goEthane, inc.

Ethane

Low carbon, Low cost, High-performance Transportation Fuel

15 October 2015
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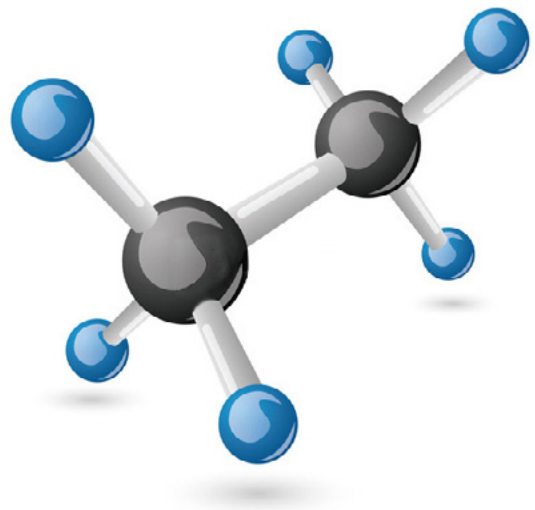

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overview

I. Introduction | The Ethane Truck

II. The Story of Ethane | The Science, The Reality

III. Business Outline & Model | Summary

IV. Why Ethane? | Ethane Can Meet Low Carbon Transportation Fuel Requirements

the ethane truck

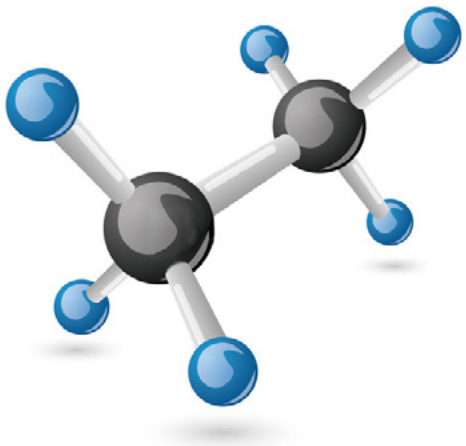
1st vehicle in the world to run on Ethane

the story of ethane

What is Ethane?

- Chemically stable hydrocarbon
- Liquifies when compressed
- Combustion products CO_2 (g), H_2O (l)
- 1° use in manufacture of plastics (ethylene)
- Operates @ lower pressure than CNG

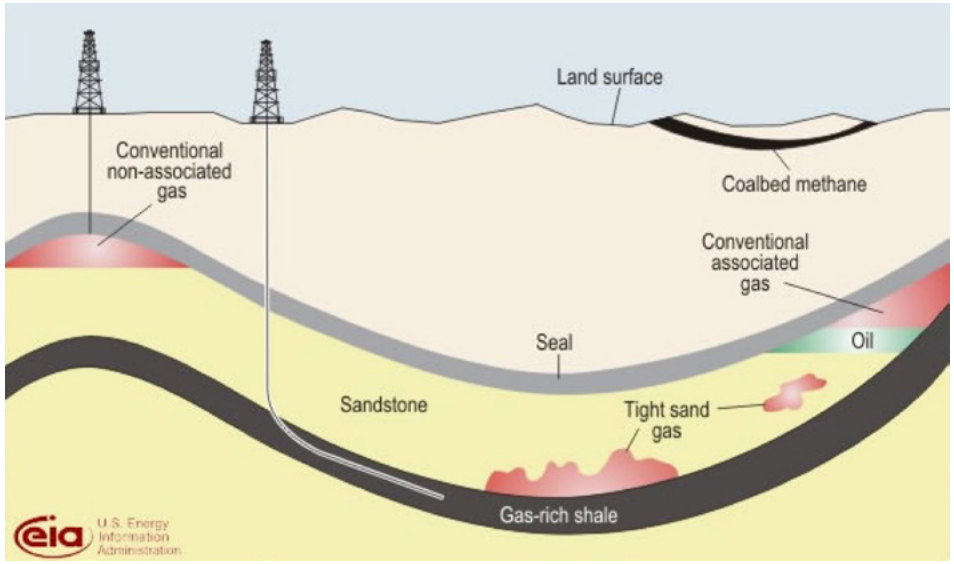
- Less CO_2/mile than gasoline **(cleaner)**
- Residence time in the atmosphere:
  - **C_2H_6 (78 days)**[1]**(greener)**
  - CH_4 (~10 years)
  - CO_2 (100s of years)



the story of ethane

Where is Ethane?

