

Electric buses at Stanford

California Higher Education Sustainability Conference (CHESC)
June 16-18, 2015



100% electric transit bus used daily @ Stanford


KEEP
CALM
and
RAISE YOUR
HAND



Who wants a free bus?



About Stanford Marguerite

Stanford's free public shuttle service travels around campus and connects to nearby transit, shopping, dining, and entertainment.

- Serviced by Parking & Transportation Services since 1976
- Funded by parking revenue
- One of many successful TDM efforts
 - 72% SOV in 2002
 - 46.8% SOV in 2013
- Fleet of 79 vehicles
- Free service 365 days a year
- 2.3 million estimated riders in 2013
- 110+ drivers & support staff
- 2,500 charters annually

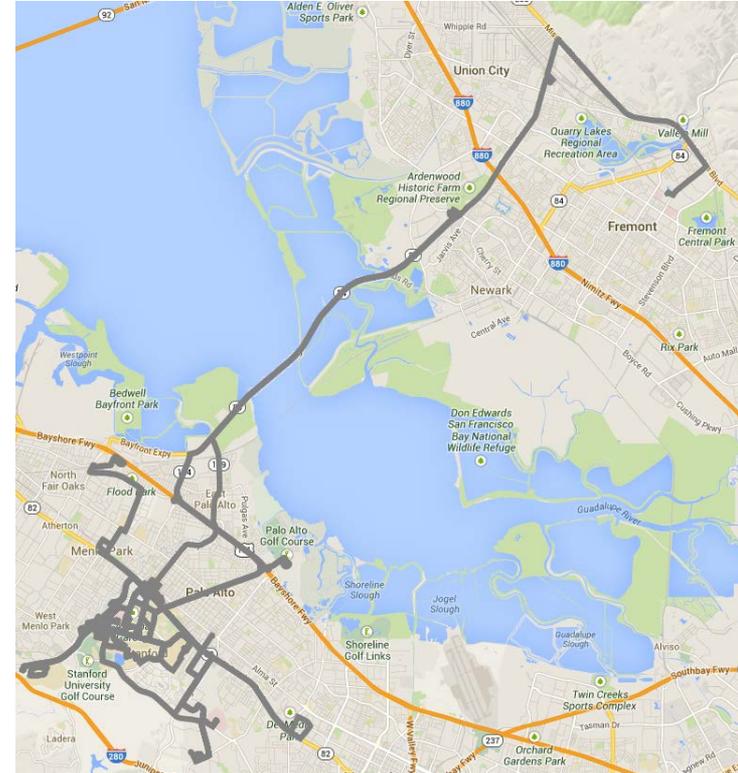


About Stanford Marguerite

- 23 Routes
- 1.1 million miles annually
- 121,000 hours of revenue service annually
- Core campus routes
 - Includes peak hour service on multiple lines
- Off campus
 - Remote offices, late night/weekend service for students to shop or get off campus
- Trans bay service
 - Early a.m., late p.m. and peak-hour service

Partnerships

- AC Transit for trans bay service with Line U, DB and DB1
- Caltrain Go Pass (heavy rail from San Francisco to San Jose)
- VTA EcoPass (bus, BRT, and Light rail for Silicon Valley)



Marguerite Fleet: *powered by combination of diesel, renewable diesel and electricity!*

**34 PASSENGER
100% ELECTRIC =
13**



**32 TO 38
PASSENGER
DIESEL ELECTRIC
HYBRID = 5**



**32 TO 37
PASSENGER
DIESEL
TRANSIT = 22**



**28 TO 30
PASSENGER
DIESEL
SHUTTLE = 18**



**14 TO 16
PASSENGER
DIESEL
SPRINTER = 17**



**TOTAL VEHICLES IN THE
MARGUERITE FLEET = 79
(OWNED AND LEASED)**

NEW TO FLEET

**13
34-Passenger
100% Electric
Buses
10 more on order for 2015
To replace shuttle fleet**



Photo Steve Castillo



**Four
49-Passenger and
one 57 Passenger
Motor Coaches**

The path to procurement



Electric Bus “Pilot Project”

Procure low floor electric bus that can handle running all day without having to recharge while in service.

