ENERGY SOLUTIONS CENTER

Track: Commercial Natural Gas I

Unit # 7: Alternative Fuel Vehicles

An overview of the Alternative Fuel Marketplace

Eric Burgis, Energy Solutions Center

1

Overview

- Alternative Fuel Market Background
- Vehicles
- Codes
- Fueling stations and Options
- Infrastructure
- New Technologies
- Alternative Fuels
- Resources

ESC

2

Alternative Fueled Vehicles / Natural Gas Vehicles

Natural gas vehicles can reduce emissions from the transportation sector, currently the largest source of emissions in the United States and second largest in Canada.

3

Why use CNG as a transportation fuel?

- **C**ompressed **N**atural **G**as is *Clean, American, Affordable & Abundant*
- CNG is the same natural gas that is piped into millions of homes for heating, domestic water heating and cooking
- CNG is better for the environment than traditional transportation fuels: approximately 25% lower levels of CO_2than gasoline, and 27% lower than diesel (*)

Carbon Dioxide (CO_2) Factors:	Pounds CO_2 Per Unit of Volume or Mass	Kilograms CO_2 Per Unit of Volume or Mass	Pounds CO_2 Per Million Btu	Kilograms CO_2 Per Million Btu
Diesel and Home Heating Fuel (Distillate Fuel Oil)	22.45 gallon	10.19 gallon	163.45	74.14
Natural Gas	120.96 thousand cubic feet	54.87 thousand cubic feet	116.65	52.91
Finished Motor Gasoline[a]	17.86 gallon	8.10 gallon	148.57	67.39
Motor Gasoline	19.37 gallon	8.78 gallon	155.77	70.66

a Includes fuel ethanol blended into motor gasoline.

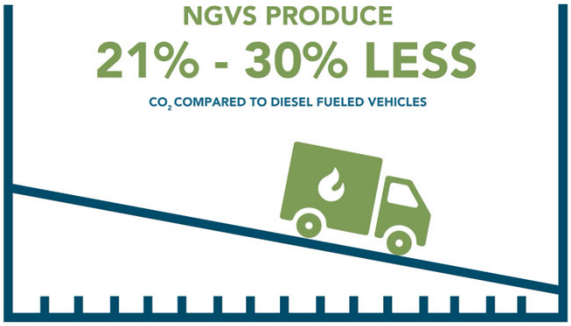
ESC

(http://www.afdc.energy.gov/vehicles/natural_gas_emissions.html)
(*) https://www.eia.gov/tools/faqs/faq.php?id=73&t=11

4

Emissions Benefits of Natural Gas Vehicles

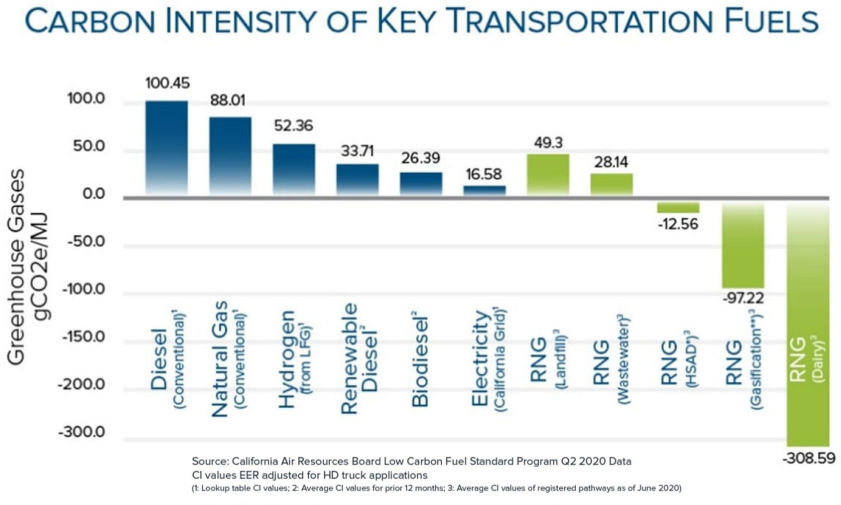
- One of the primary advantages of NGVs is that they produce significantly less tail pipe emissions than diesel vehicles. The adoption of NGVs can be an effective strategy to reduce transportation-related emissions and comply with stricter clean air regulations.



https://natural-resources.canada.ca/sites/www.nrcan.gc.ca/files/oee/pdf/transportation/alternative-fuels/resources/pdf/roadmap.pdf

5

Transportation Fuel Carbon Intensities



Source: California Air Resources Board Low Carbon Fuel Standard Program Q2 2020 Data
CI values EER adjusted for HD truck applications
(1: Lookup table CI values; 2: Average CI values for prior 12 months; 3: Average CI values of registered pathways as of June 2020)

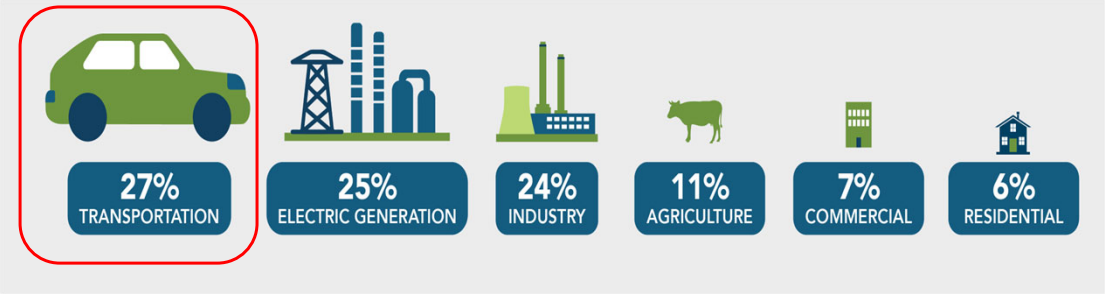
*HSAD, or High Solid Anaerobic Digestion, converts organics (e.g., food and green waste) into RNG.
**Gasification is a thermochemical process that converts organics (e.g., forest biomass) into RNG.

6

https://www.act-news.com/news/fitting-renewable-fuels-into-your-fleets-sustainability-strategy/

Greenhouse Gas Emissions by Sector

27% of greenhouse gas emissions in the U.S. comes from the transportation sector

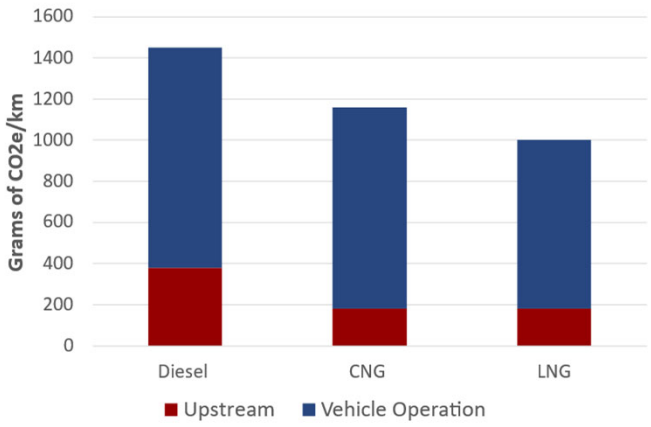


*Total U.S. Greenhouse Gas Emissions by Economic Sector in 2020

ESC

7

Emissions Benefits of Natural Gas Vehicles



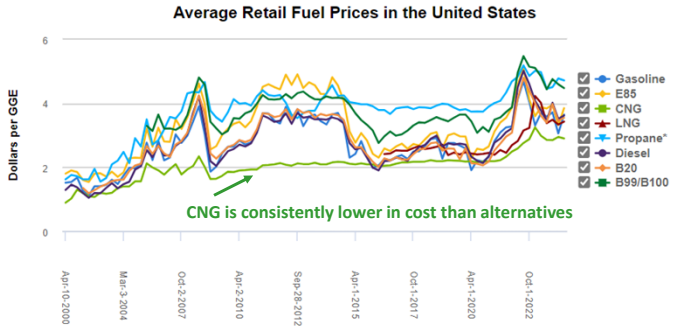
ESC

Source: Natural Gas Use in Transportation Roundtable, "Natural Gas Use in the Canadian Transportation Sector"

