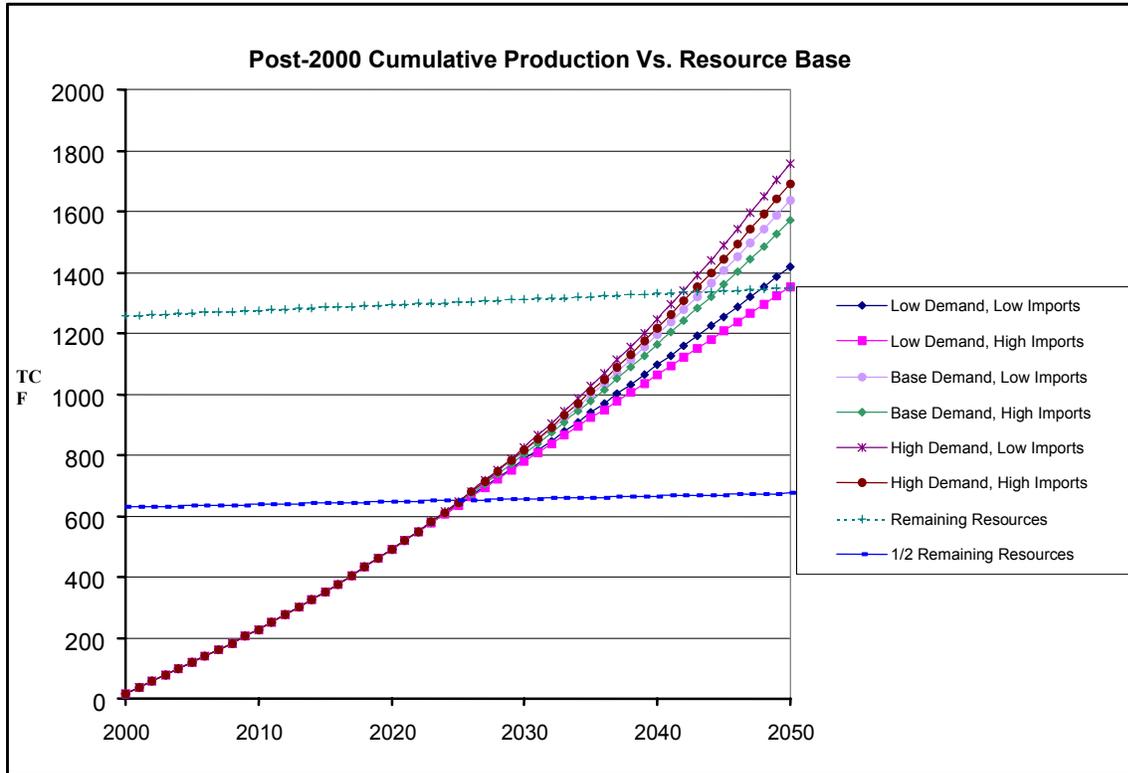


Figure 6: Effect of Non-transportation Natural Gas Production Pathways on Resource Base

Instead of the steady rise in production presented in Figure 5, production will begin to decline earlier. One possibility would be that it would begin to decline when half of all U.S. natural gas resources have been produced. For oil, geologists such as M. King Hubbert have observed that when oil fields reach the half-way point of depletion, oil production generally begins to decline (1). The same may be true of natural gas. Figure 7 then presents a potentially more realistic curve of U.S. natural gas production relative to one of the non-transportation demand scenarios (High Demand). The curve has two peaks which reflect an historic production peak (in the early 1970's) and EIA's projected production increases. This is not unusual; many countries display multiple-Hubbert curves (11). The multiple-Hubbert curve presented in Figure 7 indicates that a gap in demand versus production begins to develop just about 2020 and production never is much higher than EIA's estimate of 29 TCF for 2020.

