THE HAMILTON PROJECT

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Leveling the Playing Field for Natural Gas in Transportation

Christopher R. Knittel

MISSION STATEMENT

The Hamilton Project seeks to advance America's promise of opportunity, prosperity, and growth.

We believe that today's increasingly competitive global economy demands public policy ideas commensurate with the challenges of the 21st Century. The Project's economic strategy reflects a judgment that long-term prosperity is best achieved by fostering economic growth and broad participation in that growth, by enhancing individual economic security, and by embracing a role for effective government in making needed public investments.

Our strategy calls for combining public investment, a secure social safety net, and fiscal discipline. In that framework, the Project puts forward innovative proposals from leading economic thinkers — based on credible evidence and experience, not ideology or doctrine — to introduce new and effective policy options into the national debate.

The Project is named after Alexander Hamilton, the nation's first Treasury Secretary, who laid the foundation for the modern American economy. Hamilton stood for sound fiscal policy, believed that broad-based opportunity for advancement would drive American economic growth, and recognized that "prudent aids and encouragements on the part of government" are necessary to enhance and guide market forces. The guiding principles of the Project remain consistent with these views.

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Leveling the Playing Field for Natural Gas in Transportation

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NOTE: This discussion paper is a proposal from the author. As emphasized in The Hamilton Project's original strategy paper, the Project was designed in part to provide a forum for leading thinkers across the nation to put forward innovative and potentially important economic policy ideas that share the Project's broad goals of promoting economic growth, broad-based participation in growth, and economic security. The authors are invited to express their own ideas in discussion papers, whether or not the Project's staff or advisory council agrees with the specific proposals. This discussion paper is offered in that spirit.

BROOKINGS

Abstract

Technological advances in horizontal drilling deep underground have led to large-scale discoveries of natural gas reserves that are now economical to access. This, along with increases in oil prices, has fundamentally changed the relative price of oil and natural gas in the United States. As of December 2011, oil was trading at a 500 percent premium over natural gas. This ratio has increased over the past few months. The discovery of large, economically accessible natural gas reserves has the potential to aid in a number of policy goals related to energy. Natural gas can replace oil in transportation through a number of channels. However, the field between natural gas as a transportation fuel and petroleum-based fuels is not level. Given this uneven playing field, left to its own devices, the market is unlikely to lead to an efficient mix of petroleum- and natural gas-based fuels. This paper presents a pair of policy proposals designed to increase the nation's energy security, decrease the susceptibility of the U.S. economy to recessions caused by oil-price shocks, and reduce greenhouse gas emissions and other pollutants. First, I propose improving the natural gas fueling infrastructure in homes, at local distribution companies, and along long-haul trucking routes. Second, I offer steps to promote the use of natural gas vehicles and fuels.

Table of Contents

Chapter 1: Introduction

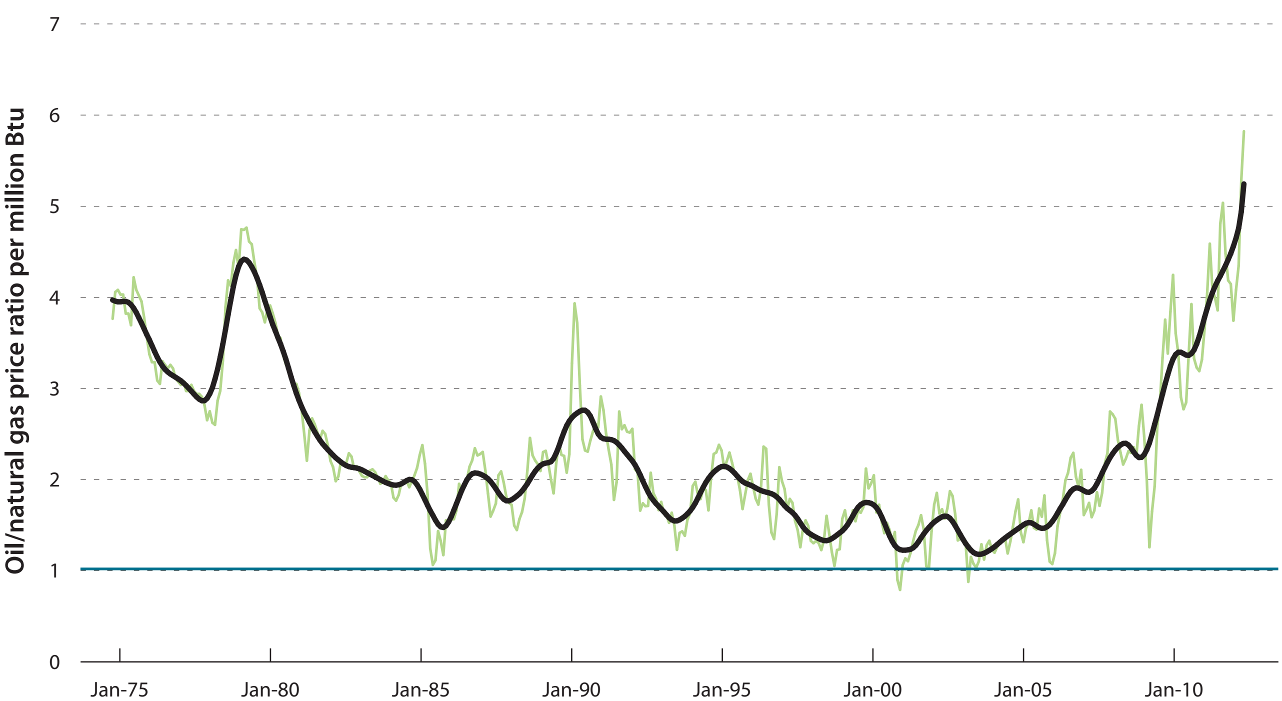
Technological advances in horizontal drilling deep underground have led to large-scale discoveries of natural gas reserves that are now economical to access. This, along with increases in oil prices, has fundamentally changed the relative price of oil and natural gas in the United States. To illustrate this, Figure 1 plots the ratio of the oil prices to natural gas prices on a per-energy basis from 1975 to the end of 2011.[1] As of December 2011, oil was trading at a 500-percent premium over natural gas. This ratio has increased over the past few months.

The discovery of large, economically accessible natural gas reserves has the potential to aid in a number of policy goals related to energy. For one, replacing oil with natural gas can reduce U.S. dependence on oil, thereby reducing the vulnerability of the U.S. economy to macroeconomic downturns caused by oil shocks. Second, because natural gas is cleaner in terms of greenhouse gas emissions and local pollutants compared to both coal and oil, replacing these other fossil fuels with natural gas can reduce U.S. greenhouse gas emissions and health problems associated with local pollution. Third, replacing oil with natural gas can increase U.S. profits associated with fossil fuel production and create excellent opportunities for the U.S. economy.

There are also compelling arguments for policymakers to consider policies designed to promote natural gas. However, we need to level the playing field between natural gas-based and petroleum-based fuels. Natural gas-based fuels carry lower, un-priced social costs than gasoline. For example, local pollution emissions are fewer from an engine burning natural gas compared to the same engine burning gasoline. If prices reflected true social costs, this would make petroleum-based fuels even more expensive than their natural gas counterparts. Petroleum therefore has an artificial advantage over natural gas

FIGURE 1.

Ratio of Oil and Natural Gas Prices per Unit of Energy



Source: U.S. Energy Information Administration.

because these other social costs are not included in the price that consumers pay. Additionally, the refueling infrastructure for natural gas is significantly less developed than the infrastructure for gasoline and diesel. While the costs of building such an infrastructure are true social costs and must be considered when comparing the merits of the two fuels, the lack of a refueling presence leads to what is known as a network externality, or a chicken-and-egg problem, that can lead to the efficient product not being selected in the market. Petroleum is then given an advantage from being part of the status quo. Given these two artificial advantages that gasoline and diesel have over natural gas-based fuels, left to its own devices, the market is unlikely to lead to an efficient mix of petroleum- and natural gas-based fuels.

Ethanol-based fuel and electric vehicles face many of the same problems as natural gas-based vehicles—they have, or may have, lower greenhouse gas emissions and lower local-pollutant emissions, and are not petroleum based, which could potentially lead to fewer oil-price-shock-induced recessions and military expenditures. Refueling infrastructure for these alternative energy sources is also lacking. Policymakers have already taken steps to address these challenges by adopting policies that encourage the use of ethanol-based fuel and electric vehicles. While these policies might begin to level the playing field between petroleum-based and ethanol- or electricity-based transportation, they distort the playing field between ethanol- and electricity-based transportation and natural gas-based transportation technologies. It is time to level this playing field.

