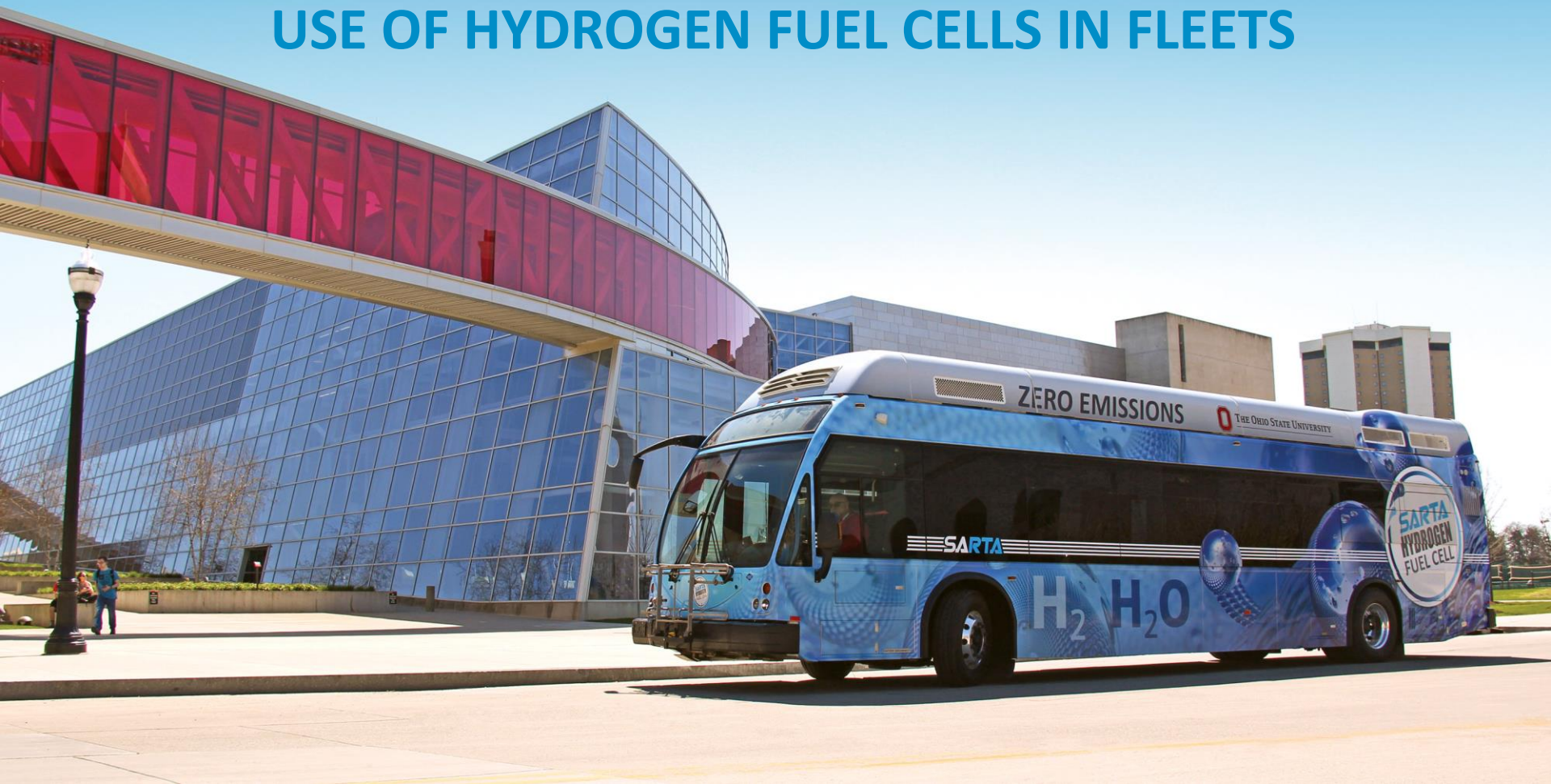
RENEWABLE
HYDROGEN
FUEL CELL
COLLABORATIVE