8

Fuel Costs

- Natural gas varies in cost from ~$0.50–$1.00 *less* per gasoline gallon equivalent (GGE)
- One GGE of natural gas is 123.57 cubic feet (3.4991 m^3)



National Average Price Between April 1 and April 15, 2024	
Fuel	Price
Biodiesel (B20)	$3.94/gallon
Biodiesel (B99-B100)	$4.57/gallon
Ethanol (E85)	$2.96/gallon
Natural Gas (CNG)	$2.90/GGE
Liquefied Natural Gas	$3.85/DGE
Propane	$3.45/gallon
Gasoline	$3.65/gallon
Diesel	$4.07/gallon

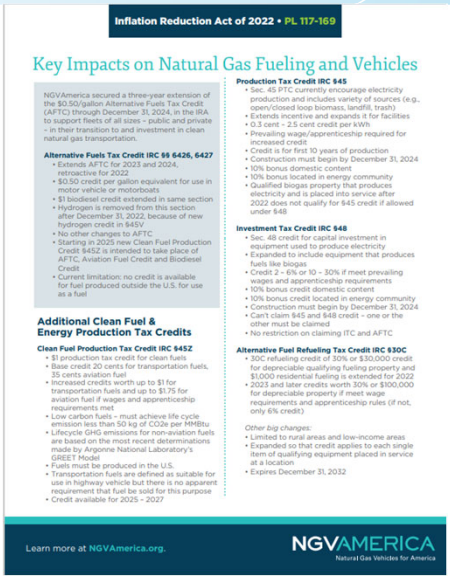
Alternative Fuel Price Report, April 2024,
https://afdc.energy.gov/fuels/prices.html

https://afdc.energy.gov/fuels/

9

Alternative Fuel Tax Credit

- LNG = $.50 per Deisel Gallon Equivalent (DGE)
- CNG = $. 50 per Gasoline Gallon Equivalent (GGE)
- State Incentives, https://afdc.energy.gov/fuels/laws/NG
- Federal Incentives, https://afdc.energy.gov/fuels/laws/NG?state=US



https://transportproject.org/wp-content/uploads/2022/08/NGV-Inflation-Reduction-Act-Fact-Sheet-8.24.22.pdf

10

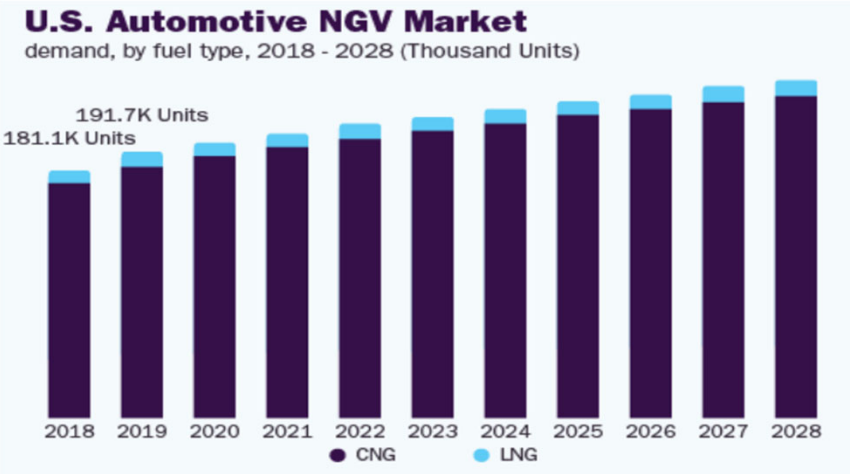
What is a GGE?

	Gasoline/E10	Low Sulfur Diesel	Biodiesel	Propane (LPG)	Compressed Natural Gas (CNG)	Liquefied Natural Gas (LNG)	Ethanol/E100	Methanol	Hydrogen	Electricity
Energy Comparison, Gasoline Gallon Equivalent (GGE)	1 gallon of gasoline has 97%–100% of the energy in 1 GGE. Standard fuel is 90% gasoline, 10% ethanol.	1 gallon of diesel has 113% of the energy in 1 GGE due to the higher energy density of diesel fuel.	1 gallon of B100 has 93% of the energy in 1 DGE, and 1 gallon of B20 has 99% of the energy in 1 DGE due to a lower energy density in biodiesel.	1 gallon of propane has 73% of the energy in 1 GGE due to the lower energy density of propane.	5.66 lb., or **123.57 ft^3, of CNG has the same energy as 1 GGE**, and 6.37 lb., or **139.30 ft^3, of CNG has the same energy as 1 DGE.**	5.37 lb. of LNG has the same energy as 1 GGE, and 6.06 lb. of LNG has the same energy as 1 DGE.	1 gallon of E85 contains 73%–83% of the energy in 1 GGE. 1 gallon of E100 has 67% of the energy in 1 GGE.	1 gallon of methanol contains 50% of the energy as 1 GGE.	2.2 lbs. (1 kg) of H_2 has the same energy as 1 GGE.	A typical battery that is the same size as a gallon of gas (0.134 ft^3), when used for transportation, can store 15.3% of the energy in 1 GGE.
Energy Content (lower heating value)	112,114–116,090 Btu/gal	128,488 Btu/gal	*B100*=119,550 Btu/gal *B20*=126,700 Btu/gal	84,250 Btu/gal	20,160 Btu/lb	21,240 Btu/lb	76,330 Btu/gal for E100	57,250 Btu/gal	51,585 Btu/lb 33.3 kWh/kg	3,414 Btu/kWh
Energy Content (higher heating value)	120,388–124,340 Btu/gal	138,490 Btu/gal	127,960 Btu/gal for B100	91,420 Btu/gal	22,453 Btu/lb	23,726 Btu/lb	84,530 Btu/gal for E100	65,200 Btu/gal	61,013 Btu/lb	3,414 Btu/kWh

ESC https://afdc.energy.gov/fuels/properties

11

NGV Market is Growing



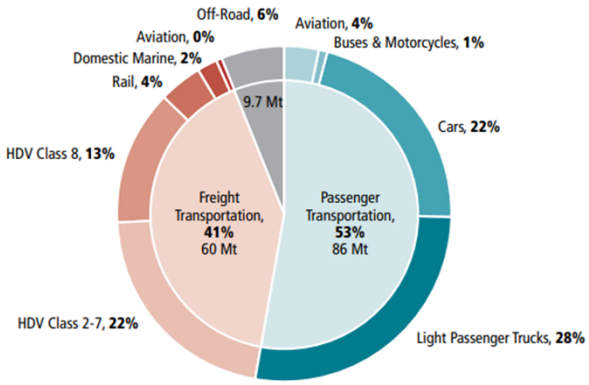
ESC

12

https://www.grandviewresearch.com/industry-analysis/automotive-natural-gas-vehicles-market

