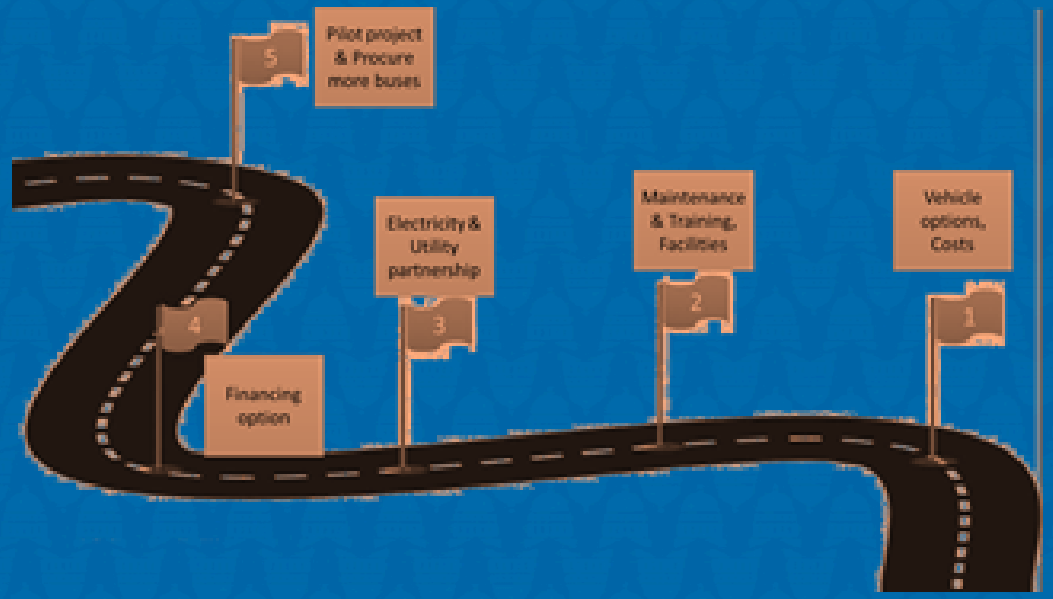
Sustainability Update:

Road to Electrification




ZeroEmission Hydrogen Fuel Cell Bus
2105

What is electrification roadmap?

https://upload.wikimedia.org/wikipedia/commons/0/04/New_Capital_Metro_MetroBus,_July_2012.jpg

DIESEL BUS

http://www.abb.com/cawp/seitp202/9315e568e4c6a1f8c1257b7400302fcd.aspx

BATTERY ELECTRIC BUS

Steps Toward Roadmap

- Provide background information and details
- Evaluate the state of electric vehicle adoption among peer agencies
- Consider steps toward a policy and plan

Zero Emission Planning

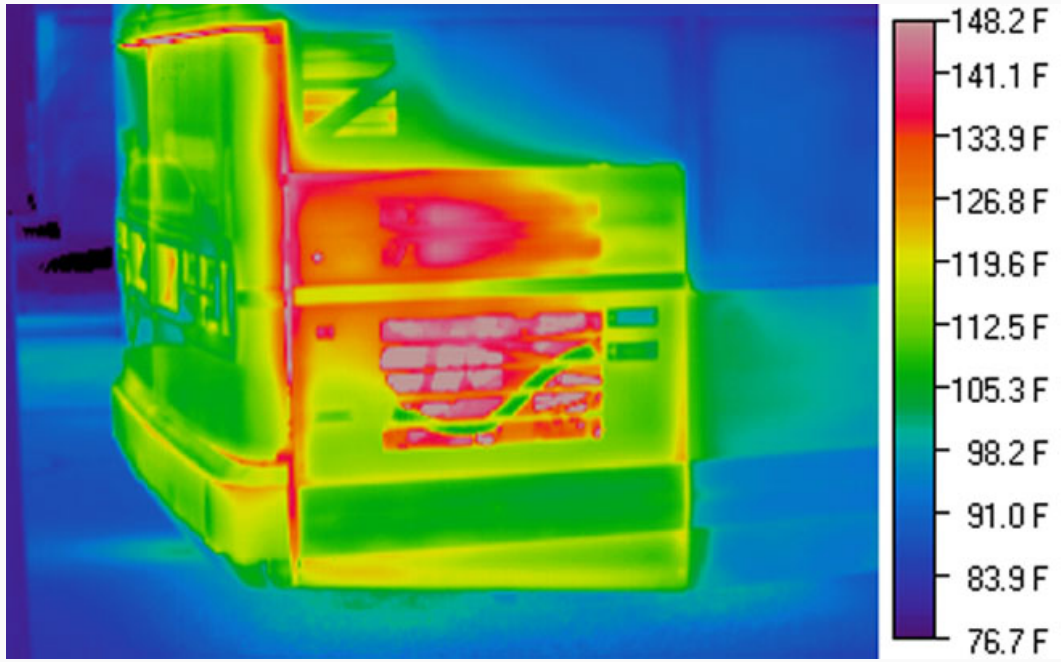
ELECTRIC > GAS

AUSTIN ENERGY
GreenChoice

net-zero

Austin COMMUNITY CLIMATE PLAN 2015

Why do we need electrification/ electric buses?



HEAT

Vehicle type	Noise level (in decibels)
Diesel bus	80-85
Electric bus	55- 65

NOISE

Why do we need electrification/ electric buses?

