Testimony to the United States Senate
Committee on Energy and Natural Resources

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Good morning Chairman Bingaman, distinguished senators, staff and guests. Thank you for the opportunity to comment on the potential for natural gas to contribute to solving America's energy problems through greater use in our transportation sector.

My first two observations may seem obvious but I think they are important. First, advanced recovery methods have greatly increased our economical natural gas resources, yet not enough to transform our energy system to one based on natural gas. There is now much more gas available but not nearly enough to satisfy all our energy needs.

Second, today's low natural gas prices are not likely to last. More likely, they will rise over time to levels consistent with the world price for LNG adjusted for the costs of liquefaction and transport. Energy markets respond slowly due to the time required for energy using capital stocks and capital-intensive resource development to adjust. But the domestic gas market is competitive and prices will adjust to reflect the long-run market value of natural gas (Figure 1).

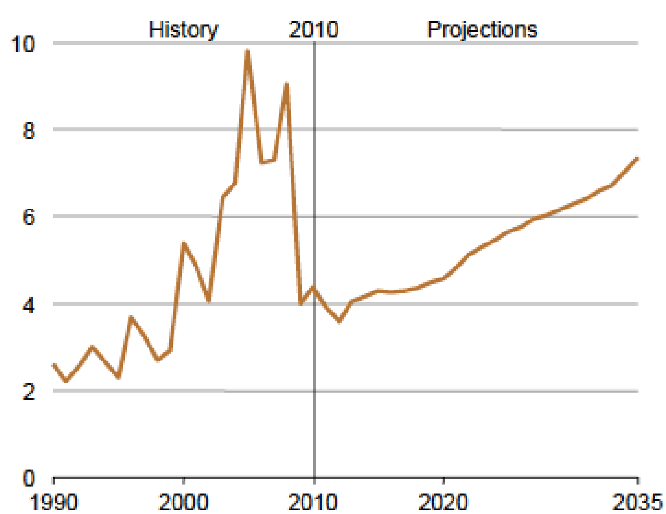

Figure 1. Annual Average Henry Hub Prices for Natural Gas ($/mcf), 1990-2035
Source: Figure 103 in EIA 2012.

I believe that increased natural gas use in transportation can and should make a relatively moderate but important contribution to reducing our dependence on petroleum for the following reasons:

1. The recent increase in natural gas resources is indeed "game changing" but market forces are likely to allocate the increased domestic production to the traditional natural gas using sectors. The new gas resources are game changing in the sense that, as the Energy Information Administration (EIA) projects, they will transform the US from a net importer to a net exporter of natural gas and keep natural gas reasonably priced for decades.
2. Electric utilities' natural gas consumption is likely to increase even more than projected if responsible efforts are undertaken to reduce greenhouse gas (GHG) emissions from electricity production.
3. Natural gas prices are almost certain to rise from their currently depressed levels to levels similar to those seen in the recent past when natural gas use in transportation was limited to niche markets.
4. Although increased use of natural gas in transportation would reduce US oil dependence and probably GHG emissions in the near term, methane is not a suitable fuel for achieving the kinds of reductions in GHG emissions likely to be necessary by 2050.
5. While substituting natural gas for gasoline or diesel fuel in motor vehicles will help reduce our dependence on petroleum, so will substituting natural gas for distillate fuel for heating buildings. This is another important opportunity to improve our energy security.

Outlook

Expansion of America's natural gas and oil resources thanks to the technologies of hydro-fracturing and directional drilling is already producing benefits to our economy and energy security and will do even more in the future. The Energy Information Administration (EIA, 2012) estimates that production of natural gas will increase from 20.6 TCF in 2010 to 27.9 TCF in 2035, with the contribution from shale gas increasing from 23% to 49% of U.S. production (Figure 2). Yet our shale gas resources are not unlimited. The EIA's 2012 Reference Case puts U.S. proved and unproved shale gas resources at 542 trillion cubic feet (TCF) out of total natural gas resources of 2,203 TCF.

Production of shale oil and natural gas liquids (NGL) (typically considered to be petroleum) is now projected to increase domestic petroleum supply from 7.3 million barrels per day (mmbd) in 2010 to 10.4 in 2020 and 9.5 by 2035, in contrast to previous expectations of continued decline and increasing imports.

