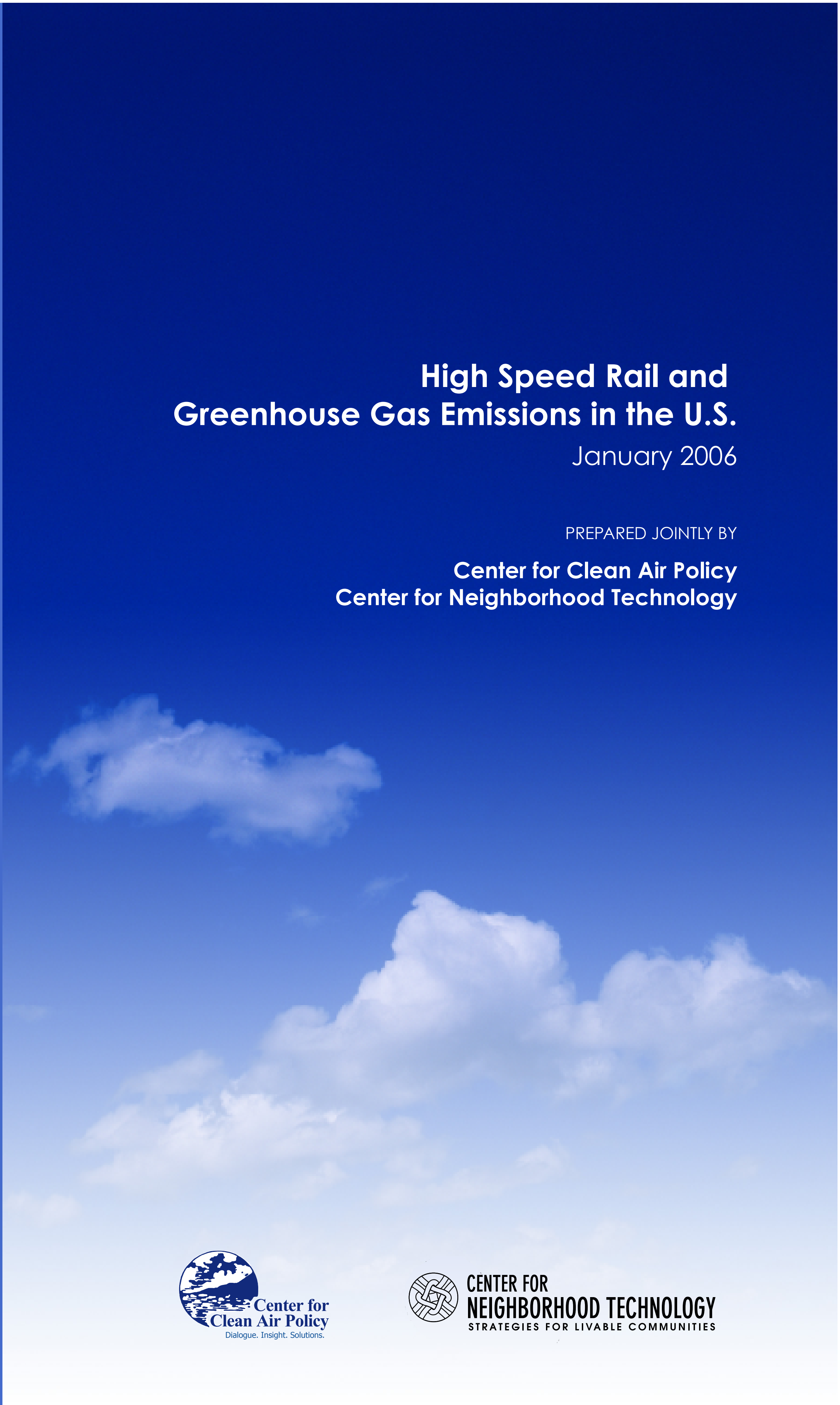
Center for Clean Air Policy
Center for Neighborhood Technology



High Speed Rail and Greenhouse Gas Emissions in the U.S.

January 2006

PREPARED JOINTLY BY

Center for Clean Air Policy
Center for Neighborhood Technology

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Acknowledgements
We would like to thank the U.S. Environmental Protection Agency Office of Atmospheric Programs for financial support through a cooperative agreement that supported the work in this report.

About the Center for Clean Air Policy

The Center for Clean Air Policy (CCAP) was established in 1985 by a group of state governors to develop and promote innovative policy solutions to energy and environmental problems. From our initial work as a key player in the development of a SO_2 trading system to help control acid rain to ongoing projects that focus on market-oriented approaches to ozone, climate change, and air toxics, we have promoted the idea that sound energy and environmental policy solutions serve both environmental and economic interests. CCAP has over 20 years of experience addressing climate change, air emissions, and energy policy in ways that are both efficient and effective. CCAP has been actively engaged in analyzing and advancing policies in all sectors of the economy-electricity, transportation and land-use, buildings, commercial, industrial, agriculture, and forestry-as well as cross-cutting experience in emissions trading and emissions registries.

CCAP's Transportation Team works to reduce mobile source emissions in the US and internationally. We lead transportation sector analyses for climate change working groups in California, Connecticut, Maine, New York and Puget Sound. These efforts focused in large part on crafting comprehensive policy packages to slow growth in travel demand (smart growth, transit, TDM), and assessments of vehicle technology measures, low-GHG fuels, and intermodal freight. The CCAP Transportation Emissions Guidebook is a tool that builds upon the Center's state experience and enables users to quantify the benefits of a variety of transportation projects and policies. Through our Low Emissions Freight program we are finding ways to reduce pollution from goods movement at key ports and for the country as a whole. Our three-year capacity building project in Chile (in collaboration with IISD) shed light on the opportunities and challenges of including transportation projects and policies in the Clean Development Mechanism of the Kyoto Protocol. We are currently working with partners in Brazil, China, India and Mexico on analyzing and implementing measures to reduce GHG emissions from passenger and freight transportation. A complete list of our projects and publications is available at www.ccap.org/trans.htm.

About the Center for Neighborhood Technology

The Center for Neighborhood Technology (CNT) was founded in 1978 to research, adapt and test new community revitalization strategies relevant to urban communities, especially strategies that harnessed the environmental and economic value of the more efficient use of natural resources. Over the years we have worked to disclose the hidden assets of the Chicagoland economy and urban areas more broadly, demonstrate the multi-bottom line benefits of a more resource-efficient set of policies and practices and show how the value of what we demonstrated could be captured to benefit communities and their residents inclusively. Our work, especially in the areas of energy, transportation, materials conservation and housing preservation, helped fuel a generation of community development institutions and learning, garnering us a reputation as an economic innovator and leader in the field of creative sustainable development.

Today, CNT serves as the umbrella for a number of projects and affiliate organizations, all of which help us to fulfill our mission to promote the development of more livable and sustainable urban communities. Our transportation work is focused on using our transportation assets to serve both the environmental and economic development goals of our regions and communities. We work to boost demand for clean, efficient and affordable mass transit; increase the supply of traditional and non-traditional mass transit services; disclose the linkages between transportation costs and housing affordability; create model value-capture mechanisms that take advantage of the intersection of efficient transportation networks with community economic development programs; and promote policy initiatives that increase public participation in investment decisions and make more resources available for sustainable investments. More information about CNT is available at www.cnt.org.

Executive Summary

High speed rail is often cited as a solution to many transportation problems: It can reduce congestion on roads and at airports, is cost effective and convenient, improves mobility and has environmental benefits. While greenhouse gas (GHG) emissions are likely to be reduced as travelers switch to high speed rail from other modes of travel, little modeling has been done to estimate this potential impact in the U.S. Those estimates that have been made simply assume a percentage of trips nationally will be diverted to rail from other modes. The Center for Neighborhood Technology (CNT) and the Center for Clean Air Policy (CCAP) have, alternatively, estimated on a corridor-by-corridor basis the annual GHG benefits of high speed rail systems in the U.S. using current plans for high speed rail development in the federally designated high speed rail corridors.

To estimate high speed rail's net emissions impact, we calculated the carbon dioxide (CO_2) emissions saved from passengers switching to high speed rail from other modes (air, conventional rail, automobile and bus) and subtracted the estimated emissions generated by high speed rail. Our calculations were based on passenger projections and diversion rates for each corridor and typical emissions rates for each mode of travel, including several different high speed rail technologies.

Current projections show that passengers would take 112 million trips on high speed rail in the U.S. in 2025, traveling more than 25 billion passenger miles. This would result in 29 million fewer automobile trips and nearly 500,000 fewer flights. We calculated a total emissions savings of 6 billion pounds of CO_2 per year (2.7 $MMTCO_2$) if all proposed high speed rail systems studied for this project are built. Savings from cancelled automobile and airplane trips are the primary sources of the emissions savings; together these two modes make up 80 percent of the estimated emissions savings from all modes.

Our modeling shows that high speed rail, if built as planned, will generate substantial GHG savings in all regions. The total emissions savings vary greatly by corridor, however, as do the source of those savings. In some regions, such as the Midwest, the impact on air travel is likely to be modest; our analysis shows just a 7 percent decrease in flights from today's levels. In California, on the other hand, 19 million passengers are projected to switch from air—a volume that would result in 114 percent of today's 192 million annual direct flights in the corridor being cancelled. Such ridership levels may be an overestimate, or may be possible if projected growth in air travel and indirect flights, including those from outside the corridor are included. To draw so many air passengers to rail will certainly require that high speed rail ticket prices be competitive with air and that service be as convenient and time-efficient. It is worth further study to see if such high levels of mode shifting are likely. In some respects, the California system, as it is currently planned, represents what will be the second generation of high speed rail in many of the other corridors. While areas like the Pacific Northwest may increase ridership sooner with an incremental approach to high speed rail that uses existing rail routes, the success of a new high speed rail system like California's could prove the value of faster trains with higher upfront capital costs.

We identify a number of areas for further research to better understand the potential impact and value of high speed rail in the U.S., including: the potential benefits of a high speed rail *network*, rather than a set of individual corridors, the likelihood of significant mode-shifting, how the presence of very high speed rail systems might change current estimates; and what social and environmental benefits could be achieved if high speed rail, air and bus travel were more closely linked through a national "Travelport" system. Finally, we also offer several policy recommendations, including that sustainable financing mechanisms for high speed rail be developed and that safety policies and train design be coordinated to support both safety and efficiency.

Table of Contents

List of Figures

List of Tables

Introduction

High speed rail is often cited as a solution to many transportation problems: It reduces congestion on roads and at airports, is cost effective and convenient, improves mobility and has environmental benefits.[1] One of the environmental benefits mentioned is a reduction in greenhouse gas emissions as travelers switch to high speed rail from other modes of travel, such as airplanes or automobiles for intercity travel.[2] But, little modeling has been done to estimate the impact of proposed high speed rail systems on greenhouse gas emissions in the U.S. When such estimates have been made, they are often done on a top-down basis by assuming a percentage of trips nationally will be diverted to rail from other modes. The Center for Neighborhood Technology (CNT) and the Center for Clean Air Policy (CCAP) set out to estimate the annual greenhouse gas benefits of high speed rail systems in the U.S. from a more bottom-up perspective by using current plans for high speed rail development in the federally designated high speed rail corridors.

High speed rail is defined in the U.S. as rail that is time competitive with air or automobile travel at distances of 100-500 miles.[3] Sample trips of this distance include San Francisco to Los Angeles (380 miles), New York City to Washington, DC (232 miles), or Chicago to Minneapolis (409 miles). According to the 1995 American Travel Survey, 58 percent of trips over 100 miles are also less than 500 miles, meaning that they match the high speed rail target market in terms of trip length, if not in terms of location. While this demonstrates a large potential market for high speed rail, this market is largely untapped by the current conventional rail system.

The primary modes of intercity travel in the U.S. today are automobile, bus, airplane and some Amtrak and commuter rail. Presently only one percent of U.S. intercity trips are rail trips, while 90 percent are automobile trips, 7 percent are air trips, and 2 percent are bus trips.[4] High speed rail planning has gained momentum in the U.S. with the success of high speed rail in Europe and Asia, as well as the launch of Amtrak's Acela trains in the Northeast, spurring plans for high speed rail around the country. There are 11 federally designated high speed rail corridors in the U.S. (see Figure 1 U.S. Potential High Speed Rail Corridors). Most of these corridors are still in the planning stages.

