Should Ethanol Made from Natural Gas be Added to the Federal Biofuel Mandate?

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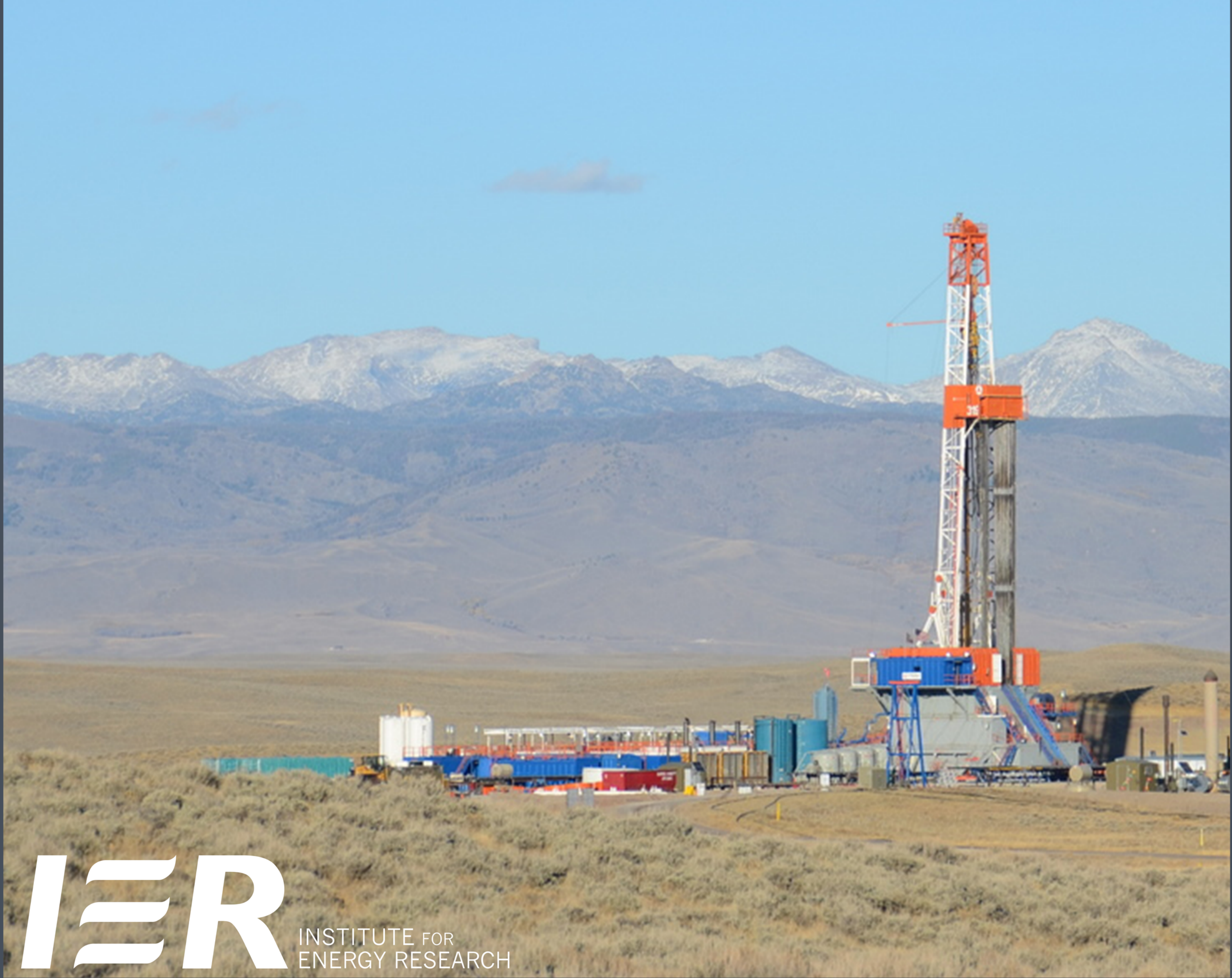

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About the Author

Mr. Lindsay Leveen obtained his BS Eng Chem in 1973, his MBA in finance and strategy in 1975, and MSChE in 1977.

