INCREASING FUEL EFFICIENCY AND ALTERNATIVE FUEL USE IN FREIGHT MOVEMENT ACROSS THE CALIFORNIA/BAJA CALIFORNIA BORDER

CONSULTANT REPORT

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Abstract

This report, which is part of a larger California Energy Commission project on energy issues in the California/Mexico border region, discusses opportunities to reduce energy consumption and emissions associated with the movement of goods across the border. After describing transportation infrastructure, trade patterns, and mode shares in the border region, the report analyzes options to improve energy efficiency of goods movement by increasing the availability of alternative freight modes. While energy and emissions benefits of the options analyzed are not sufficient to offset costs, economic benefits including congestion reduction greatly increase the cost-effectiveness of some options. Short-distance rail upgrades and short-sea shipping projects in particular warrant further study and should be considered from the perspective of their ability to shape future goods movement patterns in the border region.

Opportunities to use alternative and reformulated fuels and advanced vehicle technologies for highway, rail, marine, and aviation modes are discussed as well. Technologies generally seem more suitable for near-term implementation than alternative fuels, which typically require extensive infrastructure development both in the United States and Mexico. For operations in the border region, however, shortage of capital is a serious obstacle to adoption of new technologies as well.

There are major issues of economic development and security associated with development of the border region, and energy considerations, while not minor, are unlikely to drive the discussion. At the same time, agencies grappling with energy, climate change, petroleum consumption, and air quality issues in the states of California and Baja California can broaden the discussion of cross-border transportation investment, which to date has focused primarily on reducing delays at and near the border.

Keywords: North American Free Trade Agreement, goods movement, maquiladora, Baja California, commodity flows, port of entry, congestion, idle reduction, drayage, freight rail, intermodal, rail shuttle, San Diego and Arizona Eastern Railway, container port, Ports of Los Angeles and Long Beach, Punta Colonet, short-sea shipping, air pollution, alternative fuel, reformulated fuel, vehicle efficiency technologies

Executive Summary

Cross-Border Trade and Infrastructure

Trade between the United States and Mexico accounts for a substantial part of U.S. exports and the overwhelming majority of Mexican exports. This trade is growing rapidly, especially Mexican exports to the United States, which are growing at 9 percent per year. These rapid growth rates are reflected in trade between California and Baja California, and the accompanying border region congestion. Aside from petroleum product transport, trucks are the dominant mode for California-Baja California trade, putting heavy pressure on the three major land ports of entry. Goods crossing the border for the most part travel short distances; nearly two-thirds of truck trips start or end in Los Angeles, San Diego, or Imperial counties, while on the Mexico side, trucks for the most part remain in Baja California, where economic activity is focused on the maquiladoras—industrial facilities near the border on the Mexico side whose function is to produce and assemble goods and parts for a parent company, typically in the United States. The most important commodities in this flow of goods are electric machinery, computers, vehicles, agricultural products, and apparel.

The congestion associated with freight trucks crossing the border is an issue of considerable regional concern, and there is a wide array of projects, typically roadway capacity expansion or measures to expedite security clearance proposed to reduce delays. From a broader perspective, however, freight transportation concerns in the border area seem to be overshadowed by issues associated with overall growth in international trade. Neither the Ports of Los Angeles and Long Beach nor the Class I railroads operating in the area have extensive plans for the region; they are focused primarily on the east-west movement of freight that constitutes their main business. A regional railroad does exist in area, however, and is eager to expand its share of the freight traffic and to better serve the smaller ports of Ensenada and San Diego that lie within the border region.

The general picture that emerges from efforts to date to improve goods movement in the border region is that, despite rapid growth and time-consuming delays at the border, changes are incremental in nature and focused on expediting truck movement. Looking forward, however, the possibility exists of dramatic change due to factors ranging from construction of a major container port at Punta Colonet in Baja California to rethinking of goods movement statewide in California from a climate and emissions perspective.

Options to Improve the Efficiency of Cross-Border Goods Movement

Options considered to reduce energy consumption and emissions associated with cross-border freight trips are summarized in Table ES1.

Table ES1: Options – Pros and Cons

OPTION	EXAMPLE	PROS	CONS
Mode Shift		Viability generally will grow with increasing volumes	High capital cost; drayage requirements
Rail	Shuttle: Los Angeles-San Diego-Tijuana	Serves multiple growing markets	Switch in operator at San Diego
	San Diego-Tijuana-Tecate	Supports growth of Port of San Diego; alternative route from border area to Midwest	Small initial market; major upgrade required to connect to Midwest
	Punta Colonet-Tijuana-Los Angeles	Eliminates border crossing for goods from Asia; could boost use of rail at Mexicali	Limited impact on CA-Baja trips; implementation decisions independent of border considerations
	Calexico-Mexicali	Infrastructure largely in place; connection to rail network at both ends	Limited volumes; low interest on part of (private) operator
Short Sea Shipping	Coastal barge between Ports of Los Angeles and Long Beach and Ensenada	Goods travel offshore on CA side, avoiding congestion	Serves trips between Ports of Los Angeles/ Long Beach and Baja California only; requires scarce terminal space; volume-constrained at Baja California terminus.
Reduction in Delay			
Capacity Expansion	Roadway expansion		Ability to provide relief limited as traffic volume grows; high capital costs
	New POE	Local congestion and air pollution reduction	Ability to provide relief limited as traffic volume grows; modest energy savings
Expedited Processing	FAST expansion	Low capital cost (if existing lanes are used)	Security concerns; improvement constrained by approach lane capacity
	NAFTA program	Low capital cost; eliminates need for drayage and reduces empty backhaul	Substantial opposition based on safety, pollution, labor issues; relevant to limited portion of truck trips
Congestion Pricing	Time of day tolling	Potential revenue source; adjustable to increasing volumes	Limited time-of-day flexibility for JIT deliveries

Source: Authors

The subsequent analysis focuses on alternative mode options, treating the delay reduction options only in a cursory fashion.

Benefits and Costs of Cross-Border Goods Movement Improvement Options

None of the options presented here has an easy case to make for investment on either the public or private side. Railroads in particular have found it difficult to realize adequate return on infrastructure investment and have consequently limited their new projects to low-risk, lucrative investments. Given the drivers for the projects considered here, for example, economic development, congestion reduction, and environmental benefits, it is clear that public funding would need to play a major role in the financing of any capital-intensive options.

Even from an operating perspective, the rail options may be of limited interest to the railroads themselves. Class I railroads eliminated 175,000 miles of track between 1970 and 2000, and they are generally moving toward reducing service on existing routes. The cost components of rail operation are such that high-volume, long-distance routes are most profitable. Therefore, particularly in an area such as Southern California, where demand for rail exceeds the railroads' ability to supply new capacity, a short-distance service with comparatively modest volumes at present is not likely to be attractive to railroads. Even where the potential for profit may exist, longer-haul routes will typically bring greater profits relative to the investment required and therefore are likely to be funded first. In any case, user costs for new services would need to remain in the vicinity of trucking costs to attract users, and as shown above this is challenging for short-distance services. It is therefore probably not practical to impose additional fees to recover capital costs of new infrastructure.

On the other hand, estimates of both costs and benefits used in the analysis depended upon certain assumptions that may serve to understate alternative modes' potential. In the case of rail service between Los Angeles and Tijuana, for example, the cost estimates reflect cost of related projects designed to upgrade passenger service as well as freight service, so assigning the full costs of these projects to freight movement may not be appropriate. Most importantly, the value of the options considered depends greatly upon their ability to influence future development decisions on both sides of the border, which in turn will determine the amount of truck, rail, and marine traffic this development generates. This issue was considered only in passing in the analysis above and needs to be revisited for any option receiving further attention.

Given the complex economic considerations involved, the most appropriate approach to evaluating public investment in freight infrastructure may not be a cost-benefit analysis but rather identification of the most cost-effective option to meet a given need. This is how highway investments are typically evaluated. When the benefits of congestion relief at the border were taken into account in this chapter, some of the options appeared to have a payback that would justify public investment. The options that fared best in this preliminary analysis were rail from Punta Colonet, barge service between the San Pedro Bay ports and Ensenada, and enhanced freight rail service between Los Angeles and Tijuana. The first two of these projects rely upon other major investment decisions, however, namely the construction of the Punta Colonet container port and implementation of an entire system of short-sea shipping services centered on San Pedro Bay, respectively.

Evaluation of Fuel Options and New Transportation Technologies

Many technology options to reduce fuel consumption and emissions rely upon systems and devices that make vehicles more aerodynamic, optimize fuel usage, or use engine technologies that are readily available and can be implemented in the near term. Most alternative fuel options require construction of processing plants and new infrastructure for fuel distribution, and may require extensive engine modification or replacement. One important action that applies across modes is making available low sulfur diesel fuel in both Mexico and the United States to reduce SO_x and PM emissions.

For trucks, there are a number of technologies available in the near term that will reduce fuel usage and emissions and should be encouraged, such as: construction of facilities equipped with truck stop electrification, use of auxiliary power units, low rolling resistance tires, and installation of airfoils and side skirts to enhance vehicle aerodynamics. For the most part however, the benefits of these technologies will be limited to long-haul freight movement. In the medium term, programs should be considered that encourage the use of hybrid trucks; this would include electric hybrids for medium and long-haul operations, and hydraulic hybrids for drayage activities. Given the substantial incremental costs associated with introducing these technologies into a drayage fleet dominated by used vehicles, extensive subsidies will likely be required in this regard. Blended biofuels (B10 or B20) may also be possible in the medium term if agricultural constraints can be addressed and new processing plants built. CNG, LNG, and ethanol should be considered longer term options as they require extensive infrastructure enhancements. For natural gas options, this would include development of Mexican natural gas fields, extending the natural gas pipelines and construction of refueling stations. Ethanol requires a separate distribution system that uses corrosion-resistant materials, which would take considerable time and resources to develop. Ethanol blends (e-diesel) may be introduced earlier, as they require less infrastructure development.

For rail, the use of aluminum rail cars, covered freight cars, and driving optimization systems should be considered. Near term options also include use of hybrid engines for switching operations and genset locomotives for switching and short haul applications. These near term options should reduce fuel consumption and emissions without extensive changes to rail operations or fuel distribution. Blended biodiesel may be a viable as a medium term option to reduce emissions, but additional studies are needed to more fully evaluate long term impacts of biodiesel usage on engine components. Long term options for railways include use of CNG for switching activities and LNG for switching and long haul operations as these natural gas options require more extensive infrastructure enhancements.

Marine vessel diesel engines are able to burn a wide variety of fuels efficiently. The driving factor for shifting to alternative fuels is primarily fuel availability. The use of humid air motors could also be encouraged in the short term, to reduce NO_x emissions. Blended biodiesel, though a cleaner option than low sulfur diesel, is constrained by the availability of feedstock and processing plants. Synthetic fuels are also constrained by the lack of processing plants. In addition, the cost to construct these facilities is high, and they require advanced technical skills to operate. Both biodiesel and synthetic fuels should be viewed as medium-term options. CNG and LNG should be considered a long term option for short sea cargo shipments as they require significant changes to vessels and infrastructure, particularly on the Mexican side, where new gas fields need to be developed and gas pipeline infrastructure expanded.

Unlike some of the other transportation modes, where the focus is on fuels that existing engines use with minimal modifications, the objective in aviation is to develop fuels or blends that are identical to existing fuels meeting international specifications such as safety requirements and require no engine or infrastructure changes. The international aviation community is actively considering potential alternative fuels with the leading medium-term candidate being synthetic fuel blends. To ensure sufficient supply of these fuels to meet the needs of cross-border air cargo movements, synthetic fuel processing facilities need to be constructed in both Mexico and the United States. In the near term, fuel usage and pollutant emissions can be reduced through programs that promote use of new energy-efficient jet engines that take advantage of lightweight materials, improved compressor design, and use lean-burn combustors. These engines operate on existing aviation fuel and therefore require no changes in fuel distribution and storage.

Recommendations

Recommendation 1: Expand data collection efforts to better understand trends that influence border region transportation patterns, trends, and opportunities.

- Support the work of California Department of Transportation (Caltrans) and border area associations of governments to update and analyze origin-destination data for cross-border truck trips, including full detail on trip ends on the Mexican side.
- Investigate the feasibility of expanding the Transborder Freight Data collection to include state of origin for northbound trips.

Recommendation 2: Integrate border-region freight transportation planning into statewide and binational climate, economic, and environmental planning.

- Work with Baja California agencies and maquiladora associations to develop a coherent picture of what characteristics a transportation system must have to meet the transportation needs of the region for the next 20 years.
- Add transportation to the agenda of the cross-border energy working group.

Recommendation 3: Integrate consideration of alternative modes for the border region and elsewhere into state goods movement and port planning.

Recommendation 4: Revisit planned projects in the Los Angeles-Tijuana corridor with the aim of creating a convenient, high-speed rail service for both shipments to and from the Midwest, and shipments from the Ports of Los Angeles and Long Beach.

- Investigate the interest of businesses in locating in the border region in a scenario in which high-quality rail service is available.
- Support SANDAG projects to upgrade Los Angeles – San Diego – Tijuana freight rail infrastructure and service.

Recommendation 5: Proceed with modest upgrades to the Mexico and Southern Line segments of the San Diego and Eastern Railway; reconsider major upgrades upon completion of Tijuana corridor improvements.

Recommendation 6: Should Punta Colonet proceed to construction, develop and pursue a plan to take advantage of new opportunities for rail and shipping options serving the border region.

Recommendation 7: With public and private parties interested in pursing short-sea shipping operations serving California and Baja California ports, form a collaborative to design and evaluate a system that allows shared infrastructure and vessels, and economies of scale.

Recommendation 8: Ensure the availability of low-sulfur diesel fuel on both sides of the border.

Recommendation 9: Pursue opportunities to expand availability of alternative fuels.

- Investigate opportunities to develop Mexican natural gas fields, extend pipelines, and construct refueling stations.
- Consider compressed natural gas (CNG) for switching activities and liquefied natural gas (LNG) for switching and long-haul operations; in the long term, consider CNG and LNG for short-sea shipping operations.
- Consider introduction of ethanol blends (e-diesel) to border-area filling stations.
- In the medium to long term (5 to 20 years), consider construction of biodiesel and synthetic fuels processing plants.
- Evaluate long-term impacts of biodiesel usage on locomotive engine components.
- Construct synthetic fuel processing facilities in both Mexico and the United States.

Recommendation 10: Provide incentives for the adoption of efficiency technologies.

- Promote electrification of truck stops.
- Provide incentives for the use of auxiliary power units, low rolling resistance tires, and airfoils and side skirts to enhance vehicle aerodynamics.
- Provide incentives for hybrid technologies, including idle-off and hydraulic hybrids for dray trucks and hybrid-electrics for both dray and long-haul trucks.
- Incentivize use of hybrid engines for switching operations and genset locomotives for switching and short haul applications.
- Encourage the use of humid air motors to reduce nitrogen oxides (NO_x) emissions.
- Create programs that facilitate the use of energy-efficient jet engines using lightweight materials, improved compressor design, and lean-burn combustors.

Recommendation 11: As feasible, remove legal, regulatory, and other obstacles to improved efficiency and alternative freight modes at the border.

- Review possibility to streamline rail car cleaning process at Calexico crossing.
- Establish remote border inspection stations for freight rail to allow processing at the point of embarkation.
- Eliminate dray truck restrictions on two-way hauling.
- Pursue the Federal Highway Administration pilot project on through trucks to the extent that safety and security concerns can be addressed.
- Pursue standardization of container sizes.

- Promote the cross-border harmonization of vehicle emissions requirements.
- Eliminate requirements that maquiladora products return to parent companies for shipping.

Recommendation 12: Explore and promote an array of financing mechanisms for funding alternative modes that serve the border region.

CHAPTER 1:
Cross-Border Trade and Infrastructure

Introduction

This is the first of five chapters of a report on reducing energy consumption in the movement of freight across the California-Baja California border. Congestion at the border is an issue of major concern to residents and agencies of the border region, and numerous projects have been advanced to alleviate the problem. These typically involve increasing roadway capacity and expediting security procedures to reduce delay and air pollution. Given the rapid growth in the flow of goods across the border, however, such approaches are likely to produce only short-term relief. This report will look more broadly at opportunities to change mode of transportation, use alternative fuels, and otherwise reduce the consumption of fossil fuels in moving goods through the region.

This chapter describes the movement of goods in the California-Baja California border region, as well as the existing freight transportation infrastructure. In addition, it provides an overview of major trends and plans that will shape goods movement in the region in the coming years.

Cross-Border Trade

Background: U.S.-Mexico Trade Volumes

The movement of goods across the United States-Mexico border reflects larger trends, including the globalization of production and free trade. As goods increasingly are produced in stages in different countries around the world, more shipping is involved in their production and distribution. Similarly, as free trade agreements such as the North American Free Trade Agreement (NAFTA) are implemented, the flow of goods across borders increases rapidly. As a result of these changes in the world economy, U.S. imports have grown at a rate of 8.8 percent per year since 1997, reaching a volume of $1,918 billion in 2006 (see Table 1). U.S. exports grew at a rate of 4.7 percent per year over the same period, reaching a volume of $1,037 billion in 2006.

Trade with Mexico plays an important role in overall levels of U.S. trade. In 2006, the value of trade between the United States and Mexico reached $334 billion. Ten percent of total U.S. imports arrived from Mexico, and 13 percent of all U.S. exports were destined for Mexico.

This bilateral trade is far more important still to the Mexican economy. In 2006, imports from the United States constituted 51 percent of Mexican imports, and 85 percent of exports went to the United States. While the Mexican economy is less than one-tenth the size of the U.S. economy, it grew at a faster rate of 8.5 percent per year over the period 1997-2006.

Important as imports from the United States are to Mexico, they have been declining as a percentage of the total imports since 2001, while imports from Asia have risen commensurately (see Figure 1). Exports to Asia remain small.

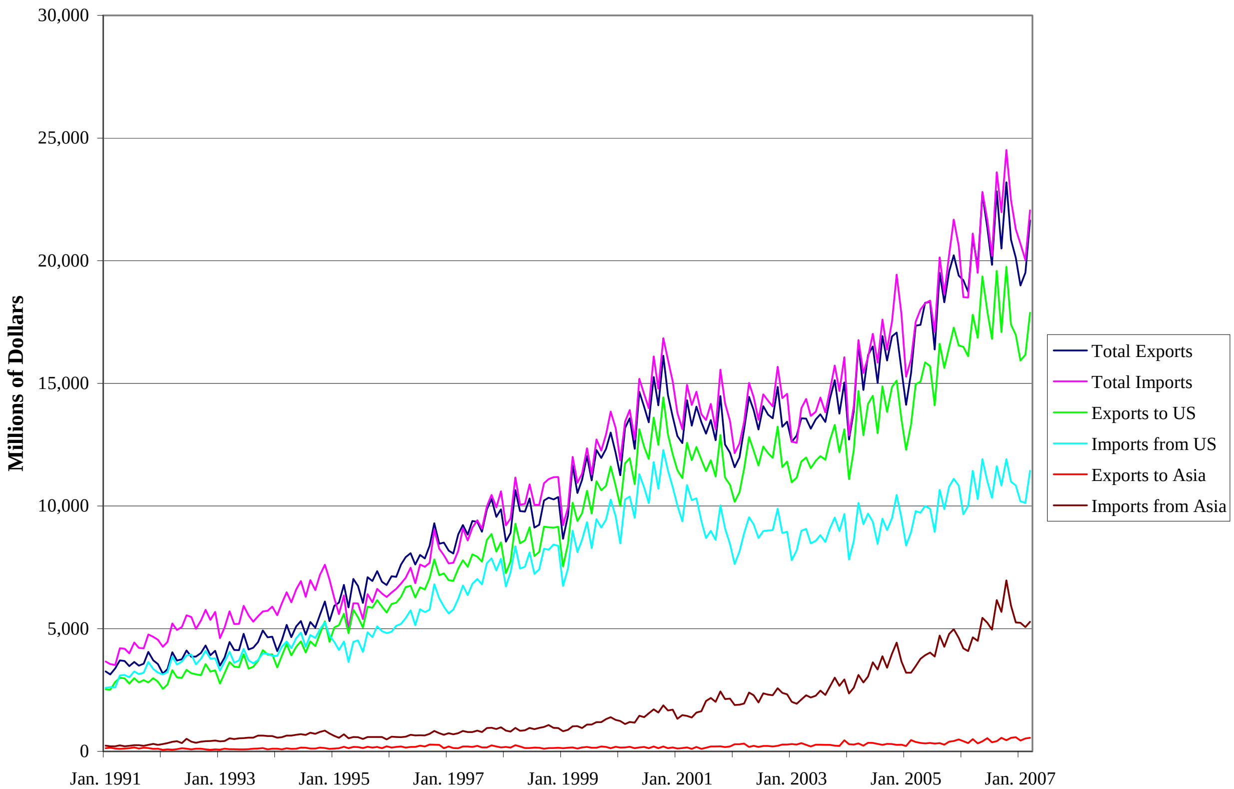
Table 1: United States and Mexican Trade Statistics 1997 and 2006
(Million Current Dollars)

U.S. Trade Statistics	1997	2006	Average Annual Growth Rate 2000-2006
U.S. Gross Domestic Product	8,250,900	13,163,870	5.3%
Total U.S. Imports	898,025	1,918,997	8.8%
U.S. Imports From Mexico*	87,120	200,500	9.7%
U.S. Imports From Mexico (% of total)	10%	10%	
Total U.S. Exports	687,533	1,037,029	4.7%
U.S. Exports to Mexico*	71,355	134,127	7.3%
U.S. Exports to Mexico (% of total)	10%	13%	
Mexican Trade Statistics			
Mexico GDP	401,480	839,182	8.5%
Total Mexican Imports	111,983	256,086	9.6%
Mexican Imports from the U.S.*	83,214	130,810	5.2%
Mexican Imports from the U.S. (% of total)	74%	51%	
Total Mexican Exports	110,047	249,961	9.5%
Mexican Exports to the U.S.*	93,019	212,132	9.6%
Mexican Exports to the U.S. (% of total)	85%	85%	

Sources: (United Nations 2008; World Bank 2008) *In the U.N. database, imports reported by one country may not coincide with exports reported by its trading partner, due to differences in conventions.

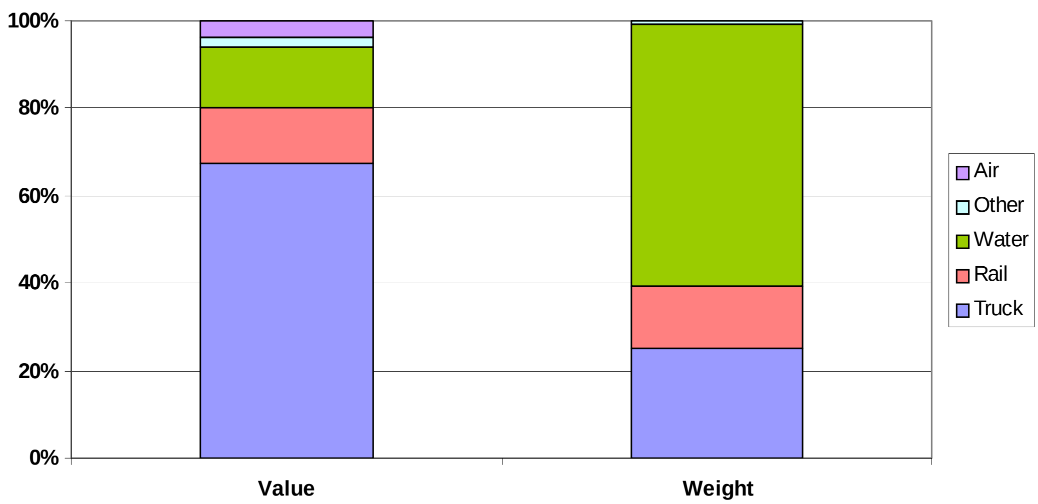
Trade travels between the United States and Mexico by surface, air, and water modes. The relative importance of modes depends greatly on the metric used to compare them. As shown in Figure 2, 66 percent of goods, by value, travels by truck, 12 percent by rail, 14 percent by water and pipeline, and 3 percent by air. By weight, water carries the largest share at 60 percent, truck and rail carry 25 and 14 percent respectively, and air carries only a fraction of a percent. More than three-quarters (77 percent) of waterborne tonnage is petroleum.

Figure 1: Monthly Mexican Trade with United States and Asia, 1991-2007



Source: Instituto Nacional de Estadistica Geografia e Informatica 2007

Figure 2: United States-Mexico Trade Volume and Tonnage by Mode, 2005



Source: Authors, based on Bureau of Transportation Statistics 2006a

Movement of Goods Across the California-Baja California Border

This report is concerned specifically with goods movement across the California-Baja California border and opportunities to reduce the energy that this activity consumes. Movements across this segment of the border reflect some of the trends of U.S.-Mexico trade shown above, in particular the high rate of growth. There are important differences as well, including differences in mode split, which will be discussed below.

Much of the data in this and other sections of the report is from the Bureau of Transportation Statistics' (BTS') Transborder Surface Freight Data (Bureau of Transportation Statistics 2007b), which tracks the movement of goods across U.S. borders by surface modes. Two important shortcomings of those data for purposes of this discussion are, first, it includes only goods with origin and final destination in North America and therefore does not include, for example, trade between Mexico and China that passes through U.S. maritime ports; and second, BTS data do not disaggregate northbound goods by Mexican state of origin. While the omission of transshipped goods is potentially quite problematic, other data sources indicate that these volumes are actually relatively small, as discussed further below. With regard to the second issue, the authors estimated Baja California's share of northbound trade through the California-Baja California ports of entry using BTS' commodity breakdown and assuming that the manufacturing products are products of maquiladora operations near the border. The resultant figures may underestimate Baja California's share by up to five percent by assuming that northbound agricultural products came from primarily other states.

Origins and Destinations

Goods passing through ports of entry on the California-Baja California border for the most part remain within those two states: approximately 70 percent, by value, of goods crossing the border have both origin and destination in California or Baja California.[1] As shown in Figure 3, 83 percent of U.S. exports through the California border crossings in 2006 were destined for Baja California. The second- and third-ranking recipients of U.S. exports through the California border are the states of México and Distrito Federal, accounting for 7 percent and 4 percent, respectively. Similarly, 82 percent of goods traveling north from Mexico through these ports of entry have final destination in California.

Below the state level, data are more difficult to come by. Data from Caltrans' 2003 Commercial Vehicle Border Crossing Survey (Caltrans 2003) show origins and destinations of truck trips, especially on the U.S. side of the border. Goods moved across the California-Baja California border, unlike those crossing the Texas segment of the border, travel almost exclusively by truck, so truck data provide a good picture of the flow of goods overall.

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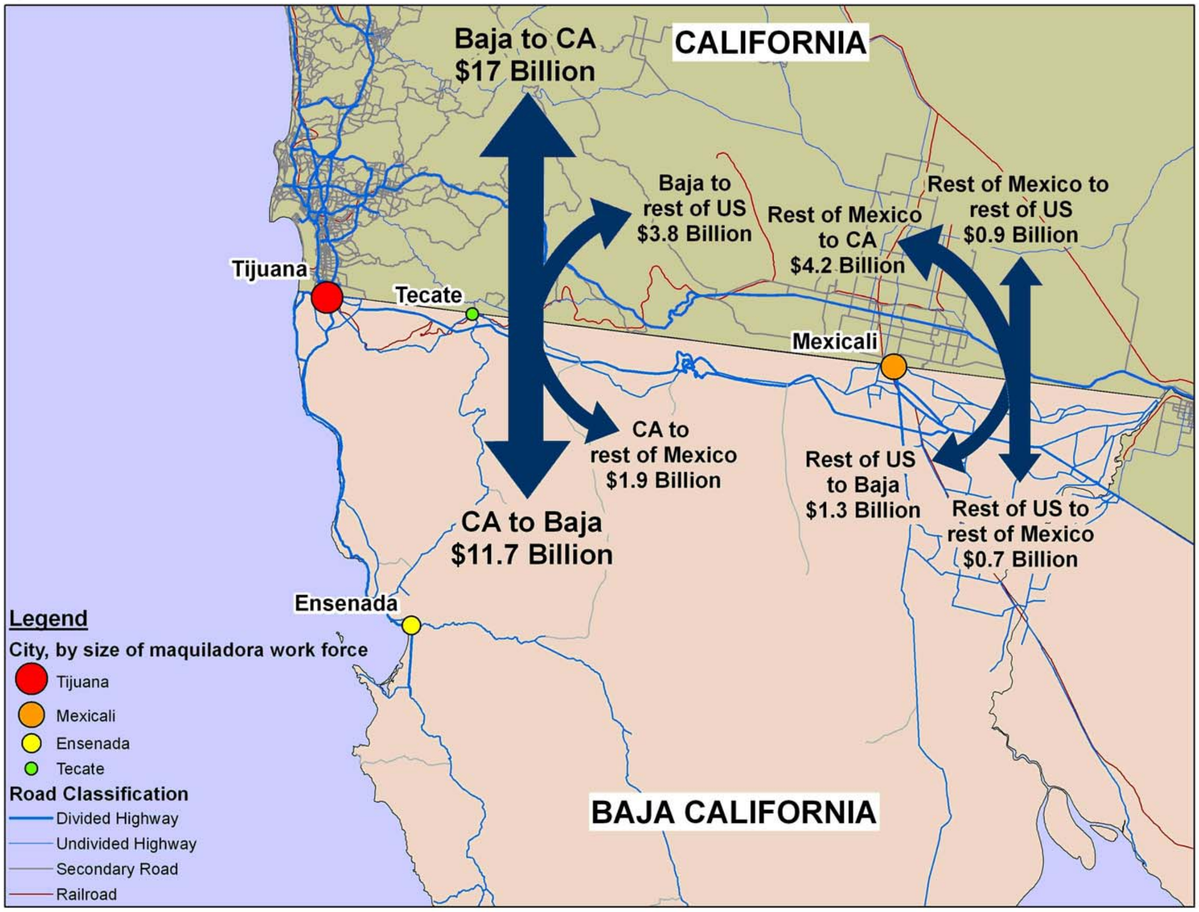
[1] Based on BTS data and, for northbound goods, estimation; see preceding discussion of BTS Transborder Freight Data.

Figure 3: Value of Goods Crossing the California-Baja California Border, 2006



Source: Authors, based on BTS Transborder Freight Data (Bureau of Transportation Statistics 2007b). Does not include transshipped goods. Baja California shares of northbound goods based on estimates unrelated to BTS data; see text.

Among the 894 records from Caltrans' 2003 survey, 32 percent of the loaded truck trips (including the 22 percent of trips in the immediate vicinity of the border) had San Diego or Imperial counties as origin or destination, and 26 percent, Los Angeles County. Twenty-two percent of trips reported had an origin or destination on the U.S. side that was outside of California (Caltrans 2003).

The Caltrans survey data also indicate that 5 percent of cross-border truck trips involve goods traveling to or from Asia. Given the rapid growth of trans-Pacific trade, and of the Ports of Los Angeles and Long Beach in particular, as well as the more-than-doubling of Mexican imports from Asia since the date of the survey (see Figure 1), Asia-related truck trips could be substantially higher. Furthermore, it is possible that many cross-border truck trips to and from Los Angeles and San Bernardino counties might involve goods in transit to or from Asia.

At the same time, the Port of Los Angeles reports minimal surface trade with Mexico (Almanza 2007). This may reflect the fact that cross-border truck trips with origins or destinations in all of Los Angeles County represent a volume of traffic only 2 percent as large as the daily flow of

40,000 trucks to and from the Ports of Los Angeles and Long Beach. These ports have as their highest priorities the Inland Empire (San Bernardino and Riverside Counties in California) and the east coast, which may contribute to the ports' limited attention to markets in Mexico (Jauregui 2007). Nonetheless, the ports have initiated outreach programs to selected commercial associations in Mexico.