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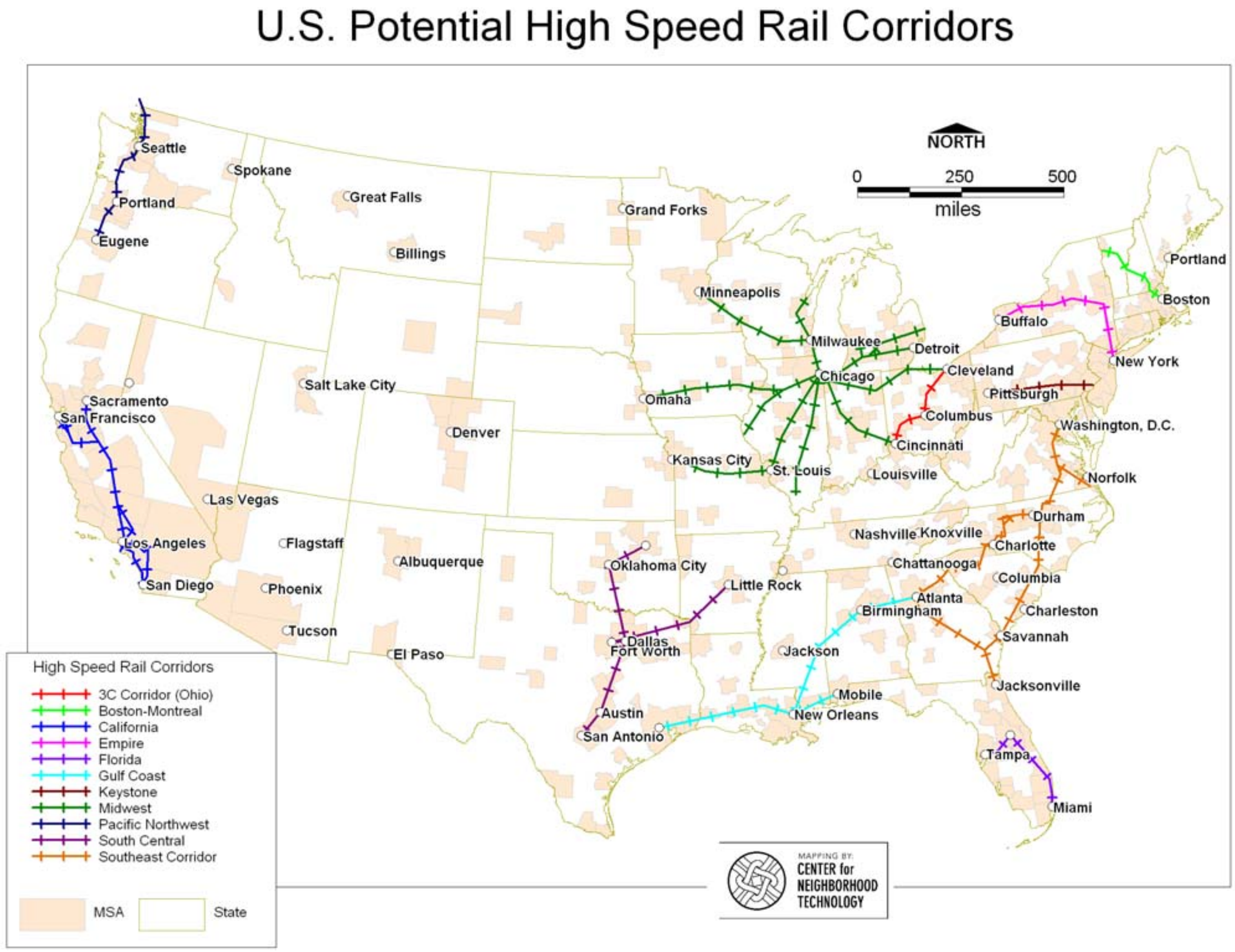
[1] See e.g. Environmental Law and Policy Center, "The Benefits of High Speed Rail." http://www.elpc.org/trans/rail/benefits.htm; Florida High Speed Rail. "Overview." http://www.floridahighspeedrail.org/1d_overview.jsp; and U.S. General Accounting Office. "Intercity Passenger Rail: Assessing the Benefits of Increased Federal Funding for Amtrak and High Speed Passenger Rail Systems." Testimony Before the Subcommittee on Transportation, Committee on Appropriations, House of Representatives. March 2001. http://www.gao.gov/new.items/d01480t.pdf; Andrés López-Pita and Francisco Robusté Anton. "The Effects of High Speed Rail on the Reduction of Air Traffic Congestion." Journal of Public Transportation. Volume 6. No. 1 2003. http://www.nctr.usf.edu/jpt/pdf/JPT%206-1.pdf

[2] U.K. Commission for Integrated Transport. "A Comparative Study of the Environmental Effects of Rail and Short-haul Air Travel." September 2001. http://www.cfit.gov.uk/reports/racomp/06.htm

[3] U.S. Department of Transportation, Federal Railroad Administration. "High Speed Ground Transportation." http://www.fra.dot.gov/us/content/31

[4] Trips over 50 miles. Bureau of Transportation Statistics. "National Household Travel Survey 2001." http://www.bts.gov/programs/national_household_travel_survey/

Figure 1 U.S. Potential High Speed Rail Corridors[5]



Methodology

Using passenger projections and diversion rates, we calculated the carbon dioxide (CO_2) emissions saved from passengers switching to high speed rail from other modes—air, conventional rail, automobile and bus—and subtracted the estimated emissions generated by high speed rail to estimate high speed rail's net emissions impact. A more detailed description of this formula is available in Appendix C.

Passenger Projections

Most of the high speed rail corridors have created planning documents for their proposed systems. We used these studies to model the potential greenhouse gas impacts of high speed rail. Our model used each corridor's projected passenger levels, as well as information on the transportation modes those passengers were diverted from (air, automobile, bus, conventional rail, or whether passengers were induced to travel based on the availability of high speed rail). We initially intended to use current travel patterns to build our estimates for future travel patterns given the availability of high speed rail, but we found that most of

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[5] Map of potential high speed rail does not include existing Northeast high speed rail between Washington, New York and Boston.

the high speed rail studies had already done this. These studies are often based on models that incorporate current travel and economic and sociological patterns, as well as future trends. The studies vary in detail and methodology, but for this project we decided to use the most recent locally developed passenger projections, when available, rather than generating our own passenger estimates.

Of the twelve high speed rail corridors we studied, we have local passenger projections for nine. These projections are from published studies or from unpublished data obtained from conversations with transportation planners. Details about the data are in Appendix B. We were unable to obtain local studies for the Empire, Northeast, and South Central corridors. For these corridors we have used estimates from the 1997 Federal Railroad Administration (FRA) study *High Speed Ground Transportation for America*. We have also used diversion rates from this study in corridors where that information was unavailable, as is noted in Appendix B.

Corridor Segments

Most of the corridors span multiple states and jurisdictions. For many of the corridors, separate plans have been developed for individual segments of the corridor. When possible, we combined the information from the separate studies into estimates for the entire corridor. We made an exception in the Midwest, however, where we studied the Ohio corridor between Cincinnati and Cleveland separately from the Midwest system (see Appendix B for details).

Diversion Rates

As with the passenger projections, we took the diversion rates used in the individual corridor passenger projection models at face value. Most studies, when they provided diversion rates, did so in the form of percent of high speed rail ridership. When a corridor offered multiple high speed rail scenarios we attempted to use the diversion rates from the same scenario as the passenger projection value we chose; specifics are noted in Appendix B.

Model Year

We used passenger projections for year 2020 or 2025, depending on which was available. Given the varied age of the available studies and the uncertainty of funding and development schedules for these systems, these passenger estimates should be taken as estimates of a build-out of each high speed rail corridor rather than a prediction for a specific year.

Alignments

Most of the high speed rail studies looked at a range of alignments and made a variety of passenger projections accordingly. Where more than one alignment or route is being considered we tried to use the passenger projections for the routes currently favored. Details of which scenarios we chose for each corridor are available in Appendix B.

High Speed Rail Technologies

Planners and high speed rail advocates in many corridors seem to have initially looked at super fast train technologies such as MagLev, and as a result, they projected very high passenger levels. When faced with the costs of such a project, however, these stakeholders began looking more carefully at a slower, incremental train system improvement with lower ridership. Through conversations and planning documents we determined that while super fast trains remain the ideal, the current trend in high speed rail seems to be an incremental approach that makes use of existing systems where available, decreases travel time and gradually expands service with the hope of eventually implementing super fast trains. Therefore, unless other information is available, we have been using the more conservative passenger estimates for slower speeds.

We have run emissions estimates for multiple train technologies to gain an understanding of the impact of these different technologies on emissions. But it should be noted that **our estimates for the faster technologies will be inherently conservative** because the shorter trip times that the faster technologies allow would likely make high speed rail attractive to more riders, drawing more passengers away from other travel modes, such as air and automobile, and saving more emissions. Because this analysis utilizes the lower speed passenger estimates, regardless of the technology, we are not accounting for these effects and, thereby, potentially limiting the savings in our results.

Trip Length

The high speed rail corridor projections all look at passenger miles for the purpose of projecting revenues and service levels, but often that data is presented as a total annual passenger mile value or an average passenger trip length. As we considered the data more closely, we realized that there might be real differences in the trip length of a passenger who switches from air to high speed rail and who is presumably on an intercity trip of at least 50 miles, as compared to a passenger who switches from automobile and is commuting to work.

We therefore calculated expected trip lengths for the diverted modes. We used air travel data from the Official Airline Guide’s (OAG) Market Analysis for Air Transport Specialists (MAX) airline schedules database of weekly scheduled flights for April 2002[6] to examine the frequency and length of direct flights originating and ending at airports within the high speed rail corridors. We then generated a weighted average passenger trip distance by estimating an average seating capacity of 60 for flights of 200 miles or less and a seating capacity of 160 for flights over 200 miles. In most cases, this calculated trip length was greater than the average high speed rail passenger trip length. We used our derived air trip length to calculate the average automobile trip length, assuming that bus and conventional rail trip lengths would match the average high speed rail trip (See Appendix B for more detail).

This is a rough calculation that assumes that passenger occupancy will be relatively even across plane sizes and that current air trip lengths will be applicable to the 2020-2025 horizon of the passenger projections we use in the model.

Vehicle Trip Cancellation

Often the emissions of high speed rail are compared on a per passenger mile basis with other modes. This is somewhat of a false notion, however, because the emissions savings do not occur when one passenger switches modes—the plane flight they would have taken is likely to occur and produce emissions, even without that passenger. Rather, savings occur when a critical mass of passengers switch modes, causing a vehicle trip to be cancelled. We initially tried to use a threshold occupancy level at which a specific trip would be cancelled in our model. For example, if the average occupancy of a current plane route is now 70 percent,[7] a flight might be canceled when the ridership drops by 20 percent and hits a threshold occupancy of 50 percent. But to properly calculate emissions savings this way we needed the 2025 projected ridership and occupancy by mode for each corridor, which was outside the scope of this study. Therefore, we ended up estimating cancelled vehicle trips by dividing diverted passengers by average vehicle occupancy for each mode. In effect, this assumes that air, bus, automobile and rail vehicle trips would be cancelled at a rate to maintain average occupancy. As we describe later, we used average

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[6] OAG Worldwide, Inc. “Official Airline Guide’s Market Analysis for Air Transport Specialists.” April 2002. http://oagdata.com/home.aspx

[7] James S. deBettencourt, PhD. Personal Communication based on analysis of OAG data.

vehicle occupancy to develop vehicle emissions factors as well. By using these same average occupancy figures in the vehicle trip calculations, we are generating the same results as if we had used emissions per passenger mile estimates. We felt that using vehicle emissions rather than passenger emissions was valuable enough to future research to make this extra step worthwhile.

