Paper 1

California High Speed Rail Project Greenhouse Gas (GHG) Emissions: A Dynamic Impact and Cost Analysis

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California High Speed Rail Project
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EXECUTIVE SUMMARY

California has established one of the most aggressive greenhouse gas (GHG) emissions reduction policies in the world. Under Assembly Bill 32 (AB32) and Governor Schwarzenegger's Executive Order number S-3-05, the state has adopted a cap and trade program to reduce GHG emissions and a requirement to reduce GHG emissions 80 percent between 1990 and 2050. The state proposes to build a high-speed rail line one objective of which is to reduce GHG emissions. This report evaluates the extent to which any GHG reduction from this proposed new rail line would arise and to put these into context, comparing the cost of such emission reductions with alternatives.

General Conclusion: **It is generally concluded that high speed rail is an ineffective and expensive strategy for reducing GHG emissions.** Under each of the scenarios examined in this report, high-speed rail would be many times more expensive per tonne of GHG emissions reduction than other alternatives, ranging from 75 times to 1,400 times the cost of carbon offsets. High-speed rail not only fails to advance the purposes of AB32, but it also retards the purposes of state law and policy by inefficiently consuming funding that could be used to obtain far greater GHG emission reductions.

1. Background

The California high speed rail line would operate from San Francisco to Los Angeles over both genuine high-speed rail and commuter rail right-of-way. The low option cost estimate is approximately $68 billion (in year of expenditure dollars), although the state is far short of the funding needed to complete the line. The Brown administration has proposed using cap and trade funds to support construction of the line.

2. California Greenhouse Gas Emission Policy

California's GHG emissions reduction policies are based on objectives set in Assembly Bill 32 (AB32) and an executive order by Governor Schwarzenegger. AB32 sets an objective to reduce California's GHG emissions to 1990 levels by 2020. Ultimately, the policies require that GHG emissions in the state be reduced 80 percent from 1990 levels by 2050. A number of strategies have already been adopted, such as a cap and trade program and the "zero emission vehicle" (ZEV) program.

It will be challenging to meet the 2050 goal. The California Air Resources Board (CARB) indicates that a substantial acceleration of annual GHG reductions will be required between 2020 and 2050.

3. The CHSRA High Speed Rail GHG Emissions Reduction Forecast

Under certain circumstances, high-speed rail reduces GHG emissions by shifting people from other modes of transport, including cars and airliners. These modes of travel rely on fossil fuels, which produce substantially more in GHG emissions per unit of consumption (a mile traveled by a rail passenger, airline passenger or vehicle driver) than the electricity generated to power high-speed rail trains, when those trains are at sufficient capacity. The construction of high-speed rail lines produces GHG emissions, which are usually offset over a period of time by the reductions from the transfer of highway and airliner passenger demand.

The California High Speed Rail Authority (CHSRA) has estimated that high-speed rail will reduce statewide GHG emissions by between 1.15 and 1.85 million metric tonnes annually by 2035. However, these estimates are likely high, due at least in part to the treatment of GHG emissions from electricity generation to power the trains and out-of-date assumptions with respect to light vehicle (automobile and light truck) fuel economy.

In addition, high-speed rail passenger projections have routinely been overly optimistic and the projections of CHSRA have been similarly criticized as being too high. Any over projection of ridership would also cause the GHG emissions reduction forecast to be high because there would be a smaller reduction in light vehicle and airliner use.

The Need for Dynamic Forecasting: Finally, and most importantly, California's policy environment could render any conventional GHG emission reduction forecast to be grossly over-optimistic. Conventional forecasting, such as performed by CHSRA, takes account of only already adopted measures and is thus "static." Yet the measures that have been formally adopted will be, according to CARB, insufficient to achieve the 2050 GHG emissions reduction objective. Indeed, assuming that California achieves its objectives, the high speed rail advantage over light vehicles in GHG emissions reductions will be virtually eliminated by 2040 (the horizon year used in this analysis). Static forecasts (such as the present CHSRA forecast) are virtually irrelevant, because CARB is obligated to adopt sufficient measures to meet the GHG emissions reduction objectives. There is a need for "dynamic" forecasting that includes the required GHG emissions reductions.

4. Alternative GHG Emissions Reduction Forecasts

This report develops alternative GHG emissions reduction forecasts, under two categories ("Dynamic Forecasts" and "Static Forecasts") for the horizon year of 2040.

> **Dynamic Forecasts:** The Dynamic Forecasts assume that California will achieve its 2050 GHG emissions reduction objective and will be on a trajectory toward that achievement in 2040. The scenarios assume the adoption of specific strategies, already some already suggested by CARB that would achieve the target.
>
> **Static Forecasts:** The Static Forecasts assume specific strategies that have already been adopted. Because these strategies are insufficient to produce the GHG emissions reductions required by California law and policy, each of the Static Forecasts would produce GHG emissions reductions that are likely to be far greater than will actually occur because light vehicle emissions are likely to be radically reduced by anticipated CARB policies (which is indicated in the Dynamic Forecasts).

Three scenarios are presented for each category, as indicated in Table ES-1.

Table ES-1 California High Speed Rail GHG Emission Reduction Scenarios	
DYNAMIC FORECASTS	
Assumptions	Adoption of additional specific strategies necessary to achieve California's 2050 GHG emission reduction objective.
Implication	That the state will achieve its 2050 GHG emissions objective and will be on a trajectory to achievement in 2040
SCENARIOS	A-1: CHSRA (Scenario [B-1] adjusted for California 2050 policies): Insufficient Information
	A-2: Adjusted CHSRA (Scenario [B-1] adjusted for California 2050 policies)
	A-3: International Experience (Scenario [B-1] adjusted for California 2050 policies)
STATIC FORECASTS	
Assumptions	Impacts of legally binding strategies that have been adopted by government agencies.
Implication	That the state will fall far short of achieving its 2050 GHG emissions reduction objective.
SCENARIOS	B-1: CHSRA (CHSRA midpoint ridership forecast with CHSRA GHG emissions reduction forecast)
	B-2: Adjusted CHSRA (CHSRA midpoint ridership forecast with independent GHG emissions reduction forecast)
	B-3: : International Experience (International ridership forecast & independent GHG emissions reduction forecast)

A model was developed to forecast the GHG emissions using the 2040 ridership projections in the *2014 Business Plan* and data from government sources.

GHG emission reductions from high speed rail range are forecast at from 0.12 million to 0.25 million tonnes annually in 2040 under the Dynamic Forecasts. This compares to the CHSRA static forecast reduction of 1.54 million tonnes. Under the other static forecasts, reductions of from 0.29 million to 0.59 million tonnes would occur (Table ES-2).

Table ES-2

Greenhouse Gas Emission Reductions from High Speed Rail: 2040

Scenarios	CHSRA	Adjusted CHSRA	International Experience
Dynamic Forecasts	Insufficient Information	-0.25	-0.12
Static Forecasts	-1.54	-0.59	-0.29
In millions of metric tonnes			
Phase 1 Blended System			
Construction GHGs not considered due to lack of data.			
Sources: CHSRA and author's calculations			

5. Cost Effectiveness of High Speed Rail GHG Emissions Reductions

To minimize disruption of the economy and economic growth , major public policy program (such as California's GHG emissions reduction program) should be cost-effective, so that the standard of living is not retarded and poverty is not increased. The importance of cost effectiveness in reducing GHG emissions has been stressed by many, including CARB.

The principal metric is the cost per ton of GHG emissions reduction. Currently, the market price of carbon credits, which corresponds to a ton of GHG emission reduction, is approximately $13 per ton (such as for tree planting programs or airline GHG offsets) . Some strategies are far more cost effective than carbon offsets. Vehicle fuel economy improvement programs by the Environmental Protection Agency and CARB have indicated *negative costs of up to $300 per tonne*.

The forecast cost per ton of GHG emissions reduction by high-speed rail range from $7,100 to $18,600 under the Dynamic Forecasts and $1,000 to $8,000 under the Static Forecasts (Table ES-3).

Table ES-3			
Cost per Metric Tonne of Greenhouse Gas Emission Reductions from High Speed Rail: 2040 (2013$)			
Low Capital Cost Option	CHSRA	Adjusted CHSRA	International Experience
Dynamic Forecasts	Insufficient Information	$ 7,100	$ 15,700
Static Forecasts	$ 1,000	$ 3,000	$ 6,800
2013$			
High Capital Cost Option	CHSRA	Adjusted CHSRA	International Experience
Dynamic Forecasts	Insufficient Information	$ 8,500	$ 18,600
Static Forecasts	$ 1,300	$ 3,700	$ 8,000
2013$			
Construction GHGs not considered due to lack of data.			
Sources: CHSRA and author's calculations			

6. Prioritizing GHG Emissions Reduction Strategies

The Legislative Analyst's Office has stressed the importance of prioritizing high-speed rail relative to other alternatives for GHG emissions reductions as a prerequisite to the use of cap and trade funding.

Under each of the scenarios, high-speed rail would be many times more expensive per tonne of GHG emissions reduction than other alternatives, ranging from 75 times to 1,400 times the cost of carbon offsets. For example, $250 million carbon offsets to abate GHG emissions are nearly equal to the required AB32 statewide reduction from all sources in 2020 compared to 2011. To state the issue in terms similar to CHSRA in its GHG emissions reduction report, $250 million could purchase carbon credits equal to taking all of the light vehicles in the San Francisco and San Jose metropolitan areas off the road for a year (with GHG reductions that would be achieved before the 2020 AB32 deadline). High-speed rail not only fails to advance the purposes of AB32, but it also retards its purposes by inefficiently consuming funding that could be used to obtain far greater GHG emission reductions.

The longer run cost intensity is illustrated by applying the minimum high speed rail 2040 costs per tonne (CHSRA Scenario [B-1]) to the required state policy that 2050 GHG emissions be 80 percent of 1990 emission levels. If the average cost per tonne of GHG emission reduction in 2050 were equal to the projected cost per tonne of reductions via high speed rail, the total cost would be, approximately $350 billion (in 2013$) , an amount equal to 1/7 the present size of California's gross domestic product (GDP). Under the more likely "Dynamic Forecast: International Ridership Scenario" (A-3) the cost could be up to $6.2 trillion (in 2013$). This is up to three times the size of California's GDP, larger than the GDP of Japan and larger than the GDPs of all countries in the world except for the United States and China in 2013.

Moreover, any GHG emissions reduction advantage of high speed rail would be fleeting. By 2040, much of the high speed rail advantage in GHG emissions relative to cars would have been eliminated by vehicle fuel economy improvements, under CARB plans. In the decade that follows, the gap would be further narrowed. By the 2060 long term horizon considered in the *2014 Business Plan*, any contribution by high speed rail toward lower GHG emissions may have been lost.

Further, diversion of cap and trade revenues for insufficiently cost effective GHG emissions reduction purposes could have political consequences. Support for the statewide GHG emissions reduction program could be diluted as it becomes clear that it is subject to political whim. Further, the failure to resolutely direct cap and trade revenues only to the most cost effective uses could further retard the state's business climate by indicating a lack of sufficient financial responsibility.

7. The Imperative for Cost-Effectiveness and Realism

High-speed rail would contribute only minimally to the reduction of GHG emissions, and its impact would be only temporary. These emissions reductions would require an exorbitant expenditure compared to other alternatives and would seem to betray a lack of seriousness with respect to GHG emissions reduction.