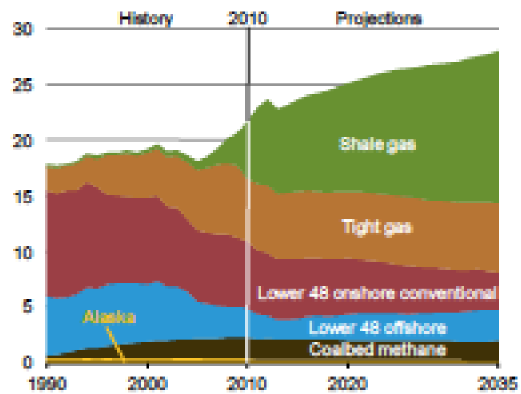

Figure 2. Projected Natural Gas Production by Source (TCF), 1990-2035.
Source: Figure 107, DOE/EIA, 2012.

Energy Security

Increased natural gas use in transportation and buildings could make an important contribution to achieving oil independence over the next 10 to 20 years. By energy independence I do not mean using no oil nor do I mean importing no oil. We can achieve energy independence by shrinking our oil dependence problem down to a size at which it will not pose an important threat to our economy (Greene, 2009). In 2008 dependence on petroleum cost our economy $500 billion in wealth transferred to oil exporting countries and reduced gross domestic product (Figure 3). From 2005 to 2010 oil dependence cost our economy approximately $2 trillion (Greene, Lee and Hopson, 2012). Increased domestic supply of crude oil and natural gas liquids due to exploitation of shale gas and oil resources, together with improvements in the energy efficiencies of light and heavy duty will benefit our economy thorough lower energy prices and improved energy security.

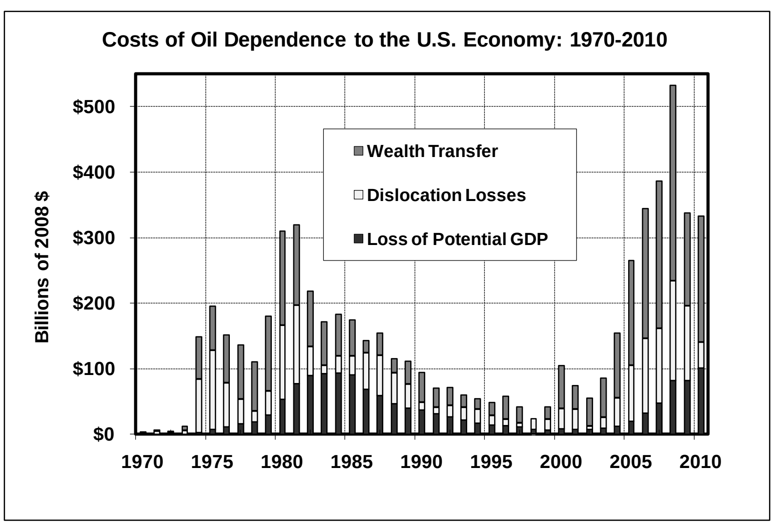

Figure 3. Estimated Costs of Oil Dependence to the U.S. Economy: 1970-2010.
Source: Greene, Lee and Hopson, 2012.

The U.S. Energy Information Administration estimates that development of the 24 billion barrels of U.S. shale oil resources (EIA, 2011) will add 1.3 million barrels per day to U.S. crude oil supply by 2025-2030 while increased NGL production from shale gas development will add another 0.9 mmbd, making up the greatest part of a 2.5 mmbd increase in domestic petroleum supply (Figure 4; EIA, 2012).

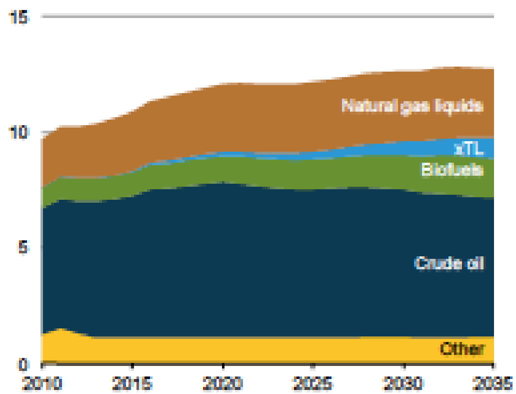

Figure 4. Projected Liquid Fuel Production by Source (TCF), 1990-2035.
Source: Figure 111, DOE/EIA, 2012.

Use of Natural Gas in Transportation

Historically, our transportation sector has used very little natural gas. Most of the 0.61 quads consumed in transport in 2010 went to power the pumps that move natural gas around the country in pipelines; transportation uses other than natural gas pipelines amounted to only 0.04 quads out of a total of 27.04 quads. Given present policies, the EIA projects that by 2035 natural gas use by transportation vehicles will quadruple to 0.16 quads. Natural gas use by electric utilities is expected to increase by 2.12 quads, use in buildings by 0.35 quads, and industrial use by 0.86 quads. From importing 2.68 quads of natural gas in 2010 the US is projected to become a net exporter of 1.36 quads by 2035.

