Using Natural Gas for Vehicles: Comparing Three Technologies

In the United States, natural gas is used primarily for electricity generation and residential, commercial, and industrial applications, but it is also used as a fuel for on-road vehicles, especially in medium- or heavy-duty vehicles in centrally-fueled fleets.

It has been proposed for greater use as a fuel for on-road vehicles, particularly in light-duty vehicles. This can mean burning natural gas in an internal combustion engine like those used in most natural gas, gasoline, diesel-powered vehicles on the road today. However, natural gas can also serve as the energy source for plug-in electric or hydrogen fuel cell electric vehicles. This fact sheet compares some efficiency and environmental metrics for three possible options for using natural gas in light-duty cars.

The analysis presented here compares these pathways. It is not intended to recommend for or against increased use of natural gas in light-duty vehicles. Related ongoing analysis considers use ofnatural gas with these three technology pathways in medium- or heavy-duty vehicles (for example, in centrally-fueled fleets that use large quantities of fuel), but will not be covered in this fact sheet.

This comparison of pathways in light-duty vehicles is based on a detailed analysis (Wang and Elgowainy 2015), which uses the GREET model (Greenhouse Gases, Regulated Emissions, and Energy use in Transportation). Scientists at Argonne National Laboratory developed GREET to estimate energy use and emissions across the entire fuel life cycle from extraction to end use in transportation.