2017 OHIO FREIGHT CONFERENCE
USE OF HYDROGEN FUEL CELLS IN FLEETS



Introduction to Hydrogen Fuel Cells

- The Renewable Hydrogen Fuel Cell Collaborative
- Fuel Cells 101
- The motivation for getting involved with fuel cells
- Hydrogen fuel cells are feasible
- Hydrogen fuel cells are happening
- The fleet business case for hydrogen fuel cells
- The future of fuel cells
- Summary

RENEWABLE HYDROGEN FUEL CELL COLLABORATIVE

THE RHFCC

The RHFCC

Vision Statement: Make the Ohio region a US and global leader in the adoption of renewable hydrogen in transportation.

History: Formed two years ago as a collaborative venture between the Stark Area Regional Transit Authority (SARTA), and The Ohio State University – Center for Automotive Research (OSU-CAR)

Initiatives:

- Education & Outreach
- Encourage adoption
- R&D

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FUEL CELLS 101

Fuel Cells 101

- A fuel cell uses an electrochemical process in which the electron is broken off from the hydrogen atom which can then travel through an external electrical circuit. The resulting positively charged hydrogen ion is pulled through the fuel cell electrolyte and combines with the oxygen in air on the other side of the electrolyte to form pure water.
- Fuel cells are 2 to 3 times as efficient as internal combustion engines and their only waste is pure water
- Hydrogen is the most common element in the universe
- Hydrogen can be produced by a number of means:
  - Electrolysis of water
  - Reformation of methane
  - New approaches

THE MOTIVATION

The Motivation for getting Involved with Fuel Cells

- No carbon
- No air pollutants (particulate, NOx, Sox, etc.)
- Use locally derived fuels to produce hydrogen
- Move to renewable and sustainable fuels
- Create jobs in the region
- Reduce noise
- Direct drop in replacement for all existing vehicles in a fleet

IT’S FEASIBLE

Hydrogen Fuel Cells are Feasible

"Fuel cells have the greatest long-term potential to solve society's environmental and energy concerns."

Steve Center, Vice President, Connected and Environmental Business Development Office, American Honda Motor Co., Inc.

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Hydrogen Fuel Cells are Feasible

Toyota has announced that starting in 2050, it will no longer sell any vehicle with an internal combustion engine in it

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Hydrogen Fuel Cells are Feasible

Mike Britt, recently retired Director of Maintenance & Engineering for UPS, believes that the use of hydrogen fuel cells is inevitable at UPS and would like to see the deployment of 100 fuel cell based UPS trucks in the near future

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Hydrogen Fuel Cells are Feasible

In the annual 2017 Global Automotive Executive Survey by KPMG, 65% of the respondents felt that EVs were not a viable long term solution because of recharging infrastructure problems, while 70% or the respondents believed fuel cells represented the best solution for the future of transportation.

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Hydrogen Fuel Cells are Feasible

By the end of 2018, SARTA will have 10 FCBs in its fleet, which will be the largest fuel cell bus fleet in the US outside of California

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Hydrogen Fuel Cells are Feasible

Warehouses are rapidly converting their battery powered forklifts to fuel cell power. There are currently over 17,000 fuel cell powered forklifts in the US with almost 1000 of them in Ohio.

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Hydrogen Fuel Cells are Feasible

In the last 2 years, Ballard Power Systems, one of the worlds largest manufacturers of fuel cell power systems, has sold more fuel cells than in the previous 36 years of its existence combined.

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IT'S HAPPENING

Hydrogen Fuel Cells are Happening

- Information Trends predicts that in 15 years, there will be 20M fuel cell cars & 5,000 fueling stations globally
- A Hydrogen Roadmap developed by CalStart for the RHFCC shows that in the Midwest over the next 15 years there will be:
  - 65,000 new jobs created related to hydrogen fuel cells
  - 135,000 FCEVs on the road
  - 250 hydrogen refueling stations in place
- 200 fuel cell buses in the world, to triple by the end of next year. In addition, China has ordered an additional 1,000 FCBs

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Hydrogen Fuel Cells are Happening