This paper presents two sets of policy proposals designed to increase the nation's energy security, decrease the susceptibility of the U.S. economy to recessions caused by oil-price shocks, and reduce greenhouse gas emissions and other pollutants. First, I propose improving the natural gas fueling infrastructure in homes, at local distribution companies, and along long-haul trucking routes. Second, I offer steps to promote the use of natural gas vehicles and fuels.

Chapter 2: Opportunities for Natural Gas in Transportation

The United States consumes roughly 20 million barrels of oil per day. This is 50 percent more than the European Union, which has 60 percent more people, and is more than twice the rate of consumption in China (CIA n.d.). The United States also produces roughly 10 million barrels of oil per day, representing about 10 percent of global oil production (CIA n.d.).

When combined with the dramatic drop in natural gas prices, the use of natural gas in transportation (see Box 1) provides significant savings to consumers and reductions in external costs associated with petroleum usage. However, in the absence of policy interventions, a lack of refueling infrastructure may prevent consumers from realizing potential cost savings and an unequal playing field will prevent society from experiencing the benefits of lower gasoline consumption. Below, I lay out the potential private and external benefits of natural gas use in transportation.

PRIVATE BENEFITS OF LIGHT- AND MEDIUM-DUTY CNG AND HEAVY-DUTY LNG VEHICLES

At current prices for natural gas and gasoline, switching to CNG or LNG may make sense from a consumer's perspective if we ignore the lack of natural gas fueling stations. I examine private costs, or the costs that consumers pay for their vehicles and at the pump. A comparison of CNG and gasoline models (see Appendix A for details) suggests that the fuel economies of the gasoline version and the CNG version of the vehicle are more or less equal. Therefore there are two key differences between CNG and gasoline vehicles: a higher upfront cost for CNG vehicles, but a lower fuel cost. Table 1 presents the savings in a comparison of natural gas vehicles with four gas-powered vehicles.

The Department of Energy (DOE) reported that nationwide average retail prices for gasoline and CNG in January

BOX 1.

Natural Gas in Transportation

Natural gas can serve as an oil replacement in transportation markets in three ways. First, natural gas can be converted to methanol—an alcohol with similar properties to ethanol—that can be burned in internal combustion engines with slight vehicle modifications.

Second, light- and medium-duty vehicles using existing engine technologies can also burn compressed natural gas (CNG). Here the natural gas is stored at pressure, typically around 3000 psi. Because of the pressure, the CNG storage tanks are larger than existing gasoline storage tanks, so vehicles often have less trunk space and can cover less distance than conventional gasoline cars without refueling. The Honda Civic GX, currently sold in the United States, for example, has a CNG capacity equivalent to eight gallons of gasoline. A number of CNG vehicles sold in Europe are bi-fuel vehicles capable of burning both CNG and gasoline in their engines. When the CNG tank empties, the engine shift to the gasoline tank for fuel. Bi-fuel vehicles will frequently use gasoline first because the cold-start properties of gasoline are better than CNG.

Third, medium- and heavy-duty vehicles can run off of either CNG or liquefied natural gas (LNG), which is stored at very low temperatures (-260 degrees Fahrenheit). The advantage of LNG over CNG is that it requires 30 percent less space (although the tanks are bulkier) allowing for longer driving distances.[2] One disadvantage of LNG is that storing it for long periods is expensive, therefore LNG is often considered as a replacement fuel for vehicles that are in continuous use (e.g., heavy duty). Most industry followers envision LNG technologies as the likely replacement for diesel in the largest classes of heavy-duty vehicles.[3]

TABLE 1.

Lifetime Private Benefits of Switching from a Conventional Gasoline Vehicle to a Natural Gas Vehicle (Dollars)

	Pickup truck (15-MPG)	Sedan (30-MPG)	Heavy-duty truck (5-MPG)	Heavy-duty truck (7-MPG)
Savings on fuel	$15,171	$7,586	$186,828	$133,449
Extra cost of natural gas car	-$11,000	-$5,500	-$70,000	-$70,000
Total private benefits	**$4,171**	**$2,086**	**$116,828**	**$63,449**

NOTE: Costs do not include the inconvenience associated with fewer refueling stations. The table assumes a gasoline price of $3.46/gallon, a diesel price of $3.81/gallon and a CNG/LNG price of $2.09/gge. Calculations for the sedan and the pickup truck assume 15,000 miles driven annually and for a lifetime total of 200,000 miles. The heavy-duty truck is assumed to be driven 100,000 miles a year for a lifetime total of 500,000 miles. Future costs and benefits are discounted at 4 percent.

2012 were $3.46 and $2.09 per gallon of gasoline equivalent (gge), respectively. At these prices, the private incentive for purchasing a CNG vehicle is considerable. After subtracting the price premium associated with buying a CNG vehicle, the net private savings is almost $2,100 for a sedan and almost $4,200 for a pickup truck.

As with light-duty vehicles, there are also private benefits from shifts to natural gas in the heavy-duty industry. While the upfront cost of conversion—about $70,000[4]—is large, the average miles travelled for combination trucks (those that tow trailers) was roughly 70,000 miles in 2010, while the average fuel economy was 5.9 miles per gallon (MPG) (FHWA 2012). Table 1 shows the resulting net savings of almost $117,000 for a 5-MPG, class 8 truck and nearly $64,000 for a 7-MPG, class 8 truck.

EXTERNAL COST BENEFITS FROM CNG AND LNG

Replacing petroleum with natural gas also could reduce many of the costs associated with petroleum use that are borne by society, but are not borne by the individuals making decisions regarding fuel use. These costs, such as the effects of global warming and pollution, are not included in the price at the gas pump. Economists call them negative externalities. Because they are not factored into the decisions of individual consumers, the market over-consumes petroleum. While markets usually lead to the efficient, or nearly efficient, mixture of goods and services, in the presence of a negative externality, basic microeconomic principles tell us that the market will be inefficient. This opens the door for public policy to improve upon market outcomes.

A variety of negative externalities exist in markets for petroleum products. Natural gas as a transportation fuel does not eliminate all of these externalities, but it reduces many of them significantly. The following discussion provides estimates of these externalities and how natural gas use may mitigate their costs.

Military Interventions. U.S. dependence on oil may increase the required size of our military and influences decisions on whether to engage in military conflicts, which lead to loss of life. Natural gas, on the other hand, does not suffer from military-related externalities because its production is domestic or based in Canada. A wide range of estimates exists as to the size of this externality, with some estimates as high as $1.50 per gallon (ICTA 1998). However, it is unclear whether these represent a true *marginal* cost.

Macroeconomic Shocks. As we saw in 2008, dependence on oil increases our economy's susceptibility to oil-price-shock-driven recessions.[5,6] For the Regulatory Impact Analysis associated with corporate average fuel economy (CAFE) standards, the National Highway Traffic Safety Association (NHTSA) estimates that the increased risk of recession costs society between 8 and 27 cents per gallon of gasoline, with a "most likely" value of 17 cents per gallon (NHTSA 2010). Natural gas would not carry this cost.

Greenhouse Gases. Burning petroleum releases greenhouse gases in atmosphere, which has been shown to lead to increased climate temperatures. While they are not without debate, estimates for the cost of greenhouse gas emissions are about 35 cents per gallon of gasoline and 39 cents per gallon of diesel.[7] Natural gas does not completely eliminate greenhouse gas emissions, but it reduces them relative to petroleum. The U.S. Environmental Protection Agency (EPA) has suggested greenhouse gas emissions from CNG vehicles are roughly 25 percent lower than from equivalent vehicles running on gasoline.[8]

Local Pollution. Finally, consumption of oil also leads to local pollution, which has been shown to lead to increases in health care costs and increased mortality.[9] The health costs associated with local pollution are about 30 cents per gallon for gasoline and 60 cents per gallon for diesel (NRC 2010). The evidence suggests that natural gas light-duty vehicles create significantly less local pollution than their gasoline counterparts on a per-gallon-of-gas equivalent (gge).[10] On the heavy-duty side, natural gas is also likely to reduce the 60 cent externality because local pollution emissions from diesel engines are particularly high.

