Planning for Tomorrow's Buses in Public Transit Facilities

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Wendel Companies

75 Years of Service with 40 Years of Transit Focus.

9 Offices in US with over 250 Employees.

Full Service Firm with Architecture, Energy Services, Engineering and Construction; All Disciplines In-house.

Wendel Projects Coast to Coast

Agenda

- Transit Fuel Sources
- Transit Vehicle Choices
- Alternative Fuel Considerations
  - Transit Centers
  - Maintenance Facilities
  - Fueling / Charging Infrastructure
- Conclusion

Transit Fuel Sources

What is the Breakdown of Fuels Powering the U.S. Transit Fleet?

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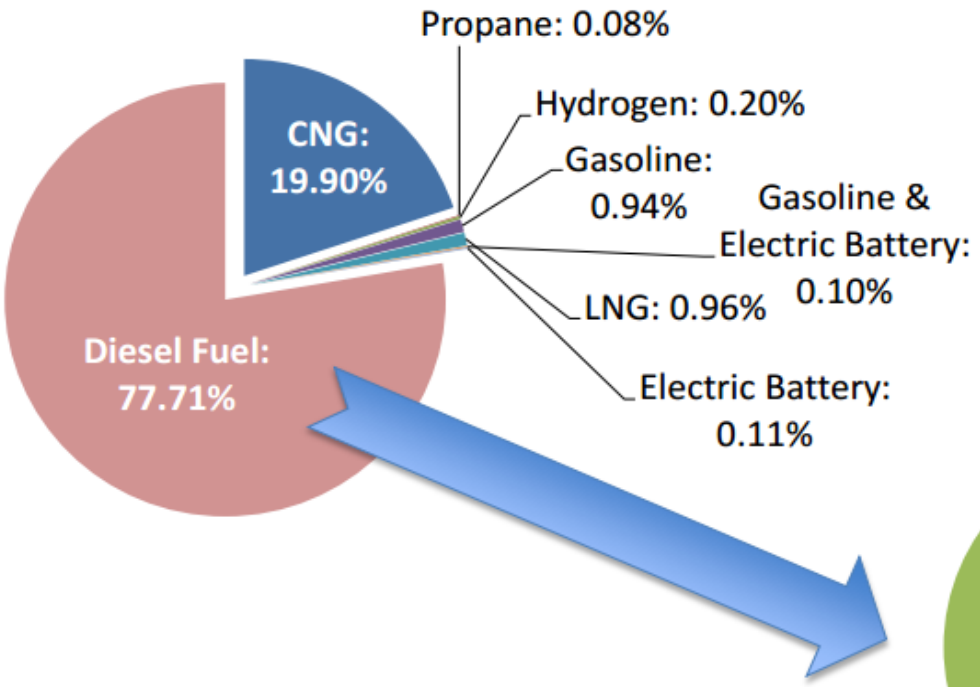
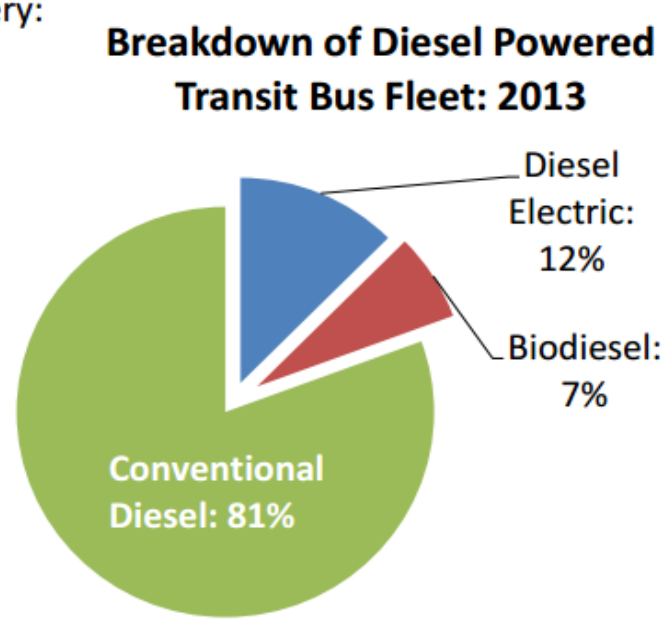
Transit Fuel Sources





SOURCE: APTA Vehicles Database, 2013

Transit Vehicle Choices

Challenge for Facility Planners: The increasing Numbers of Vehicle Configurations and Propulsion Systems Available to Transit Fleets.

