Apples to Apples: How to Accurately Compare the Efficiency and Environmental Benefits of Conventional Fuels to Electric and Alternative Fuel Vehicles

By Louisiana Clean Fuels

We are in the middle of a global shift towards the adoption of electric vehicles into the mainstream. Daily announcements from manufacturers, cities, and national fleets about their greenhouse gas reduction goals and how they plan to make electric vehicles the centerpiece of their strategies are beginning to clutter our inboxes here at Louisiana Clean Fuels. The result is an onslaught of information, articles, analysis, and infographics about the effectiveness of these new technologies from experts, enthusiasts, and those working in other industries. Often these articles and infographics make conflicting claims of the relative effectiveness of one technology over another. With so much information out there, how can the layperson determine which articles or stats are most accurate?

In this article, we will provide you with a few simple tools to help you sort through information on alternative fuel vehicles (AFVs) accurately compare different fuels by identifying and weeding out false equivalencies and misleading information.

With so many alternative fuels on the market, it's tempting to make direct comparisons between the merits of each fuel, but it's surprisingly complex and nuanced work to make comparisons fairly. The result is that many articles oversimplify the data and fail to properly account for the many variables that go into such a comparison. Each alternative fuel has its own set of benefits and pitfalls, and it's important to understand what each fuel can and can't do. It's also important to keep in mind what the priorities are when choosing between fuel types and how those priorities can or can't be met by each fuel. For the purposes of this article, we'll discuss a few of the most important variables to be aware of when comparing different fuel types.

As an overview, here are some of the most common mistakes made when comparing alternative fuels to conventional fuels.

- Incorrect Unit Comparisons: When making comparisons between fuels, consider the units (Gallons, GGEs, DGEs, kWh, etc) being discussed and make sure they're comparing "like to like." The energy content between fuel types will differ, so make sure this is considered along with the volume being compared.
- Efficiency Mistakes: Some articles don't take into consideration the efficiency of the engine at converting fuel to power; some vehicles need less fuel to travel the same distance.
- "Zero Emissions" Claims: These claims can be misleading. Terms like "Near Zero" don't always mean zero emissions. Are they referring to all pollutants/emissions (CO2, NOx, etc.) or just one type?
- Unfair Emissions Comparisons: Some articles completely ignore the "well to wheels" emissions for the fuel the author is supporting but takes it into consideration for a new technology that is perceived as a threat or competition. Know the difference between "tailpipe" emissions and "well to wheels" emissions and learn to spot when articles omit this important bit of information.

1.) Incorrect Unit Comparisons

Gaseous Fuels

We usually quantify amounts of liquid fuels by volume (ie. gallons of gasoline, diesel, propane, ethanol, liquified natural gas, etc.). However, using gallons as a unit for all these fuel types can cause significant confusion because a gallon of each will contain different amounts of energy.

Gasoline-Gallon Equivalent (GGE) and Diesel Gas Equivalent (DGE) are standardized units used to compare the energy content of all fuels. These units quantify the amount of the gaseous alternative fuel needed to match the energy content of a gallon of gasoline or diesel.

To calculate GGE and DGE, the energy content of one unit of the comparison fuel is divided by the energy content of one gallon of gasoline or diesel . Energy content is often measured in British thermal units (Btus) per gallon of fuel and is often referred to as the lower heating value of the fuel. For example, conventional gasoline has an energy content of 116,090 Btus per gallon, while propane has an energy content of 84,250 Btus per gallon. As such, 1.38 gallons of propane has the same amount of energy as one gallon of conventional gasoline. To learn more about DGEs and GGEs, check out this article: Measuring Fuels: Understanding and Using Gasoline Gallon Equivalents.

Electric Vehicles

For electricity, we measure energy in terms of kilowatt-hours (kWh), which is the amount of energy transferred by a 1 kilowatt (kW) power supply over the course of an hour. When comparing "fuel efficiency" in EVs, the terms "Mile Per Gallon Equivalent" (MPGe) and "kWh per 100 miles" are used. Unlike MPGe, the lower the kWh/100m, the better.

kWh/100m: the amount of electricity needed to drive your EV 100 miles.

To determine MPGe ratings, the U.S. Environmental Protection Agency (EPA) uses the amount of electric energy that's equal to the energy contained in 1 gallon of gasoline:

1 Gallon gasoline = 115,000 BTUs of energy = approximately 33.7 kilowatt-hours

Learn more about how to "decode" electric car MPG

Hydrogen

For hydrogen, we quantify amounts by mass (kg). Fortunately, 1kg of hydrogen contains only ~2% more energy than 1 gallon of gasoline which makes comparisons between the efficiencies of hydrogen vehicles to gasoline or diesel relatively straightforward.

2.) Efficiency Mistakes

One of the most important things to be aware of when comparing fuel types and economy is that vehicles use each fuel type differently, and efficiency can vary significantly between those fuel types. The differences in energy content of fuels can hide the true efficiency of various alternative fuels.

