Appendix 3.6-C
Energy Analysis Memorandum

Energy Analysis Memorandum

Date: February 10, 2012

To: Rebecca Kohlstrand, Bryan Porter
Copy: Rick Schmedes, Nick Brand
From: Alice Lovegrove

Subject: Comparison of energy requirement calculations and conversion factors used in the 2012 regional energy assessment compared to the 2008 Bay Area to Central Valley Program EIR energy assessment.

In the 2008 Bay Area to Central Valley Program EIR, the statewide energy impacts of the proposed HSR project were analyzed using a methodology from the 2005 Statewide Program EIR/EIS. The 2012 energy impact analysis reflects a refinement to the analysis presented in those documents. The 2012 analysis utilizes updated conversion factors, ridership forecasts, train sets and vehicle miles traveled, among other parameters. These various parameters, along with their values used in the two analyses, are presented in Table 1 and detailed below.

Energy Estimates and Analysis Parameters

In the 2012 analysis, the train proposed is the Siemens ICE-3 Velaro. The 2008 Bay Area to Central Valley Program EIR was based on an earlier model of the same Siemens ICE-3 train. In the Bay Area to Central Valley analysis an average regeneration rate of 14% was used in the calculations. For the 2012 analysis, a 15% energy savings due to regeneration from braking was used (based on data obtained from comparable HSR systems around the world). Lines 3 through 8 in the table directly compare the 2012 and 2005 EIR calculation methods when regeneration is assumed.

The 2012 analysis also calculates energy use from the mileage of 8-car trainsets rather than of the two trainsets coupled together to create a 16-car train used in the Bay Area to Central Valley Program EIR energy analysis. This is because in the 2012 operating plan a mix of single-set trains and double-set trains operate to meet fluctuations in demand throughout the day. This approach results in somewhat higher estimated average energy use per mile because it assumes that a double set train uses twice the energy of a single set train, when in fact the second train set does not experience the same value of aerodynamic resistance to motion as the lead train. Since the appropriate resistance formula for the 16-car train was not available from the manufacturer, the value was doubled in the 2012 calculations in order to remain conservative.

The current analysis assumes that 95.49 million trainset miles will be traveled in 2035 by 8-car train sets. This is estimated from the Draft Technical Memorandum, "High-Speed Train Service Plan - Full Build Network with Links to Sacramento and San Diego", January 2009, p. 18, with adjustment for 365 days a year at weekday service levels and addition of 6% for growth to 2035 and dead-head moves. This mileage results in a total traction energy consumption of 5,156 gigawatt hours (GWh) of energy per year (14.13 GWh per day) counting a 15% savings from regenerative braking. (When using regenerative braking, the train converts some kinetic energy into electrical energy and feeds this energy back into the overhead contact system to be used by other trains operating close by or to be fed back into the power supply utility network.) The Bay Area to Central Valley Program EIR assumed that regenerative braking would reduce power demand by 14%, and that 43 million miles would be traveled in 2030 by 16-car train sets, resulting in a total traction energy consumption of 3,190 GWh of energy per year or 8.74 GWh per day.

The 86 million trainset miles of the Program EIR/S (43 million train-miles times two) were based on an operations plan needed to carry loads associated with relatively high HST ridership generated by lower

fares (HST fares at 50% of air). The 95.49 million trainset miles of the 2012 operations plan are based on the same assumption of fare and ensuing ridership loads.

The 2012 analysis conservatively assumes that systemwide electrical energy requirements for the High-Speed Train HST system will total 16.55 GWh/day, which includes energy required for traction, on board service, stations, maintenance facilities, dwells, nonrevenue operation, , and transmission and transformer losses within the HST system. The Bay Area to Central Valley Program EIR did not apply additional adjustments to account for these factors.

GWh to Btu Conversion Factor

In the Bay Area to Central Valley Program EIR, the electrical energy consumption requirement of the HSR was converted from GWh units to million British thermal units (MMBtus). A british thermal unit (Btu) is a commonly used energy unit which reflects the amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit. Btus are often used as an energy unit when different energy sources are present, such as exists in the High Speed Rail analysis. The High Speed Rail analysis reflects electrical energy usage from powering the HSR system, as well as energy from fuel usage due to changes in roadway travel and plane travel. Therefore, the use of Btus as the energy unit provides a common platform for comparison. The kWh to Btu conversion factor is 3414, i.e. 1 kWh = 3414 Btus. In the Bay Area to Central Valley EIR, the conversion from kilowatt hour (kWh) to Btu was based on the 1983 Caltrans Energy Transportation Manual (page E-18), which applies a kWh to Btu conversion factor of 1 kWh = 12,458 Btus (1GWh = 12,458,000 Btus). This factor accounts for generation, transmission and AC/DC conversion losses, according a weight of 3.65 to these losses with respect to energy used for traction purposes thereby escalating the conventional kWh to Btu conversion factor by 3.65. This resulted in an annual estimated electrical demand of the HSR of 39,707,950 MMBtus or 108,789 MMBtus/day in the year 2030. In the current analysis, the more commonly used kWh to Btu conversion factor of 3,414 (1 GWh = 3,414,000 Btus) was applied. This factor is more appropriate for use because it does not take into account the energy required to produce the fuel used to generate electricity (which is outside the boundaries of this analysis), power conversion losses or transmission losses, which were accounted for separately in the electrical energy calculation. The current analysis results in an annual electrical usage of 20,622,500 MMBtus or 56,500 MMBtus/day. In addition, the current analysis presents a consistent methodology by evaluating the energy impacts due to changes in roadway vehicle miles traveled and airplane travel with conversion factors that did not include generation losses in their Btu estimates.