Emissions Factors

Automobiles

We developed estimated emissions factors for automobiles using the U.S. Department of Energy's Annual Energy Outlook projection of average on-road efficiency of 23.08 miles per gallon in 2025.[8] This translates to 0.85 pounds of CO_2 per vehicle mile if all vehicles use gasoline as fuel[9] (we did not model diesel passenger cars or alternative fuels such as biodiesel). The Annual Energy Outlook's projection is less efficient than many others—for example, that of the midsize car value used by the Greenhouse Gas (GHG) Protocol[10]—because their model assumes relatively low fuel prices and a continuing trend of drivers switching to sport utility vehicles and other light trucks. Assuming 1.6 passengers per vehicle—the average vehicle occupancy for intercity travel in the National Household Travel Survey[11]—the Annual Energy Outlook's fuel efficiency value translates to an emissions factor of 0.53 pounds of CO_2 per passenger mile.

Airplanes

We used the Annual Energy Outlook's projection of 48.3 seat miles per gallon for 2025 regional aircraft stock[12] to develop an emissions factor of 48 pounds of CO_2 per mile[13] for a regional jet with 110 seats. Assuming 70 percent occupancy, this translates this to an emissions factor of 0.62 pounds of CO_2 per passenger mile.

Buses

The Annual Energy Outlook and the GHG protocol both incorporate bus energy use data from the U.S. Department of Energy's *Transportation Energy Data Book*,[14] which cites the ENO Transportation Foundation's *Transportation in America 2001* and reports an energy use factor of 932 BTUs per passenger mile in the year 2000. We used this value as well and assumed that efficiency improvements follows recent trends of 0.3 percent improvement per year. Our derived emissions factor for 2025 is thus

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[8] U.S. Department of Energy, Energy Information Administration. "Annual Energy Outlook 2005." by Stacy C. Davis and Susan W. Diegel of Oak Ridge National Laboratory January 2005. http://www.eia.doe.gov/oiaf/aeo/index.html

[9] A gallon of gasoline produces 19.564 pounds of CO_2 when combusted according to the U.S. Department of Energy, Energy Information Administration, Voluntary Reporting of Greenhouse Gases Program. "Fuel and Energy Source Codes and Emission Coefficients." http://www.eia.doe.gov/oiaf/1605/factors.html

[10] See GHG Protocol Calculation Tools: http://www.ghgprotocol.org/

[11] U.S. Department of Transportation, Bureau of Transportation Statistics. "National Household Travel Survey 2001." http://www.bts.gov/programs/national_household_travel_survey/

[12] U.S. Department of Energy, Energy Information Administration. "Annual Energy Outlook 2005."

[13] A gallon of jet fuel produces 21.095 pounds of CO_2 when combusted according to the U.S. Department of Energy, Energy Information Administration, Voluntary Reporting of Greenhouse Gases Program. "Fuel and Energy Source Codes and Emission Coefficients." http://www.eia.doe.gov/oiaf/1605/factors.html

[14] U.S. Department of Energy, Energy Efficiency and Renewable Energy. "Transportation Energy Data Book, Edition 24." December 2004. http://cta.ornl.gov/data/index.shtml

0.14 lbs CO_2 per passenger mile,[15] which is 4.87 lbs per vehicle mile at 70 percent occupancy of a 50 seat bus.

Conventional Rail

Most discussions of Amtrak's energy use and emissions cite data from the *Transportation Energy Data Book*; however, we found some anomalies in that data. Specifically, the emissions factor for 2002 was calculated to be approximately 40 percent higher than the year 2000 emissions factor, in part because of a near doubling of Amtrak's electricity use in that time and a 50 percent increase in reported diesel use. This may be partially explained by the launch of the electric powered Acela in December 2000, but a discussion with Richard Cogswell from the Federal Railroad Administration's Office of Railroad Development revealed that freight hauling and inconsistent reporting of commuter rail data might also play a factor. We therefore used an energy use factor of 3 gallons of diesel fuel per mile that we derived from materials provided by Cogswell.[16] Our derived emissions factor based on this is 0.21 pounds of CO_2 per passenger mile.[17] The available data did not provide a reliable basis to estimate efficiency improvements for conventional rail, so the emissions rate in 2025 is estimated to be the same as the current year emissions rate.

High Speed Rail

We gathered energy use information on a number of high speed rail technologies to get a sense of the range of emissions factors. The high speed rail systems we looked at fall into three broad categories: diesel powered (also called Diesel Multiple Units or DMUs), electric powered, and MagLev (Magnetic Levitation). Our research found that most of the high speed rail corridors are considering an incremental approach to high speed rail that limits the capital improvements necessary, making diesel trains the most likely technology. Therefore, we chose the Danish IC-3, a diesel powered train that has been demonstrated in the U.S., as the primary high speed rail technology in our analysis.[18] Figure 2 shows the emissions per train and emissions per passenger mile data we have gathered for several train technologies around the world. The IC-3 has lower emissions per train, in part because of its slower speed (99 mph top speed)[19] compared to other high speed rail technologies. Its low number of seats per train (152 maximum, 138 on the route used for these calculations), however, raises its per passenger mile emissions factor to 0.26 pounds of CO_2 per passenger mile at an assumed 70 percent occupancy.

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[15] A gallon of diesel fuel produces 22.384 pounds of CO_2 when combusted according to the U.S. Department of Energy, Energy Information Administration, Voluntary Reporting of Greenhouse Gases Program. "Fuel and Energy Source Codes and Emission Coefficients." http://www.eia.doe.gov/oiaf/1605/factors.html

[16] Gilbert E. Carmichael, Administrator. U.S. Department of Transportation, Federal Railroad Administration. Letter to Representative Thomas J. Bailey, Jr. regarding passenger rail energy consumption. September 1992.

[17] This is approximately the same as emissions factors reported in: IBI Group. "Making Transportation Sustainable: A Case Study Of The Quebec City-Windsor Corridor." Prepared for the Transportation Systems Division, Air Pollution Prevention Directorate, Environment Canada. March 2002. http://www.ec.gc.ca/transport/publications/tos406/makingsustranstoc.htm

[18] For a description of other DMU trains see: National Research Council, Transportation Research Board, Transit Cooperative Research Program. "TCRP Report 52: Joint Operation of Light Rail Transit or Diesel Multiple Unit Vehicles with Railroads." National Academy Press. December 1999. http://gulliver.trb.org/publications/tcrp/tcrp_rpt_52-d.pdf

[19] Jørgensen, Morten W., Spencer C. "Sorenson Estimating Emissions from Railway Traffic: Report for the Project MEET: Methodologies For Estimating Air Pollutant Emissions From Transport." European Commission. July 1997. http://www.inrets.fr/infos/cost319/MEETDeliverable17.PDF

Figure 2 High Speed Rail Train CO_2 Emissions by Technology[20]

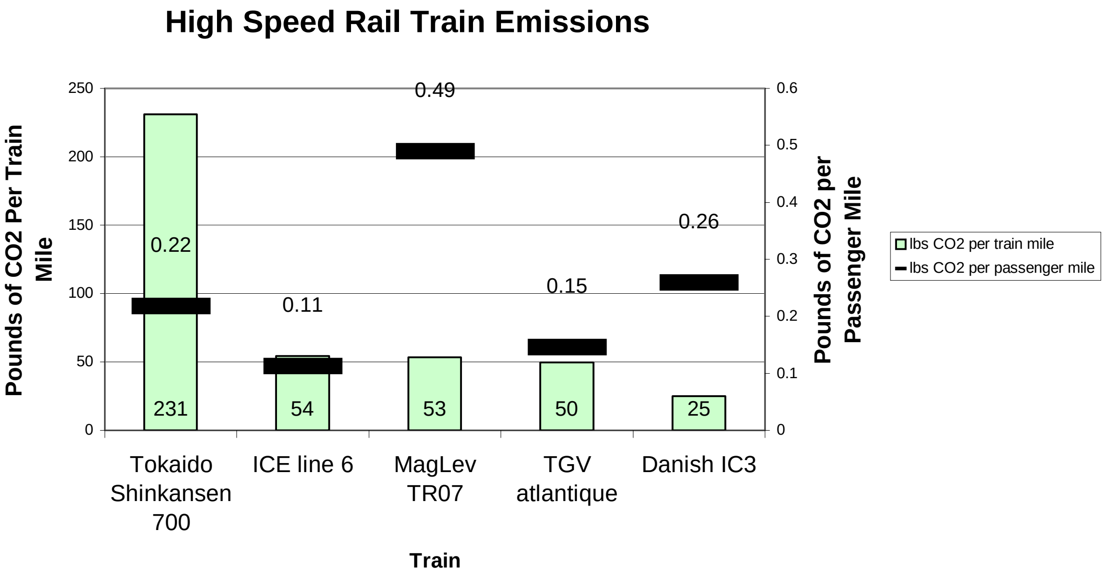

Table 1 Summary CO_2 Emissions Factors by Mode

Table 1. Summary Emissions Factors by Mode[21]

Mode	Emissions Per Passenger Mile (lbs CO_2)[22]	Emissions Per Vehicle Mile (lbs CO_2)	Passengers per Vehicle
Bus	0.14	4.87	35
Conventional Rail	0.21	66.96	322
High Speed Rail (IC-3)	0.26	25.10	97
Automobile	0.53	0.85	1.6
Airplane	0.62	48.04	77

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[20] See Appendix A for details. Assumes 70 percent occupancy. Changes in occupancy rates will change emissions per passenger mile.

[21] Calculated from: U.S. Department of Energy, Energy Information Administration. "Annual Energy Outlook 2005." by Stacy C. Davis and Susan W. Diegel of Oak Ridge National Laboratory January 2005. http://www.eia.doe.gov/oiaf/aeo/index.html ;
U.S. Department of Energy, Energy Efficiency and Renewable Energy. "Transportation Energy Data Book, Edition 24." December 2004. http://cta.ornl.gov/data/index.shtml ;
Gilbert E. Carmichael, Administrator. U.S. Department of Transportation, Federal Railroad Administration. Letter to Representative Thomas J. Bailey, Jr. regarding passenger rail energy consumption. September 1992;
Jørgensen, Morten W., Spencer C. "Sorenson Estimating Emissions from Railway Traffic: Report for the Project MEET: Methodologies For Estimating Air Pollutant Emissions From Transport." European Commission. July 1997. http://www.inrets.fr/infos/cost319/MEETDeliverable17.PDF;

[22] Assumes 70 percent occupancy for all modes except auto. Changes in occupancy rates will change emissions per passenger mile.

Boundaries

Changes and developments in one form of transportation can have ripple effects throughout the entire transportation system. For this analysis we drew some clear boundaries around our emissions estimations:

- We did not consider emissions due to access to and egress from stations;
- We did not consider potential emissions effects from feeder rail lines;
- We only considered direct flights, except where noted; and
- We only considered CO_2 emissions. Other greenhouse gases, including the potentially large impact of aircraft contrails and high altitude NO_x were not considered.

These boundaries exclude some of the important emissions impacts of high speed rail; we discuss these potential impacts further in the conclusion and recommendations section.

Results

We calculated a total emissions savings of 6 billion pounds of CO_2 per year (2.7 $MMTCO_2$)[23] if all proposed high speed rail systems studied for this project are built (Table 2). Overall, high speed rail is estimated to generate approximately half of the gross emissions it saves by enabling passengers to switch from other modes. Savings from cancelled automobile and airplane trips are the primary sources of the emissions savings; together these two modes make up 80 percent of the estimated emissions savings from all modes. The total emissions savings vary greatly by corridor, however, as do the source of those savings, as shown in Figures 3 and 4. Figure 4 looks at the emissions for every corridor except California, because its large potential savings overshadows the other corridors studied when the corridors are considered together.

Table 2 CO_2 Emissions Savings from High Speed Rail in all U.S. Corridors

Table 2. Emissions Savings from High Speed Rail in all U.S. Corridors

	Pounds of CO_2 per Year	$MMTCO_2$ per Year
Airplane Emissions Saved	5,634,626,780	2.56
Automobile Emissions Saved	4,471,974,488	2.03
Bus Emissions Saved	82,441,034	0.04
Conventional Rail Emissions Saved	2,506,574,964	1.14
Total Emissions Saved	12,695,617,266	5.76
Annual High Speed Rail Emissions Generated[24]	6,621,126,654	3.00
Net Emissions Saved[25]	**6,074,490,612**	**2.76**
Percentage Savings[26]	48%	48%

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[23] One million metric tons CO_2 ($MMTCO_2$) = 2,205 million pounds CO_2

[24] Assumes IC-3 rail technology.