These expenditures would foreclose far more cost-effective approaches , unnecessarily restricting government options to maintain and improve public services. They would also reduce funding available for expanded business investment that could lead to greater economic growth, higher standard of living, and lower levels of poverty. In short, high-speed rail, both in terms of the present proposal to use cap and trade revenues and the longer term, retards the ability of the state to achieve its GHG emissions reduction objectives.

8. Legality of Cap and Trade Funding for High Speed Rail

Questions have also been raised about the legality of using cap and trade funding for high-speed rail, which has been proposed. These include a concern that high-speed rail does not serve the objectives of AB32, because it would not reduce GHG emissions before the 2020 AB32 deadline. Further, the Legislative Counsel has indicated concern that cap and trade revenues, as mitigation fees, may not be legally spent on high speed rail.

Contents

1. BACKGROUND

California has established one of the most aggressive greenhouse gas (GHG) emissions reduction policies in the world.. Under Assembly Bill 32 (AB32) and Governor Schwarzenegger's Executive Order #S-3-05, the state has adopted a cap and trade program to reduce GHG emissions and a requirement to reduce GHG emissions 80 percent between 1990 and 2050. At the same time, the state proposes to build a high-speed rail line that would purportedly materially contribute GHG emissions reduction.

1.1 The California High Speed Rail Proposal

The California high speed rail Phase 1 Blended system is planned to operate over a genuinely high speed rail right of way for most of its route, while sharing track with commuter railways on the approaches to the northern and southern terminals (Los Angeles Union Station and San Francisco's Transbay Terminal).

Phase 1 Blended system operations would begin in 2029, offering "one-seat" service over the commuter rail and high speed rail right of way between San Francisco and Los Angeles. Travelers to and from Orange County (Anaheim) would have use Metrolink commuter trains to and from Union Station, where they would transfer between the two services.

Greenhouse Gas Emissions

One of the principal selling points of the California High Speed Rail project is its expected contribution to reducing greenhouse gas (GHG) emissions. The California High Speed Rail Authority CHSRA provided estimates of expected GHG emissions reductions in June 2013.[1] In its first year of operations, high-speed rail would reduce GHG emissions by the same amount as removing 31,000 cars from the road, which CHSRA indicated stretch for 100 miles on a single highway lane. By 2035, CHSRA indicated that an annual reduction of between 1.15 and 1.85 million metric tonnes[2] of GHG emissions would be achieved by operating high-speed rail.

Some travel by highway and airliners would be transferred to the high-speed rail system. Since the high-speed rail trains generally produce lower levels of GHG emissions per mile traveled than automobiles and airliners, it is expected that GHG emissions will be reduced. However, construction of the high-speed rail line will increase GHG emissions.

1.2 Costs and Funding

The *2012 Draft Revised Business Plan* projected the cost of the project at between $68.4 billion and $79.7 billion in "year of expenditure" dollars.[3] The low cost option has been revised to $67.6 billion in the *2014 Business Plan.*[4] Over the past two years, most of the attention with respect to costs has been on the low-

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[1] California High Speed Rail Authority (June 2013), *Contribution of the High-Speed Rail Program to Reducing California's Greenhouse Gas Emission Levels*. http://www.hsr.ca.gov/docs/programs/green_practices/HSR_Reducing_CA_GHG_Emissions_2013.pdf.

[2] At 2,205 pounds, a metric tonne is 1.10 times the weight of a short ton (2,000 pounds), which is more commonly used in the United States. The spelling "tonne" is commonly applied to metric tonnes and is used throughout this report.

[3] California High Speed Rail Authority (April 2012), California High-Speed Rail Program Draft Revised 2012 Business Plan, http://www.hsr.ca.gov/docs/about/business_plans/FINAL_Draft_2014_Business_Plan.pdf.

[4] California High Speed Rail Authority (February 2014), *2014 Business Plan*, http://www.hsr.ca.gov/docs/about/business_plans/FINAL_Draft_2014_Business_Plan.pdf

cost option, yet the project itself has experienced substantial cost escalation already.[5] Further, megaprojects tend to experience substantial cost escalation.[6] Failure to consider the higher figure could be risky to the state and its taxpayers.

The low-cost option would cost $54.9 billion in inflation adjusted dollars (2013$). It is assumed that the high-cost option cost would remain proportional to its 17 percent higher relationship from the *2012 Business Plan,* at $64.1 billion. For clarity, this report uses constant dollar costs, expressed in 2013 dollars. The high-speed rail system faces severe funding challenges and is far short of the financial commitments required to complete the Phase 1 Blended System.

The Brown Administration has proposed using $250 million in Assembly Bill (AB32)[7] cap and trade revenues from the 2014 – 2015 budget to support construction of the proposed California high speed rail project. In addition, the Administration has indicated that cap and trade funds should become an even larger share of high-speed rail funding in the future.[8]

There are considerable difficulties with this proposal. Perhaps the most important is whether AB32 cap and trade funds can be legally used for high-speed rail. It is generally agreed that high-speed rail cannot reduce GHG emissions before the 2020 horizon in AB32. Yet, the Brown Administration believes that GHG reduction from high-speed rail is so important as to justify the expenditure of cap and trade revenues. The legal issues are covered extensively by the Legislative Analyst's Office and a short summary is provided in Appendix A.

The focus of this report is a public policy evaluation of the effectiveness of high speed rail as a means for GHG emission reductions. The high priority the GHG emission reductions have received in both California legislation and policy requires that mitigation strategies be cost effective. Thus far, there has been no state or California High Speed Rail Authority GHG cost-effectiveness analysis. As the Legislative Analyst's Office has indicated, GHG emissions reduction strategies should be subjected to a consistent cost metric. This report provides an "out – of – pocket" estimate of the cost per ton of GHG emission reduction by high-speed rail. The calculations generally follow the McKinsey Corporation greenhouse gas emissions cost curve methodology.[9] The principal time horizon is 2040, the end of the first decade with full service and the year for which detailed ridership data was provided by CHSRA in its *2014 Business Plan.*

This report principally relies on state documents, especially from CHSRA and the California Air Resources Board. Reports from outside the CHSRA (such as from from CARB and the EPA) are taken at face value, with no attempt to evaluate their findings.

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[5] Joseph Vranich & Wendell Cox, " California High Speed Rail: An Updated Due Diligence Report," Reason Foundation (2013), http://reason.org/files/california_high_speed_rail_report.pdf
[6] Bent Flyvbjerg, Nils Bruzelius and Werner Rothengatter, *Megaprojects and Risk: An Anatomy of Ambition*, (Cambridge, UK: Cambridge University Press, 2003)
[7] The Global Warming Solutions Act.
[8] Chris Megerian and Ralph Vartabedian (February 24, 2014), "Gov. Jerry Brown wants polluters' fees to help fund high-speed rail," http://www.latimes.com/local/la-me-brown-rail-20140228,0,4977021.story#ixzz2ubyMC1e8.
[9] Calculated as the annual operating and capital cost, minus expected cost savings (especially from reduced energy consumption) divided by the metric tonnes of greenhouse gas emissions avoided. See: Per-Anders Enkvist, Tomas Nauclear and Jerker Rosander (2007, Number 1), "A cost curve for greenhouse gas reduction," *Mckinsey Quarterly*, http://www.epa.gov/oar/caaac/coaltech/2007_05_mckinsey.pdfhttp://www.epa.gov/oar/caaac/coaltech/2007_05_mckinsey.pdf

2. CALIFORNIA GREENHOUSE GAS EMISSION REDUCTION POLICY

California has established aggressive goals for GHG emissions reductions, which require an 80% reduction in GHG emissions by 2050. Achievement of an 80% reduction in GHG emissions by 2050 will be challenging.

Trajectory to 2050: A recent CARB commissioned[10] report reviewed three scenarios for 2050 and found that none achieved the 80 percent statewide GHG emissions reduction target. The scenarios included current policies, uncommitted GHG emissions reduction targets, and technological advances.

In its recently published *Proposed First Update to the Climate Change Scoping Plan: Building on the Framework* (*February 2014 Scoping Plan*), the California Air Resources Board (CARB) noted that to achieve the 2050 80 percent reduction target would require acceleration of annual GHG emission reductions at more than double the rate that has been necessary to achieve the 2020 targets.[11] CARB has laid out a number of policy options for strengthening GHG emissions reductions to achieve both an interim target for 2030 and the 80 percent reduction target for 2050. Figure 1 in CARB's *Vision for Cleaner Air*[12] indicates the extent of GHG emissions reduction and trend by 2050 that it seeks to meet the California objectives. The dark section of the chart represents Gasoline, Diesel and Natural Gas. The lighter section of the chart represents Hydrogen, Electricity, and Jet Fuel.

[10] Jeffery B. Greenblatt (20120, "Estimating Policy-Driven Greenhouse Gas Emissions Trajectories in California: The California Greenhouse Gas
Inventory Spreadsheet (GHGIS) Model, Ernesto Orlando Lawrence Berkeley National Laboratory http://eetd.lbl.gov/sites/all/files/lbnl-6451e.pdf.

[11] California Air Resources Board (2014), *Proposed First Update to the Climate Change Scoping Plan: Building on the Framework* (*February 2014 Scoping Plan*), http://www.arb.ca.gov/cc/scopingplan/2013_update/draft_proposed_first_update.pdf

[12] California Air Resources Board, *Vision for Cleaner Air*, http://www.arb.ca.gov/planning/vision/vision.htm and http://www.arb.ca.gov/planning/vision/docs/draft_scenario_assumptions_and_results_appendix.pdf and http://www.arb.ca.gov/planning/vision/docs/vision_for_clean_air_public_review_draft.pdf

CARB Scenario 2 Vision

2010 TO 2040

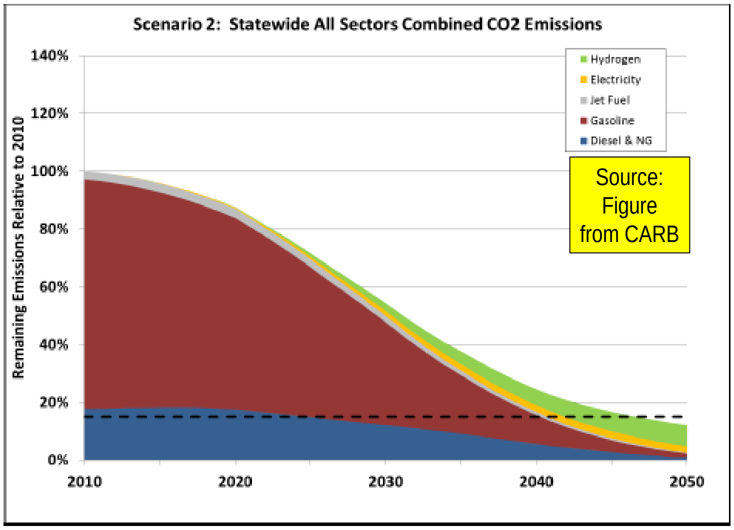

Figure 1

It will be challenging to meet these objectives. Any attempt to meet such targets should be prioritized by cost-effectiveness, which would coincidentally ensure that any negative impact on economic growth would be minimized. This would, consequently, limit any reduction in the standard of living and increase in the poverty rate.[13]

Regulations: Present and Future: Certain CARB and federal regulations are appropriate to an analysis of GHG emissions relating to high-speed rail. The principal source of reductions from high-speed rail would be the difference in GHG emissions per unit of passenger consumption ("passenger mile") between the train and alternative forms of travel, principally automobiles and airliners. Today, automobiles and airliners produce more GHG emissions per passenger mile than high-speed rail is expected to produce.