He worked from 1977 till 1982 at Air Products and Chemicals and was responsible for economic evaluation of large hydrogen facilities.

In 1982 he joined Air Liquide to lead their tonnage gas business in the US. After attending an executive development program at INSEAD, Air Liquide appointed him as VP of Group Strategic Planning in their Paris, France headquarters.

In 1988 formed ITZ A GAZ to develop products and to consult to high technology industries. For over a decade he consulted to clients such as Intel, HP, IBM, and various Asian microelectronics companies and was the project manager of over $8 billion of capital projects executed worldwide.

In 1997 and for approximately a year Mr. Leveen consulted full time to Duke - Louis Dreyfus on power generation and distribution in the deregulated power generation market that was emerging in the USA.

In 1998, Bechtel invited him to run the global business unit for the global design and construction of microelectronic facilities.

From 2005 till June of 2011, Mr. Leveen was employed by Genentech, now a member of the Roche Group, where he performed strategic planning and drug product development for this world renowned company.

In September 2011, the Northern California Chapter of the American Institute of Chemical Engineers (AIChE) gave Mr. Leveen their Professional Development award for his lifetime of work in the field of chemical engineering.

Executive Summary

The recent dramatic increase of natural gas supply in the United States and Canada thanks to the booming shale industry has resulted in the discussion of a public policy to support and subsidize the production of ethanol from natural gas (EFNG). The EFNG industry and its supporters have offered this "chemically synthesized" ethanol as a possible substitute for corn ethanol and the yet–to-be produced "cellulosic" ethanol, arguing that EFNG is both green and does not take away from the food supply.

However, an analysis of the thermodynamic, economic, and ecological merits or demerits of producing EFNG shows that EFNG is neither renewable, nor does it reduce emissions of carbon dioxide (CO2). Using assumptions about the efficiency of the EFNG conversion process, the analysis reveals that:

- There is no ecological, economic, or thermodynamic (energy efficiency) merit to producing EFNG.
- In fact, CO2 emissions are likely to increase significantly with usage of EFNG.
- 50 percent or more of the energy content of the natural gas will be lost in the process of making EFNG.
- Natural gas itself is far greener than EFNG on a pound for pound basis. This is because fuels that have high hydrogen content emit less CO2 for the same amount of energy that is used, and with 25 percent mass composition of hydrogen, natural gas can be expected to emit less CO2 as ethanol, which has only 13 percent mass composition of hydrogen.
- The full lifecycle carbon emissions from the EFNG process as well as the combustion of the resulting ethanol will exceed the lifecycle carbon emissions of traditional hydrocarbon derived gasoline, and will far exceed the lifecycle carbon emissions of compressed natural gas (CNG) as an alternate fuel.

- Used in an identical vehicle, EFNG has carbon emissions per mile traveled that are at least 23 percent higher than the baseline for gasoline set in the Renewable Fuel Standard (RFS2). In order to qualify for the RFS2, a fuel must reduce CO2 emissions by at least 20 percent, not increase CO2 emissions by 23 percent.
- Used in an identical vehicle, EFNG will approximately double the carbon emissions per mile traveled when compared with CNG.

Given these limitations, this paper finds:

- Assumptions about the proprietary EFNG conversion process show that it is unlikely to meet the minimum CO2 reductions set forth by the RFS2. However, if EFNG is somehow able to attain the 20 percent reduction threshold to qualify as a "renewable fuel," EFNG would only be able to displace corn-based ethanol. Attainment of the 50% minimum CO2 reduction threshold for "advanced biofuels" is extremely unlikely.
- EFNG is not a commercially viable product, as the estimated cost of EFNG is higher than the ethanol futures price has reached yet in 2013. Any natural gas-based ethanol industry will need long-term government support—either in the form of mandates and regulations, or monetary incentives—to allow companies to make a profit and remain competitive.
- Any public policy that supports government subsidization of EFNG will be misguided from an emissions perspective and wasteful from a fiscal perspective.
- If EFNG is deemed "renewable" and is able to meet the required CO2 reductions, it would only serve to expand and further entrench the RFS2 mandate, a policy that requires consumers to use less efficient, more expensive fuel.