- Shale gas deposits in the USA (largest worldwide)
- Oil refineries (off-gas, re-injected, used in boilers)
- NG well heads (unprocessed)



the story of ethane

Why use Ethane?

- Alternative transportation fuel vs. sending offshore (plastics manufacturing)
- Decomposes 'quickly' in the atmosphere compared to CH_4 [1]

↑ Energy independence

business outline

Incorporation

- Incorporated as a C Corporation 05/31/15 in DE

- Three equal shareholders:
  - Dany Gardi, CEO
  - Joe Marcellino, CFO
  - Lindsay Leveen, Chairman

- Kilpatrick Townsend (KT) firm lawyers:
  - Fees deferred; taking 1% stock in the company
  - Filing various patents, trademarks, incorporation services

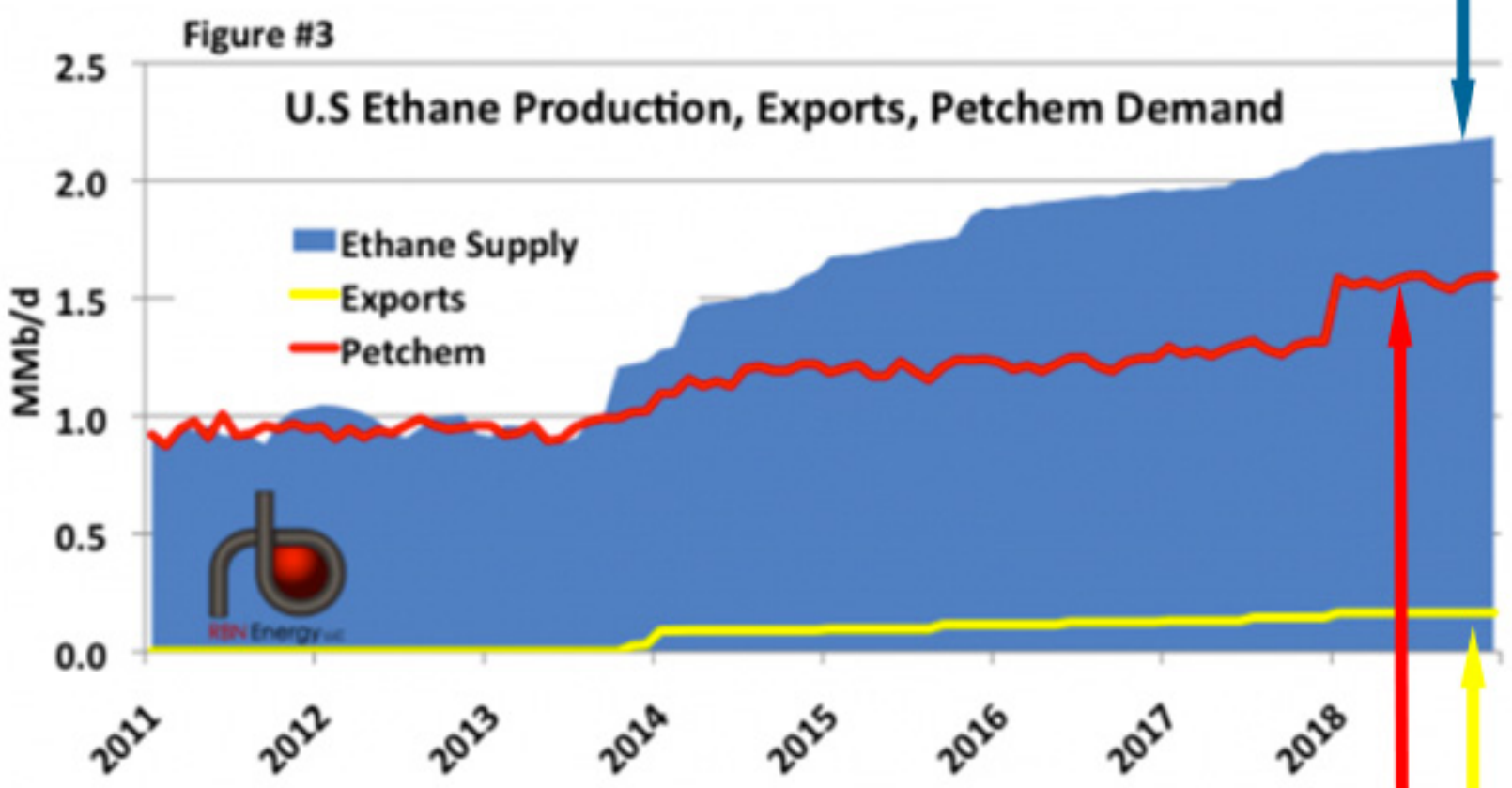
business outline

GoEthane IP

- Hardware IP relates to:
  - Controlling the flow temperature
  - Controlling the pressure of the Ethane entering the engine
- Software IP relates to engine control
- Additional IP relates to the filling of the:
  - Tube trailers for bulk supply
  - Filling of the onboard storage tanks with Ethane

business outline

Ethane Supply Far Exceeds Demand



Sad To Waste Ethane To Make More Plastics

business model

Ethane's Future

- USA Ethane surplus ~500,000 bbl/day next 10+ yrs