Combined these suggest that the externalities of CNG are roughly 39 cents less than gasoline per gge.[11] Table 2 reports the savings in external costs associated with switching to a natural gas vehicle and combines these benefits with the private benefits to show the total social benefits of converting. Reductions in external costs are $4,448 over the life of a pickup truck; for the more fuel-efficient sedan, reductions are half of this amount given that it consumes half of the fuel. As with private benefits, external cost reductions are larger for heavy-duty industry vehicles. For these trucks, the reduction in external costs is nearly $60,000.

CNG VERSUS ELECTRIC VEHICLES

There are considerable potential private and social benefits from CNG adoption relative to existing gasoline vehicles. Another natural comparison is between CNG and battery electric vehicles, either hybrid or all-electric (see Appendix B for detailed comparison of models). The hybrid version has 14

TABLE 2.

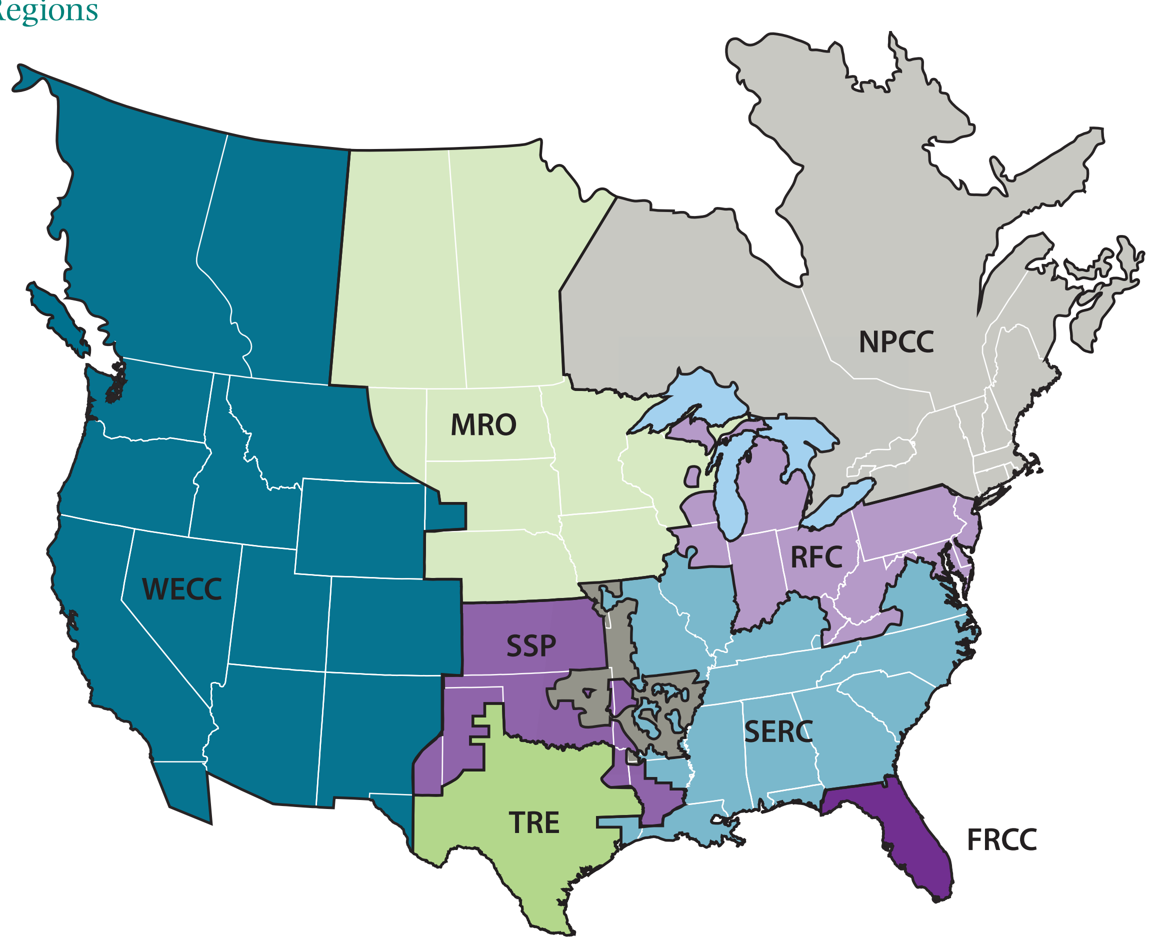
Lifetime Private and External Benefits of Switching from a Conventional Gasoline Vehicle to a Natural Gas Vehicle (Dollars)

	Pickup truck (15-MPG)	Sedan (30-MPG)	Heavy-duty truck (5-MPG)	Heavy-duty truck (7-MPG)
Private Benefits				
Savings on fuel	$15,171	$7,586	$186,828	$133,449
Extra cost of natural gas car	-$11,000	-$5,500	-$70,000	-$70,000
Total private benefits	**$4,171**	**$2,086**	**$116,828**	**$63,449**
External Benefits				
Reduction in external costs				
From lower carbon emissions	$1,093	$546	$8,768	$6,263
From fewer local pollutants	$1,661	$831	$32,586	$23,276
From lower macroeconomic externalities	$1,694	$847	$18,466	$13,190
Total external benefits	**$4,448**	**$2,224**	**$59,820**	**$42,729**
Total social benefit	**$8,620**	**$4,310**	**$176,648**	**$106,177**

Note: Social cost of carbon (SCC) of $35 per ton of carbon dioxide (CO_2), local pollution externality of 30 cents per gallon of gasoline and 60 cents per gallon of diesel, macroeconomic externality of 17 cents per gallon, and a military externality of 0 cents per gallon. The macroeconomic externality is reduced by 10 percent since approximately 10 percent of light-duty fuel is ethanol. Calculations for the sedan and the pickup assume 15,000 miles driven each year and for a lifetime total of 200,000 miles. The heavy-duty truck is assumed to be driven 100,000 miles a year and for a lifetime total of 500,000 miles. Future costs and benefits are discounted at 4 percent.

FIGURE 2.

NERC Regions



percent lower carbon dioxide (CO_2) emissions than the CNG version. If we believe that the social cost of these emissions is 35 cents per gge, then the hybrid version has a 5-cent per gge advantage over the CNG version. However, the hybrid version still suffers from the petroleum-based externalities (military and macroeconomic), so the CNG version has fewer total external costs.

The relative emissions of CNG and all-electric vehicles depend heavily on where the electric vehicles are recharged. Using the marginal greenhouse gas emission rates from Graff Zivin, Kotchen, and Mansur (2012), the per-mile emissions for both vehicles in each of the five electricity regions are shown in Table 3. Both the Nissan Leaf and Chevrolet Volt, two electric vehicles, are dirtier than the Civic CNG and Hybrid versions in two major electrical power system (North American Electric Reliability Corp. [NERC]) regions: the Midwest Reliability Organization (MRO) region and the Reliability First Corp. (RFC) region, which includes Pennsylvania, Ohio, and a large portion of Michigan (Figure 2). Emissions by NERC region and population-weighted average emissions are reported in Table 3.

As a whole, this analysis suggests that CNG vehicles can provide real tailpipe CO_2 emissions reductions compared to traditional gasoline engines and may also provide reductions comparable to all-electric vehicles. Table 4 compares the lifetime private and external benefits of switching from a traditional gasoline sedan to a CNG, hybrid, or all-electric sedan. Given the higher direct social costs of electric vehicles, further analysis suggests that the total social cost for CNG vehicles is lower than that of all-electric vehicles under a wide range of assumptions on the value of externalities.

TABLE 3.

Nissan Leaf and Chevrolet Volt Emissions by NERC Region (Grams of CO_2 per Mile)

NERC Region	Nissan Leaf	Chevy Volt, Electric	Chevy Volt, 50/50	Honda Civic, CNG	V. Passat, CNG*
NPCC	120	124	182	251	192
MRO	344	354	297	251	192
WECC	133	137	188	251	192
ERCOT	171	176	208	251	192
SERC	193	198	219	251	192
SPP	194	200	220	251	192
RFC	275	283	261	251	192
Population-weighted average	**196**	**202**	**221**	**251**	**192**

TABLE 4.

