
Potential for natural gas to reduce transportation emissions

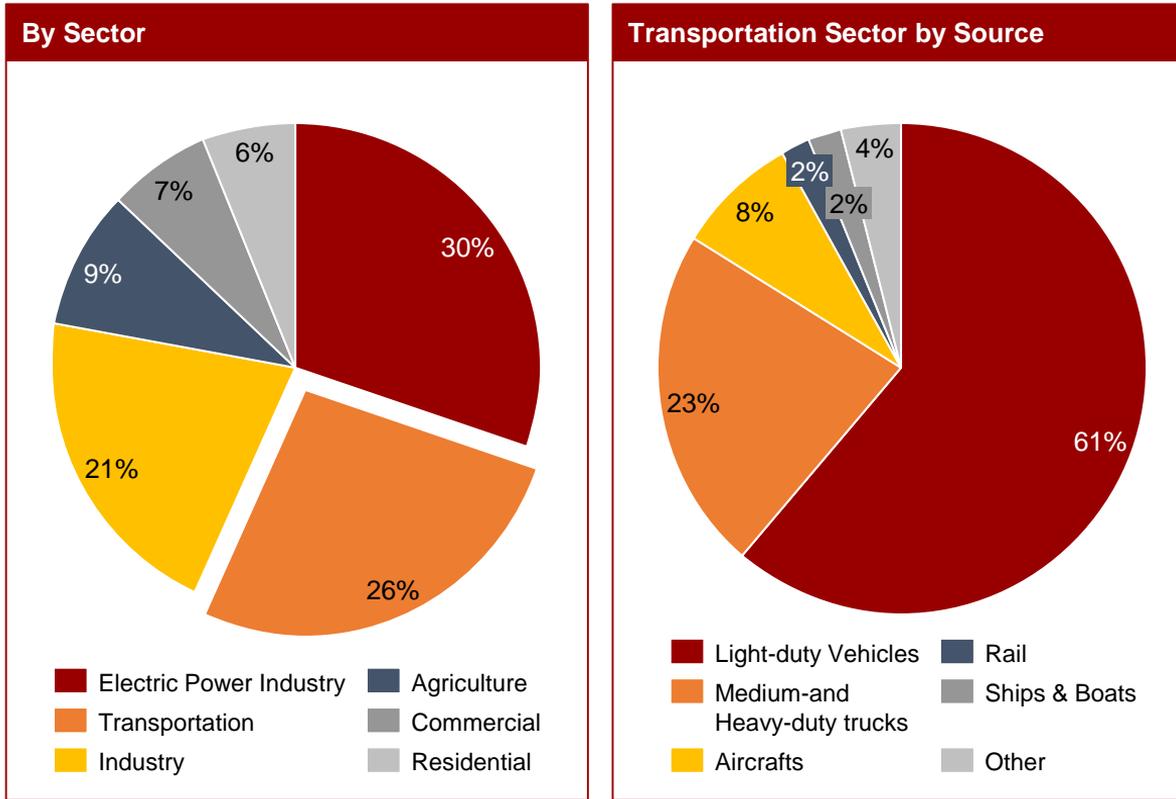
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Summary

- Natural gas can reduce transportation sector emissions with three main types of technologies:
 1. Natural gas vehicles
 2. Electric or hybrid-electric vehicles, and
 3. Hydrogen fuel cell vehicles
- With today's technologies, natural gas vehicles are 6-11% cleaner than gasoline but not as clean as hybrids or battery electrics. The potential of hydrogen fuel cell and electric vehicles (whose energy could be derived from natural gas) is much greater: emissions from hydrogen vehicles are already comparable to hybrid electric vehicles
- Challenges in the way of adoption include new infrastructure requirements and vehicle constraints (e.g. few natural gas pump stations, low energy density so it more frequent fill ups, and less space to accommodate a larger fuel tank)