- 1.6 bbl ethane == 1 bbl gasoline ~300,000 bbl/day GGE to market
- Petrochemical manufacturing:
  - Uses all the Ethane consumed today
  - Going forward - Cannot grow to consume all the Ethane to be produced
- Exports of Ethane may come about—will not bring demand into balance with supply

business model

Ethane's Value

- **The business:** To use some of the surplus Ethane as a transportation fuel
- The Mt. Belvieu price of Ethane:
  - 19.8¢/gal (today)
  - Futures price in Dec 2019 is <25¢/ gal
- Value of Ethane @ fractionators distant from petrochemical markets:
  - Is below 10¢/gal
  - Ethane is almost worthless in the Bakken Formation

business model

GoEthane will:

- Sell hardware and software to fleet owners at a moderate profit—**The Shaver**
- Make money providing logistics, transporting Ethane from the fractionator to the fleet (high-value add)—**The Blades**
- Have IP protection on vehicle hardware software for Ethane as the fuel

business model

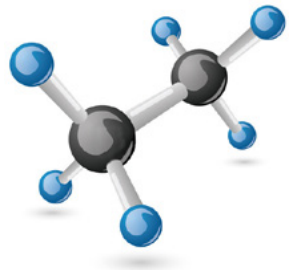
GoEthane will:

- Have IP protection for rapid filling of Ethane:
  - At the fractionator into the bulk truck
  - At the customer site into vehicle fuel tank; rapid refuelling
- GoEthane will be first in class as the logistics company for Ethane
- **GoEthane I The UPS of Ethane**