In summary, producing ethanol from natural gas is expensive, emits significant amounts of additional carbon dioxide, and is wasteful of the energy content as well as the hydrogen content of the natural gas that can be used more effectively in alternate applications. A simple alternate application such as CNG vehicles will lower overall carbon emissions and improve the efficiency of our collective energy usage in transportation, and this transition can occur in the marketplace without the use of a mandate.

Similarly, the best public policy on EFNG is not to have the government (state or federal) subsidize the EFNG industry or technology in any way, but to simply allow private industry to invest in it based on the merits of the technology and its viability in the current energy market. That being said, in the current energy marketplace, EFNG will not play a major role as a transportation fuel as it has no thermodynamic or ecologic merit, and is simply too expensive. Private investors will instead find more efficient uses for their funding, and better ways to use natural gas for transportation, electrical generation, and as a manufacturing feedstock.

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1. Introduction – Ethanol from Natural Gas and The Renewable Fuel Standard

Proponents of ethanol made from natural gas (EFNG) are trying to gain support from policymakers to allow the fuel to qualify for the federal renewable fuel standard (RFS2). This would provide EFNG a share of the guaranteed market for biofuels, as the U.S. refining industry is required to use billions of gallons of ethanol in its gasoline blends each year.

The RFS2 specifies that eligible biofuels must be made from qualifying types of renewable biomass, and that these biofuels are required to meet the following reductions of carbon dioxide over that of gasoline or diesel sold or distributed as transportation fuel in 2005:

Type of Biofuel	**Minimum Required CO2 Reduction Over Baseline Fuel**
Renewable Fuel	20%
Biomass-based Diesel	50%
Advanced Biofuel	50%
Cellulosic Biofuel	60%

As such, if EFNG were deemed an eligible "renewable fuel" as has been proposed, it would need to reduce at least 20 percent of greenhouse gas (GHG) emissions over that of 2005 baseline fuel to qualify for the RFS2. To qualify as an "advanced biofuel," EFNG would have to reduce at least 50 percent of GHG emissions relative to 2005 baseline fuel.

This paper will address whether EFNG does or does not reduce GHG emissions by at least 20 percent relative to baseline fuel, allowing it to meet the RFS2's minimum standards. These baseline levels are set at 98 kg CO2e/mmBTU for gasoline and 97 kg CO2e/mmBTU.[1] Converting these units to more understandable units of pounds CO2 per gallon of fuel, the baseline gasoline level equals 26.9 pounds CO2 per gallon and baseline diesel equals 29.6 pounds CO2 per gallon. Note gasoline is estimated to have 125,000 BTU High Heating Value (HHV) per gallon and diesel 138,700 BTU HHV per gallon.

This paper will also evaluate whether the value added in converting natural gas to ethanol is sufficient to support an industry, or whether this enterprise will continue to be reliant on government subsidy. The paper will analyze alternate uses of the natural gas such as power generation or steel manufacturing, and will compare the ecological and economic outcomes of these alternate uses against EFNG.