Vehicle Emissions in Canada

Greenhouse Gas Emissions by Vehicle Type in Canada



https://www.nrcan.gc.ca/resource-library/natural-gas-use-medium-and-heavy-duty-vehicle-transportation-sector-roadmap-20-june-2019/22111

13

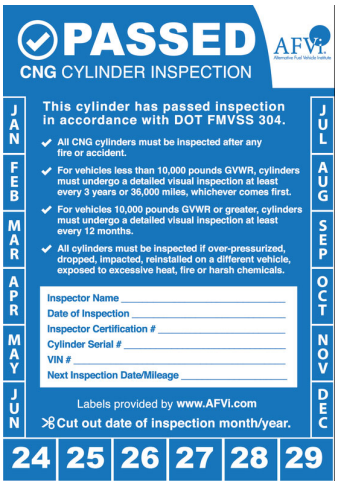
NGV Safety

- Safety of CNG vehicles is on par or higher than with gasoline
- The pressurized tank is built to withstand severe impact, temperature and environment exposure
- CNG is lighter than air. It evaporates quickly into the atmosphere when there is a leak instead of collecting as a puddle under the car like gasoline
- Natural gas has very limited flammability – it will not burn at concentrations below 5% or above about 15% when mixed with air

14

NGV Safety

- Gasoline and diesel burns at much lower concentrations and ignite at lower temperatures
- Natural gas is non-toxic when evaporated into air
- CNG storage tanks also have an automatic relief valve that is activated by temperature only (i.e. in case of thermal event)
  - When the temperature is excessive the valve will open and release the gas into the atmosphere to reduce the pressure



https://afvi.com/resources/cng-fuel-system-inspection-labels/

15

NGV Benefits

- Environment friendly
- No loss in performance
- Cost savings – CNG vs. other fuel(s)
- Extended maintenance intervals
- Operational flexibility
  - Extended driving range with dual fuel system

16

CNG vs LNG

CNG

- **Production** – Compressed natural gas, or CNG, is natural gas stored and transported under high pressure in its gaseous form, making it lighter than air. CNG is produced by compressing natural gas to less than 1 percent of its volume at standard atmospheric pressure. CNG is safer than gasoline and diesel because it is nontoxic and disperses quickly.
- **Transportation** – After exiting the ground or extracted from a biodigester, natural gas is transported by pipeline or by virtual pipeline via tanker truck where it is compressed and stored at 3,600 pounds per square inch (PSI).
- **Delivery** – CNG is transferred from storage to a CNG vehicle through a fill nozzle and receptacle.

LNG

- **Production** – Liquefied natural gas, or LNG, is natural gas stored and transported as a liquid. After being sourced from the ground or from methane-producing waste products, LNG is produced by purifying natural gas and super-cooling it to -260 degrees Fahrenheit through a process called cryogenic liquefaction.
- **Transportation** – LNG is transported via insulated truck, rail, or ship to LNG stations for distribution as a transportation fuel. Because of its greater fuel density and lower weight storage, LNG is an ideal fuel for high horsepower and long-distance transportation needs since it requires fewer tanks and space requirements.
- **Delivery** – Like CNG, LNG can be dispensed through a fill nozzle and receptacle for on-road applications.

ESC

17

NGV Markets

- Buses
  - School
  - Municipal
- Local Delivery
- Long Haul Delivery
- Utility Fleets

