

NATURAL GAS BASED LIQUID FUELS: POTENTIAL INVESTMENT OPPORTUNITIES IN THE UNITED STATES

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SYNOPSIS

This report highlights potential investment opportunities related to natural gas liquids. The research was conducted as a project for the Fuel Freedom Foundation.

Low natural gas prices and new technology present an opportunity to market and sell liquid fuels in the form of ethanol and methanol to US consumers. Per unit of energy, oil is almost four times more expensive than natural gas. This implies a potential arbitrage opportunity to convert natural gas and natural gas liquids into a liquid fuel. In the US, 14.5 million vehicles can currently utilize ethanol fuels. These are so called “Flex Fuel” vehicles, or FFVs. Another 16.1 million FFV “Twins” can utilize ethanol with a software upgrade, and 46.9 million conventional fuel vehicles can potentially be converted for \$150–\$250 each. In all, this represents 77.75 million light duty vehicles, or 31.8% of the national light duty fleet, that would potentially purchase natural gas liquid fuel, if prices were attractive.

The conversion and sale of NG based ethanol to US customers offers relatively high margins compared to other energy-arbitrage efforts, such as LNG exports, because conversion and shipping costs are lower for the local market, and because the replaced product (gasoline motor fuel) is expensive compared to natural gas. Alongside the core ethanol production opportunity, there are several related supply-chain development projects, such as production facility development, ethanol fuel marketing, fueling station upgrades, blending facility expansions, and vehicle update kits.

Table 1: Potential Fuel Replacement from Oil Based to Natural Gas Based Liquids (2014)

	2014 Fleet (Millions)	Potential Demand (Mgal)	Potential Fuel Sales* (\$ Millions)	Conventional Fuel Reduction** (\$ Millions)
FFVs	14.67	8,786	\$19,154	\$25,041
FFV Twins	16.14	9,665	\$21,070	\$27,545
Conversions	46.94	28,116	\$61,294	\$80,132
Total:	77.75	46,567	\$101,518	\$132,718

*Using wholesale price of \$2.18/gallon of ethanol.

**Using wholesale price of \$2.85/gallon of gasoline.

OVERVIEW

The growing surplus of natural gas and natural gas liquids, combined with new technology to convert natural gas into liquid ethanol or methanol, has created a potential market for non-oil based liquid fuels. A legacy of farm-based policies to encourage corn-based ethanol has created a large segment of vehicles that can now utilize ethanol. Almost all of these vehicles have never actually used a high-ethanol blend (called “E85”), due to mostly market barriers that can now be removed. Natural gas based ethanol can be produced and marketed for less than half the cost of regular unleaded fuel, representing an arbitrage opportunity for investors, and an alternative to high-cost gasoline for many American consumers.

While alternate methods of using natural gas in vehicles have emerged in developing countries, such as compressed natural gas in India and Asia – the US market for CNG is narrow but growing. Ethanol, on the other hand, can be utilized by a large segment of the vehicle fleet today (gasoline). Compared to gasoline, ethanol has a major asset. It contains high levels of octane, leading to improved vehicle performance. The energy content in ethanol is slightly lower than unleaded gasoline, so that more fuel must be injected per mile travelled, which leads to slightly lower mileage. These contradictory attributes have contributed to the confusion over ethanol fuels in the US marketplace. If a low-cost alternative to oil-based fuel would become available and accessible, consumers would begin to consider switching to a low cost option.

Low cost ethanol and methanol is made possible by a new enzyme and chemical technologies that convert natural gas into pure ethanol. According to Coskata and Celanese corporations, the marginal cost of ethanol is reported to be \$1.25 (Coscata) to - \$2.35 (Celanese) per gallon, when natural gas feedstocks are \$4.00 per million British Thermal Units (mmbtu). When blended to create (E85), a common fuel mix consisting of 85 percent ethanol and 15 percent gasoline, the net cost would be approximately \$1.65 per gallon (if the ethanol cost is \$1.50). This is possible because natural gas is currently far less expensive per unit of energy (BTU) than oil (\$4.50/mmbtu for natural gas vs. \$18.20/mmbtu for oil).

Some states are better positioned to leverage NG-based fuels than others. Midwestern states, such as Illinois and Indiana, already have a deep infrastructure for ethanol-based distribution and sale, and the population is more familiar with ethanol liquid fuel, due to legacy corn promotion efforts. However, natural gas supplies that are needed to produce ethanol in the Midwest must compete with utilities for supply.

Gas exporting states, such as Colorado, may be well suited to deploy natural gas-based ethanol fuels, because there is abundant natural gas feedstock, and there is also a high ratio of Flex-Fuel Vehicles (FFVs) per capita, although there are fewer fueling stations than the Midwest. Like other natural gas exporting states, the Colorado governor's office is interested in increasing the use of locally-produced fuels in the state. Ethanol is considered to be a clean fuel compared to unleaded gasoline, with 20%–30% lower tailpipe emissions. Tailpipe (local) emissions for newer vehicles (post 2012) lower for either fuel, due to more stringent EPA standards and to newer technology.

In order to quantify the demand for E85 in different regions of the country, relative price is paramount. However, even if prices are low, total demand is capped by the number of vehicles that can utilize E85, and the number of fueling stations that can dispense it. In this report, each region's stock of FFVs, and E85 dispensing stations is compared, and the potential demand is computed using the relative prices between E85 and unleaded gasoline. In addition to the present stock of FFVs in the US (there are approximately 14.7 million), there also exist a similar number of so-called "FFV Twins". These are identical make and model versions as the FFVs but they are not branded as FFVs. Respected technicians in Denver and Los Angeles have shown that so far – all FFV twins can be converted without any mechanical changes, simply by enabling the "flex fuel" intake programming within the onboard computer. A full study regarding on E85 conversions is listed in the references.