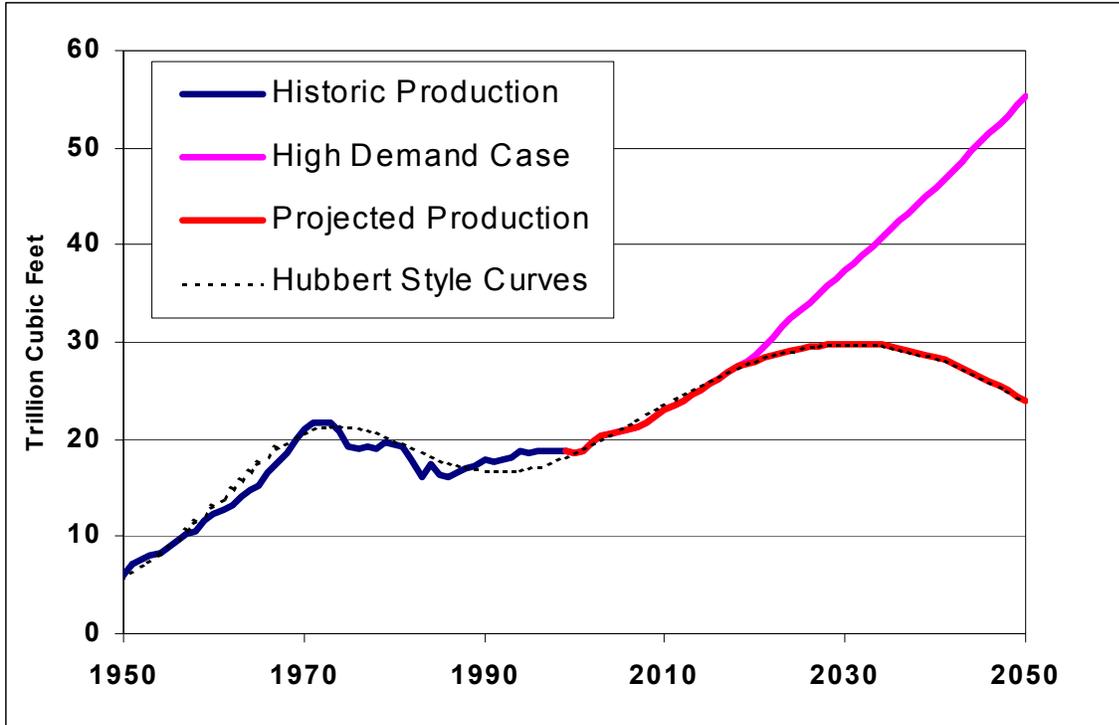


Figure 7: Projected Natural Gas Production Assuming Production Declines Once 50% of Resources Have Been Produced

Potential Availability of Natural Gas for Use in Transportation

It should be clear from the above analysis that, again assuming the PGC resource assessment is reasonably accurate, the availability of natural gas for all sectors of the economy will be U.S. supply constrained post-2020. As illustrated for two cases in Figure 8, substantial additional demand from the transportation sector would cause the depletion estimates to occur earlier. The figure assumes a transportation demand of 5 TCF/year by 2050 which is volume of natural gas that might represent approximately 10% of total transportation energy demand in 2050 (1). The transportation sector currently uses 0.02 TCF/year and EIA projects that by 2020 it will use 0.15 TCF/year.