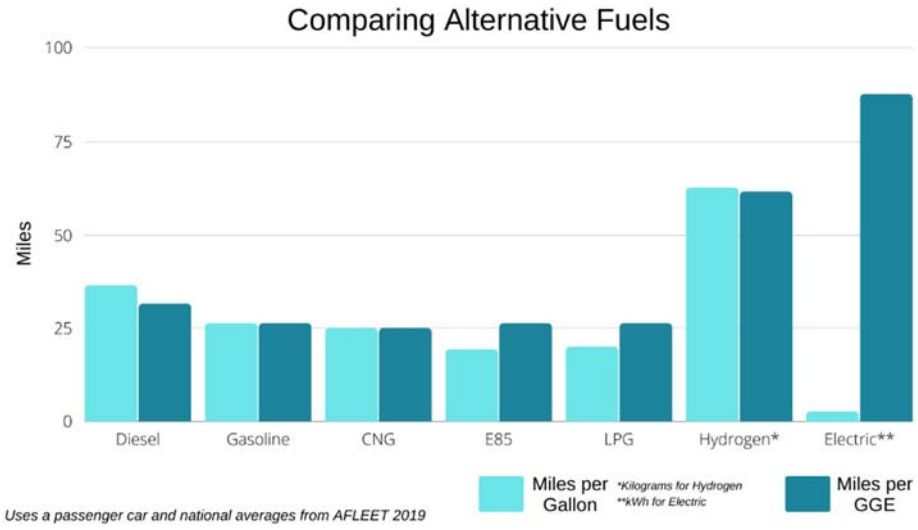
To try to compare vehicle efficiencies equivalently, MPGe, or miles per gasoline gallon equivalent, are often used. Think of MPGe as being similar to MPG, but instead of presenting miles per gallon of the vehicle's fuel type, it represents the number of miles the vehicle can go **using a quantity of fuel with the same energy content as a gallon of gasoline.** This allows a reasonable comparison between vehicles

using different fuels. For example, you can use MPGe to compare a compressed natural gas (CNG) vehicle with a gasoline vehicle; even though CNG is not measured in gallons.

QUICK TIP

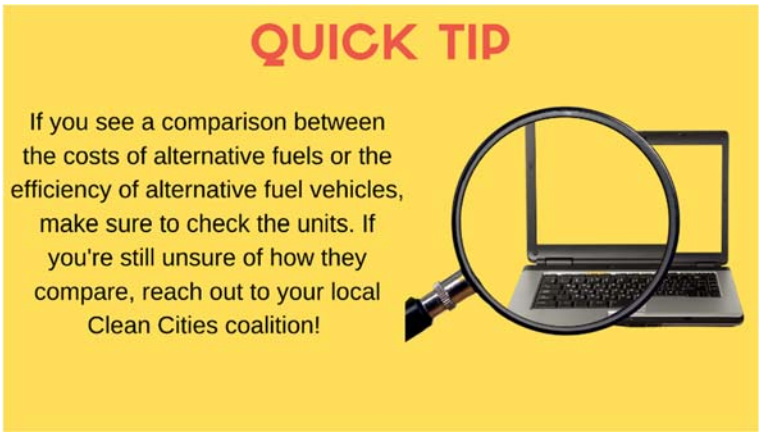
The Environmental Protection Agency (EPA) page on NAAQS is a fantastic resource and does a great job of explaining the six criteria pollutants and why each of them is important. Check out their sites linked at the end of the article to learn more!

To illustrate the issue surrounding vehicle efficiency, let's consider electric vehicles and gasoline vehicles. Electric vehicles (EVs) convert between 77% and 100% of the electrical energy from the grid to power at the wheels. Conventional gasoline vehicles only convert about 12%–30% of the energy stored in gasoline to power at the wheels (fueleconomy.gov). Because of this energy content difference, to compare electric vehicle efficiency to gasoline vehicles, utilize MPGe. As stated earlier, MPGe measures the miles traveled per 33.7 kilowatt-hours or the amount of energy contained in a gallon of gasoline.



3.) "Zero Emissions" Claims

When looking at alternative fuels, it's very important to understand the various types of vehicular emissions. Generally speaking, there are 7 emissions types that we focus on: the 6 Criteria Pollutants under the National Ambient Air Quality Standards (NAAQS) and greenhouse gases (primarily CO2).



Criteria Pollutants

All six of the NAAQS Criteria Pollutants are important to consider, but of the six pollutants in the list, two of them are most often discussed in terms of transportation and vehicle emissions: particulate matter (PM2.5) and nitrogen oxides (NOx).

PM 2.5

- Found in vehicle exhaust, especially from diesel engines
- Poses a serious threat to human health via lung or blood penetration or haze

NOx

- Form when fuel is burned at high temperatures which happens largely in diesel engine vehicles
- Worsen lung diseases such as asthma, cause acid rain and smog

Greenhouse Gases

There are plenty of gases that contribute to the Greenhouse Effect and accelerate the effects of climate change, but the primary gasses discussed are carbon dioxide (CO2) and Methane.

