

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

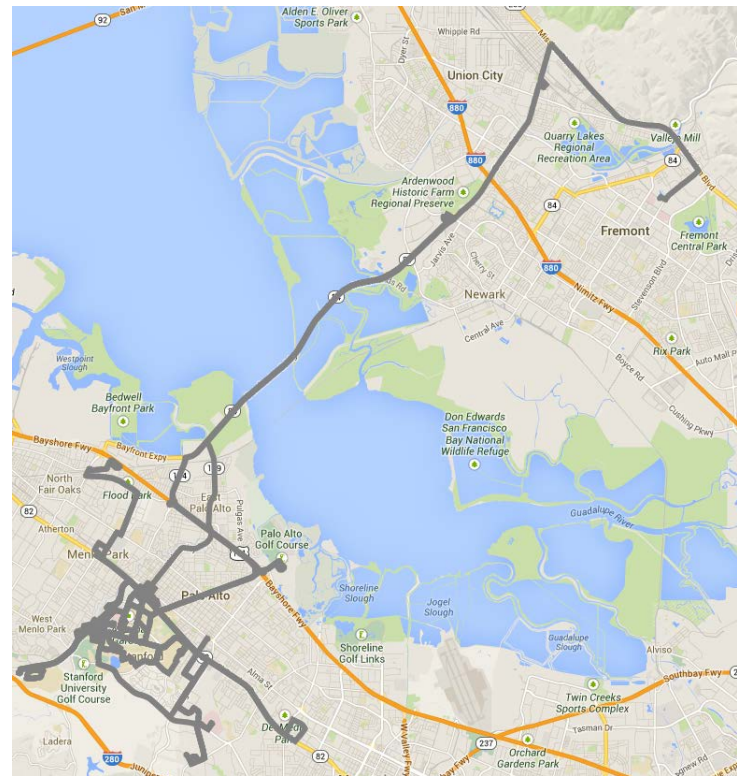


About Stanford Marguerite

- 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)

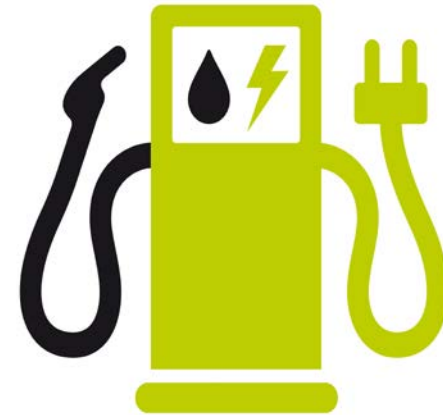
Three buses = 2,270 combined weekly route miles

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

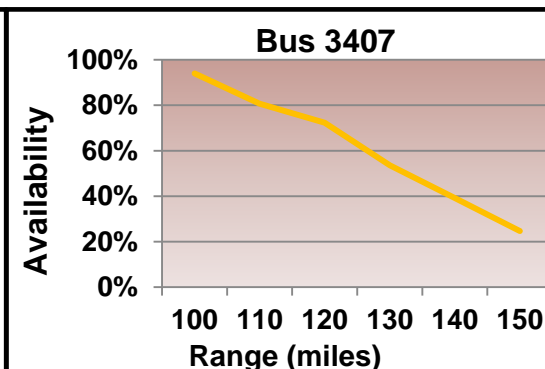
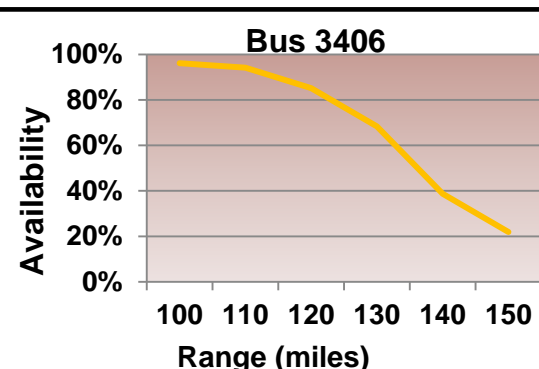
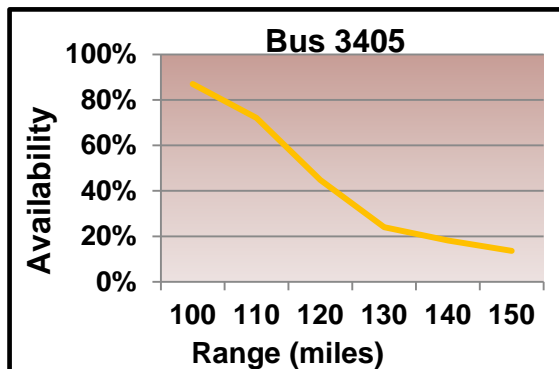
\$102,709 estimated savings per year using electricity vs. fuel consumed by diesel transit bus

By the
numbers;
actual
performance

Current Fleet Performance – September 2013 to April 2014

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%
	120	45%	85%	72%
	% Meeting Range			
	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 Electric

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

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
(Cummings /Allison)

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

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

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

OR
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!

Ward Thomas

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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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