ESC

18

CNG Heavy Duty Vehicles




ESC

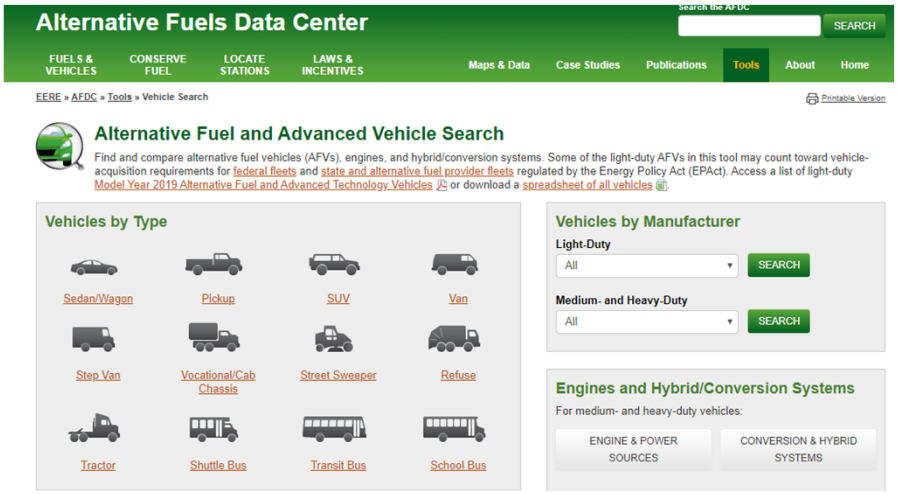
19

Natural Gas Vehicles

Vehicle Development

20

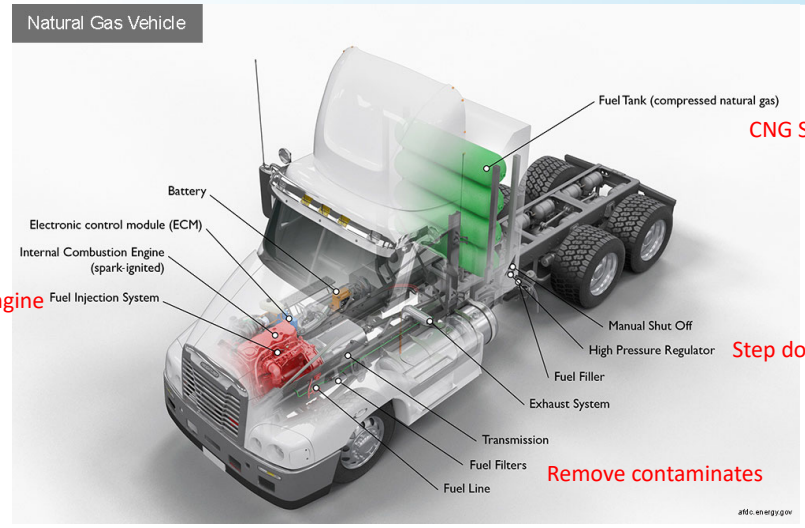
Available Vehicles



https://www.afdc.energy.gov/vehicles/search/

21

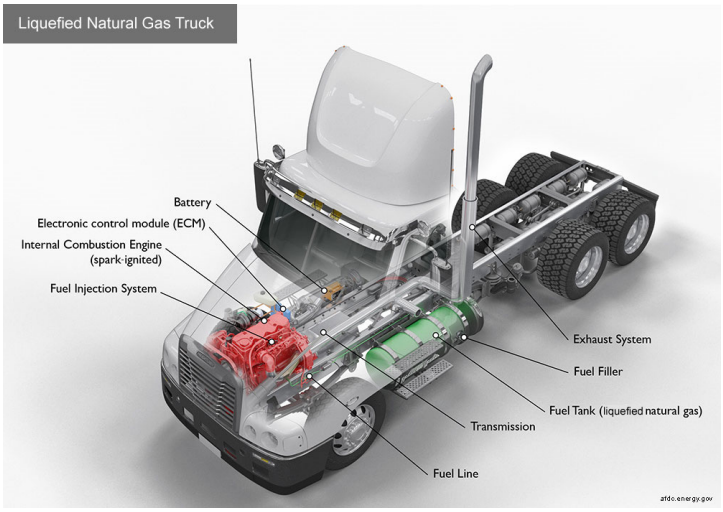
Class 8 CNG Truck



https://afdc.energy.gov/vehicles/how-do-natural-gas-class-8-trucks-work

22

LNG Truck

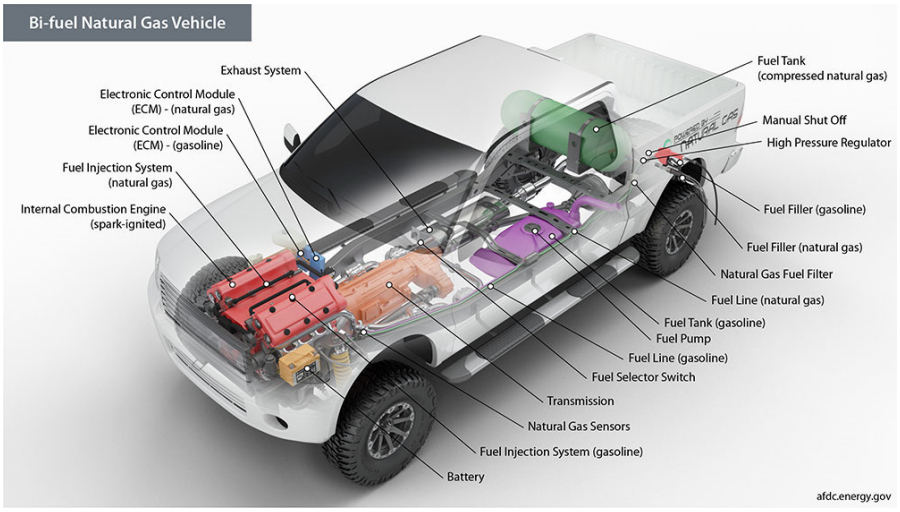


ESC

https://afdc.energy.gov/vehicles/how-do-lng-cars-work

23

Bi-Fuel Vehicle



ESC

https://afdc.energy.gov/vehicles/how-do-bifuel-natural-gas-cars-work

24

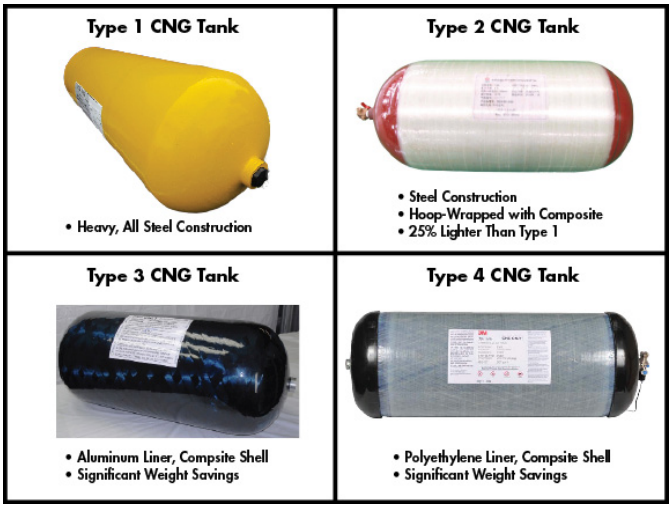
Available Vehicles

- Vehicles available as approved conversions and factory direct equipment
- Vehicle types
  - Heavy Duty
  - Heavy Haul
  - Specialty Vehicles - Sweepers
  - Sedans, Trucks & SUVs
- All aftermarket vehicles are offered as modifications to original equipment manufacturer (OEM) gasoline or diesel fueled vehicles

ESC

25

CNG Tanks



ESC

26

https://evmc2.files.wordpress.com/2015/03/04-tanks.jpg

Type 1 CNG Tank - Steel

- Solid steel
- 1st CNG storage tank available
- Steel walls of Type 1 CNG storage tanks are approx. 0.5 to 1.5” thick
- Heaviest type of CNG storage tanks
- Diameter of 11 inches for the smallest and 16 inches for largest
- Reliable & durable
- Low initial cost
- Good for bulk transportation or stationary ground storage

https://astforgetech.com/compressed-natural-gas-cng-storage-options-ultimate-guide/#Type_1_CNG_Storage_Overview

27

Type 2 CNG Tank – Steel & Composite

- Steel liner
- Hoop wrapped with one of the following composite fibers
  - Fiberglass
  - Carbon fiber
  - Wire
- Metal liner allow for storage pressure while wrap adds a safety factor
- Lighter than Type 1 tanks but heavier than Type 3 & 4 tanks

https://www.g3industries.com/page/pst-type-2-cng-cylinders

https://astforgetech.com/compressed-natural-gas-cng-storage-options-ultimate-guide/#Type_1_CNG_Storage_Overview

28

Type 3 CNG Tank – Aluminum & Carbon Fiber

- Aluminum liner
- Fully wrapped in carbon fiber
- Can hold very high pressures
  - 3600 PSI service pressure
  - Can store much higher pressures than 3600 PSI
- Aluminum liner holds more volume than other tanks of same dimension
- Lighter than Type 1 & 2 tanks
- Highest manufacturing cost of the 4 tank types
- Best tank for bulk transportation

ESC

https://astforgetech.com/compressed-natural-gas-cng-storage-options-ultimate-guide/#Type_1_CNG_Storage_Overview

29

Type 4 CNG Tank – Polymer & Carbon Fiber

- Non-metallic liner (Polymer)
- Wrapped in carbon fiber
- Lightest of the 4 tanks
- Used for on-site storage at refueling stations
- Great for CNG vehicle use

https://ngtnews.com/altech-eco-chooses-cobham-type-4-cng-cylinders

ESC

https://astforgetech.com/compressed-natural-gas-cng-storage-options-ultimate-guide/#Type_1_CNG_Storage_Overview

30

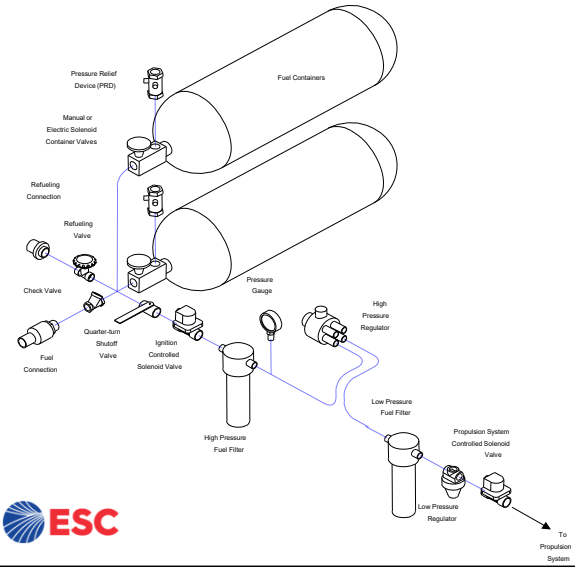
Type 3 vs Type 4 Tanks

Type 3	Type 4
Aluminum liner	HDPE liner
More expensive due to the aluminum liner material and the associated manufacturing cost	Lower cost raw material and reduced manufacturing cost
Best for bulk transportation and bulk storage	Best for slow fill CNG refueling stations
More durable because of the fabrication process	Polymer wears off after a few years
Resistant to heat exposure during the filling process	Lower heat resistance

https://astforgetech.com/compressed-natural-gas-cng-storage-options-ultimate-guide/#Type_1_CNG_Storage_Overview