Goals:

- Range of 125-145 miles a day
- Charge overnight
- Low Floor
- ADA compliant
- Lower long term cost
- On-board charging infrastructure
- Easy to maintain and operate
- Well supported



Consideration when selecting a vendor

Reputation

Chassis & Component Longevity How vendor deals with challenges

Financial resources

Cost to maintain

Parts availability

Charging options

Numbers of vehicles on the road

Options for extending range

Miles traveled w/ current

Data collection hardware

powertrain

Price

By the numbers; fuel vs. electricity

Electric buses are currently deployed on Routes X, Y, P (campus circulation) and Shopping Express (off-campus route)

Three buses = 2,270 combined weekly route miles

Per week fuel costs @ \$4.00 per gallon of renewable diesel

- \$1,515 = 378 gallons / 6 MPG for hybrid bus
- \$2,454 = 613 gallons / 3.7 MPG for diesel bus

Charging costs per week

- \$536 = 5,108 KWh @ \$.105



Bottom line savings for three vehicles over one year:

\$53,791 estimated savings per year using electricity vs. fuel consumed by Hybrid bus

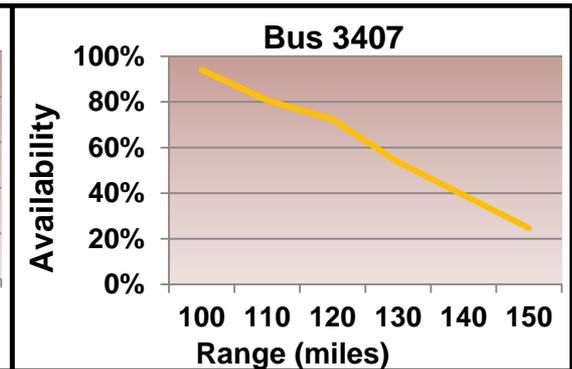
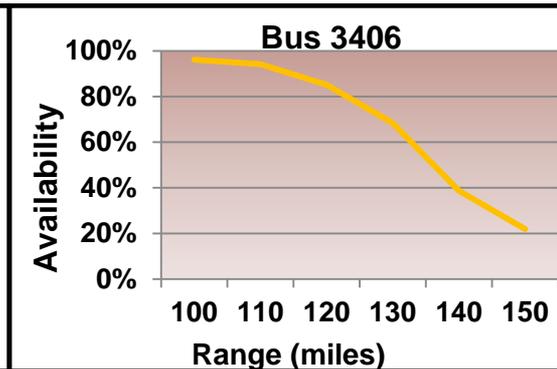
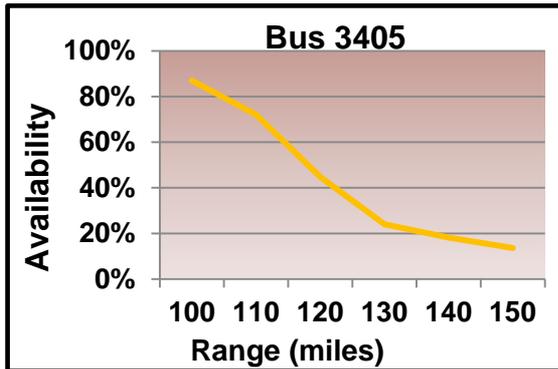
\$102,709 estimated savings per year using electricity vs. fuel consumed by diesel transit bus

Current Fleet Performance – September 2013 to April 2014

By the numbers;
actual performance

Summary Data		Bus		
		3405	3406	3407
	Days Driven	154	155	166
	Ave. Distance Driven	86	88	85
	Ave. SOC Consumed	65.2	58.4	58.7
	Ave. Consumption (kWh/m)	2.46	2.14	2.24

Expected Range	Upper SOC Limit	100			
	Lower SOC Limit	10			
		3405	3406	3407	
	Average Range	118.71	136.27	130.14	
	100	87%	96%	94%	
	110	72%	94%	81%	
	% Meeting Range	120	45%	85%	72%
	130	24%	68%	54%	
	140	18%	39%	39%	
	150	14%	22%	25%	



**Current Maintenance cost:
September 2013 to April 2014**

**By the
numbers;
actual
performance**

Electric Bus Maintenance Summary					
Service records from		9/5/2013	to		4/15/2014
Bus #	Cost	Miles	Cost/mile		
3405	\$ 1,873.00	12,085	\$		0.155
3406	\$ 2,216.39	13,268	\$		0.167
3407	\$ 5,404.39	13,054	\$		0.414

Besides schedule inspections every 45 days, the following items were addressed in the first eight months; nothing out of the ordinary.