Lifetime Private and External Benefits of Switching from a Conventional Gasoline Vehicle to a Natural Gas, Hybrid, or Electric Vehicle

	CNG	Hybrid	All-Electric, Average	All-Electric in MRO	All-Electric in MPCC
Private Benefits					
Savings on fuel	$7,586	$5,474	$12,298	$12,298	$12,298
Extra cost of car	-$5,500	-$3,500	-$15,500	-$15,500	-$15,500
Total private benefits	**$2,086**	**$1,974**	**-$3,202**	**-$3,202**	**-$3,202**
External Benefits					
Reduction in external costs					
From lower carbon emissions	$546	$625	$696	-$371	$1,246
From fewer local pollutants	$831	$475	$804	$804	$804
From lower macroeconomic externalities	$847	$242	$820	$820	$820
Total external benefits	**$2,224**	**$1,341**	**$2,319**	**$1,253**	**$2,869**
Total social benefit	**$4,310**	**$3,315**	**-$883**	**-$1,949**	**-$333**

Note: Private costs of all-electric calculation assumes average U.S. retail price for electricity and uses a 31-MPG gasoline vehicle for comparison.

Chapter 3: Detailed Policy Proposal

Realizing the benefits of natural gas in transportation for consumers and for society as whole will require policymakers to attack two challenges. The first barrier to adoption of natural gas in transportation—which Table 1 and Table 2 ignore, and which may prevent many consumers from realizing these private savings—is the lack of a refueling infrastructure for both CNG and LNG.[12] As of 2007, there were roughly 120,000 gasoline stations in the United States, according to the U.S. Census Bureau; in contrast there are fewer than 400 public CNG refueling stations—a clear disadvantage for natural gas vehicles. Large-scale adoption of natural gas vehicles requires coordination between vehicle manufacturers, consumers, and refueling stations—either existing gasoline stations or replacements. This creates a chicken-and-egg problem, or a network externality issue. Consumers are unwilling to purchase natural gas vehicles before a refueling infrastructure is built, but businesses will not invest in natural gas refueling stations until there is consumer demand. Each side would be better off if the other side acted first, but neither is willing to move without the other. Left alone, network externalities continue the dominance of the status quo technology when, from society's perspective, it should be replaced with a new technology (Farrell and Saloner 1986).

The second barrier to realizing benefits from natural gas is the costs that petroleum impose on society that are not factored into prices. Because of these costs, people will over-consume petroleum while under-consuming natural gas because natural gas prices understate its advantage relative to gasoline. The ideal starting point for addressing these externalities is for policymakers to set taxes for the externalities associated with consumption of all fuels, known as Pigouvian taxes, so that external costs are included in individual decisions. However, these are unlikely to be implemented, and further policy action would still be justified by the presence of network externalities.

Below are two policy proposals in seven steps. In the first are three steps for creating natural gas fueling infrastructure in the United States. In the second are four steps to promote the use of natural gas vehicles. Each step includes background information and an economic rationale for the policy. These steps do not need to be executed in order, but together, they form parts of a larger whole, pushing on both sides of the network externality problem and creating a more level playing field for natural gas vehicles.

INFRASTRUCTURE-BASED POLICIES

Step 1: Encourage home refueling by pricing natural gas for CNG vehicles at efficient rates.

As with electric vehicles, one of the advantages of CNG over gasoline vehicles is the ability to refuel at home. State utility commissions should require local distribution companies (LDCs) to price natural gas for refueling at marginal cost, or the cost of producing and distributing an additional unit of natural gas. The Federal Energy Regulatory Commission could, perhaps, provide guidance for these changes. Besides the upfront costs, which are roughly $4,000, a second disincentive for consumers to leverage home refueling is that retail rates for natural gas are well above marginal cost.

The high cost of natural gas delivery in homes can overwhelm the price advantage of natural gas, making natural gas artificially more expensive than petroleum. According to the U.S. Energy Information Administration (EIA), natural gas prices at the wellhead were $2.46 per thousand cubic feet in February of 2012, but the average residential price was $9.40 per thousand cubic feet. The average city gate price was $4.75 per thousand cubic feet.

Utilities likely use this pricing structure to help them recover the high costs of building pipelines to distribute gas, but such a price distortion may lead to inefficiently low amounts of adoption of CNG vehicles.[13] The preferential rates recommended are analogous to the preferential electricity rates charged for electric vehicle charging. Gasoline and diesel prices also reflect state and local taxes. To keep the three fuels (gasoline, diesel, and CNG) on an equal footing, natural gas used for CNG and electricity used for recharging electric vehicles should also include these taxes.

Step 2: Encourage local distribution companies to offer CNG stations.

State utility commissions should also allow LDCs to build natural gas fueling stations and to re-coup their investments by including them in their rate base. Again, the Federal Energy Regulatory Commission could provide guidance for these changes. According to DOE's Alternative Fuels and Advanced Vehicles Data Center (AFDC)[14] a number of CNG stations already exist at natural gas LDC facilities, presumably to refuel fleets. A rapid way to open up the infrastructure would be to turn these into retail stations.

This would solve a second potential problem with alternative fuels—the potential for market power. Not only does a small refueling network increase inconvenience and costs associated with alternative fuels, it also means that there is little competition in the CNG retail markets. This allows refueling stations to price above marginal costs. Step 2 would guard against this because state utility commissions would regulate retail prices at the LDC stations on a cost-of-service basis.

Step 3: Establish an industry consortium to investigate and coordinate on LNG refueling infrastructure.

One potential advantage of transitions in the heavy-duty industry is that the relevant stakeholders are concentrated and thus an industry consortium with vehicle manufacturers, large vehicle consumers, and fuel providers may be more effective. DOE could create such a consortium to establish so-called blue corridors—networks of refueling stations along widely used interstate routes—with provisions to ensure that LNG is priced fairly.[15]

VEHICLE- AND FUEL-BASED POLICIES

Step 4: Include methanol in the Renewable Fuel Standard.

Step 4 is for Congress to expand the Energy Independence and Security Act (EISA), which established the second phase of the federal Renewable Fuel Standard (RFS). The RFS requires certain amounts of biofuels to be sold each year. Biofuels are classified in three groups based on what they are made from and based on their lifecycle greenhouse gas (GHG) emissions. The three groups, in order from highest to lowest GHG emissions, are Conventional Fuels, Advanced Biofuels, and Cellulosic Biofuels.[16] Each has a separate quota. Quotas for the Advanced and Cellulosic groups have been eased. Conventional biofuels are essentially capped at 15 billion gallons, at least as they apply to the RFS.

The goals of the Act are clearly stated in its preamble. EISA begins with the following language:

> To move the United States toward greater energy independence and security, to increase the production of clean renewable fuels, to protect consumers, to increase the efficiency of products, buildings, and vehicles, to promote research on and deploy greenhouse gas capture and storage options, and to improve the energy performance of the Federal Government, and for other purposes.

Besides the quantity requirements for biofuels, EISA included several provisions, ranging from energy efficiency standards for automobiles, buildings, and light bulbs; research and development subsidies; and biofuel infrastructure subsidies.

The rationale for this step is that although methanol made from natural gas is not a renewable fuel, EISA's preamble states that a major goal of the act is to increase energy security and independence. Methanol produced from natural gas clearly meets these goals. Not only is it a domestic source for energy used in transportation, but it also diversifies our transportation energy sources and thus decreases the susceptibility of the U.S. economy to oil price shocks.

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Another goal of the Act is to reduce greenhouse gas emissions. Otherwise, EISA would not have differentiated fuels by their lifecycle emissions. Delucchi (2003) estimates that the lifecycle greenhouse gas emissions of methanol, made from natural gas, are more than 11 percent lower than gasoline. In contrast, Delucchi estimates that the lifecycle emissions of corn-based ethanol when distilled using the average electricity generation mix in the United States are 10 percent higher than gasoline. Other estimates suggest that the gap between corn-based ethanol and natural gas-based methanol is even larger (Argonne 2011). While it is unlikely that natural gas-based methanol would qualify for the Advanced and Cellulosic categories in terms of its lifecycle emissions, treating it as a Conventional Biofuel is entirely consistent with the goals of the Act. Furthermore, by expanding the scope of fuels included within the RFS, this recommendation could reduce the costs of compliance.[17]

Step 5: Mandate a significant share of vehicles manufactured to be able to burn gasoline, ethanol, and methanol.