Ohio Total	2017	2018	2019	2020	2021	2020	…2032
HD	3	14	19	29	52	73	2,106
MD	0	5	17	51	61	92	2,647
LD	0	0	0	0	0	0	40,500
TOTAL	**3**	**19**	**36**	**80**	**113**	**164**	**45,252**

Roll Out of FCEVs in Ohio: Midwest Hydrogen Roadmap

RENEWABLE HYDROGEN FUEL CELL COLLABORATIVE

THE BUSINESS CASE

The Fleet Business Case for Hydrogen Fuel Cells

- FCEV Operating costs (fuel and maintenance) are currently close to parity with diesel costs and are dropping
- Currently use grant money to pay for the delta in initial capital expenses for vehicles, refueling and facilities
- If CNG is in current or planned usage, initial capital costs are significantly decreased
- All FCEV costs are continuing to decrease with parity with diesel expected in the 2030s

FUEL CELL FUTURES

The Future of Fuel Cells

- Ballard $1/watt program (currently at $6/watt)
- All costs decreasing from standardization and mass production
- Strong focus on renewable H2 – use of RNG, solar & wind
- Developing direct conversion of sunlight to hydrogen
- DOE focus on Hydrogen: H2@Scale to store surplus wind and solar generated electricity in hydrogen

SUMMARY

Fuel Cell Bus Costs - Summary

- FCEVs are happening faster than most realize
- Big jobs potential in the Midwest
- Fuel and operating costs at rough parity with diesel; use grants to pay for additional capital costs
- Wide range of vehicles available, all combine FC & EV
- Expanding options for generating hydrogen including renewable pathways
- Initial use in the Midwest predicted in fleets

Perfect Fit for Fleets

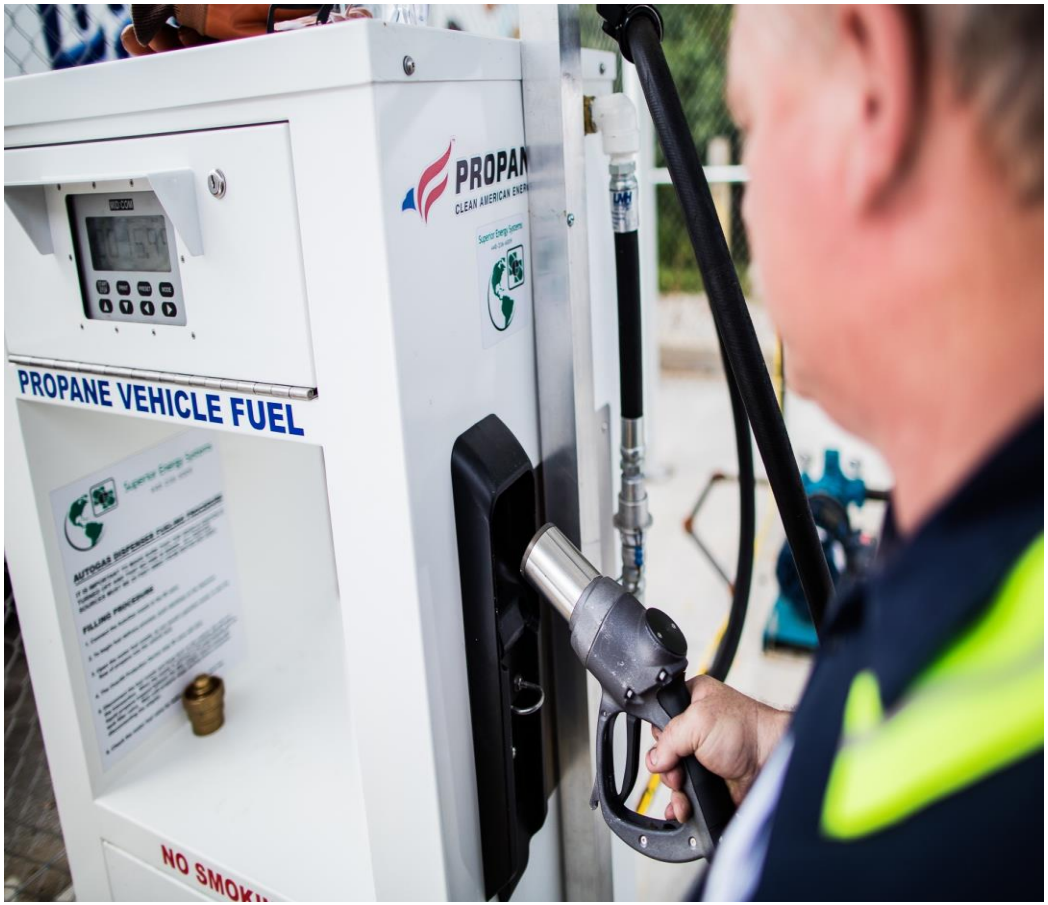
Michael Taylor
Autogas Director of Business Development