why ethane? it works well in engines

Ethane (C_2H_6) is a great transportation fuel

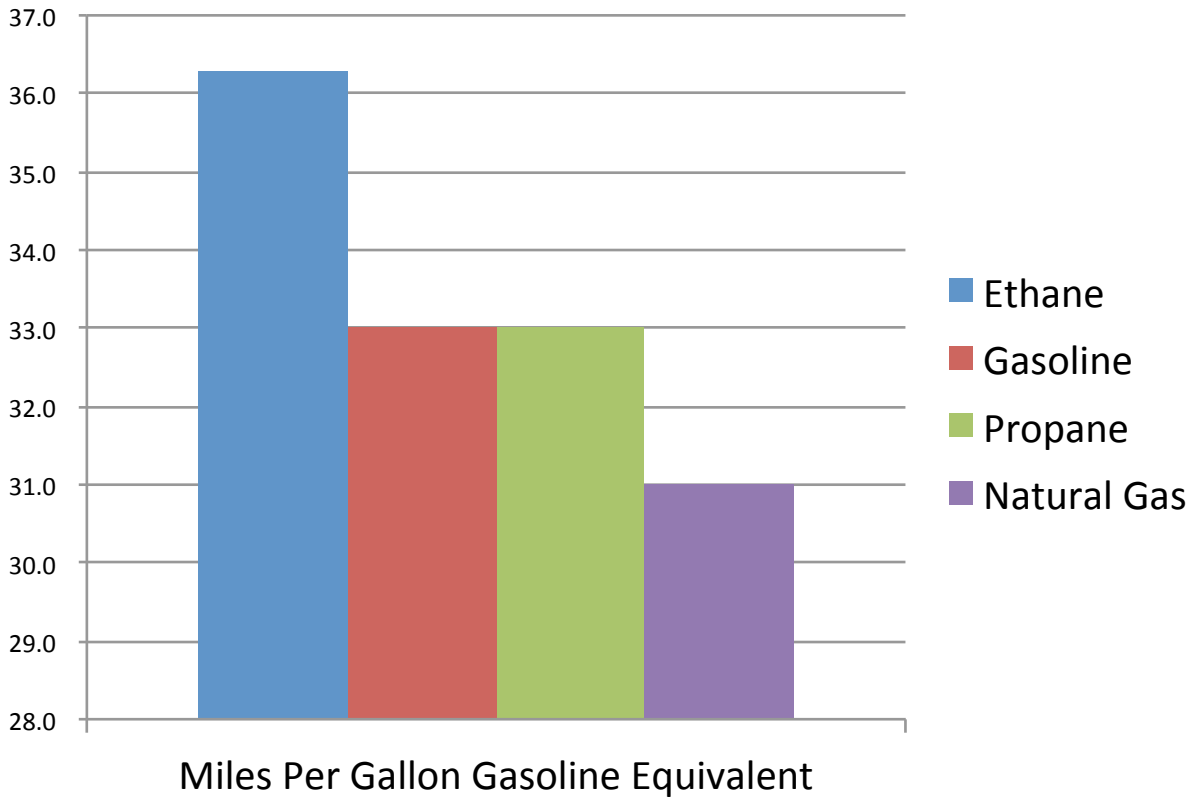
- **1st tests: 9%-17% incr. in miles/GGE vs Gasoline**
- Ethane:
  - Is a high powered fuel, high octane fuel
  - Burns completely in an engine
  - Is superior to propane as a transportation fuel



- CNG (methane):
  - Is a high powered, high octane fuel
  - Does not burn completely in an engine
  - Is not a great fuel in ICEs (much higher activation energy)

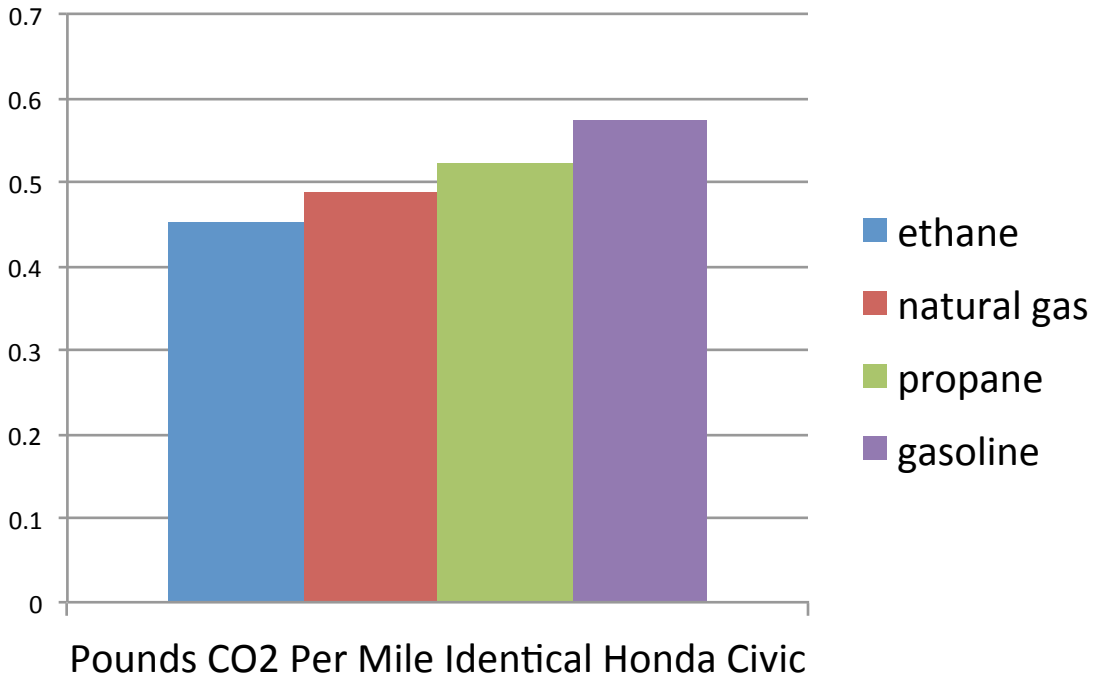
ethane is the best fuel

- More MPGs/GGE (Gasoline Gallon Equivalent)
- Vehicle modeled: Honda Civic (Gasoline or CNG)