Table 2: Summary Statistics: Regional and National Potential Demand for Natural-Gas Based Liquid Fuels (E85 and Similar)

Region	Number of Flex-Fuel Vehicles by Region			Maximum Potential Fuel Demand (Millions of Gallons Per Year)		
	Population (Millions)	FFVs	FFVs Per Capita	FFVs	FFV + Twins	FFV + Twins + Conversions
Central	25.1	1,560,000	6.22%	934.3	1,962.1	4,952.0
Southwest	39.5	2,755,000	6.97%	1,650.1	3,465.1	8,745.3
Southeast	62.4	2,975,000	4.77%	1,781.8	3,741.8	9,443.7
Northeast	73.2	2,575,000	3.52%	1,542.3	3,238.7	8,173.9
Midwest	51.9	3,200,000	6.16%	1,916.6	4,024.8	10,157.9
West	61.9	1,605,000	2.59%	961.3	2,018.7	5,094.8
Total FFVs:	314.0	14,670,000	4.67%	8,786.4	18,451.2	46,567.6
Twins:		16,100,000	5.13%			
Conversions:		46,900,000	14.94%			

Source: (US Census Est. for 2014, and Ford Motor Company FFV rolling stock, authors’ calculations. Twins & Conversions extrapolated from R.L. Polk Data.

INTRODUCTION TO ETHANOL

As noted earlier, ethanol is an alcohol fuel that has higher octane, but slightly lower energy content than conventional gasoline. Vehicles that use fuels with a high ratio of ethanol are tuned to use a slightly higher fuel to air ratio than when burning pure gasoline, or a 90%/10% gasoline/ethanol mix. Ethanol has a much higher octane rating – higher than premium unleaded gasoline, so vehicles perform better using a high ethanol mix. However, more fuel is needed per mile. By optimizing for E85 octane levels, fuel economy falls less than the BTU difference would suggest.

Table 3: Comparative Energy Content by Fuel Type

Fuel Name:	Basic Ethanol Statistics		Octane:	BTU / Gallon
	Blend:			
	Ethanol	Gasoline		
E10	10%	90%	85–87	111,000
E85	85%	15%	105–108	81,800
Gasoline	0%	100%	85	114,000
Premium Unleaded	5%	95%	92	111,250

In 2012, 13.3 billion gallons of ethanol were produced in the United States and 12.95 billion gallons were consumed. About 96% of ethanol consumption was due to a fuel-blending mandate, where gasoline must be mixed with 10% ethanol and sold as “regular unleaded” around the country. The remaining 4% is either used by the industrial sector or is exported.

Less than 0.5% of ethanol is consumed in the form of E85. Due to the E10 mandate, ethanol production has grown from 750 million gallons in 1990, to 13.3 billion gallons in 2012. The near term potential market for E85, if attractively priced, is over 45 billion gallons, or \$67.5 billion, at \$1.50 per gallon (at the wholesale price). These E85 purchases replace \$128.25 billion dollars of gasoline (at wholesale prices of \$2.85). Long term growth is greater, if existing vehicles choose to convert, and if a larger share of new-vintage vehicles are sold as FFVs for example, 25% of new-vintage vehicles are FFVs, and if 1.5% of the existing fleet converts to use ethanol blends, the potential demand would increase by \$6.513 billion, or 9.6% per year.

MARKET FOR NATURAL GAS ETHANOL – FLEX FUEL VEHICLES

Flex Fuel Vehicles (FFVs) can use any mix of ethanol and gasoline. More than 15 million FFVs have been sold in the US since 2000. Approximately 16.6% of new vintage sales are FFVs, and about 5% of all vehicles are FFVs. Most owners are unaware that their vehicle can use E85. A survey from 2005 found that 68% of FFV owners were not aware their vehicle was an FFV.¹ Conversations with a diverse group of owners in both Colorado and California suggest that a similarly large percentage of owners continue to lack knowledge that their vehicle is an FFV. Most of the FFVs are produced due to a credit under the CAFE standard, so that manufacturers can meet their requirements while still selling larger SUVs and trucks.

At the manufacturing facility, the cost of an FFV enhancement is \$70–\$100 according to manufacturer data. Most of this cost is associated with additional certification and branding, rather than equipment costs.

Table 4: Evolution of Flex Fuel Vehicles in the United States

Year	Light-Duty E85 FFVs Sold (Each Year)	Net annual increase	Total Fleet
1998	216,165	144,000	144,000
2005	735,693	683,217	4,117,109
2006	1,011,399	960,287	5,077,396
2010	1,484,945	N/A	N/A
2011	2,116,273	N/A	N/A
2012	2,466,743	N/A	N/A
2013		N/A	14,600,000
Total**	15,113,909	N/A	N/A

*Net increase is new FFVs manufactured discounted by the survival rate.

**Includes years not shown.

Source: National Renewable Energy Laboratory.

using conventional gasoline. The corresponding E85 rating is 14/20. If the vehicle has a small tank, such as an 11-gallon tank, then city driving range is reduced from 209 miles (gasoline)

An FFV with an average 25 miles per gallon (MPG) rating will attain a 40 mpg rating under the CAFE rules, so manufacturers produce FFVs to maintain their CAFE fleet averages. The CAFE credit expires in 2016, but manufacturers are expected to continue producing FFVs due to the low cost and renewed government interest in alternative fuels.