- Headlight adjustments
- HVAC
- Door adjustments and sensors
- Minor electrical

By the numbers: operating cost per year, inclusive of vehicle cost

Assumptions to achieve Net Present Value (NPV) and cost per mile derived from LCCA:

- Vehicles financed at 4.25%
- 5% discount rate
- 2.5% inflation rate
- Diesel @ \$4.00 per gallon (baseline)
- Charging cost @ \$.0930 to \$.1060 per kwh
- 30K miles annually
- Routine/major maintenance included
- charging infrastructure cost not included (10K to 600K per charging station)

Current Shuttle Bus / Cutaway vs. 100% Battery

30' Cutaway / Shuttle (7.5 Years)
\$497,744 or \$2.07 per mile

Electric

30' Electric Bus (15 Years)
\$724,756 or \$1.61 per mile

Current Diesel Electric Hybrid & Diesel vs. 100% Battery Electric options

40' Hybrid Bus (15 Years)
\$1,368,059 or \$3.04 per mile
(Cummins /Allison)

40' Re-power Electric Bus (8 years)
\$527,962 or \$2.20 per mile

40' Diesel Bus (15 Years)
\$1,159,461 or \$2.58 per mile

40' Electric Bus (15 Years)
\$1,062,950 or \$2.36 per mile

35' Electric Bus (15 Years)
\$1,204,041 or \$2.68 per mile

Implementation Approach

40' bus trial at Stanford – 2 months

- Used on each route
- explore range and how terrain impacts performance

Use on routes that maximize daily range

- Routes X, Y, P and SE
 - Average of 80% depletion each day
 - Still could work if needed

Upon delivery

- Train drivers and vehicle technicians
- Gather data on route – Goal 2 kWh per mile



Establish goal and objectives

Gain buy-in

Prepare for change

Place resources

Set expectations

Set up data sharing

Solicit feedback

Improve product and experience

Options for charging your electric bus



Currently in use at Stanford:

- Two paddle system
- Handshake required
- Charger on the bus vs. overhead
- RFID capable
- 480 volts – scalable from 50 to 80 amps
- Could also charge @ 240 volts with 25 to 40 amps (one paddle)



Charging Options

- Overhead fast charge
- Inductive charging at selected bus stops, hills in the bus yard



...along the way

Driver training

- Driver must be active participant to make it all day
 - Regenerative braking is key to success
 - HVAC controlling – on/off based on need vs. set it and forget it

Multiple contests – team with best battery utilization wins \$1,000 to share!

Emergency responders

- Emergency shut down procedures/location

Vehicle

- AC and heat issues
- Inverter shutdown
- Battery management software
- Tail dragging (low to ground)
- Abundance of caution (range anxiety)



Next steps @ Stanford

Cutaway / shuttle replacement

- 30' low-floor transit bus
- 185-200 kWh battery
- Dual doors
 - easy boarding and alighting



Re-power portion of fleet to electric for peak hour use

- Lower cost
- Uses current vehicle chassis
- Uses existing charging infrastructure on campus

Goal with administration approval

- 80%+ vehicles in transit fleet to be 100% electric by 2020

Annual Miles with Battery Electric Buses

FY 2014

3 buses

181,762 miles

17% annual miles

FY 2016

23 buses

708,246 miles

58% annual miles

FY 2015

13 buses

442,626 miles

37% annual miles

What you get without administration approval



Are electric buses an option for your campus?

Considerations to go electric

- Miles traveled by a single bus each day
 - Battery pack size and range limitations
 - Dwell time charging (overhead or inductive)
 - Mid-life battery replacement
- Annual cost per year to operate each vehicle
- Support infrastructure costs
- Passenger capacity/need by route
 - Sprinter fleet will stay in use at Stanford



How to pay for an electric bus?

- Financing/lease options from manufacturer
- State or local grants
- University Improvement Funds
- Fed funds 80/20
- Savings from fuel and maintenance cost



Thank You!

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Information on all Stanford Parking, Transportation and
TDM programs can be found @:

Transportation.Stanford.edu

Resources: Vendors below are not to be considered an endorsement by Stanford



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