ethane is the greenest fuel

- More MPGs/GGE
- Less CO_2/MMBTUs than Gasoline or Propane
- Vehicle modelled: Honda Civic Gasoline or CNG



Note: Data is burning of the fuel only. There is even more pronounced improvement when the supstream carbon footprint is included.

ethane is the low CO_2/mi fuel

Ethane (C_2H_6):

- Is more H_2 rich than Propane (C_3H_8) and Gasoline
- Emits lowest CO_2/mile for the same vehicle, beating:
  - CNG
  - Propane
  - Gasoline
- Nucor Steel Ford F150 On-road Test, Jewett, TX:
  - 31% lower than gasoline in CO_2/mile
  - 1.1 lbs/mile vs 1.6 lbs/mile in the same vehicle, same route, same traffic, same speed, same driver

ethane well-2-wheels CO_2 is low

- Not needed:
  - Refining and chemical processing (unlike Gasoline)
  - Massive energy input for storing (unlike CNG)
    - Ethane @ 600 psi
    - CNG @ 3,500 psi
  - Massive energy to liquefy (unlike LNG)
    - Ethane is a liquid at room temperature and 600 psi
    - LNG is cryogenic
- Simply needs:
  - Fractionation from NG (like Propane)

Upstream carbon footprint is similar to Propane, and lower than Gasoline, CNG, and LNG

low carbon footprint

Table 2. Upstream Emissions Factors (grams per million Btu)*

	CO_2	CH_4	N_2O	TOTAL CO_2 EQUIVALENT
ETHANOL (E85)	-14,409	113	41.0	-387
NATURAL GAS	6,995	317	1.34	16,228
PROPANE	12,867	188	0.26	18,204
GASOLINE	16,010	118	3.95	20,368
COMPRESSED NATURAL GAS	10,985	324	1.40	20,429
DIESEL	18,727	118	0.31	22,104
FUEL OIL	18,727	118	0.31	22,104
ELECTRICITY	182,897	317	2.84	192,523

Ethane

*End-use emissions are based on the lower heating value, density, and weight ratio of carbon atoms per unit volume of each fuel provided in the GREET model software. All carbon is assumed to be released as CO_2.

low NO_x, low HCs

Ethane emissions testing showed:

- Complete combustion of hydrocarbons (HCs)—No methane slip like CNG or LNG
- Very low NO_x
- 86 mg/mile of non-methane HC plus NO_x as required in vehicles (easily achievable)
- No large, nasty organic compounds formed in the Ethane engine—Ethane and other HCs react out in the catalytic converter
- Lowest emissions of all transportation fuels
  - Exception: Hydrogen made from PV energy or wind energy

next steps

On-road testing in California and other states

- Honda CNG Civics running on Ethane to prove improvement over CNG
- Side-by-side test of UPS 'Bread Truck' on Ethane against Gasoline
- Dual fuel with diesel in:
  - Large trucks
  - Locomotives
  - Ferries

citation

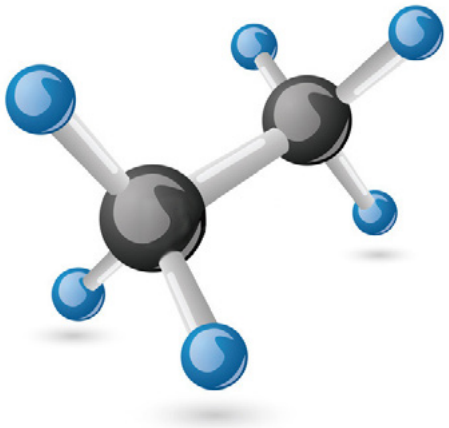
Gain with Ethane.