The Maquiladoras

A major generator of cross-border trips is the maquiladoras, which are industrial facilities near the border on the Mexico side whose function is to produce and assemble goods and parts for a parent company, typically in the United States. More than one-third of Mexico's maquiladora establishments are located in Baja, and the economy of Baja California is consequently highly concentrated in the border region (SANDAG 1999; INEGI 2004). Ninety percent of Baja California maquiladoras are in the cities of Tijuana, Mexicali and Tecate, all within close proximity to the border. Table 2 shows the distribution by location of the 898 maquiladora operations in the state, which employ 239,000 workers (Secretaria de Desarrollo Economico del Estado de Baja California 2006). Most are involved in the electronics, vehicle, wood furniture, metallurgical, or textile industries.

Table 2: Maquiladora Centers in Baja California, 2006

	Tijuana	Mexicali	Tecate	Ensenada	Total
Number of Enterprises	568	130	119	81	898
Thousands of Employees	165	51	10	13	239

Source: Secretaría de Desarrollo Económico del Estado de Baja California 2006

Increasing competition from Asia for low-wage manufacturing jobs has affected the maquiladora industries over the past decade (Brown, Caldwell, et al 2003). Baja California plants declined by 27 percent from 2001 to 2002, although this drop may largely reflect the economic downturn of late 2001. The number has remained stable since then (Mexico Now 2007), and the remaining plants are producing higher value goods, including electronics, computers, autos, and auto components (Caltrans 2006).

Maquiladora goods are produced primarily for the U.S. market, and they travel there overwhelmingly by truck. While the United States historically supplied the material inputs to maquiladora operations, much of this now comes from Asia, consistent with the national trend shown in Figure 1. A substantial amount of material for the maquiladoras reportedly comes through the Ports of Los Angeles and Long Beach (Jauregui 2007), though as noted above this is a small market from the ports' perspective.

Tijuana has the largest concentration (63 percent) of maquiladoras in the state of Baja California. Electronics lead maquiladora operations in Tijuana, employing more than 15,000 individuals and representing 30 percent of the maquiladoras in the city. A wide variety of electronics companies have operations in Tijuana including Sony, Panasonic, and Hitachi. Automotive-related manufacturing also plays an important role, employing more than 10,000 people. Other important industries in the area include plastics, wood production, medical products, metalworking tools, and aerospace products (Twin Plant News 2005; Clusters Baja California 2007).

While Mexicali is the state's capital, the concentration of maquiladoras is lower than that of Tijuana, representing approximately 15 percent of all maquiladoras in Baja California. Maquiladora operations in Mexicali have grown nearly 40 percent since NAFTA, feeding off the electronics industry in the Tijuana region (Twin Plant News 2005). Maquiladoras in Mexicali currently produce a variety of goods including electronics equipment, metalworking equipment, automotive products, plastics, aerospace products and textiles. Approximately 65 percent of Mexicali's maquiladora operations are owned by U.S. investors, while the remaining 35 percent are owned by Asian, French, and Mexican (Twin Plant News 2005).

Tecate, located 30 miles east of Tijuana (see Figure 3), is expanding (Twin Plant News 2005). The population growth rate is approximately 4 percent per year. Maquiladora industries in Tecate include electronics, household appliances, plastics, wood and furniture products, and medical products (Secretaria de Desarrollo Economico del Estado de Baja California 2007).

Future Growth

Given the high growth rate of U.S.-Mexican trade, the continued promotion of global production, and the strategic geography of California, rapid growth in both imports and exports across the U.S.-Mexican border is to be expected. Annual truck crossings are projected to continue to increase as well in the coming decades. Caltrans projects an increase in truck traffic from 2 million crossings in 2000 to 2.8 million in 2010, to 3.8 million in 2020, and 5 million in 2030 (Caltrans 2006). This represents annual growth of about 3 percent annually over the next two decades, which may be a substantial underestimate.

Commodities

Current Flows

A wide variety of goods, from televisions to tomatoes, is traded across the U.S.-Mexican border. In 2006, the value of California exports trucked to Mexico was dominated by five product categories: electric machinery (televisions, sound equipment, etc.); computer-related machinery and parts;[2] plastics, motor vehicles, and optical and medical equipment (Bureau of Transportation Statistics). [3] These five categories, totaling $9 billion of goods, comprised almost two-thirds of the total value of California's surface exports to Mexico. Electric machinery alone made up nearly 25 percent of all of California's surface exports to Mexico (by value). Figure 4 shows the values of these five export categories trucked to Baja California alone over the period 1998 to 2006.

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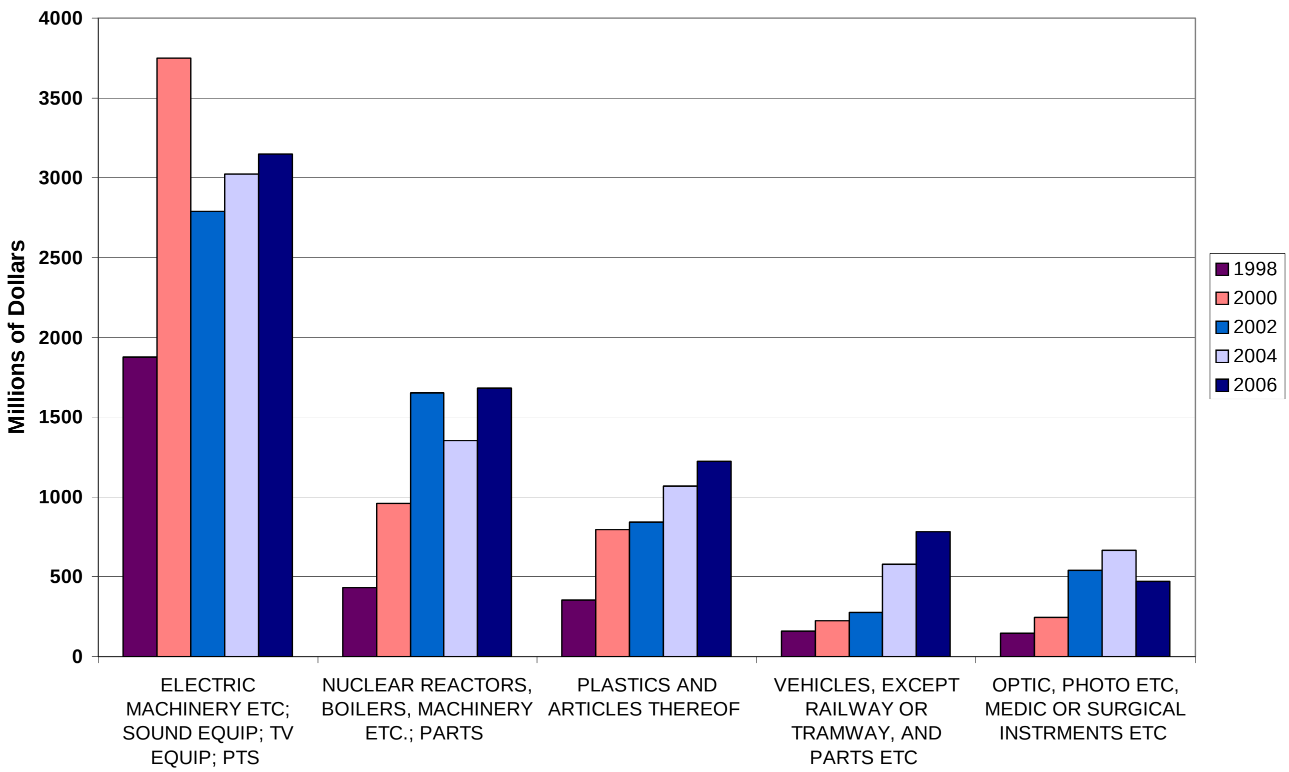
[2] The official description of this commodity class is "Nuclear reactors, boilers, machinery and parts", but according to the Bureau of Transportation Statistics, "'Nuclear reactors' is a very small portion of trade under this commodity grouping (HS 84). The majority of trade for this commodity is computer-related machinery and parts. (http://www.bts.gov/publications/north_american_freight_transportation/html/appendix_09.html)"

[3] This discussion of commodity flows reflects only truck transport, which accounts for almost all surface trade across the California-Baja California border. See the port and air discussions below for an account of commodities moving by sea and air.

Figure 4: Top Five California Exports to Baja California by Value, Truck Only

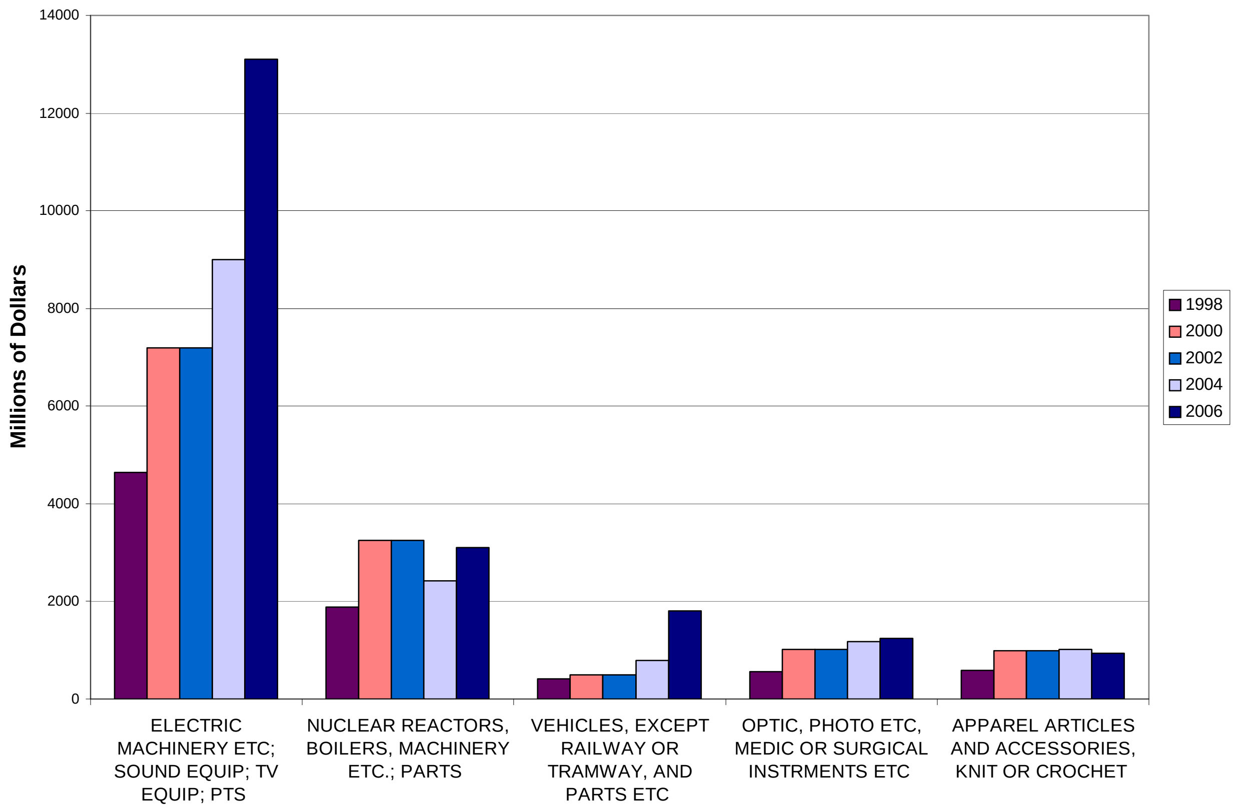


Source: Authors, based on Bureau of Transportation Statistics 2007b

The top five surface imports into California from Mexico in 2006 by value were electric machinery (46.6 percent), computer-related machinery (11 percent), vehicles (6.5 percent), optic and photographic equipment (4.4 percent), and knit or crocheted apparel (3.3 percent) with a combined value of more than $20 billion. Thus, as is the case for exports, maquiladora-related commodities clearly dominate imports in terms of value. Figure 5 shows the trajectory of these imports since 1998. Imports from Baja California alone are not available from the BTS Transborder Freight Data.

An assessment of trade by weight paints a different picture. In 2006, trucks carried more than 5 million metric tons of goods into California from Mexico. The largest component of this flow by weight was agricultural produce (843 thousand metric tons of edible vegetables and 487 thousand tons of edible fruits and nuts), which was not among the top five categories of imports by value. Following agricultural produce were electronics (589 thousand tons); computer-related machinery (248 thousand tons); vehicles (354 thousand tons); and furniture, bedding, and lamps (260 thousand tons). Thus, the ranking of goods varies greatly according to the metric used. Both weight and value, as well as volume, are relevant to the question of what alternative modes could serve to transport the various goods crossing the border.

Figure 5: Top Five California Imports from Mexico by Value, Truck Only



Source: Bureau of Transportation Statistics 2007b

Growth

Between 1998 and 2006, the value of exports trucked between California and Mexico grew at an average annual rate of 5.7 percent. A variety of export commodities experienced significantly higher rates of growth, including knitted or crocheted fabrics (53 percent), edible preparations (26 percent), rubber articles (19 percent), vehicles (15 percent), and iron and steel (6 percent).

The value of California imports from Mexico grew faster than exports, achieving an average annual rate of 9.5 percent between 1998 and 2006. Overall, imports of higher-value goods outpaced those of lower-value goods. Electric machinery, televisions, sound equipment, etc. grew at an average annual rate of 14 percent (by value), increasing its share of total imports from 34 percent in 1998 to nearly 47 percent (by value) in 2006. During the same period, vehicle imports grew by 20 percent annually, becoming the third most valuable import after electric machinery and computer-related equipment. Optic and photographic equipment imports grew by 11 percent per year, while imports of articles of base metal and edible fruit and nuts grew by 15 to 17 percent.

Transportation Infrastructure and Services

Trucking

Trucking is the dominant surface mode, by both weight and value, for transporting goods across the U.S.-Mexico border, but rail plays a substantial role as well. Across the California-Baja California border, however, trucks carry essentially all goods. Table 3 shows that rail carries less than 1 percent of all goods, by value, across the California-Baja California border.

Table 3: Value of Surface Trade Across the California-Baja California Border by Mode, 2006

Northbound	**Millions of dollars**
Truck	25,906
Rail	36
Total surface	25,942
Southbound	
Truck	15,191
Rail	311
Total surface	15,502
Total	
Truck	41,098
Rail	347
Total surface	41,444

Source: Bureau of Transportation Statistics 2007b

By weight, rail carries 2.6 percent of goods northbound across the California-Baja California border (Bureau of Transportation Statistics 2007b). BTS' Transborder Freight Data does not provide data on southbound goods by weight; but rail, unlike truck, carries much more southbound than northbound.

Ports of Entry

Two million trucks crossed the California-Baja California border in 2004 (Caltrans 2006). There are four commercial truck crossings along the border: Otay Mesa, Calexico,[4] Tecate, and Andrade. The distribution of northbound trucks among the ports of entry (POEs) in 2007 is shown in Table 4. No regular counts are taken of southbound trucks, although data on value carried by truck are available for both directions.

[4] "Calexico" in this discussion refers to the Calexico and Calexico East crossings together.

Table 4: Truck Crossings Northbound at California-Baja California Ports of Entry, 2007

		Truck Containers	
	Trucks	Loaded	Empty
Otay Mesa	738,765	477,822	257,483
Tecate	77,320	42,232	35,067
Calexico	323,348	181,114	145,272
Andrade	478	396	
TOTAL	**1,139,911**	**701,564**	**437,822**

Source: Bureau of Transportation Statistics 2008

In 2007, 65 percent of the value of goods crossing the border northbound passed through Otay Mesa, and 28 percent crossed at Calexico. Crossings at Tecate, which has limited highway infrastructure going into the United States, accounted for only 7 percent of the value, and Andrade did not account for any significant quantity of goods.

As noted previously, a large majority of goods crossing the border into the United States have California as their origin or final destination. In 2006, 88 percent of the value of goods crossing into the United States at Otay Mesa were headed for locations within California, compared with 65 percent crossing at Calexico and Tecate. Southbound, 87 percent of goods by value passing through Otay Mesa and Calexico originated in California in 2006, as did 95 percent of goods passing through Tecate (Bureau of Transportation Statistics 2007b).

Ports and Shipping

The two maritime ports closest to the California-Baja California border are the Port of San Diego and the Port of Ensenada. Far larger ports further from the border influence the operations of these two ports (Figure 6). The Ports of Los Angeles and Long Beach, 135 miles to the north, dominate Pacific maritime trade. On the Pacific Coast of mainland Mexico lie the ports of Lázaro Cárdenas and Manzanillo, which despite their locations more than 1,000 miles to the south, are relevant to the border region due to their roles in trade with China. All of these ports have experienced rapid growth in recent years, but their combined capacities are regarded as insufficient to deal with the ongoing boom in trans-Pacific trade. As a consequence, there has been extensive discussion of a new port on the Baja peninsula, at Punta Colonet, 150 miles south of the border.

Despite the great importance of containerized freight to the growth of these ports, containers typically account for around one-quarter of the goods handled by weight (Table 5). Manzanillo and Lázaro Cárdenas are outliers in this regard, with the former being almost exclusively a container port and the latter a bulk goods port.

Figure 6: Selected Pacific Ports

Source: Authors; data on cargo tonnage from AAPA 2007

Table 5: Tonnage and Container Traffic in 2006, Selected Pacific Ports

Port	Total tonnage (million metric tons)	TEUs[5] (thousand)	Container tonnage percent
San Diego	3	103	27%
Los Angeles	182	8,470	25%
Long Beach	179	7,290	22%
Ensenada	3	124	21%
Manzanillo	14	1,252	72%
Lázaro Cárdenas	18	161	5%

Sources: Authors; data from AAPA 2007, port web sites

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[5] A TEU, or 20-foot equivalent, is the standard measure of the volume of containerized goods, corresponding to the size of boxes in the early days of intermodal shipping.

San Diego

The Port of San Diego is located less than 15 miles from the border at Tijuana, 135 miles from Mexicali and 96 nautical miles southeast of Los Angeles. In recent years, harbor depth was increased to 42 feet to accommodate deeper draft vessels with containers, break bulk and bulk cargoes (Unified Port of San Diego 2005). The tonnage of goods passing through the Port is one percent of that handled by Los Angeles/Long Beach. San Diego is not a major container port and largely handles specialized goods.

The Port of San Diego contains two cargo facilities: the Tenth Avenue Marine Terminal and the National City Marine Terminal. At the Tenth Avenue Marine Terminal, inbound cargo consists of primarily refrigerated commodities, fertilizer, cement, breakbulk commodities, and forest products. Exports include refrigerated cargo, breakbulk and bulk commodities. National City Marine Terminal serves as the primary port of entry for vehicles from a variety of car manufacturers, including Honda, Acura, Volkswagen, Isuzu, Mitsubishi Fuso, and Hino Motors. Currently, the terminal processes in excess of 250,000 vehicle imports and exports each year and has a capacity of more than 500,000 vehicles per year (Unified Port of San Diego 2008). In addition to vehicle imports and exports, the terminal also handles shipments of lumber and cattle. Both San Diego terminals have on-dock rail facilities, provided by Burlington Northern-Santa Fe Railroad (BNSF), and are close to major interstates, facilitating truck transport as well.

The port has implemented an aggressive international marketing campaign with the goal of increasing its cargo activity by attracting niche cargoes, project cargo, vehicles, dry bulk commodities, liquid build, and year-round cold storage cargo. The port is targeting countries in Latin America, Asia and North America, including Mexico and Canada. While the port does not currently serve the maquiladoras to any significant extent, maquiladora containers are among the cargo it hopes to attract in the future.

Cargo vessel calls increased 11 percent between 2004 and 2005 and cargo tonnage is expected to continue to increase by 10 to 15 percent per year over the next 5 years as a result of the continued growth in off-shore manufacturing (Unified Port of San Diego 2007). At least part of the growth in cargo shipments has been attributed to the ability of the relatively small port to accommodate unconventional cargo such as bulky and fragile windmill blades. In 2006 the port expected to import more than 700 sets of windmill turbine and rotor heads for windmill energy farms in New Mexico, Iowa, Colorado, Texas, Arizona, and California. In 2005 the port also exported 197 sets of 100-foot-long windmill blades to Japan.

Ensenada

The Port of Ensenada, 70 miles south of Tijuana and the U.S. border, currently handles an annual tonnage comparable to that of the Port of San Diego. In 2007, exports comprised 43 percent of all shipping activity, while imports represented 20 percent and coastal traffic, 38 percent. Export destinations for industrial cargo include Japan, China, Thailand, Korea, Malaysia, Hong Kong, Colombia, Honduras, and Chile. Imports, largely raw materials and manufacturing components, originate in China, Hong Kong, Korea, Japan, and the United States (Administracion Portuaria Integral de Ensenada n.d.)

Ensenada ships a variety of goods. According to 2007 data, Ensenada’s primary shipping product by weight (57 percent) is bulk mineral products, primarily petroleum products, coke, and limestone. Six percent of total shipments consists of bulk agricultural products.

Approximately 31 percent is containerized goods. (Administracion Portuaria Integral de Ensenada n.d.) Containerized imports are primarily associated with maquiladora industries.

Over the past decade, Ensenada has begun to import goods for the maquiladoras , largely containerized and direct from Pacific Rim countries. These goods would otherwise be shipped from Asia to U.S. ports, then travel south to Baja California by truck. For example, border operations for the electronics company Sony now receive 65 percent of their materials through the Port of Ensenada, the remainder coming through the Ports of Los Angeles and Long Beach. In prior years, all of these materials passed through Los Angeles or Long Beach (Jauregui 2007).

Ensenada ships along the coast to Central and South America, and to a lesser extent, to the north as well. Ensenada and San Diego are presently trying to design a service involving return of empty containers (Jauregui). Ensenada experimented with a shipping service to and from the Port of Manzanillo, to the south, but without much success. This would allow truck drivers picking up and delivering at these ports to replace long trips with a larger number of short trips, but the drivers reportedly did not find this shift appealing (Jauregui 2007).

Port activity has grown tremendously over the past decade, largely due to a concerted strategy to expand the overall port capacity in Mexico. Ensenada's shipping volume grew 116 percent over the past 6 years, increasing from 1,569,689 tons in 2000 to 3,385,066 tons in 2006. Container shipments reached 501,000 tons in 2005 (75,225 TEU), up 232 percent since 2000. From 2005 to 2006 alone, container shipments grew 43 percent to 718,000 tons.

The Port of Ensenada would like to capture more of the maritime traffic moving in and out of Southern California, including the export shipping of maquiladora products to Asia and other areas for final assembly. Agricultural products and fish also represent potential areas of growth for export shipping. Over the next two years, container capacity will be doubled, to 0.5 million TEUs. No further expansion of container capacity is anticipated, however.

Many residents of Ensenada oppose a major expansion of the port and, in particular, the construction of a railroad, which they believe would pose a threat to tourism in the town, as well as to the agriculture and fishing industries. An additional obstacle to expansion is that there is not much available land for growth in the vicinity of the port. At the same time, the port has identified the lack of rail service as its primary weakness. The construction of a rail line between Ensenada and Tecate would improve the port's ability to transport maquiladora products and increase overall shipping.

These circumstances, in conjunction with the continuing rapid growth of transpacific trade, are largely responsible for the proposal to build a container port at Punta Colonet, discussed below.

Los Angeles and Long Beach

The combined Ports of Los Angeles and Long Beach form by far the largest port complex in the United States. These ports handle $260 billion in trade annually and 40 percent of U.S. container traffic. From 2005 to 2006, container traffic at Los Angeles and Long Beach grew by 13.2 percent and 8.6 percent, respectively, to a total of 15.8 million TEUs in 2006 (American Association of Port Authorities 2007).

From the perspective of this report, it is worth noting that the total value of goods passing through the ports of Los Angeles and Long Beach is comparable to, though somewhat less than, total U.S.-Mexico trade ($346 billion in 2006; see Table 1). Trade between California and Mexico, at about $50 billion, is about one-fifth the value of the throughput of the Ports of Los Angeles and Long Beach. These ports together generate on the order of 40,000 trips (one-way) per day (Air Resources Board 2006), or 12.5 million trips per year. This exceeds the 9 million truck trips annually crossing the U.S.-Mexico border.

A huge and growing surface transportation infrastructure serves the Ports of Los Angeles and Long Beach. Pollution and congestion associated with the ports has led to a concerted mitigation effort, including the maximization of rail mode share. Forty-three percent of total throughput of the ports traveled by rail as of 2006, although much of this uses near-dock or off-dock facilities and consequently requires truck transport for a short distance as well (Parsons 2006). Rail also increases throughput and reduces wait times at the ports. Both Union Pacific (UP) and BNSF provide rail access, which is primarily used to move goods eastward across the country. Goods bound for the western states generally travel by truck.

As the American center of Pacific Rim-North American trade, the Ports of Los Angeles and Long Beach inevitably play a role in the generation of trips across the border, although this is difficult to quantify, as discussed earlier. Maquiladora inputs coming from Asia through the Ports of Los Angeles and Long Beach can be assumed to far exceed maquiladora goods bound for Asia, given that maquiladora products are largely destined for U.S. markets, and Mexico's imports from Asia far exceed its exports to Asia. Mexico's exports to Asia are increasing, however, and both maquiladora goods and agricultural products from Baja California could be trucked to the Ports of Los Angeles and Long Beach for export to Asia.

The Ports of Los Angeles and Long Beach are operating at capacity. Cargo traffic from East Asia is increasing 15 per cent annually, with China leading that growth. Traffic from Asia is expected to double by 2020 (Atlantic Institute for Market Studies 2005). Highways and rail lines serving the port will reach their limits even sooner.

Various constraints make the physical expansion of the Ports of Los Angeles and Long Beach increasingly difficult. The ports do plan to accommodate growth, but this will be accomplished primarily through improving the efficiency of operations, both on- and off-site. In the meantime, shippers and carriers, among others, are seeking new container port sites on the West Coast. In addition to capacity constraints, a longshoreman's strike that immobilized the Ports of Los Angeles and Long Beach in the fall of 2004 and resulted in the diversion of goods to other ports has been cited as a rationale to develop alternative facilities.

Manzanillo and Lázaro Cárdenas

Below Baja California on Mexico's Pacific coast are several port facilities. Manzanillo and Lázaro Cárdenas, lying more than 1,000 miles south of the U.S. border, are the two most important to international trade. Neither port is directly relevant to California-Baja California goods movement today; they are inaccessible to the border region by road and rail, and they serve markets entirely different from those served by ports in the border region. Manzanillo and Lázaro Cárdenas are important to strategic port planning for Baja California, however, because the viability of a large container facility there would depend upon the ability to enter into the part of the U.S. market that the two southern ports are beginning to serve.

Manzanillo is Mexico's largest container port, by nearly a factor of two. Container traffic is growing at an annual rate of more than 15 percent per year and reached 1.3 million TEUs in 2006. Container imports are roughly equal to container exports. Manzanillo has good rail connections, including access to double-stack cargo trains, and links to U.S. rail lines at Mexicali as well as at several POEs in other states. It is also considered to be the main link between the Pacific and the industrial and commercial corridor of Mexico. According to port documentation, the port is ideally situated for international commerce with the United States, Canada, Central and South America, and with countries in the Pacific Basin.

Lázaro Cárdenas is the largest cargo port on the Pacific coast of Mexico. It is significantly larger than Ensenada or San Diego in total throughput, but is still only one-tenth the size of Los Angeles or Long Beach. It is largely an industrial port and currently lags far behind others in terms of container traffic. Hutchison Port Holdings, the largest port investor, developer, and operator in the world, has undertaken a multiphase program to increase the port's capacity in general and its ability to handle container shipments in particular. The port is located near the highest concentration of economic activity in Mexico and is well-connected by highway and rail to the interior. The railroad Kansas City Southern de México connects the port to Nuevo Laredo, Mexico on the U.S. border, where the line ties into the Class I Kansas City Southern Railroad.

Lázaro Cárdenas is seen as part of a new intermodal corridor between China and the U.S. Midwest, and proponents are investigating the options to expedite customs clearance in this corridor at the border crossing in Texas. The corridor has already purportedly delivered containers from Asia to the Midwest in four to five days less than is required by the route through Los Angeles/Long Beach, and the rail line to Lázaro Cárdenas has yet to undergo planned improvements (CalTrade Report 2006).

Punta Colonet

Punta Colonet, 150 miles south of the California border on the Pacific coast of Baja California, is much discussed as the likely location of a major new container port. Transpacific ocean carriers and major retailers such as Wal-Mart anticipate that continuing growth in trade with China will congest and eventually overwhelm the Ports of Los Angeles and Long Beach and their connections to the rest of the United States. Constraints at Ensenada preclude its expansion to a size responsive to this concern. Punta Colonet is envisioned as a container port almost comparable in size to Los Angeles or Long Beach, on the order of 6 million TEUs annually, and serving primarily the Midwest and Eastern markets of the U.S. Punta Colonet is not well-situated to serve Mexican markets, other than those in Baja California, due to the circuitous routing that would be involved.

Lázaro Cárdenas can play the role of overflow port for U.S. Pacific trade. Maritime trade interests generally believe however that, even with major expansion, the capacity of Lázaro Cárdenas will not be sufficient to meet the upcoming challenge. In fact, Hutchison Port Holdings, which either operates or has terminals at Ensenada, Manzanillo and Lázaro Cárdenas, is among those most eager to develop Punta Colonet. The Mexican and Baja governments strongly support the project, which is expected to be put out for bids in the summer of 2008, with winners to be chosen by summer 2009 (Dickerson and White 2008). It has been described prospectively as "the largest investment ever made in Mexico." (Mireles 2007)

Port development at Punta Colonet faces substantial hurdles. Construction costs for the port have been estimated at $5 to $22 billion, including rail access, which would necessitate multiple private sector investors in an inevitably complicated partnership. Given the orientation of the proposed facility to the United States, efficiency of the border crossing process would be a matter of concern for port developers. Continuing border security issues are not likely to be resolved fully for some time to come. Finally, rights to the land at Punta Colonet are disputed by a mining company and by environmental groups; this situation could at a minimum delay the project.

While a major new port at Punta Colonet serving U.S. markets would greatly increase cross-border goods movement, the net impact on truck traffic is unclear. A prerequisite for the success of the project would be adequate rail service, and in fact rail would be expected to capture most of the goods with U.S. origin or destination. With regard to the California-Baja California border, if the new port and rail line could deliver to the maquiladoras materials that currently arrive from Asia at Los Angeles or Long Beach, much as Ensenada has begun doing to a limited extent, southbound traffic at the border could be reduced. Furthermore, this same line could in principle serve to transport finished goods from the maquiladoras into the United States, reducing northbound truck traffic as well.

Coastal Shipping

As shown in Figure 2, 60 percent of the tonnage of U.S.-Mexico trade is waterborne. This is primarily crude oil and petroleum products. California's trade with Mexico also has a large marine component, much of which is petroleum-related. In 2006, California imported 5.5 million metric tons from Mexico by surface modes and 6.8 MMT by water, of which 3 MMT was crude oil and related products (BTS 2007b).

Marine vessel traffic data between the United States and Mexico are collected by the U.S. Maritime Administration (MARAD) and include all vessels that go through U.S. immigration procedures[6] which includes the following California ports:

- Crockett
- El Segundo
- Long Beach
- Los Angeles
- Martinez
- Oakland
- Port Hueneme
- Redwood City
- Richmond
- Sacramento
- San Diego
- San Francisco

[6] Such data include the previous port visited (for entrances from Mexican ports into U.S. ports) and next port traveling to (for departures from U.S. ports into Mexico). It should be noted that there are some data gaps and inconsistencies in the MARAD vessel movement data, but this data set is probably the most accurate currently available and does provide detailed vessel-specific information about traffic patterns. For this analysis, a vessel coming from and going to Mexico is identified at the first and last U.S. port of call, respectively. If a vessel goes to multiple ports within California after going though the initial port of call or before the last port of call, only the initial state entry and final state departure were considered in order to get an accurate assessment of the cross-border vessel trips.

- Stockton.

The 2005 MARAD data are the basis for the discussion that follows. Cruise ships and passenger vessels were not considered in this analysis, nor were some of the smaller California ports that have little U.S.-Mexico traffic.