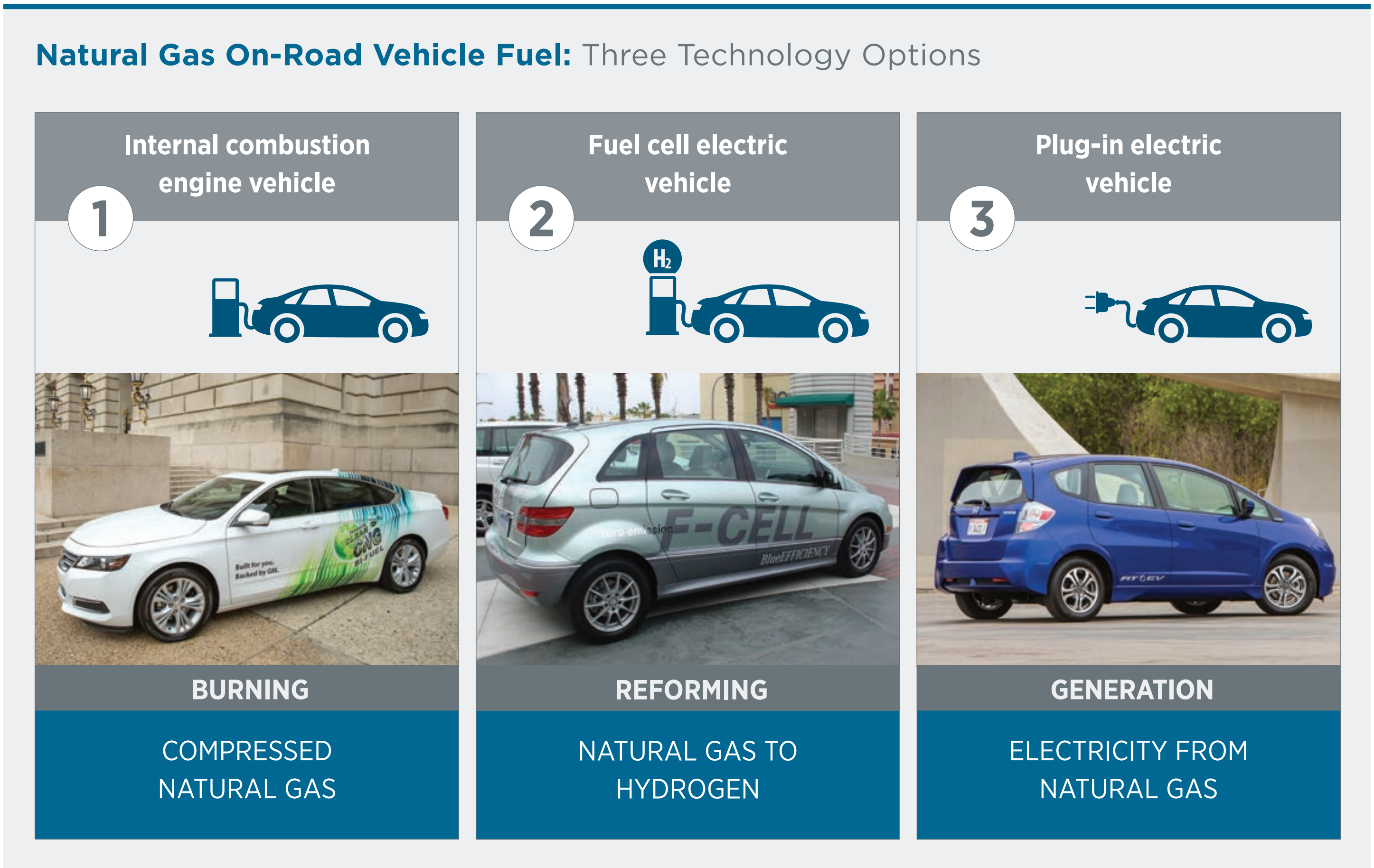

Figure 1. Compressed natural gas, natural gas to hydrogen, and electricity from natural gas

Considering Life Cycle Efficiency

Each of the three pathways for using natural gas has strengths and weaknesses that determine where efficiency losses and emissions occur across the entire life cycle. Vehicle efficiency determines only part of the story.

Figure 2, which is based on GREET results, gives a look at the fuel life cycle for the three types of natural gas cars, showing how energy conversion efficiency at each major step leads to the ultimate system efficiency for each pathway. The percentages (light blue circles) show natural gas conversion efficiencies along steps of the life cycle. Below each pathway, the changes in the height of the light blue bar show how much of the energy in one mmBtu of natural gas is used during each step.

Natural gas internal combustion engine vehicles running on compressed natural gas (CNGV) have the greatest losses during combustion at the vehicle propulsion stage. Fuel cell electric vehicles (FCEVs) have the greatest losses during hydrogen production via methane reforming and during electricity generation from hydrogen in the vehicle. In addition, plug-in electric vehicles (PEVs) have the greatest losses during electricity generation.