(1) Handbook of Atmospheric Science: Principles and Applications, pp.93-97, [Online] - [Cited: 12 October 2015] http://www.scribd.com/doc/23585958/Handbook-of-Atmospheric-sciences.

a parting thought

Gain with Ethane.

Ethane (C_2H_6) is a GREAT transportation fuel!



GOETHANE

re power `em

Ethane as a Transportation Fuel Opportunity

Oakland, CA, USA
1 January 2014

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http://www.kimgerly.com/projects/ethane.pdf

re power `em

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Presentation number 01-2014, Oakland, CA, 1 January 2014

introduction

We are at a unique juncture in history where it's time to:

- Become more rational about emotions and values.
- Be more co-collaborators, co-creative partners.
- Be open to shifting our focus to address technologies with multiple applications.
- Become greener using fossil fuels by continuing to use them wisely and appropriately.

timeliness issue

A recent report by the UCS cited nearly 2/3rds of all industrial carbon pollution in the last 150 years can be traced to 90 global actors.

Citation: Who Is Responsible for Climate Change? New Study Identifies the Top 90 Producers of Industrial Carbon Emissions, http://tinyurl.com/lys3orc

public perception

The Chevron Richmond refinery has a challenging history with the City of Richmond, California.

There IS a way Chevron can green its image…

…green Chevron's image without handout of cost, thereby also significantly improving community relations.

a question

Is the Chevron refinery burning ethane to fire boilers?

If so, don't waste the ethane to fuel boilers. Capture the ethane and use it as a transportation fuel.

GreenGas

benefits

Ethane as a transportation fuel

- Reduce CO_2 emissions -> improve health benefits of local, Richmond, CA citizenry.
- Liquefied ethane has more than triple the range of CNG in the same high pressure storage tank.
- Only about 3%-4% of energy is needed to compress ethane.

methane vs ethane

Methane (CH_4)

- Un-reactive
- Combustible
- Cleanest burning fossil fuel
- LNG
- Gaseous unless cooled below -82.6 ^oC[1]

Ethane (C_2H_6)

- Chemically stable
- Combustible
- ‘Clean fuel’
- 2nd NG constituent
- LPG
- Liquefied at normal operating temperature (Many more BTUs are stored in the same high pressure CNG tank.)[1]

methane vs ethane (more)

Methane (CH_4)

- Octane RON 135[2]
- Less CO_2/mile than gasoline
- Combustion products[3]
  - CO2(g), H2O(l), ~890 kJ/mol energy (heat)

Ethane (C_2H_6)

- Octane RON 108[2]
- Less CO_2/mile than gasoline
- Combustion products[3]
  - CO2(g), H2O(l), ~1560 kJ/mol energy (heat)
- Operates at lower pressure than CNG
- Lowest (POCP) for VOCs[4]

Citations: [1]Lindsay Leveen, The Green Machine; [2]Pedro's Garage; [3]WikiPedia; [4] EPA

the proposition

- Pilot project - Start with 100 cars in Richmond fueled by ethane.
- Convert cars and buses in the City of Richmond currently running on CNG (compressed natural gas) to ethane.

a parting thought

Out think the box.
Prepare. Respond. Adapt.

"Compressing it (ethane) and using as a transport fuel is actually even more valuable than cracking it to make ethylene."
–Lindsay Leveen, The Green Machine, Green Explored

Environmental Science & Technology

Viewpoint

pubs.acs.org/est

Ethane as a Cleaner Transportation Fuel

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The recent shale gas revolution has increased the supply of ethane to an unprecedented level. The unexpected surplus of ethane has led to exceedingly low prices and a waste of a resource.

Currently, the principal use for ethane is ethylene production. The surplus of ethane is turning into an excess of ethylene. The recent collapse of oil prices has greatly lowered the costs of petroleum-based ethylene, and limits the demand for ethane from ethylene producers.

A small proportion of ethane may be blended into natural gas, but the heat value specifications limit the amount of ethane allowed. An increasing amount of ethane will likely be flared, which is a controlled burning of the gas only to get rid of it.

Some projections suggest that U.S. ethane production may outgrow demand by hundreds of thousands barrels per day in the coming years.[1] Due to the lack of infrastructure to utilize ethane, it is considered a nuisance in shale gas development.