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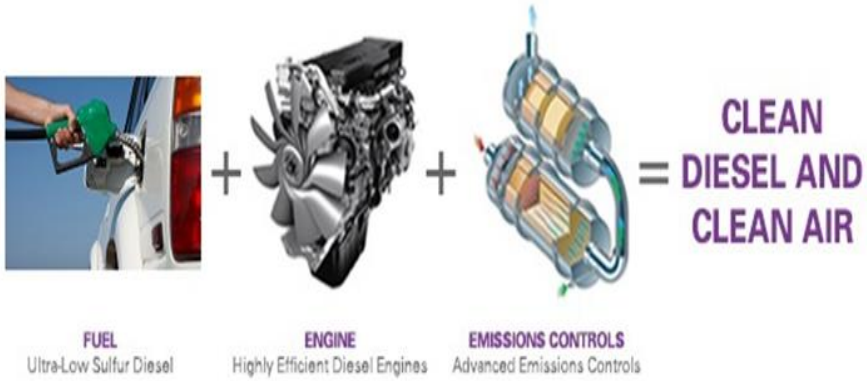
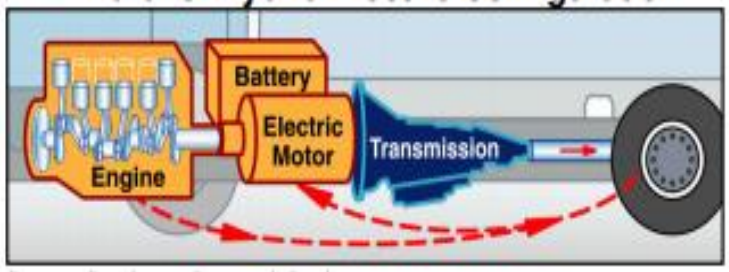
Clean Diesel Bus

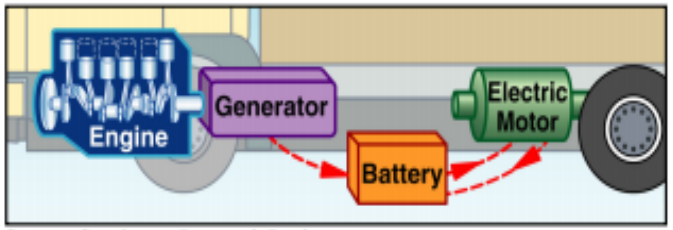


Hybrid Electric Bus (HEB)

Parallel Hybrid Electric Configuration



Series Hybrid Electric Configuration



Bus Rapid Transit (BRT)

Propane Buses

Compressed Natural Gas (CNG)