Again, fuel economy is lower for FFVs using E85. For example, the 2014 Dodge Avenger SXT, a mid-sized passenger FFV, is rated at 19/27 miles per gallon

¹ See Goettemoeller, Jeffrey; Adrian Goettemoeller (2007). Sustainable Ethanol: Biofuels, Biorefineries, Cellulosic Biomass, Flex-Fuel Vehicles, and Sustainable Farming for Energy Independence. Prairie Oak Publishing, Maryville, Missouri. pp. 56–61.

to 154 miles (E85). Up until now, most FFVs tend to be larger vehicles, with larger fuel tanks. Third-party researchers have found that actual vehicle mileage may be better than official EPA ratings.²

In its latest energy forecast report, the EIA believes that FFV production and penetration will continue to grow over the coming 25 years. In the agency's *Annual Energy Outlook [AEO]: 2014* (pre-release), the forecast for FFVs was increased from 7% of overall vehicle sales by 2040 to 11%. Of course, this forecast does not consider the possibility of a low-cost, natural gas-based ethanol supply. Such a supply has the potential to significantly change AEO forecast estimates in the future.

FFV Twins

In addition to conventional FFVs, there are so-called FFV twins. These are vehicles that are identical to existing FFVs, but are not branded as such. For example, there were 38,011 Chevrolet Silverado brand vehicles registered in Colorado as "gasoline" in 2012, but they are identical to 16,041 Silverados that are categorized as "Dual Fuel" in the same state. In all, there were 222,180 twins registered in Colorado that could potentially utilize E85 with no modification at all, or that require a check-box change to allow for E85 fuel-use profiles. The ratio of Twins to FFVs across four states is between 0.9 – 1.3, meaning that for every FFV there were 0.9-1.3 FFV twins. A ratio of 1.1 was used to derive the estimated 16.2 million FFV twins nationwide.

FFV Conversions

Conventional cars cannot legally use ethanol, but if E85 prices are sufficiently attractive, owners of conventional vehicles may be willing to pay for a "conversion" that allows their vehicle to use an ethanol blend for motor fuel. A large segment of the US vehicle fleet can be converted for a modest price (\$150–\$250), assuming the EPA approves the process and relevant products.

Testing has been applied to selected models of conventional fuel vehicles, primarily vehicles produced by General Motors between 2004 and 2010. Those models can be re-programmed with the proper spark timing and air-flow profiles to use E85 with a software update. Two vehicles that received extensive testing were the 2007 Chevrolet Cobalt, and the 2007 Chevrolet HHR LS. Over 13.9 million GM vehicles were sold in the United States that use the E37, E38, or E67 processors, all of which could be converted using a software change only.

In all, we estimate that 46.9 million light duty vehicles can be converted to FFVs for a cost between \$150–250 each. This represents 19.2% of the national rolling fleet of vehicles.

It should be noted that most newer-model vehicles can only be converted if the mechanic has appropriate encryption keys that will unlock the software. Most late-model vehicle software has been significantly upgraded by the manufacturers, and decryption for some vehicle models could be a problem.

² Some groups argue that the EPA official E85 fuel economy ratings are not accurate. These parties claim that actual fuel economy is higher if vehicles are optimized for E85 consumption. Current required testing protocols optimize for pure gasoline, even when using E85 fuel. Tests have shown that mileage can reach 95% of gasoline mileage, in properly tuned vehicles.

MODELING POTENTIAL E85 DEMAND

A demand model for E85 was developed to identify volume of E85 demanded at different E85 price points. The model includes only the key aspects of E85 that differentiate it from unleaded gasoline: energy content, and relative price.³

An FFV can travel 17% further by purchasing a gallon of gasoline compared to a gallon of E85. This sets a “reservation price” for E85 about 14% lower than gasoline.⁴ Any price above the reservation price, and demand would be zero.⁵ Equation 1 shows the base demand model mathematically:

$$D(\text{FFV}, p) = \text{FFV} * \frac{\text{VHD}}{\text{MPGe}} * \left[D_{\text{min}} + \left(\frac{\Delta p}{\bar{p}} \right)^\sigma \right] \quad (1)$$

In the first half of equation (1), the demand for E85, in millions of gallons, is a function of the number of FFVs in the US, the average number of miles driven per year, and the average MPG rating using E85 (the manufacturer mpg never represents true road condition – it is usually lower). These inputs determine the maximum potential demand for E85 in a given year. The second half of equation (1), the actual demand is scaled by the potential demand function, which depends upon relative prices between E85 and unleaded gasoline.

Potential Demand Curve

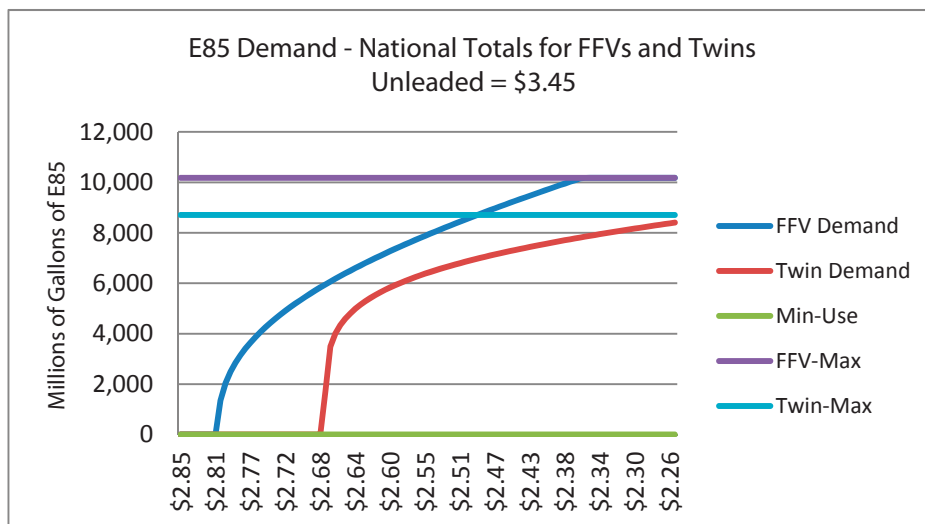
If the relevant estimates are inserted into Equation 1, then the relative price range that entices FFV drivers to purchase and use more E85 over time can be identified. This E85 demand curve for the US is presented in Figure 1.