In total, slightly more cargo leaves California destined for Mexican ports than enters California from Mexican ports. This is particularly true for bulk transfers of raw material, container ship movements, and general cargo activities. There are important exceptions, however. For example, there are more refrigeration ships carrying fruits and vegetables from Mexican ports entering California than from California ports into Mexico. The same is true for tankers and auto carriers. Note that tankers include crude oil shipments as well as other liquid and gas chemical transfers.

As Table 6 indicates, 74 percent of the tonnage of material shipped by marine vessels from Mexico to California enters through Long Beach (53 percent) and Los Angeles (21 percent). On the Mexican side, 70 percent of this northbound freight traffic originated from the ports discussed above: Manzanillo (40 percent), Ensenada (22 percent), and Lázaro Cárdenas (8 percent). As Table 7 shows, 42 percent of cargo traffic entering California is containerized freight, while 26 percent is tanker traffic and 18 percent is bulk cargo. Collectively, these three marine cargo groups account for 86 percent of the northbound marine freight traffic. Southbound, 52 percent of marine freight was associated with Long Beach (34 percent) and Los Angeles (18 percent), while the Port of Oakland (not shown separately in Table 8) accounted for an additional 29 percent. In neither direction did the Port of San Diego account for more than 4 percent of traffic.

As Tables 7 and 9 indicate, north and southbound container traffic are 42 percent and 44 percent respectively. Southbound bulk transfers (27 percent) are significantly higher than northbound transfers (18 percent), and southbound tanker traffic (17 percent) is significantly lower than northbound traffic (26 percent). General cargo, which may be a candidate for intermodal transfers, is 5 percent of the southbound California freight traffic.

Table 6: Vessel Cargo Traffic Entering California from Mexican Ports, Tons per Year

	California Ports				
Mexico Ports	**Long Beach**	**Los Angeles**	**San Diego**	**Other California**	**Total**
Ensenada	176,096	563,834	150,961	475,439	**1,366,330**
Lázaro Cárdenas	35,518	336,448	106,837	0	**478,803**
Manzanillo	2,028,434	268,039	66	202,452	**2,498,991**
Other Mexico	1,125,833	131,259	26,668	690,998	**1,974,758**
Total	**3,365,881**	**1,299,580**	**284,532**	**1,368,889**	**6,318,882**

Source: U.S. Department of Transportation 2006

Table 7: Cargo Traffic by Vessel Types Entering California from Mexican Ports, Tons per Year

Vessel Types	California Ports				Total
	Long Beach	Los Angeles	San Diego	Other California	
Bulk	335,808	354,304	0	446,552	**1,136,664**
Container	1,965,825	501,445	4,946	157,145	**2,629,361**
Dry Cargo Barge/Tug	73,703	1,298	146,944	0	**221,945**
General Cargo	34,010	77,953	9,038	68,596	**189,597**
Other	0	0	46,633	25,515	**72,148**
Refrigeration	27,636	18,769	0	0	**46,405**
Tanker	719,577	345,811	0	596,443	**1,661,831**
Vehicle Carrier	209,322	0	76,971	74,638	**360,931**
Total	**3,365,881**	**1,299,580**	**284,532**	**1,368,889**	**6,318,882**

Source: U.S. Department of Transportation 2006

Table 8: Vessel Cargo Traffic Leaving California for Mexican Ports, Tons per Year

Mexico Ports	California Ports				Total
	Long Beach	Los Angeles	San Diego	Other California	
Ensenada	335,326	183,416	144,607	1,455,587	**2,118,936**
Lázaro Cárdenas	115,899	532,684	15,326	68,751	**732,660**
Manzanillo	1,035,465	396,825	14,990	695,773	**2,143,053**
Other Mexico	963,264	185,825	130,191	869,759	**2,149,039**
Total	**2,449,954**	**1,298,750**	**305,114**	**3,089,870**	**7,143,688**

Source: U.S. Department of Transportation 2006

Table 9: Cargo Traffic by Vessel Types Leaving California for Mexican Ports, Tons per Year

Vessel Types	Mexico Ports				Total
	Ensenada	Lázaro Cárdenas	Manzanillo	Other Mexico	
Bulk	31,894	348,904	286,633	1,235,247	**1,902,678**
Container	1,326,503	346,963	1,458,668	25,466	**3,157,600**
Dry Cargo Barge/Tug	219,306	0	66	175	**219,547**
General Cargo	56,197	4,255	274,526	33,771	**368,749**
Other	0	0	52,144	0	**52,144**
Refrigeration	0	0	14,496	0	**14,496**
Tanker	481,642	0	9,393	733,297	**1,224,332**
Vehicle Carrier	3,394	32,538	47,127	121,083	**204,142**
Total	**2,118,936**	**732,660**	**2,143,053**	**2,149,039**	**7,143,688**

Source: U.S. Department of Transportation 2006

Rail

Mexico has an extensive rail system with more than17,000 kilometers of track, but the system is very limited in the state of Baja California (see Figure 7). Currently, the line through Mexicali, owned by Ferrocarril Mexicano (Ferromex), is Baja California's only direct connection to the network of rail lines throughout Mexico and is the predominant link to rail lines in the United States.

Rail service is in place at or near all of the California-Baja California ports of entry but captures a small fraction of cross-border trade (Table 10). As shown by a comparison of Tables 4 and 10, truck border crossings into California in 2005 outnumbered rail container entries by 60 to 1. These tables also show that, while trucks entering California are somewhat more likely to be loaded than empty, loaded rail containers crossing into California are vastly outnumbered by empty containers. That is due to the fact that the limited rail freight traffic across the California-Baja California border consists largely of U.S. exports to Mexico.

Figure 7: Rail Lines in the California-Baja California Border Region

Source: Authors

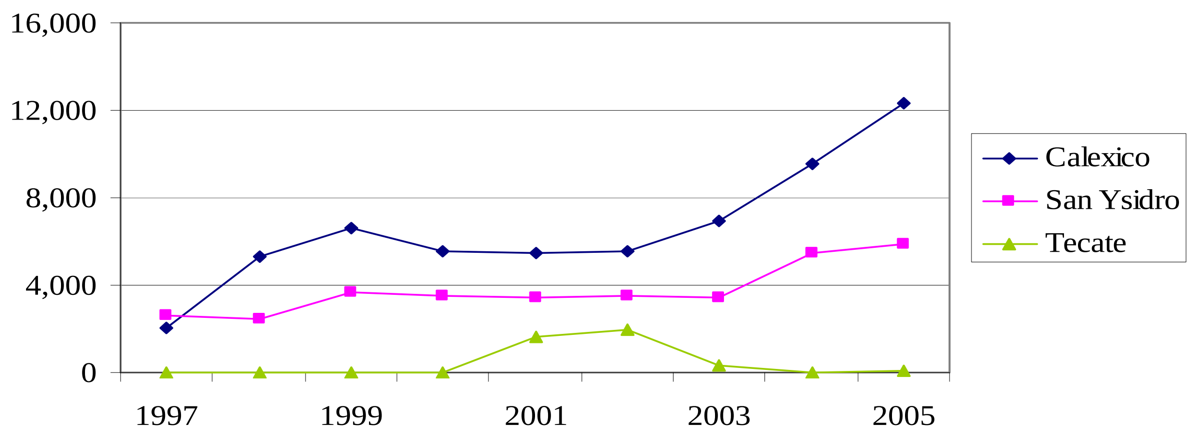
Table 10: Rail Container Crossings Northbound at California-Baja California Ports of Entry, 2005

	Rail Containers		
	Total	Loaded	Empty
San Ysidro	5,891	37	5,854
Tecate	64	0	64
Calexico	12,358	3,881	8,477
TOTAL	18,313	3,918	14,395

Source: Bureau of Transportation Statistics 2008

At the two main rail crossings, Calexico and San Ysidro, rail traffic into California is increasing rapidly, as shown in Figure 8. Northbound rail container shipments have increased from 1997 to 2005 by 134 percent, while truck entries increased 34 percent over the same period.

Figure 8: Northbound Rail Container Crossings, California-Baja California Border 2005



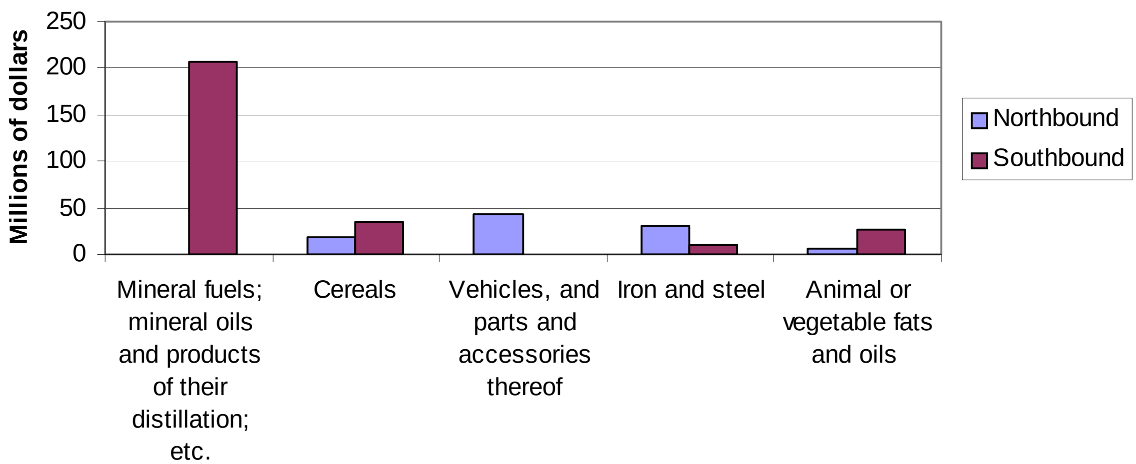
Source: Bureau of Transportation Statistics 2008

The top commodities by value carried by rail are petroleum and petroleum products (southbound only), cereals, vehicles and vehicle parts, iron and steel, and fats and oils (see Figure 9).

Class I Railroads

Both Burlington Northern – Santa Fe (BNSF) and Union Pacific (UP) Railroads link to Mexico's rail network. The rail line passing through the Calexico East POE is part of the UP system on the U.S. side and of the Ferrocarril Mexicano (Ferromex) system south of the border. The line serves Mexicali, a major center of maquiladora industries, and feeds into major rail corridors in both the United States and Mexico. Heading north into the United States, the UP line connects with the westbound line serving the Ports of Los Angeles and Long Beach. The Ferromex line heads southeast into the Mexico's main rail network.

Figure 9: Top Five Commodities Crossing the California-Baja California Border by Rail, 2007



Source: Authors; data from Bureau of Transportation Statistics 2007b

Calexico is UP's sole California crossing, but the line is lightly used, carrying only 2 percent of UP's total U.S.-Mexico volume. The Laredo, Texas, crossing dominates UP's cross-border traffic. In 2005, 239 trains crossed through Mexicali heading north, carrying an average of 20 rail cars (Bureau of Transportation Statistics 2008). Although rail car counts have increased by a factor of 6 since UP acquired the line in its merger with Southern Pacific in 1997 (see Figure 8), trucks still carry 98 percent of freight, by value, at this crossing.

Unlike cross-border goods generally, most freight (75 percent) moving on this rail line is southbound and comes largely from beyond the border states. California-to-Baja movements were only 35 percent of rail exports by value in 2006 (Table 11). On the Mexico side, almost two-thirds (63 percent) terminates in Mexicali, where there are rail spurs into several industrial parks (CaliBaja Manufacturing Services 2008).

Table 11: Rail Exports to Mexico via Calexico by Value

	Mexico	Baja California
U.S.	$106,837,956	$67,289,942
California	$41,994,572	$37,828,399

Source: Bureau of Transportation Statistics 2007b

Commodities transported on the line are primarily bulk goods. Southbound commodities contributing more than 10 percent of the total value are LPG (38 percent), animal or vegetable fats (14 percent), and cereals (12 percent). Northbound, iron and steel dominate (62 percent), with cereals (12 percent) in second place.

BNSF has a line leaving the Ports of Los Angeles and Long Beach and heading south to San Diego, where it terminates. In San Diego County, there is no cross-border Class I service into Mexico. BNSF has set up a transload (rail-to-truck) operation at National City in San Diego to handle shipments to and from Mexican plants, although it is not much used at this point (Pallares 2007). The primary regional market for the BNSF line is San Diego and its port, which it links to the Midwest via Los Angeles. The BNSF line does not generally serve to connect San Diego to the Ports of Los Angeles and Long Beach, because the distance is far too short, at least by conventional standards, and rail lines into the port are too busy to accommodate an additional stream of freight less lucrative than the long haul routes.

The biggest U.S.-Mexico carrier is Kansas City Southern (KCS) Railroad, which includes Kansas City Southern de Mexico (KCSM). KCS passes through eastern Texas (in part using trackage rights) and crosses the Texas-Mexico border at Laredo/Nuevo Laredo. In Mexico, the line serves Mexico City, Gulf ports, and the Port of Lázaro Cárdenas. On the northern end, KCS serves Chicago (Kansas City Southern). KCS has no California-Mexico crossing, however, and is not well-positioned to transport any significant amount of the freight that now crosses the California-Baja California border.

The San Diego and Arizona Eastern Railway

The San Diego and Arizona Eastern Railway (SD&AE) is a short-line railway running between the north-south BNSF and UP lines just described. The SD&AE interchanges with BNSF at its southern terminus at National City in San Diego and then runs to the Mexican border. This stretch of the SD&AE, referred to as the Main or South Line, is operated by the San Diego and Imperial Valley Railroad (SDIY). The SDIY shares track with the San Diego-Tijuana streetcar and consequently can operate at present for only 2 to 3 hours per day, at night. There are plans for a third track, but the project is not scheduled to take place for some time. The SDIY does not currently connect to the Port of San Diego, which precludes moving containers from the maquiladoras and bulk goods to the port by rail.

The SDIY connects San Diego to Tijuana through the San Ysidro POE. The line handles local movements and, by virtue of the interchange with BNSF, provides in theory a route to the Midwest. Cross-border flow is unidirectional; with the exception of a small amount of furniture moving into the United States, all goods flow south on the line (Bureau of Transportation Statistics 2007b). Exports are dominated by LPG and come from multiple U.S. sources. This flow is expected to decline as natural gas pipelines serving Tijuana directly come on line (SANDAG 1999). Aside from LPG, barley from the Midwest and Canada, polystyrene and polypropylene from Houston, and lard and steel from the eastern United States are among the major long-haul flows in the southbound rail freight flow to Tijuana and beyond. The line is also used to carry sand, corn, and feed locally (SANDAG 1999).

At Tijuana, operation of the SD&AE passes to the Carrizo Gorge Railway (CZRY). The CZRY has a contract to run the railroad through 2014 (San Diego Business Journal Online 2005). In Mexico, the line heads east to Tecate, where it crosses back into California and continues to Plaster City in Imperial County. This segment, also run by the CZRY, is known as the Desert Line. To the east of Plaster City, the Desert Line ends in an interchange with UP, tying into the UP line that passes through Calexico and Mexicali. The Desert Line had been closed since 1983, following natural disasters that collapsed bridges and made sections of track unusable, until the CZRY reopened it in 2004. The company expected total revenues to reach $6 million in 2005 and is working to upgrade the rails, crossties, tunnels, and bridges to accommodate the taller and heavier freight cars in the hopes of increasing revenue to $60 million between 2005 and 2008.

Product shipments on the Desert Line are predominately comprised of LPG (55 percent), agricultural products (23 percent), and forestry products (19 percent). Industrial products comprise only 2.2 percent of the total carloads between Tijuana and Tecate. In 2005, total annual shipments on the line included 5,752 rail cars, or 374,000 tons of cargo.

The CZRY is pursuing a link between businesses along its existing line and the Port of Ensenada. The Port of Ensenada offers maquiladoras and other shippers along the border an alternative to U.S. ports that avoids the congested border crossing. The CZRY has been in negotiations with the port to provide a rail link to Tecate, but as noted above, local opposition in Ensenada puts the viability of this project in doubt.

Another goal of the CZRY is to allow the shipment of freight from the Port of San Diego directly east, enabling the port to capture some of the maritime traffic now arriving at the Ports of Long Beach and Los Angeles. The CZRY and the Port of San Diego are interested in creating multi-modal facilities that would allow the loading and off-loading of goods and containers from trucks to rail and vice versa to facilitate port-to-rail shipping. BNSF controls rail access in and around the Port of San Diego, however, and has blocked the SDIY, and hence the CZRY, access to the port (Caltrans 2006).

Rail to Punta Colonet

Neither Class I railroad operating in the vicinity of the California-Baja California border has shown interest in expanding its service into Baja California based on current opportunities to capture cross-border freight traffic or the growth in that market. As noted in the discussion of ports above, however, the picture will change dramatically if a large container port materializes at Punta Colonet. A high level of rail service would be essential to the success of the new port, and the potential for new business is certainly adequate to attract the attention of the large railroads. Both Ferromex, which is a partner of both BNSF and UP, and KCSM stated their interest in building a line from Punta Colonet to Mexicali early on in discussions of the new port. UP has itself been a major player in proposals for the development of Punta Colonet, suggesting a rail access route that would pass from the port, in Baja California, into Sonora and then cross into the United States in Yuma County, Arizona (Neyoy 2007). UP recently withdrew from a partnership with Hutchison Port Holdings that was to bid on the development project, however, and the railroad's current commitment to the project is unknown. The Mexican government's plan for the bid specifications is said to require completion of the new rail line to Punta Colonet within three years of award of the contract.

Air

Only a very small part of the freight traveling between the U.S. and Mexico moves by air, although its percentage by value (4 percent) exceeds its percentage by weight (less than 1 percent), as shown in Figure 2. None of the three airports in the California/Baja California region handles large amounts of cargo, and given the nature of cross-border trade as discussed above, there is no reason to expect that air will become an important mode for that trade in the future. A summary of the movement of goods by air between California and Mexico is nonetheless included here, for completeness.

Data on freight that was transferred between California and Mexico in 2005 using commercial aircraft is available from BTS' T-100 segment (all carriers) dataset (Bureau of Transportation Statistics 2007a). This data set provides detailed information about individual aircraft operations, including flight origination and destination and the amount of freight carried. Tables 12 and 13 show air cargo tonnage between California and Mexico broken out for airports of interest, either because they lie in the border region or because they are major air cargo hubs.

As Table 12 indicates, more than 97 percent of air cargo from Mexico to California enters the state at the Los Angeles International Airport (LAX). Air freight services are provided at LAX for 25 Mexican airports, but two Mexican airports account for the bulk of the traffic: Mexico City and Guadalajara send 87 percent of northbound traffic and receive 97 percent of southbound traffic.

Details concerning the type of freight handled are not available specifically for California, but BTS does have some national estimates that show commodity flow patterns for air traffic between the United States as a whole and Mexico, as summarized in Table 14. Most of the air cargo traffic between the United States and Mexico is associated with the shipment of electrical and computer parts, with the United States exporting to Mexico more than it imports (see Table 14).

Table 12: Air Cargo Traffic Entering California From Mexican Airports in 2005, Tons

Mexican Airports	California Airports				Total
	Los Angeles	San Diego	San Francisco	Other California	
Guadalajara	10,620	0	91	13	**10,723**
Mexicali	44	0	0	0	**44**
Mexico City	15,795	0	182	1	**15,978**
Tijuana	0	0	0	0	**0**
Other Mexico	3,197	8	579	3	**3,388**
Total	**29,657**	**8**	**855**	**16**	**30,536**

Source: Bureau of Transportation Statistics 2006c

Table 13: Air Cargo Traffic Leaving California for Mexican Airports in 2005, Tons

Mexican Airports	California Airports				Total
	Los Angeles	San Diego	San Francisco	Other California	
Guadalajara	22,433	0	22	28	**22,482**
Mexico City	17,728	2	41	0	**17,772**
San Jose Del Cabo	108	20	22	1	**151**
Tijuana	0	0	0	0	**0**
Other Mexico	928	1	35	2	**966**
Total	**41,197**	**24**	**120**	**31**	**41,371**

Source: Bureau of Transportation Statistics 2006c

Table 14: U.S. Commodity Flow between Mexico and the United States via Air Freight Mode, Millions of U.S. Dollars

Description	Exports to MX	Imports to U.S.
Electrical machinery and equipment and parts	2,119	1,197
Computer equipment	1,543	884
Pearls, stones, metals imitation jewelry	489	250
Measuring and testing instruments	484	218
Re- importation	10	434
Pharmaceutical products	403	27
Aircraft, spacecraft, and parts thereof	247	2
Works of art, collectors' pieces and antiques	87	21
Knitted or crocheted apparel	16	82
Organic chemicals	67	29
Total, top ten commodities	5,464	3,144
Top ten share of all commodities (percentage)	91	91
Total, all commodities	**6,013**	**3,456**

Source: Bureau of Transportation Statistics 2006b

CHAPTER 2: Options to Improve the Efficiency of Cross-Border Goods Movement

This chapter assesses opportunities to shift trips across the California-Baja California border from truck to other modes, particularly rail, as a means of reducing emissions and energy consumption associated with the cross-border movement of goods. Preceding that discussion is a description of the characteristics of cross-border truck movement that contribute to both the value and the viability of such modes shifts. The chapter also discusses options other than mode shift to improve the energy efficiency of cross-border goods movement.

Truck Transport: Inefficiencies and Opportunities

Transporting goods across the border is an often complex and time-consuming process that involves not only the exchange of physical goods and documentation, but properly timed exchange of electronic information as well. A dozen or more parties are regularly involved in the exchange of a single shipment of goods, including but not limited to the original shipper, Mexican long-haul carriers, drayage carrier, Mexican customs broker, Mexican customs inspection agents, U.S. customs broker, U.S. Customs inspection agents, other U.S. agents (for example, USDA, FDA, EPA, DOT, etc.), U.S. long-haul carrier, and final goods recipient (Ojah, Villa et al. 2002).

Traffic congestion at border crossings is a regular occurrence, caused by border inspection and processing procedures, traffic volumes exceeding infrastructure limits, and vehicle breakdowns. Estimates of average time spent in the border crossing process vary widely. A Congressional Research Service estimate cites four to five hours for northbound shipments and, for southbound shipments, four to five hours for frequent carriers and up to three days for infrequent carriers (Kirk and Frittelli 2004). With regard to congestion-related delays alone, there is greater agreement, although delays vary greatly among POEs and by time of day.

Congestion and delays at the border restricting passage of goods have negative impacts in three areas: energy (excessive energy consumption associated with idling queued vehicles and the movement of trucks with empty containers), emissions (higher pollution associated with idling trucks), and economic (lost output and jobs). While cross-border trade has grown rapidly over the past two decades and will continue to do so, crossing policies and practices and infrastructure improvements to POEs have been slower (SANDAG and Caltrans 2006). The result has been increased congestion and unpredictable delays at the border, costing economies of the area an estimated $4.2 billion in output in 2005, as well as an estimated 35,000 jobs (SANDAG and Caltrans 2006). Energy- and emissions-related impacts of this congestion will be estimated in Chapter 3 of this report.

At the same time, border delays generally account for only a small fraction of the total fuel consumption and emissions of trucks that carry goods across the border, as shown later in this report (see Table 20). Consequently, efforts to address border issues need to look well beyond the border itself to best capture the opportunities to reduce energy and environmental costs of these trips.

Drayage and Mexican Customs Brokers

Because of the inefficiencies of border crossings, many long-haul carriers will pay a few hundred dollars per truck to enlist the services of drayage carriers. Drayage carriers use a separate fleet of trucks to shuttle goods short distances across the immediate U.S.-Mexico border. Granted permission to travel within commercial zones extending up to 20 miles into the neighboring country, dray truck drivers engage loaded trailers from a long-haul carrier's border depot, collect necessary documentation, handle goods and documentation through the border crossing process, and transfer the goods to the appropriate long-haul border depot on the opposite side of the border.

The use of dray trucks contributes considerably to border congestion, because empty trucks must return to their original terminal to pick up new loads. While dray trucks could theoretically be used to pick up a Mexican-bound delivery after dropping off a U.S.-bound shipment, for example, thereby minimizing the number of empty-backhaul trucks on the road, this is not common practice (Kirk and Frittelli 2004).

Trucking to and from maquiladoras occurs largely independent of drayage operations, as maquila-based goods are effectively pre-cleared for expedited delivery. This pre-clearance reduces both U.S. and Mexican crossing time and, aside from periodic selection for inspection at the border, maquiladora trucks are subject only to congestion-related delays.

There is a mutually beneficial relationship between drayage and Mexican customs brokers, and indeed they are often affiliated with one another; Mexican brokers frequently arrange for a drayage company to shuttle goods across the border. Unlike U.S. customs brokers, who verify the load and are legally responsible only for declaration form accuracy, Mexican brokers are legally liable for the actual shipment contents. As a result, Mexican brokers typically visually inspect the cargo they oversee. Time delays associated with Mexican broker requirements make drayage an appealing option to delivery firms that cannot afford to have their drivers otherwise delayed for extensive periods of time.

In addition to the complex process, local practices and policies also affect delays. Mexican customs brokers, for example, typically release trucks in groups rather than individually, and have been noted to have hours of operation that also compound congestion problems (Combs 2001).

Efficiency Opportunities for Trucking

One approach to reducing the energy consumed in cross-border trucking is to raise the fuel efficiency of the trucks themselves. Fuel efficiency technologies are discussed in Chapter 5. Improving operational efficiency of the crossing process can also improve energy efficiency because the extended idling, stop-and-go driving, and empty backhauls currently associated with border congestion serve to increase fuel consumption.

The FHWA Demonstration Project

NAFTA, which took effect in 1994, called for the phasing out of geographic trade restrictions on Mexican truckers by January 2000, given truck compliance with U.S. safety standards. The phase-out has been delayed for years, however, due to security, safety, environmental, and competitive concerns. In February 2007, Mexican and U.S. transportation officials announced a demonstration program to begin implementing NAFTA's trucking directive by allowing up to 100 approved Mexico-based carriers to operate beyond the commercial zones (U.S. Department of Transportation). The program was intended to highlight both safety programs adopted by Mexican carriers and DOT-developed monitoring and enforcement systems, but has proved tremendously controversial, sparking a lawsuit and Congressional action on the U.S. side to prevent implementation.

While through trucking at the border clearly could eliminate much inefficiency in the crossing process, the energy implications are not obvious. It would reduce the use of dray trucks, which tend to be older than long-haul trucks and consequently are likely to have higher emissions of criteria pollutants. The correlation between age and fuel consumption is not nearly as strong, however, 2002 Vehicle Inventory and Use Survey data indicate that heavy truck fuel economy improved at less than 1 percent per year on average over the period 1988-2003 (U.S. Census Bureau 2002). Eliminating dray trips could reduce fuel consumption by reducing empty backhauls, congestion, and circuitous routing, but a separate analysis would be required to estimate the size of this benefit.

Streamlining of cross-border trucking in principle could detract from the viability of certain alternatives to trucking, especially short-distance rail or shipping, whose appeal stems largely from the inefficiency of the border crossing. The magnitude of the border delay problem is such that no single remedy will be sufficient to address it, and the various options proposed here should generally be regarded as complementary, not mutually exclusive.

Expedited Crossing Programs

The Free and Secure Trade (FAST) program is a bilateral agreement between the United States and Mexico to expedite the screening and clearance of pre-approved commercial shipments at the border, improving shipment processing and minimizing border delays. It entails a coordinated international effort using common advanced technology, supply chain security, minimized customs requirements, utilization of dedicated lanes for FAST participants, and reduced physical inspection frequency for members of the program (U.S. Customs and Border Protection Unknown). The FAST program began in September 2003 in El Paso, Texas and has since spread to other ports of entry. As of August 31, 2006, FAST processing was available at Otay Mesa, Calexico, and Tecate, as well as other POEs in Texas, Arizona, and New Mexico.

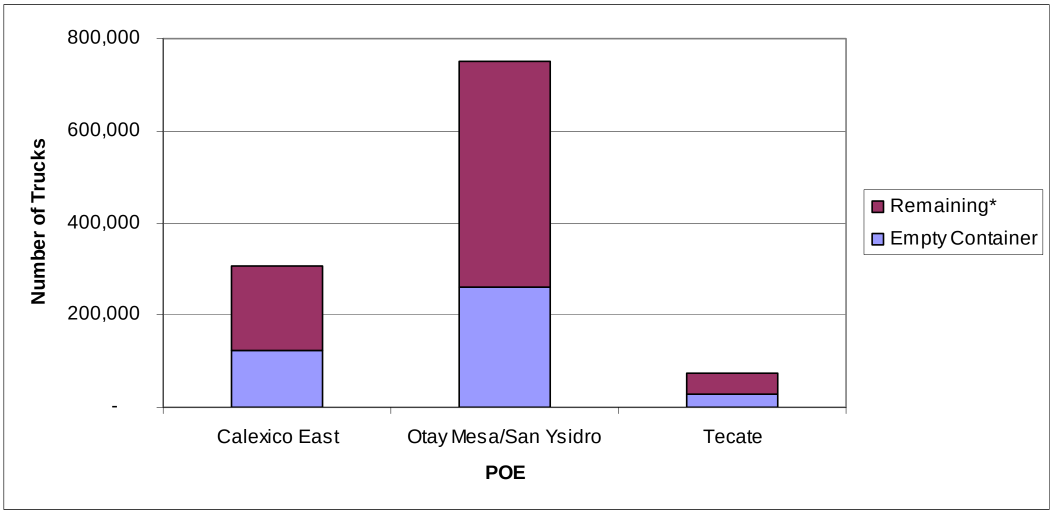
Despite the existence of dedicated facilities for expedited shipments and, in some instances, for empty trucks, extension of approach lanes would permit better utilization of these facilities. In addition, more companies could be included in these programs.

Empty Trailer Travel Reduction

Empty trailers represent a huge inefficiency in cross-border trucking. Truck carriers lacking arrangements for bidirectional shipments are often forced to return to their point of origin (or next destination) with empty trailers. This practice, known as deadheading, not only wastes fuel in moving empty trucks, but also contributes to congestion at the ports of entry.

As shown in Figure 10, DOT estimates that empty containers currently constitute between 35 and 40 percent of all U.S.-bound trucks at the three largest POEs. Other sources place those figures even higher. SANDAG estimates that at Otay Mesa, the largest commercial POE along the California-Baja California border, 45 percent of northbound trucks and 50 percent of southbound trucks carry empty trailers (SANDAG 2006a).

Figure 10: Commercial Truck Border Crossings Into the United States at Selected Ports of Entry, 2006



Sources: Beningo 2007; Bureau of Transportation Statistics 2008

*"Remaining" may not be equivalent to "loaded" due to data discrepancies.

A number of factors contribute to deadheading: timing and location mismatches between import and export loads; container ownership conflicts; physical trailer mismatches, among others. Use of a load-matching service that pairs available deliveries with empty trucks could reduce the amount of empty trailer travel to and from the border region.

Infrastructure Improvements and New Ports of Entry

Highway infrastructure improvements and the addition of new ports of entry could play a role in reducing traffic congestion and improving overall trucking system efficiencies, and a number of efforts are already underway to ease heavy congestion occurring near ports of entry. At Otay Mesa, for example, Mexican policies requiring inspection of unloaded trucks entering Mexico are causing large amounts of southbound traffic queuing. Despite the size of this POE and its large truck volume, it is connected to the California highway system only by a four-lane local street running at three times its nominal capacity (Caltrans 2006). Caltrans plans to add additional truck lanes to certain local roads, along with intersection improvements. They have also identified a long-term project of constructing a new roadway for the border frontage road, additional truck lanes on existing roadways, and emergency and dedicated truck lanes throughout the truck route. These southbound congestion relief efforts would help minimize impacts on local traffic patterns and businesses, as well as improve functionality of nearby SR-905.

Congestion on northbound trucks has been partially minimized by the 2004 completion of a northbound truck connector between the Mexican export facility and U.S. import facility (that also accommodates empty trucks). This minimizes wait time for roughly one-third of the trucks; to further minimize congestion for the remainder of trucks, two expansion plans (a short-term one-lane expansion, and a longer-term four-lane expansion) for the road connecting these facilities have been planned.

