Draft Discussion Topics on Costs
Transit Agency Workgroup Meeting
January 28, 2016

Total Cost of Ownership

The total cost of ownership includes the total costs of buying, operating, and maintaining a bus over its lifetime of 14 years, and building, operating and maintaining the charging/fueling infrastructure and maintenance bay. Staff has been collecting cost data and is currently working with transit agencies to confirm the data and assumptions to be used in the cost analysis for the Advanced Clean Transit regulation and will be updating information as more is gathered. The rule cost analysis will compare year by year costs of normal replacements and operating costs to costs with a rule in place.

Renewable fuels are widely available and the cost of renewable natural gas and renewable diesel is essentially the same as conventional fuel because the value of credits from the federal renewable fuel standard and California's Low Carbon Fuel Standard (LCFS) is offsetting the higher costs of producing renewable fuel. For future fuel cost projections, we plan to continue to model the cost of renewable diesel and renewable natural gas as equal to conventional fuels. Proposed rule requirements would not affect the ability to claim credits however, greenhouse gas emissions reductions from using renewable diesel and renewable diesel are attributable to the LCFS program and cannot be double counted in the Advanced Clean Transit regulation.

Cummins has already certified a natural gas engine to 90 percent lower NOx than today's required standard and we expect it to be commercially available before the end of 2016. Cummins is the only engine supplier for buses sold in California. Additional low NOx CNG and diesel engines are expected to become available in the next few years. We have estimated hardware costs for low NOx engines, but do not have a current estimate of the incremental cost of low NOx engines. The Board has already approved funding to offset the expected higher cost of the engine.

The total cost of ownership for battery electric buses is on par with conventional buses. Even though capital costs of battery electric buses and charger are higher, there are fuel and maintenance cost savings that can offset some or all of the initial costs. Below is a simple example based on available data that shows how the cost savings from operating battery electric buses can offset the upfront costs.

> ***Example:***
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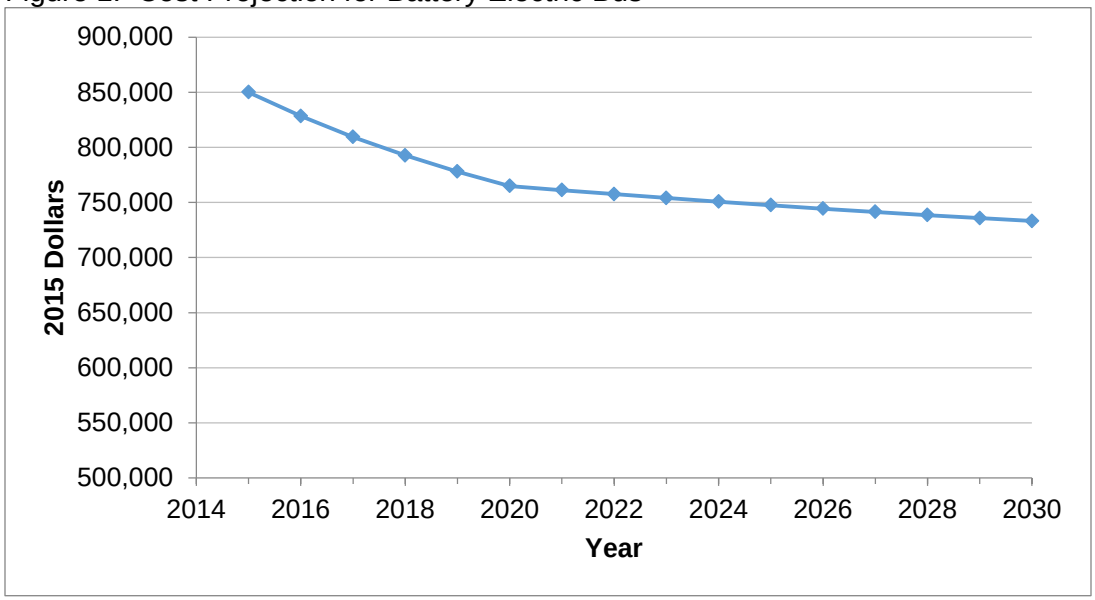
> *Electricity rate at $0.20/kWh would cost about $16,000 per year to charge a bus. The Low Carbon Fuel Standard (LCFS) credit revenue (at a credit price of $100) would reduce the cost by about $9,000 per year for a net fuel cost of $7,000. A comparable diesel bus would have $24,000 in fuel cost per year if the fuel cost is $2.5/gallon. The net annual fuel saving would be $17,000. If maintenance costs savings are lower by about $0.38 per mile it would result in another $15,000/year in savings. The present value of total fuel and maintenance costs saving over a 14-year period would be $350,000 if a 5% discount rate is used. If a 40' battery electric bus and charger costs $365,000 more than a conventional diesel bus, the costs are nearly the same. The comparison will vary with different assumptions.*