There are good reasons for the transportation sector's preference for liquid over gaseous fuels. The first is energy density: a gallon of liquefied natural gas contains about 65% of the energy of a gallon of gasoline and the energy density of compressed natural gas (CNG) is only 30% to 35% of that of gasoline, depending on the storage pressure (AFDC, 2012a). The second is the cost of storage on-board a vehicle. The EIA has estimated that storing the energy equivalent of a gallon of diesel fuel on board a heavy-duty vehicle costs $350 for CNG and $475 for LNG. These costs are an order of magnitude greater than the costs of storing diesel fuel or gasoline.

Natural gas can be converted to liquid fuels including diesel, gasoline and methanol. Depending on the process, 35% to 45% of the energy content is spent in the conversion process, much more than in traditional petroleum refining. Widespread use of methanol would require that vehicles either be adapted to flexibly accept methanol (at a cost on the order of $100 per vehicle) or designed specifically for dedicated methanol use. Methanol compatible flexibly fueled vehicles (FFV) would have only about half the range when running on methanol in comparison to gasoline, would require deployment of new refueling infrastructure, and would introduce new safety issues due to the different toxicity of methanol. Natural gas to drop-in fuels does not face these barriers. However, the EIA's 2012 Annual Energy Outlook Reference Case projection foresees no production of liquid fuels from natural gas through 2035 under current policies.

There are reasons to proceed with caution, however, and to rely as much as possible on market-based decision-making. The technology of natural gas fueled internal combustion engines is relatively mature. Vehicles running on compressed or liquefied natural gas have been in the U.S. and other countries for decades and their pros and cons are relatively well understood. For both heavy and light duty vehicles, the benefits of switching to natural gas are lower energy costs in comparison to petroleum, approximately a 20% reduction in tailpipe greenhouse gas emissions and the substitution of a domestic, competitively priced energy resource for petroleum. The downsides are 1) increased vehicle cost mainly due to the greater cost of compressed gas storage tanks, 2) reduced range and therefore increased frequency of refueling and 3) diminished cargo space due to the lower energy density of compressed natural gas. CNG, LNG and methanol additionally face the "chicken or egg" problem of developing an adequate refueling infrastructure and producing a range of vehicle makes and models that can satisfy the needs and preferences of most motorists.

Since 2002, the number of natural gas vehicles in operation has remained stable at just under 120,000, according to the latest data available from the EIA (Figure 5; Davis et al., 2011, table 6.1). CNG vehicles far outnumber LNG vehicles, largely due to the lack of LNG refueling infrastructure and the greater cost of on-board storage.

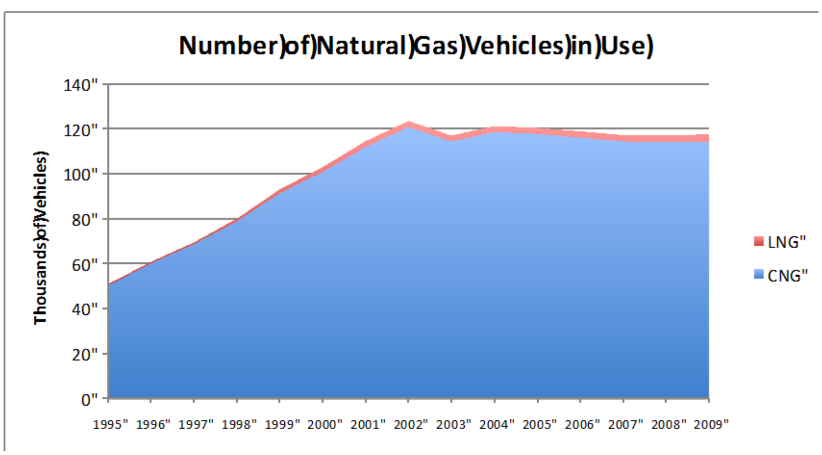

Figure 5. Number of Natural Gas Vehicles in Operation (1,000s): 1995-2009
Source: Table 6.1 in Davis, Diegel and Boundy, 2011.

Existing studies indicate that a minimally acceptable refueling infrastructure for passenger cars and light trucks would require the equivalent of 10% to 20% of the over 150,000 gasoline stations in existence today. The EIA and DOE's alternative fuel data center report that there are about 1,000 natural gas refueling stations in the U.S. today of which only about half are open to the public (table 1). Although much remains to be learned about the value of fuel availability to consumers, there is little doubt that it is important, particularly for vehicles with limited range, and that the existing low level of fuel availability is an enormous barrier to market acceptance of natural gas vehicles.

Table 1. U.S. Alternative Fuel Stations by Fuel Type.