31

CNG System Explanation



- Typical CNG Fuel System Includes:
  - Fill Receptacle
  - CNG container(s) assemblies (containers, solenoid valve, manual valve, etc)
  - Pressure relief device (PRD) system
  - High pressure filter
  - Pressure regulator
  - Low pressure filter
  - Fuel rail assembly (fuel rail and injectors)

32

Codes & Standards

33

Codes and Standards

- Designed to standardize connectors, on-board storage and on-site storage vessels
- Specifications for dispensers and dispensing equipment
- Primary authors
  - ANSI – American National Standards Institute
  - CGA - Compressed Gas Association
  - NFPA - National Fire Protection Association
  - SAE - Society of Automotive Engineers
  - CSA – Canadian Standards Association

https://ngtnews.com/socalgas-onboard-dynamics-to-test-mobile-cng-refueling-solution

ESC

34

Codes and Standards

- Principle Codes, Standards and Advisories applicable to NGVs and Infrastructure
  - NFPA 52 – Vehicular Gaseous Fuel Systems Code - new edition approved in 2019
  - ANSI NGV2 2017 Compressed Natural Gas Vehicle Fueling Connection Devices
  - ANSI NGV2 2019 Addendums 2a and 2b – Basic Requirements for Compressed Natural Gas Vehicle Fuel Containers

Complete Listing at cleanvehicle.org

35

Fueling Stations

36

Fueling Station Options

- Type of Fueling Stations
  - Time Fill Station
  - Fast Fill Stations
  - Combination Stations
  - LNG
- Public Fueling Stations
- Private Fueling Stations

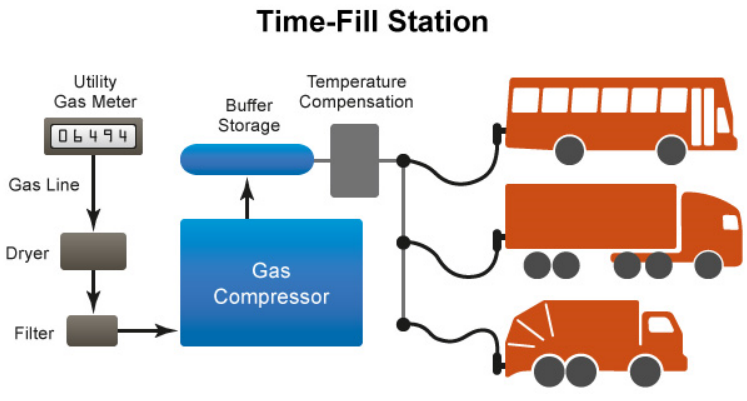
https://nelsonpope.com/portfolio/cng-fueling-station-at-elizabethtown-gas/

ESC

37

Time Fill Stations

- Use conventional reciprocating compressors
- Fuel line directly connected to vehicle
- Vehicle fueled over hours from compressor
- Used primarily by fleets and work best for vehicles with large tanks that refuel at a central location every night
- Generally filled directly from the compressor, not from fuel stored in high pressure vessels



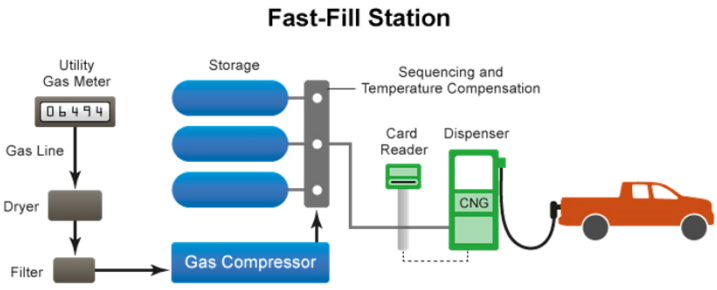
https://afdc.energy.gov/fuels/natural-gas-stations

ESC

38

Fast Fill Stations

- Use conventional reciprocating compressors
- Fuel compressed and stored in large tanks
- Vehicle fueled in minutes
- Best suited for retail situations where vehicles arrive randomly and need to fill up quickly
- Ideal for Public Fueling Stations and Fleet Operations that require rapid fueling
  - Transit systems
  - Short haul trucking firms
  - Shuttle services
- CNG typically stored at 4300 PSI



https://afdc.energy.gov/fuels/natural-gas-stations

39

Fast Fill Station

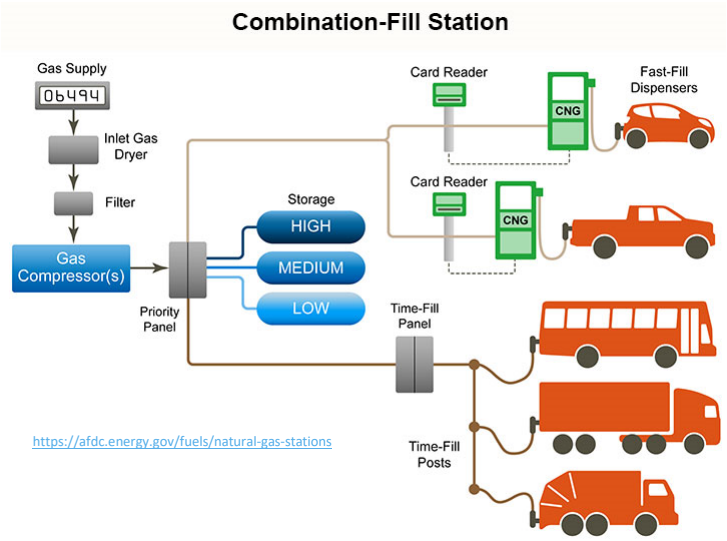
http://cleanngreenfuel.com/ny/

http://www.fleetsandfuels.com/wp-content/uploads/KwikTripnight-e1335803641906-1024x310.jpg

40

Combination Stations

- Combination-fill stations include both the fast-fill and time-fill components in one system
- The vehicles connected to the time-fill posts are filled directly from the compressor, usually overnight.
- Vehicles at the fast-fill dispensers are filled from the storage vessels or from the compressor, depending upon need

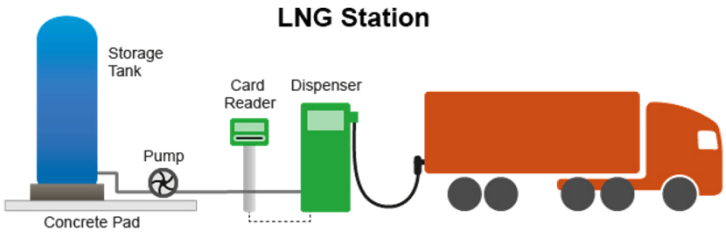


https://afdc.energy.gov/fuels/natural-gas-stations

41

LNG Stations

- Structurally similar to gasoline and diesel stations
- Have a storage tank, meters,& dispenser
- LNG dispensers deliver fuel to vehicles at pressures of 30 to 120 psi
- Because LNG is stored and dispensed as a super-cooled liquefied gas, protective clothing, face shield, and gloves are required when fueling a vehicle, and personnel must also be trained on fueling procedures