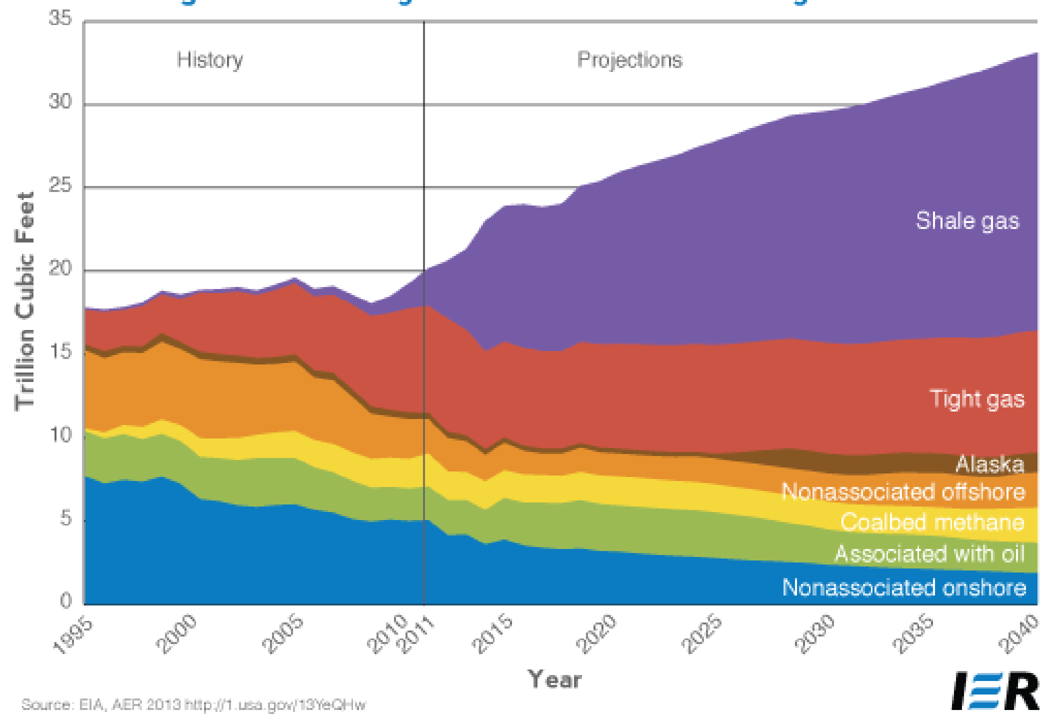
2. The Use of Natural Gas As A Transportation Fuel

To establish whether it is economically viable to convert natural gas to ethanol for transportation purposes, consideration must be given to how natural gas is currently used in the transportation sector, and what anticipated prices will be in the future.

Since 2008, the production of natural gas has surged to unprecedented highs, which in turn has led to low prices and greater consumption of CNG and liquefied natural gas (LNG) in the transportation sector. This dramatic growth in natural gas supply has been widely reported. Energy Secretary Ernest Moniz held a townhall meeting after his recent confirmation to the position, where he praised the discovery and production of shale natural gas as a "boon" to the United States.

Figure 1 from the Energy Information Administration (EIA) provides a vivid picture of the role shale gas has played, and will continue to play in the future in US natural gas production.

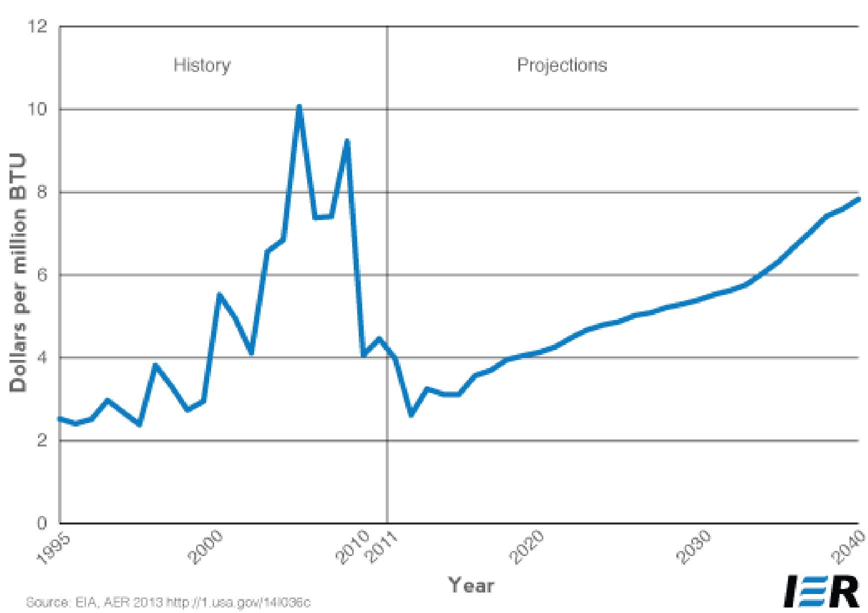
Figure 1. U.S. Dry Natural Gas Production by Source



