APPENDIX E

ECONOMIC MODEL

Appendix E

Economic Model

This appendix presents a summary of calculations used to complete the economic analysis presented in Section IV, and describes the model used to develop the cost and payback numbers presented in the Upper and Lower Bound FCV scenarios. This model, entitled “CFO Station Cost Calculator,” is included as part of this staff report.

<Include discussion of credit card fees>

Equation for estimating the number of required new CFOs:

$$Number\ of\ New\ Stations = \frac{MXDV - Existing\ supply}{Per\ station\ throughput\ volume}$$

Where:

$MXDV$ means Maximum Demand Volume for a specific designated clean fuel in gallons gasoline equivalent calculated pursuant to the equations specified in section 2304 of the regulation. The calculation uses vehicle numbers and fuel economy values by model year presented in Table IV-1.

$Existing\ supply$ upon regulation activation is the maximum annual capacity of the stations listed in Table I-1 that are anticipated to be in operation for the year in which the calculations are being made.

$Existing\ supply$ for years following the year that the regulation is activated also includes stations that were required to be constructed per the regulation in prior years and assuming that they each can supply a maximum volume equal to the per station throughput volume.

$Per\ station\ throughput\ volume$ is 146,000 kilograms per year (which equals 400 kilograms per day for 365 days per year) for hydrogen.

Equation for station initial cost annual payments:

$$Annual\ payment = \frac{Present\ Value}{PVIFA}$$

Where:

> $Present\ value$ is the total initial station cost presented in Table IV-3 in 2009 dollars.
>
> $PVIFA$ is the present value interest factor of annuity (5.5824), which represents seven annual payments with a 6 percent interest rate.

Table E-1. Annual Payments Required to Amortize Hydrogen Station Loans ($2009)

Type of 400 kg/day station	Initial Cost (Present Value)	Annual Payment
Central SMR with delivered gaseous hydrogen	$1.5 million	$269,000
Central SMR with delivered liquid hydrogen (Early years)	$1.8 million	$332,000
Central SMR with delivered liquid hydrogen (Later years)	$1.4 million	$251,000
On-site SMR	$2.4 million	$430,000

Estimating Operation and Maintenance Costs

$$Operating\ costs = fixed\ costs + variable\ costs$$

$$Variable\ costs\ (delivered\ H2) = (146{,}000\,\frac{kg}{year} \times \%\ utiliztion)\ \times (delivered\ H2\ cost + onsite\ electricity\ cost + SB1505\ premium)$$

$$Variable\ costs\ (onsite\ SMR) = \left(146{,}000\,\frac{kg}{year} \times \%\ utiliztion\right) \times (natural\ gas\ cost + onsite\ electricity\ cost + SB1505\ premium)$$

Where:

$Fixed\ costs$ include annual costs not associated with fuel throughput such as hydrogen station upkeep, regular maintenance, repair and replacement of station equipment due to normal wear and tear, and rental of retail space.

$Variable\ costs$ include costs that are dependent on hydrogen throughput such as the purchase of hydrogen (or the on-site production hydrogen) and the electricity required to chill and dispense the hydrogen at 5000 and 10,000 psi.

$SB\ 1505\ premium$ is the per kilogram incremental cost increases due to the 33 percent renewable requirements of SB 1505 including the price premium associated with purchasing renewable electricity and renewable biogas. This premium was applied to the variable costs starting 2017 in the Upper Bound Scenario and 2021 in the Lower Bound Scenario.

Table E-2 lists the assumptions and information sources for fixed and variable O&M costs used in the economic model. Station utilization rates presented in Table IV-5 are also factored into the variable costs.