ANNUAL TAILPIPE EMISSIONS

	GHG Greenhouse Gases (lbs)	CO_2 Carbon Dioxide (lbs)	CH_4 Methane (lbs)	CO Carbon Monoxide (lbs)	NO_x Nitrogen Oxide (lbs)	HC Hydrocarbon (lbs)	PM Particulate Matter (lbs)*	BC Black Carbon (lbs)
Proterra	0	0	0	0	0	0	0	0
CNG	226,000	208,560	85,455	793	237	0	0	178
Hybrid	150,000	158,400	103	38	46	7	1	579
Diesel	206,000	243,980	158	59	59	11	1	891

*PM Includes PM2.5 and PM10. Source: GREET Model Fleet Footprint Calculator and EPA Motor Vehicle Emission Simulator

EMMISSIONS

Why do we need electrification/ electric buses?

Diesel	Electric
408,083 gallons/ Month	NA

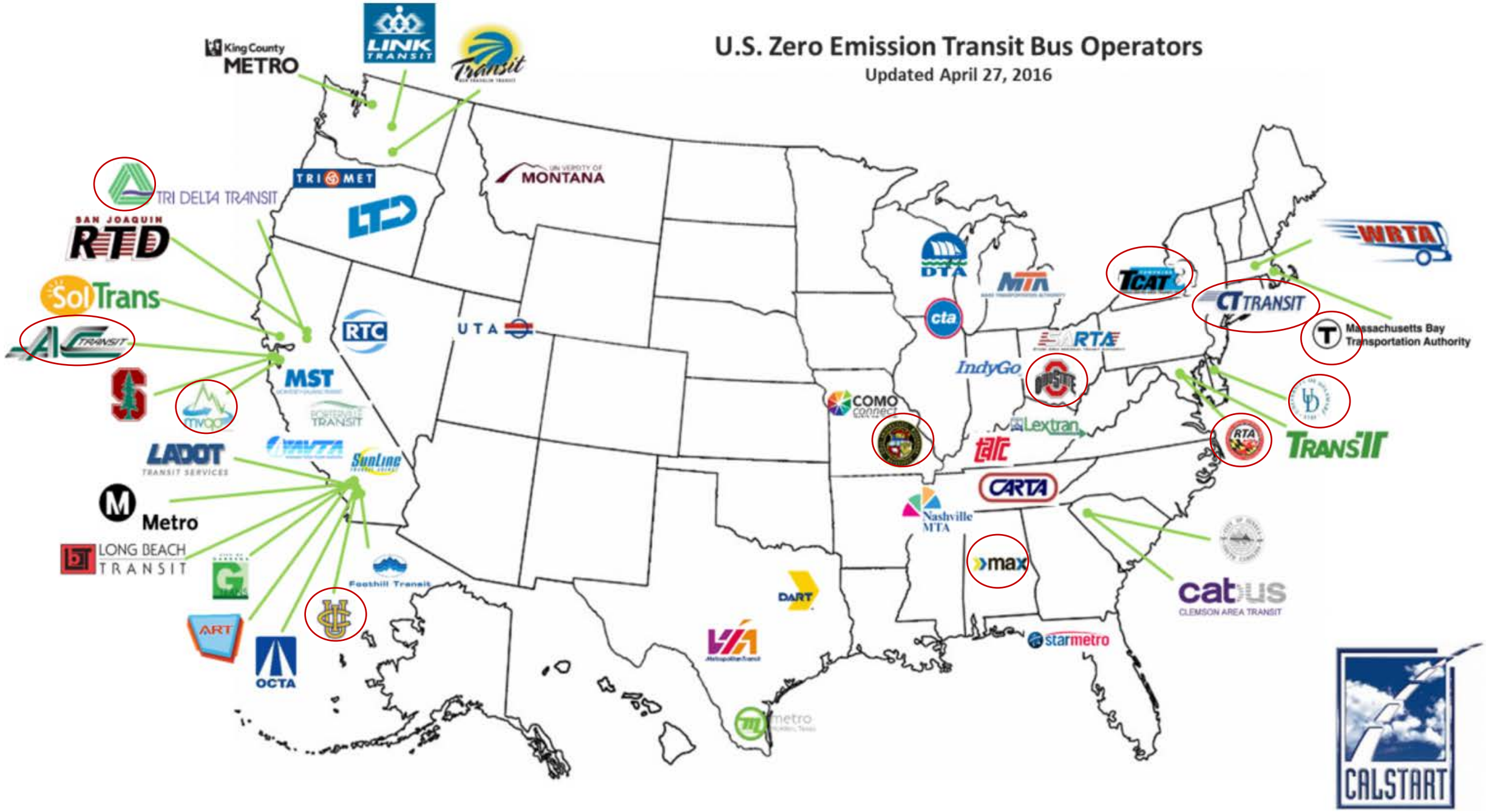
Fuel Savings

Maintenance

Operation

U.S. Zero Emission Transit Bus Operators

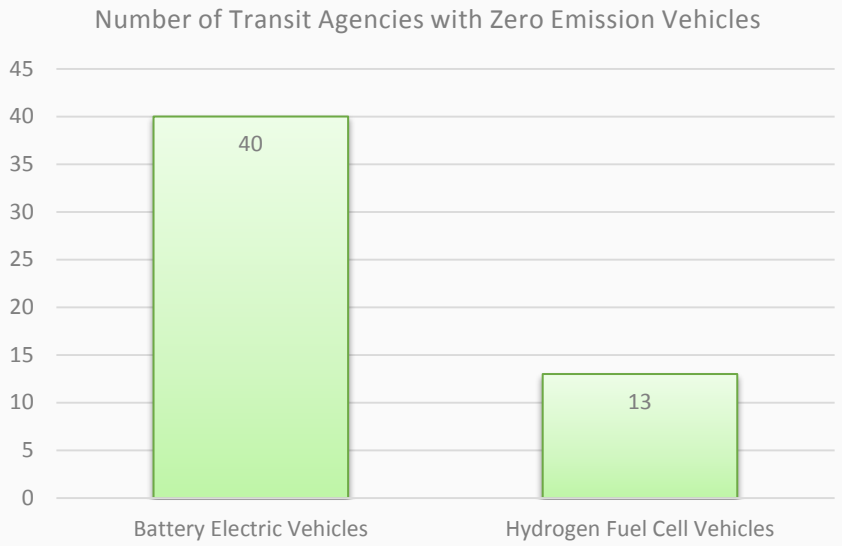
Updated April 27, 2016