The physical and chemical properties of ethane make it a good a transportation fuel. For the same volume, ethane carries slightly more energy than liquefied natural gas (LNG), but is free from the evaporation loss problem in cryogenic LNG systems.

The infrastructure required for ethane transportation are similar to those for compressed natural gas (CNG) vehicles, where the same cylinder can carry more than twice amount of energy in ethane than in CNG. A typical welding cylinder designed for CNG with 16.5 MPa pressure rating can hold liquid ethane safely. Even in hot summer days, when the liquid ethane completely evaporates, the pressure will not rise above the pressure rating.

The promotion of natural gas vehicles (NGVs) is faced with several challenges. The CNG vehicles have significantly shorter driving ranges per refill than their gasoline or diesel counterparts. The LNG vehicles have similar driving ranges to the conventional vehicles, but require expensive cryogenic supply chain. Ethane vehicles offer longer driving range than LNG vehicles without cryogenic systems. Utilizing ethane to replace natural gas in transportation could potentially lower the market barriers to a clean alternative fuel and accelerate the adoption of gas vehicles in the United States.

The end-use carbon intensity of ethane fuel is slightly higher than natural gas, but significantly lower than gasoline and diesel.[2] We were unable to locate any assessments on upstream emissions for ethane. However, because ethane is a byproduct in natural gas production, its upstream emissions should be similar to that of natural gas. Figure 1 shows the well-to-wheel carbon intensities for ethane and other major transportation fuels.[3]

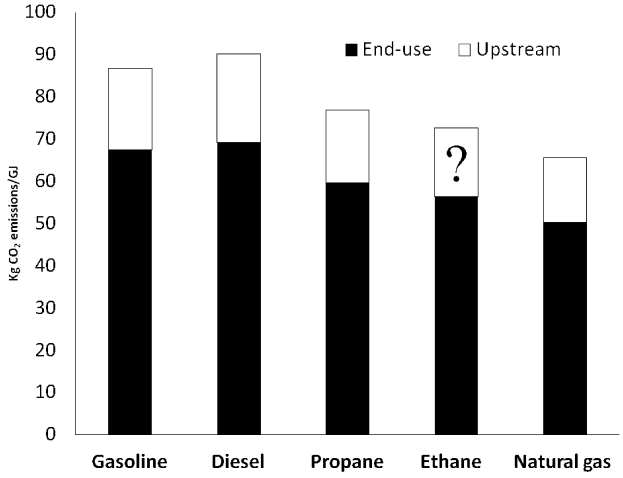

Figure 1. Comparison of well-to-wheel carbon intensities.

If ethane is leaked into the atmosphere, it is oxidized rapidly and leads to creation of ozone and carbon monoxide. The 100-year indirect global warming potential (GWP) is 5.5 for ethane,[4] much lower than the GWP of methane, which is 25. Therefore, in case of leakage, ethane has much lower global warming impact than natural gas.

Research on the emission performance of ethane fuel is extremely rare. A study revealed that the tailpipe emissions from spark-ignited engine with ethane fuel are similar to those with methane.[5]

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Environ. Sci. Technol. XXXX, XXX, XXX−XXX

Compared to gasoline vehicles, NGVs typically emit significantly less volatile organic compounds, particulate matter, and slightly less nitrogen oxide. Because ethane has similar properties with methane and propane, it is reasonable to expect ethane to have similar emissions performance.

The lack of awareness is the major barrier for using ethane as a transportation fuel. Due to this lack of awareness, very few assessments or tests have been conducted on ethane for transportation purposes.

According to the Clean Air Act, U.S. refineries and importers must register their products with the Environmental Protection Agency (EPA) before selling them as a transportation fuel. Until now, ethane has not been registered as a fuel or as a fuel additive. The EPA alternative fuel conversion program also has no certified ethane fuel conversion system. Engineering principals suggest that systems approved for both methane and propane should perform well with ethane. For decades, propane and methane have been promoted as alternative transportation fuels. There is no reason not to include ethane as well.

Converting the existing CNG fleet to utilize ethane may be a practical near-term choice with low capital investment. Over the long-term, if the supply of ethane is sustainable, the ethane fleet may be expanded accordingly. An ethane transportation program in the United States may lead the way for wider adoption of ethane as a cleaner transportation fuel.