Internal combustion engines are able to burn not only gasoline, but also ethanol and methanol, both of which are alcohols. A number of flex-fuel vehicles that can burn both gasoline and ethanol already exist on the road partly because of a provision in the CAFE standard that treats the fuel economy of these vehicles as much higher than vehicles that cannot burn ethanol.[18] Creating a tri-fuel mandate would require similar Congressional action.

As with ethanol, engines must be modified to burn methanol in large proportions. Some estimates suggest that an open fuel standard would cost, on average, $100 per vehicle for new vehicles (Open Fuel Standard of 2011 Fact Sheet).[19] Other estimates suggest that requiring vehicles to be able to burn both ethanol and methanol would add an additional $200 over vehicles that can burn gasoline and ethanol (MIT 2011).

A flex-fuel mandate is designed to overcome a network externality associated with natural gas fuels. It is conceivable that if the methanol infrastructure were in place, more consumers (and automobile manufacturers) would find it in their interest to purchase (or produce) vehicles that operate on gasoline, ethanol, and methanol. Similarly, if vehicles that could operate on methanol were to exist, it is conceivable to think that firms would find methanol infrastructure investments profitable. However, without the infrastructure, the automobiles do not exist, and without the automobiles, the infrastructure does not exist.

The small investment in each vehicle also has "option value" for the U.S. economy. Such a fuel standard would allow Americans to diversify their fuel sources if gasoline prices continue to rise. While this, by itself, is not a rationale for government intervention, this strengthens the network externality issues discussed above.

I am not the first to suggest policies requiring greater flexibility in fuel uses. Another example is a recent bill introduced by Congressmen John Shimkus (R-IL), Eliot Engel (D-NY), Roscoe Bartlett (R-MD), and Steve Israel (D-NY)—the Open Fuel Standard (OFS) Act (HR 1687). Senators Maria Cantwell (D-WA) and Dick Lugar (R-IN) have recently introduced a similar measure into the Senate (SA 1657). HR 1687 would require 50 percent of new automobiles in 2014 to be able to run on at least one alternative fuel group. This would increase to 80 percent in 2016 and 95 percent in 2017.

A qualified vehicle is defined as

- A vehicle that operates solely on natural gas, hydrogen, or biodiesel
- A flexible fuel vehicle capable of operating on gasoline, E85 (a mix of 85 percent ethanol and 15 percent gasoline), and M85 (a mix of 85 percent methanol and 15 percent gasoline)
- A plug-in electric drive vehicle
- A vehicle propelled solely by fuel cell or by something other than an internal combustion engine

I recommend two changes to the Open Fuel Standard. First, the time frame needs to be adjusted. Given the design cycle of vehicles—namely that manufacturers are often working today on vehicles that will be produced five years in the future—requiring 50 percent of vehicles to be tri-flex fuel within two years is too aggressive. Second, the language of the Act does not provide justification for the 85/15 split. Methanol or ethanol are unlikely to scale up to 85 percent of fuel consumed. A more modest fuel standard may be just as effective and less costly because vehicle costs are increasing in the maximum amount of ethanol or methanol that can be burned. Widening the range of fuels that a vehicle can accept increases the programming required and may increase the costs of other modifications. A more cost-effective implementation strategy would call for a greater number of vehicles capable of burning a lower amount of alternative fuel, rather than a high maximum amount of alternative fuel allowed with fewer vehicles. That is, requiring 80 percent of vehicles to be able to burn up to 40 percent methanol would be more cost-effective than requiring 40 percent of vehicles to be able to burn 80 percent methanol.

I would encourage a timeline that requires 50 percent of new automobiles in 2016 to be able to run on up to 50 percent of both ethanol and methanol, 80 percent of new vehicles by 2018, and 95 percent by 2020.

Step 6: Provide subsidies for natural gas vehicles commensurate with the reduction in external costs associated with their use.

Currently electric vehicles (EVs) with battery packs larger than four kilowatt-hours qualify for a federal income tax credit of $7,500. A recent budget proposed by the Obama administration calls for this to increase to $10,000.[20] The current subsidy for CNG vehicles is $4,000. CNG sedans should qualify for the same level of federal income tax credits as EVs. In addition, medium-duty CNG pickups should receive more federal tax credits than both CNG and EV sedans.

As discussed in the section of this paper on CNG versus all-electric vehicles, both types of vehicles have similar greenhouse gas emissions when comparing the direct emissions of the

TABLE 5.

Lifetime External Benefits of Switching from a Conventional Gasoline Vehicle to a CNG, All Electric, or M85 Vehicle (Dollars)

	CNG Replacement	M85 Replacement	EV Replacement, Average	EV Replacement in MRO	EV Replacement in MPCC
Pickup truck (15-MPG)	$4,448	$612			
Sedan (30-MPG)	$2,224	$306	$2,319	$1,253	$2,869

power plants used to charge electric vehicles and the tailpipe emissions from CNG. Also, neither type of vehicle carries the negative externalities associated with macroeconomic movements and military costs and losses. The savings in greenhouse gases from all-electric vehicles depend heavily on where the electric vehicle is charged. Despite this, the federal tax credit does not differentiate based on the location of the electric vehicle.

Step 6 is part of a larger recommendation regarding tax subsidies for alternative-technology vehicles—policies should not pick winners; tax subsidies should be based on a vehicle's reduction in externalities relative to the vehicle that the consumer would have purchased in the absence of policy action. Even if policy does not differentiate electric vehicles by the source of their electric charges, it is clear that CNG vehicles can lead to larger reductions in externalities if the alternative traditional vehicle is a low-mileage pickup truck; the relative levels of the two vehicles' subsidies does not reflect the relative reduction in externalities.

A more general framework for defining the level of vehicle subsidies based on the savings in externalities allows the policy to be consistent across alternative vehicles. Anything other than this is implicitly, or explicitly, picking winners. For example, such a framework could be applied to vehicles that run on methanol. Table 5 reports the potential savings in external costs for CNG vehicles, electric vehicles, and vehicles running on M85 (again, 85 percent may be an arbitrary percentage).

The current subsidy for electric vehicles is roughly three times the reduction in externalities for an electric vehicle driven 15,000 miles per year and recharged using power plants with average emissions. Based on externalities and this three-times guideline, a 15-MPG vehicle running on M85 would qualify for a subsidy of roughly $1,800. Using the electric-vehicle subsidy as a guide, an argument could be made that a 15-MPG CNG vehicle should receive a subsidy of more than $13,000.

Perhaps, more importantly, such a framework would allow policymakers to apply consistent principles to the heavy-duty industry. Table 2 makes clear the large potential social benefits from the heavy-duty industry adopting LNG vehicles. As a point of reference, the New Alternative Transportation to Give Americans Solutions (NATGAS) Act of 2011 calls for a $7,500 subsidy for CNG light-duty vehicles and up to a $64,000 subsidy for heavy-duty vehicles. Despite the large subsidy for heavy-duty vehicles, the subsidy is a much smaller percentage of the external costs savings compared to the subsidy for all-electric vehicles. In terms of reducing external costs, the $64,000 has a much higher rate of return than both the $7,500 for CNG vehicles and the current subsidy for electric vehicles.

Step 7: Streamline the retrofitting certification process for gasoline vehicle conversion to CNG.

This step would allow consumers to take advantage of the fact that, in principle, existing gasoline-powered vehicles can be retrofitted. Because new vehicles comprise roughly 8 percent of the vehicle stock in any one year, the ability to retrofit existing vehicles can increase the savings in external costs. The EPA and California Air Resource Board (CARB) have certification programs for CNG conversions. According to Natural Gas Vehicles for America,[21] there are thirteen engine families for which certified conversions are offered; all of these are General Motors, Chrysler, or Ford engines. Non-certified conversions also are offered for many more.

One reason offered for why non-certified conversions are common is the claim that the EPA and CARB certification process is unduly expensive. The Web site GreenCar.com suggests that certification for conversion systems costs as much as $200,000 per engine family.[22] These costs might be appropriate, but if not, the EPA and CARB should look at ways to streamline the process.

Chapter 4: Implementation Costs and Benefits

Step 1: Encourage home refueling by pricing natural gas for CNG vehicles at efficient rates.

The benefits of efficient rates will allow consumers to take advantage of the lower costs of natural gas, relative to gasoline, and provide the incentives for consumers to install home refueling infrastructure.