³ Additional attributes can be included into a refined version, such as pump distance, signage, and E85 familiarity. Adding these attributes would provide a richer depiction of E85 demand structure.

⁴ For example, a vehicle with 23.5 mpg rating using E10 would, on average, have a 20.0 mpg rating using E85. If fuel prices were \$3.50 per gallon, then the equivalent cost per mile using E85 is \$2.99. The E85 reservation price of \$2.99 is then \$0.51 or 14.3% lower than the gasoline price of \$3.50.

⁵ There is a minimum demand for E85, due to government mandated fleets. Most states and the federal government require fleets to purchase E85 if it is 10% above gasoline prices or less, and if a pump is within 5 miles.

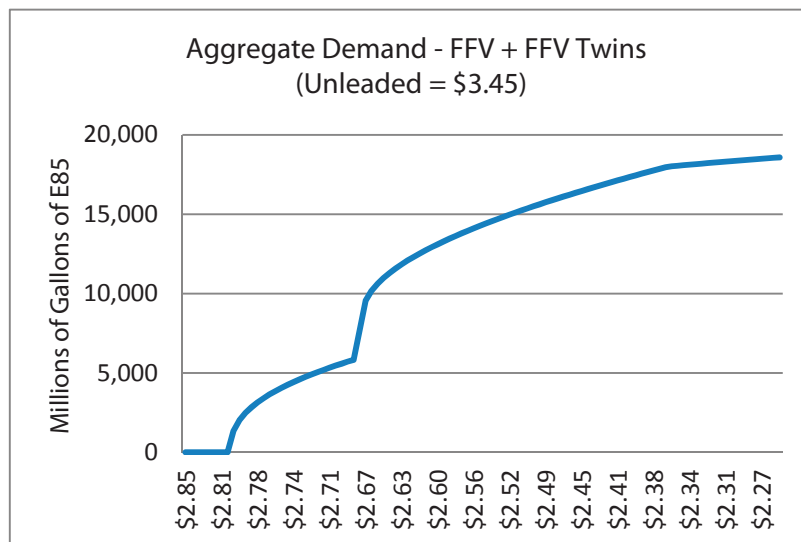
Figure 1: Potential Demand Curve: The Volume of E85 Demanded in Colorado when E85 is Competitively Priced



Source: Authors’ calculations based on business as usual (BaU) assumptions regarding FFV fleet, fuel efficiency, and elasticity of substitution. Pump distance and availability are not part of the calculations in this chart.

This curve shows that E85 demand is equal to the minimum mandated fleet demand until the average price of E85 is 18%⁶ lower than gasoline, but it then rises quickly to more than 4 Billion gallons as FFV consumers shift toward E85. Another 4 Billion is demanded by FFV Twins, for a slightly higher price spread. This demand continues to grow, but more slowly as the price difference grows.

Figure 2: Aggregate Demand Curve for FFV and FFV Twins in the United States

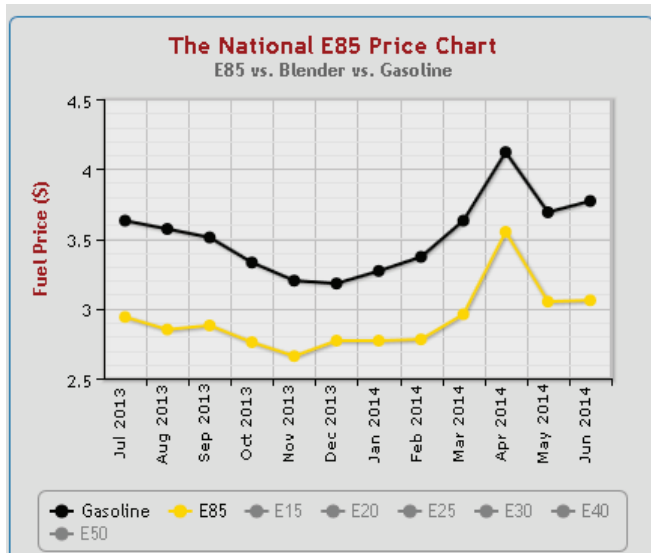


⁶ The 18% price difference in the model combines the 14% price difference due to fuel efficiency, plus a static 4% price difference to capture non-financial consumer aspects, such as distance to E85 pumps and unfamiliarity with E85 fuels.

E85 PRICING AND DISTRIBUTION

E85 PRICING

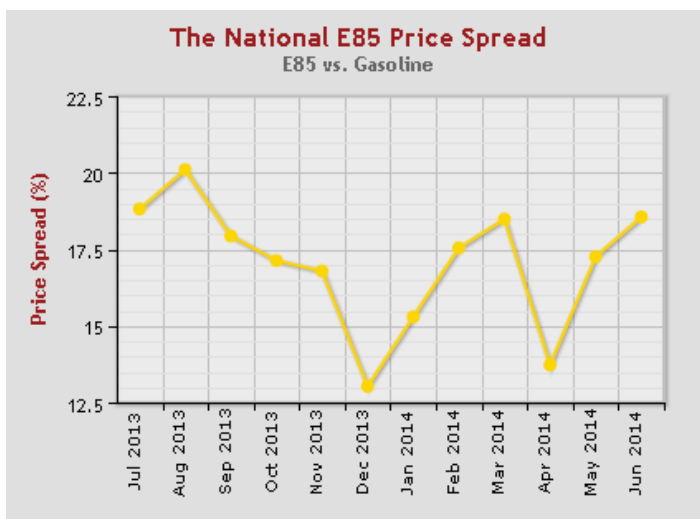
Figure 3 : E85 and Conventional Gasoline Prices over the Past Year (2013/14, \$/Gallon)



Source: <http://e85prices.com>.

they use different feedstocks. But Figure 3 shows a clear trend, where ethanol prices generally follow gasoline. It is possible that fuel distributors are choosing E85 prices based upon gasoline prices, in order to maximize profits. The optimal spread between fuel types may be larger under different conditions, such as when large supplies of low-cost ethanol are available.

