Which Alternative Fuel Technology is Best for Transit Buses?

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A policymaker guide and a policy brief

POLICYMAKER GUIDE

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POLICY BRIEF

Which alternative fuel technology is best for transit buses?

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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		Alternatives					
	Diesel		Biodiesel		Electricity		Natural Gas	
	Produced from crude oil. Conventional diesel buses comprise 60% of the existing fleet. Diesel hybrid electric buses have better fuel economy.		Biodiesel is typically made from vegetable oils, animal fats or recycled restaurant grease. Currently, producing biodiesel is expensive and the supply might be limited.		Battery electric buses have electric motors and batteries that charge en route (rapid, medium battery) or overnight (slow, large battery).		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 messages

#1. Among the choices available to transit agencies, battery electric buses are the best option due to low life cycle agency costs and environmental and health impacts from greenhouse gas and air pollutant emissions.

#2. Although there are still some barriers, such as low range, to their adoption, electric buses should be considered in both short-term experimentation and long-term planning for public transit agencies.

Battery Electric Buses Ready for Planning and Testing But Not Yet Full Implementation

Short-Term Strategies

WAIT AND OBSERVE.

Bus agencies should learn from the implementation experience of alternative fuel buses, particularly battery electric buses operated by early-adopter bus agencies.

PLAN AHEAD.

The investment in alternative fuel buses likely requires changes to the garage infrastructure and may require changes to operation scheduling. Anticipating and planning for these changes could help with the transition to alternative fuel buses.

TEST THE OPTIONS.

Before making the investment, plan on testing the buses and the potential infrastructure to ensure it meets agency needs. Update studies.

As more and better emissions data becomes available, update these studies to ensure that decisions are based on the most current information.

Long-Term Strategies

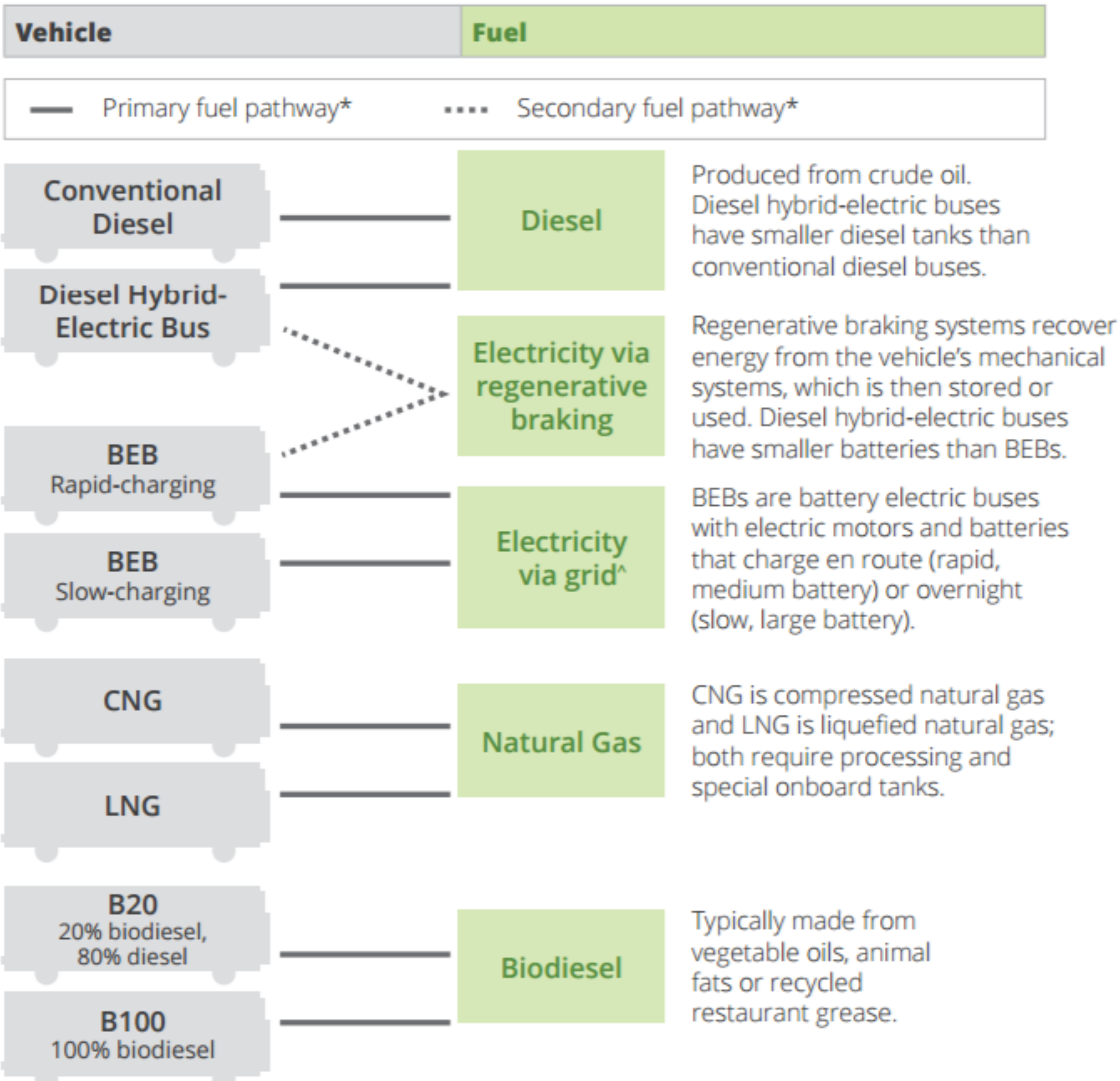
INVEST IN BATTERY ELECTRIC BUSES.