Vehicles are a large source of U.S. emissions

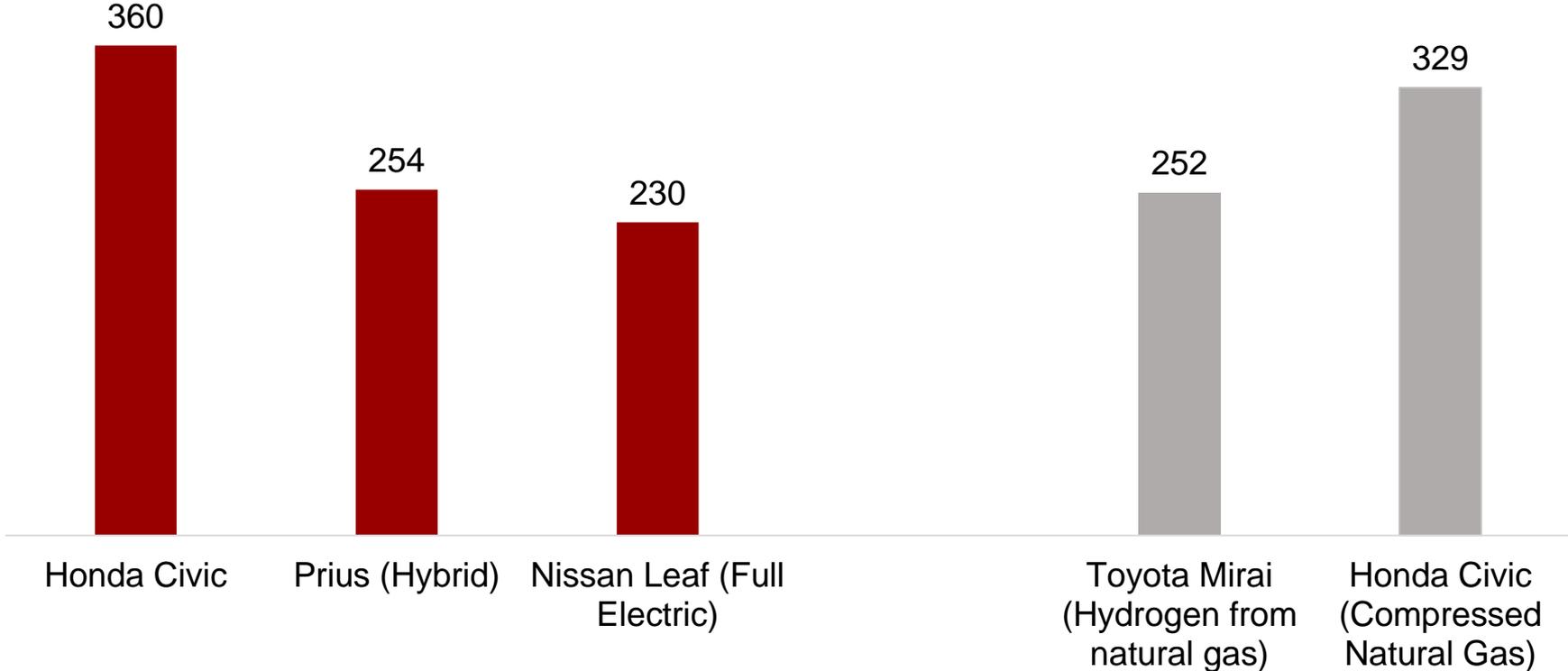
SHARE OF U.S. GHG EMISSIONS



Note: Totals may not add to 100% due to rounding
Source: Environmental Protection Agency (2014)

Today's natural gas cars can help lower emissions

Emissions (gCO₂e per mile)



Source: National Renewable Energy Laboratory

How can natural gas help?

Natural gas vehicles are cleaner than today's conventional vehicles. There are three main types of cars that can be run directly or indirectly on natural gas:



Honda Civic CNG

- 1 Natural gas vehicles** that run directly on compressed natural gas (CNG) or liquid natural gas (LNG)



Chevy Volt

- 2 Electric vehicles** and/or electric hybrids powered by a grid dominated by natural gas power plants



Toyota Mirai

- 3 Hydrogen vehicles** Powered by hydrogen derived from natural gas reforming or water splitting with natural gas energy