U.S. Alternative Fueling Stations by Fuel Type

Year	Methanol (M85)	E85	CNG	Propane	Electric*	LNG	Biodiesel**	Hydrogen	Total***
1992	43	2	349	3,297					3,691
1993	50	7	497	3,297					3,851
1994	82	32	1,042	3,299					4,455
1995	88	37	1,065	3,299	188				4,677
1996	95	68	1,419	4,252	194	72			6,100
1997	106	71	1,426	4,255	310	71			6,239
1998	91	40	1,268	5,318	486	66			7,269
1999	51	49	1,267	4,153	490	46			6,056
2000	3	113	1,217	3,268	558	44	2		5,205
2001		154	1,232	3,403	693	44	16		5,542
2002		149	1,166	3,431	873	36	79	7	5,741
2003		188	1,035	3,966	830	62	142	7	6,230
2004		200	917	3,689	671	58	176	9	5,720
2005		436	787	2,995	588	40	304	14	5,164
2006		762	732	2,619	465	37	459	17	5,091
2007		1,208	721	2,371	442	35	742	32	5,551
2008		1,644	778	2,175	430	38	645	46	5,756
2009		1,928	772	2,468	465	36	679	63	6,411
2010		2,142	841	2,647	541	39	644	58	6,912
2011		2,442	910	2,597	3,394	45	627	56	10,071

Data Source:
Alternative Fuels Data Center (AFDC), either directly (www.afdc.energy.gov/afdc/fuels/stations_counts.html) or from historical Transportation Energy Data Books (www.osti.gov/bridge/basicsearch.jsp)

It would probably not be worthwhile to deploy a full-scale natural gas refueling infrastructure. While shale gas provides an enormously important new resource for the U.S., it is not large enough to supply even a large fraction of transportation's energy use in addition to expanding traditional uses in other sectors. And although natural gas produces lower tailpipe GHG emissions than petroleum, those emissions are not low enough to meet the reductions that will be required in the future to protect the global climate. If a large-scale national natural gas infrastructure were deployed by, say, 2030 it would need to be substantially dismantled by 2050 to achieve overall reductions in GHG emissions on the order of 60% to 80%. On a well-to-wheel basis, future compressed natural gas vehicles are expected to generate 80% of the emissions of an advanced gasoline powered vehicle (Davis et al., 2012, figure 11.3). But such estimates are highly dependent on assumptions about upstream methane emissions. Alvarez et al. (2012) note the very large uncertainty about emissions from methane infrastructure, citing estimates ranging from 1% to 9% of gross production. According to their estimates, upstream emissions must be 1% or less for heavy-duty vehicles and 1.6% or less for light-duty vehicles if there are to be any GHG benefits from a switch to natural gas.

Summary Observations

Natural gas can play a constructive role in reducing the petroleum use and greenhouse gas emissions of transportation vehicles but it is by no means a panacea. In my opinion, we should act cautiously to encourage greater use of natural gas in those applications where it is a cost-effective solution by facilitating the deployment of refueling infrastructure and by pursuing fuel neutral policies that provide markets with clear signals to improve energy efficiency, choose environmentally sustainable fuels, and enhance our energy security.

Our current fuel economy and emissions standards are currently the most important such policies. Other policies worth considering include feebates for new vehicle purchases and restructuring of highway user fees on motor vehicles. Feebates can be structured analogously to the fuel economy and emissions standards (e.g., footprint based and reflecting similar values for reducing petroleum use and GHG emissions) to encourage market demand for more efficient vehicles and technologies. They can also be designed to be revenue neutral. As the University of California's analysis of feebates for the California Air Resources Board showed, feebates can reduce petroleum use and GHG emissions at negative cost (Bunch and Greene, 2011).

As work is defined in the physical sciences, transportation is work: force applied over a distance to overcome inertia and friction. The laws of physics require that energy must be used to do work and, energy efficiency held constant, the amount of energy used is directly proportional to the amount of work done. Holding energy efficiency constant, the amount of energy used by a vehicle is an accurate measure of the amount of transportation work done. But current and proposed increases in light- and heavy-duty vehicle fuel economy will decouple energy use from vehicle travel, just as they did following the first round of fuel economy standards in 1975. By converting motor fuel taxes to energy user fees indexed to the average energy efficiency of all vehicles on the road we could maintain the financial integrity of surface transportation while creating a continuously increasing incentive for energy efficient vehicles and fuels.

Increased use of natural gas in transportation can make measured but important contributions to economic growth, environmental protection and energy security. However, attempting a large-scale transition from petroleum to natural gas would be a mistake. Expanding use of natural gas in specialized markets where the economics are favorable and adequate fuel availability can be deployed cost-effectively can be an important part of a comprehensive energy policy.

Thank you for the opportunity to comment. I look forward to your questions.

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