Two miles east of Otay Mesa is the planned site of the East Otay Mesa POE, which will provide alternate cross-border routes for commercial and passenger vehicles. It is projected that 25,000 vehicles per day will cross at East Otay Mesa by 2020 (Caltrans 2006).

Development of a POE at Jacumba/Jacume would ease congestion in the Tecate POE, which is expected to see significant growth in commercial traffic. A new POE at Jacumba could divert between 1,500 and 5,900 vehicles per day from other POEs (Caltrans 2006). The project would cost between $10 million and $60 million, and at this time there is no schedule for project implementation. Other congestion relief projects include State Route 11, Tecate Commercial Vehicle Enforcement Facility, SR-78 "Brawley Bypass," I-8/Imperial Avenue interchange, and SR-98.

Conveyor Belts

Aggregate Products received a Presidential Permit in April 2003 for a Calexico-Mexicali conveyor belt that would bring construction materials into the United States. The belt has been completed, but the owner has had difficulty in obtaining all of the required Mexican permits. The project is expected to begin operation at the end of 2008. In Otay Mesa, Austin Industries has been awaiting a Presidential Permit since 2001 for conveyor belt that would deliver aggregate from Baja California to California (Economic Research Bureau 2007). Caltrans has expressed concerns that the project could affect Otay Mesa East development.

Variations on the conveyor belt concept may warrant consideration for other cross-border product flows. To date, proposals have been limited to movement of bulk products.

Rail Opportunities

This section explores the potential for greater use of rail to move goods across the California-Baja California border. Rail already plays an important role in the movement of goods across the U.S.-Mexico border as a whole. For the upper Midwest, for example, rail is the dominant mode for trade with Mexico (TransSystems Corporation 2006).

Along California's stretch of the border, however, rail plays a much smaller role in freight movement today. The primary goods movement corridors of the region, namely the two north-south corridors through Tijuana and Mexicali and the east-west corridor along the border, all have freight rail service, but these lines are not heavily used.

Overview

As discussed in Chapter 1, goods movement across the California-Baja California border is largely short-distance trade, with most goods originating or terminating in the bottom 135 miles of California and clustered even closer to the border on the Mexican side. The distance at which intermodal rail service becomes competitive with trucking is generally taken to be around 500 miles and, for carload freight, considerably further. The greater handling required for rail moves, including drayage (in this context, short moves by truck at either end of the trip), and the need to assemble large quantities of goods for a single train are large advantages for door-to-door trucking at shorter distances. Furthermore, trends toward less concentrated industrial development, expanded highways, and abandonment of rail sidings have all contributed to a dramatic decline in railroads' freight share of goods moved over the past 60 years.

More recently, however, congestion, energy price and supply issues, and environmental concerns have all led to a reexamination of rail's role in goods movement. This coincides with a dramatic increase in international trade and the rise of intermodalism, which also call for a rethinking of established railroad practices and principles. In particular, there has been an effort to find ways to make freight rail work at distances of less than 500 miles, especially where the trucks face high levels of congestion and the impacts of truck traffic are particularly severe.

Conventional short line railroads operate over distances of well under 500 miles and often travel just a few miles. These are typically special purpose railroads, however, serving to carry loads too heavy to carry by truck, to meet the needs of a particular client or location, or to provide a feeder service for a major railroad.

New short-distance rail services under consideration today are shuttle trains to carry goods from crowded centers of activity to nearby distribution facilities, or "inland ports," often 50 to 100 miles away. Several ports in the United States have considered shuttle services to reduce pollution and congestion, save energy, and increase the flexibility of the goods movement network. However, the circumstances in which a shuttle service can make economic sense are limited. Proposals for shuttles have been made on various occasions in California, but neither BNSF nor UP has been eager even to test one (Business Transportation and Housing Agency and California Environmental Protection Agency 2007).

From this perspective, rail opportunities in the California-Baja California border region warrant serious consideration, despite the preponderance of short trips. Relevant features of goods movement in the region include the presence of concentrated freight generators, including seaports, land ports, and maquiladoras; heavy traffic congestion and long wait times at the border; the practice of draying goods across the border; and high levels of concern about air quality and emissions.

In view of these considerations, the principal questions investigated in this section are whether improvements to rail service can capture more of the long-distance portion of cross-border trade; whether short lines or nontraditional rail options can serve a substantial portion of shorter-distance moves; and whether major changes in the quantity or character of cross-border trade are likely to introduce new opportunities for rail in the near future.

North-South Corridors

This section evaluates the potential to attract more cross-border freight to rail in the two principal north-south corridors, in light of the discussion in the previous section. In this assessment and those in succeeding sections, the authors' objective was to identify options that merit further consideration. Therefore, the approach was designed to estimate the largest plausible volumes of freight that could be captured by the various options considered.

Approach

To assess potential rail markets, the authors disaggregated the flow of goods by characteristics that determine whether and how the goods might be diverted to rail. They divided goods that are now trucked across the border at Otay Mesa and Calexico into high- and low-value goods, and by distance traveled (long or short).

BTS Transborder Freight Data (BTS 2007b) provides data, by POE, on the value and tonnage of goods trucked north, and on value only for goods trucked south. The authors used the northbound data to generate dollar-per-ton values for each commodity and then to estimate the tonnage of southbound goods of each commodity type by assuming the same dollar-per-ton values for each commodity as for northbound goods. They then classified goods trucked in each direction as high-value or low-value, taking $1,000 per ton as the dividing line. Value serves as a surrogate for time sensitivity, an important factor in determining what can be diverted to rail. Goods that must move quickly and arrive at a predictable time are poor candidates for diversion to conventional rail service. In this analysis, perishable products were classified as high value, even if valued at less than $1,000 per ton, because they are time sensitive.[7]

To separate long- and short-distance flows southbound, the authors used BTS state-level data (BTS 2007b), which provide the amount of each commodity traveling from each U.S. state to each state in Mexico. For simplicity, they defined short-distance trips to be those between California and Baja California, and long-distance to be those with either origin or destination outside these two states.[8]

For northbound goods, BTS data does not include Mexican state-of-origin information. In this case, the authors took the short-distance percentage of each commodity flow through a POE to be the fraction of northbound trips ending in California (86 percent for Otay Mesa and 66 percent for Calexico). This estimate fails to distinguish between trips from Baja California and trips from all of Mexico, and applies the same factor to all commodities, but the result should be adequate for this preliminary assessment of options.

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[7] The dollar-per-ton threshold for traditional rail service is often taken to be far lower than $1000 per ton; in fact, goods of this value might be regarded as beyond the reach even of intermodal service (see for example, AASHTO (n.d.). The purpose of choosing high value thresholds here is to begin with an optimistic view of the potential for rail, allowing for nonstandard services appropriate to the circumstances at the border.

[8] This characterization ignores the fact that parts of California are more than 500 miles from the study area, while other states such as Nevada and Arizona are largely within 500 miles; but freight flows to and from these areas are small enough that the basic conclusions of this section will not be affected by this approximation.

Using this approach, the authors partitioned existing truck tonnage at each crossing into four flows: low value, short distance; high value, short distance; low value, long distance; and high value, long distance, shown in Table 15. The next step was to estimate the tonnage in each flow that could be captured by a rail. To inform these estimates, the authors first considered issues associated with the existing north-south rail lines, as described in the next section.

Table 15: Truck Tonnage by Flow Characteristics and Crossing, Metric Tons, 2007

	Calexico		Otay Mesa	
Flow characteristics	**Northbound**	**Southbound**	**Northbound**	**Southbound**
Low value, short distance	398,755	585,244	282,378	703,288
High value, short distance	669,405	562,199	2,123,218	1,469,523
Low value, long distance	205,419	246,766	45,968	197,080
High value, long distance	344,845	163,528	345,640	526,123

Source: Authors, based on data from BTS 2007b

Existing Rail Service Issues

The SDIY South Line from San Diego to Tijuana parallels the truck route through the Otay Mesa POE but crosses five miles to the west at San Ysidro. In principle, goods from throughout the BNSF system could travel to Los Angeles by rail, then south to BNSF's interchange with the SDIY at National City in San Diego, and on to Tijuana via the South Line. Capacity constraints and inadequate connections limit traffic along this route at present, however. The BNSF line from Los Angeles shares track with both the Amtrak route from San Luis Obispo to San Diego and the Coaster commuter line. In addition, the South Line has only a 3-hour operating window each day because it shares track with the San Diego trolley. Finally, storage yard capacity is lacking in the area (Pallares 2007).

Projects to address these issues have been under consideration for some time. These include completion of a third track along the South Line or, alternatively, acquisition of trolley cars meeting federal crash standards, which would allow passenger and freight traffic to share the tracks during the day (Hoegemeier 2006). Federal funding is already in place for 80 percent of the total cost of a rail storage yard at San Ysidro. However, while there is enthusiasm for improvements to the line among public and private interests in San Diego, BNSF does not believe that demand for the connection to Mexico is sufficient to make it a priority for development at this time (Rodriguez 2007).

While one might expect that the rapid growth of Ports of Los Angeles and Long Beach would accelerate rail upgrades in this corridor, these ports generate only 56,000 of the 345,000 loaded truck trips to and from Los Angeles County that cross the border annually, according to best available estimates (Caltrans 2006). The Mexican market is not currently large enough for the Ports of Los Angeles and Long Beach to place high priority on the movement of goods across the Mexican border, given the many other transportation needs associated with the ports' meteoric growth, although the Port of Los Angeles is interested in increasing the flow of agricultural products from central Mexico by water (Almanza 2007b). Furthermore, both UP and BNSF are facing severe capacity constraints in Southern California associated with growth at the Ports of Los Angeles and Long Beach, and they generally will prioritize the largest freight flows, namely those traveling cross-country along east-west corridors, in their capital investment plans and service improvements.

In the Calexico corridor, the existing UP line transports bulk goods but is not equipped to handle intermodal traffic. Ferromex's rudimentary yard in Mexicali is the extent of intermodal facilities in the general vicinity of the crossing. UP currently drays goods from this area to Los Angeles to transfer them to rail (Hernandez 2007). UP has not expressed any interest in upgrading the line and notes, more generally, that it is reducing, not increasing, the number of lines that handle intermodal freight (Baker 2007). At the same time, UP's east-west Sunset Route into which the line through Calexico runs, is undergoing a major upgrade to handle intermodal traffic.

The viability of higher-volume rail service in either of these freight corridors is enhanced by the delays and other inefficiencies of trucking goods across the border. In this regard, the San Ysidro/Otay Mesa corridor is a better prospect for rail, in that congestion at that crossing is far more severe; while bottlenecks during peak hours and delays northbound are routine at Calexico, typical time to cross the border there is about half as long as at Otay Mesa (SANDAG and Caltrans 2003).

Rail Markets in the North/South Corridors

Using the partition of current cross-border truck tonnage into four flows, as shown in Table 15, the authors estimated the maximum fraction of each of these flows that could plausibly be captured by suitable rail service. Suitable service for the four flows might be defined as follows: short-haul bulk and carload rail service for low-value, short-distance trips; shuttle services similar to those under consideration for today's overcrowded maritime ports for high-value, short-distance trips; traditional long-haul service for low-value, long-distance goods; and intermodal service for long-distance, higher-value goods.

The authors estimates of maximum capture rates range from 0 to 40 percent (Table 16). At the Ports of Los Angeles and Long Beach, where there is a well-developed rail infrastructure, rail transports 43 percent of goods moving in and out, including on-dock, near-dock, and off-dock rail transfers (Parsons 2006). The authors took this as an upper bound for achievable mode share for rail crossing the border, reflecting the substantial degree of dispersion of origins and destinations on the U.S. side.

The estimates in Table 16 are the authors' judgments based on several considerations, including the level of rail service available today, concentration of shippers and receivers along the line and at either end of the line, and key commodities in each flow. For example, the existing rail line through Calexico already offers service appropriate for low-value, long-haul goods, so the authors assumed that there is little opportunity to divert additional goods of this kind to rail. On the other hand, intermodal along this line is unavailable at present, and provision of such service could likely attract customers among the Mexicali maquiladoras.

Table 16: Maximum Freight Capture Rates and Rail Markets in Metric Tons per Year

		Calexico		Otay Mesa	
	Service Type	Northbound	Southbound	Northbound	Southbound
Capture Rate	Low value, short distance	0	0	0.2	0.1
	High value, short distance	0.3	0.2	0.3	0.2
	Low value, long distance	0	0	0.3	0.2
	High value, long distance	0.4	0.4	0.4	0.4
Market Size	Low value, short distance	0	0	56,476	70,329
	High value, short distance	200,821	112,440	636,965	293,905
	Low value, long distance	0	0	13,791	39,416
	High value, long distance	137,938	65,411	138,256	210,449

Source: Authors

Multiplying the capture rates by the tonnages in Table 15 gives estimates of the market size in tons for each rail service, as shown in Table 16. Table 17 shows the rail market estimated in Table 16 as percentages of the total tonnage currently trucked through each POE.

Table 17: Diversion Percentages of Cross-Border Tonnage by POE and Flow Type

	Calexico	Otay Mesa
Low value, short distance	0%	2%
High value, short distance	10%	16%
Low value, long distance	0%	1%
High value, long distance	6%	6%
TOTAL diversion potential	16%	25%

Source: Authors

It should be noted that this analysis does not consider the economic feasibility of the rail services required to meet the needs of these four freight flows. A shuttle service to carry intermodal freight short distances (high value, short distance), for example, which shows the highest potential to capture cross-border tonnage, would be a novel rail service for the border region and carries a heavy burden of proof of feasibility. The economics of these services will be considered in the next chapter.

The East-West Corridor

The rail corridor between the two north-south lines is crucial to the discussion as well. Further rehabilitation and restoration to modern service of both the Mexico and Desert Lines the SD&AE are necessary to improve the market potential of this route. A fully functioning rail line in this corridor could attract new, rail-dependent businesses between Tijuana and Tecate (SANDAG 2007) and provide a connection from the border region to the main U.S. rail network that does not pass through the congested Los Angeles area.

A detailed analysis of the potential markets for the SD&AE Line was conducted for SANDAG to assess the benefits of rehabilitating the Desert Line, which was then out of service (SANDAG 1999). Not all of the markets considered in the study involve border crossings, and the information is outdated, but the analysis nonetheless provides a wealth of insights and estimates that are still relevant. The analysis is based on considerations specific to commodity, service type, direction, and length of trip.

One conclusion of the SANDAG study was that the SD&AE line has the potential to divert 32,185 truck trailer equivalents per year, 10 years into the operation of a "modern" service on the line. This amounts to about 7 percent of today's northbound loaded truck traffic through Otay Mesa. "Modern" was defined as having the capacity to handle double-stack rail cars and supporting facilities such as storage yards and an intermodal transfer facility. Some of the diversions represent eastbound San Diego traffic and are therefore not border-related per se; they include municipal solid waste containers traveling to eastern California, intermodal containers from the Port of San Diego, and diversions from long-haul trucks bound for eastern markets. However, about one-third of the diversions are associated with cross-border trips between the U.S. and maquiladora operations in Tijuana and Mexicali.

The Mexico and Desert Lines today provide short-haul service only, but they relate to the above analysis of rail markets in the north-south corridors in several ways. First, these lines pass through an area of industrial activity that generates a need for raw materials from the United States. This need can better be met by a rail service that connects to long-haul rail lines. Second, the Mexico and Desert Lines create, through the UP connection in Plaster City, an alternative option for goods in the Tijuana area to access the Class I rail network for trips to the U.S. Midwest and East Coast. Third, they support expansion of container handling capacity at the Ports of Ensenada and San Diego. An intermodal terminal hosting customs facilities has been proposed along the line, midway between Tijuana and Tecate, to promote the transfer of goods arriving through Ensenada to rail (Freire 2005). In the absence of a rail connection directly to Ensenada, however, it is not clear that such a facility would contribute substantially to the rail market (SANDAG 1999).

SANDAG is supportive of efforts to improve rail in the area and has proposed rehabilitation of track on the Mexico Line (SANDAG 2007). A number of additional projects have been identified by SANDAG as important to achieving the above stated benefits:

- Improving track alignments and tunnel clearances to accommodate modern freight vehicles that carry double-stack containers and automobiles.
- Locating an accessible site within the San Diego/Tijuana region for an intermodal yard to handle truck-to-rail transfers.
- Building additional storage yards at the Port of San Diego and San Ysidro to accommodate increased freight movements.

CZRY personnel are optimistic about the potential for rail to capture a substantial fraction of containers now crossing the California-Baja California. Finished goods that are trucked from the maquiladoras to the U.S. interior contend with border congestion at Otay Mesa, then drive to Los Angeles for transloading to rail to Chicago. Sending these goods directly to the east on the Desert Line and up into the UP network could compete with a truck-to-rail route such as this on price and, in some cases, on time (Wear 2007).

New Rail Lines

In addition to the potential growth in demand for rail in the corridors discussed above, other markets exist or may materialize in corridors that do not yet have rail lines.

Ensenada-Tecate

The proposal to construct a rail link between the Port of Ensenada and the border is mentioned frequently but shows little sign of advancing at present. While CZRY shows interest in pursuing this connection, broader interest in the proposal is directly tied to the possibility of a major expansion of intermodal capacity at Ensenada. This in turn relates to the prospects for other Mexican ports.

For the time being, interest in the development of Punta Colonet and public opposition to a rail line to Ensenada seem to relegate this matter to a back burner. The Port of Ensenada's current position that expansion of the port's capacity will stop at 250,000 containers per year limits the potential market for a rail connection to the SD&AE Line, as well as the relief it could provide to cross-border truck traffic.

Punta Colonet

Construction of Punta Colonet would greatly increase rail movement from Baja California to the United States. The role of Punta Colonet as an alternative access port for Asian markets exporting to the Midwestern and Eastern United States means that goods arriving at the port typically would be traveling far in excess of the 500-mile distance considered appropriate to rail intermodal service.

The net implications of the development of Punta Colonet for cross-border truck traffic are unclear. Existing rail configurations on the U.S. side of the border are such that the rail line from the new port into the United States would head northeast across Baja California and cross the border near Mexicali or Yuma County, Arizona. A new high-volume intermodal route through Mexicali would not only provide a much-improved level of service for the long-distance rail market there, but could also add to the growth of maquiladora industries in Mexicali.

This arrangement would leave interest in a more western rail connection from Baja California to the United States unresolved, however. California-bound goods from the maquiladoras and northbound truck traffic at Otay Mesa would be largely unaffected by the new service. Goods shipped into Punta Colonet and heading to California could even increase this traffic, but California will not be a major market for the new port. To the extent that materials for the maquiladoras arrived from Asia at Punta Colonet rather than at U.S. ports, cross-border truck trips would decline.

Ports and Maritime Transportation

Given the geography of the border region, opportunities to eliminate cross-border truck trips through greater and more efficient use of maritime options warrants consideration. Potential opportunities include expansion of shipping along the California-Baja Coast and expanded direct service between Baja California and Asia to capture goods that are now diverted through California ports and trucked across the border.

Short-Sea Shipping

Along with crude oil and petroleum products, containerized goods constitute a major component of maritime shipments between Mexico and California. As shown in Tables 7 and 8 in Chapter 1, container ships carry 43 percent by weight of waterborne trade between Mexico and California. These container ships call on Pacific Coast ports in California or Mexico, then move on to one or more ports on the other side of the border a day later. Other containers with Mexico as final destination are unloaded in California and travel across the border in trucks.

An alternative to surface modes in congested corridors near major container ports that is receiving considerable attention nationwide is short-sea shipping. The target market for short-sea shipping would be international containers that could be loaded efficiently onto ships or barges and forwarded to or from larger container ports.

Several services of this type are under consideration in California, including overnight service carrying trailers between the Ports of Los Angeles and Long Beach and the San Francisco Bay area, and a container barge between the Ports of Los Angeles and Long Beach and the Ports of San Diego and Hueneme (Business Transportation and Housing Agency and California Environmental Protection Agency 2007).

The Port of Los Angeles has tried pilot projects with Pacific Coast ports in Mexico on at least one occasion, with Manzanillo (Santich 2007), but volumes did not appear to be adequate to sustain a regular service. In addition, the port's inquiries regarding shipping possibilities to Ensenada brought a negative reaction from border region truckers. Nevertheless, the Port of Los Angeles is continuing its investigation of such opportunities going forward.

Opportunities and Obstacles

A short-sea shipping service between the Ports of Los Angeles and Long Beach and the Port of Ensenada has the potential to divert cross-border truck trips. Trucks from elsewhere in Los Angeles County would not be likely to use this service, given the inefficiency of transporting the goods into a terminal at the already-congested California ports. Using SANDAG’s 2003 estimate of 56,400 loaded trucks annually crossing the California-Baja border en route to or from the Ports of Los Angeles and Long Beach, and applying the 8-percent growth rate of port traffic, the authors estimate there are currently 77,000 such trucks.

Westar Transport has proposed a system of short-sea shipping services on the West Coast, providing next-day service within distances of up to 400 miles (Silva 2006). Westar’s model involves moving containers by truck from ocean-going container ships to a roll-on/roll-off terminal within a port, then loading to smaller ships or barges that carry 500 to 700 trailers or containers on chassis (Silva 2007). A market of 77,000 truck trips could therefore translate to 100 to 150 ship or barge trips, or 2 to 3 per week. This level of service could compromise the service’s ability to compete with trucks on time, although a review of the details of container ship arrivals and departures from Asia would be required to determine whether this is a fatal flaw. The rapid growth of Pacific Rim cargo should also be taken into account; at current rates of growth, volumes could be expected to justify five trips per week within a decade.

Current container traffic at Ensenada is 124,000 TEU per year, half of the 250,000 TEU capacity. Assuming two TEUs per truck trip, Ensenada can therefore accommodate additional goods diverted from 63,000 truck trips per year. Thus there is at present a good match between the potential market for a short-sea shipping service and capacity, and Ensenada proposes to double capacity in the coming years.

Just as for rail, the question arises whether the distances involved, for example, the 185-mile trip from the Ports of Los Angeles and Long Beach to Ensenada, are sufficient to allow a service of this kind to compete with trucking. Given that international containers often sit for days in ports awaiting transfer to truck or rail, however, a water route could in principle reduce time to destination, even on a short-distance route.

Other proposals in addition to Westar's have been advanced to establish barge or vessel services connecting west coast ports by sea as a means of circumventing highway congestion and lowering costs. One such proposal is the California Inter-Regional Intermodal System (CIRIS) studied by the San Joaquin Council of Governments (The Tioga Group, Railroad Industries et al. 2006). Generally, a barge service would be used to forward international containers from one west coast port to another, while a faster-moving vessel would move more time-sensitive, domestic freight. Barges could accommodate containers or a roll-on, roll-off (RO-RO) service, while vessels would be RO-RO operations only. RO-RO operations bring trailers or containers on chassis aboard, making them operationally efficient with respect to the drayage at either end. This sacrifices the efficiency of the water move itself, however, since no stacking of boxes is permitted, which dramatically reduces the volume of goods that can be carried on each trip.

Obstacles to establishing a short-sea shipping service include the shortage of port terminal acreage and multiple cost considerations. Among these is that the Jones Act requires ships traveling between domestic ports be built in the United States, which adds substantially to cost. While the Jones Act would not impact ships dedicated to service between Mexico and the United States, it might impact the shipping lines' flexibility in how they use their fleets, which could be seen as an indirect cost. Another cost concern is that the flow described here is largely one-directional, since Baja exports very little to Asia; the implications of this fact for the financial viability of the service needs to be considered.

Trans-Pacific Trade

Another approach to reducing truck travel associated with maquiladora trade with Asia is to divert this trade from the Ports of Los Angeles and Long Beach to other ports.

Ensenada

From a business perspective, the Port of Ensenada has several advantages over the Ports of Los Angeles and Long Beach as a recipient of containers coming from Asia to Mexico, namely it:

- Is located close to the maquiladora operations in Baja California.
- Eliminates the need for border crossing, saving $80-$120 per container.
- Experiences far less congestion than the Los Angeles area.
- Has fewer labor issues because labor is not unionized.

Furthermore, Mexican containers are allowed to carry more weight per container than are those in California (for example, 40-ft containers in Mexico carry 25 to 28 tons, while California has a 20-ton maximum).

As mentioned earlier, the Port does not anticipate being permitted to expand its capacity beyond 500,000 TEU annually. While this precludes the development of a major container port at Ensenada, this capacity is sufficient to accommodate the diversion of the 77,000 truck trips annually that carry goods between the Ports of Los Angeles and Long Beach and Baja California.

San Diego

As discussed in Chapter 1, the Unified Port of San Diego also plans to expand its capacity. While more activity at the port would increase truck traffic in San Diego, the net effect should be a decline in truck traffic. Goods now shipped through the Ports of Los Angeles and Long Beach could travel directly to San Diego, reducing truck miles for both San Diego and Imperial County trade with Asia, as well as for certain cross-border trips. In addition, greater activity at the Port of San Diego together with improvements to the SD&AE Railroad could promote a shift to rail as well as a shortening of trips.

Punta Colonet

While Punta Colonet is discussed primarily as a gateway for Pacific Rim shipments to reach the U.S. Midwest, it also raises the possibility of shipping more inbound maquiladora freight directly to Baja California. The potential market for this service is the same as that discussed above in connection with the Port of Ensenada, except that the capacity constraint of 500,000 TEU per year would not be relevant to Punta Colonet. Unlike Ensenada, Punta Colonet would not be a likely terminus for a short-sea shipping operation connecting to California ports due to the much longer dray trip to the maquiladoras.

Despite strong interest within the port community, much uncertainty remains about the development of Punta Colonet, in part due to its projected multi-billion dollar cost. The current Mexican government has made upgrading of infrastructure a focal point of its economic development program, however, and the bid process for Punta Colonet began in August 2008, with the winner to be announced in 2009. The port would be operational by 2014 at the earliest (Dickerson 2008).

Air Freight

The profile of air cargo flows between California and Mexico in Chapter 1 shows very little involvement of airports in the border region. Air cargo volumes in the area’s airports are increasing, although growth at San Diego International Airport is constrained by infrastructure limitations, and growth rates have fallen from the high levels of the years before 2001 (SANDAG 2007). Proposed projects to expand air cargo capacity in Baja California include a 148-acre air cargo distribution and multi-modal center in the Tijuana Airport and a FedEx air cargo hub between Ensenada and Tecate (Olivieri 2007).

In general, air transport is used by high-value, time-sensitive goods traveling large distances. Cost and value issues, rather than border delays and surface mode fuel costs, will drive decisions of whether or not to send goods by air. Therefore, diversion of goods to or from air cargo will not figure significantly in our analysis. However, as maquiladoras' production of high-value goods increases further, parts may be increasingly flown in from other parts of the United States or Asia. If San Diego International is the receiving airport, this practice will contribute to cross-border truck traffic. Use of an expanded facility at Tijuana Airport instead could mitigate this problem, but it is not clear that this is a practical solution. Most air cargo flies in passenger aircraft, and Tijuana Airport has almost no U.S.-bound flights.

Projections of the future use of air cargo to deliver parts to growing, high-value industries such as computers and aeronautics will be required to determine the importance of this issue for cross-border goods movement. It is unlikely to become a major concern in the near future, however, given the very small volumes involved.

CHAPTER 3: Benefits and Costs of Cross-Border Goods Movement Improvement Options

Introduction

The benefits and costs of goods movement and its infrastructure are shared by many parties in the private and public sectors. Aside from highways, freight infrastructure historically has been funded by the private sector. Steadily growing congestion in U.S. goods movement corridors and high levels of air pollution in areas of concentrated freight activity have prompted the public sector to take an active role in efforts to relieve congestion and facilitate goods movement, however. In California, these concerns led to the development of a Goods Movement Action Plan, completed in 2007 (Business Transportation and Housing Agency and California Environmental Protection Agency 2007), which focused on four priority corridors and regions, including the California/Baja California border region (the "San Diego/Border Corridor"). Concerns about petroleum dependence and greenhouse gas (GHG) emissions increasingly drive the activities of government agencies as well. Several funding programs allow strategic public investment in freight infrastructure. The idea of public funding of operating expenses has met with less enthusiasm, however (Casgar, DeBoer et al. 2003; Roop, Roco et al. 2003; Silva 2006).

Consequently, the discussion in this chapter deals separately with public and private benefits and costs. It begins with a comparison of public benefits and capital costs for each option to determine the project's cost effectiveness. This provides an indicator of the project's claim to public investment. The authors also compared operating costs and revenues for a single option (a rail shuttle from Los Angeles to Tijuana) to illustrate the considerations that would determine whether private sector operation of this option would be viable.

This is a rudimentary approach to a complex set of issues that in fact varies greatly from option to option. A detailed assessment of benefits and costs is beyond the scope of this report, however. The purpose of this discussion is to evaluate the various options with respect to the primary benefits of concern here, namely energy use and air pollution, and then to make some observations regarding the options' viability based on these and other benefits and capital and costs. The additional benefits, for example congestion levels, are in reality much greater drivers of investment decisions than either energy or air quality.

It should be noted that insufficient data is a barrier to a satisfactory assessment of the options discussed here. In particular, the distinction between intermediate and final destination of goods is not well-captured in the available data. For example, Asia-North American trade is generally believed to be a large generator of cross-border truck movements, but this is hard to substantiate. The viability of a short-sea or rail shuttle option, as well as the implications of Punta Colonet for the California-Baja border, depend on the degree to which this notion is borne out. This report relies upon data indicating that the Ports of Los Angeles and Long Beach generate only about 5 percent of loaded cross-border trips, but the actual percentage may be higher.

Table 18 displays the set of options discussed in Chapter 2, several of which will be further evaluated in this chapter. These options serve a variety of purposes and in many cases could work in concert to improve cross-border goods movement.

Table 18: Options – Pros and Cons

OPTION	EXAMPLE	PROS	CONS
Mode Shift		Viability generally will grow with increasing volumes	High capital cost; drayage requirements
Rail	Shuttle: Los Angeles-San Diego-Tijuana	Serves multiple growing markets	Switch in operator at San Diego
	San Diego-Tijuana-Tecate	Supports growth of Port of San Diego; alternative route from border area to Midwest	Small initial market; major upgrade required to connect to Midwest
	Punta Colonet-Tijuana-Los Angeles	Eliminates border crossing for goods from Asia; could boost use of rail at Mexicali	Limited impact on CA-Baja trips; implementation decisions independent of border considerations
	Calexico-Mexicali	Infrastructure largely in place; connection to rail network at both ends	Limited volumes; low interest on part of (private) operator
Short Sea Shipping	Coastal barge between Ports of Los Angeles and Long Beach and Ensenada	Goods travel offshore on CA side, avoiding congestion	Serves trips between Ports of Los Angeles/ Long Beach and Baja California only; requires scarce terminal space; volume-constrained at Baja California terminus.
Reduction in Delay			
Capacity Expansion	Roadway expansion		Ability to provide relief limited as traffic volume grows; high capital costs
	New POE	Local congestion and air pollution reduction	Ability to provide relief limited as traffic volume grows; modest energy savings
Expedited Processing	FAST expansion	Low capital cost (if existing lanes are used)	Security concerns; improvement constrained by approach lane capacity
	NAFTA program	Low capital cost; eliminates need for drayage and reduces empty backhaul	Substantial opposition based on safety, pollution, labor issues;
Congestion Pricing	Time of day tolling	Potential revenue source; adjustable to increasing volumes	Limited time-of-day flexibility for JIT deliveries

Source: Authors

Public Benefits

Public benefits, ranging from environmental benefits to congestion relief, help justify public funding for freight projects. In the border region in particular, economic development and congestion relief are likely to be major drivers of infrastructure development and public investment.

Energy Use and Emissions of Current Operations

The public benefits of the goods movement improvement options considered here arise from the elimination of cross-border truck trips and of truck idling at POEs. To create a baseline for estimating those benefits, the authors first calculated the fuel use and emissions associated with cross-border trucking in 2003, the only year for which detailed data about truck trips is available, and then projected forward to 2010.