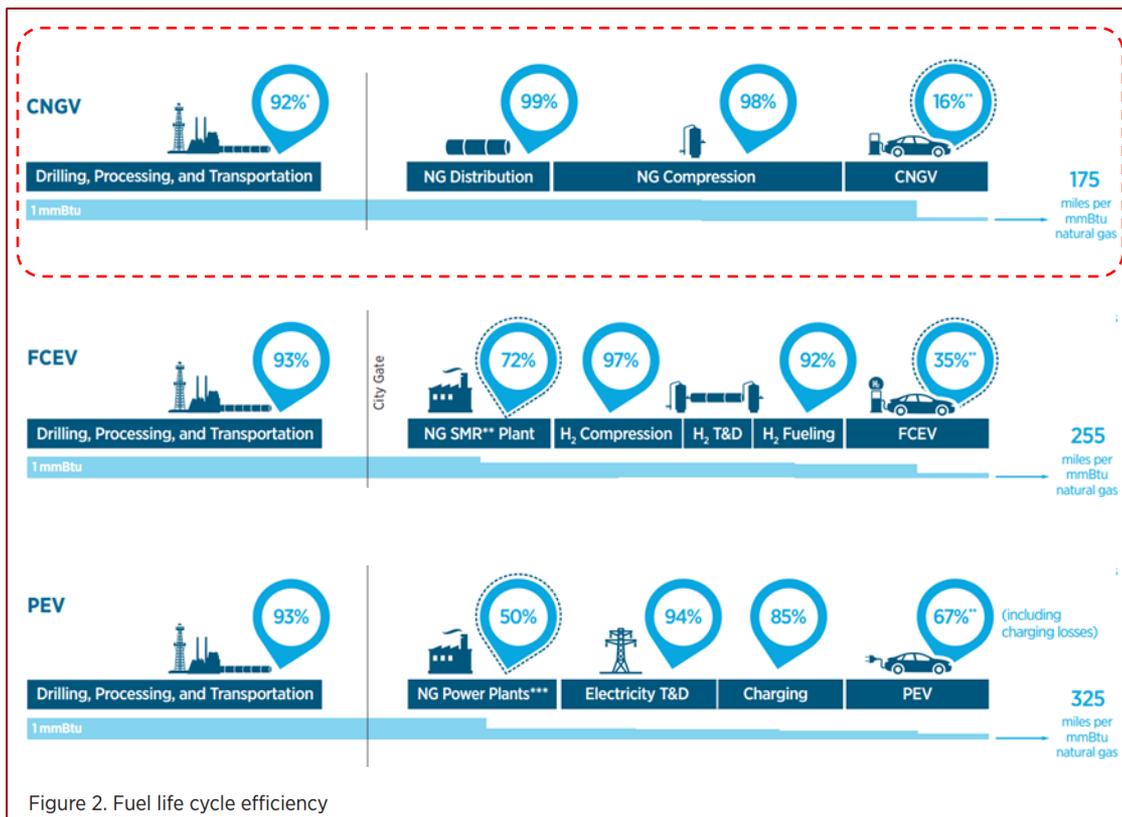
1 Natural gas vehicles

Benefits

- Natural gas cars run cleaner than conventional gasoline cars. Per mile, they can reduce carbon emissions by about 6-11%. The emission benefits vary by study, assumptions and specific use cases.

Challenges

- Very little **built infrastructure**
- Range anxiety (Requires more frequent fill ups because the fuel is not energy dense)
- Less cargo space (needs large fuel tank)



2 Hydrogen fuel cell vehicles

Benefits

- Hydrogen fuel cell vehicles produce zero emissions when driven. Hydrogen fuel is most commonly made from natural gas, but can also be made by splitting water into hydrogen and oxygen
- The U.S. Department of Energy projects that a mid-size Fuel Cell Vehicle around 2040, powered by hydrogen from natural gas, will have lifecycle GHG emissions about 15% lower than that for an hybrid electric vehicle powered by gasoline