Figure 4: Average Price Differential Between Conventional Gasoline and E85 in 2013/2014 (% of Gasoline Price)



Source: <http://e85prices.com>.

E85 has 26% less energy content than unleaded, lowering the miles per gallon by approximately 14%, depending upon how the vehicle is tuned. Therefore, consumers will not purchase E85 unless it costs at least 14% less than gasoline. Crowd-sourced price aggregation websites, such as E85Prices.com, indicate that national E85 prices were 18.4% lower than gasoline prices in May, 2014. The national average E85 cost \$3.08 per gallon, whereas unleaded cost \$3.78 per gallon during this month.

The price spread is different for each state. The spread is larger in corn-producing states and smaller in oil-producing states.

There is no reason why ethanol and gasoline prices should move in tandem, since

In August 2013, the price spread was highest, at 20.5% per gallon. This occurred during the peak summer fuel season. The price spread was lowest in December, during the winter when average gasoline prices are lower. The small price spread in April 2014 was caused by a spike in ethanol prices, due to rail-car shortages that limited distribution of ethanol between producers and blending stations.

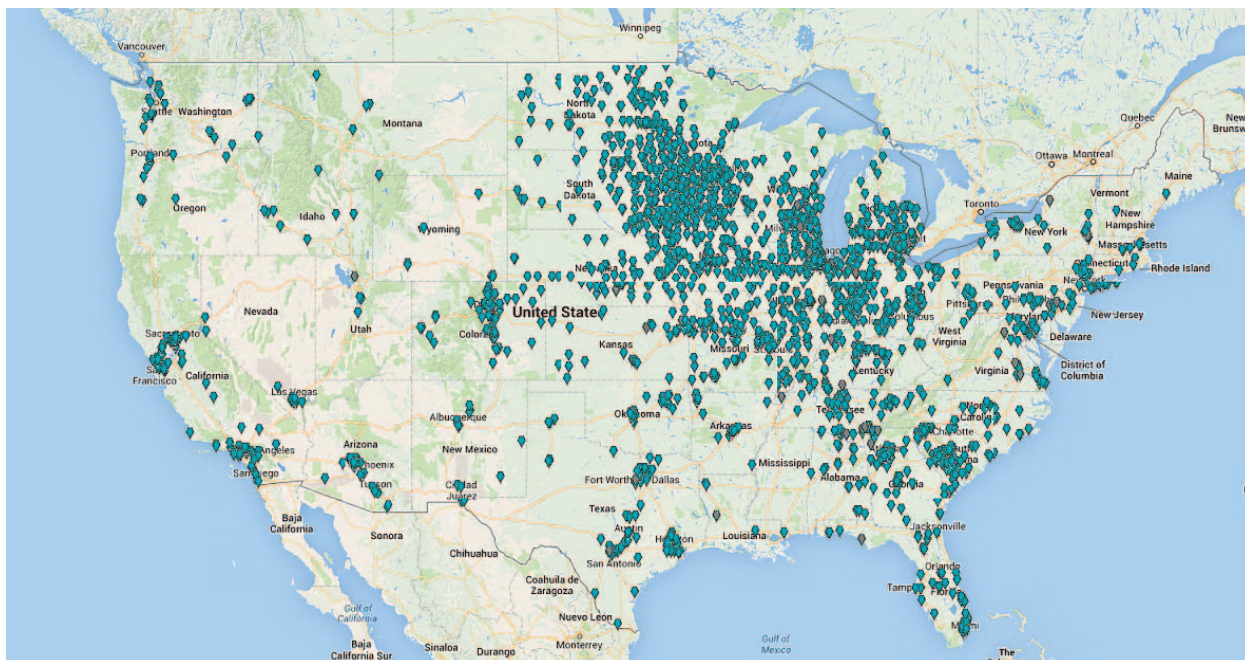
E85 DISTRIBUTION

E85 Fueling Stations

According to the U.S. Department of Energy’s Alternative Fuels Data Center (AFDC), there are currently 2,394 fueling stations in the United States that can dispense E85 ethanol, and according to

the crowd-sourcing website called e85prices.com, there were 2,678 fueling stations in May, 2014. By far, the majority of stations are located in the Midwest, near to the ethanol production facilities

Figure 5: Ethanol Fueling Stations in the United States



Source: U.S. Department of Energy, Alternative Fuels Data Center. <http://www.afdc.energy.gov/locator/stations> accessed on June 3, 2014.

Certain convenience store chains, such as *Western Convenience*, based in Denver, Colorado have included E85 fueling options at every store location as a policy.

E85 PRODUCTION FROM NATURAL GAS

This section considers the cost of natural gas-based ethanol production. A production facility would be designed to convert natural gas into ethanol and then blended with gasoline to produce E85 for sale as motor fuel, or to be sold to other customers outside of the state. Comparative capital and unit costs are presented below for alternative liquid fuel technologies.