Regulations have been adopted to materially improve fuel economy for new light vehicles. By 2025, EPA regulations require the average new car to achieve 54.5 miles per gallon. Fuel economy improvements have a one to one relationship between motor fuel consumed and GHG emissions reductions --- each gallon of gasoline combusted produces the same volume of GHG emissions.

In addition, CARB has adopted a Low Carbon Fuel Standard (LCFS), which essentially requires a 10 percent reduction in GHG emissions from fuels (in addition to the improvement in fuel economy).

Perhaps the most significant CARB regulation authorizes the "zero emission vehicle" (ZEV). Beginning in 2017, two percent of light vehicles sold must be ZEVs. This rises to 16 percent in 2025. Substantial strengthening of the regulation is anticipated according to CARB: [14]

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[13] California has the highest poverty rate in the United States, adjusted for housing costs, according to the US Bureau of the Census.

[14] California Air Resources Board (2014), *Proposed First Update to the Climate Change Scoping Plan: Building on the Framework* (*February 2014 Scoping Plan*), http://www.arb.ca.gov/cc/scopingplan/2013_update/draft_proposed_first_update.pdf

> *Achieving our long-term climate goal and 2032 ozone standards will require a much deeper penetration of ZEVs into the fleet. As outlined in the 2009 ZEV Review and the 2012 Vision for Clean Air, and several independent studies (See Chapter III), the light-duty vehicle segment will need to become largely electrified by 2050 in order to meet California's emission reduction goals.*

CARB documentation indicates that 87 percent of the light vehicle fleet in the state will be ZEV vehicles by 2050.[15] Virtually 100 percent of vehicles in the state would be ZEVs at some point during the following decade (Figure 2). CARB also recommends increasing the LCFS to between 15 and 20 percent in the future.[16]

CARB Vehicle Fleet Projection

2000 TO 2040

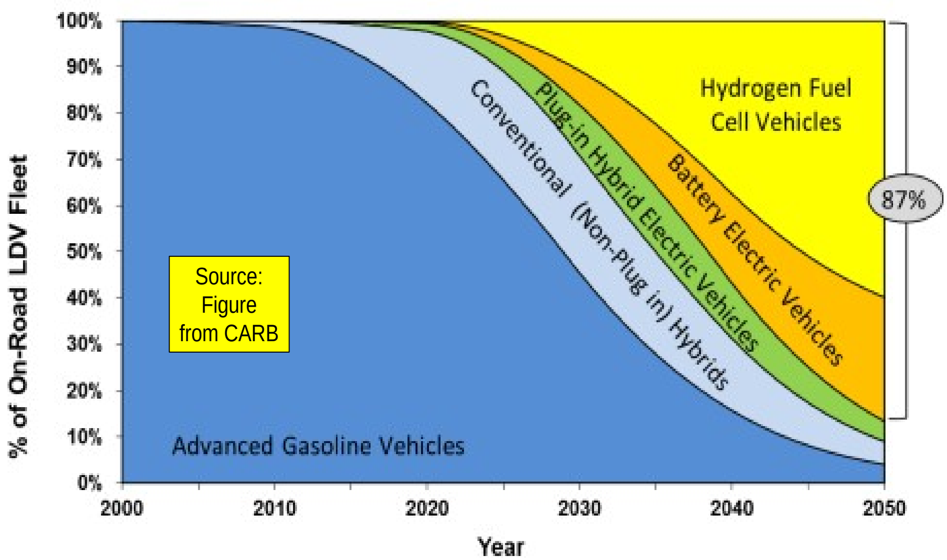

Figure 2

3. THE CHSRA HIGH SPEED RAIL GHG EMISSIONS REDUCTION FORECAST

Generally, the international transportation literature indicates that high-speed rail results in a reduction of GHG emissions compared to driving and from airline operations, if there is a sufficient diversion of demand. This is because GHG emissions from cars and airline operations are higher per passenger mile (miles traveled by a passenger) than from high speed rail, which can spread a train's emissions over a lot of passengers. High speed rail GHG emissions are produced by the generation of electricity to power the trains, supportive functions (station operations and construction.

[15] California Air Resources Board, Public Hearing to Consider Advanced Clean Cars Program, http://www.arb.ca.gov/board/books/2012/012612/12-1-2pres.pdf.

[16] California Air Resources Board (2014), *Proposed First Update to the Climate Change Scoping Plan: Building on the Framework* (*February 2014 Scoping Plan*), http://www.arb.ca.gov/cc/scopingplan/2013_update/draft_proposed_first_update.pdf

In addition to the GHG that occur from attracting riders from cars and planes, high-speed rail itself produces GHG emissions during construction. It is generally assumed that the GHG emissions produced during construction will be recovered by greater GHG emissions reductions that occur from operating the high-speed rail system.

3.1 GHG Emissions from Construction

Construction activity GHG emissions estimates have varied significantly. One independent report indicated that it could take up to 70 years to offset the construction related GHG emissions with the anticipated GHG emissions reductions from operating trains .[17] The California high-Speed Rail Authority has estimated that construction GHG emissions would be offset by GHG reductions from operations 2.8 years over the Fresno to Bakersfield segment.[18]

The Legislative Analyst's Office expects that a longer period will be required to recover the construction activity GHG emissions increases:[19]

> *...an independent study found that—if the high–speed rail system met its ridership targets and renewable electricity commitments—construction and operation of the system would emit more GHG emissions than it would reduce for approximately the first 30 years.*

CHSRA intends to offset the GHG emissions additions by purchasing carbon credits through a tree planting program. Because of insufficient CHSRA documentation, construction GHG emissions are not evaluated further in this report.

3.2 GHG Emissions from Operations

CHSRA has indicated high speed rail operations will reduce GHG emissions from 1.15 to 1.85 million tonnes per year by 2035,[20] after the Phase 1 Blended System has been in operation for six years. By 2050, the reduction would be between 1.24 and 1.99 million tonnes per year. This report uses the year 2040 for its analysis of GHG emissions impacts. The year 2040 is used for analysis because corresponding ridership data was provided in the *2014 Business Plan.*[21] Based on the 2035 and 2050 CHSRA forecasts, the corresponding GHG emissions reduction range for 2040 would be approximately 1.18 million to 1.90 million tonnes per year.

3.3Analysis of the CHSRA GHG Emissions Reduction Projections

CHSRA provides only a summary description of the method used in its projection of GHG emissions reductions from operations. This makes a detailed analysis of the CHSRA GHG emissions reduction

[17] Mikhail Chester and Arpad Horvath (2010), *Life-Cycle Environmental Assessment of California High Speed Rail*, Access.
[18] California High Speed Rail Authority, *Draft Environmental Impact Report/Statement: Fresno to Bakersfield,* Table 3.3-17, http://www.hsr.ca.gov/docs/programs/fresno-baker-eir/drft_EIR_FresBaker_Vol1_3_3.pdf
[19] Legislative Analyst's Office, *The 2012-13 Budget: Funding Requests for High-Speed Rail,* http://www.lao.ca.gov/analysis/2012/transportation/high-speed-rail-041712.aspx
[20] Previously, CHSRA had projected that the Phase 1 Blended System would reduce GHG emissions 4.8 million tonnes (Table 3.3-13, CHSRA, *Draft Environmental Impact Report/Statement: Fresno to Bakersfield,* http://www.hsr.ca.gov/docs/programs/fresno-baker-eir/drft_EIR_FresBaker_Vol1_3_3.pdf).
[21] The ridership projections in the *2014 Business Plan* is provided between major regions (such as the San Francisco Bay Area, Southern California, and the San Joaquin Valley), although not specifically between stations.

projection impossible. Even with the limited information, there are indications of concerns that could have resulted in the GHG emissions reduction projections being high.

GHG Emissions from Electricity Production: The GHG emissions reduction forecasts may be overly optimistic from treatment of GHG emissions production from electricity generation. CHSRA indicated plans to purchase only electricity that is produced with renewable resources. Renewable resources generally produce lower levels of GHG emissions than fossil fuels.[22]

> *... the assumption for power emissions is that the Authority has purchased a renewable power mix of 20 percent solar, 40 percent wind, 35 percent geothermal, and 5 percent biogas converted to electricity.*[23]

Yet the use of renewable resources would not reduce the GHG emissions of high speed rail to any greater extent than it does any other business or household in the pool of California electricity consumers. Renewable energy is scarce. To the extent that CHSRA uses renewable electricity, it is likely to preclude such use by others. This suggests that when CHSRA buys renewable electricity the total available electricity supply remains the same, but the renewable portion is allocated differently between users. Any credit taken by CHSRA for renewable power use that exceeds the generation mix in the state, could effectively crowd out consumption by other consumers. GHG emissions from electricity used in the state are reduced only when total emissions are reduced, not when they are reallocated between consumers.

Light Vehicle Emissions: The CHSRA GHG emissions reduction forecast may also be overly optimistic. CHSRA used the CARB EMFAC2011 model to project GHG emissions reductions from light vehicles. The EMFAC2011 model does not include the effect of the new more stringent 2016 to 2025 fuel economy standards adopted by the Obama Administration, which are reflected in the latest US Department of Energy projections.[24] This would result in an overstatement of GHG emissions reductions.

However, without a more detailed description of their methodology and data used, CHSRA's GHG emissions reduction forecast cannot be analyzed in detail.

California GHG Emissions Reduction Policy: Further, the CHSRA GHG emissions reduction projections were based on conventional assumptions that include only adopted public policy measures. Under normal circumstances, this would be sufficient. However, the public policy situation in California is unprecedented, with substantial additional policy adoptions virtually assured. As a result, a conventional "static" forecasting approach is likely to produce far higher reductions in GHG emissions than are likely in California's policy environment. A more dynamic forecasting method is thus required, as is described below.

California is strongly committed to reaching an 80 percent reduction in GHG emissions by 2050. It is clear that the California Air Resources Board intends to implement such measures as are necessary to achieve this objective.