August 2017

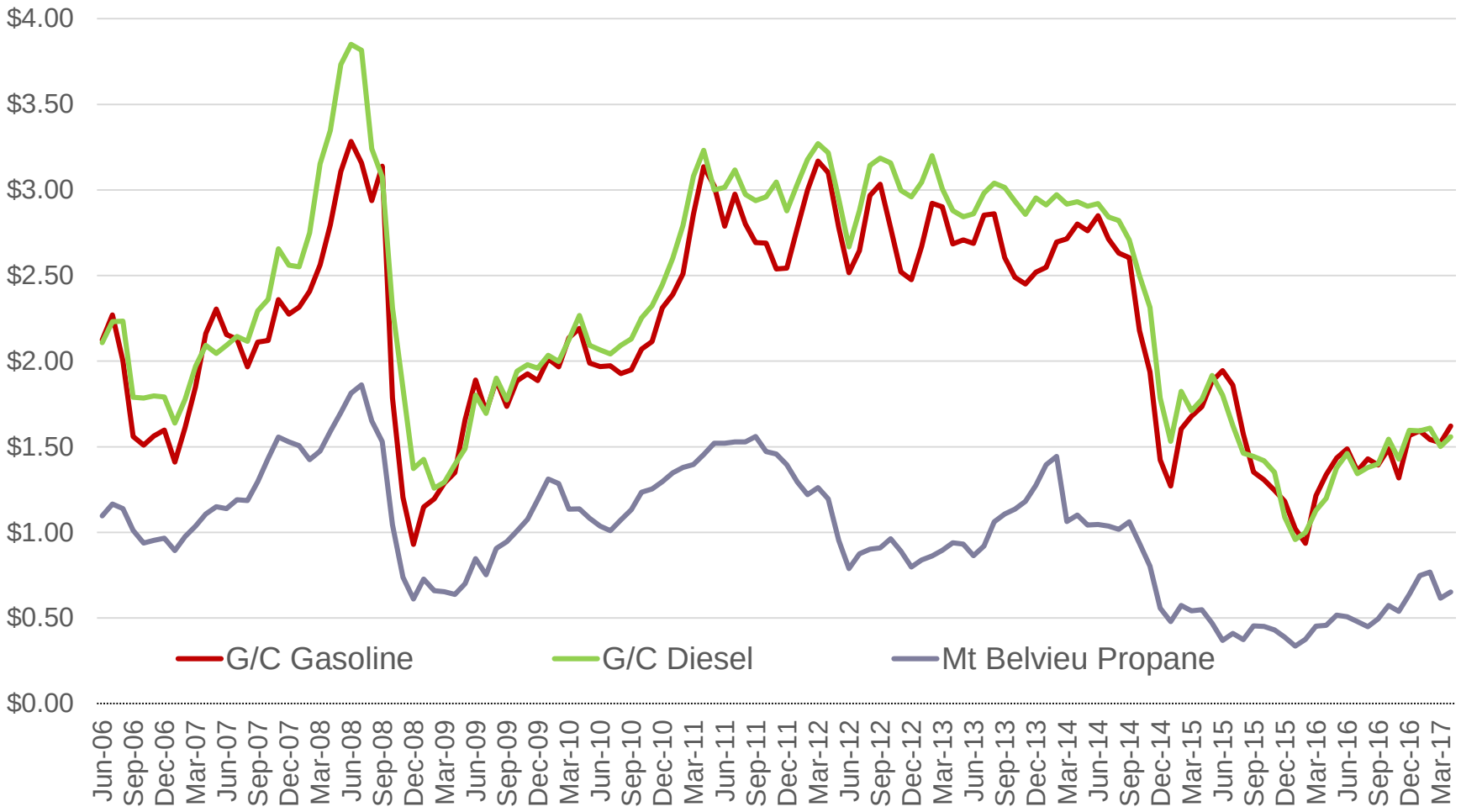
The Perfect Fit for Fleets

- Lowest total cost-of-ownership.
- Reliable operation in all climates.
- Environmental impact is significant.
- Affordable infrastructure.
- No garaging, maintenance and repair concerns.

Refueling Solutions



US ENERGY PRICE COMPARISON 2006–2017



Source: EIA.gov

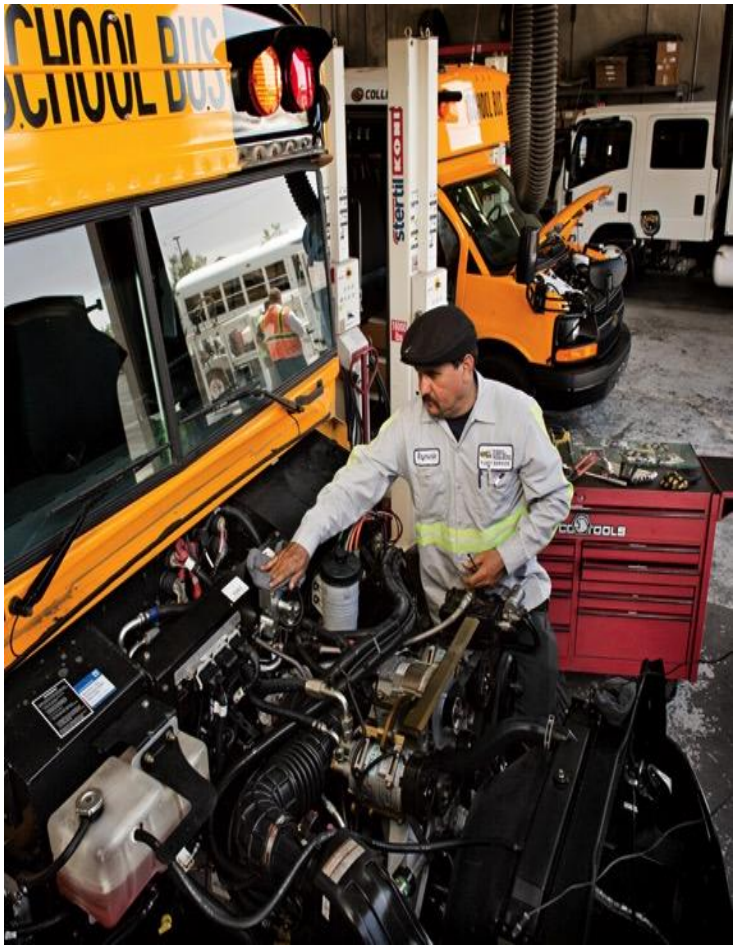

SCHOOL BUS
STOP
3316


160254

Reliable Operation

Propane Autogas…

- Cranks reliably down to -40F.
- No block heaters.
- No fuel conditioners.
- Fast warm up without lengthy idle times.
- Produces consistent heat throughout the passenger compartment.




KINGSPORT


DOOSAN


POLICE


Ford


Propane Vehicle


Sara Lee
www.saraleebread.com


Ready Refresh
YOU choose WE deliver!
ReadyRefresh.com
CLEAN BURNING PROPANE AUTOGAS


GF4
PROPANE
1075


SHERIFF


POLICE


SEATTLE FIRE DEPT.
M 1
SEATTLE FIRE DEPT.
SAFETY

Material Handling

- Approximately 65,000 propane forklifts sold in 2016.