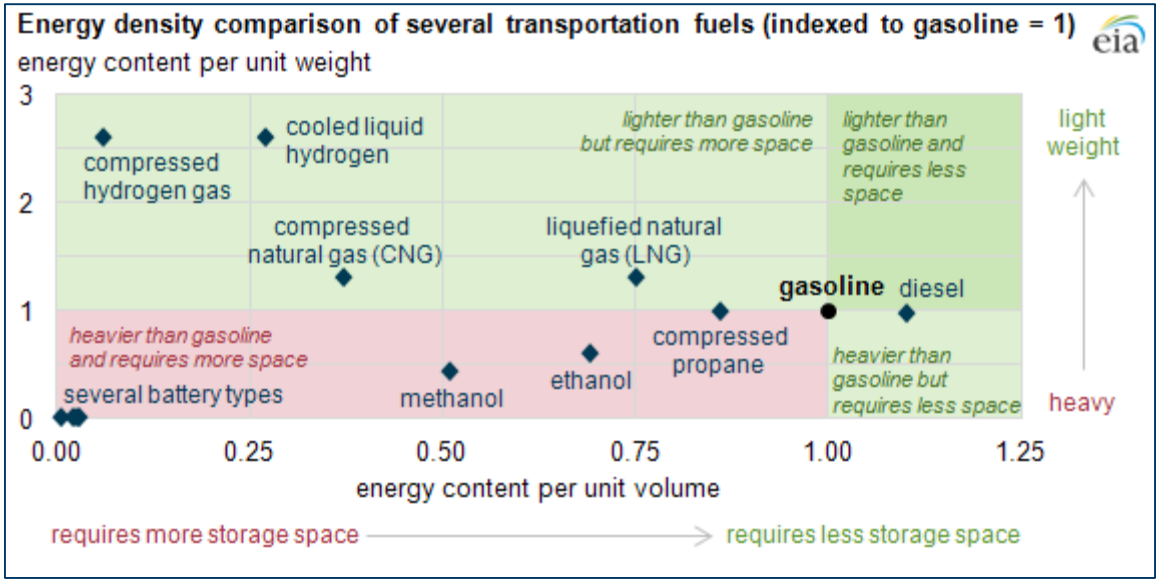
Natural Gas Conversions

SCF: 1 standard cubic foot of gas; contains about 1,000 BTU of energy. It takes about 100 SCF of gas to equal 1 therm.

SCFM: Standard cubic feet per minute; standard measure of output for CNG compressor systems

DGE: Diesel gallon equivalent = about 135 SCF of gas, or 1.35 therms

GGE: Gasoline gallon equivalent = about 127 SCF of gas or 1.27 therms



Source: U.S. Energy Information Administration, based on the National Defense University

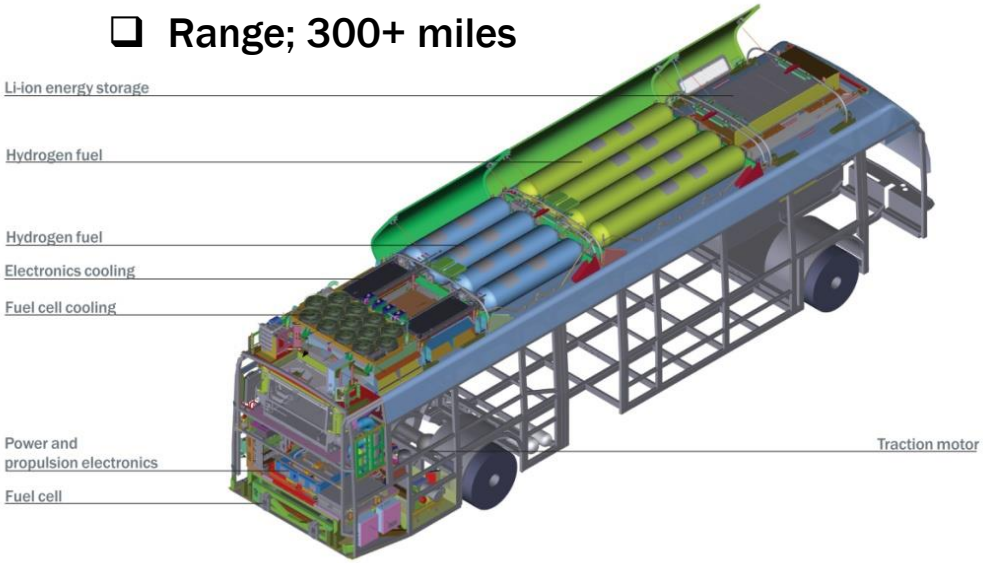
Battery Electric Bus (BEB)

(BEB) Charging

- MPGe – Miles per gallon of gasoline equivalent
- 33.7 kWh of electricity is equivalent to one gallon of gasoline
- 98 MPGe = 34 kWh 100 miles