[25] The potential net savings from high speed rail varies with the high speed rail technology assumed: from a low of 213,092,381 pounds of CO_2 (0.097 $MMTCO_2$) saved, or 2%, if MagLev technology is used to a high of 9,828,925,474 pounds CO_2 (4.46 $MMTCO_2$) saved, or 77% if ICE technology is used. See Appendix A.

[26] Percentage savings is as compared to baseline emissions of high speed rail travelers if they had taken another mode, not as compared to all transportation emissions in corridor. Emissions from all transportation sources in the U.S. were 1,874.7 $MMTCO_2$ in 2003 according the U.S. Department of Energy, Energy Information Administration. "Emissions of Greenhouse Gases in the United States, 2003." December 13, 2004. http://www.eia.doe.gov/oiaf/1605/ggrpt/executive_summary.html

Figure 3 CO_2 Emissions by Corridor

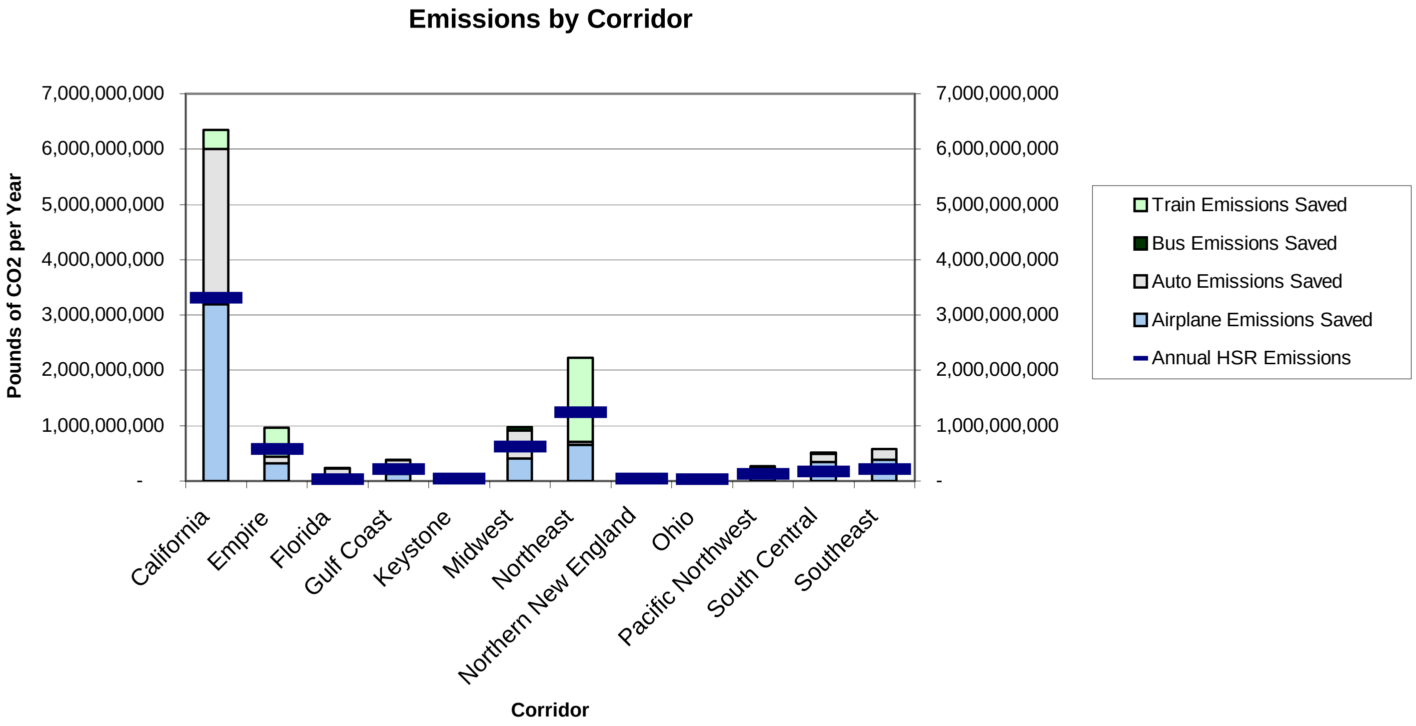
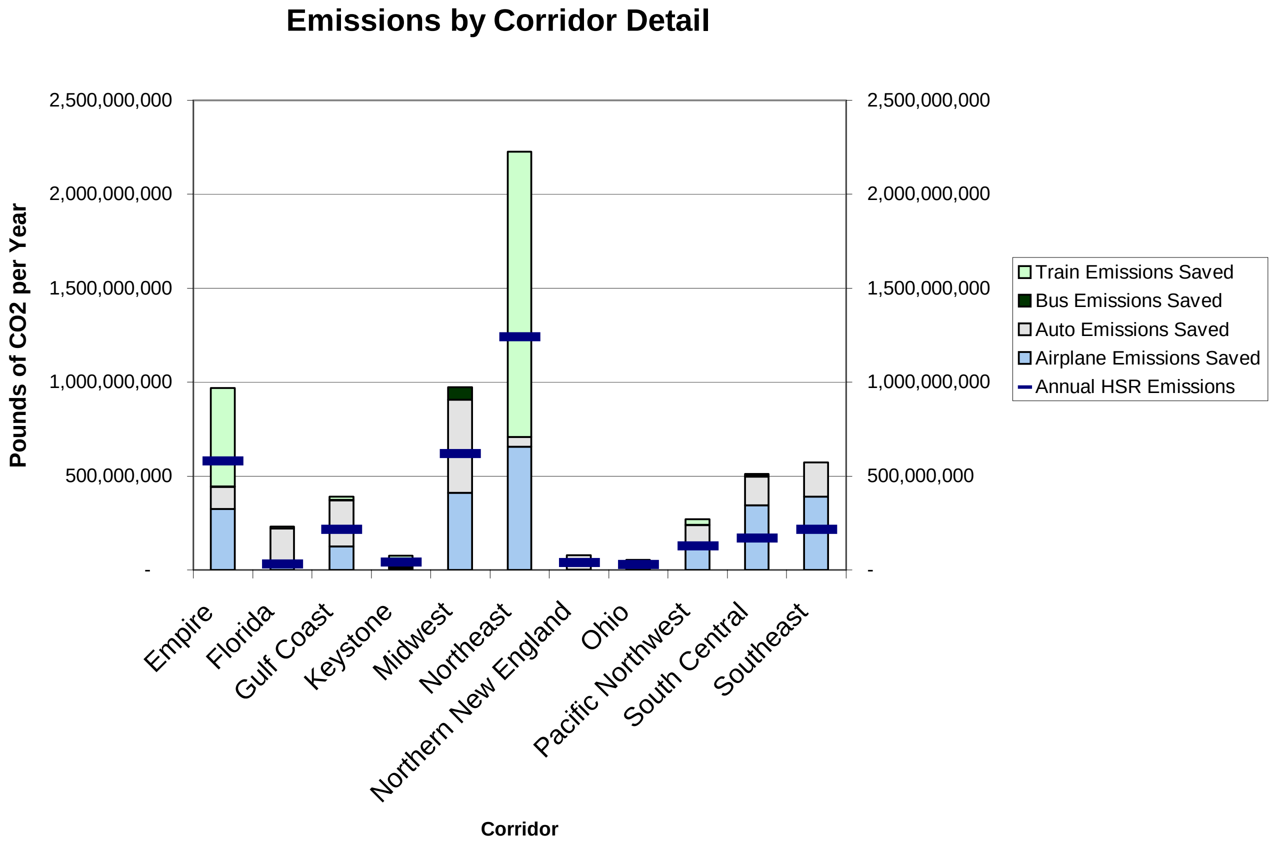


Figure 4 CO_2 Emissions by Corridor Detail (Excludes California)



Analysis and Discussion

Our modeling shows that high speed rail, if built as planned, will generate substantial greenhouse gas savings in all regions. The size of the emissions savings is dependent on the number of high speed rail passengers projected to be diverted from other modes and the rail technology used. Emissions savings are also greater when passengers are diverted primarily from air and automobiles, which generate more emissions per passenger than high speed rail technologies; conventional rail and bus generate fewer emissions per passenger than high speed rail (See Table 1).

Total Ridership

Current projections show that passengers would take 112 million trips on high speed rail in the U.S. in 2025, traveling more than 25 billion passenger miles. A transportation system that includes high speed rail would look very different from today's intercity travel network. There would be 29 million fewer automobile trips and nearly 500,000 fewer flights. In some regions, such as the Midwest, the impact on air travel is likely to be modest; our analysis shows just a 7 percent decrease in flights from today's levels based on projected diverted airline passengers in the Midwest.

In other areas, the impact of high speed rail may be much greater. The Empire corridor has projections of 2.3 million air passengers switching to high speed rail, but we found only 38,000 current annual direct flights between airports in the Empire corridor. Similarly, the number of passengers projected to switch to California's high speed rail system from air is 19 million, a volume that would result in 114 percent of today's 192,000,000 annual direct flights in the corridor being cancelled. It may be that passenger projections in these corridors overestimate the number of travelers switching from air, in which case the emissions savings in these corridors would be overestimated as well. If one accounts for projected growth in air travel, as well as indirect flights and flights from outside the corridor, which were not included in our model, this level of mode switching is not impossible. It is worth further study to see if such high levels of mode shifting are likely. Such changes in ridership would have fundamental impacts on the transportation system. To draw so many air passengers to rail will require that high speed rail ticket prices be competitive with air and that service be as convenient and time-efficient.

California's Big Impact

The projected impacts of California's high speed rail system seem to be on a completely different scale than the other corridors. The emissions savings in California are estimated to be approximately equal to the combined total savings from all other corridors. This is due to both the high projected ridership of the California high speed rail corridor (42 million passengers in 2020) and the large percentage of passengers projected to switch from air to rail (45.8 percent). Only the Northeast corridor, which connects major population centers including New York and Washington, DC, comes close to the California system in terms of projected ridership—it is estimated to have 25 million riders in 2020.

In some respects, the California system, as it is currently planned, represents what will be the second generation of high speed rail in many of the other corridors. While areas like the Pacific Northwest may increase ridership sooner with an incremental approach to high speed rail that uses existing rail routes, the success of a new high speed rail system like California's could prove the value of faster trains with higher upfront capital costs.

The Unknown Impact of Bus and Conventional Rail

We primarily relied on local corridor passenger projections for our analysis. Unfortunately, a number of the corridors do not estimate ridership by passengers diverted from intercity buses, or do so on a very limited basis. One explanation given for this is that intercity bus ridership data is proprietary to the private operators and the public entities creating most of these passenger studies did not have access to it. So, rather than overestimate high speed rail ridership by guessing at bus ridership, many chose simply to leave it out. The impact of this on our model is somewhat unknown. By our estimates, a trip taken by bus generates just half of the emissions of a trip taken by high speed rail (see Table 1). If high speed rail passengers diverted from bus have been truly excluded from passenger projections, then all of the bus riders in the system would be additional, and the impact on system wide emissions savings would be negative (lowering the net emissions savings). The size of this impact would be dependent on the number of these passengers. However, if by overtly excluding bus riders the models have implicitly included their ridership under the induced category then the overall emissions profile of the system might improve once bus riders are included. As with air travelers, the number of bus riders that ultimately decide to switch to high speed rail will be greatly dependent on the competitiveness of ticket prices, travel times, and convenience. Price may be the most important decision factor for intercity bus travelers, many of whom are lower-income.

Similar issues arise with conventional rail, although the net emissions impact of a mode switch from conventional rail is much smaller than the impact from bus ridership. Passenger diversion from conventional rail was projected as zero for a number of the corridors; however, many of these corridors have current Amtrak or commuter rail service. For example, the Midwest corridor passenger projections use a conventional rail conversion factor of zero, but fiscal year 2004 Amtrak data shows 366,291 passengers on the Chicago-Detroit line. It is unclear, therefore, where these current rail passengers go when the high speed rail is built. Is it assumed that they all continue to ride conventional rail? Is the high speed rail going to simply replace the conventional rail? If the latter were the case, then one would expect this to be reflected in the passenger diversion rates. As it is not, the impact of these riders on emissions is unknown.