In the long term, battery electric bus batteries should become less expensive and have longer range. The benefits of reduced emissions and the use of external funding for capital investments make this an attractive option.

INVESTIGATE RENEWABLE ENERGY SOURCES.

With a switch to battery electric buses, a large contributor to the life cycle emissions is from grid electricity. Although the grid in Pennsylvania is likely to become cleaner, having independent, renewable energy sources at Port Authority facilities could be a cost-effective option from an emissions standpoint.

Variety of Bus Fueling Options Available



ACRONYM KEY:

B20 A blend of 20% biodiesel and 80% petroleum diesel

B100 Biodiesel (pure)

BEB Battery electric bus

CAP Criteria air pollutant

CNG Compressed natural gas

GHG Greenhouse gas

HEB Hybrid-electric bus

LNG Liquefied natural gas

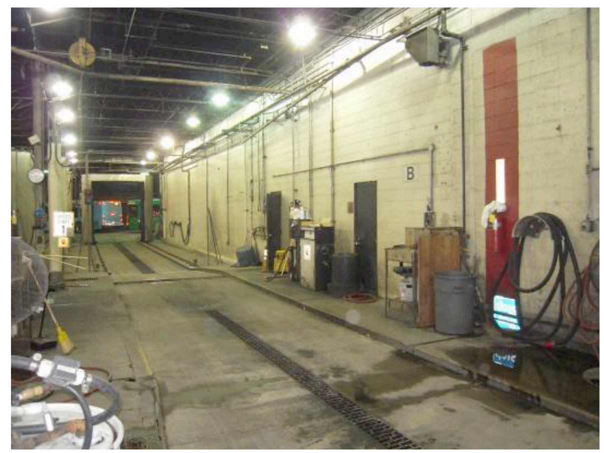
O&M Operation and maintenance

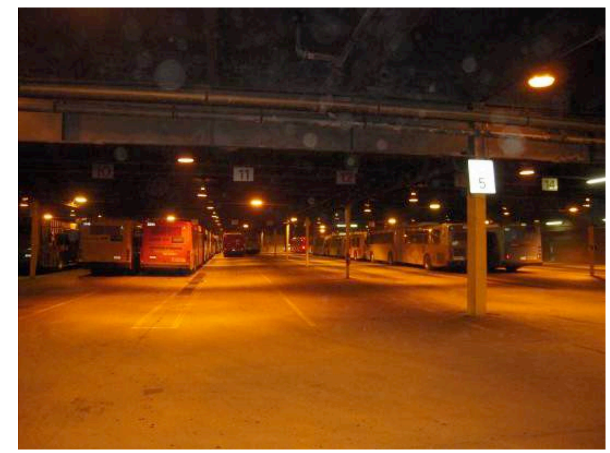
Transit Agencies Need to Consider Both Agency Costs and Social Costs Caused by Air Emissions

Agency costs

- Transit bus – purchase costs, operation & maintenance costs.
- Infrastructure – refueling station, garage, and parking lot.