Table 5: Indicative Capital and Operating Costs for Ethanol Systems versus LNG

Technology	Capital Investment (\$ Mil.)	Capital Investment (per MT product)	Revenue (per MT)	Operating Cost (per MT)	Margin (per MT)	ROIC
Enzyme Ethanol	\$650	\$1,128	\$830	\$313	\$517	46%
Enzyme Methanol	\$800	\$800	\$450	\$210	\$240	30%
Celanese TCX®	\$2,500	\$2,273	\$830	\$498	\$332	15%
LNG	\$12,000	\$2,000	\$832	\$546	\$286	14%

Notes: MT = metric ton. Source: Enzyme: Costkata corporation; LNG: Platts & CB&I; TCX: Celanese Indonesian coal to ethanol facility. Information is proprietary to Costkata Corp.

The marginal cost of production for natural gas-based ethanol is a straightforward calculation. The capital cost of an ethanol production facility depends upon the cost of site procurement and construction of the facility. Marginal cost depends almost entirely upon the price of the natural gas feedstock. Two major companies have access to natural gas conversion technology today, Coskata, Inc., a privately-held Illinois-based energy corporation, and the Celanese Corporation, a large publically-held company based in Texas. Each firm uses a slightly different production technology, but both firms have detailed cost estimates of full-scale facility construction costs and per-unit production costs, based upon the input price of natural gas.

The Celanese Corporation has provided an estimate for the marginal cost of producing ethanol by using its TCX process. The cost depends primarily upon the price of the natural gas as a feedstock (denoted below in dollars per thousand cubic feet [mcf]):

$$\text{TCX ethanol cost (\$/gal)} = 1.2691 + 0.1367 * \text{NG price (\$/mcf)}^7$$

The cost function applies to a plant producing 380 million gallons of ethanol per year, enough to supply E85 fuel to about 290,000 FFVs for a year, assuming 100% reliance on E85.

Table 6 shows a list of ethanol output prices using the TCX process as it relates to natural gas, and a list of gasoline prices as it relates to crude oil. The price of ethanol appears to be less sensitive to natural gas than gasoline is to crude oil pricing. A 75% increase in natural gas prices (from \$3.58 to \$6.29) causes a 21.6% increase in ethanol prices, whereas a 46% increase in crude oil prices causes a 24% increase in gasoline prices.

Table 6 : Wholesale Fuel Cost Projections for Ethanol Using the TCX Process, And Gasoline Using Petroleum (2012–2030)

Year	Natural Gas Based Fuel		Petroleum Based Fuel		Difference (\$/gge)
	NG price (\$/million Btu)	TCX ethanol cost (\$/gge)	Average crude oil price (\$/bbl)	Gasoline wholesale prices (\$/gal)	
2012	3.58	\$2.31	94.73	\$2.78	\$0.47
2015	4.29	2.44	116.91	3.02	\$0.58
2020	4.58	2.49	126.68	3.19	\$0.70
2025	5.63	2.68	132.56	3.34	\$0.66
2030	6.29	2.80	138.49	3.45	\$0.65

Source: RFF Report on Alternative Fuels, Table 2.3, page 12.

Notes: All prices are in 2010 dollars per unit.⁸

Coskata has reported production costs that are even lower than reported by Celanese Corporation. For example, Coskata has indicated (informally) that their enzyme-based ethanol process would yield one gallon of ethanol for a cost of \$1.25, if the natural gas feedstock price is

⁷ For a full functional description of the TCX cost, see Resources for the Future (RFF), *Cheaper Fuels for the Light Duty Fleet*, Working Paper, 2013, page 9.

⁸ Citation below will be updated by using the RFF revised report version from January 2014, which includes a discussion of the Coskata process and costs. <http://www.rff.org/Publications/Pages/PublicationDetails.aspx?PublicationID=22250>.

\$4.00/mmbtu. This is much lower than the TCX process estimate of \$2.44 per gallon of ethanol when natural gas prices are \$4.29/mmbtu, as shown in Table 6.

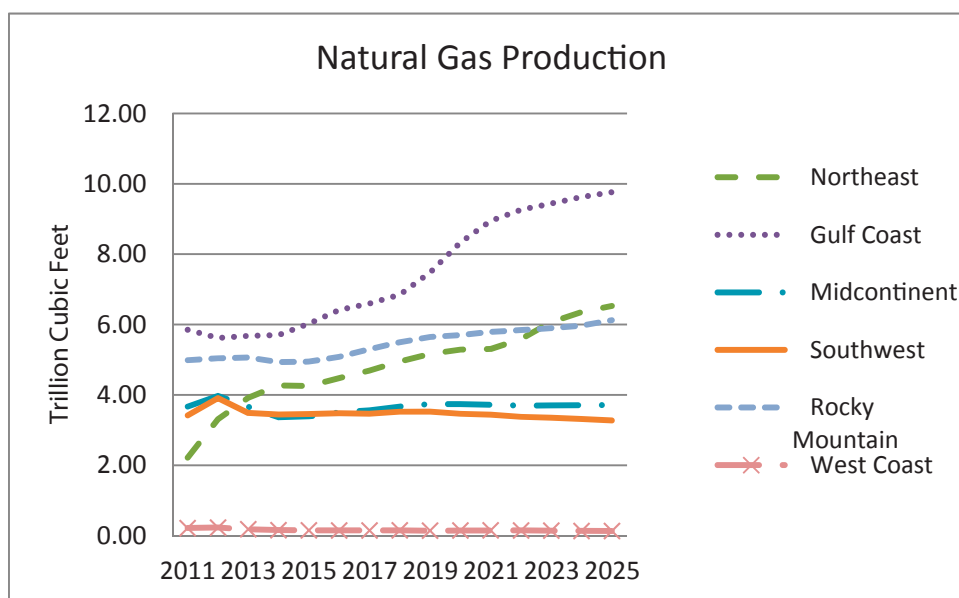
An important consideration for the production of ethanol is the forward market price for ethanol traded on futures exchanges. Although natural gas based ethanol does not qualify as a renewable fuel, the sales price of ethanol can be seen on futures market exchanges.