Other Environmental Impacts

Any discussion of the greenhouse gas impacts of transportation must mention the other air pollution impacts of fossil fuel combustion. Diesel powered trains seem to be the technology of choice for most of the high speed corridors, but diesel trains generate criteria pollutant emissions, such as particulate matter and nitrogen oxides, which can aggravate, and possibly cause, health problems such as asthma. Therefore, decisions about train technologies should not be made simply on the basis of CO_2 alone. The full environmental impact must be considered. For example, in an area with a cleaner than average electricity generation portfolio—such as from wind power or cogeneration—electricity may be a much more environmentally sound high speed rail fuel than diesel.

Conclusion and Recommendations

Areas for Further Research

As we conducted this study we found a number of areas where further research should be supported to better understand the potential impact and value of high speed rail in the U.S.:

- **Improved Energy and Emissions Data**
  Research is needed to improve our understanding of the energy use and emissions impact of intercity travel. As is discussed in the methodology, we had a difficult time finding reliable energy use data for many modes, but the conventional rail data was especially lacking.

- **Inclusion of Network Effects**
  In this study we modeled each high speed rail corridor independently, and all total impacts are simply a sum of the parts. In reality, however, there will be network effects as high speed rail systems are linked in cities such as Washington, DC and Atlanta. Most of the passenger projection studies do not

account for the effect of these corridor linkages, and they should be studied further. Such an analysis would also require consistent ridership forecast assumptions for each corridor.

- **Account for Increased Ridership with Very High Speed Systems**
  Many corridors are taking an incremental approach to high speed rail by increasing speeds on current routes rather than installing new super fast systems. The decreased travel times that very high speed systems could provide would likely encourage greater ridership and additional emissions savings. Further study of the costs and benefits of such technologies in the U.S. is warranted.

- **Travelports: Linking HSR with Air and Bus Travel**
  Just as linking the corridors will have network effects, so might creating direct links between air, bus, and high speed rail to enable intermodal travel. A passenger who can easily make a connection to high speed rail at the airport might be more willing to substitute high speed rail for air travel on a short leg of a journey. The linkage could benefit operators of both modes as it increases passenger convenience and decreases airport congestion. The Center for Neighborhood Technology has begun to study the potential for such linkages, or "travelports" as we are calling them, through our partnership, Reconnecting America's Transportation Networks.[27] However, the emissions impacts of such linkages have not been looked at in any detail. A review of European experiences with air/rail links would be an important component of this assessment.

- **Better Intergovernmental Coordination**
  There are likely many opportunities for better coordination among the multiple levels of government involved in high speed rail funding and development. An assessment of these opportunities and an analysis of best practices in other countries and other fields could foster coordination and increase the likelihood that the proposed high speed rail systems are built.

Recommendations

In addition to our identification of areas for further research, we have a number of recommendations to high speed rail planners about how high speed rail and its emissions benefits can be improved.

- **Encourage Intermodal Transportation**
  For the types of trips in which high speed rail is time competitive with air travel, it also has an emissions benefit on a per passenger mile basis. Encouraging intermodal trips so that a traveler may take one leg of a trip by air and another by high speed rail will have emissions benefits. High speed rail systems can encourage intermodal travel by directly linking to airports and enabling seamless ticketing and baggage transfer between modes. Similar links to intercity bus and conventional rail lines would likely have emissions benefits if they encourage passengers to make combinations of bus and rail an alternative to air or automobile travel.

- **Develop Sustainable Finance Mechanisms for HSR**
  As recent Congressional debates illustrate, funding intercity passenger rail transportation continues to be a challenging, but critical issue in the US. The consistent service and quality that sustainable financing can help ensure is likely to increase ridership and the resultant emissions benefit of any high speed rail system.

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[27] See Reconnecting America's Transportation Networks, "Missed Connections II," December 2003. http://www.reconnectingamerica.org/pdfs/FullMissedConn.pdf

- **Convince More People to Switch to High Speed Rail from Solo Auto Usage**
  Encouraging smart development around high speed rail stations can encourage commuters to use high speed rail as an alternative to driving alone. Trains such as CalTrain's Baby Bullet are showing that fast intercity train travel can be a big draw for commuters who appreciate avoiding rush hour congestion and being able to read or work during their commute. An average commuter who switches from driving alone 40 miles per day to commuting via rail could save more than 6,000 pounds of CO2 per year.[28]

- **Reduce Train Emissions**
  The most direct way to impact the emissions associated with high speed rail is to improve the efficiency of the trains themselves. More efficient diesel locomotive engines and other improvements, such as regenerative braking, are being developed, and some of the high speed rail corridors have plans to make use of these improved technologies. In addition, safety policies and train designs need to be coordinated to support both safety and efficiency. Present U.S. safety regulations may reduce train efficiency by requiring U.S. trains to be much heavier than similar designs in other countries.[29] Use of alternative fuels such as biodiesel would also reduce the greenhouse gas emissions of trains. For electrified trains, the indirect emissions associated with electricity generation can be reduced by the purchase of green power—wind, solar, or hydroelectric. Finally, ensuring that high speed rail systems run efficiently, with high passenger loads and low idling times, would maximize the emissions benefits of the system.

- **Reduce Associated Emissions**
  Although we did not measure access and egress emissions in our model, the mode passengers take to and from the train stations has an important emissions impact. High speed rail can reduce travel emissions by making stations interconnected with many forms of transportation so that passengers can access high speed rail by bus, light rail, or other modes, rather than driving to the station. High speed rail stations have the potential to become focal points in transit-oriented communities. Station design and integrated planning with the surrounding community should enable access to jobs and amenities without use of an automobile.

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[28] Based on the following assumptions: Auto emissions per year = 0.85 lbs CO_2 per vehicle mile in 2025 x 40 miles per day x 5 days per week x 52 weeks per year = 8,840; HSR Emissions per year = 0.26 lbs CO_2 per passenger mile (from Danish IC3 train) x 40 miles per day x 5 days per week x 52 weeks per year = 2,703; Difference = 6,137 lbs CO_2 per year

[29] U.S. House of Representatives, Transportation Committee, Subcommittee on Railroads. "Hearing on Getting Acela Back On Track." May 11, 2005. http://www.house.gov/transportation/rail/05-11-05/05-11-05memo.html

Appendix A: High Speed Rail Technologies and Emissions Factors and Model Results

Emissions Factors

In Appendix A we review the research and calculations we used to derive the emissions factors for each type of high speed rail technology studied. We then show the system wide potential net emissions savings using each of the different high speed rail technologies. Unfortunately, we could not get reliable data on the electricity use of the Acela Express trains in the Northeast corridor in time for this publication, so that is not one of the technologies we examine, but as a point of reference, it has been widely noted that they use more power than other electric high speed rail lines because U.S. safety regulations require them to be much heavier.[30]

Shinkansen

The Shinkansen "Bullet Train" in Japan runs at a maximum speed of 300 km/hour using electricity as fuel.[31] According to the manufacturer website, the series 700 train uses 349 kilojoules per passenger kilometer.[32] Using an average U.S. electricity emissions factor forecast of 1.40 pounds of CO_2 ($6.4x10^{-10}$ $MMTCO_2$) per kWh for 2025, that translates into 0.22 lbs CO_2 ($1.0x10^{-10}$ $MMTCO_2$) per passenger mile if this technology was used in the U.S. with similar passenger loads and operational efficiencies.

Table A- 1 Shinkansen CO_2 Emissions Factor

Shinkansen Emissions Factor	
349	Kilojoules passenger km
349000	Joules per passenger km
3600000	Joules per kWh
0.097	kWh per passenger km
1.61	Km per mile
0.156	kWh per passenger mile
1.40	Lbs CO_2 per kWh
0.22	Lbs CO_2 passenger mile

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[30] U.S. House of Representatives, Transportation Committee, Subcommittee on Railroads. "Hearing on Getting Acela Back On Track." May 11, 2005. http://www.house.gov/transportation/rail/05-11-05/05-11-05memo.html

[31] Railway-Technology.Com. "Shinkansen High-Speed 'Bullet Train', Japan." http://www.railway-technology.com/projects/shinkansen/

[32] JR Central. "Tokaido Shinkansen Company Information: Environmental Issues, Comparison with Respect to Transportation Mode." http://jr-central.co.jp/english.nsf/doc/environment

TGV

The TGV in France runs at maximum speeds of 300 km/hour using electricity.[33] Estimates of energy use for the TGV Atlantique are in the range of 22 kWh per train seat km.[34] This translates to 0.15 lbs CO_2 (6.8×10^{-11} $MMTCO_2$) per passenger mile at 70 percent occupancy.

Table A- 2 TGV CO_2 Emissions Factor

TGV Atlantique Emissions Factor	
22	kWh per train km
485	seats per vehicle
0.045	kWh per seat km
1.40	lbs CO_2 per kWh
0.06	lbs CO_2 per seat kilometer
0.10	lbs CO_2 per seat mile
0.7	passengers per seat
0.15	lbs CO_2 per passenger mile

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[33] Railway-Technology.Com. "TGV France." http://www.railway-technology.com/projects/frenchtgv/

[34] Jørgensen, Morten W., Spencer C. "Sorenson Estimating Emissions from Railway Traffic: Report for the Project MEET: Methodologies For Estimating Air Pollutant Emissions From Transport." European Commission. July 1997. http://www.inrets.fr/infos/cost319/MEETDeliverable17.PDF also Levinson, David, Jean Michel Mathieu, David Gillen, and Adib Kanafani. "The full cost of high-speed rail: an Engineering Approach." Annals of Regional Science 31 (Spring 1997): 189–215. http://www.ce.umn.edu/~levinson/Papers/HighSpeedRail.pdf

ICE

The German Intercity Express (ICE) line connecting Hamburg, Frankfurt and Munich (line 6) travels at an average speed of 131 kilometers per hour (81 mph) and consumes 24.09 kWh per train kilometer.[35] This is quite similar to the TGV energy consumption, but because of the larger number of seats on the ICE trains, the per passenger CO_2 emissions rate is calculated at 0.11 lbs ($5.0x10^{-11}$ $MMTCO_2$) per passenger mile at a 70 percent occupancy rate. According to Jørgensen and Sorenson, the actual occupancy rate for this train in 1992-1993 was 61.4 percent. Lower passenger occupancies raise the emissions per passenger mile factor, but we chose to assign a constant passenger occupancy to all of the high speed rail technologies because the passenger occupancies of proposed high speed rail systems in the U.S. in 2025 are unknown, so it is better to compare consistent measures.

Table A- 3 ICE CO_2 Emissions Factor

ICE line 6 Emissions Factor	
24.09	kWh/train km
689	seats per train
0.035	kWh per seat km
0.056	kWh per seat mile
1.40	lbs CO_2 per kWh[36]
0.079	lbs CO_2 per seat mile
0.7	passengers per seat
0.11	lbs CO_2 per pass mile

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[35] Jørgensen and Sorenson 1997.

[36] DOE's Annual Energy Outlook forecasts 3314 million metric tons CO_2 emissions from electricity in 2025 and 5520 billion kWh consumed in 2025, for an emissions value of 1.40 pounds CO_2 per kWh. National Average from U.S. Department of Energy, Energy Information Administration. "Average Electricity Emission Factors by State and Region." updated April 2002. http://www.eia.doe.gov/oiaf/1605/e-factor.html has a U.S. average emissions factor of 1.34 pounds CO_2 per kWh.

IC-3

The Danish IC-3 is a diesel fuel train system with a top speed of 160 kilometers per hour (99 mph).[37] This profile is much more similar to the high speed rail systems being proposed in corridors around the U.S. today than other higher speed electricity powered or MagLev train technologies considered here. The IC-3 uses 2.22 kg diesel per train km, which would generate approximately 0.26 pounds of CO_2 ($1.2\text{x}10^{-10}$ $MMTCO_2$) per passenger mile at 70 percent occupancy.[38] Actual occupancy of this train is reported at 56 percent, which would increase the per passenger emissions to 0.32 pounds CO_2 ($1.5\text{x}10^{-10}$ $MMTCO_2$) per passenger mile, but as discussed above, we chose to use a consistent occupancy rate of 70 percent among the technologies.

Table A- 4 IC-3 CO_2 Emissions Factor

Danish IC-3 Emissions Factor	
436.5	kg diesel per train per trip
197	km per trip
2.22	kg diesel per train km
138	seats per train
0.84	grams per ml diesel
0.000264172	gallon per ml
3.18	kg per gallon diesel
0.696	gallon diesel per km
1.609344	km per mile
1.12	gallon diesel per train mile
0.008	gallon diesel per seat mile
22.384	lbs CO_2 per gallon diesel
0.18	lbs CO_2 per seat mile
0.26	lbs CO_2 per pass mile

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[37] Jørgensen and Sorenson 1997.