The potential progress is indicated in Figure 3, showing projected trends in high speed rail and light vehicle emissions to 2040. Virtually all of high speed rail's advantage relative to ZEV vehicles could be

[22] National Renewable Energy Laboratory (January 2013), *Life Cycle Greenhouse Gas Emissions from Electricity Generation*, http://www.nrel.gov/docs/fy13osti/57187.pdf.
[23] California High Speed Rail Authority (June 2013), *Contribution of the High-Speed Rail Program to Reducing California's Greenhouse Gas Emission Levels*.
[24] US Department of Transportation, Energy Information Administration, *Annual Energy Outlook 2014.*

eliminated at the likely unachievable 85 percent load factor[25] forecast by CHSRA. At the lower ridership level indicated in international research, light vehicles could *eliminate* the GHG emissions advantage of high-speed rail per highway mile.[26]

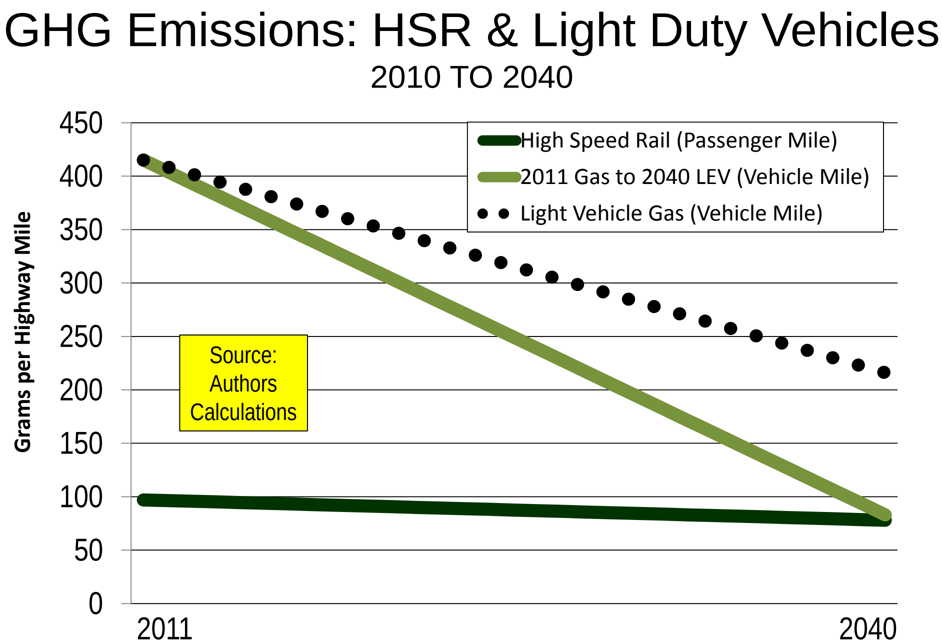

Figure 3

The conventional "static" GHG emissions reduction forecasting method used by CHSRA produces results that imply California will not reach its GHG emissions reductions objectives. Indeed, were the GHG emissions reduction scenario to emerge on which the CHSRA static forecasts are based, ***California's GHG emissions reduction program will have resulted in material failure.*** This is because CHSRA assumes future automobile fuel economy improvements that are far more pessimistic than state policy requires. Dynamic forecasting, on the other hand, assumes that California will reach its policy objectives, which the Brown Administration and CARB are determined to accomplish.

4. ALTERNATIVE GHG EMISSIONS REDUCTION FORECASTS

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[25] The highly touted Madrid to Barcelona high speed rail line has an average load factor of approximately 60 percent, according to Frontier Economics, Atkins ITS (March 2011), *Appendix I: High Speed Railway Madrid-Barcelona*, European Commission, http://ec.europa.eu/regional_policy/sources/docgener/evaluation/pdf/expost2006/wpb_cs1_barcelona.pdf. Other high speed rail systems also have considerably lower load factors. See Wendell Cox and Joseph Vranich, *The California High Speed Rail Proposal: A Due Diligence Report* (2008), Reason Foundation, http://reason.org/files/1b544eba6f1d5f9e8012a8c36676ea7e.pdf .

[26] Highway vehicle mile is used because CHSRA forecasts most of its travelers will have previously traveled by car. High speed rail travel requires longer distances than highway travel (for example, from San Francisco to Los Angeles the highway distance is approximately one-quarter shorter than by high speed rail. For highway travel, the appropriate comparison is highway miles, rather than miles of travel by train. It is conservatively assumed that *all* travelers attracted from cars to high speed rail would be drivers. The airline distance between San Francisco and Los Angeles is approximately one-third shorter than high speed rail). These longer distances increase GHG emissions from high speed rail.

The expected impacts of California's policy initiatives and the tendency of passenger forecasts to the overly optimistic suggest the necessity of alternative GHG emissions reduction forecasts.

4.1 Forecast Categories

Two general categories of forecasts are presented. The first category, "Dynamic Forecasts," is based on the underlying assumption that California will achieve its 2050 GHG emissions reduction target. The second category. "Static Forecasts," is limited to the effects of already adopted measures. These categories and three scenarios within each are illustrated in Table 1.

Table 1
California High Speed Rail GHG Emission Reduction Scenarios

DYNAMIC FORECASTS	
Assumptions	Adoption of additional specific strategies necessary to achieve California's 2050 GHG emission reduction objective.
Implication	That the state will achieve its 2050 GHG emissions objective and will be on a trajectory to achievement in 2040
SCENARIOS	A-1: CHSRA (Scenario [B-1] adjusted for California 2050 policies): Insufficient Information
	A-2: Adjusted CHSRA (Scenario [B-1] adjusted for California 2050 policies)
	A-3: International Experience (Scenario [B-1] adjusted for California 2050 policies)
STATIC FORECASTS	
Assumptions	Impacts of legally binding strategies that have been adopted by government agencies.
Implication	That the state will fall far short of achieving its 2050 GHG emissions reduction objective.
SCENARIOS	B-1: CHSRA (CHSRA midpoint ridership forecast with CHSRA GHG emissions reduction forecast)
	B-2: Adjusted CHSRA (CHSRA midpoint ridership forecast with independent GHG emissions reduction forecast)
	B-3: : International Experience (International ridership forecast & independent GHG emissions reduction forecast)

A model was developed to estimated the GHG emissions reduction from the lower level light vehicle and airline for which high speed rail travel is substituted. Ridership data is from the CHSRA's *2014 Business Plan*, [27] which included updated forecasts between regions of California for 2040.[28] Based on these projections, this report provides independent estimates of high speed rail GHG emissions reductions at ridership indicated in the scenarios.

The model estimates the increase in GHG emissions reductions from the electricity generated and transmitted to power the trains,[29] other operating functions, such as stations, maintenance facilities and maintaining rail rights of way, as well as the additional light vehicle use that occurs as rail riders travel to stations to meet their trains. The methodology is described in Appendix A.

4.2 Dynamic Forecasts and Results

The Dynamic Forecasts assume that California will achieve its 80 percent GHG emissions reduction by 2050 and will be on a trajectory toward that accomplishment in 2040. Each of the Dynamic Forecasts

[27] *2014 Business Plan*
[28] Projected ridership between stations is not provided.
[29] High speed rail's electricity consumption (and thus its indirect GHG emissions) are increased by its less direct routing. Trains will travel approximately 505 miles from Los Angeles to San Francisco. This compares to a more direct 345 miles by airline and 380 miles by highway.

represents an attempt to replicate the projections in CARB's *Vision for Clean Air*.[30] It can be expected that the GHG emissions reductions from high speed rail under the Dynamic Forecasts will be significantly lower than under the Static Forecasts (The methodology is described in Appendix A).

This is because the GHG emissions that occur from light vehicles drop much more rapidly than the emissions from the high-speed rail system, as the conversion to ZEV vehicles continues (Figure 3, above). Once the ultimate ZEV share of the vehicle fleet is achieved, high-speed rail and light vehicle GHG emissions will be similar and can be expected to rise or fall at the same rate.[31]Further, it is expected that airline GHG emissions per passenger mile will also improve, although not as substantially that of light vehicles.

The Dynamic Forecast scenarios and corresponding GHG emissions reduction results are as follows:

> (A-1) CHSRA Scenario: The CHSRA scenario would have adjusted Scenario B-1 (ridership assumed at the CHSRA midpoint) for consistency with the 2040 trajectory required for achievement of California's 2050 GHG emissions reduction objective (an 80 percent decline). CHSRA's GHG emissions reduction report[32] does not provide sufficient information to report a figure for Scenario A-1.
>
> (A-2) Adjusted CHSRA Scenario: The Adjusted CHSRA scenario revises Scenario B-1 (ridership assumed at the CHSRA midpoint) for consistency with the 2040 trajectory required for achievement of California's 2050 GHG emissions reduction objective (an 80 percent decline). The 2040 annual reduction in high speed rail GHG emissions for Scenario B-2 is forecast at approximately 250,000 tonnes. As indicated in Box 1, this ridership would be much lower due to substantial reductions in the cost of driving relative to high speed rail that are expected to result from the CARB ZEV program. This would make the GHG emissions reductions from high speed rail smaller and could even result in an increase in GHG emissions (Section 3.3).
>
> (A-3) International Experience Scenario: The International Experience scenario adjusts Scenario B-1 (ridership assumed at the international experience level) for consistency with the 2040 trajectory required for achievement of California's 2050 GHG emissions reduction objective (an 80 percent decline). The 2040 annual reduction in high speed rail GHG emissions for Scenario A-3 is forecast at approximately 120,000 tonnes. As indicated in Box 1, this ridership could be much lower due to substantial reductions in the cost of driving relative to high speed rail that are expected to result from the CARB ZEV program. This would make the GHG emissions reductions from high speed rail smaller and could even result in an increase in GHG emissions (Section 3.3).

4.3 Static Forecasts and Results

The Static Forecast GHG emissions scenarios are limited to the specific measures that have already been adopted by the state, CARB and the federal government. As noted in Section 2, in these measures will not be sufficient to meet California's 2050 GHG emissions reduction objectives.

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30 California Air Resources Board, *Vision for Cleaner Air*, http://www.arb.ca.gov/planning/vision/vision.htm and http://www.arb.ca.gov/planning/vision/docs/draft_scenario_assumptions_and_results_appendix.pdf and http://www.arb.ca.gov/planning/vision/docs/vision_for_clean_air_public_review_draft.pdf

31 This assumes a constant relationship between high speed rail ridership and automobile use.

32 California High Speed Rail Authority (June 2013), *Contribution of the High-Speed Rail Program to Reducing California's Greenhouse Gas Emission Levels*, http://www.hsr.ca.gov/docs/programs/green_practices/HSR_Reducing_CA_GHG_Emissions_2013.pdf.

The Static Forecast scenarios and corresponding GHG emissions reduction results are as follows:

> (B-1) CHSRA Scenario: The CHSRA Scenario (Static Forecast) is limited to the effects of already adopted measures and assumes that no further policies to improve GHG emissions will be adopted by CARB, EPA or any other regulatory authority before 2040. CHSRA's 2040 GHG emissions reduction and midpoint 2040 ridership forecasts are assumed. The 2040 annual reduction in high speed rail GHG emissions for Scenario B-2 is forecast at approximately 1.54 million tonnes (the estimated midpoint for 2040 from the CHSRA GHG emissions reduction report[33]).
>
> (B-2) Adjusted CHSRA Scenario: The Adjusted CHSRA Scenario (Static Forecast) is limited to the effects of already adopted measures and assumes that no further policies to improve GHG emissions will be adopted by CARB, EPA or any other regulatory authority before 2040. The scenario assumes an independent GHG emissions reduction based on current government and others forecasts and uses the CHSRA 2040 midpoint ridership (as in Scenario A-2). The 2040 annual reduction in high speed rail GHG emissions for Scenario B-2 is forecast at approximately 0.59 million tonnes.
>
> (B-3) International Ridership Scenario: The International Ridership Scenario (Static Forecast) is limited to the effects of already adopted measures and assumes that no further policies to improve GHG emissions will be adopted by CARB, EPA or any other regulatory authority before 2040. The scenario assumes an independent GHG emissions reduction based on current government and others forecasts uses the CHSRA ridership forecast reduced to account for the average inaccuracy indicated in the international research (Box 1). The 2040 annual reduction in high speed rail GHG emissions for Scenario B-3 is forecast at approximately 0.29 million tonnes.

Box 1 Ridership Projections
CHSRA ridership projections have been criticized for years as too optimistic. International research has indicated that passenger rail programs are routinely projected to carry many more passengers than they usually do. This is acknowledged in the "peer group report" appended to the *2014 Business Plan*, which references *Megaprojects and Risk: An Anatomy of Ambition*, the authoritative volume on the subject of infrastructure forecasting errors (both ridership and cost).[34] The principal author, Bent Flyvbjerg and associates have the research, which provides further illustration of the excessive optimism typical of rail passenger projections (Figure 4), indicating that 70 percent of projects have been more than 40 percent inaccurate in their passenger projections.[35] On average, passenger rail projects were found to draw 51.4

[33] California High Speed Rail Authority (June 2013), *Contribution of the High-Speed Rail Program to Reducing California's Greenhouse Gas Emission Levels*, http://www.hsr.ca.gov/docs/programs/green_practices/HSR_Reducing_CA_GHG_Emissions_2013.pdf.