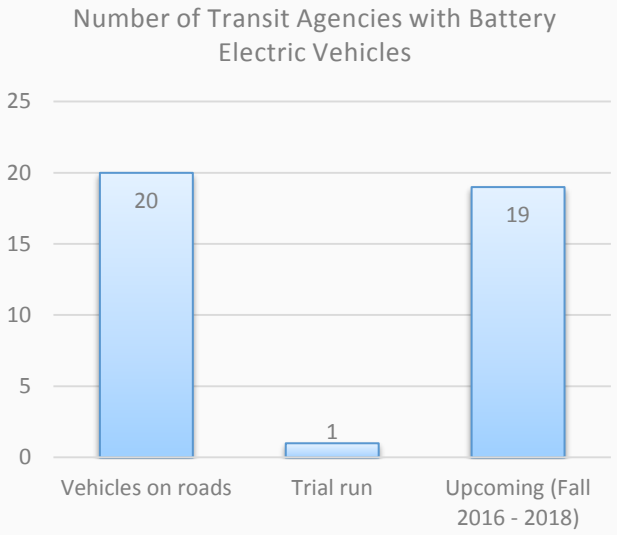


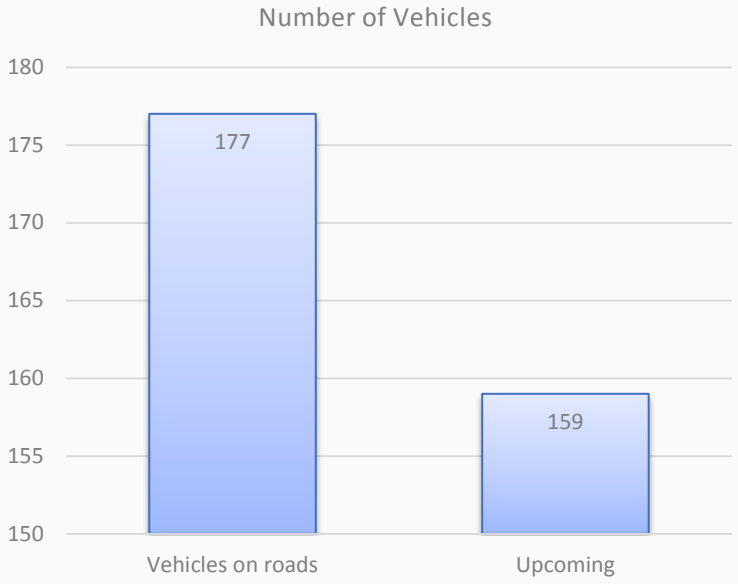
US Zero Emission Transit Bus Operators (Low- No Emission Grantees 2016)

- Central Contra Costa Transit
- Long Beach
- Santa Clara Valley
- Santa Cruz Metropolitan
- SunLine Transit
- Delaware Transit
- Miami-Dade
- Chicago Transit
- TARC
- Shreveport
- City of Columbia
- City of Clemson
- Port Arthur Transit
- Utah DOT
- Capital District Transit
- Lane Transit
- Tri-County Metro
- Everett
- Pierce County

US Zero Emission Transit Bus Operators (April 27, 2016)





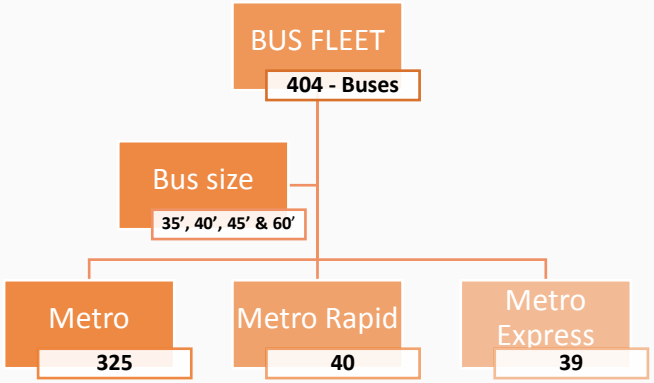


Fleet Profile

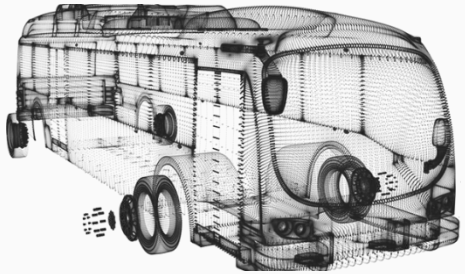
Year	2016	2017	2018	2019	2020	2021	2022	2023	2025	2026	2027	2028
Number of buses	46	78	48	28	31	21	24	27	30	24	40	1