- New engines for 2017:
  - PSI 2.0L, 2.4L, & 4X (4.3L)
  - Nissan K21 & K25
  - Kubota 3.8L
  - Isuzu 4.6L


HOT
UltraCut 52


JOHN DEERE

The Future

ADVANCED DIRECT INJECTION ENGINES

Cook-Illinois

MICHAEL TAYLOR

DIRECTOR OF AUTOGAS BUSINESS DEVELOPMENT
PROPANE EDUCATION & RESEARCH COUNCIL

1.859.409.1439
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Clean Fuels Ohio Presentation

By Wade Thorson

August, 2017

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Why EPA Regulates Diesel Fuel

- The amount of **sulfur** in diesel fuel is directly linked to the amount of pollution produced when the fuel is burned in an engine. Higher levels of sulfur increase pollutants.
- When diesel fuel is burned in engines, the emissions that result contributes to air pollution that has serious human health and environmental effects.
  - Pollution from diesel exhaust includes:
    - Soot or particulate matter (PM);
    - Oxides of nitrogen (NOx) which contributes to the production of ground-level ozone (smog) and acid rain;
    - Hydrocarbons (HC);
    - Carbon monoxide (CO); and
    - Other hazardous air pollutants (HAPs) and air toxics.
- This air pollution can cause heart and lung disease and a range of other health effects. It can also damage plants, animals, crops, and water resources.

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Worldwide Petroleum Consumption 2015

Tue Aug 01 2017 20:34:46 GMT-0400 (Eastern Daylight Time)

Source: U.S. Energy Information Administration

Units: Thousand Barrels Per Day

Ranking	Country	Value	Percent
1	United States	19531	20
2	China	12020	13
3	India	4142	4
4	Japan	4120	4
5	Russia	3554	4
6	Saudi Arabia	3237	3
7	Brazil	2992	3
8	Korea, South	2407	3
9	Canada	2406	3
10	Germany	2372	2
11	Mexico	2007	2
12	Iran	1912	2
13	France	1691	2
14	Indonesia	1648	2
15	United Kingdom	1545	2
16	Singapore	1340	1
17	Thailand	1272	1
18	Italy	1266	1
19	Spain	1241	1
20	Australia	1116	1

95.3 Million barrels per day

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What does 95.3 million barrels a day look like?

A drum is typically 55 gallons,
but a Barrel of Oil is 42 gallons

Oil was discovered in 1859 in NW Pennsylvania, and
It so happened that the most common sized container
Used for shipping was 42 gallons, and weighed 300 pounds
When filled with oil….
About as much as a man could reasonably wrestle……

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What does 95.3 million barrels a day look like?

95,366,000 Barrels
42 Gallons per Barrell
4,005,372,000 4 Billion Gallons per Day Consumed

95,366,000 Barrels
Cubic Feet in 1
5.6148 Barrell
535,461,017 535 Million Cubic Feet per Day Consumed

260,000 Walmart Supercenter in Square Feet
24 feet tall
6,240,000 6.2 Million cubic feet

535,461,017 535 Million Cubic Feet per Day Consumed
6,240,000 6.2 Million cubic feet
85.8 Roughly 86 Walmart Supercenters full - per day

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What does 95.3 million barrels (4 billion gallons) a day look like?

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And that was just 1 day……
34,784,500,000 Billion gallons per year