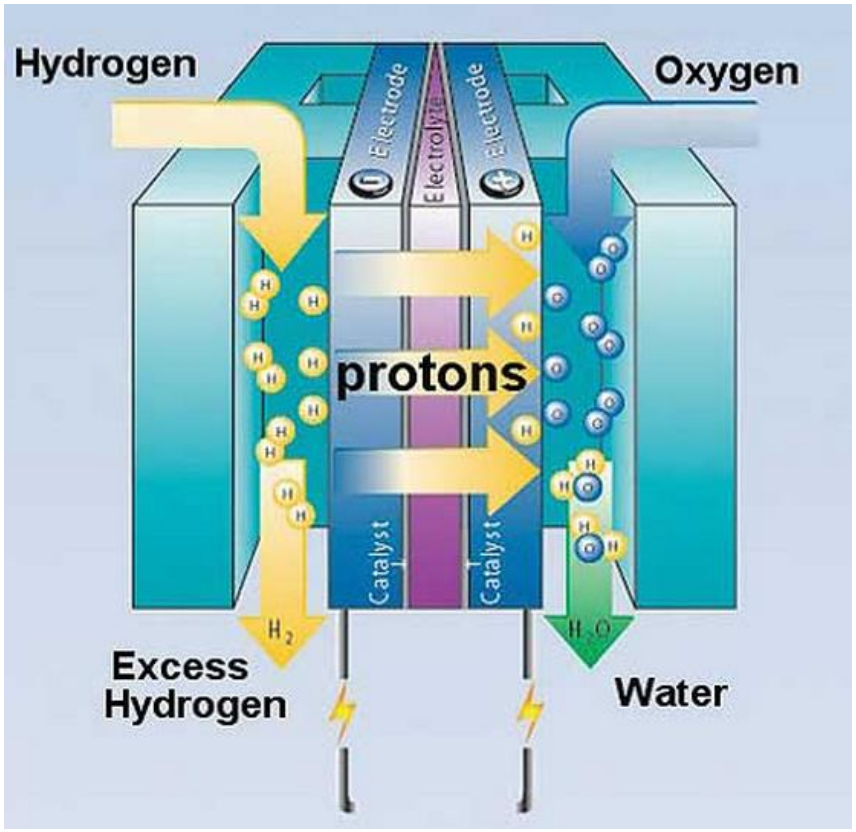
Fuel Cell Electric Bus (FCEB)

- ❑ Zero emissions, 100% of the time
- ❑ Hydrogen fuel cell; power plant source
- ❑ All-electric accessories
- ❑ Range; 300+ miles



Hydrogen Fuel Cell

A zero emission electrochemical generator.
A fuel cell never needs recharging.

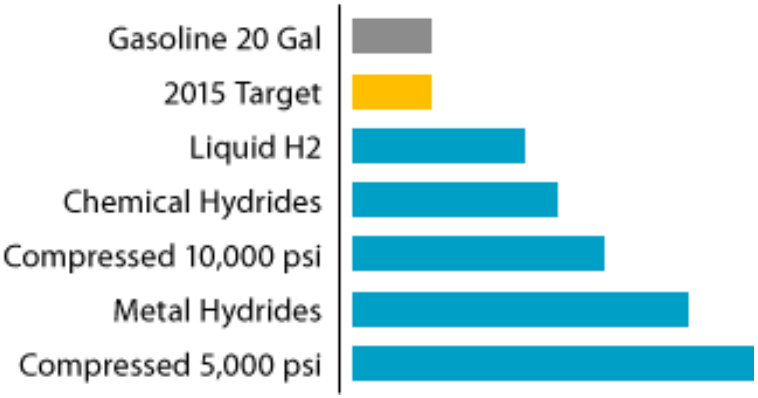


- In a fuel cell, the protons from hydrogen pass through a membrane to the other side of the cell.
- The electrons can't pass through the membrane, so they reach the other side through a circuit producing electricity.
- The protons, electrons and oxygen from the air combine to form water.

Hydrogen

- Hydrogen, 14 times lighter than air, when used in a fuel cell, is an emissions-free alternative fuel that can be produced from diverse domestic energy sources.
- Research and commercial efforts are under way to build the hydrogen fueling infrastructure and produce hydrogen fuel cell vehicles that are practical for widespread use.

Relative Volume Needed for Hydrogen Storage to Achieve > 300 Mile Range



Costs – GGE cost

A very small sample (6 points) of hydrogen information was received: Two of the six locations for which data was received reported hydrogen at zero cost for vehicle use, with an average price for the four other hydrogen stations of $8.96 per gasoline gallon equivalent.