Projected Replacement Schedule

- Lifetime of each bus: 14-16 years
- Range of a bus: 300 – 360 miles/full tank



Considerations



Available vehicles

Charging systems

Battery options

Maintenance

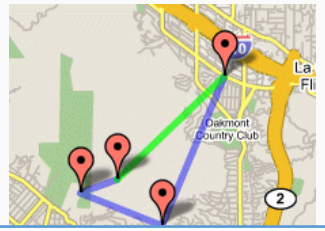
Facilities

Electricity

Training

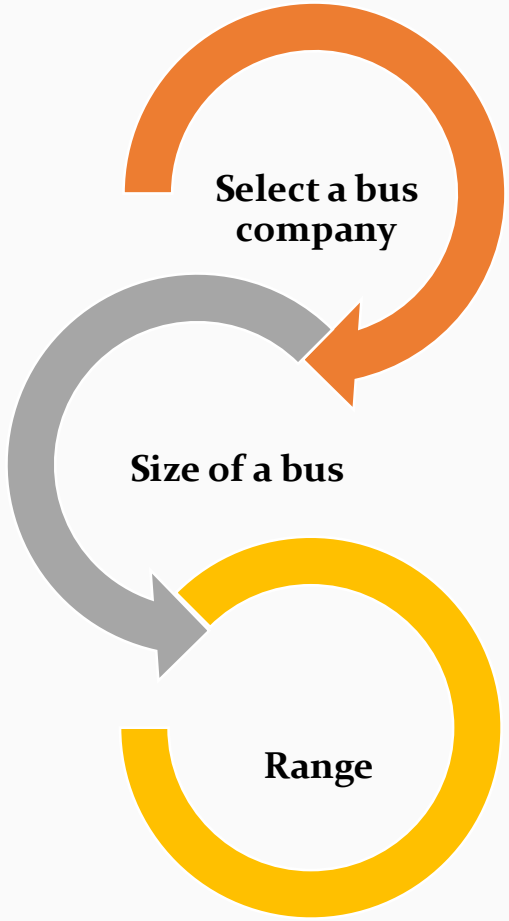
Warranty

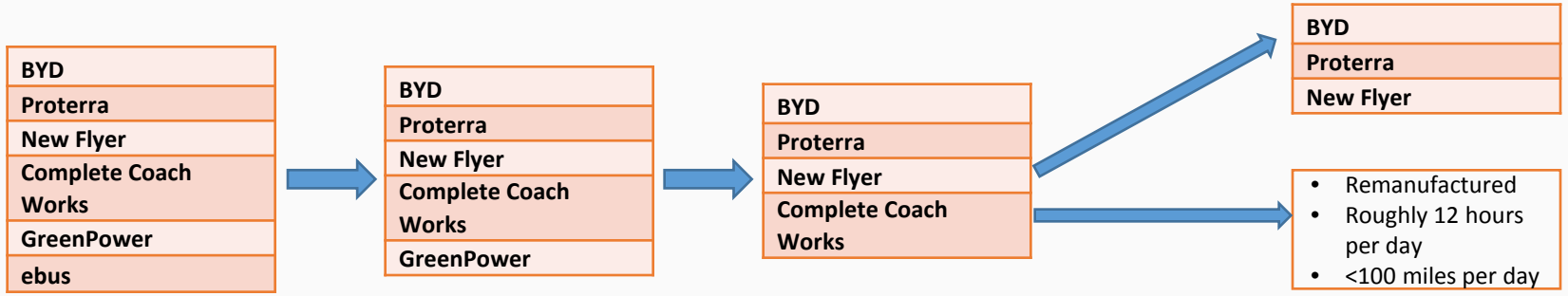
Costs/ financing options



Route Planning

Available Vehicles

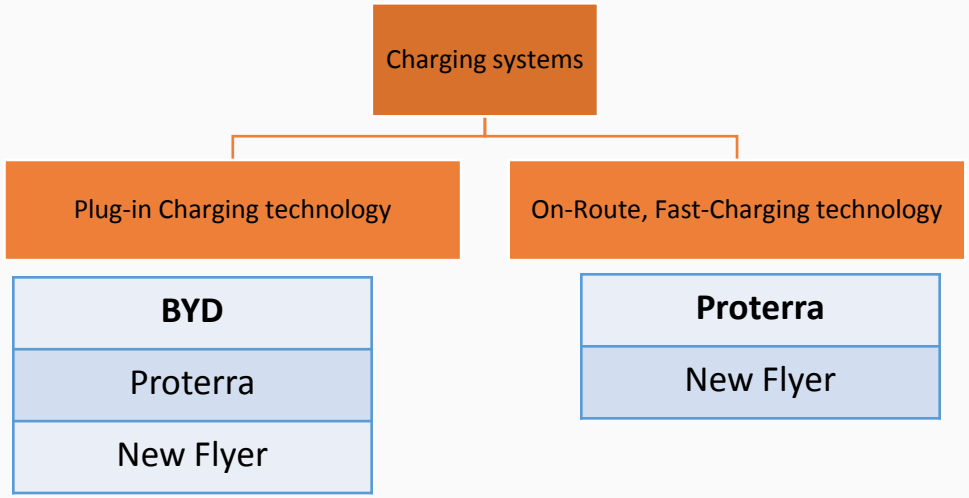




BYD	PROTERRA	NEW FLYER
30’, 35’, 40’, 45’, 60’; Coaches:23’,40’ & 45’	35’, 40’	40’, 60’

	BYD									Proterra		New Flyer	
Size	30’	35’	40’	45’	60’	23’ coach	40’ coach	45’ coach		35’	40’	40’	60’
Range (Miles)	144	165	155	124	200	130	155	200	240	UPTO 65*/ UPTO 194		94	73