86 Walmarts/day x 365 = 31,390 Walmarts

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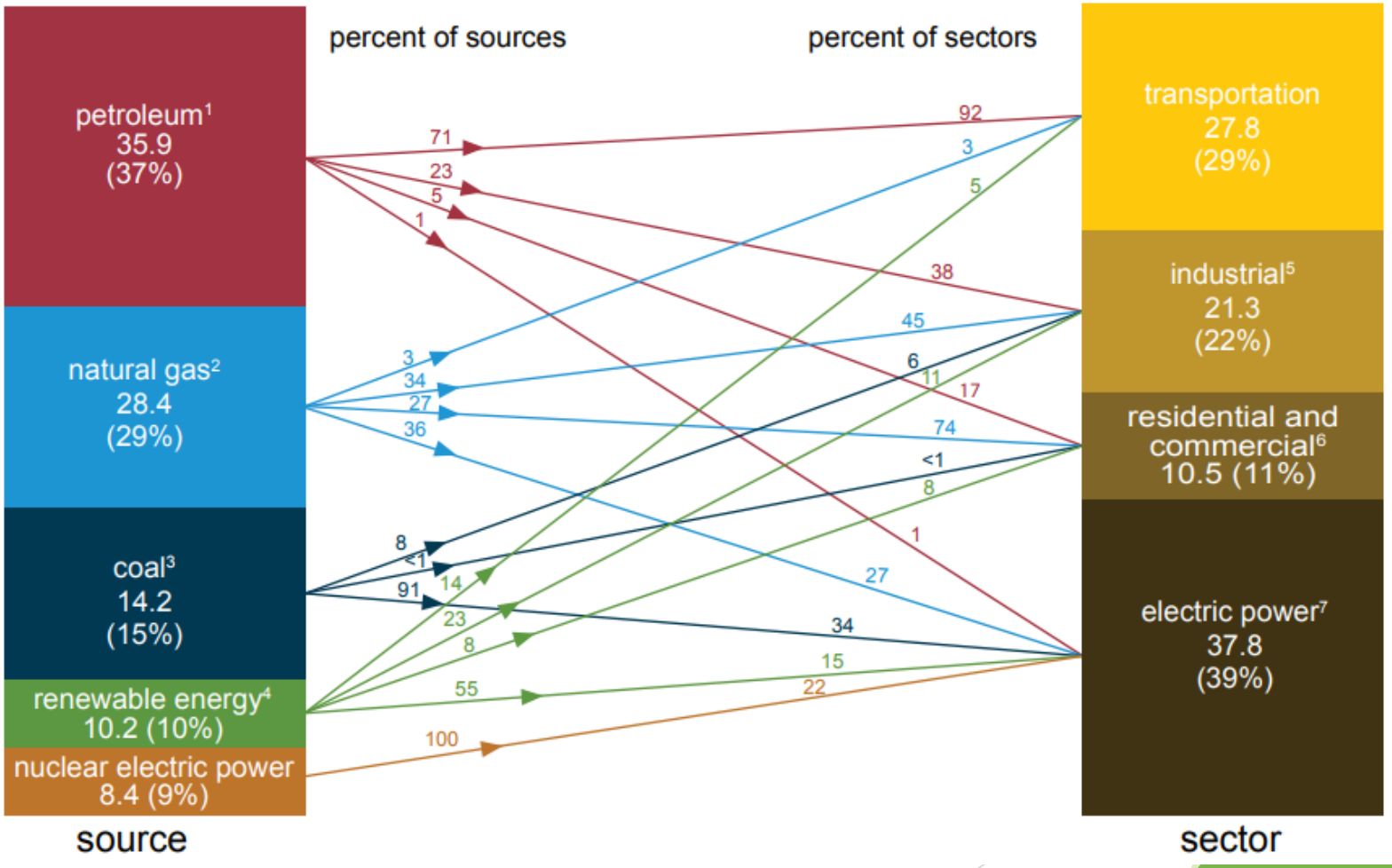
U.S. Energy Consumption 2016

Ultra Low Sulfur Biodiesel

U.S. primary energy consumption by source and sector, 2016

Total = 97.4 quadrillion British thermal units (Btu)



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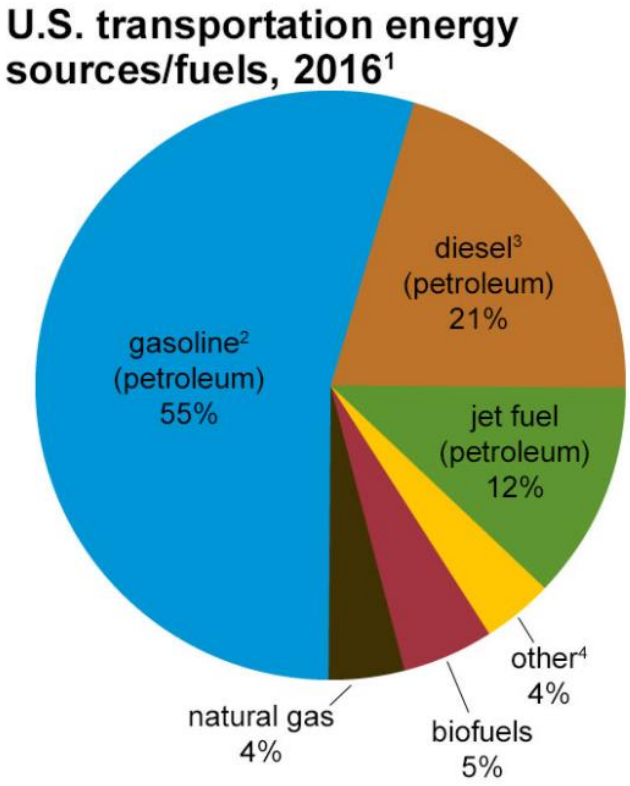
How much Transportation Fuel does the United States Consume?



