Appendix 3.6-C
Energy Analysis Memorandum

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Subject: Comparison of energy requirement calculations and conversion factors used in the 2011 regional energy assessment compared to the 2005 Bay Area to Central Valley Program EIR energy assessment.

In the 2005 Bay Area to Central Valley Program EIR, the statewide energy impacts of the proposed HSR project were analyzed. The 2011 energy impact analysis reflects a refinement to the analysis presented in that document. The 2011 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 2011 analysis, the train proposed is the Siemens ICE-3 Velaro. The 2005 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 2011 analysis, a 15% regeneration rate was used (based on data obtained from comparable HSR systems around the world). Lines 3 through 8 in the table directly compare the 2011 and 2005 EIR calculation methods when regeneration is assumed. However, in the 2011 analysis this factor was eliminated in the total system energy consumption calculations to cover the possibility that the braking energy cannot be reused by other trains in the system (lines 9 to 12 in the table).

The 2011 analysis also assumes two 8-car train sets rather than one 16-car train set used in the Bay Area to Central Valley Program EIR energy analysis. Using two 8-car train set results in a higher estimate of traction energy required than presented in the Bay Area to Central Valley EIR. The higher energy per 16-car train mile results from a conservative assumption that a 16-car train uses two times the energy of an 8-car train set. This is not actually the case because the second train set does not experience the same value of aerodynamic resistance to motion as the lead train (referred to as the Davis Formula). Since the Davis formula for the 16-car train was not available from the manufacturer, the value was doubled in the 2011 calculations.

The current analysis assumes that 43.1 million annual train miles will be traveled in 2035 by 8-car train sets, resulting in a total traction energy consumption of 2,327 gigawatt hours (GWh) of energy per year (6.38 GWh per day) with regenerative braking or 7.1 GWh per day (without 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 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 2011 analysis conservatively assumes that systemwide electrical energy requirements for the High-Speed Train HST system will total 8 GWh/day, which includes energy required for traction, stations, facilities, dwells, maintenance, etc. and does not include the benefit of energy produced through brake regeneration. Applying a 4% transmission loss factor to this estimate, the total electrical energy required by the HST system is estimated to be 8.32 GWh per day. The transmission loss factor reflects the

percentage of energy lost from generation point to consumption point. 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 2.65 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 10,367,643 MMBtus or 28,404.5MMBtus/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 2011 refinements resulted in an 8.32 GWh per day, 2035 total system usage compared to a 8.74 GWh per day, 2030 totally system usage in the 2008 Bay Area to Central Valley Program EIR, but the analyses differed because the 2011 calculations are based on 8-car train sets and no regeneration versus 16-car train sets and regeneration.

Therefore, despite the different assumptions and operating patterns, the energy usage calculated by both methods yielded similar results (8.32GWhr/day vs. 8.74GWhr/day). However, the significant difference in energy consumption figures when stated in Btus, results from the incorrect application of large generation and conversion loss factors of 2.65 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 28,404.5 MMBtus calculated in the 2011 analysis. The refined 2011 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 2011 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

	Methodology	Current Analysis PB EMT Traction Power Load Modeling				Bay Area to Central Valley Program EIR		
		Value/Unit		Remarks		Value/Unit		Remarks
	Trainset Definition			Siemens ICE-3 Velaro				Siemens ICE-3
1	Traction energy consumed per trainset-mile (8-car train)	60.00	kWh	Without regeneration: Ref. Traction Power Simulation Studies				Not calculated
2	Assume regeneration under braking	51.00	kWh	15% energy savings assumed				Regenerative braking assumption of 14% is included in the J+S analysis
3	Traction energy consumed per train (16-car)-mile	102.00	kWh	Multiply by two times the 8-car train value. [1]		68.40	kWh	Energy per 16-car train with regeneration: Basis - DE Consult Report for 400m train (ICE 3)
4	On-board services consumption	6.00	kWh	Per 16-car train-mile		5.80	kWh	DE Consult report for 400m (16-car)
5	Energy consumed	108.00	kWh	Per 16-car train-mile		74.20	kWh	Energy per 16-car train-mile with regeneration: Basis - DE Consult Report for 400m train (ICE 3)
6	Annual Train-miles expected in the horizon year	43.10	million	Business Plan 2009 (Table H, Page 79) 8-car trains - Year 2035		43.00	million	-

	Methodology	Current Analysis PB EMT Traction Power Load Modeling				Bay Area to Central Valley Program EIR		
7	Traction energy Consumed per Year	2327.00	GWh	In horizon year 2035 (54kWh per trainset x 43.1 million trainset miles)		3190.00	GWh	2030 74.2 x 43 million
8	Traction energy Consumed per Day	6.38	GWh/day	Divide by 365 days - with regeneration		8.74	GWh/day	Divide by 365 days - with regeneration
9	Total traction energy	7.10	GWh/day	Without regeneration				
10	Total energy including stations, facilities, dwells, maintenace, empty moves, etc. (2035)	8.00	GWh/day	Conservative figure which does not take regeneration into account				
11	Transmission losses	0.04		Total of 4% - Includes 3% transmission line loss and 1% (2x0.5) transformer losses				No additional adjustments made
12	Total system energy (2035)	8.32	GWh	Per day (8GWh/day x 1.04) = 8.32 Including losses		8.74	GWh	Per day
13						2.65	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)
14	Total System Energy including losses	28,404.50	MMBTU/day	1 kWh = 3,414 BTU		108,879.00	MMBTU/day	1 kWh = 12,458 BTU (3.65 x 3414)
15		**10,367,643**	**MMBTU/yr**	Multiply by 365		**39,707,950**	**MMBTU/yr**	Multiply by 365

Notes:

1. A conservative figure of 2 times the 8-car train value has been used because the Davis Formula for resistance to motion for a 16-car train was not available from the Trainset manufacturer.