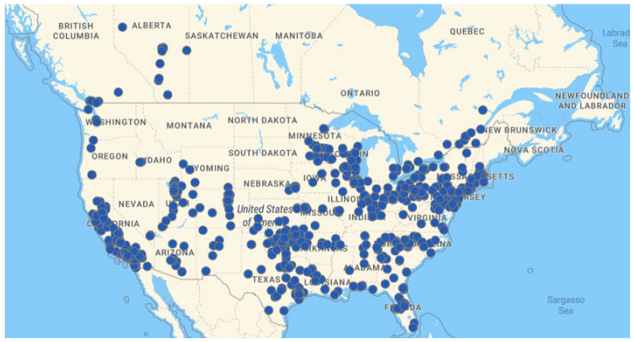


https://afdc.energy.gov/fuels/natural-gas-stations

42

CNG Fueling Public Stations

CNG = 776



LNG= 50

Hydrogen= 62

https://afdc.energy.gov/fuels/natural_gas_locations.html#/find/nearest?fuel=CNG

Infrastructure

44

Building the Infrastructure

- Options
  - Utility builds and rate bases the cost of the facility
  - Work with other entities to build infrastructure
    - Loves - Trillium CNG
    - Clean Energy
    - US Gain
    - True Star Energy
    - Others
  - Virtual Pipeline

ESC

45

Utility Station Issues

- Public access to fueling locations
- Maintenance
- Billing/Collections
- Facility liabilities

https://www.dranderson.com/cng-filling-stations

ESC

46

Virtual Pipelines

- Supplement conventional pipeline
  - To reach customers who are in difficult to reach locations
  - Used during times of peak demand
  - Used to alleviate pipeline congestion
  - Used when repairing pipelines

ESC

47

New Technologies

- Ultra Low Emissions Engines
- Low Pressure Storage
- Conforming Tank

48

Near Zero Emissions Engine Development

- NGVs engines meet the strictest emission standards, including California's Low NOx Emissions standard
  - CA Optional Low NOx Standard is 90% lower than the current EPA standard of 0.02 gr/bhp-hr

https://www.eia.gov/outlooks/aeo/

CWI 6.7N

CWI L9N

CWI ISX12N

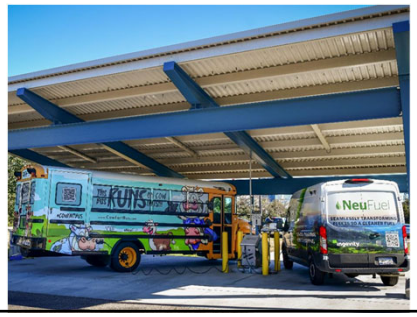
Tank Development

- Lower Pressures
- Weight of tank
- New Materials:
  - Ingevity's Nuchar® FuelSorb™ activated carbon monoliths

NueFuel Product Line

- Light Duty Trucks (new & used vehicles):
  - 6.2 L Ford F-250 (2020 – 2022)
  - 6.8 L Ford F-250 (2023+)
  - 3.5 L PFDI Ford Transit (2020 – Pres)
  - 5.0 L Ford F-150 (2020 – Present)
- In-Service Diesel School Bus for Cummins 6.7 (covers 8 model yrs)

NeuFuel



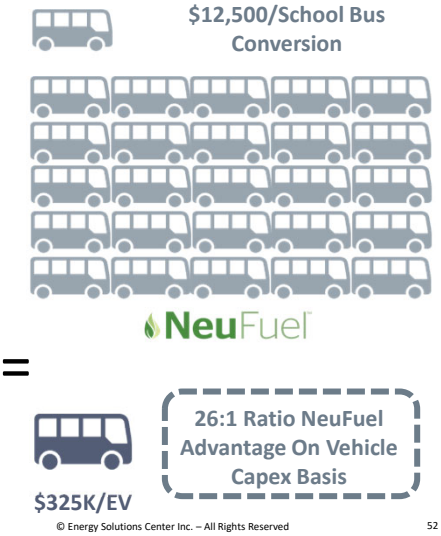
ESC

NeuFuel Presentation at ESC TMAF April 12, 2024

51

NueFuel versus EV Busses

- **Low-Cost Conversion**
  - $12,500 per bus – tank & installation
  - $2,500/bus refueling appliance
- **Fleet Savings and Economics**
  - Reduction in fuel costs to $1 per DGE for displaced diesel
  - Annual fuel savings of $3,200/bus
  - 4.5-year payback implying 18% 10-year IRR
  - Convert 26 in-place diesel school buses for cost of 1 EV



ESC

NeuFuel Presentation at ESC TMAF April 12, 2024

52

Stations Carrying Alternative Fuels

- Developed Alternative Fuels Fueling Station for all alternate fuels
  - CNG (compressed natural gas)
  - LNG (liquid natural gas)
  - Propane
  - Biodiesel (B5, B20)
  - E-85
  - Various EV charging systems

ESC

53

Alternative Fuel Options

54

Alternative Fuel Options

- CNG
- RNG
- LNG
- Hydrogen
- Electric

55

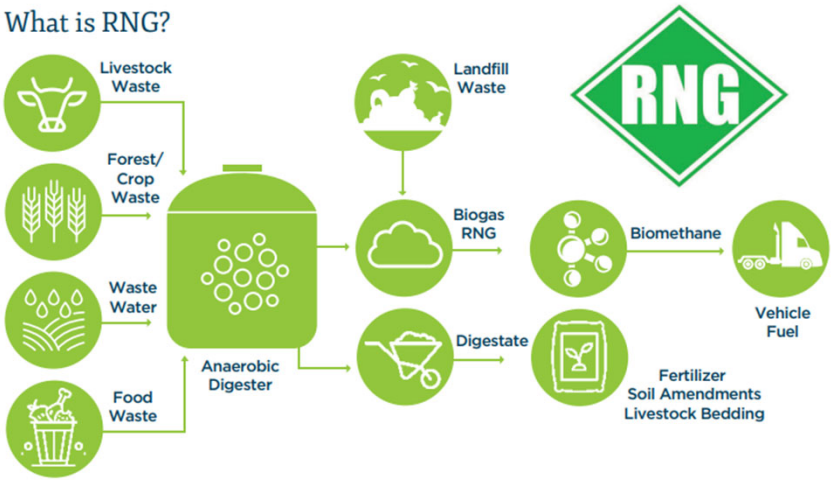
Compressed Natural Gas (CNG)

- Natural Gas in Gaseous Form
- Can be transported to fueling stations or stored in pressurized tanks[1]
- Takes up less space compared to conventional natural gas
- Used in a range of on-road vehicles

[1]Energy Education, Compressed Natural Gas, 2018

56

Renewable Natural Gas - RNG



https://transportproject.org/wp-content/uploads/2023/04/NGV-Fly-In-4pg-final.pdf

RNG Production & Feedstocks

- *Landfill gas (LFG)*
- *Animal manure*
- *Water resource recovery facilities (WRRF)*
- *Food waste*