<u>Long Term Forecasted Price Of Natural Gas</u>

EIA also has a forecast for the long-term price of natural gas as shown in Figure 2:

Figure 2. Annual Average Henry Hub Spot Natural Gas Prices



Source: U.S. Energy Information Administration, Annual Energy Outlook 2013, Market Trends, April 15, 2013

Natural gas is presently priced at approximately $4.00 per million British Thermal Units (BTUs). EIA estimates that imported oil has 5.99 million BTUs in a barrel, and domestic production has 5.80 million BTUs per barrel.[2] The average of imported and domestic oil is therefore approximately 5.9 million BTUs per barrel. Oil at $100 per barrel is priced at $19.64 per million BTU. Clearly natural gas is significantly cheaper than oil, hence the impetus by some to convert natural gas liquid transportation fuels including ethanol.

Ethanol has 84,530 BTUs per gallon and had a value of $2.525 per gallon on the exchange on June 5, 2013, the time this paper was written.[3] [4] This equates to $29.87 per million BTUs. This is a very large arbitrage between the value of natural gas and the spot value of ethanol.

3. Converting Natural Gas to Ethanol

Because of this large price differential, several companies have sought to use cheap natural gas to produce ethanol, a more expensive product with a potentially guaranteed market. Celanese, a leading player in the Methanol market, recently announced a new technology to convert natural gas into ethanol to capitalize on this opportunity. While it is very common to produce methanol from natural gas, producing ethanol from natural gas has been somewhat of a holy grail and the Celanese announcement that they have a "commercial" technology called the TCX® Process has generated interest.[5]

The exact process by which Celanese accomplishes the EFNG conversion is proprietary; however, a review of the patents Celanese has received over three decades shows that the company has patented the conversion of methanol to ethanol by reaction of the methanol with synthesis gas made from natural gas together with specialized catalysts. As such, it is likely that the EFNG conversion process uses methanol as a starting material and then makes ethanol from the methanol.

To bolster demand for its product, Celanese has been lobbying strongly for several years to gain RFS2-eligibility for EFNG. It has done so principally by arguing that increased EFNG production will be an incentive for the company to invest in facilities in the USA. Celanese is constructing an ethanol TCX® facility in China but will use coal as the feedstock rather than natural gas.[6]

Recently this lobbying effort has gained traction. On May 1, 2013, Representative Pete Olson of Texas introduced a bill to the house to amend the renewable fuel program to include ethanol produced from natural gas.[7] [8]

The Cost of EFNG

As noted above there is significant arbitrage between the cost of natural gas and the spot value of ethanol. Presently this arbitrage is approximately $25 per million BTUs. On the surface the arbitrage without the mandate's guaranteed market should support the EFNG business; however, further review reveals that the conversion process may entail significant costs that diminish the fuel's profitability in the absence of subsidies.

Assuming the TCX® process does use methanol as a starting point and that methanol has a value of $350 per metric ton, the value of methanol at this price is $16.17 per million BTUs. Theoretically the reaction to make ethanol from methanol requires one mole of methanol plus one mole of carbon monoxide plus two moles of hydrogen. Performing the mass and heat balance with a 90 percent yield, and placing a value of $7.50 per million BTU on the hydrogen as well as the carbon monoxide, the raw material cost to make ethanol from methanol is estimated at $1.15 per gallon. Adding all the other operating costs that are estimated as well as recovering the capital spent with a payout period of five years, the full price of ethanol produced in the TCX® process could be as much as $2.65 per gallon – a level that is higher than the ethanol futures price has reached yet in 2013. This high cost of manufacturing EFNG indicates the reason why companies such as Celanese are lobbying strongly for federal mandates that impose their cost on motorists.

