POLICY BRIEF

Which alternative fuel technology is best for transit buses?

Carnegie Mellon University
Scott Institute
for Energy Innovation

traffic21
a transportation research initiative of Carnegie Mellon University

Transit agencies are continually planning for their future bus purchases. Today, most transit buses run on conventional diesel fuel. However, many transit agencies are considering other options, such as biodiesel, electricity and natural gas. So, how do the different options compare?

Conventional

Diesel

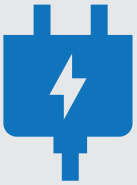
Produced from crude oil. Conventional diesel buses comprise 60% of the existing fleet. Diesel hybrid electric buses have better fuel economy.

Alternatives

Biodiesel

Biodiesel is typically made from vegetable oils, animal fats or recycled restaurant grease. Currently, producing biodiesel is expensive and the supply might be limited.

Electricity



Battery electric buses have electric motors and batteries that charge en route (rapid, medium battery) or overnight (slow, large battery).

Natural Gas

Requires dedicated refueling infrastructure, modifications to garages and special onboard tanks.

	CV	HEB	B20	B100	BEB	BEB	CNG	LNG
	Conventional Diesel	Diesel Hybrid Electric Bus	20% Biodiesel + 80% Diesel	100% Biodiesel	Battery Electric Bus (Rapid-Charge)	Battery Electric Bus (Slow-Charge)	Compressed Natural Gas	Liquefied Natural Gas
Battery								
Range								
Social Cost*[1]	$5.00	$4.30	$4.60	$3.00	$4.70	$5.80	$6.30	$7.70
Agency Cost*[1]	$59.40	$56.50	$60.20	$64.90	$44.90	$47.80	$59.60	$68.00

Finding

Battery electric buses have the lowest overall life cycle cost, particularly when support from federal funding is available.[1] However, they also have the shortest driving range, which will need to improve before they are widely adopted.

*Costs are in units of $1,000/bus/year in 2015 dollars.
Results assume: a 40-foot bus with federal funding; 12-year lifetime for the bus; 1% discount rate; Port Authority of Allegheny County data.

Key Factors in Transit Bus Selection

When deciding on bus purchases, transit agencies need to consider not only the cost of the bus, but also the infrastructure needs for storing and fueling buses, range, as well as societal impacts.

Agency Costs

- Bus Purchase
- Fuel Purchase
- Operations & Maintenance
- Refueling & Depot Infrastructure

Electric and natural gas powered bus options would require changes in garage and refueling infrastructure.[1] Some federal funding can be used for these costs, but they would still require significant investment.

Social Costs

- Greenhouse Gases**
- Criteria Air Pollutants**

In addition to the agency costs for the buses, infrastructure, fuel and operation and maintenance, the life cycle cost of using different energy sources is considered. We estimate environmental and health damages from greenhouse gas emissions and criteria air pollutants.[2] Social costs are relatively small compared to agency costs, but alternative fuel technologies that use a lot of coal-based electricity have larger social costs.[2]

Range

The range of a bus is important for the daily operations of transit agencies. On average, a transit bus operated by the Port Authority travels 100 miles per day, and is refueled overnight. The alternative fuel technologies for transit buses, except battery electric buses, have significantly higher ranges than 100 miles. Battery electric buses travel only 40-130 miles on a full charge, and may require changes to bus scheduling and operation.

Recommendation

Serious consideration should be given to battery electric buses in short-term planning and long-term purchasing as the electricity grid in many regions becomes cleaner, and their driving range improves.[3,4]

* A life cycle analysis approach looks at a product or pathway from the extraction of resources to build it until its end of life disposal.[5]

** Greenhouse gases are found to contribute to global warming, and include: carbon dioxide, methane and nitrous oxide. Criteria air pollutants are found to contribute to environmental and health damages, and include: nitrogen oxides, carbon monoxide, volatile organic compounds, particulate matter and sulfur dioxide.

[1] Tong, F., C. Hendrickson, A. Biehler, P. Jaramillo, and S. M. Seki. Life Cycle Economic and Social Costs of Alternative Fuel Options for Transit Buses. Under review at Transportation Research Part D, 2016.

[2] Port Authority of Allegheny County Compressed Natural Gas Fueling Project Design Report. Gladstein Neandross & Associates (GNA), Pittsburgh, PA, 2012.

[3] U.S. Environmental Protection Agency (EPA). Clean Power Plan, 2016. www.epa.gov/cleanpowerplan

[4] U.S. Energy Information Administration (EIA). Clean Power Plan accelerates the growth of renewable generation throughout United States, 2016. www.eia.gov/todayinenergy/detail.cfm?id=26712.

[5] Matthews, H. S., C. T. Hendrickson, and D. H. Matthews. Life Cycle Assessment: Quantitative Approaches for Decisions That Matter, 2015. Retrieved from www.lcatextbook.com.

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www.cmu.edu/energy

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traffic21.heinz.cmu.edu

For questions or more information, please email the.scott.institute@gmail.com.

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