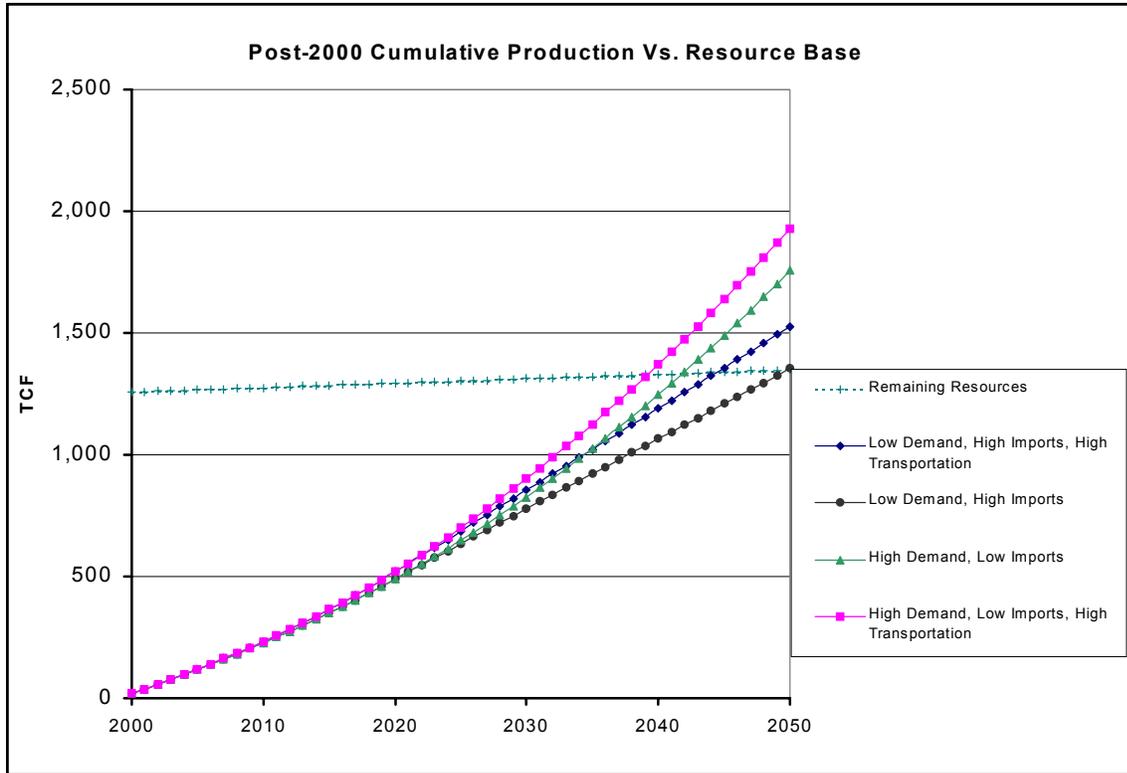


Figure 8 Selected Natural Gas Production Pathways Including Substantial Transportation Demand

Conclusions

The U.S. transportation system will have to reduce its reliance on “conventional” oil because conventional petroleum production will decline early in this century. Other fuels will need to be developed to help meet U.S. transportation demand. Natural gas could be one of those fuels. The preliminary assessment discussed here does not make any conclusions regarding whether or not natural gas can be used in large quantities to directly fuel NGVs, converted in large quantities into hydrogen for FCVs, converted in large quantities to F-T diesel, and/or imported in large quantities in liquid form (as F-T diesel or LNG) from overseas. What it does conclude, based on the assumptions made in this analysis, is that:

- a) domestic natural gas will be supply constrained post-2020; and
- b) if natural gas use in transportation grows substantially, the transportation sector will have to compete with other sectors of the economy for the use of domestic supply-constrained natural gas.

How might these conclusions change government programs designed to promote the use of natural gas in transportation? This question, after all, was the impetus for this preliminary assessment. Two responses are suggested here. One, the conclusions of this preliminary assessment need to be analyzed further by such programs. DOE is conducting one such study

which will evaluate alternative natural gas resource assessments as well as the price effects of increased natural gas demand and market conditions related to other transportation energy sources (3). Two, programs designed to promote the use of natural gas in transportation could be structured to more specifically focus on a) developing vehicles which use a fuel which can be derived from several fuels, including natural gas and b) ways to increase the blending of fuels derived from natural gas with conventional fuels such as diesel fuel. The primary example of the first focus is FCVs operating on hydrogen and the primary example of the second is F-T diesel. With success in either technology, natural gas would add to the flexibility of the U.S. transportation energy system.

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