Gasoline – 368 million gallons
Diesel – 145 million gallons
Jet – 72 million gallons
Biofuels – 33 million gallons
Nat Gas – 20 million gallons
Other – 20 million gallons

US TOTAL - 657 million gallons

…….PER DAY

The US Total yearly number is 240 trillion gallon.

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BENCHMARK BIODIESEL

Ultra Low Sulfur Biodiesel

How much Transportation Fuel does the OHIO Consume?

Gasoline – 11.9 million gal/day
(4.4 billion gallons per year)

Diesel – 4.6 million gal/day
(1.7 billion gallons per year)

1/3 of a Walmart - day

129 Walmarts - year

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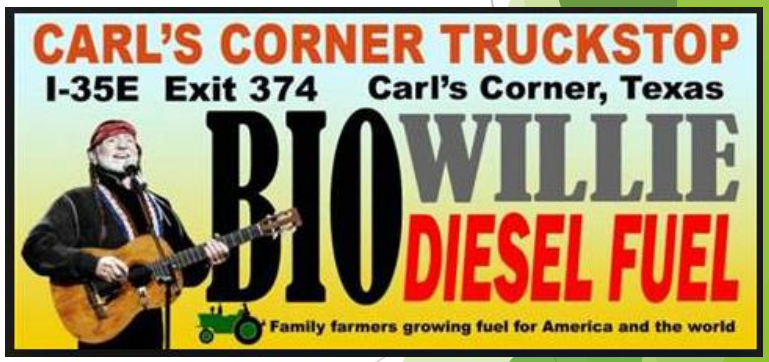
Fuel Advantages

- **No Engine Modifications Necessary**
  - Biodiesel runs in ALL diesel engines without any modifications.
- **Reduces Air pollution**
- **Higher Cetane**
  - Biodiesel has a higher cetane rating for quicker ignition.
- **More Lubrication**
  - More lubricity means less wear and tear on your engine, resulting in less maintenance and longer engine life. A B2 (2%) blend of biodiesel will raises lubricity levels back to pre-ULSD levels.
- **Cleaner burning, Smells better**
- **Renewable Energy**
  - Biodiesel is made from Renewable Resources (soybean oil) and made in America – reducing our dependence on foreign oil.
- **Costs the same or less than Diesel**



"I am absolutely a fan of biodiesel," says Willie Nelson.

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Benchmark Biodiesel

Ultra Low Sulfur Biodiesel

- ESTABLISHED: Benchmark BioDiesel, Inc ("Benchmark") is an Ohio corporation established in 2007 to distribute biodiesel throughout Ohio.
- BIODIESEL: Biodiesel is made from vegetable oils and animal fats which are chemically reacted to produce a very clean burning alternative fuel that is good for the environment, economy, and America's energy security.
- BLENDS: Biodiesel is blended with diesel fuel, and is used in any diesel engine without modification.
- FUEL DISTRIBUTION TERMINAL – Benchmark has the only biodiesel blending fuel terminal in Columbus, Ohio with over 600,000 gallons of heated and insulated fuel storage capacity. The fuel terminal distributes Soybean Biodiesel and Ultra Low Sulfur Diesel (ULSD) blends according to each customers needs, on a wholesale basis for both on-road and off-road consumption.

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