

**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 fuel cell vehicles (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:

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

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:**

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

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 H<sub>2</sub>) = (146,000  $\frac{kg}{year}$  × % utilization) × (delivered H<sub>2</sub> cost + onsite electricity cost + SB1505 premium)*

*Variable costs (onsite SMR) = (146,000  $\frac{kg}{year}$  × % utilization) × (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) <sup>1</sup>				
Variable costs	Dollars per kilogram of hydrogen produced/dispensed				
Hydrogen Pathway	Delivered H2 Cost		On-site Electricity	On-site Natural Gas	SB 1505 Premium <sup>2</sup>
Delivered Gaseous	Molecule <sup>3</sup>	\$2.03	\$0.15 <sup>4</sup> (1 kwh/kg) <sup>5</sup>	N/A	\$0.70
	Compression, Storage & Distribution <sup>6</sup>	\$2.46			
	Total	\$4.49			
Delivered Liquid	Molecule <sup>7</sup>	\$2.03	\$0.15 (1 kwh/kg)	N/A	\$0.70
	Liquefaction, Distribution <sup>8</sup>	\$2.15			
	Total	\$4.18			
On-site SMR	N/A		\$0.45 (3 kwh/kg)	\$1.27 <sup>9,10</sup>	\$0.70

### 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<sub>i</sub>* is the annual payment plus annual operating costs for station *i* in year *y*.

<sup>1</sup> UCD, 2011.

<sup>2</sup> 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.

<sup>3</sup> US DOE, 2012. United States Department of Energy. Dillich, Sara and Todd Ramsden and Marc Melaina. "DOE Hydrogen and Fuel Cells Program Record." Record # 12024. September 24, 2012.

<sup>4</sup> Based on average commercial electricity for California's three investor-owned utilities.

<sup>5</sup> UCD, 2011.

<sup>6</sup> US DOE, 2012.

<sup>7</sup> US DOE, 2012.

<sup>8</sup> 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. Slide 31-Liquid H2 Costs: Terminal cost of \$1.90/gge and Liquid H2 truck delivery cost of \$0.25/gge.

<sup>9</sup> US DOE, 2001. United States Department of Energy, National Renewable Energy Laboratory. Spath, Pamala, L. and Margaret K. Mann. "Life Cycle Assessment of Hydrogen Production via Natural Gas." Document No. NREL/TP-570-27637. Revised February 2001. Provided following data to support \$1.27/kg cost: 158 scf of natural gas is needed to produce one kg of hydrogen via SMR.

<sup>10</sup> EIA, 2013. United States Energy Information Administration. US Natural Gas Price. January 29, 2013. Website. <http://www.eia.gov/dnav/ng/hist/n3035us3m.htm>. Accessed Jan. 29, 2013. Supports average price for natural gas of \$8.00/1000 standard cubic feet used to determine \$1.27 cost.

$kg\ hydrogen\ sold_i$  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:

$$Total\ investment_{year\ 1} = \sum_{year\ 1} (7 \times annual\ payment)_i + (1 \times fixed\ and\ variable\ operating\ cost)_i + Decommissioning\ cost_i$$

*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<sub>i</sub>* is the annual payment for station  $i$ . The calculation assumes that regulated parties will have incurred 100 percent of their initial costs for *year 1* stations.

*fixed and variable operating cost<sub>i</sub>* is the fixed annual cost of \$100,000 from Table E-2 applied to each station plus one year of variable operating costs assuming 25 percent station utilization. The calculation assumes that operating costs will be incurred by *year 1* stations and for only one year.

*Decommissioning cost<sub>i</sub>* is assumed to be \$100,000.<sup>11</sup>

75% *investment<sub>year 2</sub>* is 75 percent of the total initial cost for all stations required to be installed in *year 2*.

10% *investment<sub>year 3</sub>* is 10 percent of the total initial cost of all stations required to be installed in *year 3*.

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<sup>11</sup> Decommissioning cost is estimated to be \$50,000 to \$10,000. Source: bids received by CaFCP to decommission their liquid delivery hydrogen fueling station in West Sacramento. \$100,000 was used in the above estimates.