Pacific Ethanol (PEIX on the Nasdaq) had a recent analysts call for their first quarter earning report. Their CFO reported the following:

> "For the first quarter of 2013, we reported net sales of $225 million compared to $198 million in the first quarter of 2012. The growth in net sales reflects an increase in average sales price per gallon of ethanol sold from $2.34 to $2.60. Gross profit for the first quarter of 2013 was $850,000 compared to a gross loss of $7.5 million in the first quarter of 2012, due to improvements in crush and commodity margins in the latter part of the quarter."[9]

The price of $2.60 per gallon of ethanol that Pacific Ethanol attained was not sufficient to support a profitable business with ethanol made out of corn. Pacific Ethanol reported a loss of over $5.4 million for the first quarter in 2013. This loss occurred despite the RFS mandate for corn ethanol. It is likely that EFNG with higher production costs will also be an industry that needs more government intervention and tax payer support to survive.

4. Can Natural Gas Ethanol Qualify for the RFS2?

While the potentially high cost of EFNG alone may preclude it becoming commercially viable, the cost of the mandated fuel is, unfortunately, not a factor when it comes to the RFS' qualification requirements. Rather, its eligibility for the existing RFS will be determined by its ability to meet the emissions reductions threshold. This remains to be determined, but a preliminary analysis—based on assumptions made about the EFNG conversion process—raises doubt about whether these reductions are attainable for EFNG.

Energy Loss In Conversion Process

As previously discussed, the expected process to produce ethanol is to make methanol first and then to react that methanol with a hydrogen and carbon monoxide mixture to form ethanol. To simplify the analysis it is assumed that this process will have a conversion efficiency of 50 percent. This assumption is based on two factors: methanol synthesis is approximately 60 percent thermally efficient, and a further reduction in the efficiency occurs when the added reaction to produce ethanol is performed.[10] Under these assumptions, 50 percent is the *maximum* probable efficiency of the Celanese natural gas to ethanol technology.

Half of the BTUS in the natural gas are simply wasted in the conversion process. For comparison, only 3 to 4 percent of the BTUs in natural gas are consumed to produce CNG and 9 to 10 percent of the BTUs are consumed to produce LNG. CNG and LNG are far better transportation alternates from an energy efficiency and sustainability perspective.

Lifecycle CO2 Emissions of Celanese Ethanol From Gas

The RFS2 specifies that a fuel must reduce GHG emissions by at least 20 percent relative to the displaced baseline fuel to qualify as a renewable fuel, and by at least 50 percent to qualify as an advanced biofuel. However, an analysis of the aggregate CO2 emissions that are produced during the making of natural gas ethanol demonstrates that its ability to achieve the requisite level of CO2 reductions is dubious at best.

With half of the BTUs in the natural gas (methane or CH4) being lost in the conversion process, this means half of the carbon in the methane will end up as CO2 emissions at the plant that produces the ethanol. This will result in each gallon of ethanol produced requiring an additional 84,530 BTUs of natural gas that ends up as CO2 emissions.

EPA provides data that each million BTUs of natural gas that are combusted will result in 117 pounds of CO2 emissions. Therefore 84,530 BTUs of natural gas will result in 9.89 pounds of CO2 emissions at the factory for each gallon of EFNG produced.

Combusting a gallon of ethanol produces 12.57 pounds of CO2 emissions.[11] Adding the 9.89 pounds per gallon emitted at the factory results in a total of 22.46 pounds of CO2 emissions per gallon of ethanol. Note this does not include the CO2 emissions involved in the exploration, production and transportation of the natural gas or any emissions of methane.

Though the EIA rates each gallon of gasoline as producing 19.64 pounds of CO2, this figure does not include the exploration, production, transport, and refining of crude oil.[12] Adding these lifecycle emissions in, total emissions will be approximately 25.15 pounds of CO2 for the full lifecycle of a gallon of gasoline.[13] This closely mirrors the carbon intensity of 2005 baseline gasoline used in the RFS2, which is 26.9 pounds of carbon per gallon of gasoline.

Gasoline has far higher energy content per gallon than does ethanol. At 125,000 BTUs HHV per gallon of gasoline versus 84,530 BTUs HHV per gallon of ethanol there is an additional fuel value of 47.9 percent.[14] An automobile using pure gasoline will, in all likelihood, travel 47 percent further on a gallon of gasoline versus a gallon of ethanol. Therefore, the CO2 emissions per mile travelled in the same vehicle using ethanol produced from natural gas are at least 23 percent higher than gasoline.