Conclusion

The energy analysis presented in the Bay Area to Central Valley Program EIR was based on the best available data at the time of the analysis. The current analysis reflects the various operational, design and analysis refinements that have occurred since the Bay Area to Central Valley Program EIR was published. These 2012 refinements resulted in an 16.55 GWh per day, 2035 total system usage compared to a 8.74 GWh per day 2030 total system usage in the 2008 Bay Area to Central Valley Program EIR. The 2012 calculations are higher and more conservative because they include power requirements for stations, maintenance facilities, etc., are based on 8-car train sets versus 16-car train sets and include transmission losses, none of which were used in the 2008 calculations.

The significant difference in energy consumption figures when stated in Btus, results from the incorrect application of large generation and conversion loss factors of 3.65 to the conversion ratio of 1 kWh = 3414 Btus. This factor results in an overstated daily energy usage of 108,879 MMBtus calculated in the 2008 EIR, compared to 56,500 MMBtus calculated in the 2012 analysis. The refined 2012 calculations show that the operation of the HST system will use less energy than previously predicted. Since these figures are used to draw comparisons to other modes of transportation and from which other environmental impacts are assessed, the program will use the updated calculations as the basis for the 2012 environmental impact analysis.

Table 1 - Methodology for Calculating California High Speed Rail System Energy Usage Comparison of Results Between Current Analysis and Bay Area to Central Valley Program EIR

		Current Analysis - Year 2035 PB EMT Traction Power Load Modeling			Year 2030 Bay Area to Central Valley Program EIR		
	Item	Value	Unit	Remarks	Value	Unit	Remarks
0	Trainset Definition			Siemens ICE-3 Velaro			Siemens ICE-3
1	Traction energy consumed per trainset-mile (8-cars)	60.0	kWh	Without regeneration: Ref. Traction Power Simulation Studies			Not calculated
2	Regeneration under braking	51.0	kWh	15% energy savings assumed			Regenerative braking assumption of 14% is included in the J+S analysis
3	Traction energy consumed per train-mile	n.a.	n.a.	Dependent on whether train consists of one trainset or two trainsets. If two, traction and on-board services power consumption conservatively assumed to be double that of one.	68.40	kWh	Energy per 16-car train with regeneration: Basis - DE Consult Report for 400m train (ICE 3)
4	On-board services consumption	3.0	kWh	Per trainset-mile (8 cars)	5.80	kWh	DE Consult report for 400m (per 16-car train-mile)
5	Energy consumed	54.0	kWh	Per trainset-mile	74.20	kWh	Energy per 16-car train-mile with regeneration: Basis - DE Consult Report for 400m train (ICE 3)
7	Traction energy Consumed per Year	5,156.29	GWh	In horizon year 2035 (54 kWh per trainset -mile X 95.49 million trainset miles for Full System, HST fare at 50% of air)	3190.0	GWh	2030 74.2 X 43 million 16-car train miles for Full System, HST fare at 50% of air
8	Traction energy Consumed per Day	14.13	GWh/day	Divide by 365 days - with regeneration	8.74	GWh/day	Divide by 365 days - with regeneration

		Current Analysis - Year 2035 PB EMT Traction Power Load Modeling			Year 2030 Bay Area to Central Valley Program EIR		
	Item	**Value**	**Unit**	**Remarks**	**Value**	**Unit**	**Remarks**
9	Total power consumption	15.92	GWh / day	Assumes 12.67% increase for power for stations, maintenance facilities, dwells, empty moves, etc.			
10	Transmission losses	0.64	GWh / day	Total of 4% - Includes 3% transmission line loss and 1% (2x0.5) transformer losses	n.a.		No additional adjustments made
11	Total system energy including losses (2035)	**16.55**	**GWh / day**		8.74	GWh	Per day (no losses)
12	Generation, conversion, & transmission loss factor	**n.a.**	**n.a.**		3.65	factor	Total of approx. 365% - Generation and transmission, and AC/DC conversion losses are assumed. Based on 1983 Caltrans Energy Transportation Manual (page e-18)
13	Daily Total System Energy including losses	56,500	MMBTU / day	1 kWh = 3,414 BTU	108,879	MMBTU/day	1 kWh = 12,458 BTU (3.65 x 3414)
14	Annual Total System Energy including losses	**20,622,500**	**MMBTU / yr**	Multiply by 365	**39,707,950**	**MMBTU/yr**	Multiply by 365