Charging Systems



http://www.busandcoachbuyer.com/wp-content/uploads/2014/01/Two-charging-stations-each-with-two-chargers-have-been-installed-at-Waterloo.jpg

In-depot charger - BYD

In-depot charger - New Flyer

http://photos.newswire.ca/images/20160818_C4234_PHOTO_EN_755784.jpg

On-route charger - New Flyer

https://c2.staticflickr.com/6/5346/7193295054_0b2a1949d7_b.jpg

On-route charger - Proterra

Maintenance

Tools requirement

- Propulsion service kit
- Accessories tools
- Battery pack and inverter lifting jigs
- Computer
- Other bus tools

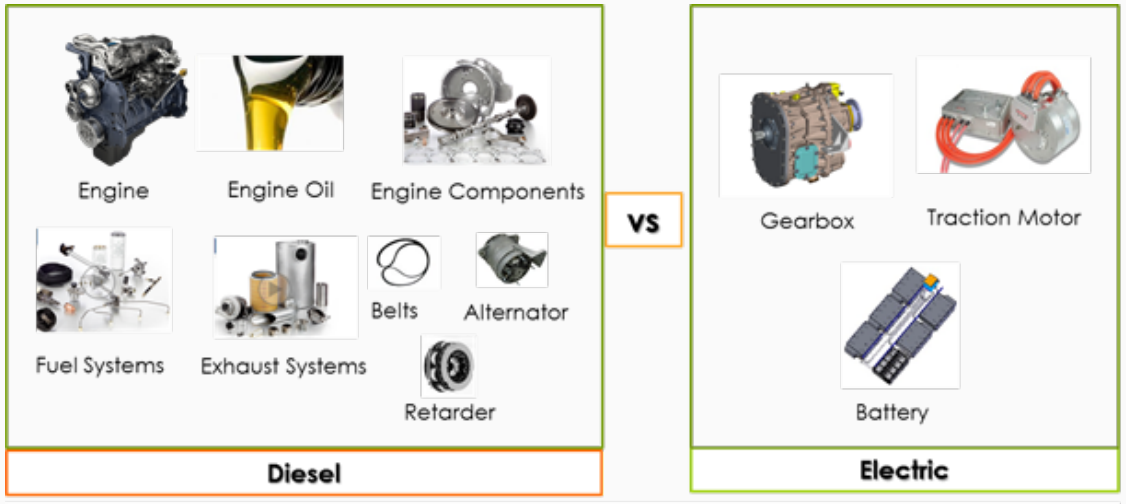


Table ES-1. Summary of Evaluation Results

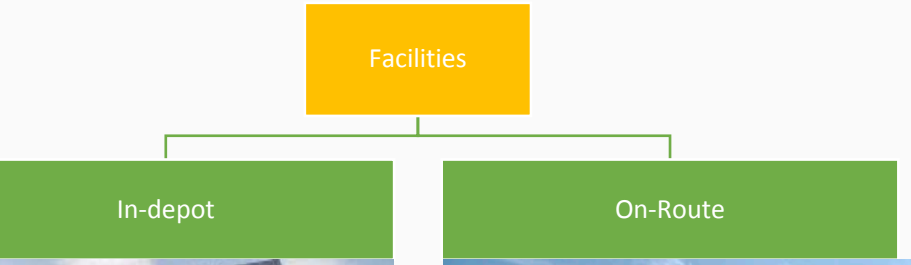
Data Item	BEB	CNG
Number of buses	12	8
Data period	4/14–7/15	10/14–7/15
Number of months	16	10
Total mileage in period	401,244	364,373
Average total miles per bus	33,437	45,547
Average monthly mileage per bus	2,333	4,555
Total operating hours	47,462	—
Availability (85% is target)	90	94
Fuel economy (kWh/mile or miles/GGE[a])	2.15	4.04
Fuel economy (miles/DGE[b])	17.48	4.51
Average speed (mph)	10.6	17.6
Miles between roadcalls (MBRC) – bus	9,331	45,547
MBRC – propulsion system only	25,078	91,093
MBRC – ESS[c] only	133,748	—
Total maintenance ($/mile)[d]	$0.16	$0.18
Maintenance – propulsion system only ($/mile)	$0.02	$0.08

[a] Gasoline gallon equivalent.
[b] Diesel gallon equivalent.
[c] Energy storage system.
[d] Work order maintenance cost.

Source: Foothill Transit Battery Electric Bus Demonstration Results by NREL

Facilities

- Dedicated parking space for an e-bus
- It is recommended to install a charger near to the transformer
- It requires an internet connection



- Dedicated charging space to install a charger
- It is recommended to install a charger near to the transformer
- It requires an internet connection

In-depot charger

On-route charger

In-depot Electricity requirements

	BYD	Proterra	New Flyer
Input voltage	480V, 3 phase	480 VAC, 3 Phase 4 wire	480VAC 3-phase
Input Current	80 amps	80 amps	80 amps
Input Frequency	60 Hz	60 Hz	60 Hz
Output Power	80kW	50 kW - 90 kW	80kW

Electricity requirements

	Proterra	New Flyer
Charger	500kW	300kW
Input voltage	480VAC: 800A Breaker to support 650A peak load	480VAC 3-phase

Electricity

Provider: Austin Energy

Pricing

- **Rate & Conservation rebates** are determined by the amount of electricity used