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Notes

The authors declare no competing financial interest.

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(2) Voluntary Reporting of Greenhouse Gases Program, U.S. Energy Information Administration. http://www.eia.gov/oiaf/1605/coefficients.html#tbl2.

(3) *The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model*; Argonne National Laboratory: Lemont, IL, 2014.

(4) *Climate Change 2007*; Intergovernmental Panel on Climate Change: Geneva, Switzerland, 2007.

(5) Kaiser, E. W.; et al. Effect of fuel structure on emissions from a spark-ignited engine. *Environ. Sci. Technol.* **1991**, *25*, 2006−2012.

DOI: 10.1021/acs.est.5b00575
Environ. Sci. Technol. XXXX, XXX, XXX−XXX

A Green(er) Story

Ethane as a transporation fuel opportunity

Natural Gas Distribution

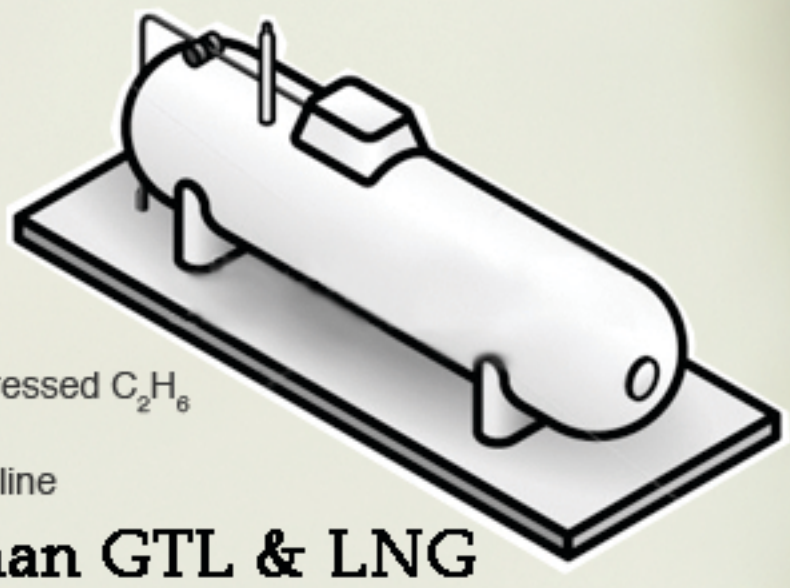
C_2H_6 liquifies when compressed

3%-4% energy required to compress
Critical pressure 48.72 bar (706.6 psi)
Critical temperature 32.17 °C (89.9 °F)
LNG is gaseous unless cooled below -82.6 °C

Driving range not limited

2.5x energy for same volume & mass of storage as CH_4

Gas Vehicle Comparison (BTU/tank)



- 17.5% CNG
- 48.6% Compressed C_2H_6
- 65.4% LNG
- 100.0% Gasoline

Green(er) than GTL & LNG

- 6% less CO_2/mile [cars]
- 7%-8% less CO_2 [boilers]

Less hassle, Less capital intensive to build

- Not cryogenic
- Compression station – 2 months
- Ethane cracker – 4 years

Natural Gas Wells

[Mixed CH_4, C_2H_6, C_3H_8, C_4H_{10}]

CH_4 - Methane
C_2H_6 - Ethane
C_3H_8 - Propane
C_4H_{10} - Butane

Separation & Processing

Compression Station

RECOVERY

[Two Pathways]

Pathway 1

Natural Gas to Pipeline

OR

Flaring

OR

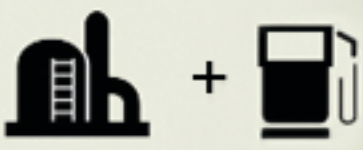
Reinjection

Pathway 2 .. C_2H_6 ..

Compress liquid in bulk tankers

NB: Current market is the petrochemical industry

Storage Tank



Delivery Truck Depot

200 trucks/depot x 40 depots = 8,000 trucks
10,000,000 gal/month
$140mil Gross Margin

OR

C_3H_8 C_4H_{10}

Market

Sources: Lindsay Leveen, The Green Machine