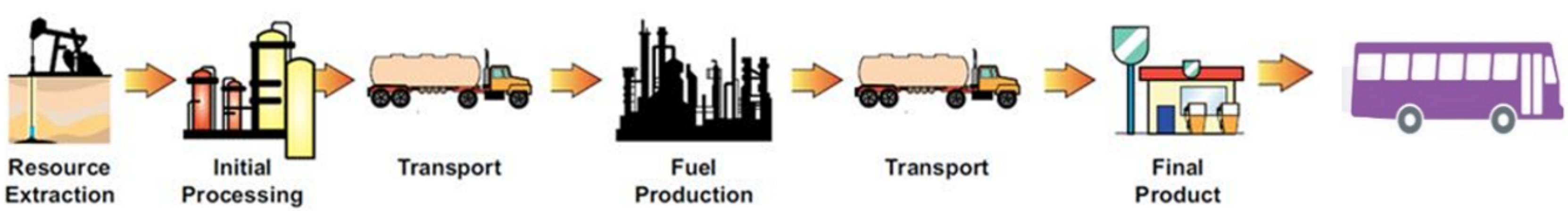
http://www.bus-history.org/blog/?p=84


Gladstein Neandross & Associates (2012)


Gladstein Neandross & Associates (2012)

Social costs caused by air emissions

- Greenhouse gas emissions – climate change impacts
- Criteria air pollutants – health impacts



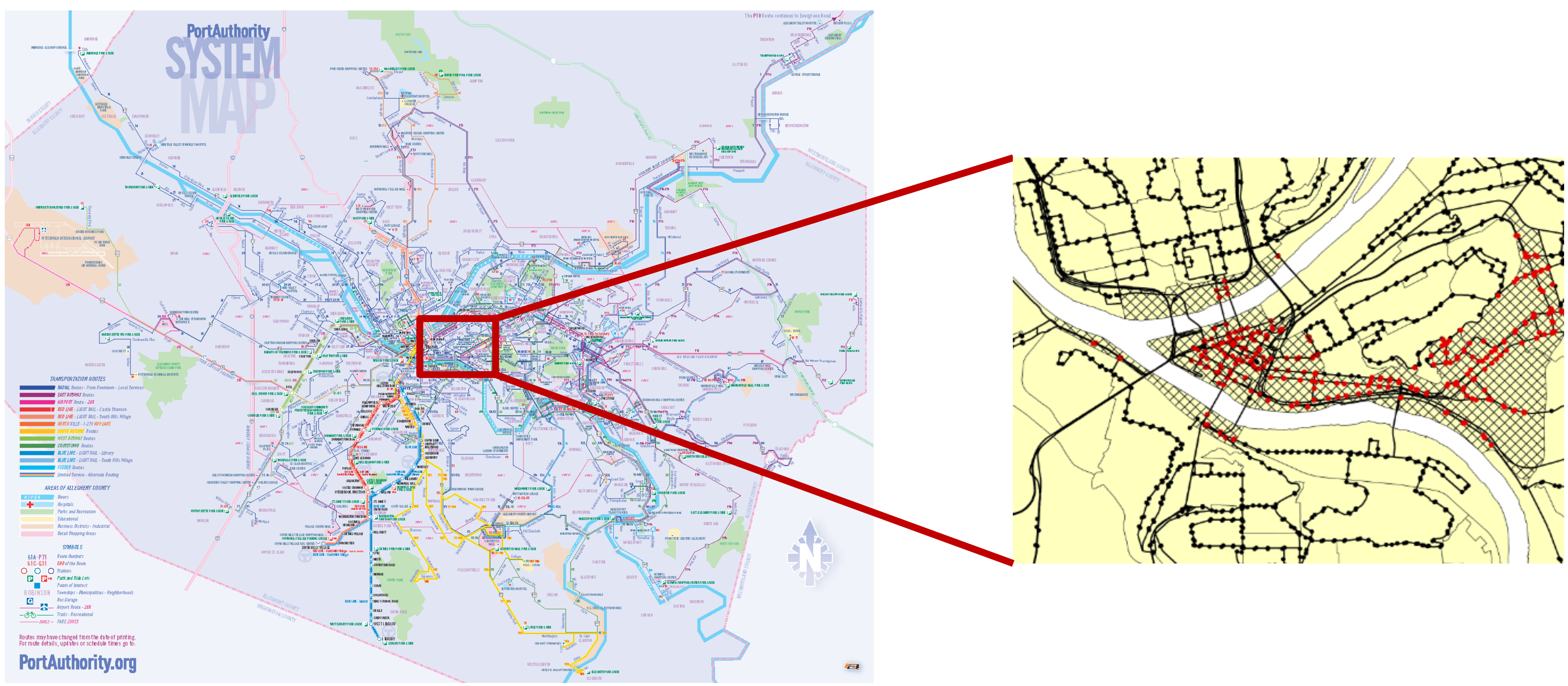
Modified from a GREET model presentation (Argonne National Lab)