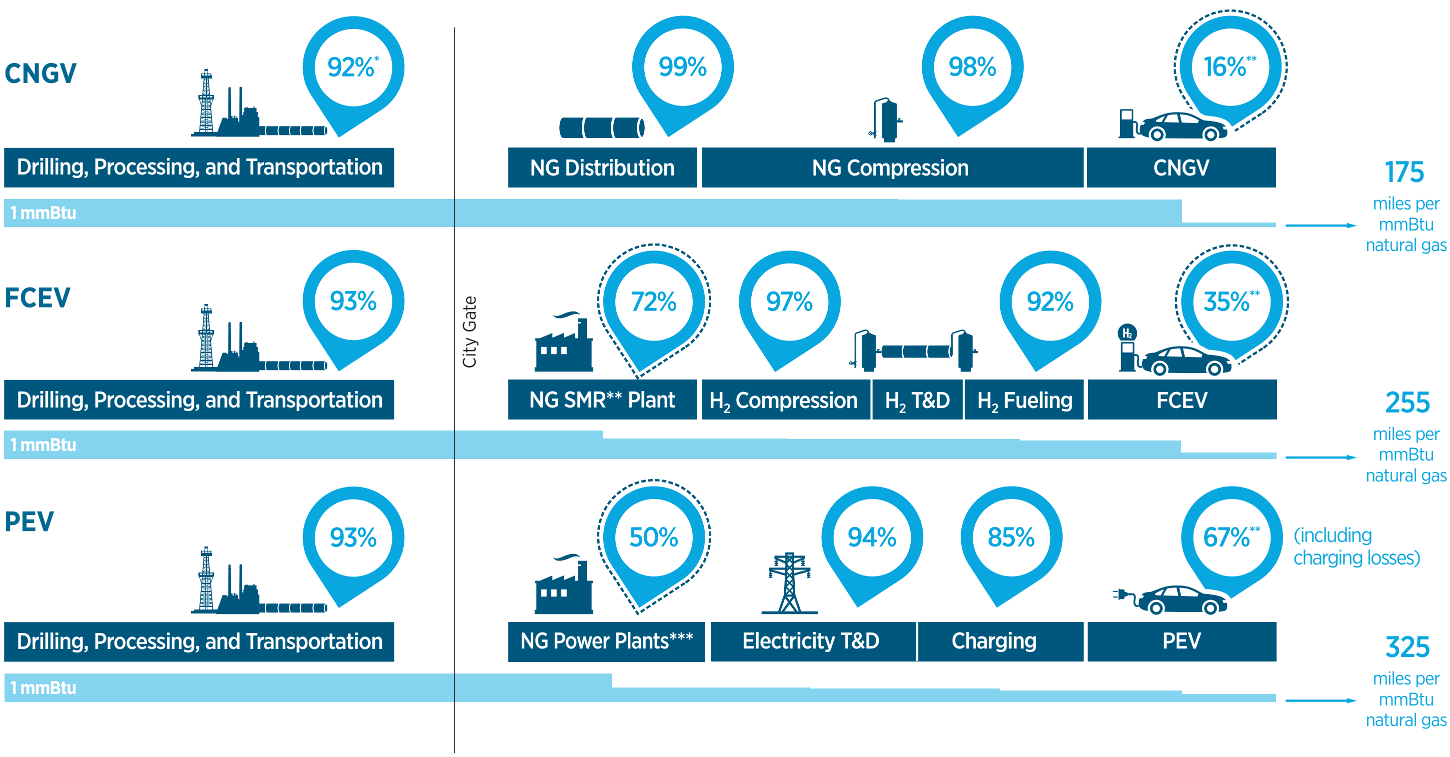

Figure 2. Fuel life cycle efficiency

Energy conversion efficiency   Key loss steps   Remaining energy

* Efficiency of drilling, processing, and transportation varies slightly between pathways due to expected differences in pipeline distance to use, as shown in Wang and Elgowainy (2015).

** Actual end-use efficiency will depend on drive cycle and other factors. Efficiency values here are representative based on an estimate of 17% average efficiency of gasoline engines for typical drive cycles and the relative MPGGE of each vehicle. Drive cycle simulations adjusted for on-road performance were used to estimate miles/mmBtu.

*** Primarily from natural gas combined cycle plants.

Reference: Wang, Michael and Amgad Elgowainy (2015). "Well-to-Wheels GHG Emissions of Natural Gas Use in Transportation: CNGVs, LNGVs, EVs, and FCVs. Presented October 10, 2014. Argonne National Laboratory. *https://greet.es.anl.gov/publication-EERE-LCA-NG*.

Understanding Life Cycle Greenhouse Gas Emissions

An accounting of greenhouse gas emissions involves more than vehicle fuel economy and life cycle system efficiency. With natural gas, a variable and uncertain portion of greenhouse gas emission occurs due to leakage of methane throughout the life cycle. Using GREET, greenhouse gas emissions can be compared across pathways with very different distributions of emissions across the fuel life cycle.

In Figure 3, the grey bars show how greenhouse gas emissions (in carbon dioxide equivalents) are distributed across different steps of the life cycle for each pathway. The figure also shows how the different fuel economies in the light blue circles contribute to the final grams of emissions per mile shown in figures 3 and 4. (Wang and Elgowainy 2015).