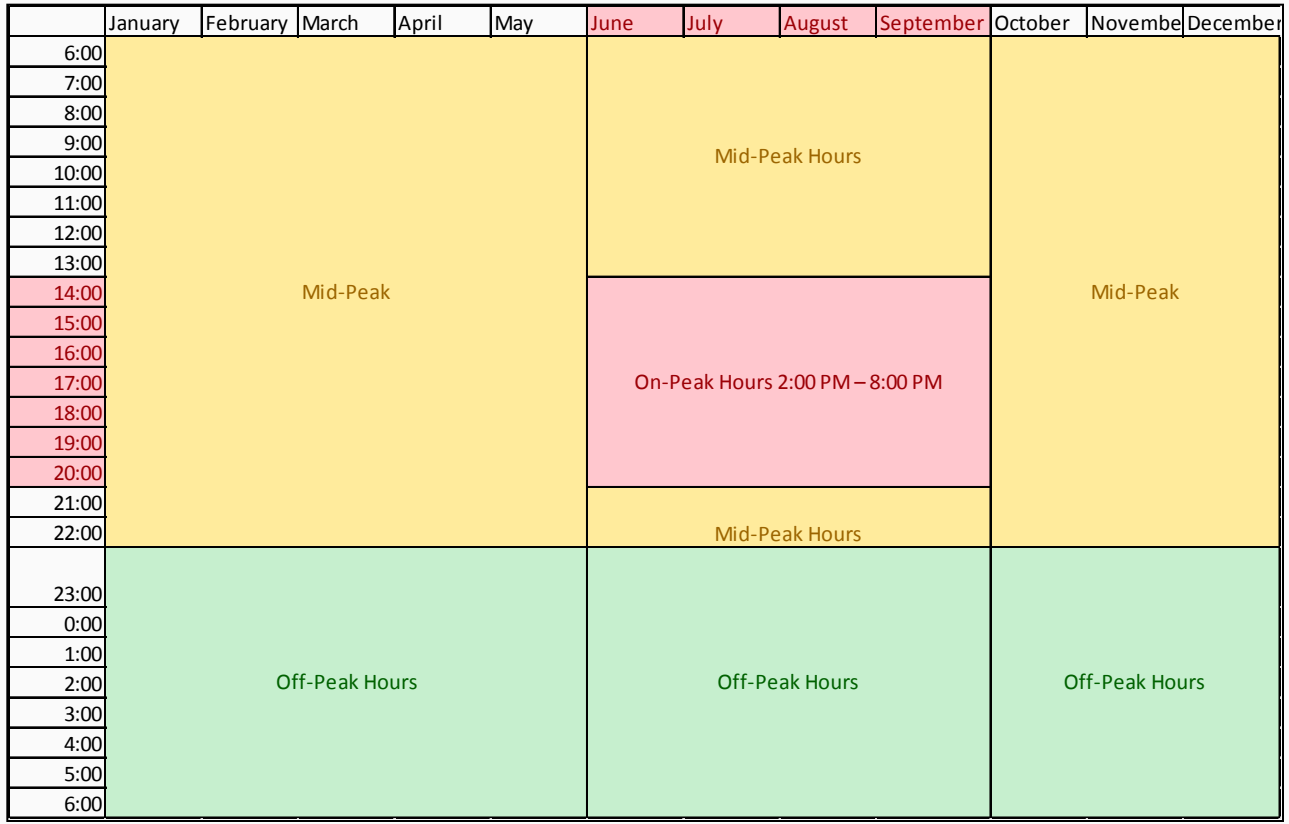
Demand & Peak management

- Usage of electricity increases at certain periods of time (time of day or seasonal)
- Causes extra demand on system

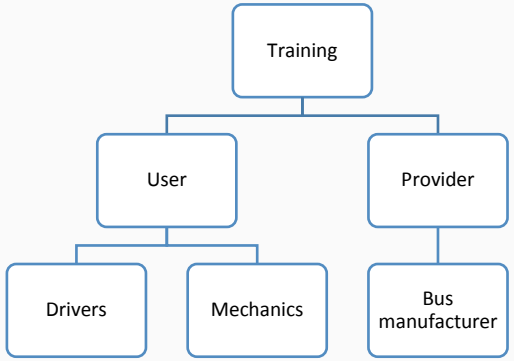
Site assessment is recommended by the Austin Energy

- lowest price/economical to install a charging station
- Minimum infrastructure up gradation
- Maximum utilization