There are potential costs. Because natural gas LDCs are subject to cost-of-service regulations, reductions in retail rates for CNG vehicle consumers may lower the rate-of-return earned on capital. If the return on capital fell, it would require an increase in retail rates for other consumers. Another way to keep LDCs at their current returns on capital is to charge a fixed monthly fee for access to the CNG rates. This is the standard "two-part tariff" that increases the efficiency of the rate structure. The advantage of this is that the rates of other LDC products would not have to increase, and CNG owners would still have the correct incentives on the margin.

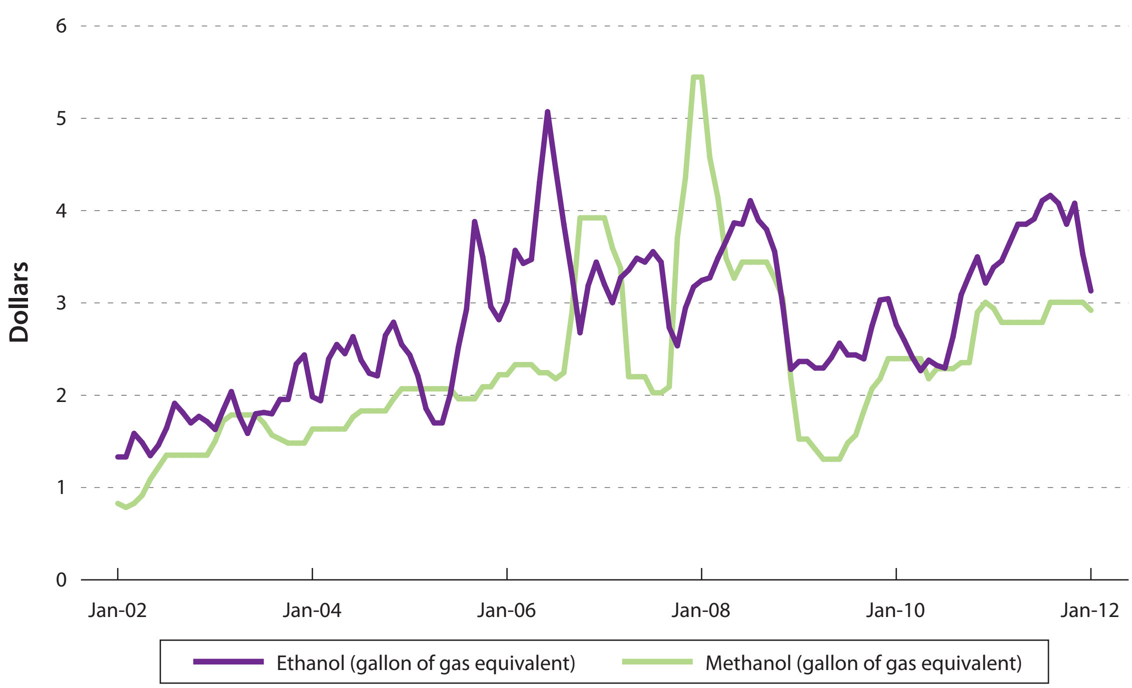
Step 2: Encourage local distribution companies to offer CNG stations.

As noted in the previous section, there are two major benefits from allowing local distribution companies to open CNG refueling stations to the public. It is a step toward solving the network externalities associated with alternative fuels and technologies. The other benefit is that it supplies a set of CNG refueling stations operated via a cost-for-service model to alleviate some of the potential market power that retail CNG stations may enjoy in the early part of the market.

The costs associated with this recommendation are the costs of the refueling centers. Given the regulatory structure of LDCs, it is straightforward to ensure that these costs are borne by the consumers using the service and not all natural gas consumers.

FIGURE 3.

Wholesale Prices of Methanol and Ethanol Over Time



Source: Nebraska Energy Office and Methanex.

TABLE 6.

Lifetime External Benefits of Switching from a Conventional Gasoline Vehicle to a CNG or Methanol Vehicle (Dollars)

	CNG Replacement	M50 Replacement	M85 Replacement
Pick-up truck (15-MPG)	$4,448	$282	$612
Sedan (30-MPG)	$2,224	$141	$306

Step 3: Establish an industry consortium to investigate and coordinate on LNG refueling infrastructure.

Establishing an industry consortium to coordinate the creation of blue corridors is an effective way to solve the network externality issues associated with LNG. Such consortia appear to have been effective in Europe; a number of LNG refueling terminals exist and many more are being proposed.[23] The cost of coordinating efforts among industry stakeholders seems to be minimal.

Step 4: Include methanol in the Renewable Fuel Standard.

There are no direct costs of this recommendation, but there are indirect cost reductions. The benefits will depend on how scalable methanol is from current production levels and how "binding" the RFS regulation is—that is, by how much the RFS incentivizes shifts to ethanol and methanol. Current wholesale ethanol and methanol prices suggest that the benefits may be large. Figure 3 plots wholesale ethanol and methanol prices since 2002 on a gge basis. The average price difference over this time has been 84 cents and $1 since 2009. While it is doubtful such a price difference would continue if we ramped methanol production to the entire RFS level (and ethanol production down to zero), these data suggest that methanol may reduce the compliance costs of the RFS.

Step 5: Mandate a significant share of vehicles manufactured to be able to burn gasoline, ethanol, and methanol.

The social benefits of this recommendation come from both solving the network externality market failure associated with fuel and vehicles, as well as reducing the external costs of driving. Table 6 lists the reduction in external costs from shifting a vehicle from gasoline to M50 or M85. Even if we were to ignore the benefits associated with alleviating the network externality, the social benefits from a reduction in external costs exceed the estimated increase in the cost of the vehicle, especially for a 15-MPG vehicle.

TABLE 7.

Aggregate Benefits of Natural Gas Vehicle Penetration (Billions of Dollars)

	Scenario	Savings in private costs	Savings in external costs
CNG replacement of light-duty vehicles	5 percent	8.4	2.4
	10 percent	16.8	4.8
	25 percent	41.9	12.0
	50 percent	83.8	24.0
CNG/LNG replacement of medium- and heavy-duty vehicles	5 percent	3.9	1.3
	10 percent	7.7	2.6
	25 percent	19.3	6.4
	50 percent	38.7	12.8

Step 6: Provide subsidies for natural gas vehicles commensurate with the reduction in external costs associated with their use.

We can also place bounds on the social benefits from subsidizing CNG by measuring the reduction in externalities over the life of the vehicles. This is a lower bound on the benefits since it ignores the network externality justifications for subsidizing alternative technologies. These are repeated in Table 6. As discussed in the previous section, the reduction in external costs for CNG vehicles with a fuel economy of 30 MPG, relative to the $7,500, is similar in magnitude to today's subsidies for all electric vehicles; the reduction in external costs for CNG vehicles with a fuel economy of 15 MPG is twice as large.

The social benefits from incentivizing shifts from diesel-based, heavy-duty trucks to LNG are even greater. The upfront investment also is greater. However, a more important comparison is the social rate of return, that is, the ratio of the benefits to the subsidy. While a heavy-duty subsidy does not currently exist, for all-electric vehicles the social benefits are roughly one-third the subsidy. For a high fuel economy CNG (say, 30 MPG) vehicle, the social returns are roughly 60 percent of current subsidies; for a low fuel economy CNG (say, 15 MPG) vehicle, the social return of a $4,000 subsidy is 110 percent.

These simple calculations underline the point that the current structure of subsidies is not uniform across technologies, at least when we focus on the social benefits of shifts to the different technologies. The payoffs range from 110 percent of the subsidy for low fuel economy CNG vehicles to 33 percent for electric vehicles. If we were to apply this range to LNG vehicles, the range of subsidies would be roughly $55,000 using current subsidies for CNG medium-duty vehicles ($60k/1.10), to more than $180,000 ($60k/0.33) using current subsidies for electric vehicles, for 5-MPG heavy-duty trucks, and $39,000 to $130,000 for 7-MPG heavy-duty trucks ($43k/1.10 to $43k/0.33).

These calculations suggest that recent proposals to offer subsidies of up to $64,000 for the heavy-duty industry (NATGAS Act) have a high rate of return relative to existing subsidy programs. Therefore, shifts away from low rate-of-return subsidies to high rate-of-return subsidies can actually decrease the aggregate budget associated with subsidy programs, while keeping the reduction in external costs constant. Alternatively, holding fixed the aggregate subsidy budget, we can increase the reduction in external costs by making such shifts.