Battery Electric Buses Have Zero Tailpipe Emissions

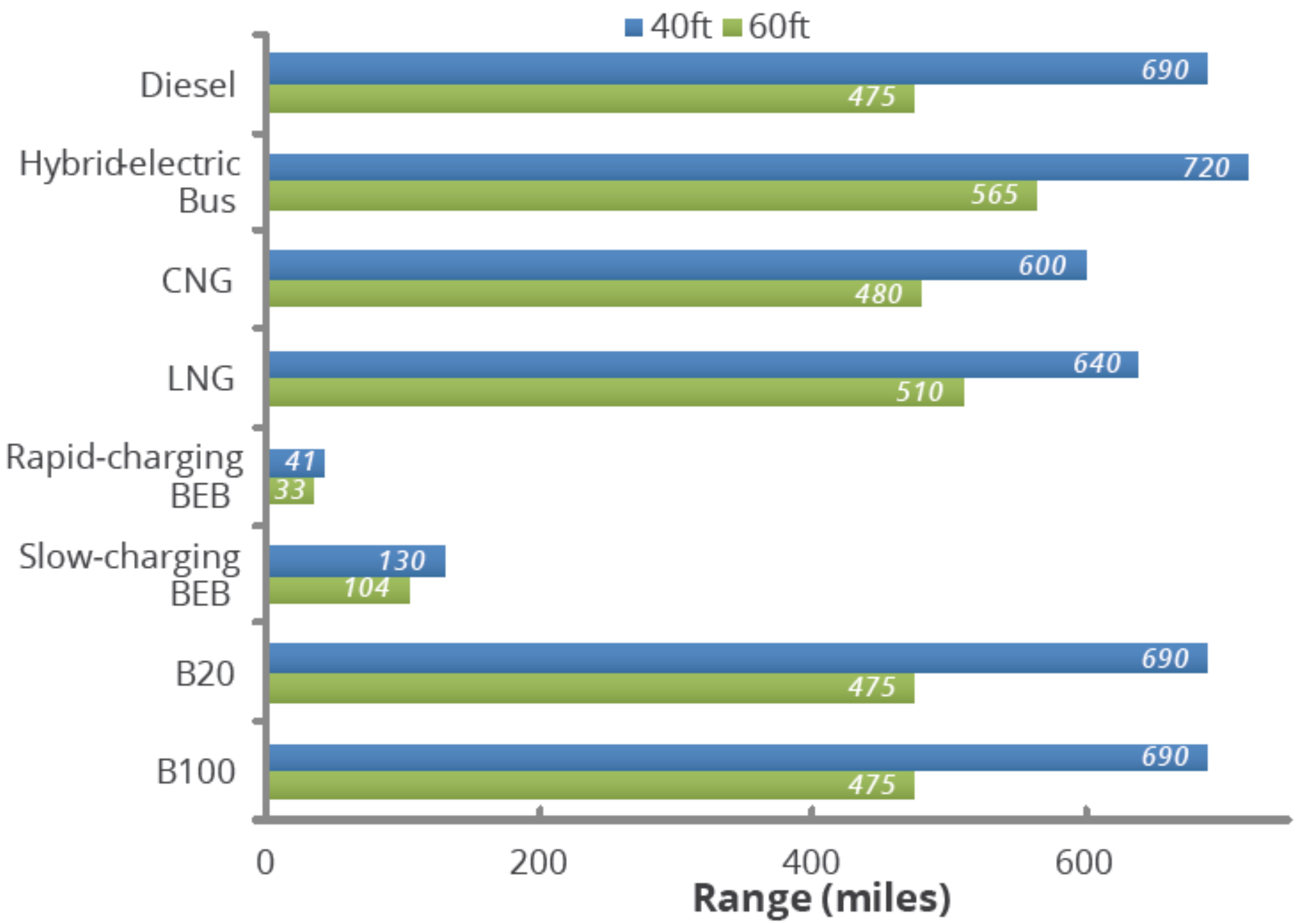
Transit buses contribute to 1% of direct $PM_{2.5}$ emissions from mobile sources in Allegheny County.

Diesel particulate matter is the leading additive cancer risk air toxics in Downtown Pittsburgh and in Allegheny County.

Battery electric buses have zero tailpipe emissions.