Mid-Peak Hours:
6:00 A.M. – 10:00 P.M. Saturday – Sunday



Training

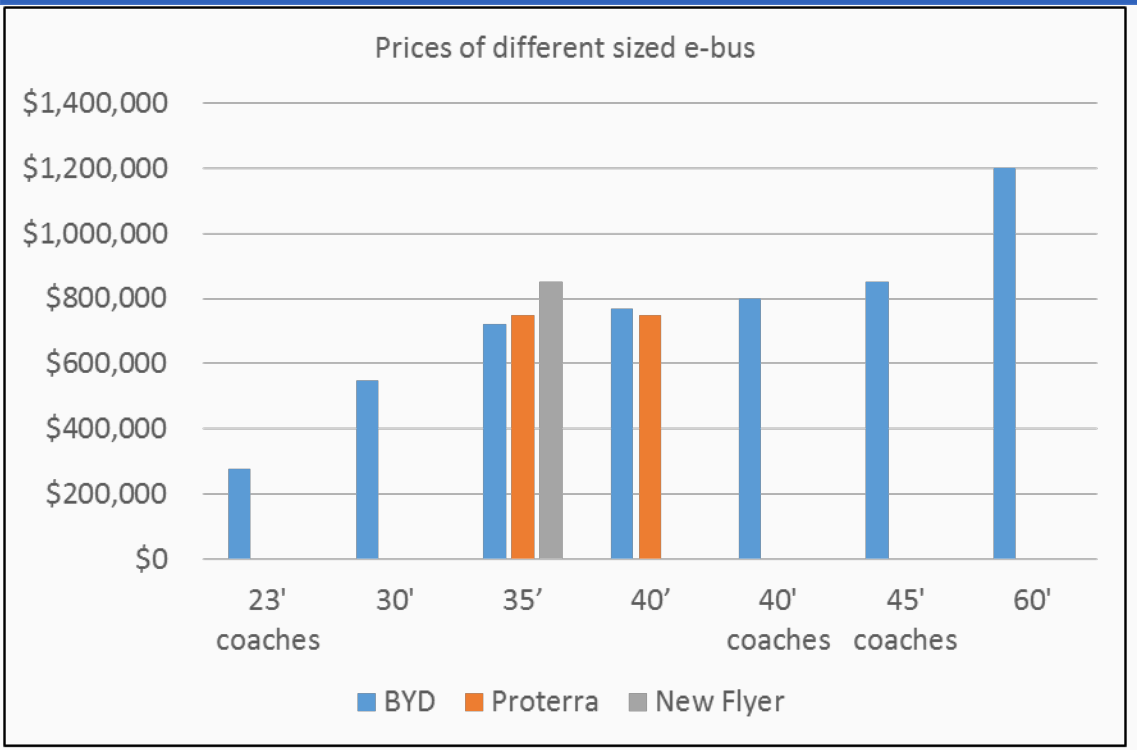


http://www.charterbusamerica.com/images/charter-bus-rentals-driver.jpg

Drivers

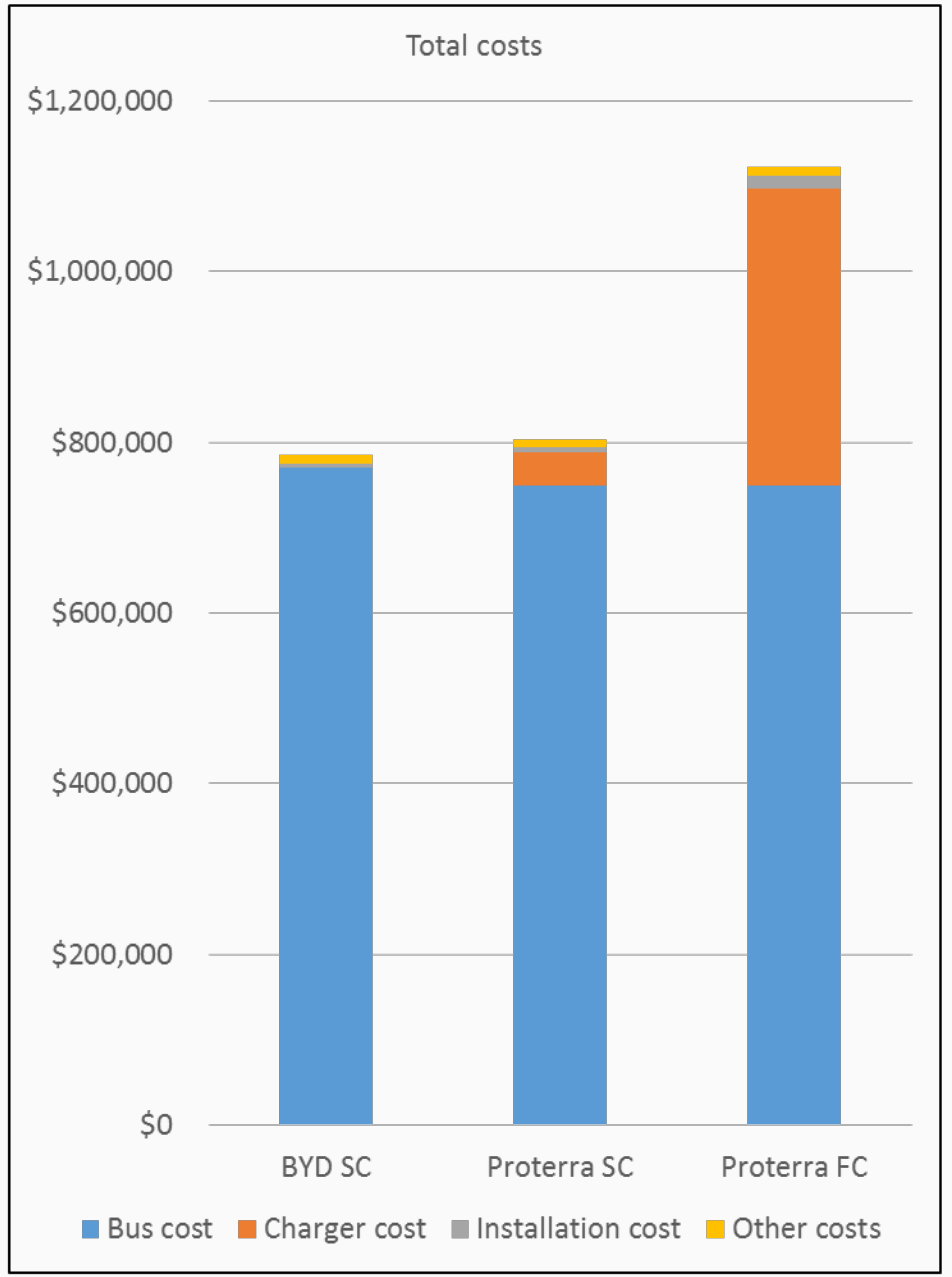
Mechanics

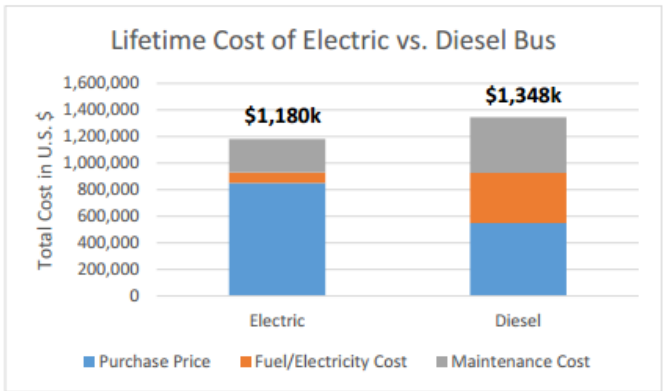
Costs

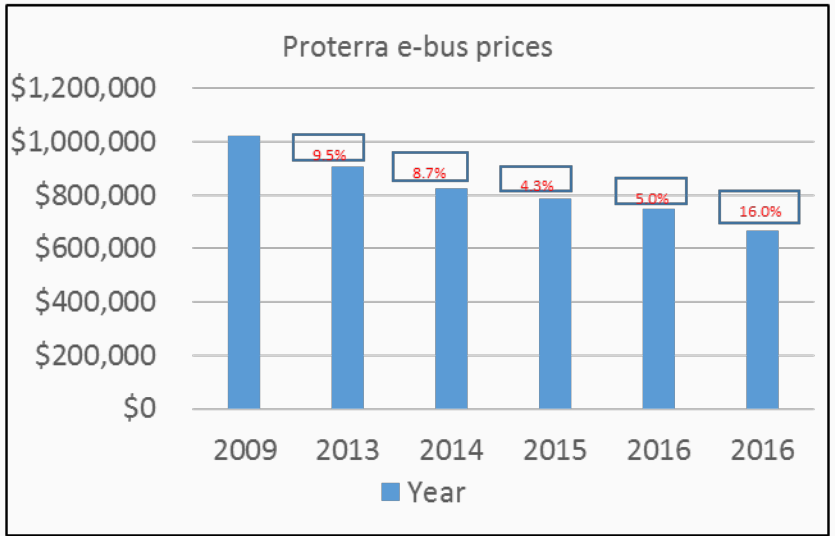


Financing options:

- Full payment
- Lease
- Finance







Source: Electric Bus Analysis for NYC Transit by J Aber Columbia University - May 2016

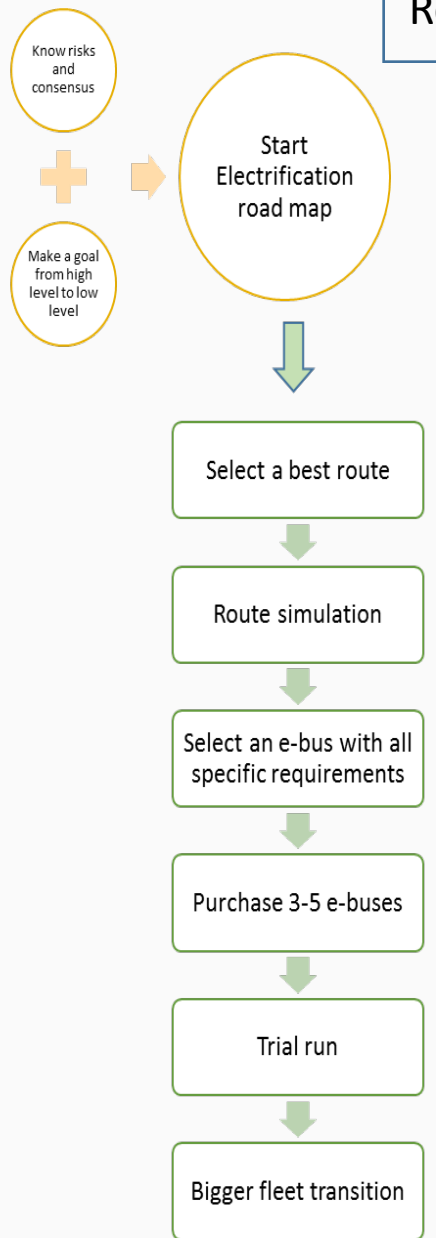
Survey Details

Bus Manufacturers

Transit Agencies

Transit Agencies	Foothill Transit	King County METRO	Transit Authority of River City
Total buses	330	1200	179
Diesel	0	200	0
CNG	315	0	0
Hybrid	0	827	32
Trolley (electric)	0	170	0
Battery Electric	**15**	**3**	**15**
% of Battery Electric	**4.5**	**0.3**	**8.4**
Bus Manufacturer	Proterra	Proterra	Proterra
launch date	2009	2015	2015
No. of charging stations	2 FC	1 FC	2 FC, 1 SC
On-route	1	1	2
Depot	1	0	1
Charging time	7-8 minutes	5-7 minutes	Circulator: 3 minutes; local: 9 - 11 miles
Cost for each charger	NA	~$700,000/ charging station	<$500,000
Future buses & chargers	15 buses	8 buses	6 buses
Range	NA	23 mile route	Circulator: 4- 8 miles; local: 14-22 miles

Recommendations



Next Steps...

- Gather information from New Flyer, other potential manufacturers
- Further facility surveys and route
- Electricity pricing and conservation rebates
- Pilot project
- Fleet transition