These figures show that gasoline refined from crude oil is a significantly "greener" alternative than ethanol produced from natural gas. The comparison to using compressed natural gas instead of gasoline is even more skewed in favor of compressing the natural gas rather than converting the gas into ethanol.

EFNG is also less efficient and a higher emitting fuel than CNG. Compressing natural gas to high pressure in CNG vehicles will only sacrifice approximately 4 to 5 percent of the energy content of the gas. As mentioned previously, half of the energy in the natural gas is lost in the Celanese conversion process. The compression of natural gas into CNG in a vehicle will almost double the distance the same vehicle will travel compared with converting the natural gas into ethanol. Because a million BTUs of gas emits 117 pounds of CO2 when combusted and a million BTUs of ethanol yields 149 pounds of CO2 when combusted (higher carbon to hydrogen ratio in ethanol versus natural gas) and a car travels nearly twice as far if powered by CNG, the alternative of converting natural gas to ethanol will emit 2.65 times the quantity of CO2 per mile traveled versus simply compressing the natural gas.[15] [16]

5. Other Efficient Alternatives For Natural Gas

Should EFNG be added as an eligible fuel under the RFS, it will not only serve to support a policy that mandates the use of more expensive, less efficient fuel, but it will also result in the diversion of natural gas away from more economically beneficial uses in the marketplace. Natural gas is an energy-dense fuel that is cheap and abundant at present; converting it to a less efficient fuel to take advantage of the RFS will have a deleterious effect on natural gas supply for uses such as electric power generation, steel production, fertilizer manufacture, methanol production, compressed and liquefied natural gas vehicles, gas to liquids, and plans for LNG exportations that have been announced.

Nucor, a leading US producer of steel, has announced a large project in Convent, Louisiana to produce direct reduced iron for steel making using natural gas instead of coking coal. Nucor had originally intended to build a traditional steel making facility using coke at the Convent site but switched to natural gas after the developments in shale gas production.

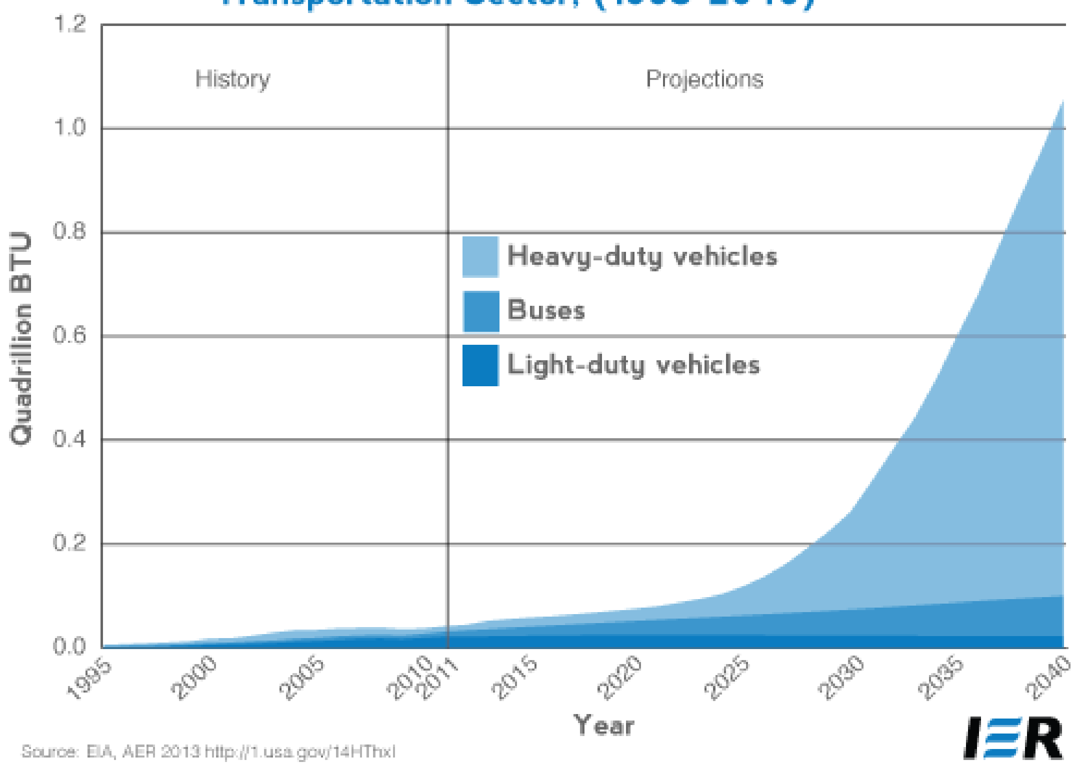
In fact, Nucor recently announced a major investment program with Encana[1]to partner on the exploration and production of shale gas that will allow Nucor to develop a physical hedge for the long term supply of natural gas to the Convent site.[17] [18] [19] Nucor has committed over $3 billion to the gas partnership and almost a billion dollars to the Convent plant. This project, done without government clean energy subsidies, will significantly lower Nucor's carbon emissions in steel production to less than one quarter the carbon emissions of comparable imported Chinese steel.