- *Agricultural residue*
- *Forestry and forest product residue*
- *Energy crops*
- *Municipal solid waste (MSW)*

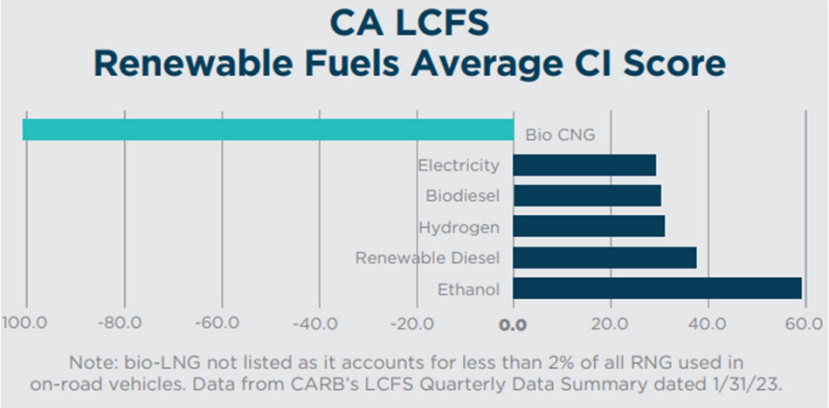
- *Renewable electricity*

58

https://gasfoundation.org/wp-content/uploads/2019/12/AGA_3894-RNG-2-Pager_V-11.pdf

RNG: Carbon-negative Transportation Fuel

RNG can be carbon negative when used in Vehicles. The energy weighted carbon intensity (CI) values of California's RNG vehicle fuel portfolio (bio-CNG) is below zero at -111.7 gC02e/MJ

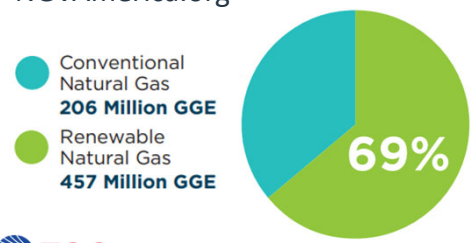


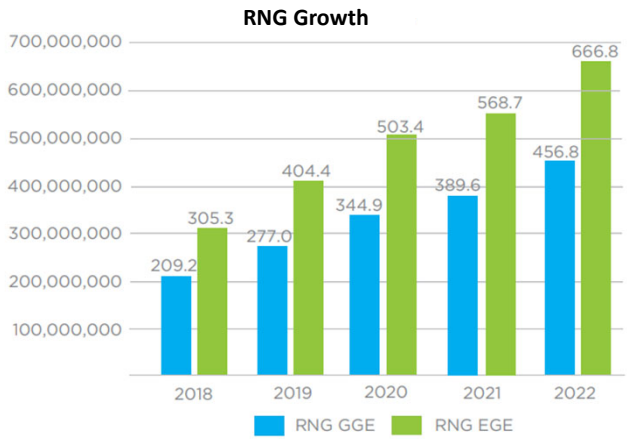
https://transportproject.org/wp-content/uploads/2023/04/NGV-Fly-In-4pg-final.pdf

59

RNG Transportation Fuel Growth

- RNG offers potential negative carbon footprint that no other alternative fuel offers
- 69% of all on-road fuel used in natural gas vehicles is RNG
- More details are available on NGVAmerica.org





https://transportproject.org/wp-content/uploads/2023/04/NGV-RNG-Decarbonize-CY-2022-FINAL.pdf

60

Liquefied Natural Gas (LNG)

- Cooled Into A Liquid
- Kept At Very Low Temperatures For Storage And Shipping
- Takes Up Less Volume Than CNG[2]
- Used In A Range Of On-Road Vehicles

[1]Energy Education, Compressed Natural Gas, 2018. [2]U.S. DOE, Liquified Natural Ga

ESC

61

Liquified Natural Gas (LNG)

- LNG is not intended for long-term storage in vehicle fuel tanks
- Pressure in the fuel tank will increase to approximately 230 PSI and the primary pressure relief valve will vent a limited amount of the gas to atmosphere.
- A secondary pressure relief valve also exists on every LNG tank in case of primary relief valve failure.
- As required by codes in the USA and Canada, LNG vehicle tanks are designed to contain the LNG for at least 5 days without venting
- It is extremely rare for gas to be vented through the pressure relief valves as few commercial operators have trucks immobile for five days, and pressure is typically relieved as fuel is consumed during normal operation of a vehicle
- Vent stack plumbing exists from the primary pressure relief valve so that the gas is released in a well-ventilated area near the top of the vehicle

https://www.kinetrexenergy.com/definitive-guide-lng-fleets/

ESC

62

LNG Safety

- In case of a leak, the vehicle's methane detection system will sound an audible and visual alarm at 20% of the lower flammable limit.
- Methane detectors exist in the engine and driver compartments and in any enclosed compartment that contains fuel tanks
- All buildings containing LNG will also be equipped with methane detectors that activate audible and visual latched alarms both inside and outside the buildings at 20% of the lower flammable limit
- Fuel tanks and plumbing are potential fire hazards if they leak
- Vehicle fire will have no effect on LNG contained within the tank because of the safeguards built into the LNG tank
- Most LNG vehicle fires originate from components on the vehicle having no relationship to the LNG fuel system

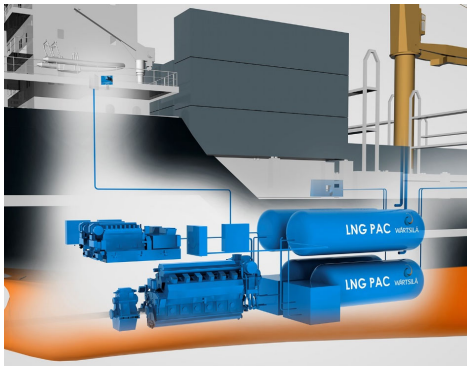
https://www.kinetrexenergy.com/definitive-guide-lng-fleets/