Based on its 2003 truck survey (Caltrans 2003), Caltrans identified the origins and destinations of loaded cross-border truck trips at their endpoints north of the border. California endpoints were grouped by county, while others were grouped by state. Aside from short-haul border traffic between the maquiladoras and points just north of the border, Caltrans did not aggregate trip ends in Mexico by location. The authors therefore used the estimate that 85 percent of cross-border trips start or end in Baja California (see discussion in Chapter 1) to divide the remaining trip ends in Mexico between Baja California and other states.

With this distribution of trip ends, the authors calculated miles traveled by trucks crossing the border, using approximate distances between the endpoints and the border. Only miles traveled in California and Baja California were counted, because the estimated benefits were for those states only.

Tractor-trailers dominate cross-border truck traffic (SAIC 2003), and these were assumed to have an average fuel economy of 5.8 miles per gallon, the current average for such trucks operating in California (California Air Resources Board 2008a). Approximately one-third of trucks crossing through the commercial POEs are smaller trucks, however (Lutsey 2008); these were assumed for purposes of this analysis to consume half as much fuel per mile as the Class 8 trucks. Consequently, the overall average truck fuel economy used for the analysis was 7 miles per gallon.

The authors calculated fuel consumption associated with all loaded cross-border trips based on the miles traveled and fuel economy as described above. To this they added fuel consumed in border idling, using average reported wait times at Otay Mesa and Calexico and a fuel use rate at idle of 1 gallon per hour. Finally, the authors scaled this number up from loaded truck trips to all truck trips by multiplying by a factor of 1.82 based on the estimate that, of the 2 million annual cross-border truck trips, 900,000 are empty trucks. This yields an estimate of total fuel use in California and Baja California by cross-border trucking of 66 million gallons in 2003. Intermediate results of the calculation are shown in Table 19.

Table 19: Fuel Consumption of Cross-Border Truck Trips, 2003

	Segment	Loaded Trips	Distance in CA (miles)	Time	Fuel Usage (Gal)
CA County	Alameda	5,014	420		302,254
	Del Norte	1,253	709		127,629
	Fresno	6,267	305		274,668
	Imperial (without border trips)	32,589	100		467,256
	Los Angeles	289,541	123		5,129,728
	Merced	1,253	359		64,606
	Monterrey	12,534	323		582,156
	Orange	50,137	72		517,794
	Riverside	22,562	92		297,429
	Sacramento	1,253	449		80,870
	San Benito	1,253	337		60,757
	San Bernardino	70,192	151		1,526,003
	San Diego (without border trips)	124,089	29		510,820
	San Francisco	2,507	444		159,784
	San Joaquin	2,507	417		150,229
	San Luis Obisbo	6,267	252		226,614
	Santa Barbara	2,507	206		74,202
	Santa Cruz	2,507	391		140,919
	Tulare	1,253	393		70,718
	Ventura	2,507	253		91,075
		637,992	118		**10,855,513**
International	Asia	56,404	123		996,795
Other destinations	Canada	10,027	**804**		1,158,291
Other destinations	N states (WA + OR)	12,534	804		1,447,893
Other destinations	E states + Europe	156,679	180		4,052,043
		235,644	**226**		**7,655,022**
Maquiladoras	Border - San Diego and Imperial	202,421	20		**581,670**
	Total	**1,076,057**	**123**		**19,092,205**
	Border - Maquiladoras	202,421	40		1,163,339
	Border - Baja	712,228	68		6,958,546
	Border - Sonora	161,409	145		3,362,679
		1,076,057	74		**11,484,564**
Idling	Border	1,076,057		100	**1,793,429**
				min/veh	
Total Onroad Fuel Usage/ Emissions for Loaded Trucks					**32,370,197**
Adjustment to include empty truck traffic (900,000 trips per year)					26,484,707
Total adjusted Onroad Fuel Usage/ Emissions					**58,854,904**

Source: Caltrans 2003 and authors' estimates

Next, the authors projected these trip and fuel usage numbers out to 2010, because none of options to be discussed could be completed before then. Freight movement in the SANDAG region is projected to grow at 5 percent per year in the next two decades (SANDAG 2006b), so with the exception of Asian trade, trips were assumed to increase at that rate. For Asian trade, the authors applied Port of Los Angeles figures for recent and projected annual growth in throughput of the Ports of Los Angeles and Long Beach (Port of Los Angeles 2007), which range from 6 percent to 11 percent over the period 2003-2020. Applying these growth rates to the various trip types shown in Table 19 gave projections of miles traveled, leading to the fuel usage and associated CO_2 emissions shown in Table 20.

Also shown in Table 20 are projected emissions of oxides of nitrogen, hydrocarbons, and particulate matter from cross-border truck movements in 2010, generated using the projections of miles traveled and year-by-year heavy truck grams-per-mile emissions factors for U.S. and Mexican trucks from U.S. EPA's MOBILE 6.2 model, together with a stock turnover model. As explained above, approximately two-thirds of the trucks crossing the border are tractor-trailers, so Class 8 truck emissions factors were used here. Emissions of the smaller trucks are consequently overstated here. This discrepancy is well within the limits of precision of these emissions estimates, however.

Table 20: Fuel Use and Emissions Associated With Truck Trips Across the California-Baja California Border, Estimated 2010

	Trips	Fuel Use (gallons)	NO_x (tons)	VOC (tons)	CO (tons)	PM_{10} (tons)	CO_2 (tons)
Loaded truck travel in U.S. (CA segment only)							
Short-haul cross-border	284,827	818,467	55	3	15	2	9,112
Other California	897,719	14,012,589	1,022	56	276	32	156,002
Non-California (including foreign destination)	345,897	10,228,140	738	41	199	23	113,870
CA total – loaded	1,528,442	25,059,197	1,815	100	489	56	278,984
CA total - loaded and unloaded	**2,778,986**	**45,562,177**	**3,299**	**182**	**890**	**102**	**507,244**
Loaded truck travel in Mexico (BC segment only)							
Short-haul cross-border	284,827	1,636,935	173	9	55	22	18,224
Baja California	1,014,349	9,910,310	1,050	54	335	135	110,332
Other Mexico	229,266	4,776,383	506	26	161	65	53,176
BC total – loaded	1,528,442	16,323,628	1,729	89	551	223	181,731
BC total -- loaded and unloaded	**2,778,986**	**29,679,324**	**3,145**	**162**	**1,003**	**405**	**330,420**
Border Idling	**2,778,986**	**4,631,644**	**227**	**24**	**191**	**13**	**51,564**
TOTAL		**79,873,144**	**6,670**	**367**	**2,083**	**521**	**889,228**

Source: Authors

It should be noted that fuel consumed in idling at the border represents only 6 percent of the total fuel consumption associated with goods crossing the border by truck, as shown in Table 20. Emissions associated with border idling range from 3 percent (PM_{10}) to 9 percent (CO) of total emissions using EPA MOBILE6.2 and the Mexican MOBILE model emissions factors. These emissions nonetheless represent a local air pollution problem, and the economic costs of the border delay are very large, as discussed below, so trucking impacts at the border remain a major consideration.

Fuel Use and Emissions Reductions of Goods Movement Options

This section provides estimates of reductions in fuel consumption and emissions that would result from implementing the various goods movement improvement options discussed in Chapter 2. These estimates reflect not only truck trips or truck idling eliminated by a given option, but also the fuel use and emissions associated with any alternative mode employed and new dray trucks trips associated with the use of that mode.

North-South Rail Lines

Based on the estimates in Chapter 2 of the potential diversion of goods to rail and the above estimate of total fuel use and emissions today, fuel and emissions reduction benefits of rail projects can be calculated. The Chapter 2 discussion partitioned goods now moving by truck according to value (low or high) and distance traveled (long or short), then estimated a percentage of current goods volumes of each type that might be susceptible to diversion. While each of these four flows calls in principle for a different type of service, this discussion assumes that all four could be accommodated by the same basic infrastructure improvements. A detailed assessment would be needed to determine which types of services could plausibly share tracks, rail yards, and other infrastructure.

For north-south rail service, the authors estimated that up to 25 percent of all goods trucked through the Otay Mesa POE are potentially divertible to rail and 16 percent from the Calexico crossing (Table 17). They used the short-distance/long-distance breakdown from those estimates to assign divertible trips to one of the trip types listed in Table 19, which allowed a calculation of reduced truck-miles traveled and the associated fuel savings and emissions reductions.

To determine net reductions, however, it was necessary to estimate fuel usage and emissions associated with the additional rail service and dray trips at either end. For this purpose, the authors used a factor of 0.133 to represent line-haul rail fuel use per ton mile as a fraction of line-haul truck fuel use per ton mile (Forkenbrock 2001). They then computed criteria pollutant emissions using average grams per gallon figures for locomotives from the U.S.EPA. The results are shown in Table 21. It should be noted that these results probably underestimate emissions reductions, because California has adopted measures to reduce in-use locomotive emissions, including the use of low-sulfur diesel, ahead of the federal government (California Air Resources Board 2006).

With regard to drayage, the calculations assumed an average trip of 40 miles at the northern end and 20 miles at the southern end of the rail move, reflecting the higher concentration of trip ends among the maquiladora centers. The authors used the same MOBILE model truck emissions factors for the dray trucks that were used to calculate the baseline emissions in Table 20, although dray trucks, being older on average than on-road trucks as a whole, in fact would tend to have higher emissions (Stromberg 2006). Two dray trips were assigned to each diversion of a loaded truck but none to diversion of an empty truck.

Table 21: Fuel Savings and Emissions Reduction Potential of Improved Rail Service in North/South Corridors, 2010

	Trips	Fuel use (gallons)	NO_x (tons)	VOC (tons)	CO (tons)	PM_{10} (tons)	CO_2 (tons)
Otay Mesa/San Ysidro corridor							
Divertible truck trips	498,719	14,558,994	1,132	63	352	82	162,085
Additional rail fuel use/emissions		1,830,373	369	21	62	13	19,841
New drayage	548,591	2,547,482	198	11	63	15	28,361
Net reductions		10,181,139	**565**	**31**	**227**	**55**	113,883
Calexico corridor							
Divertible truck trips	135,603	4,774,538	372	20	114	27	53,155
Additional rail fuel use/emissions		606,471	122	7	21	4	6,574
New drayage	149,163	692,665	53	3	16	4	7,711
Net reductions		3,475,402	**197**	**11**	**78**	**19**	38,869

Source: Authors

The rail infrastructure needed to realize these truck diversions is not currently in place. Given the high cost of expanding rail infrastructure and the intense competition for both public and private resources to enhance freight movement in California and Baja California, a major rail project in the border region showing diversion potential based only on today's conditions and background growth rates will not be able to attract support. A project will need to demonstrate its potential to shape the region's growth in a way that addresses the huge transportation challenges looming. In the case of the north-south rail lines evaluated here, the exercise of estimating how much of today's truck freight could be diverted by enhanced rail service is less important than consideration of whether and how the development of a high-quality freight rail line across the border could attract to the area, and retain in the area, companies interested in making good use of such a service and are prepared to design their sites and operations accordingly.

With this in mind, the authors considered how truck diversions would grow between 2010 and 2020 if, in addition to overall growth in traffic of 5 percent per year, the percentage of goods captured by a new north-south rail service were to grow by 5 percent annually. Table 22 shows the resulting savings in 2020. The fuel savings numbers reflect the improved efficiency of long-haul tractor trailers operating on the California side of the border expected to result from the Heavy Duty Vehicle Greenhouse Gas Reduction Measure adopted by the Air Resources Board in December 2008 (California Air Resources Board 2008b). The ARB calculates that the measure, which requires tractor-trailers operating in California to begin adopting EPA Smartway fuel economy packages beginning in 2010, will reduce fuel consumption of those vehicles by 7 to 10 percent (California Air Resources Board 2008a).

Estimates of criteria pollutant emissions are not included for 2020, because California recently adopted measures that will further reduce truck emissions by that date, beyond federal requirements (California Air Resources Board 2008b). In fact, emissions per ton mile for trucks are likely to fall below emissions per ton mile for rail before 2020 unless additional steps are taken to reduce locomotive emissions (California Air Resources Board 2006). Projections of average emissions for either trucks or locomotives in California 2020 are difficult to make at this time.

Table 22: Fuel Savings and Emissions Reduction Potential of Improved Rail Service in North/South Corridors, 2020

	Trips	Fuel use (gallons)	CO_2 (tons)
Otay Mesa/San Ysidro corridor			
Divertible truck trips	1,226,435	33,797,216	376,265
Additional rail fuel use/emissions		4,233,754	45,894
New drayage	1,349,079	6,264,686	69,745
Net reductions		23,298,775	260,626
Calexico corridor			
Divertible truck trips	333,470	11,047,489	122,992
Additional rail fuel use/emissions		1,398,894	15,164
New drayage	366,817	1,703,379	18,964
Net reductions		7,945,216	88,864

Source: Authors

The SD&AE Line

Benefits of improving the SD&AE Line depend greatly on the purpose, and corresponding extent, of the infrastructure investments. The assumption used here was that the portions of the line extending from San Diego to San Ysidro (the South Line, operated by SDIY) and from San Ysidro to Tecate (the Mexico Line, operated by CZRY) would be expanded to allow the movement of freight throughout the day, that connectivity would be improved, and that intermodal infrastructure would be added. The authors also assumed major upgrades to the Desert Line, including modernization to allow double-stack rail cars and double-tracking of the line so that the SD&AE Line can capture eastbound goods that would otherwise have traveled north from the border and through Los Angeles to the Midwest. The methodology used to estimate fuel use and emissions reductions was similar to the approach used for the north-south lines and yielded the estimate of benefits in Table 23.

Table 23: Fuel Savings and Emissions Reduction Potential of Improved Rail Service on the SD&AE Railway, 2010

	Trips	Fuel use (gallons)	NO_x (tons)	VOC (tons)	CO (tons)	PM_{10} (tons)	CO_2 (tons)
Divertible truck trips	349,273	8,644,944	1,029	47	307	65	96,244
Additional rail fuel use/emissions		1,075,043	247	13	36	9	11,968
New drayage	384,200	1,508,095	177	8	55	11	16,790
Net reductions		**6,061,806**	**605**	**25**	**215**	**46**	**67,486**

Source: Authors

Rail from Punta Colonet

The construction of a container port at Punta Colonet would clearly have great importance to the evolution of trade patterns between Asia and the Pacific Coast of North America. Direct effects in the California-Baja border area would be limited, however, given Punta Colonet's presumed orientation towards the U.S. Midwest and east coast markets.

A new port at Punta Colonet could reduce cross-border trips by attracting goods that currently enter at Los Angeles-Long Beach and are trucked across the border to the maquiladoras. These goods could instead be shipped from Asia to Punta Colonet and then trucked or sent by train to the border region. Given that San Pedro Bay and Punta Colonet are roughly equidistant from the border, the economic advantage of shipping goods bound for the border region to Punta Colonet is that this avoids the time-consuming drayage process and congestion at the ports of entry and their approach roads.

As shown in the above account of baseline fuel use and emissions of cross-border trucks, elimination of border idling reduces total emissions of cross-border trucks by only a small percentage. Therefore, to realize a direct environmental benefit for California and Baja California from Punta Colonet, the authors assumed that goods are transported from Punta Colonet to the maquiladoras by rail. This would require construction of a rail line from Punta Colonet to Tijuana, probably by way of Ensenada, and a connection between the new rail line from Punta Colonet to the U.S. border and the Ferromex line through Mexicali. This new line, essential to the viability of Punta Colonet, would connect to major routes to the U.S. Midwest and East Coast.

This configuration leads to the secondary, and probably more important, benefit of the construction of Punta Colonet for cross-border traffic between California and Baja California, namely that the accompanying rail line would provide access to a high-volume service between Mexicali and the eastern half of the United States. This is a scenario more likely to divert long-distance cross-border truck trips from Mexicali to rail than the improvement of the UP line in the Calexico/Mexicali corridor discussed previously.

Table 24 shows estimated fuel savings and emissions reductions from the Punta Colonet scenario, reflecting both rail transfer of goods from the port to maquiladoras and the diversion to rail of long-distance, eastbound truck trips from Mexicali into the United States. Such truck trip diversions were assumed to be triple the number assumed in the analysis of rail in the Calexico corridor above, because the businesses in the Mexicali area would be much more likely to use rail to reach the Midwest and East Coast if a high-volume, high-frequency service from Punta Colonet were to pass close by. Construction of Punta Colonet will not take place until after 2010, so the savings shown in Table 24 could not actually materialize in 2010. The table is intended only to allow comparison of the diversion potential of this option using the same background goods movement activity assumed in the analysis of other options.

Table 24: Fuel Savings and Emissions Reduction Potential of Rail Service to Punta Colonet, 2010

	Trips	Fuel use (gallons)	NO_x (tons)	VOC (tons)	CO (tons)	PM_{10} (tons)	CO_2 (tons)
Divertible truck trips	330,470	11,479,530	906	50	279	68	127,802
Additional rail fuel use/emissions		949,627	218	12	32	8	10,572
New drayage	181,759	582,881	59	3	21	7	6,489
Net reductions		**9,947,021**	**629**	**35**	**226**	**53**	**110,740**

Source: Authors

Short-Sea Shipping

A barge service between the Ports of Los Angeles and Long Beach and Ensenada, like the construction of Punta Colonet, would allow goods arriving from Asia to be delivered to maquiladoras without generating any cross-border truck trips. The authors assumed that the barge service would be accompanied by construction of a rail connection from Ensenada to the SD&AE line, which would bring goods close to manufacturing facilities along the border and directly to those facilities that build sidings. As a result, there is very little drayage associated with this option, since goods are transferred from container ship to rail at the Ports of Los Angeles and Long Beach. As discussed in Chapter 2, however, opposition to major growth at Ensenada could prove an insuperable obstacle to this option.

Net benefits of this option depend in part upon fuel consumption and emissions of tugs used to pull the barges. Fuel usage of maritime vessels is highly speed-dependent (Lombardo, Mulligan et al. 2004). Typically, speed is also a major factor in determining the competitiveness of a short-sea shipping operation. When the goods to be transported are in containers that have been shipped from Asia, however, time is less critical, in that containers to be loaded on trucks and rail often sit at the port for serveral days. Consequently, moderate speeds should suffice for this service. The emissions estimates assumed a rate of CO_2 emissions 73 percent that of rail on a ton-mile basis, but the actual emissions rate could be substantially different based on the characteristics of the barge service (Lombardo, Mulligan et al. 2004). Table 25 shows fuel savings and emissions reductions associated with this option.

Table 25: Fuel Savings and Emissions Reduction Potential of Barge Service From the Ports of Los Angeles and Long Beach and Ensenada, 2010

	Trips	Fuel use (gallons)	NO_x (tons)	VOC (tons)	CO (tons)	PM_{10} (tons)	CO_2 (tons)
Divertible truck trips	170,342	5,241,193	422	23	132	34	58,350
Additional marine vessel fuel use/emissions		489,488	168	5	3	13	5,525
Additional road vessel fuel use/emissions		267,587	54	3	9	2	2,979
New drayage	187,376	171,492	16	1	6	2	1,909
Net reductions		**4,312,626**	**183**	**14**	**114**	**17**	**47,937**

Source: Authors

Truck Capacity Expansion

A host of options has been proposed to reduce delay at the border, including new ports of entry, expedited processing, and tolling. Studies of border congestion have listed their merits and drawbacks (Western Governors' Association 2001 [revised]), and that discussion is not reproduced here. Instead, the authors considered one of the proposed projects, namely a new port of entry, as a point of reference for comparing these options with mode shift options (Table 26).

Table 26: Fuel Savings and Emissions Reduction Potential of a New Port of Entry, 2010

	Fuel use (gallons)	NO_x (tons)	VOC (tons)	CO (tons)	PM_{10} (tons)	CO_2 (tons)
Net reductions	**1,907,147**	**93**	**10**	**79**	**5**	**21,232**

Source: Authors

Economic Benefits of Reducing Border Delays

Benefits of cross-border goods movement options considered thus far in this chapter have been limited to fuel savings and emissions reductions. Benefits to the economy are a critical determinant of the options' viability because they will strongly influence the priority of the project in obtaining public funding. The authors considered the economic benefits of congestion reduction. Other issues, such as public infrastructure damage and crashes, would be included in a comprehensive analysis of potential benefits of these options, but are not discussed here.

Delays at the border are of particular concern among the impacts of the system of freight movement currently in place. In general terms, there are two kinds of delays at the border: congestion and procedural delays. The two are related, in that inspection processes contribute to congestion and congestion increases the time required for clearance procedures, but processing requirements, for example, can add many hours to a given vehicle's crossing time independent of congestion. The multi-vehicle crossing process described earlier associated with restrictions on cross-border trucking and the related practices of border warehousing, drayage, and customs brokerage, call for solutions completely different from those to address shortage of capacity.

Both congestion and the broader issues of crossing policies and practices are the subjects of much discussion in several forums and have been studied at length. The economic stakes are high; the competitiveness of the maquiladora industry, the health of the San Diego-area economy, and companies' location decisions all hinge to some extent upon progress in resolving these problems. Perhaps the most anticipated measure to address the inefficiency of truck border crossings is the lifting of the prohibition against long-distance travel in both the United States and Mexico by a single truck. This step, a key point of NAFTA, has provoked a contentious debate over issues that go well beyond economics to safety and security. In this context, energy use is likely to be a relatively minor consideration for the parties involved.

Neither macroeconomic analysis of congestion impacts nor modeling of traffic flow is within the scope of our analysis. However, SANDAG and the Imperial Valley Association of Governments (IVAG) have each, together with Caltrans, analyzed costs of delays to freight trucks at the California-Baja Crossings, using an input-output model to estimate the impacts of congestion on economic output, income, and employment (SANDAG and Caltrans 2006; IVAG and Caltrans 2007). They concluded that the delays caused a loss in annual economic output of more than $4 billion in the United States and Mexico (Table 27).

Table 27: Economic Impacts of Freight Delays at San Diego-Baja California Crossings

	San Diego County		Imperial County	
	Output Loss, Millions of 2005 $	**Job Loss**	**Output Loss, Millions of 2005 $**	**Job Loss**
U.S.	1,256	7,646	371	2,259
California	716	3,654	223	1,138
Mexico	2,069	10,889	467	2,459
Baja California	1,317	6,929	297	1,561

Source: SANDAG and Caltrans 2006 and IVAG and Caltrans 2007

This finding suggests that there could be considerable economic benefits associated with projects that reduce traffic congestion at the border. Using the simplifying assumption that congestion is reduced in proportion to the reduction in cross-border traffic leads to economic benefits for the options as shown in Table 28.

Table 28: Economic Benefits of Options Due to Delay Reductions, 2010

	Percent reduction in border crossings	Value of congestion reduction ($mill)
Otay rail	18%	$169
Calexico rail	5%	$46
SD&AE rail	13%	$118
Punta Colonet rail	12%	$108
Short sea shipping	6%	$54
New POE	50%	$470

Source: Authors

In fact, reducing volume generally reduces congestion more than proportionately (U.S. EPA 1998). A direct calculation of the congestion benefits of the proposed options requires traffic modeling and is beyond the scope of this report, however, and in any case the truck diversion potential associated with the various options would require much more extensive analysis to warrant modeling of congestion benefits.

Capital Costs

Multiple governmental entities on both sides of the border, including SANDAG and the cities of San Diego and Tijuana, are eager to accommodate and promote the increase in cross-border trade. Major governmental contributions to capital expenses for rail infrastructure could be critical to realizing a cross-border rail project. The San Diego region is currently considering what its economic priorities should be in the coming decades. According to SANDAG: "[t]he San Diego region…faces an extraordinary economic opportunity and policy choice concerning whether to accept an expanded role in the emerging global economy and international trade." This regional perspective not only increases the range of funding options, but also can fundamentally alter the economic assessment of projects by highlighting their ability to shape future transportation patterns and thereby attract new businesses. As attested to by the California Goods Movement Action Plan (Business Transportation and Housing Agency and California Environmental Protection Agency 2007), shortcomings in freight infrastructure are a high-profile issue at the state level as well.

Costs of Options

The SANDAG Regional Transportation Plan

There are extensive plans to improve goods movement in the border region and throughout Southern California. The 2030 Regional Transportation Plan (RTP) of the San Diego Association of Governments (SANDAG) lists multiple projects expanding freight infrastructure in San Diego and the surrounding regions in the coming decades (San Diego Association of Governments 2007). Several projects in the RTP relate to options explored in this report, and for those the authors used RTP cost figures to the extent possible.

Rail investments in the RTP are shown in Table 29, grouped into four lines: the north-south line coming down from Los Angeles along the coast, into San Diego and leading to the Tijuana corridor discussed above; the South and Mexico lines, which are parts of the SD&AE Railway, connecting San Diego to the border at San Ysidro and then to Tecate; the Desert Line, between Tecate and El Centro; and an alternative north-south line that SANDAG proposes along an inland alignment. Total project costs for each line are shown in Table 29, broken out into three SANDAG funding scenarios: "revenue-constrained," "reasonably expected," and "unconstrained." The "revenue-constrained" scenario is "based on current sources and levels of federal, state, and local transportation revenue projected out to the year 2030." The "reasonably expected" scenario adds projects that will be programmed assuming "higher levels of state and federal discretionary funds, increases in state and federal gas taxes based on historical trends, and other potential federal, state, and local sources." The "unconstrained scenario" shows projects considered necessary but not included in either of the two preceding scenarios (SANDAG 2007).

Table 29: Cost of Selected Rail Projects in the SANDAG 2030 RTP (Millions of Dollars)

	Revenue-constrained	Reasonably expected	Unconstrained
Coastal Line	$1,825	$0	$110
South and Mexico Lines	$0	$359	$466
Desert Line	$0	$0	$2,312
Inland (high-speed) Line	$0	$0	$3,961

Source: SANDAG 2007

The coastal line elements of this plan include improvements to the shared-use BNSF line lying within San Diego County and north of the city of San Diego; these are the only freight rail projects in the "revenue-constrained" scenario. South Line projects include sidings, passing track, yards, and improved connectivity with the Mexico Line (reasonably expected), as well as San Ysidro yard improvements and a spur to Otay Mesa (unconstrained). Improvements to the Mexico Line include rehabilitation, a transload facility, and a maquiladora spur (reasonably expected), as well as mainline capacity increases (unconstrained).

The Desert Line is listed in three phases: basic service ($15 million), modernization (double stack; $166 million), and double tracking ($2,130 million). Despite the extensive consideration this line has received for many years as a means of building up the Port of San Diego and facilitating commerce in the border region and between San Diego County and Imperial County, all three phases of the Desert Line are in the unconstrained scenario.

Finally, the inland rail project is envisioned as a high-speed, combined passenger-freight line that would run the length of San Diego County and cross into Mexico near the Otay Mesa port of entry (POE) and interchange with the SD&AE line between Tijuana and Tecate. At a cost of nearly $4 billion, this project appears only in the "unconstrained" budget scenario.

Several major capacity increases for trucks are under consideration as well. A new POE is planned east of Otay Mesa at a cost of $1.5 billion, and connecting roadways are also required to serve the new POE. Several major capacity expansions are planned for the north-south roadways in San Diego County leading to the border crossings, as well. These include widening of routes I-5, I-15, and I-805. Table 30 shows the construction costs for these projects, as listed in the SANDAG RTP. Unlike the freight rail improvements, these projects all fall within the "revenue-constrained" and "reasonably expected" scenarios, despite their having received in many cases a far lower score on SANDAG's 100-point freight project evaluation scale.

Table 30: Cost of Otay Mesa East Port of Entry and Connecting Roadways (Millions of Dollars)

	Revenue-constrained	Reasonably expected
Otay Mesa East POE (including SR11)	$855	$643
SR905	$970	$0
I-5	$2,811	$934
I-15	$1,941	$0
I-805	$1,936	$1,400

Source: SANDAG 2007

Los Angeles-Tijuana Rail

The north-south rail corridors considered in the discussion of benefits above are defined by the POE from which they would divert truck traffic: Otay Mesa and Calexico/Mexicali. The corridor identified with Otay Mesa connects Los Angeles and Tijuana and is served by the first two groupings of rail investments in Table 29: the coastal line and the South and Mexico Lines. While the Mexico Line serves an east-west corridor, it is included as part of this option because it allows goods traveling from Los Angeles by rail direct access to maquiladoras in both Tijuana and Tecate, which is central to the ability of this option to divert truck traffic. Hence the capital cost estimate for this option is $2.9 billion.

The analysis of benefits assumed that this option could serve both high- and low-value goods, as well as both long- and short-distance trips in the corridor. The question of whether the coastal line and its southern extension could plausibly provide the expedited service associated with the concept of a short-haul shuttle is crucial, and certain aspects of this question are revisited in the discussion of operating costs below. In a different context, however, an electric freight rail service has been proposed for California, with the north-south corridor being identified as perhaps more promising than the east-west corridor that typically draws the most attention (Farrell 2007).

An alternative estimate of the cost of a shuttle in this corridor can be generated from information provided by the Texas Transportation Institute (TTI), which has championed for several years an innovative freight shuttle concept. The TTI shuttle relies on a new technology involving a highly automated system to move containers or trailers short distances at low cost. TTI estimates that per-mile costs would fall in the range of $6 million to $8.5 million per mile (Roop, Roco et al. 2003), which leads to an estimate in the vicinity of $1 billion for a Los Angeles-Tijuana service. Based on the cost estimates in the RTP for all transportation infrastructure projects, however, it appears that costs in this region are much higher than a generic, per-mile estimate would indicate.

Calexico-Mexicali Rail

The Calexico-Mexicali crossing lies in Imperial County and is therefore not included in the SANDAG RTP. The corresponding entity, IVAG, has not identified expansion of rail service in the corridor as a priority.

While the potential demand for this service appears to be only one-third the potential demand for rail in the Los Angeles-Tijuana corridor, the need for investment would also be much smaller. There are no passenger-freight conflicts on the line, and it does not pass through a major metropolitan area. The existing rail line is already served by a single operator and could in principle accommodate more traffic, either carload or intermodal freight, though the latter would require new yards and equipment. Furthermore, UP has already started to double-track the Sunset Route, which provides the link from this line to Los Angeles and also to points north and east. For later discussion, the authors estimated the cost of upgrading this line to be $1 billion, comparable to that of upgrading the South and Mexico Lines, which are together of similar length and have similar upgrade requirements, such as intermodal yards and maquiladora spurs.

UP has yet to indicate an interest in increasing service on the line, either intermodal service to the Los Angeles area or expanded carload freight to Chicago or the Northeast. This corridor is therefore an unlikely candidate for rail investment, either public or private, except in support of a larger development project. Mexicali has emerged as a center of aerospace manufacturing and assembly and if rail service into the area were improved and an intermodal yard built, new businesses locating there might be interested in designing their facilities and supply chains around a rail-based, rather than truck-based, delivery service. The other scenario in which major improvements to rail might be expected in Mexicali is the development of Punta Colonet.

SD&AE Upgrade

Upgrading the east-west SD&AE Line to provide full intermodal service would involve the projects in both the Desert Line grouping and the South and Mexico Lines grouping in Table 29. Total cost would therefore be $3.3 billion.

It should be noted that much of the value of the entire SD&AE Line, from San Diego to El Centro, is not captured in the discussion of benefits above. In the San Diego area, the line already acts as a short line for bulk commodities, including some that are not amenable to movement by truck. In addition, a modernized SD&AE is a precondition for further development of the Port of San Diego. The ability to move goods out to the Midwest and Northeast by connecting to UP in Imperial County would allow port traffic to avoid the highly congested Los Angeles area.

Rail from Punta Colonet

The option discussed above to take advantage of the construction of Punta Colonet and an accompanying rail line to the United States involves construction of a rail connection from Punta Colonet to Tijuana or Tecate and a tie-in between the new line and the Ferromex line through Mexicali. For a Punta Colonet-Tecate rail connection, the authors assume a cost of $448 million, four times an earlier consultant estimate of $112 million for an Ensenada-Tecate connection (SANDAG 1999). This is based on the facts that Punta Colonet is twice as far from Tecate, costs have increased since the estimate was made, and the connection would require at least two logistics centers and intermodal yards. Adding in the tie-in to Mexicali, the authors estimate this option to cost $800 million.