Methanex, a global producer of methanol has decided to relocate two methanol facilities from Chile to Geismar, Louisiana due to the availability of natural gas.[20] The two facilities in Chile are being dismantled in Chile and relocated to the US. Methanex did not receive green credits for these projects but found that lower cost natural gas in the US offset the cost of relocating the plants from Chile where natural gas is in short supply and more expensive. Methanex competes in the global market against Chinese methanol made from coal. By using natural gas with a thermal efficiency of 60%, its carbon footprint for methanol produced in Geismar will be significantly lower than that of coal-based Chinese competition, resulting in 64 percent less CO2 emissions.[21] China has promoted the widespread use of coal-derived methanol to augment gasoline supply. Methanol usage in gasoline is now approaching 8 percent of the fuel mix in China.[22]

Nucor and Methanex are but a few of many examples of private enterprise willing to make large capital investment in global scale facilities based on the advantage of abundant and affordable US natural gas. No government subsidies were needed to induce these companies to make these investments that provide high paying manufacturing jobs and significant ecological benefits over coal-based steel and methanol. These ecological benefits include carbon, land and water footprint reductions as well as the elimination of toxic ash and sulfur emissions.

Lastly, if the goal of federal policymakers is to craft policies that will result in better uses of transportation fuel with fewer CO2 emissions—which are primary objectives of the RFS2—using natural gas for ENFG is counterproductive. Natural gas in the form of LNG and CNG emits far less CO2. This is because fuels that have high hydrogen content emit less CO2 for the same amount of energy that is used, and with 25 percent mass composition of hydrogen, natural gas can be expected to emit about half as much CO2 as ethanol, which has only 13 percent mass composition of hydrogen. And it is equally as important to note that CNG and LNG will be utilized in the economy regardless of a mandate. In its 2013 *Annual Energy Outlook*, the EIA predicts that natural gas use for transportation will have an annual average growth rate of 11.9 percent, mostly led by its use in heavy-duty vehicles:

Figure 3. Natural Gas Consumption in the Transportation Sector, (1995-2040)



In sum, when deciding whether to designate EFNG as a mandate-eligible fuel, policymakers should consider the effect this decision would have on the various electrical generation, transportation, and manufacturing industries that depend on natural gas remaining abundant and affordable. Diversion of this resource to satisfy the RFS2 mandate will likely have negative impacts on these other uses of the resource.

6. Conclusion

Given that there is no economic or ecologic merit to any policy that subsidizes the production of ethanol transportation fuel from natural gas, proposals to add this fuel to the RFS2 are misguided—even according to the rationale of the RFS2 program. In fact, the ethanol will have far higher carbon emissions on a lifecycle basis than gasoline produced from crude oil. If the intention is to reduce overall carbon emissions while providing the most benefit to the US economy, natural gas would be best used in the generation of electricity, the production of steel, the production of methanol, or as compressed natural gas for transportation.

Endnotes

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