Transportation Costs: Most ethanol production is expected to reside relatively near existing wellheads if possible. A key variable that will be important to developers will be locations also near population areas. Colorado is a good example of where both objectives can be met, particularly in the front range of the state.

NATURAL GAS SUPPLY AND AVAILABILITY

The supply of natural gas in the United States is expected to remain high and prices are expected to remain low for the foreseeable future. The US Energy Information Agency is considered the best publically-available forecast for long-term energy prices and demand. According to the Annual Energy Outlook, natural gas prices will slowly increase, from \$4.15/mmbtu.

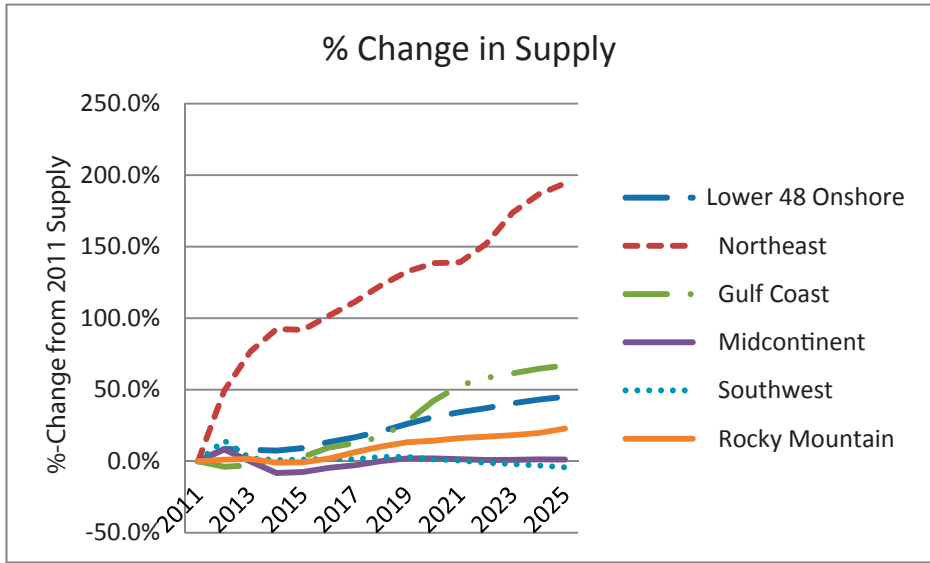
Figure 6: Natural Gas Production by Region



The AEO 2014 forecast, as it relates to natural gas and ethanol supply, demand, and price, is summarized in Figure 7 below. Gulf Coast output will continue climbing, and Rocky Mountain output remains high. The largest increase will come from the Marcellus shale reserve in Pennsylvania, which is expected to increase natural gas production in the region by 100% by 2016, and by 200% by 2025, according to the US Energy Information Agency.

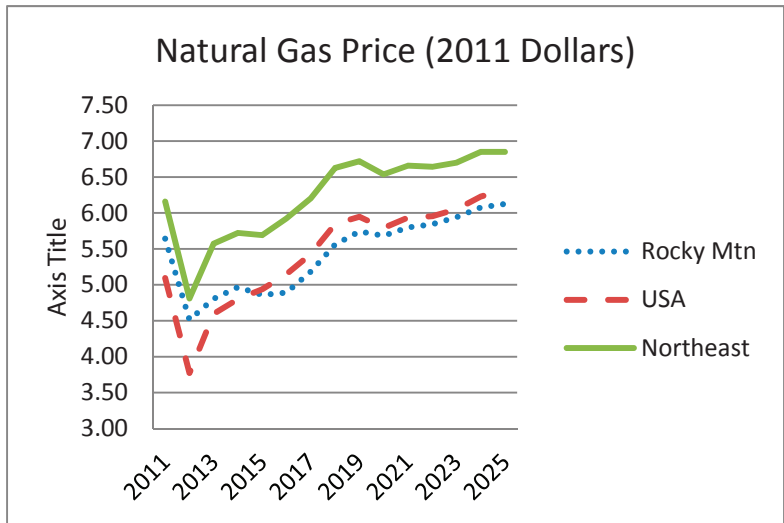
The figure can also be viewed in percentage terms.

Figure 7: Natural Gas Production Forecast – Percentage Change from 2011 by Region



Prices in the Rocky Mountain region are inexorably linked to Henry Hub prices and national demand. However, due to high levels of production and occasional limited gas pipeline capacity, prices in the Rocky Mountain region are often lower than in the East and West coasts, where demand is much higher than supply.

Figure 8: Natural Gas Price Forecast for Industrial Supplies – 2011 to 2025 in Real 2011 Dollars



Source: EIA, Annual Energy Outlook, Reference Case, 2014. Supplemental Tables 13, 15, 10.

Based upon the EIA forecast, an industrial user in the Rocky Mountain region can expect long-term natural gas prices to lie between \$4.00 per mmbtu and \$6.10/mmbtu in 2024. This represents an average delivered price of \$5.00/mmbtu.

ENVIRONMENTAL CONSIDERATIONS

When vehicles use E85 as their primary fuel, there are environmental benefits. Tailpipe emissions are generally lower for E85 than gasoline, especially in older-vintage vehicles. Using a 2008 model passenger vehicle, Yanowitz and McCormick found emissions of key particulates and volatile organic compounds were reduced between 20%–36%. Total nitrogen oxides (NO_x) declined by approximately 20%, particulate matter (PM_{2.5} and PM₁₀) declined by 35%, carbon monoxide (CO) declined by 20%.