Short-Sea Shipping

For an estimate of capital costs for a barge operation between the San Pedro Bay ports and Ensenada, the Westar Transport proposal (Silva 2006). Westar estimates up-front capital costs of $3 billion to $4 billion over 3 to 4 years for a six-vessel start-up operation. This would encompass services from San Pedro Bay to multiple west coast destinations. Assuming the service to Ensenada would occupy a single vessel, the share of start-up costs associated with the Los Angeles-Ensenada operation would be $600 million. This vessel could serve Los Angeles/Long Beach-San Diego moves as well.

Discussion: Cost-Effectiveness

The net energy and environmental benefits, in terms of fuel saved and emissions reduced, and estimated capital costs of the options are summarized in Table 31.

Cost-effectiveness of the options based on these benefits alone is unfavorable. For example, if the lifetime of the infrastructure investment is defined to be 30 years and future savings of fuel and emissions are discounted at 5 percent per year, the cost of fuel savings for the various options ranges from $5 to $33 per gallon, and CO_2 reductions range from $460 to $2,959 per ton, as shown in Table 32. The cost per gallon of fuel saved should be compared to the external costs of fuel use only; the pump price of fuel to freight shippers is more relevant to a discussion of private costs and benefits of the options.

Table 31: Capital Costs, Annual Fuel Savings, and Annual Emissions Reduction Potential of Freight Movement Options, 2010

	Fuel savings (million gallons)	NO_x (tons)	VOC (tons)	CO (tons)	PM_{10} (tons)	CO_2 (tons)	Capital cost ($ millions)
Tijuana rail	10.2	605	33	234	56	113,883	$2,760
Calexico rail	3.5	210	11	80	19	38,869	$1,000
SD&AE rail	6.1	392	21	153	43	67,486	$3,137
Punta Colonet rail	9.9	652	36	230	54	110,740	$800
Short sea shipping	4.3	208	15	115	19	47,937	$600

Source: Authors

Table 32: Selected Cost-Effectiveness Measures of Options Assuming 30-Year Investment Life and 5-Percent Annual Discount of Savings

	Cost per gallon	Cost per ton CO_2
Tijuana rail	$17	$1,543
Calexico rail	$18	$1,638
SD&AE rail	$33	$2,959
Punta Colonet rail	$5	$460
Short sea shipping	$9	$797

Source: Authors

The public benefits of these projects go well beyond energy and environmental benefits, however, and cost-effectiveness measures of an entirely different kind would typically be used in evaluating freight projects. SANDAG, for instance, defines cost-effectiveness as "increase in freight throughput divided by total capital plus operating costs." (SANDAG 2006b) Moreover, cost-effectiveness is only one of three types of criteria SANDAG uses to rank freight projects.

For some purposes it is desirable to monetize projected benefits so they can be compared to project costs. Some intermodal analysts recommend the use of the Federal Highway Administration's (FHWA) Highway Cost Allocation Study (HCAS) to quantify the benefits of eliminating truck trips (Casgar, DeBoer et al. 2003). FHWA conducted the HCAS for some years to estimate the breakdown among motor vehicle classes of all costs incurred on U.S. highways. FHWA last conducted the HCAS in 1997, and followed with an Addendum in 2000, so the findings are dated, but they are widely cited nonetheless. Table 33 shows marginal cost per mile attributed by HCAS to a Class 8 truck on an urban highway.

Table 33: Marginal Costs for a 60,000 lb., 5-Axle Truck on an Urban Interstate, 2000 (Cents per Mile)

Pavement	Bridge Costs	Congestion	Crash	Air Pollution	Noise	Total
10.47	0.4	18.59	1.15	4.49	2.75	37.65

Source: Federal Highway Cost Allocation Study, as cited in Casgar et al. 2003

These costs are partially offset by revenues collected from truck operators, which for an average state total 7 to 8 cents per mile. The net marginal cost to the state of a truck trip is therefore approximately $0.30 per mile according to this approach. Applying this cost-per-mile figure to miles eliminated under the options considered here gives one measure of the monetary value of the resulting public benefits. For the Otay Mesa/San Ysidro corridor rail project, for example, the methodology used above to calculate benefits provides an estimate that the rail service would eliminate 79 million miles per year initially, increasing to 194 million per year by 2020. At a cost of $0.30 per mile, this amounts to $24 to $58 million per year, not a large contribution to a $3 billion project, even assuming a long amortization period.

The congestion costs reflected in the above calculation are those associated with line haul congestion, however, and do not reflect border congestion. Adding the congestion reduction benefits shown in Table 28 to the benefits from miles eliminated allows a rough comparison between the public benefits and the capital costs of the options, as shown in Table 34. This estimate omits the pollution reduction benefits of eliminating idling at the border, but as noted earlier, this is a small fraction of the pollution associated with the line haul portions of these truck trips. It should also be noted that the payback figures are quite sensitive to assumptions about the options that could easily be changed. For example, if the SD&AE improvements were to follow the improvements to the Los Angeles-Tijuana line, rather than being a freestanding project, the cost of the SD&AE would fall by $1 billion, and the payback period would be 18 years instead of 26.

Table 34: Comparison of Costs and Monetized Benefits of Options

	Capital cost ($ millions)	Value of truck miles eliminated ($ million)	Value of congestion reduction ($million)	Simple payback
Tijuana rail	$2,760	$24	$169	16
Calexico rail	$1,000	$8	$46	22
SD&AE rail	$3,137	$14	$118	27
Punta Colonet rail	$800	$22	$112	7
Short sea shipping	$600	$10	$58	10

Source: Authors

A more precise assessment would consider the present value of the benefits of the options over time. However, the rate of growth in benefits is somewhat greater than 5 percent, which is a reasonable discount rate for public investment. The two effects therefore roughly offset each other over time, so this calculation is adequate for the level of evaluation offered here, although it likely understates the benefits of certain projects. A detailed methodology to calculate benefits and costs of freight projects is laid out in the DOT report *Guide to Quantifying the Impacts of Federal Investments in Large-Scale Freight Transportation Projects* (Cambridge Systematics Inc., Economic Development Research Group Inc. et al. 2006).

Operating Costs and Revenues

The foregoing discussion considers the viability of goods movement options from the perspective of capital costs and public benefits. As explained in the beginning of the chapter, the authors assumed that public investment would be exclusively or largely confined to capital costs and that operating costs would have to be covered by operating revenues.

The ability of the alternative mode options discussed here to be self sustaining with respect to operating costs is far from evident, however. Rail is little used at present for cross-border traffic due to limited infrastructure and to the short distances traveled by a large percentage of trucks. The vast majority of cross-border trips are much shorter than the 400 to 500 miles generally accepted as the minimum distance for rail service to break even. At a minimum, several years would elapse before revenues would be expected to offset operating costs to any significant degree. Development of the markets that could best be served by the projects considered here would occur over a decade or more.

The costs and delays associated with the border crossing alter the economics of short-haul alternatives to trucking, however. Here the authors illustrate the issues determining the viability of these operations by considering the example of rail service in the Los Angeles-Tijuana corridor.

Rail shuttle services are now under consideration in locations across the country, most frequently to serve "inland ports" for the nation's rapidly growing maritime ports. Existing and proposed inland ports located well within the conventional "truck-only" radius around ports reflect the high land values and level of congestion there. Containerized goods are brought out to inland ports on single- or double-stacked rail cars and then undergo redistribution and, in some cases addition of value, before being shipped out by truck or rail.

While the border area does not serve as an inland port to Los Angeles in the usual sense, the determinants of economic viability of a rail shuttle in the two cases have some important similarities. In view of the relatively high value of the cargo to use the proposed service, one prerequisite for viability would be volumes sufficient to warrant a daily service, so that goods do not need to wait overnight to be sent.

The authors applied the methodology used in a report by the Foundation for Intermodal Research & Education (FIRE) to evaluate the viability of rail shuttles to inland ports from the perspective of operating costs (Casgar, DeBoer et al. 2003). Total operating costs for a single train run were calculated as the sum of terminal costs, drayage, switching, locomotive and rail car hourly costs, crew wages, fuel, and so forth. Dividing by the distance covered by the service and the number of boxes carried gives a cost per box-mile, which allowed a comparison with trucking costs; a box is the container- or trailer-equivalent of one tractor-trailer.

The high "fixed" costs (that is, costs independent of the length of the line) clearly show the challenge of short-haul rail services (Table 35). For the 135-mile route in question, total cost per box-mile is $2.29, 64 percent higher than the standard truck cost per mile of $1.40. Based on this calculation, rail service would not be competitive from an operating cost standpoint. However, the costs and delays associated with truck border crossings alter the economics of this situation. In fact, the cross-border drayage operation attaches the same kinds of costs to trucking that undermine the viability of short-haul rail, namely the need to transfer goods from one conveyance to another. Adding a drayage cost of $75 to $150 to each box crossing the border (Haralambides and Londono-Kent 2004) brings the effective per-mile truck costs to $2.23. This rough comparison of costs suggests that, if trains experience minimal border delays, cross-border drayage considerations bring the costs of trucking much closer to those of rail. In fact, the cost of drayage does not capture the full private cost of border crossings. According to the SANDAG/Caltrans study of border delay, "Most companies feel that the border adds about half a day to the product cycle" (SANDAG and Caltrans 2006). On the other hand, it is also true that at present trains lose considerable time at the border due to security inspections and, in some locations, a requirement that rail cars be washed before crossing. A successful rail shuttle would require, among other things, an arrangement allowing security inspections to occur at the loading point, rather than at the border.

Table 35: Los Angeles to Tijuana Rail Shuttle vs. Trucking: Operating Costs

Line haul				Truck costs	
	Total train-mile costs	$477		Cost per mile	$1.40
	Crew	$1,152		Drayage cost	$75-$150
	Maintenance of way	$119		Cost per mile w/drayage	$2.23
	Switching	$0			
	Locomotive maintenance	$316			
	Fuel	$1,620			
	Locomotive capital costs	$378			
	Daily car lease costs	$680			
	Per mile car costs	$138			
	Subtotal	$4,879			
Terminal		$17,711			
Drayage		$21,253			
TOTAL		$43,842			
Total per box		$309			
Distance traveled (miles)		135			
Cost per box-mile		$2.29			

Source: Authors, based on Casgar, DeBoer et al. 2003

Whether rail operating costs approach trucking costs or even fall below, railroads probably would not be eager to offer a service of this kind, especially in an area like Southern California where overall demand for rail service exceeds capacity. Returns would be small at best and much less than profits for long-distance services. In fact, the FIRE study increases the calculated cost per box-mile by a "variable cost multiplier" of 1.4 to reflect the railroads' profit expectations (Casgar, DeBoer et al. 2003). This factor would elevate rail costs well beyond truck costs once again. Thus, one would expect public sector initiative, not operator interest, would be the driver of any project of this kind at present.

Conclusions

This chapter considered the viability of rail and barge services between Southern California and northern Baja California in terms of project costs and benefits. The discussion assumed that capital costs would be publicly funded and that operating costs would be borne by the operators. While other funding arrangements could be considered, none of the options presented here has an easy case to make for investment on either the public or private side, and rearranging the sources of funding would not lead to dramatically different conclusions.

Railroads in particular have found it difficult to realize adequate return on infrastructure investment and have consequently limited their new projects to low-risk, lucrative investments. Given the drivers for the projects considered here, for example, economic development, congestion reduction, and environmental benefits, it is clear that public funding would need to play a major role in the financing of any capital-intensive options. This section shows that making the case for public investment on the basis of energy and environmental benefits alone is difficult.

Even from an operating perspective, the rail options may be of limited interest to the railroads themselves. Class I railroads eliminated 175,000 miles of track between 1970 and 2000 (Casgar, DeBoer et al. 2003), and they are generally moving towards reducing service on existing routes. The cost components of rail operation are such that high-volume, long-distance routes are most profitable. Therefore, particularly in an area such as Southern California, where demand for rail exceeds the railroads' ability to supply new capacity, a short-distance service with comparatively modest volumes at present is not likely to be attractive to railroads. Even where the potential for profit may exist, longer-haul routes will typically bring greater profits relative to the investment required and therefore are likely to be funded first. In any case, user costs for new services would need to remain in the vicinity of trucking costs to attract users, and as shown above this is challenging for short-distance services. It is therefore probably not practical to impose additional fees to recover capital costs of new infrastructure.

Estimates of both costs and benefits used in the analysis depended upon numerous assumptions that may prove unwarranted. In the case of rail service between Los Angeles and Tijuana, for example, cost estimates were based upon the costs of related projects from the SANDAG RTP. The relevant SANDAG projects are designed to upgrade passenger service as well as rail service, however, so assigning the full costs of these projects to freight movement may not be appropriate. Most importantly, the value of the options considered depends greatly on their ability to influence future development decisions on both sides of the border, which in turn will determine the amount of truck, rail and marine traffic this development generates. This issue was considered only in passing in the analysis above and needs to be revisited for any option receiving further attention.

Given the complex economic considerations involved, the most appropriate approach to evaluating public investment in freight infrastructure may not be a cost-benefit analysis but rather identification of the most cost-effective option to meet a given need. This is how highway investments are typically evaluated. When the benefits of congestion relief at the border were taken into account in this chapter, some of the options appeared to have a payback that would justify public investment. The options that fared best in this preliminary analysis were rail from Punta Colonet, barge service between the San Pedro Bay ports and Ensenada, and enhanced freight rail service between Los Angeles and Tijuana. The first two of these projects rely upon other major investment decisions, however, namely the construction of the Punta Colonet container port and implementation of an entire system of short-sea shipping services centered on San Pedro Bay, respectively.

CHAPTER 4:
Evaluation of Fuel Options and New Transportation Technologies

Introduction

Research regarding alternative fuels and new technologies that reduce fuel consumption and reliance on the international petroleum fuel market and reduce emission of pollutants has been on going for many years. The majority of this research focuses on highway vehicles, and to a lesser extent rail and marine vessels. There is considerable overlap between these modes of transportation, as they all use diesel engines of varying design and size. Alternative aviation fuels are more challenging because the fuel characteristics required for commercial jet engines limit possible options.

To the extent possible, this analysis considered existing infrastructure in Mexico and the United States. Many of the fuel options presented in this chapter require considerable resources to implement (for example, expansion of refinery capacity, extension of distribution pipelines, and modification or replacement of vehicle/vessel engines) compared to technological changes, which in many cases can be introduced incrementally.

This assessment evaluates the fuel and technology options for each mode (that is, on-road, rail, marine, and aviation). Where data are available, performance, maintenance, and safety issues are discussed along with fuel storage and distribution. Economic data about fuel cost are included in this report as available. Required changes to engines to use the candidate fuel or technology are noted. Some fuels, though they may reduce emission of one pollutant, may increase emissions of another pollutant. These cases are noted where support test data are available.

In the appendix to this chapter are several comparison tables of alternative fuel and technology options. These comparison tables highlight the advantages and disadvantages of each alternative fuel and technology by transportation mode. The fuel and technology options included in this analysis were developed by the research team, taking into consideration only those options that relate to trans-border movement of freight that could possibly be implemented in the United States and Mexico. The focus of this study was the use of alternative fuels and technologies, not changes in operation or user behaviors. Advantages and barriers to the application of the candidate fuels and technologies are discussed in the following section of the report for each transportation mode.

In the discussion of viable fuels and technologies there is some overlap between the transportation modes, though the issues of greatest concern are usually different. For example, biodiesel was evaluated for each mode and led to a variety of conclusions. Because of aviation fuel specifications and fuel characteristics at low temperatures and high altitudes, pure biodiesel is not a good option for jet fuel. On the other hand, marine vessels are designed to use a wide range of fuels, and biodiesel is probably one of the cleanest options. The rail industry has concerns about how use of biodiesel will affect copper engine components in the long term. For all transportation modes there is considerable concern about the long-term availability of biodiesel in the United States and Mexico.

In the concluding section of this chapter, the fuel and technology options for each transportation mode studied are ranked relative to the context of freight movement between United States and Mexico and the likelihood of adoption. Due to the complexity of the existing market and drivers in the United States and Mexico, the recommendations provided in this chapter are more qualitative than quantitative and focus on options that can be implemented in a range of time spans.

Summary of Fuels and Technology Options by Transportation Mode

On-Road Fuels and Technologies

On-road fuels and technologies can be evaluated from two principal perspectives; haul duration (short or long), and area of operation (United States or Mexico). For instance, certain fuel efficiency and emission reduction technologies may be perfectly appropriate for trucks making short trips in urban settings, but not for highway travel. Similarly, certain fuels may have production, infrastructure, or cost limitation on one side of the border, severely limiting near-term and possibly long-term availability.

This report evaluates the following on-road fuel and technology options for heavy-duty freight movement from these two perspectives:

Table 36: On-Road Fuels and Technologies

Fuels	Technologies
Low sulfur diesel	Hybrid engines
Biodiesel	Idle reduction technologies
Methanol & methanol blends	Fuel Cells
Ethanol & ethanol blends	Electric-powered vehicles
LPG	Improved aerodynamics
Natural gas	Low rolling resistance tires
Synthetic fuels	
Hydrogen	

Certain fuels and technologies in Table 36 are too speculative at this point for any application, regardless of location, and are not evaluated further. These include hydrogen-fueled trucks, fuel cell engines, and battery-powered electric engines (excluding hybrid applications, which are discussed below).

Reformulated and Alternative Fuels

Low Sulfur Diesel Fuels

In January 2001 the U.S. Environmental Protection Agency (EPA) finalized the Highway Diesel Rules, which implemented more stringent standards for new diesel engines and fuels. The rule mandated the use of lower sulfur fuels in diesel engines beginning in 2006 for highway vehicles. These new diesel fuels will decrease the allowable levels of sulfur by 99 percent relative to conventional highway vehicles fuels. Besides reducing sulfur and particulate matter (PM) emissions, the lower sulfur concentration of diesel fuel will allow for application of advanced emission control systems that can reduce carbon monoxide (CO) and volatile organic compounds (VOC) emissions substantially. Note that if high-sulfur fuel is used on vehicles equipped with certain advanced control technologies such as diesel oxidation catalysts, these devices will be contaminated and have to be replaced to realize the expected air quality benefits associated with these devices.

At this time there are no Federal regulations requiring Mexican trucks to comply with current U.S. emission standards. In lieu of federal regulations, California passed Asesmbly Bill (AB 1009) (Pavley, Chapter 873, Statutes of 2004), which amended the Health and Safety Code to adopt regulations, to the extent possible under federal law, requiring any commercial truck more than 10,000 pounds gross vehicle weight operating in the state to possess evidence that its engine meets the U.S EPA emission standards. As of July 2008, Mexico was to have new engine standards for heavy-duty diesel engines. To be in compliance, new Mexican engines will need to meet either the U.S. 2004 standards or the Euro IV standards. Euro IV requires ultra low sulfur diesel, U.S. 2004 standards do not. Implementation of standards comparable with Euro IV will require that ultra-low sulfur diesel (ULSD) be available throughout Mexico.

Motor vehicle fuels in Mexico are distributed exclusively by the national oil company Petróleos Mexicanos (PEMEX). The Mexican government made ULSD diesel generally available in border communities in January 2007 and should be available nation wide by late 2008 (Garcia 2006). Although Mexico has been importing approximately 65,000 barrels per day of ULSD from the United States for use on the eastern end of the border, especially in Ciudad Juarez, it has also been importing ULSD from other countries to supply Baja California border communities. It is anticipated that in the short term United States and other foreign refineries may have to continue to supplement Mexican refinery production of low sulfur diesel in order to meet cross border traffic demand.

For this analysis it was assumed that ULSD will be the baseline on-road fuel used on both sides of the border in the immediate future. While there is considerable concern when such fuels will be available in Mexico, it is planned that the immediate vicinity of the border will be the first region that receives this fuel. In addition, ULSD can be used in any current on-road diesel engine application, although a slight fuel efficiency decrease might be noticed as a result of ULSD's slightly lower energy content. Power output should not be affected, however (Washington State Department of Ecology 2007).

Engine maintenance should be stepped up for any fleet adopting ULSD. This may be particularly important for the older Mexican truck fleet, as a small number of older engines have developed fuel system leaks and filter plugging after moving from higher sulfur fuels. These ULSD fuels will require additives to maintain lubricity and limit corrosion, but these should be added before retail sale, and shouldn't be a concern to the fleet operator (Clean Diesel Fuel Alliance Information Center 2007).

Finally, according to EPA, ULSD will increase retail fuel costs in the United States by 4 to 5 cents more than conventional diesel (Washington State Department of Ecology 2007).

Alternative Diesel Formulations

There are a number of different ways of producing clean diesel formulations using different feedstocks and processing mechanisms. The resulting diesel fuels can have very attractive emission reduction and efficiency properties, such as increased cetane number and lowered aromatic levels. Common alternative diesel formulations include Fischer-Tropsch diesel, hydrogenation-derived renewable diesel, and biomass-to-liquids diesel. All of these fuels also have the potential advantage of using the existing diesel distribution infrastructure and do not require engine or fuel tank modifications. However, due to technical and economic constraints none of these fuels are likely to attain large-scale production and distribution in the United States or Mexico for many years.

The State of California has established its own diesel formulation requirements, specifying limits to aromatic and polycyclic aromatic hydrocarbon content above and beyond federal standards (ARB, August 2004). Alternative formulation options such as ECD-1 have also been approved for sale by the California Air Resource Board (ARB) and are widely available throughout the state. Incremental costs for California diesel are estimated between 5 and 10 cents per gallon relative to federal low-sulfur diesel (U.S. Department of Energy (U.S. DOE), February 2003).

Biodiesel

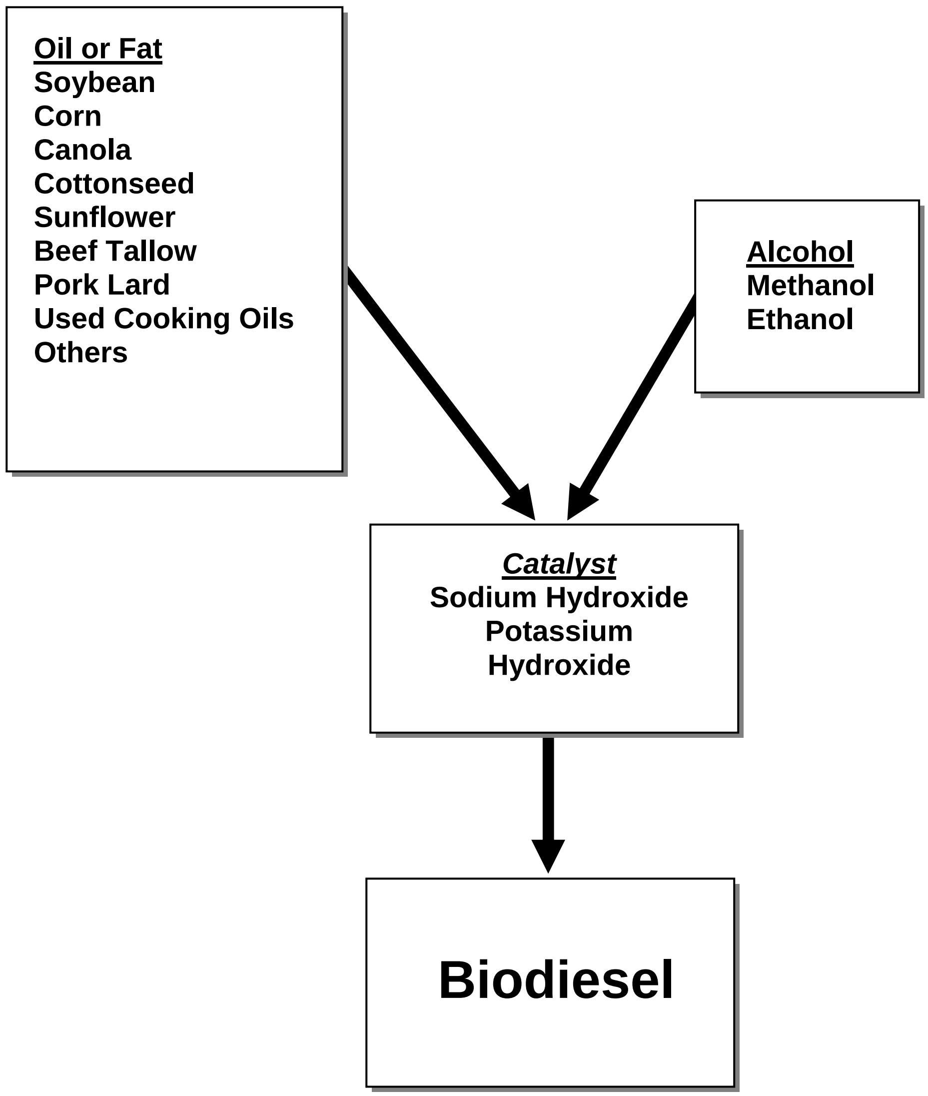
Biodiesel can be derived from soybean, canola oil, sunflower, and cottonseed oil, and also animal fats, as noted in Figure 11. Feedstocks can be grown or obtained from recycling used oil such as cooking grease. Most U.S. biodiesel uses soybean oil due to the abundance of this feedstock.

Biodiesel can be used in its pure form, known as "neat biodiesel" or B100. In addition, it is available in various blends with petroleum diesel, the most common of which is known as B20 (20 percent biodiesel and 80 percent petroleum diesel). It is also used in smaller percentages as a lubricating fuel additive. Biodiesel can be used in any concentration without modification to highway engines, fuel distribution, or storage tank systems. In fact, biodiesel has better lubricity than standard diesel and may limit engine wear.

Biodiesel's energy content is about 11 percent less than that of petroleum diesel, resulting in a correspondingly lower miles per gallon. This effect is diminished according to the extent of blending with petroleum diesel. Blended biodiesel formulations do not affect power output and are appropriate for both short and long-haul applications (U.S. DOE/EIA 2007a).

Biodiesel acts as a solvent to some fuel system components and concrete-lined tanks. This solvent effect can release deposits that have accumulated on tank walls and pipes from previous diesel fuel storage, causing fuel filter clogs initially; as a result, vehicle owners should change the fuel filter after the first tank of fuel (American Solar Challenge 2005).

Figure 11: Biodiesel Process



Source: Authors

In addition, biodiesel has been shown to soften and degrade certain types of elastomers and natural rubber compounds over time, which can impact fuel system components such as fuel hoses and fuel pump seals. While most engine manufacturers will not void their warranties with the use of B20 or lesser blends, higher concentrations may not be covered (National Biodiesel Board 2007b).

Biodiesel is biodegradable, which means that it will dissipate quickly after a spill. In fact, it degrades four times faster than petroleum diesel. When mixed with a blend of petroleum diesel, the petroleum diesel portion of a spill is still a problem, but less so than with 100 percent petroleum diesel.

Biodiesel can be integrated into existing petroleum infrastructure easily and safely. As biodiesel has a higher flash point, it does not ignite as easily as conventional diesel and it is safer to transport. Biodiesel fuels tend to gel at low temperatures. This problem is more pronounced as the biodiesel concentration is increased, but it has been successfully addressed by blending kerosene in with the biodiesel.

The near absence of sulfur and high oxygen content of biodiesel results in substantial reductions in PM, VOC, and CO emissions. And since biodiesel feedstocks are renewable, CO_2 emissions can be reduced significantly; even use of B20 can result in lifecycle CO_2 reductions of about 16 percent. While preliminary analyses indicated a slight increase in nitrogen oxides (NO_x) emissions with biodiesel, more recent analyses have found no statistically significant difference from petroleum diesel.

While biodiesel use is a promising means of reducing criteria and GHG emissions in the trucking industry in any country, its ultimate benefit will likely be constrained by limited availability. In the United States, even optimistic production estimates from the National Biodiesel Board are limited to 5 percent of the national market by 2015 (ICIS, February 2007). Nevertheless, niche applications are feasible, with more than 25 public access biodiesel stations currently operating in California (U.S. DOE/EERE, September 2007a).

Pump price is also a consideration. B100 currently costs approximately 15 cents per gallon more than diesel in California, although cost differentials can vary substantially due to the use of different feedstocks in making biodiesel and the current volatile petroleum diesel pricing (U.S. DOE/EERE, July 2007a). To make these fuels more competitive with petroleum diesel fuels, it may be necessary to consider use of tax incentives or subsidies to compensate for the cost differential.

Biodiesel availability is an even greater constraint in Mexico, with production limited to a handful of small plants. At this time, biodiesel is not available in Baja California. On the other hand, a recent Mexican government study found that potential biodiesel production using safflower, sunflower, rapeseed, or jatropha could be economically competitive (on a pre-tax basis) with standard PEMEX diesel. Nevertheless, there are serious agricultural constraints in Mexico requiring tradeoffs between growing crops for human consumption versus growing them for vehicular fuel. There are also issues related to differing product yields. For example, one acre of soybeans can yield 60 gallons of biofuel; however, one acre planted in switchgrass can produce 500 gallons of ethanol. The choice of which to grow will be driven by market factors, technology constraints, and potential applications. With these issues in play, concerns exist about the sustainability of supply and the location (from a market distribution standpoint) of biofuels. These factors will likely limit the availability of biodiesel in the future (U.S. DOE/FAS, June 2007).

Methanol and Methanol Blends

Methanol, also known as wood alcohol, can be produced using a variety of feedstocks including natural gas. When used in high concentrations (typically 85 percent + blends with gasoline), hydrocarbon emissions can fall substantially. While methanol has been evaluated in different heavy transportation applications such as buses and trucks, no research projects involving heavy-duty methanol vehicles were identified since the mid-1990s in the United States (U.S. DOE/EERE, September 2007c).

Given the lack of recent research and development regarding heavy-duty methanol engines and the fact that methanol is not available for retail sale in Mexico, and only at a small number of facilities in California (primarily for fuel cell demonstration projects) (California Fuel Cell Partnership 2002), methanol was not seen as a viable on-road fueling option at this time.

Ethanol and Ethanol Blends

While most typically blended at low levels with gasoline (10 percent or less) improve gasoline vehicle emissions performance, ethanol can also be used in vehicles at much higher volumes, up to 100 percent, termed E100. Several research projects in the mid and late 1990s demonstrated the technical feasibility of ethanol use in heavy-duty applications. However, ethanol's lower energy density (relative to diesel) typically results in reduced vehicle range, making it potentially less applicable to long-haul applications (unless fuel tanks are correspondingly increased in size).

Aside from its ability to significantly lower PM and hydrocarbon emissions, ethanol is non-toxic when pure and fully biodegradable. It is perhaps most importantly attractive as a source of renewable fuel, and can be made from a number of biomass feedstocks. In the United States, the vast majority of ethanol is blended with gasoline (E10) as an oxygenate. Currently there are dozens of research initiatives underway to facilitate increased ethanol production that may result in increased availability of higher ethanol blended fuels. Nevertheless, ethanol is corrosive to traditional fuel pipeline and storage systems, and so must be distributed by truck or rail using special containment vessels. Accordingly, transportation costs are increased relative to traditional gasoline and diesel, which rely heavily on pipeline deliveries (U.S. DOE/EERE, September 2007a).

At this time, most ethanol produced in Mexico is exported to the United States to meet rising demand for E10 blends. To encourage ethanol production in Mexico, the Mexican Congress recently promulgated the Bio-Fuels Promotion and Development Law. While certain feedstocks such as sorghum may prove economically competitive with traditional fuel sources such as petroleum, Mexico's arid farmland is a serious constraint to expanding agriculture for fuel production (U.S. DOA/FAS, June 2007).

In any case, the lack of ethanol distribution networks in the United States and Mexico, the high demand for ethanol as a low-level gasoline additive, and the lack of commercially available heavy-duty spark ignition engines make high-concentration ethanol fuel (E85+) a highly unlikely candidate for significant penetration into the heavy-duty freight fleet in the foreseeable future.