Overall Average Fuel Prices – Clean Cities Alternative Fuel Price Report October 2014

Hydrogen

- On Earth, hydrogen is only found bound together with other elements, in compounds such as water (H_20), and natural gas (CH_4). Hydrogen is not toxic and doesn't pollute.
- The energy in 2.2 pounds (1 kilogram) of hydrogen gas contains about the same as the energy in 1 gallon of gasoline. (DGE not published)
- The energy in 2.5 pounds (1.136 kilogram) of hydrogen gas contains about the same as the energy in 1 gallon of diesel. (Except bio-diesel or #2 diesel - DGE not officially published)
- Because hydrogen has a low volumetric energy density, additional steps are needed to store enough hydrogen onboard fuel cell vehicles to achieve the driving range of conventional vehicles.
- Most current applications use high-pressure tanks capable of storing hydrogen as a gas at either 5,000 or 10,000 psi at 70˚F.
- Can be stored as a gas (H_2) or a liquid (LH_2) cooled to -423˚F

Hydrogen

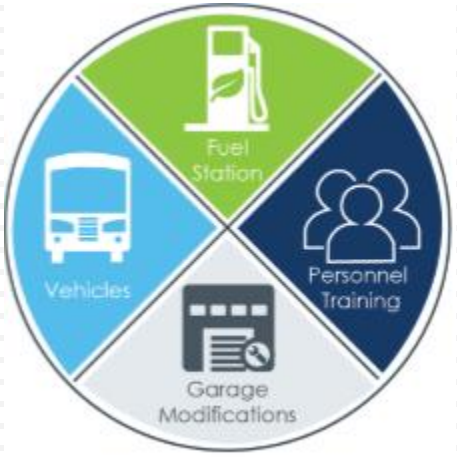
- Production (Thermal, Electrolytic, Photolytic)
  - Natural Gas Reforming/Gasification
  - Electrolysis
  - Renewable Liquid Reforming
  - Fermentation
- Distribution
  - Pipeline: Only ≈ 700 miles exist
  - High-Pressure Tube Trailers: < 200 miles
  - Liquefied Hydrogen Tankers: Boil off
- Centralized vs. Distributed production
  - Centralized production – Lower cost infrastructure, higher cost distribution
  - Producing hydrogen at the point of end-use – Lower distribution costs, higher production costs
- Current on-site production construction costs range from $2-4M each, depending on technologies, site requirements, permitting, etc.

The Impacts of All These Choices?

"The future, in a word, is "flexibility" to deal with the next generation of vehicles and vehicle types."

Alternative Fuel Considerations

* Transit Centers
* Maintenance Facility
* Fueling Infrastructure



"There is not always a one-size fits all alternative fuels solution."

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Transit Centers – Charging In Service

https://wendelcompanies.com/future-transit-center-design/

Solar Electric Generation

Electricity – Solar Energy

- kW is a unit of power, kWh is a unit of energy
- If a 100 watt light bulb is left on for one hour, it will consume 100 watt-hours of energy. Left on for 10 hours, it will consume 1000 watt-hours, which is the same as 1 kilowatt-hour, or 1 kWh.
- A common power rating for a solar panel is 345 watts. The size of this panel is about 61″ by 41″ or about 17.3 square feet. This panel, at its maximum, puts out 345 watts from sunlight falling on its 17.3 ft^2 area, or at its maximum, 20 watts per square foot
- If a 345 watt solar panel is left in the brightest sun for 1 hour, it will generate 345 watt-hours of energy. Under those same ideal conditions, after three hours, it will generate a little over 1 kWh.

Maintenance Facility Design – Fuel Flexibility

NFPA 52, NFPA 30A, NFPA 70, National Electric Code, NFPA 88A – Parking structures, Uniform Fire Code, Uniform Building Code, Uniform Plumbing Code, Energy Codes, etc. (Major Repair? Minor Repair?) AHJ's – Code Enforcement

Parking and Storage Considerations

Paint Booth Considerations

Fueling Options

Dispenser Options

Bio-Diesel

Propane

Natural Gas

Hydrogen

Electric

Fueling Stations – Outdoor/Indoor

Conclusions

* It's Complicated
* Find an Expert Who Can Help

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Questions

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