[34] Bent Flyvbjerg, Nils Bruzelius and Werner Rothengatter, *Megaprojects and Risk: An Anatomy of Ambition*, (Cambridge, UK: Cambridge University Press, 2003)

[35] One of the most egregious cases of ridership over-projection is the London to Paris and Brussels *Eurostar*, which operates through the Channel Tunnel. As of 2011, *Eurostar's* ridership remained 60 percent below the original projection made for 2006. See: Joseph Vranich & Wendell Cox, " California High Speed Rail: An Updated Due Diligence Report," Reason Foundation (2013), http://reason.org/files/california_high_speed_rail_report.pdf.

percent fewer riders than projected.[36] This figure is used for the International Ridership Scenarios in this report (calculated from the CHSRA Midpoint ridership forecasts.

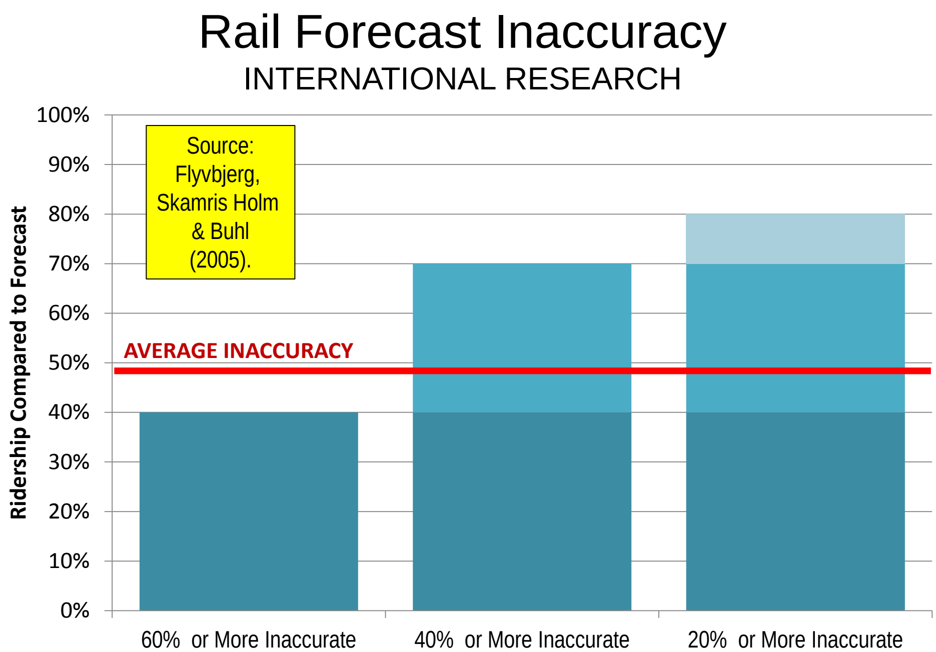

Figure 4

Further, CARB's ZEV program could substantially reduce the cost of travel by light vehicle. For example, the present fuel cost of travel by electric vehicles is approximately half that.[37] This would reduce the forecast attraction of high speed rail, because its fares would be higher relative to the cost of traveling by light vehicle and could substantially reduce high speed rail ridership. This would reduce or eliminate GHG emissions reductions from high speed rail.

The estimated GHG emissions reductions are indicated in Figure 5, Table 2 and Appendix Table B-1.

[36] Bent Flyvbjerg, Mette Skamris Holm, Søren L. Buhl (2005), How (In)accurate Are Demand Forecasts in Public Works Projects? The Case of Transportation, http://www.tandfonline.com/doi/abs/10.1080/01944360508976688#.UwjoLvldV5s.

[37] Assumes electricity consumption by light vehicles of 30 kilowatt hours per 100 miles.

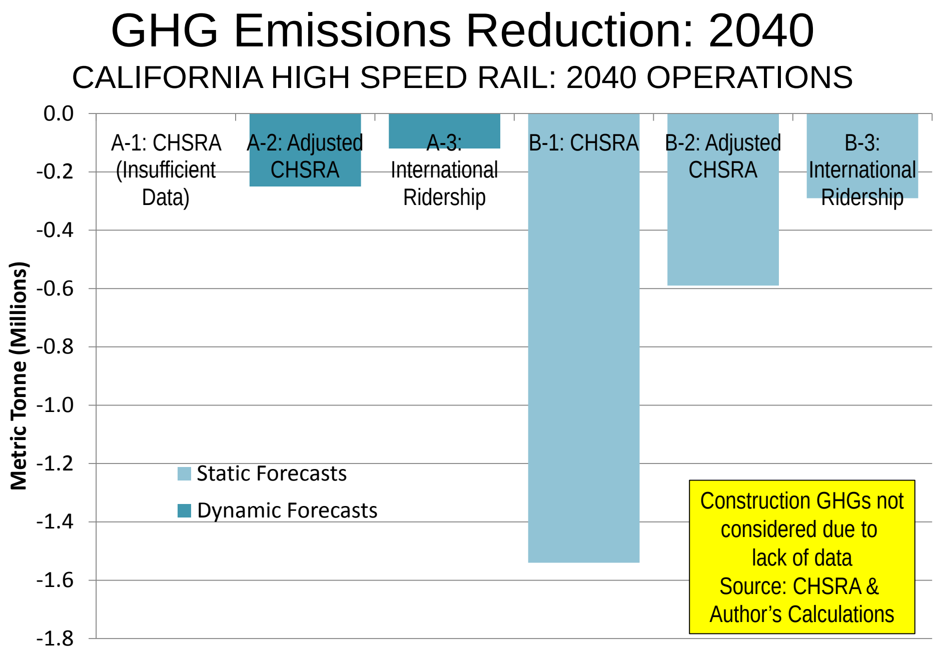

Figure 5

Table 2			
Greenhouse Gas Emission Reductions from High Speed Rail: 2040			
Scenarios	CHSRA	Adjusted CHSRA	International Experience
Dynamic Forecasts	Insufficient Information	-0.25	-0.12
Static Forecasts	-1.54	-0.59	-0.29
In millions of metric tonnes			
Phase 1 Blended System			
Construction GHGs not considered due to lack of data.			
Sources: CHSRA and author's calculations			

5. COST EFFECTIVENESS OF HIGH SPEED RAIL GHG EMISSIONS REDUCTIONS

As is noted above, California's GHG emissions reduction objectives are aggressive and will be challenging to meet.

5.1 The Importance of Cost Effectiveness

The chances that California's objective will be enhanced if the strategies selected are the most cost effective. A prioritization by cost-effectiveness is key for two reasons.

(1) The funds for reducing GHG emissions are limited. Expenditures on strategies that are not optimally cost-effective reduce the GHG emission reduction that is possible. In effect, less cost effective strategies "crowd out" the cost effective strategies.

(2) The use of less cost effective strategies necessarily increases the cost of reducing GHG emissions. These higher costs will take a toll on the economy, requiring higher levels of mitigation fees and taxation, resulting in an overall lower standard of living (as measured by discretionary household income) and higher rates of poverty.

There is general agreement that the GHG emissions reduction requires that cost-effectiveness metrics be applied to proposed strategies. For example:

> The European Conference of Ministers of Transport said in a policy document: *It is important to achieve the required emissions reductions at the lowest overall cost to avoid damaging welfare and economic growth.*[38]

CARB has also stressed the importance of cost effectiveness in its *February 2014 Scoping Report.*

5.2 The Cost of Reducing GHG Emissions

The most common metric for GHG emissions reduction is the cost per metric ton. There are various cost effectiveness estimates for reducing GHG emissions, which are taken at face value in this report:

1. McKinsey & Company has estimated GHG emissions sufficient to achieve IPCC recommended reduction rates to 2030 can be achieved at an average cost of *minus* $9 per ton, with a range of from minus $250 to plus $116.[39] McKinsey & Company estimated that 35 percent of the reductions were possible for less than $0. 40 percent from $0 to $29 and 10 percent from $29 to $58.[40]

2. Carbon credits can be purchased, with the intention of reducing GHG emissions by one ton per credit. This is the mechanism CHSRA intends to use to offset its GHG emissions from construction, through tree planting programs. Carbon credits can also be purchased by consumers to offset the GHG emissions from air travel. The cost per ton of GHG emissions

[38] European Conference of Ministers of Transport (2006), *Transport and Environment: Review of CO2 Abatement Policies for the Transport Sector Conclusions and Recommendations*, European Council of Ministers of Transport. http://www.internationaltransportforum.org/Topics/pdf/07CO2summary.pdf

[39] The original figures are stated in 2006 Euros and converted here to 2013$. See: McKinsey and Company (2010), *The Impact of the Financial Crisis on Carbon Economics: Version 2.1 of the Global Greenhouse Gas Abatement Cost Curve*, http://www.mckinsey.com/~/media/McKinsey/dotcom/client_service/Sustainability/cost%20curve%20PDFs/ImpactFinancialCrisisCarbonEconomicsGHGcostcurveV21.ashx

[40] The United Nations Intergovernmental Panel on Climate Change (IPCC) indicated that there is a high level of confidence that a cost range of $20 to $50 annually per GHG ton “reached globally in 2020–2030 and sustained or increased thereafter would deliver deep emission reductions by midcentury. Terry Barker, Igor Bashmakov, et al, “Mitigation from a cross-sectoral perspective,” Intergovernmental Panel on Climate Change, 2008, www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter11.pdf p. 660

> reduction is approximately $13.[41] This is slightly higher than the clearing price in the November 2013 California cap and trade auction ($11.48).

There are indications that the costs above may higher than necessary. United States Environmental Protection Agency (EPA) and CARB programs are expected to reduce GHG emissions at costs of *less than zero.*

> Two Obama administration regulatory actions have been adopted to improve light vehicle fuel efficiency through 2017 and 2025. Under each of these already adopted regulations, the EPA estimated that the cost for GHG emission ton removed would be approximately *minus* $200 by 2040 and *minus* $300 by 2050.[42]
>
> CARB has estimated that its ZEV vehicle program will produce consumer savings that are more than double its costs, which like the EPA programs, means that costs were negative.[43]

In short, it does not appear to be necessary to spend more than an average of near zero per ton of GHG emissions reduction.

5.3 Cost Effectiveness of GHG Emissions Reductions from High Speed Rail

As in the case of the GHG emissions reduction analysis above, costs are estimated for the year 2040 and indicated in year 2013 constant dollars. Generally, the cost of high-speed rail is the total annual capital and operating costs of the system minus costs that are saved as a result of a reduction in light vehicle use and airline flights (The methodology is described in Appendix A).

These costs are divided by the GHG emissions reductions projected for each scenario in Section 4. The results of the cost analysis are:

Dynamic Forecasts: Under the dynamic forecasts, the cost per tonne of GHG emission reductions would range from $7,100 to $18,600. As is indicated in Section 6, these figures are is many times international metrics for cost effective GHG emission reductions.

Static Forecasts: Under the static forecasts, which assume today's policies and no further initiatives to improve automobiles fuel economy, the cost per tonne of GHG emissions would range from $1,000 to $8,000. These figures are also many times international metrics for cost effective GHG emission reductions.