Step 7: Streamline the retrofitting certification process for gasoline vehicle conversion to CNG.

The direct costs associated with this recommendation are the added manpower required to investigate the certification process. The potential benefits come from reducing the costs of retrofitting the existing fleet. Because, in any given year, only 8 percent of all vehicles are new, reducing costs associated with retrofits can have large benefits.

Combined private and external benefits.

Projections as to how these policies would change the adoption of natural gas vehicles are difficult to make, since the evolution of the fleet depends on many things. One could, however, calculate the savings in private and external costs under different penetration rates of natural gas. Here, I focus on the penetration of CNG and LNG.

Table 7 reports the aggregate savings in private and external costs under penetration levels of 5, 10, 25, and 50 percent. To calculate these, I use gasoline and diesel consumption for 2010 broken down by vehicle type, reported by the Bureau of Transportation Statistics. The table illustrates that even under modest penetration rates, given the sheer size of the transportation sector significant private and external costs savings would occur. A 10 percent penetration rate, alone, would reduce annual private costs by nearly $25 billion and external costs by over $7 billion.

Chapter 5: Questions and Concerns

Recently there has been a focus on so-called fugitive methane emissions—methane leaks along the transportation network. Fugitive emissions undermine the greenhouse gas benefits from shifting to CNG vehicles, and the lifecycle emissions of methanol. Because of the higher radiative force of methane relative to CO_2, methane emissions have a global warming potential that is twenty-five times that of CO_2 over a 100-year period and seventy-two times that of CO_2 over a 20-year period (Shindell et al.). Alvaraz et al. (2011) find that if the EPA's estimate of fugitive emissions is 2.4 percent of total production (and this figure is applied to scaling up natural gas production) shifts to natural gas in the light-duty market increase global warming for the first 80 years and shifts to natural gas in the heavy-duty market increase global warming for the first 280 years. They also find that if fugitive emissions are reduced to roughly 1.5 percent, shifts to CNG lead to immediate global warming benefits in the light-duty market; if fugitive emissions fall to 1 percent, immediate benefits are found for the heavy-duty industry.

Three points are worth noting. First, the current level of emissions may reveal little about the cost of reducing them. It may be relatively costless to do so. The EPA has recently taken steps to reduce fugitive emissions by altering air regulations. Future fugitive emissions and the success of these changes should be monitored.

Second, the EPA's assumption that 2.4 percent of natural gas is leaked into the atmosphere is not without controversy. The natural gas industry, not surprisingly, contends that actual emissions are much lower and noted that the EPA's figure is based on data taken from old natural gas wells; the implication is that newer wells will have a smaller rate of lifetime fugitive emissions.

Finally, greenhouse gas emissions reductions are only one benefit from shifts to natural gas as a transportation fuel. The private benefits discussed above do not depend on greenhouse gas reductions. In addition, there are three additional market failures. If I estimate the reduction in external costs assuming that greenhouse gas benefits are zero, the reduction in external costs is still substantial, falling only 25 percent from the previous external benefits of CNG vehicles. The reduction in external costs for heavy-duty vehicles remains high as well, falling by roughly 15 percent (see Table 8).

A second issue is that the first recommendation (including methanol in the RFS) is likely to shift economic rents or profits from firms inside the corn-based ethanol supply chain to firms inside the methanol supply chain. While this is not a cost to society, such a transfer is likely to lead to resistance of this recommendation from firms involved in the corn-ethanol supply chain.

TABLE 8.

Lifetime External Benefits of Switching from a Conventional Gasoline Vehicle to a CNG Vehicle, Assuming No Greenhouse Gas Benefits (Dollars)

	Pick-up truck (15-MPG)	Sedan (30-MPG)	Heavy-duty truck (5-MPG)	Heavy-duty truck (7-MPG)
Reduction in external costs				
From fewer local pollutants	$1,661	$831	$32,586	$23,276
From lower macroeconomic externalities	$1,694	$847	$18,466	$13,190
Total external benefits	**$3,355**	**$1,678**	**$51,052**	**$36,466**

Chapter 6: Conclusion

Recent advances in natural gas drilling as well as increases in oil prices appear to have made natural gas competitive with oil in the long run. For many reasons, such a change in price may not be enough to cause the United States to substitute natural gas for oil in the transportation sector, even when it is socially beneficial to do so. The playing field across alternative transportation fuels is simply not level. While policy has promoted ethanol and electric vehicles as the future substitute for petroleum-based vehicles, methanol CNG vehicles offer similar, if not greater, benefits at a lower cost. In this paper, I lay out a proposal for leveling the playing field between petroleum, ethanol, electricity, and natural gas.

Appendices

APPENDIX A. COMPARISON OF CNG AND GASOLINE VEHICLES

Currently, while a number of CNG and bi-fuel (vehicles that run on both CNG and gasoline) vehicles are sold in Europe, only one CNG vehicle is sold in the United States—the Honda Civic. Chrysler, Ford, and GM have all recently announced plans to offer CNG pickup trucks and vans in the medium-duty classes. Appendix Table 1 reports the fuel economy of the CNG version Civic (on a gallon-of-gas-equivalent [gge] basis) and the gasoline version. On a combined-fuel-economy basis, they have the same fuel economy.

To calculate the price premium for the Civic CNG and hybrid sedans, I used Honda's on-line comparison tool and compared the CNG version to the EX version with cloth seats. The tool adjusts for differences in standard features. To calculate the price comparisons with the Nissan Leaf and Chevrolet Volt, I used truedelta.com's price comparison tool. This too adjusts for differences in features.

APPENDIX TABLE 1.

Comparison of Honda and Volkswagen CNG Models to Their Closest Gasoline Counterpart

	Honda Civic CNG	Honda Civic Gasoline	Honda Civic HEV	Volkswagen Passat CNG, running on CNG	Volkswagen Passat CNG, running on gasoline
Engine Type	4-Cylinder	4-Cylinder	4-Cylinder	4-Cylinder Turbocharged	4-Cylinder Turbocharged
Displacement (cc)	1798	1798	1497	1390	1390
Horsepower	110	140	110	150	150
Torque (lb.-ft.)	106	128	127	220	220
Transmission	5-Speed Auto	5-Speed Auto	CVT	7-Speed Auto	7-Speed Auto
Weight	2848	2705	2853		
Length (in)	177.3	177.3	177.3	187.8	187.8
Width (in)	69.0	69.0	69.0	71.7	71.7
Wheelbase (in)	105.1	105.1	105.1	106.8	106.8
EPA Mileage Estimate					
City (MPGge)	27	28	44	26	27
Highway (MPGge)	38	36	44	44	42
Combined (MPGge)	31	31	44	36	35
Range (miles)	249	409	581	303	283
CO_2 Emissions (g/mi, electricity/tailpipe)	251	306	217	192	254
Price relative to gasoline version	5,500		3,500		

APPENDIX B: COMPARISON OF CNG AND ELECTRIC VEHICLES

The Honda Civic, Nissan Leaf, and Chevrolet Volt compare favorably to each other. Appendix Table 2 shows specifications for the Nissan Leaf, Chevrolet Volt, and the three versions of the Honda Civic. The three vehicles are similar in length, width, and wheelbase. The weight is difficult to compare because the Leaf's battery and control module weigh approximately 400 pounds, while the Volt has both an internal combustion engine and electric technologies. The Leaf and CNG Civic have identical horsepower, although the Leaf's torque is much higher, a benefit of electric motors. The Volt and Civic gasoline versions have similar horsepower, and again, the Volt has much more torque. The distance range of the CNG Civic is over three times the Leaf's; the range for the Volt is very high considering that it has access to the internal combustion engine to recharge the batteries. The upfront cost of the vehicles is the key difference. Using truedelta.com's comparison tool, which allows the user to control for different features, both the Leaf and the Volt are over $10,000 more expensive than the comparably equipped CNG Civic.

APPENDIX TABLE 2.