ESC

63

LNG Vehicle Opportunities

Truck using LNG as Fuel



Ship using LNG as Fuel

ESC

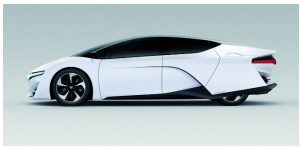
64

Hydrogen Vehicles

HD Transit Bus

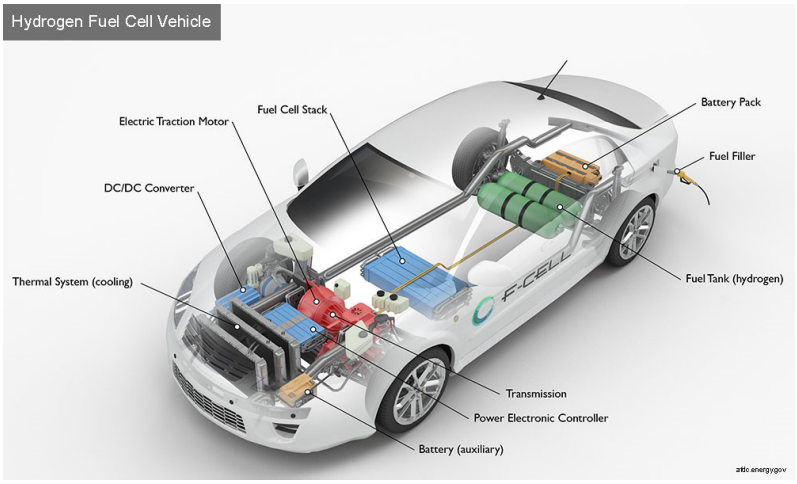
HD Truck

LD Vehicle



65

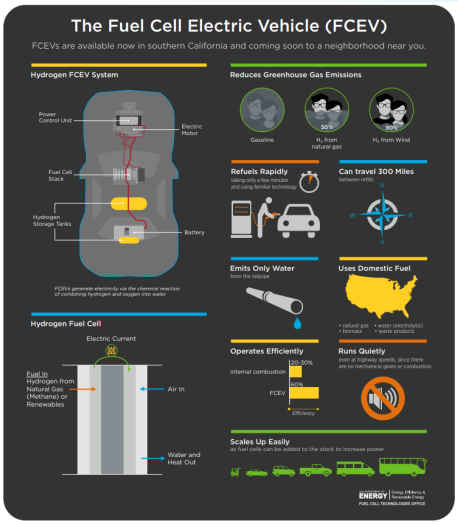
Hydrogen Fuel Cell Electric Vehicles



https://afdc.energy.gov/vehicles/how-do-fuel-cell-electric-cars-work

66

Hydrogen Fuel Cell Electric Vehicles



https://www.energy.gov/sites/prod/files/2015/07/f24/fcto_fcev_infographic_0.pdf

Benefits

- Zero Greenhouse Gas Emissions, emits only water vapor
- Eliminate pollution caused by burning fossil fuels
- Superb daily reliability and long-term durability
- Minimal cold-weather effects compared with battery electric vehicles
- Longer range than traditional electric vehicles: 300+ miles
- Quiet and smooth EV operation
- Full Refueling in under 10 minutes

HFCEV – Light Duty

	2020 Honda Clarity	2020 Hyundai Nexo	2020 Hyundai Nexo Blue	2020 Toyota Mirai
				Photo Not Available 
Fuel Economy				
Mi/Kg	66 comb / 67 city / 66 hwy	56 comb / 58 city / 53 hwy	60 comb / 64 city / 56 hwy	66 comb / 65 city / 66 hwy
MPGE	68 comb / 68 city / 67 hwy	57 comb / 59 city / 54 hwy	61 comb / 65 city / 58 hwy	67 comb / 67 city / 67 hwy
Other Estimates				
Range (miles)	360	354	380	312
Vehicle Characteristics				
Vehicle Class	Midsize Car	Small SUV - 2WD	Small SUV - 2WD	Subcompact Car
Motor	AC Permanent Magnet Synchronous (130 kW)	Interior Permanent Magnet Synchronous (120 kW)	Interior Permanent Magnet Synchronous (120 kW)	AC Synchronous (113 kW)
Battery	346 V Lithium Ion	240 V Lithium Ion	240 V Lithium Ion	245 V NiMH
Availability	Select dealers in California	California only	California only	Dealers in California & Hawaii

kW = kilowatt; V = volt; kg = kilogram; NiMH = nickel metal hydride

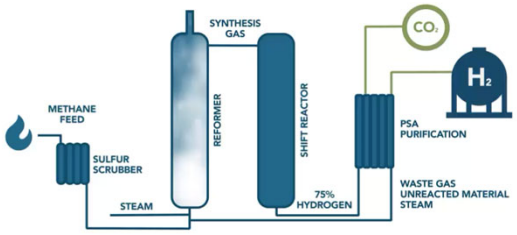
https://www.fueleconomy.gov/feg/fcv_sbs.shtml

Hydrogen Production

Hydrogen can be produced in several ways. The two most common methods include:

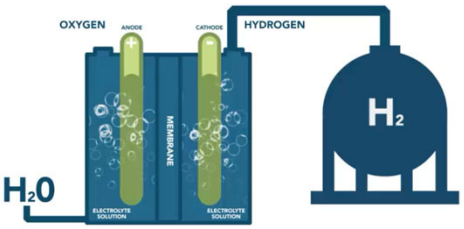
STEAM-METHANE REFORMING (SMR)

SMR uses high-temperature steam to heat methane from natural gas, producing hydrogen and carbon dioxide. More than 90% of hydrogen produced today is through SMR.*



ELECTROLYSIS

Electrolysis uses an electrical current to split water molecules into oxygen and hydrogen.



*Florence School of Regulation, Hydrogen in the Energy Transition, 2020

69

Electric Vehicles

HD Truck

Transit Bus

MD Truck

LD Vehicle

70

Key Attributes of Different Fuel Types

FUEL TYPE	CO_2 REDUCTION*	ENGINE OUT NOX*	ENERGY CONTENT*	CHALLENGES
DIESEL	BASELINE	BASELINE	BASELINE	
NATURAL GAS	13% to 18%	Very low	25% of diesel on volumetric basis	
RENEWABLE NATURAL GAS	Better than 100% for animal waste; 50% to 80% from diesel with other feedstocks	Very low	Same as natural gas	Somewhat limited availability
BIODIESEL (B20)	10% to 15%	About the same as fossil diesel	About the same as fossil diesel	Waxing and some storage/microbial growth issues
ETHANOL (E85)	~30% to 40%	Very low	60% of diesel	No available engines. Assumes E98 corn-based ethanol.
HYDROGEN (USED IN ICE ENGINE)	0% to 100% depending on creation method, transportation and storage	Very low (specific to ICE engine)	About 2.5 times diesel by mass	Liquid vs. gaseous storage in transport and on vehicle very important to relative levels vs.other fuels
METHANOL	0% to 90% Depends on feedstock	Very low	45% of diesel	High unburned HC corrosion

71

Additional Resources

72

Associations & Resources

- ESC – Energy Solutions Center
  - Located in Washington, DC
  - Consortium of utility companies interested in the promotion of gas technologies
  - Offering an NGV Workgroup
  - www.escenter.org

ENERGY SOLUTIONS CENTER

73

Associations & Resources

- NGVAmerica – Natural Gas Vehicles for America
- Located in Washington, DC
  - Represents more than 200 companies, environmental groups, and government organizations
  - www.ngvc.org

NGVAMERICA
Natural Gas Vehicles for America

ESC

74

Associations & Resources

- Canadian Natural Gas Vehicle Alliance
  - Located in Ottawa, ON
  - Advocates on behalf of Canada's natural gas vehicle industry
  - www.cngva.org
  - www.gowithnaturalgas.ca

ESC

75

Associations & Resources

- NGVi – Natural Gas Vehicle Institute
- Located in Las Vegas, NV
  - Established in 1989
  - Provide training and consulting on natural gas as a transportation fuel
  - www.ngvi.com

ESC

76

Associations & Resources

- ANSI – American National Standards Institute
- Located in Washington, DC
  - Established in 1918
  - Oversees the creation, promulgation and use of guidelines that directly impact businesses in nearly every sector
  - www.ansi.org

ANSI American National Standards Institute

ESC

77

Associations & Resources

- CGA – Compressed Gas Association
- Located in Chantilly VA
- Established in 19183
- Dedicated to the development and promotion of safety standards and safe practices in the industrial gas industry
- www.cganet.com

CGA Compressed Gas Association The Standard For Safety Since 1913

ESC

78