Battery Electric Buses Cannot Go Far Before Needing to Recharge Relative to Alternatives



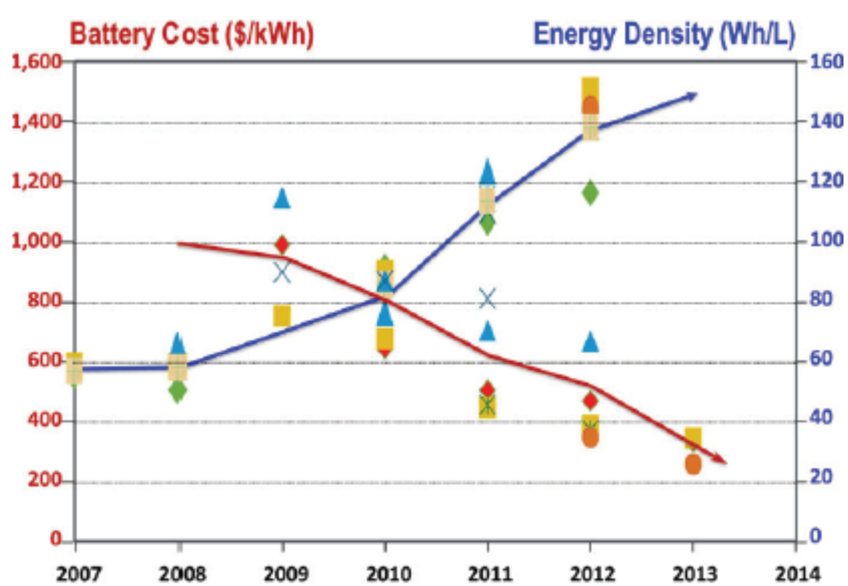
Transit buses run on average 100 miles per day according to Port Authority in Pittsburgh and several transit agencies in California.

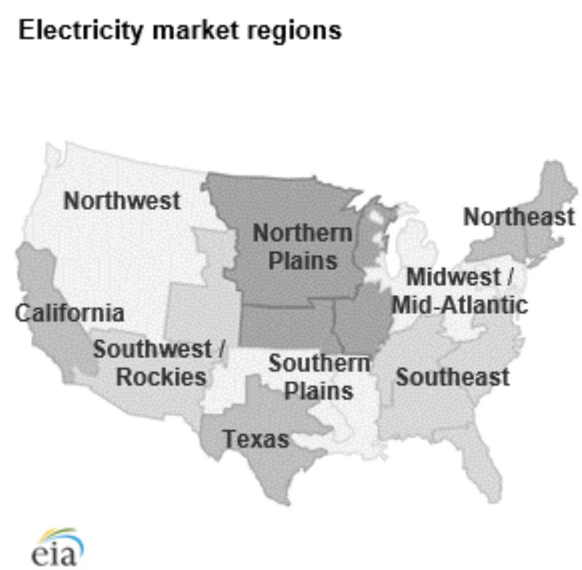
Battery Electric Buses are Improving in Cost and Performance

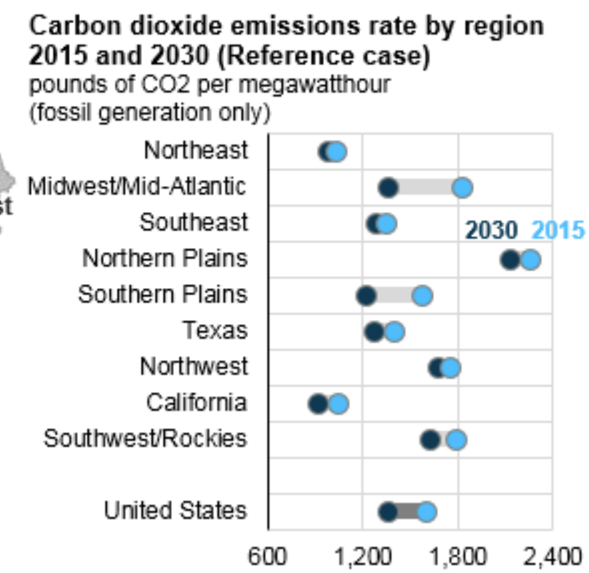
More adoption leads to increasing technology maturity level. Less than 100 battery electric buses in the U.S. now (~40 in CA).

Battery costs and performance are improving fast, suggesting better economics and longer range for battery electric buses in the near future.

Cleaner electricity grid results in lower social costs.







Left: DOE (2014); right: EIA (2016)

For more information

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    Its goal is to design, test, deploy and evaluate information and communications technology based solutions to address the problems facing the transportation system of the Pittsburgh region and the nation.
  - Scott Institute for Energy Innovation.

- Publication
  - The policymaker guide and policy brief are available at http://www.cmu.edu/energy/public-policy/guides.html.
  - Tong, F.; Hendrickson, C; Biehler, A.; Jaramillo, P.; & Seki, S. (2016). Life Cycle Ownership and Social Costs of Alternative Fuel Options for Transit Buses. Invited to revise and resubmit to Transportation Research Part D: Transport and Environment.