This simple example does not include future projections of fuel costs, electricity costs, LCFS credits, bus prices and other start-up costs that will be part of a thorough analysis.

Battery Electric Cost Projection

Costs for battery electric buses are expected to decrease over time compared to conventional buses (in constant dollars). Battery costs are the single largest driver for overall BEV incremental costs. Based only on the projected battery cost reduction, the cost of a battery electric bus with a 300 kWh battery system would decrease from $850,000 in 2015 to around $730,000 in 2030. In this vehicle cost projection, staff assumes only the cost of battery pack would decrease and the costs of other bus components remain the same. In addition, the increase in production volume of battery electric buses should further decrease the cost. We are interested in obtaining prices and cost projections for various bus models and types. The cost projection for battery electric bus is presented in Figure 1.

Figure 1. Cost Projection for Battery Electric Bus



Credits from Low Carbon Fuel Standard to Offset the Cost of Certain Fuels

Transit agencies may generate LCFS credits for certain low-carbon fuels. The LCFS credit revenue can offset some of the fuel cost for those fuels.

Transit agencies may opt-in to LCFS under the categories of electric vehicle (EV) fleet operators, battery switch station owners, and fixed guideway system operators. For hydrogen transportation fuel, the credit generator is initially the person who owns the finished hydrogen fuel. If the transit agency doesn't own the fuel as it is finished, they can still be the credit generator through a negotiated agreement with the fuel provider. For fuel consisting solely of fossil CNG or LNG, the credit generator is the entity that owns the natural gas fueling equipment at the facility at which the fuel is dispensed to motor vehicles for their transportation use. Under this category, the transit agencies may opt-in to the LCFS program to generate credits. With respect to the bio-CNG or bio-LNG, the credit generator is the producer or importer of the biomethane injected into the pipeline for delivery to the dispensing station. The ability to generate credits can be transferred to the transit agency if the two parties agree by a written contract.

The estimated LCFS credit revenue per mile and annual credit revenue for transit buses based on an annual mileage of 40,000 are presented in Table 1.

Table 1. Potential Revenue for Transit Buses from Low Carbon Fuel Standard

Bus Fuel Type	Fuel efficiency	Credit revenue per mile (LCFS credit value $100)	Credit Revenue Total (LCFS credit value $100)
Diesel	3.8 mile/dge	$0.00	$0
Renewable diesel	3.8 mile/dge	$0.24	$9,549*
Avg. of conventional LNG & CNG	3.4 mile/dge	$0.07	$2,858
Renewable natural gas	3.4 mile/dge	$0.29	$11,415*
Electricity**	0.5 mile/kWh	$0.23	$9,064
Hydrogen	6.5 mile/kg	$0.20	$8,102*