[38] Jørgensen and Sorenson 1997.

MagLev

Magnetic Levitation (MagLev) trains are propelled by electricity, but unlike the other high speed rail technologies looked at here, they use magnetic force to lift and propel the train so it does not rely on steel wheels on tracks. These trains can run at speeds of 300 miles per hour and faster. An Army Corps of Engineers Report from 1998 examined MagLev technologies and provided energy use data for the German Transrapid 07 (TR07) MagLev train, showing that it uses 23.75 kWh per train kilometer, which would generate 0.49 lbs of CO_2 ($2.2x10^{-10}$ $MMTCO_2$) per passenger mile.[39]

Table A- 5 MagLev CO_2 Emissions Factor

MagLev TR07 Emissions Factor	
23.75	kWh per train km
1.609344	km per mile
38.22	kWh per train mile
1.40	pounds CO_2 per kWh
53.50	pounds CO_2 per train mile
156	seats per train
0.34	lbs CO_2 per seat mile
0.49	lbs CO_2 per passenger mile

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[39] Lever, James H. (Ed.) "Technical Assessment of Maglev System Concepts Final Report by the Government Maglev System Assessment Team." U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory. October 1998. http://www.crrel.usace.army.mil/techpub/CRREL_Reports/html_files/SR98_12.html

Model Results

We used the IC-3 as the technology for our modeling in this study because it closely resembled the type of trains being considered in the corridors. We thought, however, it would be informative to examine the emissions impacts of other train technologies. The results of this modeling are shown in Table A-6. (See Appendix B for impacts of these technologies in specific corridors.)

Table A- 6 High Speed Rail CO_2 Emissions Savings in All Corridors by Train Technology

High Speed Rail Emissions Savings in All Corridors by Train Technology		
	Pounds of CO_2 per Year for all Corridors	MMTCO_2 per Year for all Corridors
Total Emissions Saved from Air, Automobile, Bus and Conventional Rail	12,695,617,266	5.76
Total projected HSR passenger miles	25,479,848,166	11.56
HSR Using Conventional Rail Technology:		
Emissions per passenger mile	0.21	9.53x10^{-11}
Annual HSR Emissions	5,298,333,161	2.40
Net Emissions Saved	7,397,284,106	3.36
Percentage Saved	58%	58%
HSR Using TGV Technology:		
Emissions per passenger mile	0.15	6.80 x10^{-11}
Annual HSR Emissions	3,719,155,760	1.69
Net Emissions Saved	8,976,461,507	4.07
Percentage Saved	71%	71%
HSR Using Shinkansen Technology:		
Emissions per passenger mile	0.22	9.98 x10^{-11}
Annual HSR Emissions	5,563,965,022	2.52
Net Emissions Saved	7,131,652,244	3.23
Percentage Saved	56%	56%
HSR Using ICE Technology:		
Emissions per passenger mile	0.11	4.99 x10^{-11}
Annual HSR Emissions	2,866,691,793	1.30
Net Emissions Saved	9,828,925,474	4.46
Percentage Saved	77%	77%
HSR Using IC-3 Technology:		
Emissions per passenger mile	0.26	1.18 x10^{-10}
Annual HSR Emissions	6,621,126,654	3.00
Net Emissions Saved	6,074,490,612	2.76
Percentage Saved	48%	48%
HSR Using MagLev Technology:		
Emissions per passenger mile	0.49	2.22 x10^{-10}
Annual HSR Emissions	12,482,524,885	5.66
Net Emissions Saved	213,092,381	0.10
Percentage Saved	2%	2%

Unsurprisingly, the greatest emissions savings come from the electric ICE technology with its low estimated emissions factor of 0.11 pounds of CO_2 ($5.0x10^{-11}$ $MMTCO_2$) per passenger mile. High speed rail using conventional rail technology, such as is used by Amtrak today, would generate the significant savings—7.4 billion pounds CO_2 (3.36 $MMTCO_2$), but it is unlikely that any corridor would rely on current technology with no improvements in speed, and in general greater speed requires greater energy use and emissions. The electric Shinkansen trains create an estimated emissions savings of 7 billion pounds of CO_2 (3.18 $MMTCO_2$) annually, but the low emissions per passenger rate of these trains comes from their very large seating capacity—a capacity that is too large to be reasonable for many of the corridors studied.

The lowest emissions savings come from the MagLev technology with its relatively high emissions per passenger mile. The MagLev model resulted in a net emissions generation, rather than savings, in five of the eleven corridors studied, as shown in Table A-7. Corridors with negative emissions savings are generally those with larger portions of their high speed rail ridership induced to ridership or diverted from conventional rail or bus modes—modes with lower emissions per passenger mile than MagLev.

Table A- 7 . CO_2 Emissions Impacts by Corridor of High Speed Rail Using MagLev Technology

Emissions Impacts by Corridor of High Speed Rail Using MagLev Technology (lbs CO_2)[40]

	California	**Empire**	**Florida**	**Gulf Coast**	**Keystone**	**Midwest**
Total Emissions Saved from Airplane, Automobile, Bus and Conventional Rail	6,347,004,982	968,455,135	230,491,798	389,783,588	75,195,614	972,300,492
Total Projected Annual Passenger Trips	42,002,103	9,416,700	3,441,000	5,192,648	1,100,000	14,824,000
Total Passenger Miles	12,726,637,209	2,228,813,572	120,753,000	834,025,715	165,000,000	2,388,000,000
Annual HSR Emissions (lbs CO_2)	6,234,753,231	1,091,891,157	59,156,645	408,587,472	80,833,159	1,169,876,258
Net Emissions Saved (lbs CO_2)	112,251,751	(123,436,021)	171,335,153	(18,803,884)	(5,637,545)	(197,575,766)
Percentage Saved	2%	-13%	74%	-5%	-7%	-20%
	Northeast	**Northern New England**	**Ohio**	**Pacific Northwest**	**South Central**	**Southeast**
Total Emissions Saved from Airplane, Automobile, Bus and Conventional Rail	2,225,925,493	79,356,196	53,001,231	269,870,875	510,703,328	573,528,535
Total Projected Annual Passenger Trips	24,800,000	683,666	1,183,533	3,200,000	3,200,000	3,239,800
Total Passenger Miles	4,773,000,000	153,542,442	111,514,286	493,000,000	653,000,000	832,561,941
Annual HSR Emissions (lbs CO_2)	2,338,282,822	75,220,125	54,630,618	241,519,680	319,903,349	407,870,372
Net Emissions Saved (lbs CO_2)	(112,357,330)	4,136,071	(1,629,387)	28,351,195	190,799,980	165,658,163
Percentage Saved	-5%	5%	-3%	11%	37%	29%

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[40] 1 pound CO_2 is equal to $4.53592 x^{-10}$ Million Metric Tons CO_2 ($MMTCO_2$)

Appendix B. Corridor Notes and Detailed Data

Table B- 1 Airplane CO_2 Emissions Saved by Corridor

Airplane Emissions Saved (lbs CO_2)														
	California	**Empire**	**Florida**	**Gulf Coast**	**Keystone**	**Midwest**	**Northeast**	**Northern New England**	**Ohio**	**Pacific Northwest**	**South Central**	**Southeast**	**Total**	**Average**
Seats Per Plane	126	119	110	125	102	125	110	104	110	91	115	144		115
Passenger Occupancy	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%		70%
Passengers Per Plane	88	83	77	87	72	87	77	73	77	64	80	101		81
Percent Of Passengers Diverted From Air	46%	25%	17%	14%	6%	17%	22%	2%	1%	27%	35%	18%		19%
Number Of Diverted Airline Passengers	19,236,963	2,310,980	584,970	726,971	69,000	2,490,432	5,456,000	13,340	11,835	864,000	1,120,000	579,098	33,463,589	2,788,632
Airline Trips Displaced	218,142	27,769	7,597	8,334	963	28,466	70,857	184	190	13,533	28,806	22,909	427,749	35,646
Trip Length	305	244	136	313	207	300	193	243	154	196	248	355		241
Emissions Per Vehicle Mile In 2025 (lbs CO2)	48.04	48.04	48.04	48.04	48.04	48.04	48.04	48.04	48.04	48.04	48.04	48.04		48.04
Total Airplane Passenger Miles Displaced	5,859,575,006	563,699,657	79,555,920	227,533,431	14,283,085	747,409,364	1,053,008,000	3,238,167	1,822,641	169,480,663	278,097,027	205,382,024	9,203,084,986	766,923,749
Total Airplane Miles Displaced	66,445,964	6,773,513	1,033,194	2,608,340	199,252	8,542,862	13,675,429	44,587	29,330	2,654,560	7,152,553	8,124,767	117,284,352	9,773,696
Airplane Emissions Saved (lbs CO2)	3,192,226,440	325,416,114	49,637,153	125,311,012	9,572,550	410,419,984	657,000,999	2,142,092	1,409,108	127,531,554	343,626,120	390,333,655	5,634,626,780	469,552,232

Table B- 2 Automobile CO_2 Emissions Saved by Corridor

Automobile Emissions Saved (lbs CO_2)														
	California	**Empire**	**Florida**	**Gulf Coast**	**Keystone**	**Midwest**	**Northeast**	**Northern New England**	**Ohio**	**Pacific Northwest**	**South Central**	**Southeast**	**Total**	**Average**
Emissions Per Vehicle Mile In 2025 (lbs CO2)	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85		0.85
Percent Of Passengers Diverted From Autos	42%	11%	69%	70%	5%	49%	2%	95%	86%	47%	44%	48%		47%
Number Of Diverted Auto Passengers	17,598,881	1,074,212	2,374,290	3,582,927	55,000	7,222,253	496,000	646,974	1,011,921	1,504,000	1,408,000	1,565,709	38,540,167	3,211,681
Trip Length	301	207	136	130	150	130	193	225	94	139	205	221		178
Average Occupancy	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60		1.60
Total Auto Passenger Miles Displaced	5,301,685,826	222,251,514	322,903,440	466,290,339	8,250,000	939,484,751	95,728,000	145,302,007	95,344,553	209,399,337	288,640,000	345,789,232	8,441,068,999	703,422,417
Total Miles Of Auto Trips Displaced	3,313,553,642	138,907,196	201,814,650	291,431,462	5,156,250	587,177,970	59,830,000	90,813,754	59,590,346	130,874,585	180,400,000	216,118,270	5,275,668,124	439,639,010
Auto Emissions Saved (lbs CO2)	2,808,767,913	117,746,117	171,070,269	247,034,884	4,370,748	497,727,461	50,715,516	76,979,215	50,512,371	110,937,192	152,917,920	183,194,880	4,471,974,488	372,664,541

Table B- 3 Bus CO_2 Emissions Saved by Corridor

Bus Emissions Saved (lbs CO_2)														
	California	**Empire**	**Florida**	**Gulf Coast**	**Keystone**	**Midwest**	**Northeast**	**Northern New England**	**Ohio**	**Pacific Northwest**	**South Central**	**Southeast**	**Total**	**Average**
Seats Per Bus	50	50	50	50	50	50	50	50	50	50	50	50		50
Passenger Occupancy	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%		70%
Passengers Per Bus	35	35	35	35	35	35	35	35	35	35	35	35		35
Percent Of Passengers Diverted From Bus	0%	1%	2%	2%		19%	0%	1%	7%	5%	9%	0%		4%
Number Of Diverted Bus Passengers		53,562	68,820	103,853		2,863,997	-	6,670	81,664	160,000	288,000	-	3,626,566	362,657
Bus Trips Displaced	-	1,530	1,966	2,967	-	81,828	-	191	2,333	4,571	8,229	-	103,616	8,635
Trip Length		211	136	161		161	193	253	95	160	205			175
Bus Emission Per Vehicle Mile In 2025 (lbs CO2)	4.870	4.870	4.870	4.870	4.870	4.870	4.870	4.870	4.870	4.870	4.870	4.870		4.870
Total Bus Passenger Miles Displaced	-	11,316,822	9,359,520	16,680,514	-	461,103,485	-	1,688,270	7,760,771	25,600,000	59,040,000	-	592,549,382	49,379,115
Total Bus Miles Displaced	-	323,338	267,415	476,586	-	13,174,385	-	48,236	221,736	731,429	1,686,857	-	16,929,982	1,410,832
Bus Emissions Saved (lbs CO2)	-	1,574,502	1,302,184	2,320,750	-	64,153,047	-	234,888	1,079,751	3,561,712	8,214,199	-	82,441,034	6,870,086