Challenges

1. Very little **built infrastructure**
2. Poor consumer knowledge
3. Cost competitiveness
4. New safety considerations

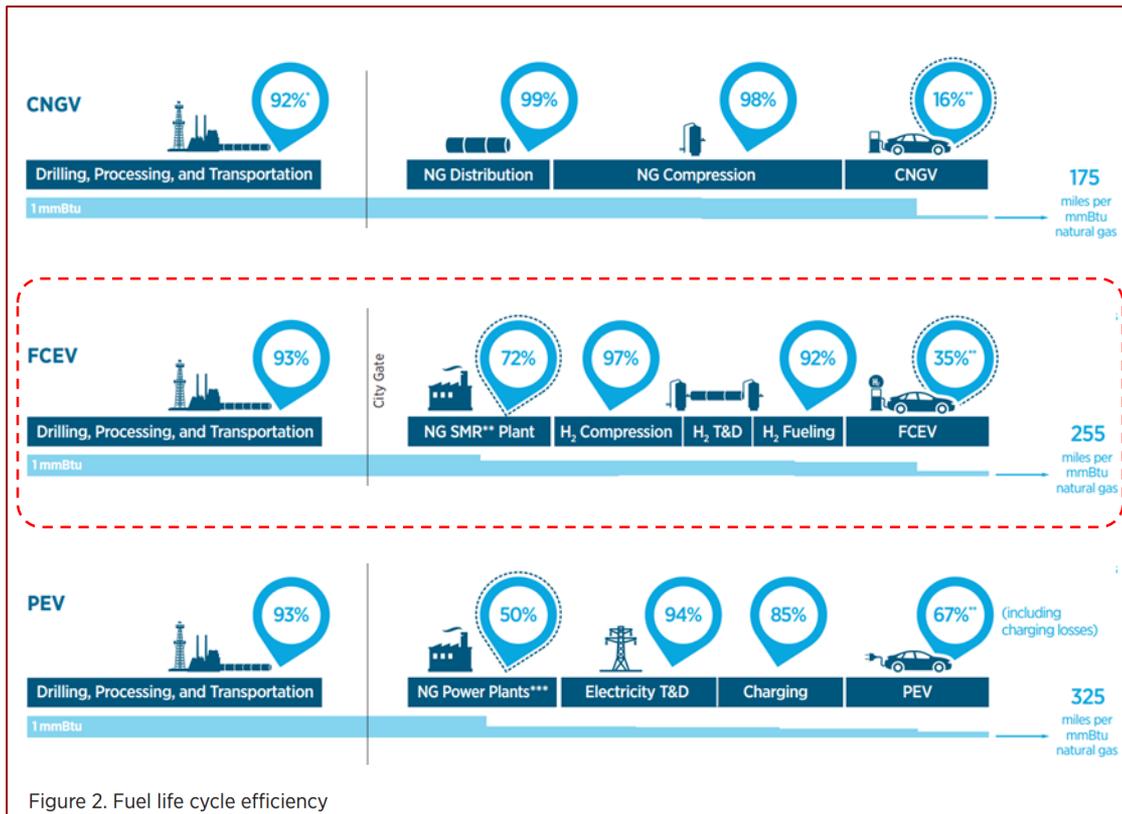


Figure 2. Fuel life cycle efficiency

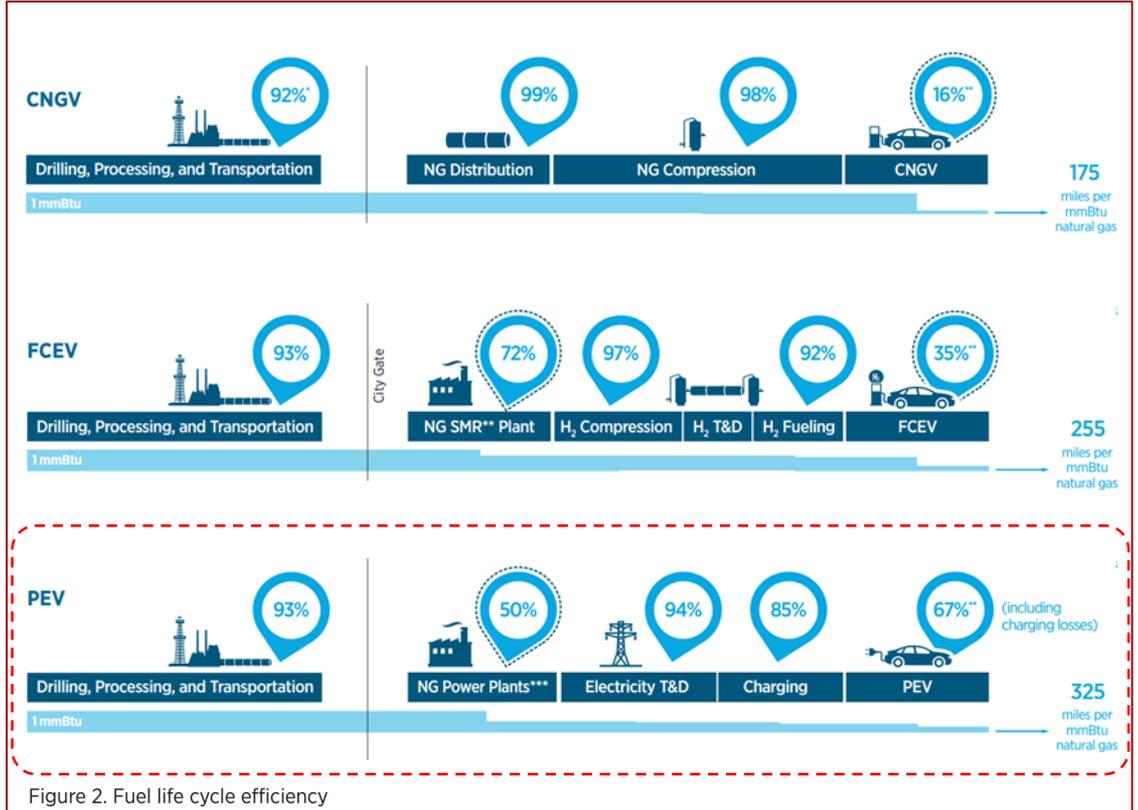
3 Electric vehicles

Benefits

- Hybrid and battery electric vehicles are already cleaner than the average gasoline vehicle across the country. With a continued transition from coal to natural gas, miles per gallon will increase

Challenges

- Requires massive build out in infrastructure (e.g. charging stations)
- Limited battery range
- Cost competitiveness



Natural gas cars could be zero-emission

Technologies coming down the pipeline could make natural gas cars cleaner and cheaper

- A new natural gas power plant (NET Power) that is built to capture carbon could create electricity with zero emissions and at prices cheaper than natural gas combined cycle power plants
- A hybrid hydrogen, electric vehicle system can decrease production costs and improve performance

Advanced vehicles also have longer range

Natural Gas Internal
Combustion Engine

175 miles

390

gCO₂e/mi



Fuel Cell Vehicle on Hydrogen
from Natural Gas

255 miles

255

gCO₂e/mi



Electric Vehicle on Electricity
from Natural Gas

325 miles

200

gCO₂e/mi



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.