The net high speed rail costs are illustrated in Table 3. The costs per tonne are indicated by scenario in Figure 6, Figure 7, Table 4 and Appendix Table B-2.

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[41] See "Terrpass.com," http://www.terrapass.com/shop/, accessed February 22, 2014.

[42] US Environmental Protection Agency, *Regulatory Impact Analysis: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards,* http://www.epa.gov/otaq/climate/documents/420r12016.pdf and *Final Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards Regulatory Impact Analysis,* http://www.epa.gov/otaq/climate/regulations/420r10009.pdf

[43] California Air Resources Board (2012), *Proposed LEV III Economic Analysis: Technical Support Document*, http://www.arb.ca.gov/regact/2012/leviiighg2012/levapps.pdf

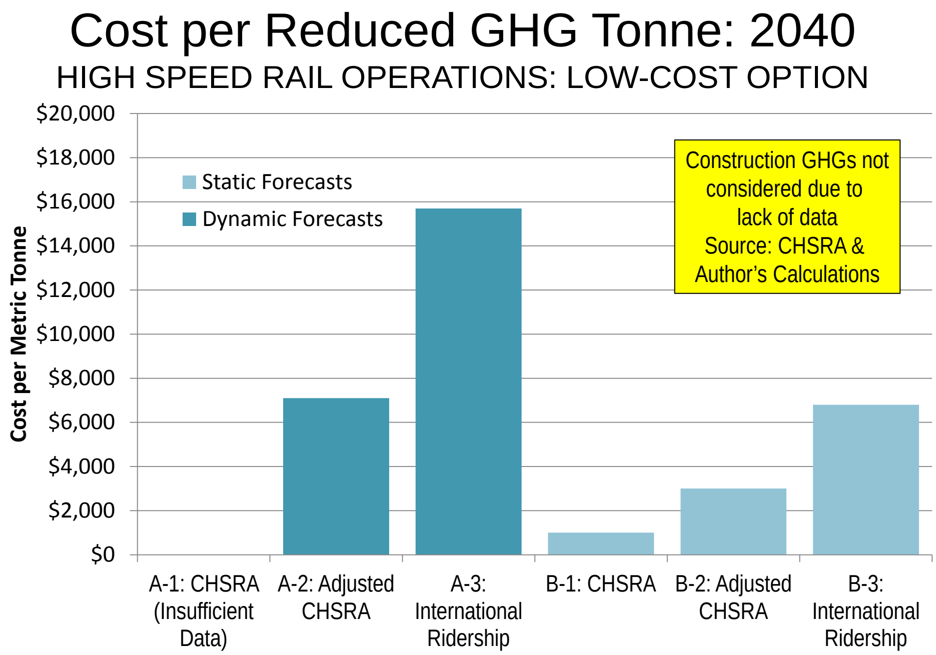

Figure 6

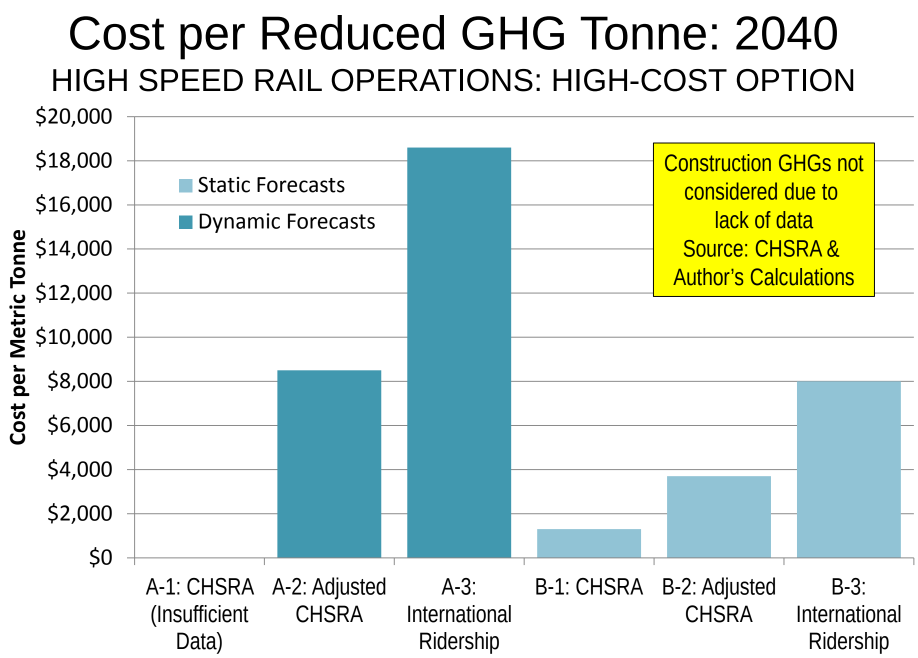

Figure 7

Table 3			
Costs of Greenhouse Gas Emission Reductions from High Speed Rail: 2040 (2013$)			
	CHSRA	Adjusted CHSRA	International Experience
Low Capital Cost Option	$1.57	$ 1.78	$ 1.96
High Capital Cost Option	$1.93	$ 2.14	$ 2.31
In billions of 2013$			
Sources: CHSRA and author's calculations			

Table 4			
Cost per Metric Tonne of Greenhouse Gas Emission Reductions from High Speed Rail: 2040 (2013$)			
Low Capital Cost Option	CHSRA	Adjusted CHSRA	International Experience
Dynamic Forecasts	Insufficient Information	$ 7,100	$ 15,700
Static Forecasts	$ 1,000	$ 3,000	$ 6,800
2013$			
High Capital Cost Option	CHSRA	Adjusted CHSRA	International Experience
Dynamic Forecasts	Insufficient Information	$ 8,500	$ 18,600
Static Forecasts	$ 1,300	$ 3,700	$ 8,000
2013$			
Construction GHGs not considered due to lack of data.			
Sources: CHSRA and author's calculations			

6. PRIORITIZING GHG EMISSIONS REDUCTION STRATEGIES

The Legislative Analyst's Office recommended that GHG emissions reductions program be prioritized based on their cost effectiveness, in analyzing the Governor's 2012-2013 budget proposal to use cap and trade revenues for high speed rail.

> *... we recommend that the Legislature prioritize GHG mitigation programs that have the greatest potential return on investment in terms of emission reductions per dollar invested.*[44]

The Legislative Analyst's Office continues, stressing the importance of avoiding unnecessary economic disruption by a rational prioritization of projects:[45]

> *In order to minimize the negative economic impact of cap-and-trade, it is important that auction revenues be invested in a way that maximizes GHG emission reductions for a given level of spending.*

[44] Legislative Analyst's Office, *The 2012-13 Budget: Funding Requests for High-Speed Rail*, http://www.lao.ca.gov/analysis/2012/transportation/high-speed-rail-041712.aspx
[45] Mac Taylor (February 24, 2014), The 2014-15 Budget: Cap-and-Trade Auction Revenue Expenditure Plan, Legislative Analyst's Office, http://www.lao.ca.gov/reports/2014/budget/cap-and-trade/auction-revenue-expenditure-022414.aspx.

> *Given these concerns, we recommend that the Legislature direct ARB to develop metrics for departments to use in order to prospectively evaluate the potential GHG emission benefits of proposed projects, as well as direct the board to establish a set of guidelines for how departments should incorporate these metrics into their decision-making processes. Having such metrics to use as part of departments' decision-making processes when determining how program funding will be spent would provide greater certainty regarding the potential GHG emission reductions of projects being considered for funding*

Such a program is a necessary pre-condition to any serious and defensible program for meeting the state's GHG emissions reduction objectives.

The high-speed rail system has not been prioritized based on its cost effectiveness compared to other strategies for reducing GHG emissions. Yet, the costs per ton of GHG emissions reduction from high speed rail is substantially higher than both the metrics and the experience in EPA and CARB programs cited above. The cost of high-speed rail GHG emissions reduction is from 75 to 1,400 times that of current market offset programs such as purchasing carbon offsets (Table 5).

Table 5

Comparision: Cost of GHG Emissions Reductions per Tonne

Abatement Cost	Low Capital Cost Option	HSR Times Carbon Offset Programs	High Capital Cost Option	HSR Times Carbon Offset Programs
EPA Fuel Economy Standards 2040	-$200		-$200	
Carbon Offsets per Tonne	$13	1	$13	1
California AB32 Cap & Trade Auction (November 2013)	$11		$11	
McKinsey & Company Average	-$9		-$9	
UN IPCC	$20 - $50		$20 - $50	
Dynamic Forecasts				
A-1: CHSRA	Insufficient Information	Insufficient Information	Insufficient Information	Insufficient Information
A-2: CHSRA Adjusted	$7,100	537	$8,500	643
A-3: International Experience	$15,700	1,188	$18,600	1,408
Static Forecasts				
B-1: CHSRA	$1,000	76	$1,300	98
B-2: CHSRA Adjusted	$3,000	227	$3,700	280
B-3: International Experience	$6,800	515	$8,000	606
Construction GHGs not considered due to lack of data.				
Sources: Authors calculations and text				

Diverting Cap and Trade Funds

The proposal in the 2012 – 2013 budget to fund the high-speed rail from cap and trade revenues was dropped after political opposition. Yet, the 2013 – 2014 budget included a loan from cap and trade funding to the state for general purposes. There is also the 2014 – 2015 budget proposal to transfer $250 million of cap and trade revenues to high-speed rail. In addition, the Administration has indicated that cap and trade funds should become an even larger share of high-speed rail funding in the future.[46]

[46] Chris Megerian and Ralph Vartabedian (February 24, 2014), "Gov. Jerry Brown wants polluters' fees to help fund high-speed rail," http://www.latimes.com/local/la-me-brown-rail-20140228,0,4977021.story#ixzz2ubyMC1e8.

As indicated above, GHG emission reductions from high-speed rail are far more expensive than necessary and the improvements in light vehicle emissions from CARB policies will substantially diminish these reductions in future years (Section 3.3). The result is an egregiously inefficient use of cap and trade revenues.

The context of the $250 million is illustrated by the fact that it is sufficient to purchase carbon offsets at the current market rate nearly equal to 90 percent of the GHG emissions reduction required between 2011 and 2020.[47]

To place this in terms parallel to those expressed by CHSRA, the GHG emissions reduction from the $250 million in cap and trade revenue, spent on carbon credits would *before 2020* be the equivalent of 3,800,000 cars taken off the road annually.[48] That many cars would stretch 38,000 miles on a single highway lane – equal to circling the world 1.5 times – and is nearly equals the total number of light vehicles in the San Francisco and San Jose metropolitan areas.[49] (As noted above, CHSRA stated that in its first year of operations [2022], high-speed rail would reduce GHG emissions by the equivalent of 31,000 cars, which it said would stretch 100 miles on a single lane highway).

Longer Term Implications

The longer term impacts are even more stark. This is illustrated by applying the costs of high speed rail GHG emissions reductions in 2040 to the reductions required to achieve the 2050 state objective of an 80 percent reduction.

Based on the 1990 statewide GHG emissions figure, the 80 percent reduction to 2050 would represent approximately 340 million annual tonnes.

The longer run cost intensity is illustrated by applying the minimum high speed rail 2040 costs per tonne (CHSRA Scenario [B-1]) to 80 percent annual 2050 GHG emissions reduction required by state policy from 1990. This calculates to nearly $350 billion (2013$), which is approximately 1/7 the present size of California's gross domestic product (GDP). Under the more likely Dynamic Forecast: International Ridership Scenario (A-3) the cost would be up to $6.2 trillion (2013$). This is up to three times the size of California's GDP, larger than the GDP of Japan and larger than the output of every country in the world except for the United States and China in 2013.