Table 7: Estimated Emissions Benefits of E85 Use in Colorado FFVs

Pollutant	Vehicle Type	Tailpipe Emissions: Gasoline vs. E85			
		Grams per mile			
		Gasoline	E85	Difference	%
CO	Passenger car	9.4000	7.5200	1.8800	20%
	Truck	11.8400	9.4720	2.3680	20%
NO _x	Passenger car	0.6930	0.5613	0.1317	19%
	Truck	0.9500	0.7695	0.1805	19%
PM _{2.5}	Passenger car	0.0044	0.0029	0.0015	34%
	Truck	0.0049	0.0032	0.0017	35%
PM ₁₀	Passenger car	0.0041	0.0027	0.0014	34%
	Truck	0.0045	0.0029	0.0016	36%

Source: Authors' calculations. Mtons stands for "Metric Tons".

These findings indicate that environmental issues are unlikely to become an impediment to large-scale E85 adoption and that public interest may be served by fuel switching. Potentially large CO₂ benefits emerge when the enzyme production technology is adopted. This occurs because CO₂ is an *input* to the production process, thereby reducing CO₂ emissions. For example, a typical enzyme production facility absorbs approximately 300,000 tons of CO₂ per year, which is enough CO₂ to offset a 40 megawatt coal-fired power plant. Colorado's new commission regulations will also reduce problems related to flaring and methane/ethanol emissions.

OBSTACLES AND OPPORTUNITIES – A SUMMARY

As indicated earlier, there exist obstacles to deployment of natural gas liquid fuels – as is common with new and disruptive technologies. On the consumer side, unfamiliarity with ethanol fuels suggest that adoption rates will require some time and consumer education. Access in ethanol to E85 stations currently is not a major limitation. However, easy access to fuel stations to consumers in most states is difficult given the relatively small number of stations. Large-scale adoption will require expansion of current supply networks. Finally, pricing at the pump is the most important determinant for adoption of an alternative fuel type. A low-price fuel marketing strategy over a long and continuous period will help consumers identify their options more clearly. From the viewpoint of the retailers and distributors, if E85 fuel prices are low enough, then fueling franchises and convenience stores will be eager to add ethanol pumps in order to attract new customers, which then converts price-point challenges into an opportunity for infrastructure developers and marketers.

As discussed earlier, several ancillary opportunities exist along the market supply chain. For natural gas liquid fuels, this supply chain includes the following areas:

- Feedstock supply: marketing and transport of natural gas feedstocks to ethanol producers as an alternative to corn or oil.
- Oil and Gas Well Upgrades: development and installation of gas and ethane capture technology onto oil-wells, as part of new state air quality requirements. For example, as of 2014, Colorado State requires ethane and natural gas capture, instead of gas flaring.
- Ethanol production facility development: construction and development of medium-scale facilities for enzyme or chemical based production of ethanol liquid fuels
- Fuel Blending and distribution: install and upgrade fuel retailers for ethanol sale, as low-cost fuel is utilized by convenience stores as a loss-leader for high margin concessions. Big box stores are adding fuel stations for product bundling.
- Vehicle upgrades and conversions: deploy conversion techniques and software upgrades nationally to dealers and repair shops.

To summarize, the advent of large-scale natural gas supply is introducing new arbitrage opportunities in the United States transportation market. Energy arbitrage between oil and natural gas liquids appears to be a more direct method compared to other natural gas arbitrage efforts, such as LNG exports or CNG deployment. Among various liquid fuels, ethanol has the highest near-term potential demand.

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3. Nebraska Energy Office, Ethanol Division: <http://www.neo.ne.gov/statshtml/122.htm>
4. EIA Office of Alternative Fuels:
5. National Renewable Energy Laboratories – Alternative Fuels Division: <http://www.afdc.energy.gov/data/>
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STATE INCENTIVES TO PROMOTE ALTERNATIVE FUEL USE

- Alternative Fuel, Advanced Vehicle, and Idle Reduction Technology Tax Credit (<http://www.afdc.energy.gov/laws/law/CO/5246>)
- Plug-in Electric Vehicle (PEV) and Electric Vehicle Supply Equipment (EVSE) Grants (<http://www.afdc.energy.gov/laws/law/CO/6578>)
- Biofuels Research Grants (<http://www.afdc.energy.gov/laws/law/CO/6290>)
- Ethanol Infrastructure Grants (<http://www.afdc.energy.gov/laws/law/CO/8740>)
- Low Emission Vehicle (LEV) Sales Tax Exemption (<http://www.afdc.energy.gov/laws/law/CO/202>)
- Hybrid Electric Vehicle (HEV) High Occupancy Vehicle (HOV) Lane Exemption (<http://www.afdc.energy.gov/laws/law/CO/4273>)
- Alternative Fuel Vehicle (AFV) Weight Limit Exemption (<http://www.afdc.energy.gov/laws/law/CO/4272>)
- Natural Gas Fueling Station Air Quality Permit Exemption (<http://www.afdc.energy.gov/laws/law/CO/10572>)

STATE LAWS AND REGULATIONS TO PROMOTE ALTERNATIVE FUELS

- Alternative Fuel and Advanced Vehicle Tax (<http://www.afdc.energy.gov/laws/law/CO/10858>)
- Alternative Fuel Resale and Generation Regulations (<http://www.afdc.energy.gov/laws/law/CO/10014>)
- Alternative Fuel Vehicle (AFV) Registration (<http://www.afdc.energy.gov/laws/law/CO/5887>)
- Promulgation of Renewable Fuel Storage Tank Regulations (<http://www.afdc.energy.gov/laws/law/CO/6293>)
- State Agency Alternative Fuel Use and Vehicle Acquisition Requirement (<http://www.afdc.energy.gov/laws/law/CO/5619>)
- Alternative Fuel Definition (<http://www.afdc.energy.gov/laws/law/CO/6289>)
- Gasoline Gallon Equivalent (GGE) Definition (<http://www.afdc.energy.gov/laws/law/CO/4274>)