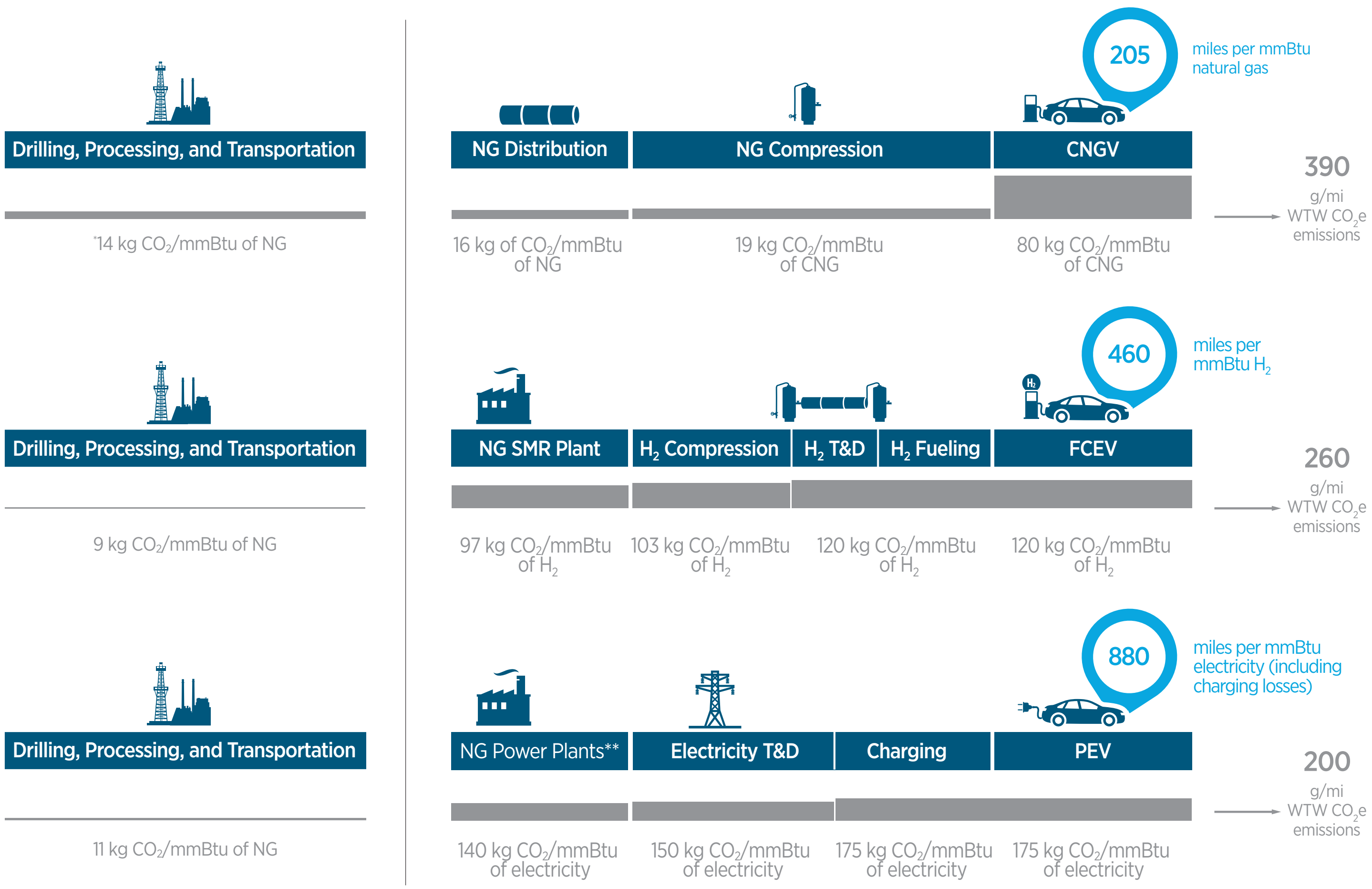

Figure 3. Fuel life cycle greenhouse gas emissions

Vehicle fuel economy (not WTW)

CO_2e emissions (cumulative, including upstream steps)

CO_2e emissions are due to both energy use and methane leakage

* Efficiency of drilling, processing, and transportation varies slightly between pathways due to expected differences in pipeline distance to use.

** Primarily from natural gas combined cycle plants.

Acronyms and Abbreviations

Btu	British thermal unit	g/mi	grams per mile	NG	natural gas
CNG	compressed natural gas	GHG	greenhouse gas	PEV	plug-in electric vehicle
CNGV	compressed natural gas vehicle	H_2	hydrogen	SMR	steam methane reforming
CO_2e	carbon dioxide equivalent	kg	kilogram	T&D	transmission and distribution
FCEV	fuel cell electric vehicle	MPGGE	miles per gallon gasoline equivalent	WTW	wheel to wheel
		mmBtu	million Btu		

Summary: How Far Can Natural Gas Take a Car?

It depends on how we use it. Figure 4 compares system efficiencies, showing how far differently powered cars can go on one mmBtu of natural gas, which is equivalent to about nine gallons of gasoline. Gasoline vehicles can travel 200 miles on this much energy. On this same amount of energy from natural gas, fuel cell vehicles can go about 255 miles, electric vehicles can travel 325 miles—with battery size determining the number of charging events needed—and internal combustion engine natural gas vehicles can go 175 miles. The key difference among these technology pathways, as detailed above, is the efficiency with which they convert natural gas to other forms of energy. Combustion of natural gas in engines on board a vehicle tends to be much less efficient than natural gas use in a modern combined cycle electric generation plant or through reforming to hydrogen and use in a fuel cell.