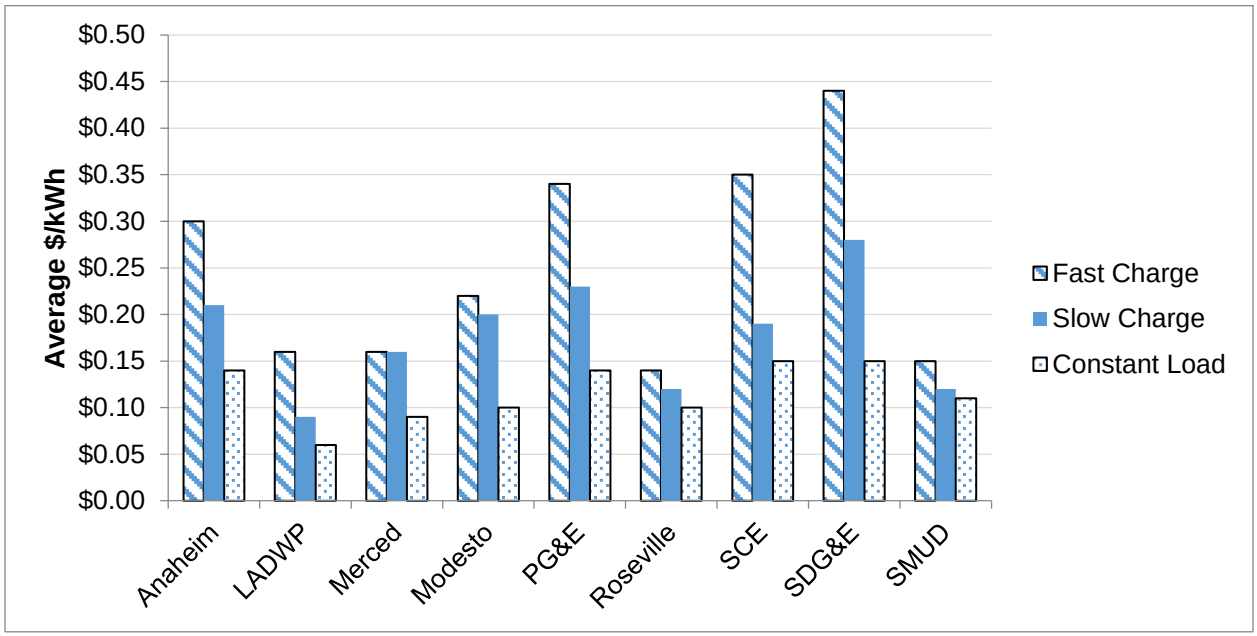
* Generally fuel producers/providers claim most or all of the credits.
** LCFS credit revenue for electricity is based on the current California grid electricity mix. The credit revenue will be higher as renewable electricity in the grid increases.

Electricity Rates

Standard electricity rates vary by utility, schedule, total customer demand, and season. Commercial customer electricity rates commonly have a demand charge on top of the electricity usage rate. The demand charge is based on the maximum power in kilowatts (kW) used during an interval, for example, a 15-minute interval. Electricity rates are a combination of demand charges, usage charges and meter fees. Usage charges are based on total electricity consumed and also vary by time of use. Figure 2 illustrates electricity costs for standard rate schedules from several utilities in California for examples of charging electric buses. For comparison, the same rates are shown for a constant load at 500 kW with the same rate schedules. The following assumptions are used in this example:

- Fast charge: 50% of the charging demand will be during peak hours and 50% during mid-peak, assuming 6 buses charging at 500 kW.
- Slow charge: 25% of the demand comes during mid-peak hours and 75% during off-peak hours, assuming 6 buses charging at 80 kW.
- Constant load: 500 kW load at peak demand for 24 hours.

Figure 2. Electricity Cost to Charge a Battery Electric Bus by Utility



Areas Need Input

Staff continues to work with the Transit Agency Subcommittee to collect the following cost information for existing buses:

- Additional costs transit agencies would incur if they pay the contract price for a fuel, e.g., electricity cost to compress natural gas
- Maintenance costs for different bus vintage
- Mid-life drivetrain and component replacement costs
- Capital and O&M costs of fueling infrastructure and maintenance bays

Staff also would like to solicit the cost projections on the following items from the Advanced Clean Transit Workgroup:

- Battery or battery electric buses
- Fuel cell stack or fuel cell buses
- Incremental cost of low NOx engines
- Natural gas fueling station
- Battery electric bus charging infrastructure (both slow and fast)
- Hydrogen fueling station