High Speed Rail: A Temporary Strategy? By 2040 the gap between high-speed rail GHG emissions and light vehicle GHG emissions per passenger mile that is presently so large will have been substantially closed. Within the next decade, further improvements in fuel economy are expected by CARB, which would lead to a virtual elimination of the GHG emissions advantage of high speed rail over cars (at any level of ridership). Thus, high-speed rail would no longer make even its modest commitment to GHG

[47] In 2011, the statewide GHG emissions were 448 million tonnes. The 2020 objective is 427 million tonnes. At $13.21 per tonne for a tree planting program (as CHSRA intends to use to abate its construction GHG emission increases), approximately $275 million would be required. The proposed $250 million cap and trade funds expenditure of $250 million is approximately 90 percent of $275 million.
[48] This calculation uses the automobile GHG emissions and lane capacity assumptions in California High Speed Rail Authority (June 2013), *Contribution of the High-Speed Rail Program to Reducing California's Greenhouse Gas Emission Levels*,
[49] According to the US Census Bureau American Community Survey, households in the San Francisco and San Jose metropolitan areas had slightly fewer than 4.0 million vehicles available in 2012. At 5 metric tonnes of GHG annually, the 20 million annual emissions would be 20 million tonnes. This compares to the 19 million tonne reduction required in 2020 relative to 2011.

emissions reductions by the 2060 planning horizon indicated in the *2014 Business Plan*. The impact of high-speed rail on GHG emissions reductions could thus be only temporary, yet hugely expensive.

Political Sustainability

The purpose of California's GHG emissions reduction program is environmental sustainability. Yet, in the final analysis, the survival of public policies requires sufficient public support. Environmental sustainability rests on a foundation of political sustainability.

Appropriation of cap and trade revenues to cost-inefficient strategies such as high-speed rail may not be politically sustainable. A perception that cap and trade revenues are simply a source of funds subject to political whim could fuel political pressure that leads to dilution or abandonment of the state GHG emissions reduction objectives. Over the three and one-half decades between now and 2050, there will be countless opportunities for "raids" on cap and trade revenues.

Moreover, such developments could worsen California's business climate and competitive position relative to other states. Business expansion and site selection in the state could be discouraged by fear that the failure to properly use cap and trade revenues, which are meant to mitigate GHG emissions, would create a demand for even greater financial or regulatory burdens.

7. THE IMPERATIVE FOR COST-EFFECTIVENESS AND REALISM

The Legislative Analyst's Office concluded that the high-speed rail project would contribute little to the GHG emissions reductions in the state,[50] a conclusion echoed in this report. High-speed rail would not advance the objectives of AB32 because its reductions would all occur after its 2020 deadline. Further, high-speed rail would retard achieving AB32 objectives by using cap and trade funds for purposes that cannot compete in an objective prioritization of cost-effective uses.

The longer-term implications are even more counter-productive. At most, high-speed rail would contribute one half of one percent (0.5 percent) of the required GHG emissions required in 2050 (Figure 8).[51] The greater likelihood is that the contribution will be much smaller, due not only to the likely over-projection of ridership, but also the diminishing, if not disappearing gap between GHG emissions reductions per mile traveled on high speed rail versus light vehicles (Section 3.3). This anticipated policy outcome illustrates the importance of GHG emissions analysis that is dynamic, rather than static. Planning and analysis can only be justified to the extent that it is based in reality.

It is not surprising that high-speed rail is so costly as a strategy for reducing GHG emissions. The most important national and state strategies for reducing GHG emissions from transportation --- programs by the EPA and CARB to improve fuel economy --- are projected to reduce GHG emissions at negative costs of more than $200 per tonne. By contrast, California's high speed rail line would result in comparatively small reductions in the state by comparison, yet would require substantial capital and operating costs.

[50] Legislative Analyst's Office, *The 2014-15 Budget: Overview of the Governor's Budget 2014-5*, http://www.lao.ca.gov/reports/2014/budget/overview/budget-overview-2014.aspx

[51] This would require the achievement of CHSRA's midpoint GHG emissions reduction forecast in 2050, which is highly unlikely (as this report indicates).

High-speed rail would be a hideously expensive strategy that would consume resources that could be more effectively used to reduce GHG emissions. The use of cap and trade revenues for any use other than the most effective suggests a lack of seriousness toward GHG emissions reduction. There is no doubt that reaching California's goals will be challenging. Success is not guaranteed. If California's GHG emissions reduction goals are imperative, then it is equally imperative that they be pursued with the maximum cost effectiveness.

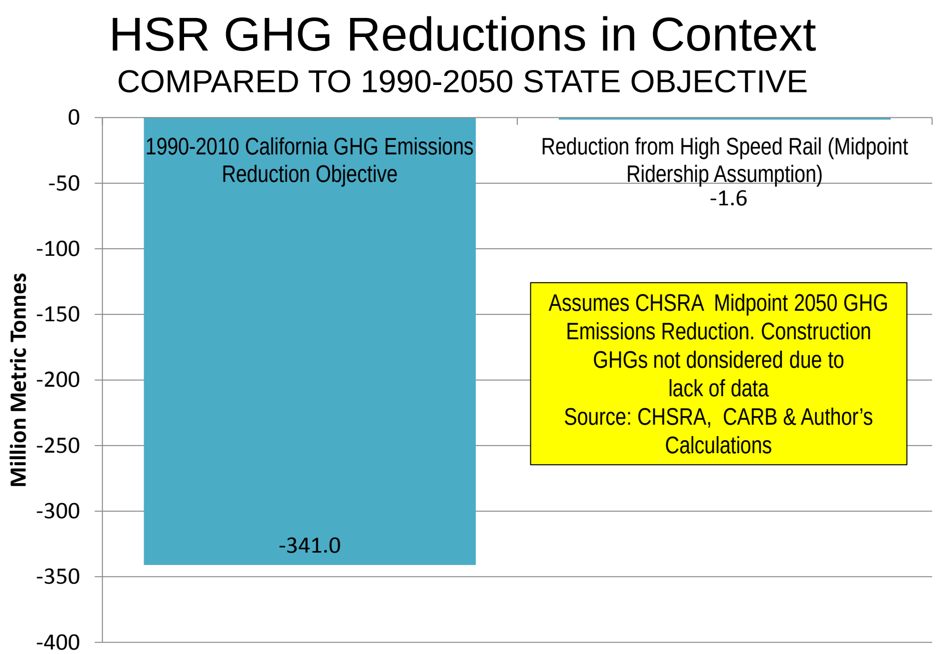

Figure 8

8. LEGALITY OF CAP AND TRADE FUNDING FOR HIGH SPEED RAIL

The principal purpose of this report is to assess the GHG emissions reduction potential of the California high-speed rail line and the relative costs per tonne of any such reduction. There are also considerable legal issues with respect to the use of cap and trade revenues, as proposed by the Brown Administration.

Use of AB32 cap and trade revenues for high-speed rail could be illegal. The Legislative Counsel has advised the Legislative Analyst's Office that funds from cap and trade auctions are "mitigation fees," and that their use for high-speed rail could be illegal.

Use of cap and trade revenues for high-speed rail may be legally challenged as an inappropriate use of "mitigation fees." The Legislative Counsel has advised the Legislative Analyst's Office that funds from cap and trade auctions are "mitigation fees," and that their use for high-speed rail could be illegal for failure to meet the "Sinclair nexus test." A subsequent court ruling found that cap and trade revenues are not taxes.[52]

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[52] Legislative Analyst's Office, *The 2012–13 Budget: Cap–and–Trade Auction Revenues*, http://www.lao.ca.gov/analysis/2012/resources/cap-and-trade-auction-revenues-021612.aspx

Further, using cap and trade funds for high-speed rail could violate the intent of the authorizing legislation, AB32. According to the Legislative Analyst's Office:

> *The primary goal of AB 32 is to reduce California's GHG emissions statewide to 1990 levels by 2020. Under the revised draft business plan, the IOS would not be completed until 2021 and Phase 1 Blended would not be completed until 2028. Thus, while the high-speed rail project could eventually help reduce GHG emissions somewhat in the very long run, given the project's timeline, it would not help achieve AB 32's primary goal of reducing GHG emissions by 2020. As a result, there could be serious legal concerns regarding this potential use of cap-and-trade revenues. It would be important for the Legislature to seek the advice of Legislative Counsel and consider any potential legal risks,*[53]

In addition to the potential legal problems with using AB32 revenues for high speed rail, high speed rail is not a cost effective GHG emissions reduction strategy (Section 6).

APPENDIX A: METHODOLOGY

CHSRA does not provide a sufficiently detailed methodology to replicate their GHG emissions impacts. As a result, a model was developed for this report that estimates GHG emissions impacts from other information in CHSRA documentation and other sources.

GHG Emissions Impact Estimates

The year 2040 is chosen for analysis, because the *Draft 2014 Business Plan* provides detailed ridership projections between the major markets. These ridership data are used to estimate the extent of passenger travel (in passenger miles). For simplicity, all longer distance demand (more than 300 miles) is assumed to have been diverted from airlines and all shorter distance demand from light vehicles.

CHSRA's June 2013 report did not specifically denote its projected GHG emissions reduction for 2040. However, information was provided for 2035 and 2050, making it possible to estimate a figure for 2040. It is assumed that the CHSRA 2040 figure for GHG emissions reduction would range from 1.18 million annual tonnes to 1.90 million annual tonnes.[54]

Static Forecasts: The reduced GHG emissions that would occur from the transfer of riders to high-speed rail is then estimated for each of the former modes of travel under the Static Forecasts.
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> ***Former light vehicle drivers***: CO2 emissions are estimated using a base of the 2040 US Department of Energy, Energy Information Administration (*2014 Annual Energy Outlook*) projected mile for the light vehicle stock of 216 grams per vehicle mile.[55] This figure is increased 5 percent to account for the difference between CO2 emissions and CO2 equivalent emissions,

[53] Legislative Analyst's Office, *The 2012-13 Budget: Funding Requests for High-Speed Rail*, http://www.lao.ca.gov/analysis/2012/transportation/high-speed-rail-041712.aspx

[54] California High Speed Rail Authority (June 2013), *Contribution of the High-Speed Rail Program to Reducing California's Greenhouse Gas Emission Levels*,

[55] US Department of Transportation, Energy Information Administration, *Annual Energy Outlook 2014.*

because greenhouse gases other than CO2 are not included.[56] All of the miles driven are then adjusted by the share of travel in city driving versus highway driving. Each of these figures is then reduced by 10% to account for the impact of the California Low Carbon Fuel Standard. It is assumed that all train travelers attracted from cars had driven alone previously.

Former airline passengers*:* CO2 emissions are estimated using data from the *SAS Advanced Emission Calculator* for flights in California.[57] This figure is adjusted downward by approximately 6 percent to account for the improvement in airline fuel efficiency to 2040 as indicated in the *2014 Annual Energy Outlook*, and increased 5 percent to account for the difference between CO2 emissions and CO2 equivalent emissions.