Comparison of Nissan Leaf and Chevrolet Volt to Honda Civic CNG, Gasoline, and Hybrid Versions

	Nissan Leaf	Chevrolet Volt	Honda Civic CNG	Honda Civic Gasoline	Honda Civic HEV
Engine Type	—	4-Cylinder	4-Cylinder	4-Cylinder	4-Cylinder
Displacement (cc)	—	1400	1798	1798	1497
Horsepower	110	149	110	140	110
Torque (lb.-ft.)	207	273	106	128	127
Transmission			5-Speed Auto	5-Speed Auto	CVT
Weight	3366	3755	2848	2705	2853
Length (in)	175	177.1	177.3	177.3	177.3
Width (in)	69.7	70.4	69.0	69.0	69.0
Wheelbase (in)	106.3	105.7	105.1	105.1	105.1
EPA Mileage Estimate					
City (MPGge)	106	95/35	27	28	44
Highway (MPGge)	92	93/36	38	36	44
Combined (MPGge)	99	94/35	31	31	44
Range (miles)	73	36/310	249	409	581
CO_2 Emissions (g/mi, electricity/tailpipe)	124-354	127-364/240	251	306	217
Price relative to gasoline version			5,500		3,500
TrueDelta Value Comparison to Volt			-11,240	-16,740	-13,240
TrueDelta Value Comparison to Leaf			-9,625	-15,125	-11,625

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Endnotes

1. The figure also includes a Lowess smoothed line, which is similar in nature to a moving average, but smooths both backwards and forwards.
2. See NGVAmerica.org.
3. Peterbilt and Kenworth both offer LNG versions of class 8 trucks using the Westport LNG fuel system (http://www.westport-hd.com).
4. Personal conversations with Westport suggest that the LNG feature adds roughly $70,000 to the cost of a tractor trailer.
5. See, for example, Hamilton (1983, 2009, and 2011).
6. A common misconception is that if the United States produced enough oil to satisfy its consumption, the country would be insulated completely from oil price shocks. This is not the case. Because oil is easily transported across the world, the oil market is a global market. Imagine that U.S. production matched consumption. If the world price of oil increased either through an increase in world demand or a supply shock, the oil prices faced by the United States would also increase because U.S. producers have the option to sell on the world market. Absent large trade barriers in the form of export taxes, the U.S. economy would still face world oil price shocks. While domestic profits for oil-producing firms would increase and thus reduce the shock to some degree, prices for products based on oil (e.g., gasoline and diesel) would still increase.
7. These estimates include tailpipe emissions but not upstream emissions. Greenstone et al. (2011) have an average social cost of carbon (SCC) at a 3 percent discount rate of $24 per ton of carbon dioxide (CO_2) in 2015 and an average of $35 in 2015 using a 2.5 percent discount rate. A gallon of gasoline generates roughly 20 pounds of CO_2 when burned, while a gallon of diesel generates roughly 22 pounds.
8. This is consistent with several side-by-side comparisons of bi-fuel vehicles—vehicles that are designed to burn and carry both gasoline and CNG—offered in Europe. For example, Volkswagen offers a bi-fuel Passat that carries both 21 kg of CNG (equivalent to 8.5 gallons of gasoline) and 8.3 gallons of gasoline. (Appendix Table 1 describes the details of this vehicle.) Volkswagen reports tailpipe emissions from the Passat are 192 g/mile when burning CNG and 254 g/mile when burning gasoline, a 24.4 percent reduction. In many ways, this is the ideal experiment since every other feature of the vehicle is held constant. Unlike the Passat, the Civic runs only on CNG, but we can compare the Civic CNG and Civic gasoline versions. Appendix Table 1 suggests that the tailpipe emissions from the CNG version are 18 percent lower than the gasoline version. This is somewhat of an overstatement of the emission reductions since the gasoline version has 30 more horsepower than the CNG version (140 HP v. 110 HP).
9. There is a long literature in economics documenting the link between criteria pollutants and health. See, for example, Chay and Greenstone (2003a and 2003b). For studies that directly relate health outcomes to driving, see Currie and Walker (2011) and Knittel, Miller, and Sanders (2011).
10. See, for example, http://www.afdc.energy.gov/afdc/pdfs/epa_cng.pdf, which reports reductions in carbon monoxide emissions of 90 percent to 97 percent, reductions in nitrogen oxide emissions of 35 percent to 60 percent, and potential reductions in non-methane hydrocarbon emissions of 50 percent to 70 percent, as well as other local pollution benefits. The Web site http://www.fueleconomy.gov/feg/bifueltech.shtml reports CNG vehicles have 60 percent to 90 percent less smog-forming emissions.
11. 0 + 17*.9 + 30*.5 + 35*.25. Since roughly 10 of light-duty fuel is ethanol, I reduce the macroeconomic externality by 10 percent. And, if LNG or CNG cuts diesel criteria pollutant emissions to those of gasoline-power vehicles, natural gas has externalities that are $0.55 less than a gallon of diesel.
12. It also ignores any additional maintenance costs associated with CNG vehicles, although a study of CNG taxis in New York suggests that maintenance costs might be lower. See http://www.consumerreports.org/cro/2012/03/the-natural-gas-alternative/index.htm.
13. This markup may also be viewed as a tax that prices some of the externalities associated with natural gas, but a recent paper by Lucas Davis and Erich Muehlegger (2010) suggests that the average residential and commercial markup over marginal costs exceeds 40 percent; this is equivalent to a tax of $50 per ton of CO2 (Davis and Muehlegger 2010). This exceeds the external costs estimates of Greenstone et al. (2011). In the absence of a tax for gasoline of the same size, this will distort the decision to use home refueling.
14. See http://www.afdc.energy.gov.
15. DOE has been active in encouraging fleets of heavy-duty vehicles to convert to natural gas as part of its Clean Cities initiative (http://energy.gov/articles/national-clean-fleets-partnership-moves-forward), and so could be well-placed to do something similar for long-haul trucks.
16. Advanced biofuels can be made from a variety of feed stocks but must have lifecycle greenhouse gas emission at least 50 percent less than the baseline fuel. Cellulosic biofuels must be made from cellulose, hemi-cellulose, or lignin derived from renewable biomass and have lifecycle emissions at least 60 percent less than the baseline fuel. Conventional biofuels are derived from cornstarch.
17. Holland et al. (2011) illustrate that the RFS is an expensive way to reduce greenhouse gas emissions and oil consumption, relative to Pigouvian taxes.
18. These vehicles are capable of burning up to 85 percent ethanol; the EPA recently ruled that non-flex fuel vehicles are able to safely burn fuel with up to 15 percent ethanol.
19. See http://openfuelstandard.blogspot.com/2011/05/ofs-fact-sheet.html.
20. See http://content.usatoday.com/communities/driveon/post/2012/02/president-obama-budget-electric-car-subsidies-chevrolet-volt/1#.T2jM-DVGi5sQ.
21. See NGVAmerica.org.
22. See http://www.greencar.com/articles/can-convert-natural-gas.php.
23. See http://www.gie.eu/maps_data/downloads/2011/GLE_LNG_August2011_MAP.pdf.

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Highlights

Christopher R. Knittel of MIT puts forward policies to support the development of natural gas fueling infrastructure and to encourage the use of natural gas fuels and vehicles. These measures take advantage of the opportunity offered by the shale gas revolution to substitute natural gas for petroleum, increasing U.S. energy security and reducing the environmental and health costs of our energy choices.

The Proposal

A. Support the development of natural gas fueling infrastructure

- Step 1: Encourage home refueling by pricing natural gas for CNG vehicles at efficient rates.
- Step 2: Encourage natural gas local distribution companies to offer CNG stations.
- Step 3: Establish an industry consortium to investigate and coordinate on LNG refueling stations.

B. Encourage the use of natural gas fuels and vehicles

- Step 4: Include methanol in the Renewable Fuel Standard.
- Step 5: Mandate a significant share of vehicles manufactured to be able to burn gasoline, ethanol, and methanol.
- Step 6: Provide subsidies for natural gas vehicles commensurate with the reduction in external costs associated with their use.
- Step 7: Streamline the retrofitting certification process for gasoline vehicle conversion to CNG.

Benefits

These proposals will help overcome obstacles in establishing a critical mass of natural gas fueling stations and generating the initial demand necessary to sustain these stations. The creation of this network of stations allows consumers to realize the cost savings promised by cheap natural gas. An overall shift to natural gas will also benefit society, because natural gas emits fewer greenhouse gases and local pollutants than petroleum. Finally, these proposals will reduce U.S. dependence on oil, increase U.S. energy security, and diversify our energy sources.

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