Comparing Technology Options

When natural gas is inexpensive relative to other fuels for on-road vehicles, it could benefit consumers and the economy. However, all three natural gas pathways provide energy security by helping reduce reliance on petroleum-based fuels in the transportation sector. Environmental performance, including life cycle greenhouse gas emissions, is also a key metric to compare technological alternatives. Considering the options for using natural gas for transportation—and their energy and environmental consequences—can help ensure that we get the most possible value from this new era of natural gas.

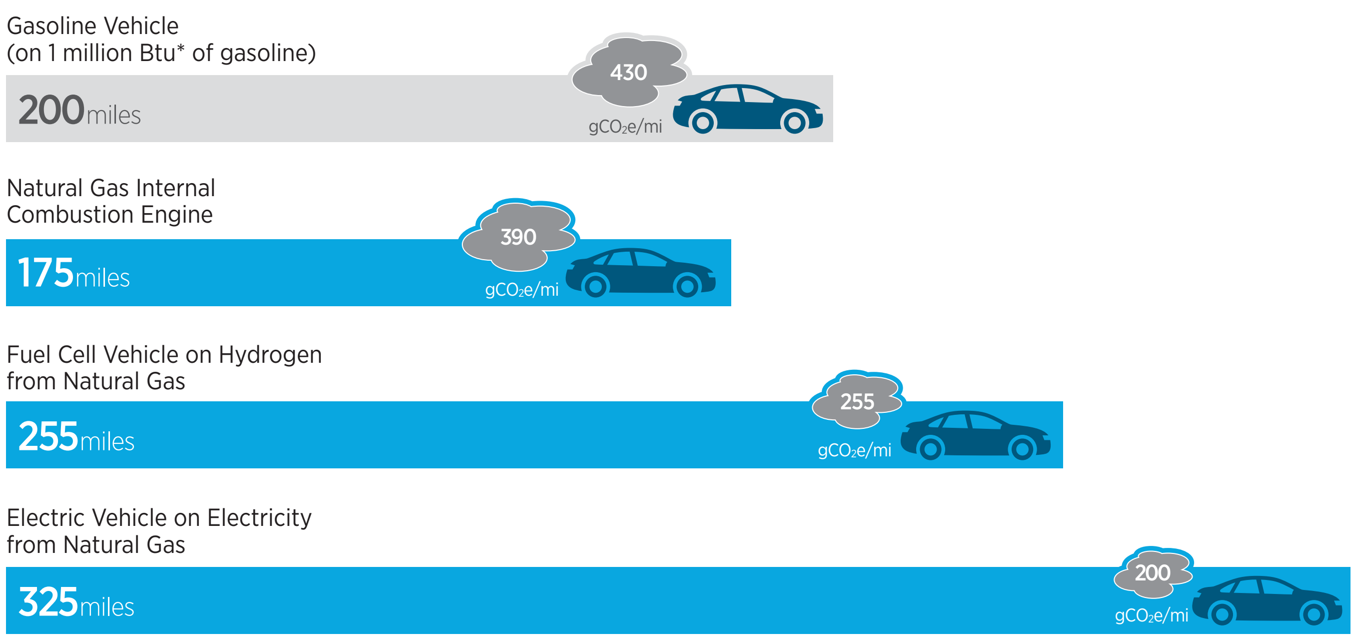

Figure 4. How far can a car go on 1 million Btu of natural gas?

Miles traveled per million Btu of natural gas

Well-to-wheel emissions (area proportional to emissions)

* One million Btu is the energy contained in approximately nine gallons of gasoline.

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Energy Efficiency & Renewable Energy

For information on the GREET Model see *greet.es.anl.gov*

For more information, visit: *www.energy.gov/eere/about-us/policy-and-analysis-team*

Cover images from left: Chevy Impala CNG vehicle from General Motors Corportation; Keith Wipke, NREL 18281; Honda Fit EV

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