An alternative diesel formulation containing up to 15 percent ethanol, termed "e-diesel," has shown promise in reducing PM, CO, and NO_x emissions, and corresponding CO_2 reductions from use of a renewable fuel (E85 Safety.com, June 2006). However, initial formulations have resulted in a substantially lower flash point (the temperature at which autoignition of the fuel occurs) than conventional diesel, which may need to be addressed through additional reformulation or other means.

Liquefied Petroleum Gas (LPG)

LPG, often referred to as propane, is a common byproduct of the petroleum refining process, and is widely available in both the United States and Mexico. Mexico actually produces more LPG than is required to meet local demands and exports the surplus to the United States.

Commercial LPG has a minimum of 90 percent propane and not more than 5 percent propylene, together with various quantities of butane and other light gases. LPG prices generally follow other petroleum product costs over the long-run. LPG is stored under moderate pressures as a liquid and has been used for decades for light-duty vehicles. LPG offers substantial potential reduction in PM, VOC, NO_x, and CO emissions relative to diesel. While power, acceleration, and performance are similar to diesel fuel, LPG has several limitations that severely limit its potential heavy-duty applications in the near and medium term, on both sides of the border:

- LPG use requires spark-ignition rather than diesel engines, requiring entirely new engines rather than a retrofit.
- LPG's lower energy density reduces vehicle range absent corresponding increases in fuel storage capacity.
- Heavy-duty LPG engines suitable for Class 8 trucks are currently not available.[9]
- Marginal production and consumption of LPG for transportation uses will always be tightly constrained by limited supply, as LPG is a byproduct of petroleum refining.

For these reasons LPG is not considered a viable option for heavy-heavy duty on-road transportation at this time.

Natural Gas

Natural gas is primarily composed of methane (70 to 90 percent) extracted from gas wells or as a byproduct of oil production. Natural gas can be used for transportation applications in two forms, as compressed natural gas (CNG) and liquefied natural gas (LNG). CNG is compressed to between 3,000 and 3,600 pounds per square inch (psi). To liquefy natural gas, it must be cooled to -260 degrees Fahrenheit. The liquefaction process used for LNG removes most though not all impurities, such as water, dust, and heavy hydrocarbons, that when combusted may increase emissions.

While either CNG or LNG may be used for short-haul on-road applications, LNG is preferred for long-haul applications due to its much higher energy density and resulting vehicle range. Even with LNG, truck range is substantially less than with comparable diesel units, often being reduced by 40 to 50 percent.[10]

CNG and LNG are inherently clean-burning fuels, with drastically lower PM levels compared to pre-2007 diesel engines. VOC and NO_x impacts relative to these engines are also substantial, with NO_x reductions ranging from 17% to 80%, and VOC reductions from 4% to as high as 96%,

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[9] The Cummins B5.9 Liquefied Petroleum Gas (LPG) engines have been successfully demonstrated in several medium-heavy duty applications such as small buses and delivery vehicles, but are not appropriate for heavier applications – see http://www.cleanairnet.org/infopool/1411/propertyvalue-17732.html#h2_1.

[10] For example, see http://www.nrel.gov/docs/fy00osti/27678.pdf

depending upon vehicle type and drive cycle (U.S. DOE 2008). However, these advantages effectively disappear with the introduction of diesel engines meeting the 2007 and 2010 emission standards.

Lifecycle GHG emissions for natural gas vehicles are likely to be lower than those for diesel trucks (by roughly 10 percent), although the benefit quickly diminishes with increasing fugitive methane emissions (Australian Department of the Environment and Water Resources 2006).

In the United States, CNG is available for vehicular use; in California there are more than 110 public access stations capable of dispensing CNG (U.S. DOE/EERE, September 2007b). However, there are only five CNG stations in all of Mexico at this point (Prospectiva de Gas Natural 2007). In addition, natural gas is available only in two industrial parks in the Tijuana region. Given the lack of existing gas delivery infrastructure in the region, obtaining CNG south of the border is highly unlikely in the foreseeable future.

LNG availability for transportation use is somewhat more limited, with only 26 public access stations located in California at this time (Interstate Clean Transportation Corridor 2007). While no LNG dispensing facilities are currently operating in the border area, Shell Oil recently announced plans to provide LNG to a regasification facility in Baja California. While the Shell shipments are intended for utility use, the receiving facility provides potential infrastructure to assist with LNG distribution in the future.

Despite the fact that Mexico has a limited number of natural gas refueling facilities, this option should not be rejected out of hand, as Mexico has large untapped reserves of natural gas in the northeast section of the country, though at this time, these reserves have not been developed. Currently Mexican demand slightly exceeds supply. The U.S. DOE believes that the Mexican government does not have the resources needed to develop their natural gas reserves and has been unsuccessful in attracting foreign capital as only the state oil and natural gas company, PEMEX, is allowed to have any ownership interest in Mexico's oil and natural gas reserves, making participation in the development of Mexico's oil and gas resources unattractive to foreign investors.

In addition to the uncertainty in CNG/LNG fuel supplies in the border region, these fuels face a number of other obstacles to implementation:

- Gaseous fuels require spark-ignition rather than compression engines. Therefore adopting either of these fuels would require either re-engining or the purchase of a new vehicle.
- Even if public fueling stations can be accessed, under most operation scenarios supplemental fueling stations would need to be developed. The capital requirements for a reasonably sized LNG station can be high, between $350,000 and $1,000,000 (Idaho National Laboratory 2007).
- At this time heavy-duty natural gas engines are not being manufactured specifically for tractor-trailer rigs, although certain models have been adopted for use by sanitation trucks that have similar horsepower requirements (Natural Gas Vehicles for America, July 2006).
- Heavy duty CNG and LNG typically cost $40k-$50k more than the diesel counterpart, and the compressor station/LNG station adds a nominal $30k higher cost per vehicle.

- It is not certain that heavy-duty diesel manufacturers will offer natural gas vehicles after 2010 when the new standards may eliminate the criteria pollutant advantage of natural gas, although fuel cost savings may persist.

High-Pressure Direct Injection LNG/Diesel. As a result of the ever-increasing stringency of the U.S. federal exhaust standards, advanced technologies are being developed using natural gas, supplemented with a small amount of diesel (~10 percent), in a compression ignition system. Specifically, the Cummins Westport high-pressure direct injection (HPDI) technology has been successfully certified to meet both the U.S. 2007 and 2010 advanced diesel emission standards (U.S. DOE/EERE, July 2007b). Of most relevance to this study, the Westport ISL-G engine is capable of tractor-trailer operation suitable for freight transportation (Cummings Westport 2007).

The HPDI system has been demonstrated in a number of applications, with drivers reporting improved engine performance relative to diesel, although fuel economy was reduced by about 10 percent. As with previous CNG field studies, maintenance costs were also about two times higher than with equivalent diesel units, due to intermittent problems with the LNG pump and the HPDI injectors. Some or all of these costs may be eliminated in the future as maintenance personnel become better acquainted with the HPDI system, however. Additional filtration was required on the HPDI trucks to eliminate contaminants in the LNG fuel, which can easily foul the HPDI system (U.S. DOE/EERE, July 2004).

Hydrogen/CNG Engines. A heavy-duty engine technology has been developed using a combination of 20 percent hydrogen and 80 percent CNG. The hydrogen/CNG technology has been successfully demonstrated in bus fleets in the United States, showing promise for substantial PM, CO, NO_x, and VOC reductions relative to diesel. Though this technology has not been demonstrated for Class 8 freight trucks, a high percentage of vehicles that cross the border at Otay Mesa are smaller and may eventually be an appropriate match.

One of the biggest issues for the adoption of hydrogen/CNG engines is that the future distribution and sale of hydrogen for fleet use in any significant volume is highly uncertain. High incremental fuel costs for hydrogen present yet another substantial challenge.

Advanced Technologies

A number of technologies have emerged in recent years to improve the efficiency and lower emissions from standard diesel trucks. Some of these approaches entail complete replacement of the engine and drive train, while others involve relatively minor retrofits. The strategies fall into four broad categories: hybrid engines/drive trains; waste heat recovery strategies; idle reduction technologies; and non-engine design modifications. Unlike alternative fuel strategies, most advanced technology strategies are not constrained by fuel availability but should be equally available on either side of the border, given adequate funding. Each of these strategies is discussed below with respect to its potential application to cross-border freight transportation.

Hybrid Engines and Drive Trains

All standard internal combustion engines operate most efficiently under steady-state conditions, in a relatively small operation window (that is, near optimal RPM and torque outputs). Hybrid diesel vehicles improve overall efficiency by supplementing power demand outside the diesel engine's optimal range using alternative sources of energy. Heavy-duty hybrids typically use one of two alternative power sources: electric batteries and motors, or hydraulic reservoirs and associated components.

Heavy-duty hybrid-electric systems are similar to the familiar light-duty applications such as the Toyota Prius, utilizing supplemental power from the diesel engine and braking to maintain battery (or ultracapacitor) charge, and calling upon battery power to assist the engine with acceleration and high-load events. Hydraulic hybrids rely exclusively on regenerative braking to store the supplemental energy, and are primarily restricted to heavy-duty vehicles, although Ford may offer a hydraulic hybrid option F-Series pick-up truck as early as 2008 (FordMuscle, 2006). Because of their reliance on braking, hydraulic hybrids are best suited to applications such as delivery vehicles and refuse trucks which undergo very frequent start and stop episodes. Both of these technologies can also provide auxiliary power at idle, further improving vehicle efficiencies. Both also have the advantage of utilizing the existing diesel fueling infrastructure.

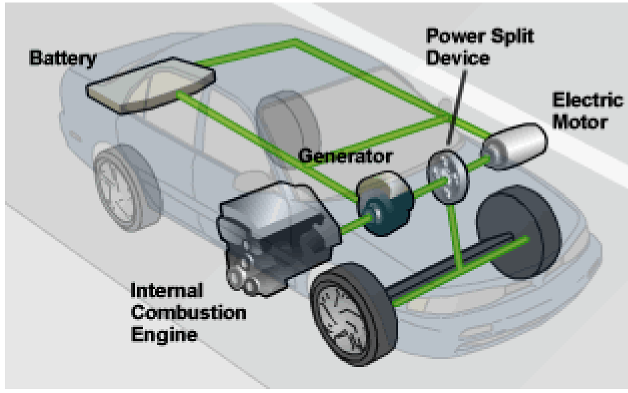
Hybrid Electric Vehicles. A hybrid electric powertrain uses electricity stored in batteries to run an electric motor that provides vehicles propulsion, as noted in Figure 12. As the energy from the batteries is depleted, an efficient diesel engine is used to recharge the batteries and provide additional energy for periods of high demand, such as acceleration. Hybrids are especially promising for vehicles whose duty cycles include extensive stop-and-go operation.

Given the short distances and low speeds of dray truck operations, some degree of hybridization could in principle be useful, but high costs would be an overwhelming barrier to this traditionally low-margin business. Compared to long-haul trucks, dray trucks are dated and more polluting, a reflection of the fact that these fleets have limited resources and in particular are unlikely to purchase new trucks. They may be receptive to options such as low-cost loans to retrofit vehicles, though such a policy would require Mexican support, as the dray truck business is predominantly Mexican.

An important advantage of hybrids can be to eliminate idling. Vehicles having only the capability to shut down and restart the engine automatically in stop-and-go traffic ("micro-hybrids") could offer substantial benefit to the dray fleet at fairly low cost. Micro-hybrids are not a retrofit technology, however. Because drayage is infrequently the vocation of new trucks, it is unclear how a technology of this kind would enter the dray truck stock.

Hybrid electric applications have been demonstrated fairly extensively for medium-duty applications and for heavy refuse haulers and transit buses, resulting in efficiency improvements up to 40 percent (E-trucker.com 2007 and Maryland Energy Administration, March 2007). Hybrid electric vehicles have also been developed using alternative fuels such as ethanol and CNG in transit bus applications, with similar fuel economy improvements relative to equivalent diesel units. Reliability of the hybrid systems is similar to that of diesel vehicles as well.

Figure 12: Hybrid Vehicle Design



Source: United States Department of Energy, 2007

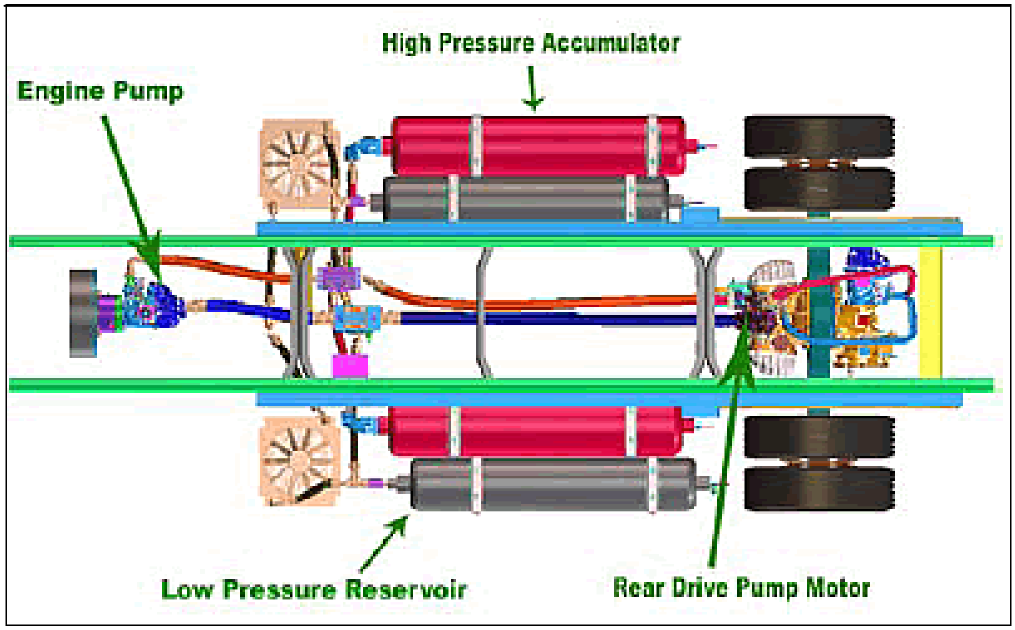
There has been only one field test of a hybrid electric configuration in a Class 8 tractor-trailer application to date, involving the Peterbilt/Eaton 386 model, recently deployed by Walmart. Field testing has found a 5 to 7 percent fuel economy improvement for these engines relative to comparable diesel units (Peterbilt Motors Company, March 2007). At this time the models are not commercially available. Industry experts estimate incremental costs at approximately 10 percent relative to standard diesel rigs, once full production volumes are achieved (Transportation Topic Online, October 2007). Depending upon diesel costs, payback on incremental costs could be obtained quickly (for example, in less than two years).

While hybrid electric vehicles show substantial promise for cost-effectively improving fuel efficiency and reducing associated emissions in Class 8 freight trucks, the current lack of availability and uncertainty associated with costs and maintenance requirements makes the future market for this technology uncertain.

Hydraulic Hybrids. U.S. EPA has partnered with United Parcel Service (UPS) in an advanced technology demonstration project to evaluate the feasibility and benefits of hydraulic hybrids in delivery applications. Hydraulic hybrid engines convert energy from braking into hydraulic pressure, which is stored in the accumulator tank as noted in Figure 13.

The pressurized hydraulic fluid is used to assists vehicle acceleration once the vehicle starts to move again. These engines are promising, as they provide 60-70 percent improvement in fuel economy, a 40 percent reduction in CO_2 emissions, and payback for incremental costs (~$7,000) in three years or less, assuming current diesel prices (U.S. EPA, June 2006). Considering the extended life of most heavy diesel engines, lifetime fuel and cost savings could be very substantial.

Figure 13: Hydraulic Hybrid Design



Source: Mike Millikin, Green Car Congress, 2007

At this time hydraulic hybrids have not been demonstrated in Class 8 tractor trailer applications, although engineering analyses predict a substantial fuel economy improvement for these vehicles, similar to medium-duty vehicle efficiency improvements. In fact, hydraulic hybrids are likely to be more cost-effective in short haul drayage applications than hybrid electrics, primarily due to the high energy density and relatively low cost of the hydraulic storage system compared with conventional batteries and ultra-capacitors. On the other hand, hydraulic hybrids do not offer significant improvements in long-haul applications due to the lack of frequent braking events (Design News, July 2007).

Of the available fuel and technology options evaluated for this study, hydraulic hybrid applications appear to be the most promising for widescale deployment in drayage applications in the medium to long-term (for example, 5+ years). Nevertheless, Class 8 drayage trucks based in Mexico are typically converted from long-haul trucks and would therefore be unlikely to be purchased as hydraulic hybrids. For this reason financial incentives may be needed to help introduce new hydraulic hybrids into the drayage fleet in the future.

Waste Heat Recovery Strategies

More than 50 percent of the energy released during diesel fuel combustion is ultimately lost as waste heat (Fairbanks, 2004). Several methods have been identified for potentially recovering some of this waste heat for use in vehicle traction and auxiliary power. While incremental efficiency improvements are possible for a number of standard components (including coolant and air pumps, thermostats and valves—Wambsganss 1999), two technology options have been identified that may provide particularly significant efficiency improvements in the future.

Turbocompounding. Turbocompounding involves routing the hot exhaust gases from a conventional turbocharger through an additional turbine to generate additional power.

Mechanical turbocompounding systems provide this additional energy directly to the vehicle drive shaft as supplementary power, while electrical systems may supplement engine power or auxiliaries.

Turbocompounding systems have found limited truck applications in Europe in Scania engines, although no systems have been commercialized for the U.S. market to date (Scania 2007).

Several manufacturers of Class 8 truck engines are investigating the feasibility, cost, and potential benefits of electric turbocompounding for the U.S. market, including Caterpillar, Mack, and Detroit Diesel (U.S. DOE 2005). Caterpillar estimates a fuel efficiency improvement between 5 and 10 percent for such systems at a cost ranging from $2,000 to $3,400 per unit, providing payback in approximately one to three years (Hopmann 2004). The U.S. DOE cooperative research program investigating turbocompounding feasibility estimates this technology will be ready for commercialization sometime after 2009 (Fairbanks 2005).

Thermoelectric Technologies. Research is also being conducted regarding the potential use of thermoelectric technologies in on-road diesel applications. These approaches use a quantum effect whereby electricity is generated in certain materials in the presence of a temperature differential. In general, the greater the temperature differential, the greater the effect. Therefore these technologies offer the greatest potential benefit in the engine exhaust stream, although braking systems and the EGR loop may also provide effective locations for system placement. By 2010 U.S. DOE estimates that thermoelectric generators may be available providing up to a 10 percent fuel economy benefit. In 10 to 15 years, U.S. DOE estimates this technology, when fully integrated with advanced electronic control systems, can increase overall truck efficiency on the order of 30 percent relative to today's models. However, system evaluation is still in the laboratory stage, and no cost estimates were identified for this technology yet.

Idle Reduction Technologies

An alternative means of reducing heavy-duty freight vehicle fuel consumption and emissions is to improve operational efficiency during idling. Reducing the amount of idling time and/or the associated power demand during this time also reduces engine wear and maintenance costs.

Several technology options have been developed over the last several years with these goals in mind, including auxiliary power units (APUs), automatic engine stop-start controls, cylinder deactivation, and improvements to auxiliaries such as air conditioning and heating systems.

Heavy-duty engine idling events are of two types: short-term and extended idling. Extended idling typically occurs during driver rest periods, where the engine is used to run auxiliary equipment such as A/C units and provide power for other amenities. Extended idling is most cost-effectively addressed through truck-stop electrification where it is available (U.S. DOE/EERE, September 2007e). Such strategies are not applicable to cross-border drayage operations, however, for which idling is associated with queuing at intermodal facilities and POEs. Engine idle-off capability is more suitable for drayage operations.

Truck-Stop Electrification (TSE). TSE systems provide long-haul truckers with an alternative, land-based power source for cab air conditioning and heating and for other auxiliaries, for a fee. TSE systems can be stand-alone or may require on-board equipment such as in inverter or other hardware. At this time there are 13 truck stops offering TSE services in California (U.S. DOE/EERE, 2007b). No TSE systems are available in Mexico at this time. System installation costs are estimated at about $4,000 per truck parking space (ARB, June 2004). Resulting user fees are estimated to be low (for example, $1.25/hr), providing a substantial cost savings over diesel fuel consumed during idling (Washington State University 2007).

Fuel savings and emission reductions associated with TSE systems can be comparable to or greater than those obtained through APU use, with NO_x reductions greater than 90 percent possible (U.S EPA, February 2004).

Auxiliary Power Units (APUs). APUs are designed to provide the power for the air conditioning and heating of a truck's cab space, and electricity for appliances such as TVs and microwaves, without reliance on the engine. APUs generally employ a small diesel engine, a generator, and a heat recovery system. Future systems may cost-effectively use gasoline or diesel fuel cells as power sources. APUs have been available in the marketplace for years and are a proven technology. Numerous vendors provide various models for installation between $1,500 and $7,000 (U.S. DOE/EERE, October 2007a). APU fuel consumption rates are typically one quarter or less idling consumption rates (that is, a one-gallon-per-hour fuel savings is typical), leading to corresponding reductions in CO_2 emissions. PM reductions can be 70 percent or more (Cummins Power Generation 2005). NO_x reductions can vary substantially depending upon the size of the APU engine, ranging from roughly 10 percent to more than a two thirds reduction (North Central Texas Council of Governments, January 2007). Fuel savings from APU installation can provide payback on investment in roughly three years under typical operating conditions (ARB, March 2005). However, given the relatively modest fuel consumption rates of diesel engines at idle, even widescale installation of APUs will result in only a relatively modest overall fuel savings.

There are several other technological improvements that can be made to traditional diesel tractor-trailer rigs that can result in modest to substantial fuel savings and associated emission reductions. Additional on-board strategies include a number of options, including: automatic engine stop-start controls for sleeper climate control (widely available in late model engines for about $1,000); cylinder deactivation to reduce the number of combusting chambers during idling (not currently available); fuel fired heaters (essentially low-cost APUs only providing heat to the cab at roughly $2,000 per unit); and dedicated air conditioners for sleeper cabs (U.S. DOE/EERE, October 2007b). Like APUs and TSE, these strategies have the potential to provide modest fuel and maintenance cost savings of several hundred to a few thousand dollars per year per vehicle (ARB, June 2004).

Other Fuel Economy Strategies

There are several other technologies that can significantly improve Class 8 truck fuel economy and emissions by using new low rolling resistance tires and enhancements to vehicle aerodynamics.

Technologies to Decrease Rolling Resistance. Energy losses associated with tire rolling resistance can range from 15 to 30 percent of total losses for heavy-duty trucks (U.S. DOE/EERE, September 2007d). Two approaches are currently available for reducing rolling resistance and thus improving fuel economy. First, low rolling resistance tires can replace standard tires, resulting in a fuel savings of 4 to 5 percent (ICF, October 2006). Low rolling resistance tires are already available in the U.S. market for only a few hundred dollars more than standard tires per set (E-Trucker, October 2005).

The second approach is super-single tires. Super-single tires are substantially wider than standard tractor-trailer truck tires, and replace the dual tire configuration. By reducing the total number of tires and overall weight (by adopting aluminum rather than steel wheels), super-wide tires can reduce fuel consumption in the range of 4 percent, at a cost of about $5,600. Under current operating conditions payback can be obtained quickly, often in less than 18 months U.S. EPA, December 2006). Costs with trade-in of old tires and wheels can be substantially less, at about $2,800 (ExpeditersOnLine.com, October 2007). Weight reduction between 800 and 1,300 pounds also increases available payload for additional revenue generation (Michelin America 2007). While earlier models required extensive truck modifications (for example, gear ratio adjustment) models are now available that can be installed directly with new wheels.

Maintenance considerations are similar to traditional tires (for example, single-wides are retreadable). However, claims have surfaced implying increased tread wear rates and reduced wet traction, although other operators contend comparable or even superior performance in both regards. In addition, when blow-outs occur, trucks cannot "limp" home on a remaining dual tire as before. The lack of widely available super-wides on the road makes this issue an even greater concern for operators. On the other hand, automatic tire pressure monitoring systems available with super wides may tend to lower incidence rates for flats. On the whole, despite the potential fuel and cost savings benefit, super-wides have yet to see wide market penetration in the United States (ExpeditersOnLine.com, October 2007). At this time, most penetration has occurred in short-haul fleets, where the disruption associated with blow-outs is less. Extension to line-haul fleets will most likely be deferred until a regional or nationwide road call network is adequately demonstrated (Modern Tire Dealer, August 2003).

Aerodynamic Improvements. Traditional tractor-trailer rigs can be retrofit with airfoils (nose cones and trailer tails) and side skirts to reduce drag (as noted in Figure 14), improving fuel economy by approximately 5 percent, with comparable reductions in CO_2 and NO_x emissions (ICF, October 2006). An aerodynamic retrofit kit developed under EPA's SmartWay program is available for $2,400, providing quick payback via fuel savings (U.S. EPA, December 2006).

Implementing a combination of APUs, idle control measures, rolling resistance improvements and aerodynamic improvements can result in fuel reductions up to 20 percent (Minnesota Pollution Control Agency, May 2006).

Figure 14: Aerodynamic Truck - Small Radiator, Rounded Corners, Recessed Lamps, Built in Aeroshield

Source: Presentation by Fred Browand, Aerospace & Mechanical Engineering, University of Southern California

Railroad Fuels and Technologies

Railroad intermodal facilities include line haul engines that move freight over long distances and yard or switcher engines that tend to operate at or in the vicinity of a intermodal yard. Yard engines are involved in disassembling and combining freight cars into trains relative to their ultimate destination. As increasing cross border intermodal traffic would impact both line haul and yard engines, both engine types were included in this evaluation. Railway fuels and technologies included in this assessment can be grouped into the following categories:

Table 37: Railroad Fuels and Technologies

Fuels	Technologies
Low sulfur diesel	Hybrid engines
Biodiesel	Gensets
Natural gas	Fuel cells
Synthetic fuels	Mag/Lev
	Auxiliary power units

Synthetic fuels (for example, dymethylether), hydrogen-fueled engines, Mag/Lev systems, and fuel cell-powered locomotives are being studied, are all at relatively early stages of development and would require complicated infrastructure to support. For these reasons these technologies were not evaluated in this assessment.

Auxiliary power units in rail applications are slightly different than those used for on-road vehicles. For rail applications, APUs operate basic functions (for example, battery charging, fluid heating and circulation) without having to use the main propulsion engines, thereby reducing idling emissions. Such use of APUs tends to be more appropriate for colder climates, where the engine needs to be run periodically to maintain acceptable engine and transmission fluids temperatures. As the climatic conditions around the California/Mexico border area do not necessitate the use of APUs, they were also not included in this evaluation.

Reformulated and Alternative Fuels

Low- Sulfur Diesel Fuels

In May 2004, as part of the Clean Air Nonroad Diesel Rule, EPA finalized new requirements for nonroad diesel fuel that decrease the allowable levels of sulfur in fuel used in locomotives by 99 percent. In addition to the use of low-and ultra-low-sulfur fuels, the EPA proposed a three part program in March 2007 to reduce emissions from diesel locomotives of all types: line-haul, switch, and passenger rail. The proposal aims to take advantage of the new low-sulfur fuels, which will allow for the application of control devices that cut PM emissions from these engines by 90 percent and NO_x emissions by 80 percent. The new standard is expected to begin in 2009. The proposal will also set long-term, Tier 4 standards for newly-built engines based on the application of high-efficiency locomotive catalytic exhaust after-treatment technology beginning in 2015 (U.S. EPA 2007).

As noted earlier, transportation fuels in Mexico are distributed exclusively by the national oil company PEMEX. At this time it is uncertain when sufficient low-sulfur railroad fuel will be available for locomotive operations. This will be a concern for Mexican and U.S. locomotives transiting the border area as Mexican locomotives will not be able to comply with U.S. locomotive fuel standards and U.S. locomotives equipped with advanced control technology will not be able to travel far into Mexico, as refueling with high-sulfur diesel will poison air pollution control devices needed to meet the new emission standards.

Biodiesel

As noted in the on-road section of this chapter, biodiesel is produced in a catalytic reaction with vegetable oils and methanol or ethanol (U.S. Environmental Protection Agency, October 2006). Pure biodiesel (B100) is blended with diesel fuel in a variety of formulations, with B20 being the most common. Recent testing of B20 on locomotives indicates that PM and CO emissions can be reduced by 12 percent, while SO_x were reduced by 20 percent (National Biodiesel Board 2007a).

Railroad companies have been hesitant about using biodiesel, primarily because there have been very few studies on the long-term effects biodiesel has on railroad engines. For example, unlike on-road engines, locomotive engine components tend to be made of copper, which is more flexible than steel and can better handle vibrations. At this time there is little information available indicating how biodiesel reacts with copper.

There are also significant issues concerning the supply of biodiesel for railroad applications. The U.S. rail industry uses approximately 4 billion gallons of fuel per year. Assuming a 20 percent biodiesel blend, this would require a supply of 800 million gallons of biodiesel. Presently, total biodiesel production for all transportation modes in the United States is approximately 300 million gallons.

Natural Gases

As noted earlier, natural gas, as either LNG or CNG, is clean-burning and emits lower levels of potentially harmful byproducts into the air than diesel (California Energy Commission, February 2006c). As with on-road applications, LNG is more applicable for long-haul railroad operations because the fuel density is five times greater than CNG, reducing the space requirement and the frequency of refueling. LNG can be stored in a separate tender car that is constructed as a double-walled stainless shell similar in design to a Thermos bottle. This design is capable of keeping the LNG cold for periods up to 14 days. A heat exchanger converts the LNG back to a gaseous state that is piped to the engine (International Union of Railroads, October 2002b).

To facilitate combustion of LNG in a compression engine, dual LNG and diesel fueled engines have been developed and used by Burlington Northern Santa Fe for more than a decade. The diesel fuel acts as an ignition source for LNG combustion and can also be used as a backup fuel if there is a failure in the LNG fuel supply.

Because CNG has lower energy density than LNG, CNG-powered engines require more frequent fueling, and therefore are more appropriate for switch engine applications, as these engines are limited to the railyard and nearby facilities. Typically yard engines are idle for between 60 and 80 percent of the time, providing plenty of opportunities for refueling (U.S. EPA, April 1998).

Use of natural gas for transportation applications generates 50 percent less VOC and PM emissions. CO_2 emissions are also reduced by 25 percent. After-treatment devices may be needed to control NO_x emissions as there is some evidence to indicate that NO_x emissions may be slightly higher using natural gas fuels. It should also be noted that because natural gas is primarily methane, there are higher methane emissions associated with the use of this fuel. Methane is a potent GHG.

An important factor for shifting to natural gas powered locomotives is fuel cost savings. A study developed in 1994 for Burlington Northern Santa Fe quantified that the cost of moving coal with natural gas powered engines was $6,756 per round trip compared with a diesel fueled engine for the same trip which was $9,774, providing a cost savings of 31 percent. Between 1994 and 2006, natural gas prices have increased 121 percent, while diesel prices have increased 144 percent, so that the cost differential now is probably even more significant than in 1994. This cost comparison does not include cost savings associated with reduced maintenance and longer engine life, nor does it include the cost to convert diesel powered locomotives into dual fuel engines.

Natural gas should be seen as a significant long term option for cross-border rail traffic. Currently there are natural gas pipelines in Southern California; and though resources will also be needed to expand the natural gas distribution infrastructure in Mexico, it has been previously noted that Mexico has significant untapped reserves of natural gas, though at this time, these reserves have not been developed and Mexican demand slightly exceed supply.

LPG

LPG was initially used as a railway fuel for gas turbine locomotives (Model Turbine 57, using an Alco- General Electric (GE) gas turbine electric engine) developed after World War II for

Union Pacific (Locomotive Engineering Journal, 1948), but these locomotives proved to be uneconomical for general freight rail operations.