Table E-2. Fixed and Variable Operation and Maintenance Costs (2009 dollars)

Fixed Costs	$100,000 per year (all pathways)[1]			
Variable costs	**Dollars per kilogram of hydrogen produced/dispensed**			
Hydrogen Pathway	**Delivered H2 Cost[2]**	**On-site Electricity**	**On-site Natural Gas**	**SB 1505 Premium[3]**
Delivered Gaseous	$2.85	$0.15[4] (1 kwh/kg)[5]	N/A	$0.70
Delivered Liquid	$2.70	$0.15 (1 kwh/kg)	N/A	$0.70
On-site SMR	N/A	$0.45 (3 kwh/kg)	$1.00[6]	$0.70

[1] UCD, 2011. University of California, Davis. Ogden, Joan et al. UCD Institute of Transportation Studies. “Analysis of a “Cluster” Strategy for Introducing Hydrogen Fuel Cell Vehicles and Infrastructure in Southern California.” Sept. 16, 2011. Revised Oct. 5, 2011.
[2] US DOE, 2011b. United States Department of Energy. Satyapal, Sunita. US DOE Fuel Cell Technologies Program. “Overview of Hydrogen and Fuel Cells.” March 3, 2011.
[3] Staff assumed that a kilowatt-hour of renewable electricity would cost almost three times that of commercial grid electricity, and biogas inputs would cost 2.5 times that of conventional natural gas.
[4] Based on average commercial electricity for California’s three investor-owned utilities.
[5] UCD, 2011. University of California, Davis. Ogden, Joan et al. UCD Institute of Transportation Studies. “Analysis of a “Cluster” Strategy for Introducing Hydrogen Fuel Cell Vehicles and Infrastructure in Southern California.” Sept. 16, 2011. Revised Oct. 5, 2011.
[6] Estimate base on data from US DOE, 2001, and EIA, 2011.

Calculating annual costs to all regulated parties

$$Total\ annual\ cost_y = \sum_y Annual\ cost_i - \sum_y (kg\ hydrogen\ sold_i \times price)$$

Where:

> $Annual\ cost_i$ is the annual payment plus annual operating costs for station i in year y.
>
> $kg\ hydrogen\ sold_i$ is the estimated amount of hydrogen in kilograms sold at station i in year y. For the economic model, $kg\ hydrogen\ sold\ at\ each\ station = 146{,}000 \times \%\ utilization$.
>
> $Price$ is the example per-kilogram hydrogen price from Table IV-6. For this analysis, credit card fees are assumed to be included in the example hydrogen price. It is difficult to predict how credit card fees affect the cost to provide hydrogen since fees will vary from station to station and will not be applied when fuel is purchased with cash or a gas card.

Calculating cost to regulated parties if stations are not utilized – worst case scenario

$$Total\ cost = total\ investment_{year\ 1} + 75\%\ investment_{year\ 2} + 10\%\ investment_{year\ 3}$$

Where:

> $Total\ investment_{year\ 1} = \sum_{year\ 1}(7 \times annual\ payment)_i + (1 \times fixed\ operating\ cost)_i + Decommissioning\ cost_i$
>
> $year\ 1$ applies to the stations installed for the first compliance year for which the vehicle trigger has been reached. This would be 2018 in the Lower Bound Scenario and 2015 in the Upper Bound Scenario.
>
> $year\ 2$ applies to the stations required to be installed for the second compliance year after the vehicle trigger has been reached. This would be 2019 in the Lower Bound Scenario and 2016 in the Upper Bound Scenario.
>
> $year\ 3$ applies to the stations required to be installed in for the third compliance year after the vehicle trigger has been reached. This would be 2020 in the Lower Bound Scenario and 2017 in the Upper Bound Scenario.

$annual\ payment_i$ is the annual payment for station i. The calculation assumes that regulated parites will have incurred 100 percent of their initial costs for $year\ 1$ stations.

$fixed\ operating\ cost\ _i$ is the fixed annual cost of $100,000 from Table E-2 applied to each station. The calculation assumes that fixed costs will be incurred by $year\ 1$ stations and for only one year.

$Decommissioning\ cost_i$ is assumed to be $100,000.[7]

$75\%\ investment_{year\ 2}$ is 75% of the total initial cost for all stations required to be installed in $year\ 2$.

$10\%\ investment_{year\ 3}$ is 10% of the total initial cost of all stations required to be installed in $year\ 3$.

[7] Decommissioning cost is estimated to be $50,000 to $100,000. Sources: bids received by CaFCP to decommission their liquid delivery hydrogen fueling station in West Sacramento. $100,000 was used in the above estimates.