CO2

- Primary product gases from burning hydrocarbon fuels such as diesel, gasoline, propane, and natural gas
- Large contributor to climate change as a greenhouse gas, smog, and air pollution

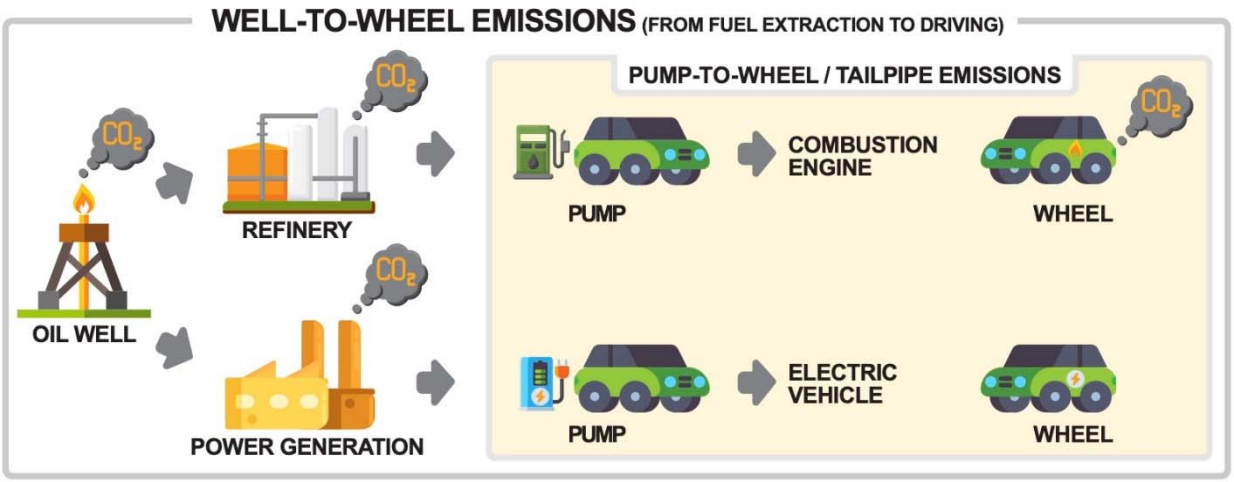
Methane

- Second most important greenhouse gas after CO2, accounting for 20% of human-related (anthropogenic) GHG emission
- Primary component of natural gas, and sources include the oil and gas industry, livestock, and landfills

4.) Unfair Emission Comparisons

When comparing vehicle emissions, there are two forms of analysis: tailpipe and well-to-wheels. Tailpipe emissions are those coming from the use of the vehicle and are also known as direct emissions. While electric vehicles do not have tailpipes to produce tailpipe emissions, there are still emissions associated with these vehicles. Well-to-wheel emissions include **all emissions** related to fuel production, processing, distribution, and use. For gasoline vehicles, well-to-wheel emissions include emissions from

the extraction, refining, and distribution of petroleum, while electric vehicle emissions are produced by the electric power plants and the extraction and processing of the primary energy sources used for electricity production. The image below illustrates a simplified version of the differences explained here.



It's common for electric vehicles (and hydrogen fuel-cell vehicles) to be referred to as "Zero Emission." While electric vehicles don't have tailpipe emissions and usually have significantly lower lifetime GHG and criteria pollutant emissions than their gasoline and diesel counterparts, unless they are charged by zero-carbon electricity, they are not completely zero-carbon themselves. This is because there are still emissions related to their power generation, as shown above.

You can find your local Clean Cities coalition here: https://cleancities.energy.gov/coalitions/

Conclusion

We hope that this article has shed some light on the issue of making comparisons between various fuel types. As we've discussed, there are several factors that go into making a valid comparison between fuel types, and things are often more complicated than they may seem. With the tips outlined above in mind, we hope that you feel more confident when reading articles and infographics about alternative fuels with the knowledge that you understand what they're talking about and what they might be neglecting to mention. If you are ever in doubt about the claims of any information you come across, feel free to reach out to your local Clean Cities coalition; we would be more than happy to help you tease apart fact from fiction.

Sources:

Energy Content: http://nhcleancities.org/2017/04/can-compare-energy-content-alternative-fuels-gasoline-diesel/

NOx Health/Ecology Effects from EPA: https://www.epa.gov/no2-pollution/basic-information-about-no2

Global Warming Potential: https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

Methane Emissions: https://www.epa.gov/ghgemissions/overview-greenhouse-gases#methane

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CARB CI Scores: https://ww2.arb.ca.gov/resources/documents/lcfs-pathway-certified-carbon-intensities

Decoding Electric Car MPG: https://www.edmunds.com/fuel-economy/decoding-electric-car-mpg.html

Fuel Economy Information: https://www.fueleconomy.gov/feg/evtech.shtml

AFLEET Tool: https://afdc.energy.gov/tools or https://greet.es.anl.gov/afleet

Customizable Fuel Property Comparison: https://afdc.energy.gov/fuels/properties