Table B- 4 Train CO_2 Emissions Saved by Corridor

Train Emissions Saved (lbs CO_2)

	California	Empire	Florida	Gulf Coast	Keystone	Midwest	Northeast	Northern New England	Ohio	Pacific Northwest	South Central	Southeast	Total	Average
Seats Per Train	321	321	321	321	321	321	321	321		321	321	321		321
Average Occupancy	46%	46%	46%	46%	46%	46%	46%	46%	46%	46%	46%	46%		46%
Passengers Per Train	148	148	148	148	148	148	148			148	148	148		148
Percent Of HSR Passengers Diverted From Train	6%	58%	4%	4%	82%	0%	70%	0%	0%	12%	2%	0%		20%
Number Of Diverted Train Passengers	2,520,126	5,477,607	137,640	207,706	901,170	-	17,360,000		-	384,000	64,000		27,052,249	2,705,225
Train Trips Displaced	17,055	37,070	931	1,406	6,099	-	117,483			2,599	433		183,075	20,342
Trip Length	303	211	136	161	150	161	193			160	205			187
Emissions Per Vehicle Mile In 2025 (lbs CO2)	67	67	67	67	67	67	67	67	67	67	67	67		67
Total Train Passenger Miles Displaced	763,598,233	1,155,775,033	18,719,040	33,361,029	135,175,500	-	3,350,480,000			61,440,000	13,120,000	-	5,531,668,834	553,166,883
Total Train Miles Displaced	5,167,627	7,821,671	126,681	225,770	914,796	-	22,674,267			415,793	88,789	-	37,435,393	3,743,539
Train Emissions Saved (lbs CO2)	346,010,629	523,718,402	8,482,192	15,116,942	61,252,315	-	1,518,208,978	-	-	27,840,417	5,945,089	-	2,506,574,964	208,881,247

Table B- 5 Total Gross CO_2 Emissions Saved by Corridor

Total Gross Emissions Saved (lbs CO_2)

	California	Empire	Florida	Gulf Coast	Keystone	Midwest	Northeast	Northern New England	Ohio	Pacific Northwest	South Central	Southeast	Total	Average
Total Emissions Saved From All Modes (lbs CO2)*	6,347,004,982	968,455,135	230,491,798	389,783,588	75,195,614	972,300,492	2,225,925,493	79,356,196	53,001,231	269,870,875	510,703,328	573,528,535	12,695,617,266	1,057,968,106

*Sum of Air, Auto, Bus, and Conventional Rail Emissions Savings

Table B- 6 Projected HSR Annual CO_2 Emissions with Conventional Rail Technology

Projected HSR Annual Emissions with Conventional Rail Technology (lbs CO_2)														
	California	**Empire**	**Florida**	**Gulf Coast**	**Keystone**	**Midwest**	**Northeast**	**Northern New England**	**Ohio**	**Pacific Northwest**	**South Central**	**Southeast**	**Total**	**Average**
Emissions Per Passenger Mile (lbs CO2)	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21		0.21
Total Projected Annual Passenger Trips	42,002,103	9,416,700	3,441,000	5,192,648	1,100,000	14,824,000	24,800,000	683,666	1,183,533	3,200,000	3,200,000	3,239,800	112,283,450	9,356,954
Total Passenger Miles	12,726,637,209	2,228,813,572	120,753,000	834,025,715	165,000,000	2,388,000,000	4,773,000,000	153,542,442	111,514,286	493,000,000	653,000,000	832,561,941	25,479,848,166	2,123,320,680
Annual HSR Emissions (lbs CO2)	2,646,403,680	463,464,177	25,109,633	173,429,059	34,310,447	496,565,737	992,507,648	31,927,938	23,188,515	102,515,456	135,786,192	173,124,679	5,298,333,161	441,527,763
Net Emissions Saved (lbs CO2)	3,700,601,302	504,990,958	205,382,166	216,354,529	40,885,167	475,734,755	1,233,417,845	47,428,258	29,812,716	167,355,419	374,917,137	400,403,856	7,397,284,106	616,440,342
Percentage Saved	58%	52%	89%	56%	54%	49%	55%	60%	56%	62%	73%	70%	58%	

Table B- 7 Projected HSR Annual CO_2 Emissions with TGV Technology

Projected HSR Annual Emissions with TGV Technology (lbs CO_2)														
	California	**Empire**	**Florida**	**Gulf Coast**	**Keystone**	**Midwest**	**Northeast**	**Northern New England**	**Ohio**	**Pacific Northwest**	**South Central**	**Southeast**	**Total**	**Average**
Emissions Per Passenger Mile (lbs CO2)	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15		0.15
Total Projected Annual Passenger Trips	42,002,103	9,416,700	3,441,000	5,192,648	1,100,000	14,824,000	24,800,000	683,666	1,183,533	3,200,000	3,200,000	3,239,800	112,283,450	9,356,954
Total Passenger Miles	12,726,637,209	2,228,813,572	120,753,000	834,025,715	165,000,000	2,388,000,000	4,773,000,000	153,542,442	111,514,286	493,000,000	653,000,000	832,561,941	25,479,848,166	2,123,320,680
Annual HSR Emissions (lbs CO2)	1,857,638,467	325,327,874	17,625,663	121,738,227	24,084,158	348,563,457	696,689,020	22,411,761	16,277,138	71,960,546	95,314,882	121,524,568	3,719,155,760	309,929,647
Net Emissions Saved (lbs CO2)	4,489,366,515	643,127,261	212,866,135	268,045,361	51,111,455	623,737,035	1,529,236,473	56,944,435	36,724,093	197,910,329	415,388,447	452,003,967	8,976,461,507	748,038,459
Percentage Saved	71%	66%	92%	69%	68%	64%	69%	72%	69%	73%	81%	79%	71%	73%

Table B- 8 Projected HSR Annual CO_2 Emissions with Shinkansen Technology

Projected HSR Annual Emissions with Shinkansen Technology (lbs CO_2)

	California	**Empire**	**Florida**	**Gulf Coast**	**Keystone**	**Midwest**	**Northeast**	**Northern New England**	**Ohio**	**Pacific Northwest**	**South Central**	**Southeast**	**Total**	**Average**
Emissions Per Passenger Mile (lbs CO2)	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22		0.22
Total Projected Annual Passenger Trips	42,002,103	9,416,700	3,441,000	5,192,648	1,100,000	14,824,000	24,800,000	683,666	1,183,533	3,200,000	3,200,000	3,239,800	112,283,450	9,356,954
Total Passenger Miles	12,726,637,209	2,228,813,572	120,753,000	834,025,715	165,000,000	2,388,000,000	4,773,000,000	153,542,442	111,514,286	493,000,000	653,000,000	832,561,941	25,479,848,166	2,123,320,680
Annual HSR Emissions (lbs CO2)	2,779,081,093	486,699,947	26,368,504	182,123,923	36,030,600	521,461,054	1,042,267,006	33,528,645	24,351,071	107,655,067	142,593,831	181,804,283	5,563,965,022	463,663,752
Net Emissions Saved (lbs CO2)	3,567,923,889	481,755,188	204,123,295	207,659,665	39,165,013	450,839,438	1,183,658,487	45,827,551	28,650,160	162,215,808	368,109,498	391,724,252	7,131,652,244	594,304,354
Percentage Saved	56%	50%	89%	53%	52%	46%	53%	58%	54%	60%	72%	68%	56%	59%

Table B- 9 Projected HSR Annual CO_2 Emissions with IC-3 Technology

Projected HSR Annual Emissions with IC-3 Technology (lbs CO_2)

	California	**Empire**	**Florida**	**Gulf Coast**	**Keystone**	**Midwest**	**Northeast**	**Northern New England**	**Ohio**	**Pacific Northwest**	**South Central**	**Southeast**	**Total**	**Average**
Emissions Per Passenger Mile (lbs CO2)	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26		0.26
Total Projected Annual Passenger Trips	42,002,103	9,416,700	3,441,000	5,192,648	1,100,000	14,824,000	24,800,000	683,666	1,183,533	3,200,000	3,200,000	3,239,800	112,283,450	9,356,954
Total Passenger Miles	12,726,637,209	2,228,813,572	120,753,000	834,025,715	165,000,000	2,388,000,000	4,773,000,000	153,542,442	111,514,286	493,000,000	653,000,000	832,561,941	25,479,848,166	2,123,320,680
Annual HSR Emissions (lbs CO2)	3,307,110,635	579,173,661	31,378,559	216,727,739	42,876,468	620,539,430	1,240,299,287	39,899,137	28,977,810	128,109,690	169,686,871	216,347,367	6,621,126,654	551,760,555
Net Emissions Saved (lbs CO2)	3,039,894,347	389,281,474	199,113,240	173,055,849	32,319,146	351,761,062	985,626,205	39,457,058	24,023,420	141,761,185	341,016,458	357,181,168	6,074,490,612	506,207,551
Percentage Saved	48%	40%	86%	44%	43%	36%	44%	50%	45%	53%	67%	62%	48%	52%

Table B- 10 Projected HSR Annual CO_2 Emissions with MagLev Technology

Projected HSR Annual Emissions with MagLev Technology (lbs CO_2)														
	California	**Empire**	**Florida**	**Gulf Coast**	**Keystone**	**Midwest**	**Northeast**	**Northern New England**	**Ohio**	**Pacific Northwest**	**South Central**	**Southeast**	**Total**	**Average**
Emissions Per Passenger Mile (lbs CO2)	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49		0.49
Total Projected Annual Passenger Trips	42,002,103	9,416,700	3,441,000	5,192,648	1,100,000	14,824,000	24,800,000	683,666	1,183,533	3,200,000	3,200,000	3,239,800	112,283,450	9,356,954
Total Passenger Miles	12,726,637,209	2,228,813,572	120,753,000	834,025,715	165,000,000	2,388,000,000	4,773,000,000	153,542,442	111,514,286	493,000,000	653,000,000	832,561,941	25,479,848,166	2,123,320,680
Annual HSR Emissions (lbs CO2)	6,234,753,231	1,091,891,157	59,156,645	408,587,472	80,833,159	1,169,876,258	2,338,282,822	75,220,125	54,630,618	241,519,680	319,903,349	407,870,372	12,482,524,885	1,040,210,407
Net Emissions Saved (lbs CO2)	112,251,751	(123,436,021)	171,335,153	(18,803,884)	(5,637,545)	(197,575,766)	(112,357,330)	4,136,071	(1,629,387)	28,351,195	190,799,980	165,658,163	213,092,381	17,757,698
Percentage Saved	2%	-13%	74%	-5%	-7%	-20%	-5%	5%	-3%	11%	37%	29%	2%	9%

California Corridor

The California High Speed Rail Authority "Ridership and Revenue Forecasts" authored by Charles Rivers and Associates in 2000 predicts a HSR ridership of 32 million passenger trips in 2020 for trips longer than 150 miles. The forecasters performed a sensitivity analysis on their model, however, that shows a maximum annual ridership of 58,397,253 trips in 2020 based on increased growth in air and auto travel, increased travel times for air and auto travel (likely due to congestion), and a 150% increase in air fares. In addition, they estimate 10 million long distance commuters traveling less than 150 miles.

The Environmental Impact Report uses the higher value in its energy analysis, but we chose the more conservative and well-documented value of 32 million intercity riders plus 10 million commuters (42 million total annual riders) that is used elsewhere in the Environmental Impact Report.