Amtrak: New GHG emissions reductions are assumed for passengers transferring from conventional (Amtrak) services to high-speed rail. Amtrak's "San Joaquin" service operates from Oakland to Bakersfield and serves stations that would not be served by high-speed rail, including Oakland, Emeryville, Richmond, Martinez, Antioch-Pittsburg, Stockton, Turlock, Modesto, Merced, Corcoran and Wasco. It is assumed that Amtrak trains will continue to operate without service reductions and as a result there would be little or no reduction in GHG emissions from passengers who use high-speed rail instead.

Induced Travel: All other travel on high-speed rail would be by passengers who would not have made the trip if the high-speed rail system had not been available. Because these induced travelers did not travel previously, it is assumed that there would be no change in GHG emissions.

Light Vehicle Access to High Speed Rail Stations: Additional light vehicle travel will be required traveling to and from high-speed rail stations. This will increase GHG emissions. Overall, it is assumed that 75 percent of station access will be by light vehicle. For origins or destinations without high speed rail stations, the one way travel distance between the nearest station and the urban center is used (such as San Diego and Sacramento. Between the San Francisco Bay Area and Los Angeles no access factor is added, on the assumption that passengers will simply use their previous travel mode of airport access to reach train stations. In other markets, access distance per train trip of between five and 10 miles is assumed, depending on the size of the urban area. Overall, 75 percent of train riders are assumed to access stations by light vehicle. These conservative assumptions are used because no alternate source of such estimates was identified.

Powering High Speed Rail Trains: The literature indicates a wide range of electricity power consumption by high-speed rail. This model assumes the 0.04 kilowatt hours per seat kilometer (per seat kilometer) indicated for trains with top speeds of up to 186 miles per hour (300 kilometers per hour.[58] However, California's high-speed rail trains are planned to operate at a top speed of 220 miles per hour (354 kilometers per hour), a speed that has been approached only in China (350 kilometers per hour), which has since reduced operating speeds to a maximum of approximately 193 miles per hour (310

[56] This is consistent with the treatment in California High Speed Rail Authority, *Draft Environmental Impact Report/Statement: Fresno to Bakersfield*, Table 3.3-17, http://www.hsr.ca.gov/docs/programs/fresno-baker-eir/drft_EIR_FresBaker_Vol1_3_3.pdf.

[57] *SAS Advanced Emission Calculator*, http://www.flysas.com/en/us/travel-info/other/co2-compensation/

[58] Yuki Tanaka, Louis S. Thompson, Lee Schipper, Andrew Kosinski, and Elizabeth Deakin (2010), Analysis of High Speed Rail's Potential to Reduce CO2 Emissions from Transportation in the United States, Paper presented to the World Conference on Transportation Research.

kilometers per hour). Research in China[59] indicates that 28 percent more in power is required to operate trains at such speeds compared to 186 miles per hour (300 kilometers per hour), which was formerly the highest speeds attained by high speed rail. It is assumed that the trains would reach 350 miles per hour on the genuine high speed rail right of way and no more than 120 miles per hour on the commuter rail right of way (and power requirements are assumed to be lower at 120 miles per hour, consistent with the relationship in the China research.

Consistent with CHSRA data, it is assumed that each train set would have 450 seats.

GHG Emissions from the Train: The trains will not directly produce GHG emissions, however the generation and transmission of electricity for the trains produces GHG emissions. It is assumed that high-speed rail trains will indirectly produce GHG emissions at the average generation and transmission loss mix of electricity consumed in California. According to the California Air Resources Board, California electricity generation and transmission losses produced 0.318 GHG tonnes per megawatt hour consumed in 2011.[60] This figure is adjusted downward to achieve the 33 percent renewable power standard implemented by CARB for 2020 and beyond.

Other High Speed Rail Functions: It is assumed that the GHG emissions from day to day functioning of high-speed rail stations, maintenance facilities and maintenance rail rights of way would be at the same relationship of GHG emissions from the trains (see *Propulsion Power* above), as is indicated in CHSRA documentation in the Fresno to Bakersfield corridor.[61]

Dynamic Forecasts

The "Dynamic Forecasts" adjust the Static Forecasts to replicate an underlying assumption that California will, in 2040, beyond the trajectory to achieve its 2050 GHG emissions reductions, particularly in the transportation sector.

Examples of adjustment to the methodology include:

> Adoption of an additional 10 percent Low Carbon Fuel Standard.
>
> Achievement of an 87 percent ZEV share of light vehicles. [62]
>
> Achievement of the Federal Aviation Administration "CLEEN" airline fuel efficiency standards.[63]

[59] Zhang Xing chen, Feng Xuesong, Mac Baohua, Jia Shunping and Feng, Xujie (2011), *Simulation Research on the Traction Energy Consumption of High Speed Trains in China,* Journal of Transportation Systems Engineering and Information Technology.
[60] Calculated from data in California Air Resources Board (October 2, 2013), *California Greenhouse Gas Emissions for 2000 to 2011, – Trends of Emissions and Other Indicators*, http://www.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_trends_00-11_2013-10-02.pdf
[61] As indicated in California High Speed Rail Authority, *Draft Environmental Impact Report/Statement: Fresno to Bakersfield*, Table 3.3-17, http://www.hsr.ca.gov/docs/programs/fresno-baker-eir/drft_EIR_FresBaker_Vol1_3_3.pdf
[62] California Air Resources Board, Public Hearing to Consider Advanced Clean Cars Program, http://www.arb.ca.gov/board/books/2012/012612/12-1-2pres.pdf.
[63] *United States Aviation Greenhouse Gas Emission Reduction Plan* (2012), https://www.faa.gov/about/office_org/headquarters_offices/apl/environ_policy_guidance/policy/media/Aviation_Greenhouse_Gas_Emissions_Reduction_Plan.pdf

Costs under the Dynamic Forecasts are unchanged, principally because of uncertainties about the operating costs of light vehicles with alternative technologies in 2040.

Cost Impacts:

All costs are express in inflation adjusted 2013 dollars and apply to the year 2040.

Annual Capital Cost: Equivalent annual capital costs are developed for the low-cost option and the high cost option using a real interest rate of 3 percent is used over 50 years. There has been considerable variation in federal guidance on annualization rates for capital costs in recent years. As late as 2003, federal guidance recommended the use of real discount rates of 7 percent and 3 percent.[64] More recently, this has been reduced to 1.9 percent. The US Department of Transportation, Federal Transit Administration (FTA) requires a 2.0 percent rate.[65] Over the last 30 years, the average real US Treasury bond rate has been 3.3 percent.[66] It seems likely that the annualization rate will increase toward more historic rate as the Federal Reserve Board's quantitative easing policy is phased out. Virtually all of the high speed capital costs are to be incurred in future years, and an annualization rate of 3.0 percent seems appropriate.

> A sensitivity analysis was performed to estimate the differences in cost per tonne of GHG emissions from high speed rail at varying annualization rates. At the FTA real annualization rate of 2.0 percent, the cost per GHG emission tonne reduction would be approximately $800, compared to the $1,000 at the 3.0 percent rate for the most favorable scenario in this report (Static Forecast: CHSRA Scenario). At the former OMB real annualization rate of 7.0 percent, the cost per GHG emission tonne reduction would be $2,200. The use of shorter annualization periods would increase the annualized capital costs.

Annual Operating and Maintenance Cost: The annual operating cost is taken from the *Draft 2014 Business Plan.*

Airline Cost: The savings in airline cost per passenger is based on the passenger fare assumption in the *Draft 2014 Business Plan.*

Light vehicle Cost: The savings in light vehicle cost per vehicle mile is based on the per mile assumptions in the *Draft 2014 Business Plan.*

CHSRA Cost Analysis: CHSRA's GHG emissions reduction report does not include a cost analysis (from which a cost per tonne could be calculated). As a result, the independent cost analysis developed for the Adjusted CHSRA Scenario is used for the CHSRA Scenario.

Caveats

This report produces "dynamic forecasts" of GHG emissions reductions. Dynamic forecasting is generally not employed by public agencies and can be inconsistent with planning guidelines. However, the failure to employ dynamic forecasting --- as may be required by planning regulations and convention --- in

[64] US Office of Management and the Budget (September 3, 2003), *Circular A*-4, http://www.whitehouse.gov/sites/default/files/omb/assets/regulatory_matters_pdf/a-4.pdf.

[65] Federal Transit Administration, *New and Small Starts Rating and Evaluation Process Final Policy Guidance August 2013*, http://www.fta.dot.gov/documents/NS-SS_Final_PolicyGuidance_August_2013.pdf.

[66] Calculated from Office of Management and Budget (December 26, 2013), *Budget Assumptions*, http://www.whitehouse.gov/sites/default/files/omb/assets/a94/dischist-2014.pdf.

California's transformative GHG emissions reduction policy environment can render conventional static forecasting to be grossly inaccurate and of little relevance.

This report represents a provisional attempt to develop dynamic forecasts, although it is expected that public agencies, with their far greater resources could substantially improve both the methodology and accuracy. In developing the dynamic forecasts, this report has tended toward conservative assumptions that give the "benefit of the doubt" to high speed rail.

Moreover, the forecasts are at substantial variance with GHG emissions reduction cost metrics. Thus, improvements to the methodology would not be likely to result in differences material enough to alter the public policy conclusion that high speed rail is an exceedingly expensive, and only a temporary measure for reducing GHG emissions.

Further, because no credible assumption was identified the average vehicle occupancy of cars whose occupants travel instead by high speed rail, it was assumed that each car taken off the road had a single occupant, the driver. A more likely higher assumption (such as two passengers per light vehicle) would reduce the GHG emissions reduction per light vehicle and reduce the high speed rail advantage. Similarly, the attraction of a light vehicle passenger who is not the driver to high speed rail would not result in a reduction of GHG emissions by high speed rail. This 1.0 light vehicle occupancy assumption results in *higher* high speed rail GHG emissions reductions than are likely.

APPENDIX B: SUPPLEMENTAL TABLES

Table B-1

High Speed Rail Greenhouse Gas Emission Impacts: 2040: Static Forecasts

	Dynamic Forecasts		
OPERATIONS & MAINTENANCE	CHSRA	Adjusted CHSRA	International Experience
Automobile Travel	Unknown	(0.35)	(0.18)
Airline Travel	unknown	(0.31)	(0.15)
Trains: Indirect Power	unknown	0.35	0.17
Stations, Facilities & Maintenance of Way	unknown	0.07	0.03
Total	unknown	(0.25)	(0.12)
	Static Forecasts		
OPERATIONS & MAINTENANCE	CHSRA	Adjusted CHSRA	International Experience
Automobile Travel	Unknown	-0.56	-0.28
Airline Travel	unknown	-0.44	-0.22
Trains: Indirect Power	unknown	0.35	0.17
Stations, Facilities & Maintenance of Way	unknown	0.07	0.03
Total	-1.54	-0.59	-0.29

In millions of tons

Construction GHGs not considered due to lack of data.

Sources: CHSRA & authors calculations

Table B-2			
High Speed Rail 2040 Costs			
In Billions of 2013$	CHSRA	Adjusted CHSRA	International Experience
Capital: Equivalent Annual Cost: Low	unknown	$2.13	$2.13
Capital: Equivalent Annual Cost: High	unknown	$2.49	$2.49
Automobile Cost	unknown	($0.83)	($0.41)
AirlineCost	unknown	($0.40)	($0.20)
High Speed Rail Operations & Maintenance	unknown	$0.87	$0.43
Total with Low Capital Cost	$1.57	$1.78	$1.96
Total with High Capital Cost	$1.93	$2.14	$2.31
In millions of tons			
Sources: CHSRA & authors calculations			