California passenger diversion rates are from the California High Speed Rail Ridership and Revenue Study.[41] We used the average high speed rail trip length from the FRA High Speed Rail Study, "New HSR Option" scenario, because the local ridership study only looked at trips over 150 miles. Average air trip length was calculated from the OAG database.[42]

Empire Corridor

We used data from the FRA High Speed Rail study for the Empire Corridor. Ridership figures are from the "Accelerail 125F: Extension" scenario. That scenario did not provide diversion rates, so we used diversion rates from the "New HSR: Empire/Northeast System" scenario. The Empire Corridor is already running trains at maximum speeds of 100 mph. Fiscal year 2004 Amtrak ridership in this corridor was 1,093,965 according to Amtrak's September 2004 monthly report.[43]

Florida

The future of high speed rail in Florida in uncertain. In 2000, voters passed a constitutional amendment mandating construction on a high speed rail system, but in another ballot initiative in 2004 voters repealed the amendment, essentially halting high speed rail development in Florida. The Florida High Speed Rail Authority is wrapping up its planning work in the hopes that the project will be picked up again in the future.[44] Based on this possibility, we have included this system in our study.

We used 2025 ridership projections for the Beeline Alignment—indicated as the currently favored alignment—which were prepared by Wilbur Smith Associates.[45] While the Florida ridership study considered passenger diversion from various modes, it did not provide passenger diversion rates in a format consistent with other corridors, so we used the values from the FRA High Speed Rail study.

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[41] California High Speed Rail Authority. "Independent Ridership and Passenger Projections for High Speed Rail Alternatives in California." Prepared by Charles River and Associates Incorporated. January 2000 http://www.cahighspeedrail.ca.gov/plan/pdf/Ridership_Revenue.pdf

[42] OAG Worldwide, Inc. "Official Airline Guide's Market Analysis for Air Transport Specialists." April 2002 http://oagdata.com/home.aspx

[43] Amtrak. "Monthly Performance Report for September 2004." November 1, 2004. http://www.amtrak.com/pdf/0409monthly.pdf

[44] Florida High Speed Rail Authority. "Overview." accessed May 2005. http://www.floridahighspeedrail.org/1_overview.jsp

[45] Florida High Speed Rail Authority. "Investment Grade Ridership Study: Summary Report." November 2002. http://www.floridahighspeedrail.org/uploaddocuments/p25/Ridership%20Study%20-%20all%20reports.pdf

Gulf Coast Corridor

Southern Rapid Rail Transit Commission is the lead organization in the Gulf Coast Corridor. We used their passenger projections for the buildout scenario at 12 trains per day and 110 mph maximum speed.[46] The study did not provide passenger diversion rates, and the FRA High Speed Rail study did not include this corridor, so we used the diversion rates from the FRA study's scenario for Florida based on an assumption that the intercity travel profile of the two adjacent corridors would be similar.

Keystone Corridor

Based on a conversation with Toby Fauber at the Pennsylvania Department of Transportation, we used an annual passenger trip value of 1.1 million. Mr. Fauber said the current ridership in the corridor is 700,000-800,000.

Midwest

The federally designated corridor called the "Chicago Hub Corridor" is being planned by two separate local initiatives, the Ohio segment (also called the 3C corridor because it would connect Cincinnati, Columbus, and Cleveland) and the Midwest corridor. These two corridors are planned to be linked at both Cleveland and Cincinnati, but at the recommendation of the planners we modeled them separately. Moreover, we used the Midwest Regional Rail Initiative's definition of their corridor, which is slightly different than the federal definition; for example, it includes a segment to Omaha that is not in the federal map.

Based on discussions with Rick Harnesh at the Midwest High Speed Rail Association and Randy Wade and Ethan Johnson at the Wisconsin Department of Transportation, we used passenger projections and diversion rates developed by Transportation Economics and Management Systems, Inc. for the Midwest Regional Rail System.[47]

Northeast Corridor

Despite the large amount written about Acela and high speed rail in the Northeast Corridor, we had a hard time finding passenger projections for this corridor. We used projections and diversion rates from the FRA High Speed Rail study, which projects 24.8 million riders in 2020. According to Amtrak, fiscal year 2004 Acela Express ridership was 2.6 million, while ridership in the Northeast Corridor as a whole, including Acela, Metroliner, Regional, and Clocker ridership was 11.3 million.[48]

Northern New England Corridor

We used passenger ridership data from the Boston-Montreal High Speed Rail planning and feasibility study prepared by the consulting firm Parsons Brinkerhoff Quade and Douglas.[49] The study writeup did not provide the diversion rates that went into the ridership model, but it did provide a breakdown of current intercity travel volume by mode. Lacking better data, we used this as a substitute for the diversion rates, although it is likely to over count auto diversions and undercount air travel diversions. In addition, we estimated flight frequencies and

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[46] Southern Rapid Rail Transit Commission. "Gulf Coast High Speed Rail Corridor, Feasibility Study Phase II Draft Report." Prepared by Morrison Knudsen Corporation with Fredric R. Harris, Inc. and Salzan and Associates, Inc. No date given. http://www.srrtc.org/PDFs/GulfCoastHighSpeedRail.pdf

[47] Midwest Regional Rail Initiative. "MWRRI Project Notebook." Prepared by Transportation Economic and Management Systems, Inc. June 2004. In possession of author.

[48] Amtrak. "Monthly Performance Report for September 2004." November 1, 2004. http://www.amtrak.com/pdf/0409monthly.pdf

[49] Vermont Agency of Transportation, et. al. "Boston to Montreal High-Speed Rail Planning and Feasibility Study, Phase I, Final Report." Prepared by Parsons Brinkerhoff Quade and Douglas, et. al. April 2003. http://www.bostonmontrealhsr.org/documents/Final_Repor_%20Boston-Montreal_HSR-Phase1.pdf

distances to and from Montreal based on information from travel websites, as the OAG flight data we used for our analysis did not include Canadian airports.

Ohio

As mentioned previously, based on discussions with local planners we considered the high speed rail system being proposed in Ohio separately from the Midwest system, even though the federal Chicago Hub Corridor includes both systems as one Corridor. We used ridership projections and diversion rates from the Cleveland-Columbus-Cincinnati High-Speed Rail Study of 2001 prepared by Transportation Economics & Management Systems, Inc.[50]

Pacific Northwest Corridor

Based on discussions with Kurk Fredrickson at the Washington Department of Transportation and Jonathan Hutchinson at the Oregon Department of Transportation we used a ridership estimate of 3.2 million for the Pacific Northwest Corridor at buildout (approximately 20 years in the future). This estimate is based on a diesel train system with maximum speeds of 110 mph using passive tilt technology. This is a fairly conservative estimate that does not include any growth in intercity travel or any increase in fuel price, both of which would likely increase ridership. We used the passenger diversion rates from the FRA High Speed Rail Study. As with the Northern New England Corridor, we used travel websites to estimate Canadian flight frequencies to Vancouver.

South Central Corridor

The South Central Corridor is a Y shaped corridor that runs between Texas, Oklahoma, and Arkansas. We could not find passenger projections for this corridor, but the FRA High Speed Rail study created projections for the Texas Triangle, a high speed rail system linking Houston, San Antonio and Dallas, that was planned in the 1990's but Displaced.[51] We used these FRA projections as an approximation for the high speed rail potential in this region.

Southeast Corridor

A number of passenger ridership studies have been created for segments of the Southeast Corridor from Jacksonville to Washington, DC. After discussions with David Foster at the North Carolina Department of Transportation and Analyst Bruce Williams we summed the passenger estimates for the segments. The segments for which we found passenger data were Jacksonville, FL to Macon, GA; Macon, GA to Charlotte, NC; Charlotte, NC to Washington, DC; and Richmond, VA to Hampton Roads, VA. We did not find any passenger projections for the segment from Jacksonville, FL to Raleigh, NC that is planned to run through Savannah, GA and Columbia, SC.[52]

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[50] Ohio Rail Development Corporation. "Cleveland-Columbus-Cincinnati High-Speed Rail Study" Prepared by Transportation Economics and Management Systems, Inc. July 2001.

[51] See Trainweb.org "The Texas TGV." http://www.trainweb.org/tgvpages/texastgv.html

[52] The Georgia Rail Passenger Authority. "Atlanta-Macon-Jesup-Jacksonville Intercity Rail Passenger Service Study." by Georgia Rail Consultants and Amtrak. July 28, 2004. http://www.garail.com/Pages/pdf/2004jaxreport.pdf ;
Georgia Department of Transportation, et. al. "Macon-Charlotte Southeast High Speed Rail Corridor Plan." by Georgia Rail Consultants. May 2004. http://www.sehsr.org/reports/MACCLTrept2004.pdf ;
Southeast High Speed Rail "Washington, DC to Charlotte, NC Tier 1 Final Environmental Impact Statement." June 2002. http://www.sehsr.org/reports/FEISesch1.pdf ;
Virginia Department of Rail and Public Transportation. "Richmond to South Hampton Roads High-Speed Rail Feasibility Study: Task 3 - Ridership And Revenue." by AECOM Consulting Transportation Group, Inc. and Parsons Transportation Group. May 2002. http://www.drpt.virginia.gov/downloads/files/shrridership.pdf

Appendix C. Trip Length and Net Emissions Equations

Trip Length Calculations

The corridor studies generally provided high speed rail passenger trip length as an average over the entire system and all types of passengers. However, as trip length is an important part of the model we developed to estimate emissions, we felt that the passenger trip length warranted a closer look. We reasoned that on average a passenger flying within the corridor would be taking a longer trip than a passenger driving. Therefore, we looked at the weighted average flight trip distance within the corridor (direct flights only) and calculated an automobile trip length using this information as is described below.

Weighted Average Miles per Passenger = [Sum of (Flights per week * Distance per flight * Seats per flight) for all city pairs in corridor] / [Sum of (seats per flight * flights per week)]

Where seats per flight were set at 60 seats for flights 200 miles and less and 160 seats for flights more than 200 miles.[53]

$$\text{Average Auto Trip Length} = \frac{(TLh - (TLar * Par) - (TLb * Pb) - (TLr * Pr) - (TLi * Pi))}{Pau}$$

Where:

TLh	=	Average HSR Passenger Trip Length		
Tlar	=	Average Air Trip Length	=	Weighted average of direct flight distances in corridor
TLb	=	Average Bus Trip Length	=	Average HSR Passenger Trip Length
TLr	=	Conventional Rail Trip Length	=	Average HSR Passenger Trip Length
Tli	=	Average Induced Passenger Trip Length	=	Average HSR Passenger Trip Length
Par	=	Percent HSR Passengers Diverted From Air		
Pb	=	Percent HSR Passengers Diverted From Bus		
Pr	=	Percent HSR Passengers Diverted From Conventional Rail		
Pi	=	Percent HSR Passengers Induced		
Pau	=	Percent of Passengers Diverted From Autos		

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[53] Based on Regional Jet (50-110 seats) such as Candair RJ100 and Narrow Body Jet (120-180 seats) such as Airbus 320 or Boeing 737.

Equation to Determine the Emissions Impact of High Speed Rail.

Net annual emissions savings = Esar + Esau + Esb + ESr + ES – Eghsr

Where

Esar	=	Airplane emissions saved	=	Total airplane miles canceled x emissions per mile in year Y
	Where	Total airplane miles canceled	=	Number of airplane trips canceled x trip length
	Where	Airplane trips canceled	=	Number of diverted airplane passengers / Average passengers per plane
	Where	Average passengers per plane	=	Seats per plane x average %passenger occupancy
Esau	=	Auto emissions saved	=	Total miles of auto trips canceled x emissions per mile in year Y
	Where	Total miles of auto trips canceled	=	(number of diverted auto passengers x trip length) / average occupancy
Esb	=	Bus emissions saved	=	Total bus miles canceled x emissions per mile in year Y
	Where	Total bus miles canceled	=	Number of bus trips canceled x trip length
	Where	Bus trips canceled	=	Number of diverted bus passengers / average passengers per bus
	Where	Average passengers per bus	=	Seats per bus x Average %passenger occupancy
ESr	=	Train emissions saved	=	Total train miles canceled x emissions per mile in year Y
	Where	Total train miles canceled	=	Number of train trips canceled x trip length
	Where	Train trips canceled	=	Number of diverted train passengers / average passengers per train
	Where	Passengers per train	=	Seats per train x average %passenger occupancy
Eghsr	=	Projected high speed rail annual emissions	=	Emissions per mile for expected technology x total projected annual system miles (preferred)
OR				
Eghsr	=	Projected high speed rail annual emissions	=	Emissions per passenger per mile for expected technology x total passenger miles
	Where	Total passenger miles	=	Total projected annual passengers x passenger trip length
	OR			
	Where	Total passenger miles	=	Total passenger miles from revenue projections

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