The use of LPG as a railway fuel for rail freight movement is currently being re-evaluated in a study for the state of Texas. Preliminary studies indicate that the NO_x produced by switcher engines could be reduced by 120-200 tons per year by using LPG powered locomotives (Propane Council 2002). However, without financial incentives to offset capital and operating costs, these locomotives will be more costly to operate than diesel-powered locomotives.

Advanced Technologies

Gensets

A typical yard locomotive has one large 2,000 horsepower diesel engine. The new genset yard locomotive uses multiple smaller (700 horsepower) diesel engines (see Figure 15). These newer smaller diesel engines are certified as EPA Tier III nonroad engines that comply with more stringent emission standards than the current EPA Tier II locomotive standards. Gensets' improved efficiency is also due to the use of electronic controls that regulate the engine performance to optimize fuel consumption and reduce emissions. For example, these engines reduce fuel consumption by 35 to 50 percent and provide an 80 percent reduction in NO_X and PM emissions. Electronic engine controls reduce wheel slippage, which enhances traction by 50 to 65 percent relative to traditional diesel engines (National Railway Company 2007).

Figure 15: National Railway Company Genset Locomotive

Source: National Railway Company, 2007

Part of the fuel savings and emission reductions are due to the fact that these engines are also equipped with idle reduction technologies that shut off the engine when not needed. Idle reduction technologies also reduce maintenance activities, as the engine's operating hours are reduced. This technology can save between 15 and 24 gallons of diesel fuel per locomotive, per day (National Railway Company 2007).

Normally the purchase cost of new engines can be between $1 million and $2 million; the National Railway Equipment Company refits older locomotives, converting them to genset locomotives at approximately 60 percent of the cost of a new locomotive (National Railway Company 2007).

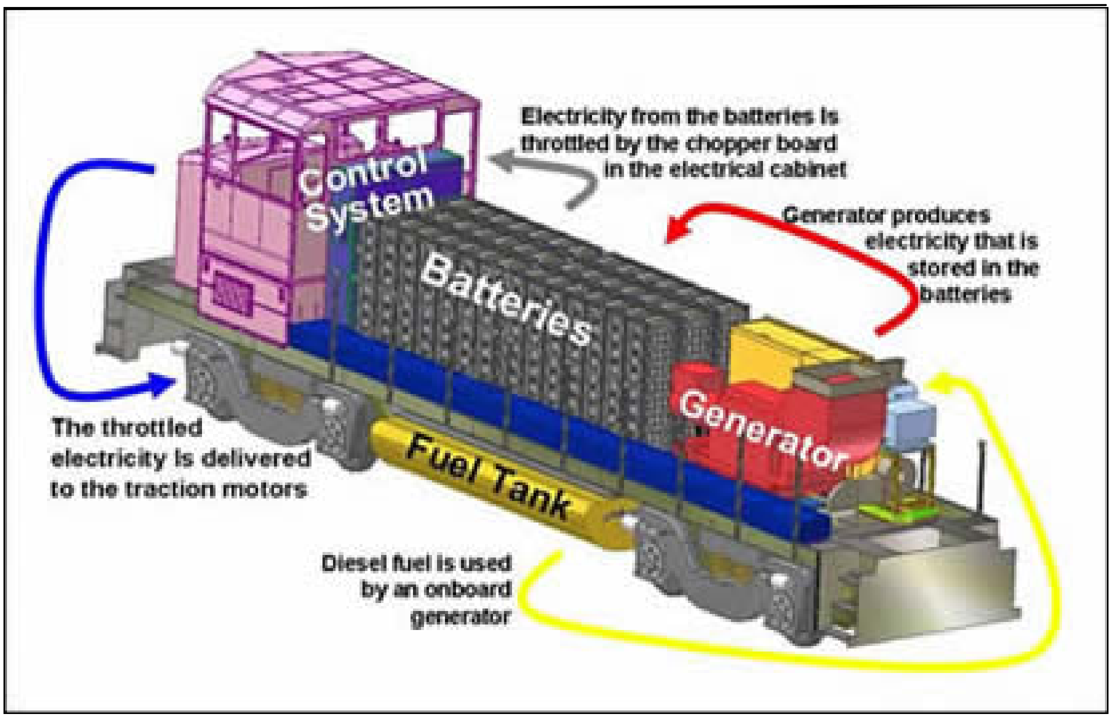
Currently, Union Pacific operates 60 genset switchers in the Southern California area (Diesel Technology Forum, August 2005).

Genset locomotives do not need special fuels or infrastructure to operate, making them viable candidates for use in the Northern Mexico States, Southern California, and cross border transfers.

Hybrid Engines

Unlike traditional yard locomotives, hybrids are equipped with small, highly efficient diesel engines similar to those found in gensets that provide power to large banks of long-life, recyclable batteries, as noted in Figure 16. These engines operate only when the batteries need to be recharged to their optimum levels.

Figure 16: Hybrid Switch Engine Design



Source: Railpower Technologies Corporation, 2007

Typically switcher locomotives tend to operate in a "stop-go" manner, which is an inefficient mode of operation for a typical diesel engine, increasing fuel consumption and emission of pollutants. "Stop-go" operations also increase necessary engine maintenance activities, due to increased wear and tear on engine components. Operating in a "stop-go" manner is less of an issue for hybrids, as the electric motors draw off of the batteries as needed, and the batteries are recharged by the smaller diesel engines which are operating at a constant optimal load, thereby improving fuel efficiency and reducing emissions and maintenance activities. For example, RailPower's operating data for their hybrid switch engine shows that the Green Goat® has the potential to reduce fuel consumption and GHG emissions by 40 percent to 70 percent and would decrease emission of criteria air pollutants, which includes NO_x and diesel particulates, by 80 percent to 90 percent while significantly lowering operating and maintenance costs (Diesel Technology Forum, August 2005). In standard yard service, one hybrid yard locomotive will typically reduce GHG emissions by 271 tonnes per year and criteria pollutants by 5 tonnes per year, with greater reductions where heavy-duty switching is carried out continuously (RailPower Technologies Corp. 2007).

Typically diesel switcher engines spend between 60 and 80 percent of operating hours in idle mode; by design, hybrid engines operate only when required and therefore are not operating during idling periods (U.S. EPA, April 1998).

Hybrids are particularly suitable for switch engine activities as they require banks of batteries that are very heavy. The weight of these batteries can be a problem for other modes of transportation where lighter vehicles are more fuel efficient and generate less pollutants. Switcher engines are deliberately designed to be heavy to maximum traction, such that the weight of the batteries can improve the functionality of switcher engines (RailPower Technologies Corp. 2007). At this time, Union Pacific has 12 hybrid yard locomotives operating in Southern California (Union Pacific 2008).

For the most part, hybrid locomotive are being used for yard activities, GE has recently developed a 2000 horsepower hybrid locomotive for line haul operations that has a 10 percent improvement in fuel usage and emission reductions (GE 2007).

Hybrid locomotives do not need special fuels or infrastructure to operate, making them viable candidates for use in intermodal yards in the northern Mexico states and Southern California.

Other Fuel Economy Strategies

In addition to the technologies and fuels discussed above, there are several other technological approaches available to help reduce fuel consumption and emission of pollutants. These include:

- Aluminum rail cars.
- Covered freight cars.
- Driving optimization systems.
- Diesel engine improvements.

Aluminum rail cars are two thirds the weight of comparable steel cars, allowing for the construction of larger cars (Aluminum Association Inc. 2004). Despite the higher cost of the aluminum stock, the difference can be paid back in less than two years due to lower fuel costs or higher carrying capacity (International Union of Railroads, October 2002a).

Freight trains use a high share of their energy to overcome air drag. This can be mainly attributed to the aerodynamically unfavorable shape of freight trains: the space between cars is not shielded, many cars have no roof or cover and when empty, and therefore air drag is maximized (Vollmer 1989). Studies indicate that because of poor aerodynamics, a locomotive pulling open empty cars (on level topography) consumes more energy than one traveling with full freight cars with a better aerodynamic profile. Covering freight cars has the potential to increase fuel savings and reduce emission reductions by more than 10 percent (Institute for Futures Studies and Technology Assessment, March 2003).

Driving optimization systems use satellite position data, engine operating data, and information on track geometry and load to provide the optimal speed and power setting to move freight quickly, while reducing fuel consumption and emissions (Sanftleben, 2001 and GE, 2007).

In addition to the technical options discussed above, improvements continue to be made in diesel engine design, including use of advanced turbocharging and enhancement of fuel injector systems, which both lead to a reduction in fuel consumption and emission of pollutants (GE, 2007).

Marine Fuels and Technologies

Marine fuels and technologies evaluated in this assessment can be grouped into the following categories:

Table 38: Marine Vessel Fuels and Technologies

Fuels	Technologies
Low-sulfur Diesel	Wind/solar powered
Biodiesel	Fuel Cells
Natural Gas	
Synthetic Fuels	
Hydrogen	

Hybrid solar/wind/biodiesel vessels (see Figure 17), hydrogen fuel, and fuel cell-powered ships are currently being studied for large vessel operations. These technologies are in a relatively early stage of development, and therefore the focus of this research was on the more viable alternative fuels and technologies. It is recommended that future research consider hybrid/electric biodiesel ferries, which use 50 percent less biodiesel than a conventional ferry running on biodiesel. The initial capital cost of the new hybrid technology is significantly more than that of the incumbent technology. For example the capital cost of a conventional 149 passenger ferry in the United States is approx $1.8 million compared to a similar hybrid/electric vessel that costs approximately $3.4 million.

Figure 17: Solar Sailor-Solar/Wind Powered Ferry Currently in Use at the Sydney Harbor and Being Considered for Applications in San Francisco and San Diego

Source: Solar Sailor, 2007

Reformulated and Alternative Fuels

In order to evaluate alternative marine fuels, it is necessary to understand the diverse marine fuels currently available for shipping activities. Over the years, marine diesel engines have evolved to burn a wider variety of grades of fuel oil, allowing ship operators to save operating cost by burning cheaper blends of high sulfur distillate and residual fuels as they are available in different ports throughout the world. Marine vessel fuel is often referred to as bunker fuel which is technically any type of fuel oil used aboard ships. Marine bunker fuels include a wide range of fuel grades: 1) distillate diesel fuels (for example, DMX, DMA, DMB, and DMC), sometimes referred to as gas oils or marine gas oils; 2) fuels derived from the remaining petroleum refinery residuum (for example, RML) are called fuel oils or residual fuels; and 3) intermediate fuel oils (for example, DMC, IFO 180, IFO 380, RMA, RMB, RMC, RMD, RME, RMF, RMG, and RMH) which are a blend of the distillate and residual fractions often referred to as marine diesel fuels. The distillate component of intermediates varies (80-100 percent for DMC, 12 percent for RMA-RMF, and 2 percent for RMG-H) (U.S. EPA 1999).

Marine fuels require less refining than land-based diesel fuels, such that they tend to be more viscous, have a higher flashpoint and higher sulfur content, and are associated with higher particulate emissions than diesel fuels used for land-based operations. For example, marine fuels have, a flash point of 60^{o}C, a sulfur content of 1.5 to 2.0 percent sulfur, and an ash percent of 0.01 to 0.2; compared with low sulfur highway fuels that have a flash point between 38^{o} - 52^{o}C, sulfur content of 0.05 to 0.5 percent, and an ash percent of 0.01. Depending upon the grade, marine fuels tend to cost significantly less than their land-based counter parts, making them particularly attractive for marine vessel operators (U.S. EPA 1999).

Marine distillate fuels are generally used for smaller vessels such as tug boats, fishing boats, offshore support vessels, drilling rigs and ferry boats. Larger ships that are used to transport cargo tend to use intermediate or residual fuels while at sea, but may store and use distillate fuels to run auxiliary engines or propulsion engines while in port.

Internationally, there is concern about the impacts shipping is having on areas downwind of shipping lanes and ports due to sulfur emissions. The Marine Pollution (MARPOL) Annex VI Regulations 14 and 18 have been developed to reduce emissions in designated SO_x Emission Control Areas (SECA). This regulation applies to ships of 400 gross registered tonnage (GRT) and above. While a ship is operating in a SECA, the sulfur content of fuel oil used on board must not exceed 1.5 percent as documented in the fuel bunker delivery notice, which is provided to the ship's captain after refueling MARPOL 1997).

Alternatively, ships may use an exhaust gas cleaning system or any other technological method to limit SO_x emissions while operating in a SECA. The first SECA became effective on May 19, 2006, and is located in the Baltic Sea. The North Sea SECA went into effect on November 22, 2007. Currently, the U.S. EPA is evaluating whether a North America-wide SECA or separate SECAs for the West Coast, East Coast, Great Lakes, and the Gulf of Mexico should be developed.

Low-Sulfur Diesel Fuels

Beginning June 1, 2006, refiners were required to produce clean ultra-low-sulfur diesel fuel for use in highway diesel engines. Intrastate marine diesel fuels used in harbor craft transitioned to 15 ppm ULSD fuel on January 1, 2007. Beginning in 2012, the U.S. EPA is requiring that all marine diesel fuel must meet the ULSD fuel standard of 15 ppm sulfur.

As noted repeatedly in previous sections of this report, besides reducing emissions from the existing diesel fleet, these low-sulfur fuels will enable the use of advanced after-treatment technologies to reduce other criteria and hazardous air pollutants. Technologies like particulate traps, selective catalytic reduction, and seawater scrubbing are capable of reducing emissions by 90 percent or more, depending upon the pollutant and the add-on control device.

Transportation fuels in Mexico are distributed exclusively by the national oil company PEMEX. Diesel fuel for marine applications is colored and currently has an upper sulfur limit of 5000 ppm. Mexican refineries can produce marine fuel at 4000 ppm, but the supply is unreliable. Furthermore, there is considerable uncertainty when lower sulfur fuels will be available for use by commercial marine vessels. It is unclear at this time how the North American SECAs will be defined. It is possible that ships traveling between the United States and Mexico will need to purchase and store low sulfur fuel from U.S. ports and use these fuels while transiting U.S. waters. Such dual-fuel vessels are not uncommon, but they cannot be equipped with advanced control technologies without damaging these control devices during the periods when the vessels are using high sulfur fuels.

Biodiesel

As noted in previous sections, biodiesel is an alternative fuel that can be used as a replacement fuel or blended with diesel fuel. Given the wide range of fuels that marine diesel engines can use, biodiesel is probably one of the cleaner options, requiring minimal engine modifications (California Energy Commission, February 2006). It should be noted that at this time there are no studies of the use of biofuels on larger Category 3 marine vessels, typically involved in cargo transfers.

In 2006, the National Oceanic and Atmospheric Administration (NOAA) implemented the Green Ship Initiative, which converted all research vessels in the Great Lakes region to B100 biodiesel derived from soy. The conversion included propulsion and auxiliary diesel engines for generating electricity. NOAA documented higher lubricity and cleaner injectors with the use of biodiesel, Furthermore, NOAA has reported that the cost of B100 is 20 to 50 cents per gallon less than marine distillate fuel previous used. The NOAA initiative has noted that SO_x emission were negligible, CO and PM were 50 percent lower, and VOCs were 70 percent lower with the use of B100. NO_x on the other hand is 10 percent higher (NOAA, 2006). Emission testing of B-20 provided similar results indicating that VOC and SO_x emissions were reduced by 20 percent, PM emissions were 12 percent lower, as were CO emission, but the NO_x emissions were higher by 2 to 10 percent (Diesel Fuel News, December 2002).

As noted earlier, biodiesel can be integrated into existing petroleum infrastructure easily and safely. Biodiesel fuels tend to gel at low temperatures. This is not a problem for some large vessels that use heavy residual fuel oils. However, these residual fuel oils must be heated to allow them to flow through the engine's fuel distribution system. For vessels not equipped with fuel heating systems, the issue can also be addressed by blending kerosene or marine diesel in with the biodiesel.

Probably the most significant issue concerning biodiesel relates to the limited availability and distribution of biodiesel fuel, both in California and Mexico, as discussed in the earlier sections of this report.

Natural Gas Fuels

LNG tanker ships have been using boil-off gas as a fuel source since 1964. These tankers have a long and positive experience with natural gas as a propulsion fuel to run steam turbines. Since 1982, at least 18 natural gas powered ships have been built worldwide that use CNG, LNG, or CNG/Diesel fuel in a compression engine. Most of these natural gas-powered vessels are ferries that are currently operating in Australia, Canada, Netherlands, Russia, Norway, and the United States (Hampton, Virginia and San Antonio, Texas) (Zbaraza, June 2004). Most of these vessels use a dual diesel/CNG fuel configuration with excellent maintenance histories.

Since 2000, Norwegian shipping lines have been developing increasingly larger vessels that use LNG. There are six LNG ferries and four LNG offshore vessels (See Figure 18) engaged in regular coastal or short sea shipping services (Osberg, June 2007) similar to what may be envisioned for the Mexico/California shipping trade. Several large European ship builders are currently designing even larger LNG powered vessels.

Figure 18: Viking Adavant, LNG-Powered Vessel

Source: Eidesvik (2008)

These natural gas-powered vessels reduce CO_2 emission by 20 to 25 percent and reduce PM and SO_x emissions to negligible levels. Fugitive methane emissions may occur during refueling operations or due to equipment leakage. There is conflicting information about NO_x emissions. Side-by-side testing of diesel and compressed natural gas (CNG) ferries in Norfolk, Va., showed that CNG actually had higher NO_x emissions at full speed than the diesel ferry (*Diesel Fuel News*, December 2002); while European Union studies of LNG vessels showed a 70 percent reduction in NO_x (EU 2007).

Though natural gas powered vessels look promising, a considerable amount of additional infrastructure will be needed to use these vessels successfully for Mexico-California cargo transfers. Vessels will have to be purchased that use natural gas, the existing natural gas distribution infrastructure in Mexico will need to be expanded, and Mexico's natural gas reserves will need to be developed; making this an interesting, but difficult option to implement.

LPG

LPG-powered vessels have been used in marine applications as a replacement for gasoline-powered vessels. As noted earlier, due to the difference in LPG's energy content, there is a 10 to 15 percent power loss at high speed especially under load. At this time LPG is being used in Europe to reduce pollution from recreational and smaller fishing vessels. These engines tend to be relatively small (from 5-60 horsepower) (Primagaz 2007)and therefore not appropriate for movement of freight.

For marine vessel applications, there is also a safety concern regarding the use of LPG. As LPG is denser than air, it tends to accumulate in the ship hulls in concentrations that could be explosive (Irish Department of Transportation 2002).

Though LPG is readily available in California and Mexico, it should not be considered a viable alternative fuel for cross border freight shipments.

Synthetic Fuels

Synthetic fuels are derived from coal, shale (kerogen), natural gas, or biomass. A more complete discussion of synthetic fuels is provided in the aviation fuel section of this report.

Synthetic fuels do not have any special handling or storage requirements, and therefore they can use existing infrastructure for distribution. Because synthetic fuels do not contain sulfur, there are no sulfur emissions; in fact exhaust emissions in general are much lower than those associated with other marine fuels. Synthetic fuels also are less toxic than other marine fuels. These fuels have long-term stability and have excellent low temperature properties. One of the problems associated with synthetic fuels is that they have lower content of aromatics, which play a role in lubricating the cylinder wall of an engine. In addition, synthetic fuels that use a fossil feed stock may have life cycle GHG emissions far in excess of conventional fuels' GHG emissions.

Most of the research on synthetic fuel applications for marine vessels has been implemented by the U.S. Department of Defense. For national security reasons, details concerning this research are not public.

Another major issue concerning the use of synthetic fuels for cross border freight movement is the lack of refineries in either the United States or Mexico. The limited availability of the fuels implies that they are not a viable option at this time.

Advanced Technologies

Fuel Emulsification Systems

Fuel emulsions have been in use since 1984 on stationary low-speed diesel engine plants. Tests have been conducted with up to a 50 percent water/fuel mixture, resulting in a 50 percent reduction in engine NO_x emissions. This NO_x reduction occurs because the water added to the combustion processes reduces the combustion temperature and limits the amount of NO_x emitted. There are a number of ways that water can be added to the combustion process; these technologies include:

- Use of emulsified fuels.
- Direct cylinder water injection system.
- Water emulsification systems of on-board fuel.
- Humid air motors.

The expected reduction in NO_x and the required engine modifications are presented in Table 39. Many of the approaches noted in the table require extensive changes to the engine and a considerable amount of space to make and store water used for emulsification or injection, to house equipment used to humidify the air, or to store extra fuel to compensate for the reduced energy content of the emulsified fuel. Because of the space requirements, these approaches are considered to be more appropriate for large oceangoing vessel than for railroad and on-road trucks that have greater space constraints.

Table 39: Summary of Marine Water/Fuel Technologies

Technology	Extent of Modification		NO_x Reduction
Emulsified Fuels (off engine - i.e. pre-treatment)	Modified low pressure part of fuel system	▪ Maximum percentage of added water depends on capacity of injection pumps	Up to 60%
Water Injection (on engine i.e. primary)	New cylinder heads, camshafts, injectors, fuel and water systems	▪ Increased cost for injection equipment ▪ Requires water making facilities	Up to 60%
Water Emulsification of on-board fuels	New injectors, fuel pumps, etc. Modification of engine control system, water supply systems and fuel supply systems	▪ Increased cost for engine and auxiliary equipment ▪ Requires facilities for fresh water production	Up to 50%
Humid Air Motor	Place for humidifier and droplet separator	▪ Relatively simple to implement ▪ Requires specialized manufacturing skill	Up to 80%

Source: California Air Resource Board (2002) & U.S. EPA Clean Ports USA: Emission Reduction Strategies (2007)

Recently, tests have been conducted on marine vessels that have been modified to use emulsified fuels or outfitted with technologies to inject water into the engines cylinder or mix water in the vessel's fuel supply just before combustion.

A Canadian vessel testing program found that using water injection into the engine's manifold led to a 10 to 30 percent reduction in NO_x emissions with little change in the fuel consumption rate. However, this study, along with others, noted that as NO_x emissions were reduced, PM emissions increased by 20 to 50 percent. There was a similar increase in CO emissions as the water concentration in the fuel increased (Radloff 2004 and Winkler 2004).

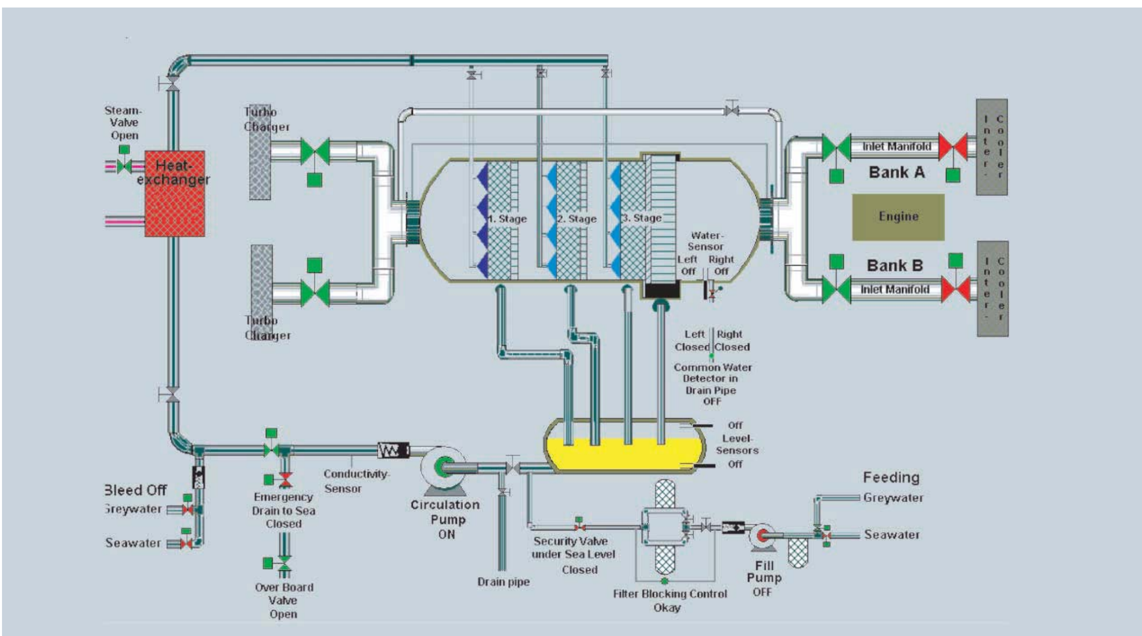
There are several additional problems with use of emulsified fuels, such as the energy content of the emulsified fuels. As water is added to the fuel, more fuel is needed to get the same amount of power. This is particularly true for marine vessels which tend to operate at 80 to 90 percent of engine design load. Thus, the NO_x emission reductions associated with emulsified fuels are negated by the increased fuel consumption needed to obtain sufficient equivalent BTUS to power the vessel.

Pre-emulsified fuels also require constant mixing both at the distribution point and on board. Mixing keeps the water in suspension in the fuel; otherwise the water and fuel separate.

In addition to the modifications required to the engine, there are other issues concerning the use of water/fuel mixture systems. For example, the effect on engine components and lubricating oil is not known, but is the subject of continuing research International Council on Combustion Engines 2000).

Of the emulsification technologies evaluated for this task the humid air motor is the only option that should be considered as a possible alternative technology at this time. Humid air motors are able to get significant emission reductions without relying upon costly selective catalytic reduction systems. Humid air motors do not directly mix fuel and water. Instead, these engines humidify intake air compressed by the engine's turbocharger, which is supplied to the combustion cylinder and mixed with fuel vapor inside the cylinder of the engine. Currently, MAN B&W has used this technology in their 3V40/50 diesel engine which was installed in a large roll-on/roll-off ferry operating in the Baltic Sea in July 1999 (see configuration in Figure 19). After 6,000 hours of operation, no major problems were encountered. The humid air motor has reduced NO_x emissions by 70 to 80 percent with no measurable increase in fuel consumption (MAN B&W 2002).

Figure 19: Humid Air Motor Design



Source: Man B&W 40/50 Diesel Engine (Accessed 4/30/2008) http://www.manbw.com/files/news/filesof1265/Aufsatz%2009.pdf

Aviation Fuels and Technology

Unlike marine diesel engines that can operate on a wide range of fuels, aircraft engines require fuels with specific characteristics, making alternative aviation fuel options for commercial air freight more challenging, often requiring extensive study to evaluate safety concerns. Considering the international nature of air travel and the infrastructure requirements, changes to aviation fuels require international consensus. This section is limited to evaluating the following aviation fuel options:

Table 40: Aviation Fuels

Fuels	Technologies
Cryogenic Fuels	Jet engine modifications
Alcohols	Fuel Cell APUs
Biofuels	
Synthetic Fuels	

The design of jet propulsion engines has been refined over the years to be more fuel-efficient, particularly during periods when fuel costs have increased. For example, GE has recently come out with a new line of jet engines that deliver 15 percent better fuel consumption and reduces emissions by roughly 95 percent below 2008 regulatory limits (GE 2008).

In addition to an aircraft's propulsion engines, commercial aircraft also operate auxiliary power units typically located near the rear of the aircraft (see Figure 20). These small gas turbines generate electricity and provide air conditioning for the cabin while the aircraft is at the gate and also provide compressed air to the main propulsion engines during the startup period. Some auxiliary power units can also direct hot air to the wings, thus reducing the need for deicing during winter months.

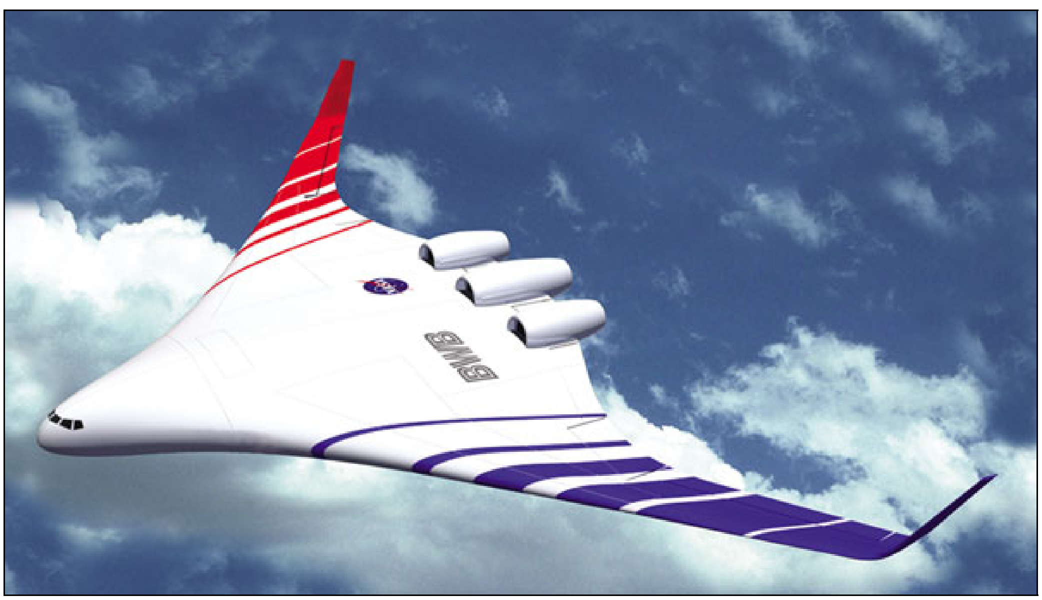
Auxiliary power units tend to be a more significant emission source for passenger air travel then for air cargo transfers. Though there is considerable research regarding the possible use of fuel cells as a replacement for auxiliary power units, this technology was not evaluated in this report as the anticipated impact on emissions is expected to be small.

Other than refinements to jet propulsion engines, aircraft technology has not changed significantly in the past 40 years. New aviation technologies are being studied, though they are futuristic in design such as the blended wing aircraft shown in Figure 21. The introduction of these new aircraft is highly uncertain and beyond the time frame considered in this study.

Figure 20: Auxiliary Power Unit

Source: Boeing 737 Technical Site, 2008

Figure 21: Blended Wing Aircraft



Source: NASA, 2008.

Reformulated and Alternative Fuels

Commercial aviation jet engine aircraft are currently powered by various grades of jet fuels obtained from refining crude oil. Commercial carriers mainly use grades known as Jet-A and Jet-B. Jet-A is an unleaded, paraffin-based fuel produced to a set of internationally recognized specifications (IPCC 1999). Jet-A is also known as a kerosene fuel and is the standard jet fuel used in the United States. Jet-B is a lighter, more flammable jet fuel produced in the naphtha-kerosene range that is designed for use in colder climates. Both fuels can contain additives such as antioxidants, anti-corrosives, icing inhibitors, and antistatic agents. Military aircraft generally use different jet fuel grades, known by the designation JP, formulated expressly for their use (CSG Network 2007 and Blackwell 2007).

Current aircraft fleets, fuel distribution networks, and airport fuel storage and handling systems have been designed around kerosene-based jet fuels. Although Jet-A is highly combustible, the industry considers it to be a safe fuel. Jet-A fuel has an energy content (per volume) on par with synthetic and biofuel alternatives. It has a higher energy content than cryogenic and alcohol fuels. The combustion of kerosene jet fuels releases most criteria pollutants (CO, NO_x, SO_x, PM, hydrocarbons), some air toxics, and GHGs such as CO_2. CO_2 emissions are estimated at 156-175 lbs per MMBtu of heat input (URS 2003 and U.S. DOE/EIAb 2007).

Conventional petroleum-based jet fuels are consumed by aircraft at nearly 3,500 airports worldwide. For 2005, estimates pegged global consumption of conventional jet fuels at approximately 55 billion gallons. This level of jet fuel use amounts to roughly 6 percent of global oil consumption (Chevron 2006 and Daggett 2006). With ever increasing prices for crude oil, jet fuel costs are escalating at a very significant rate for airlines. There is significant interest in the development of alternative, non-petroleum-based fuels for commercial jet aircraft.

Four general classes of alternative fuels have been identified and are receiving the most research attention. The four fuels classes are cryogenic fuels (for example, liquid hydrogen), alcohol fuels (for example, ethanol, methanol), synthetic fuels, and biofuels. The current status of each of these alternatives and issues affecting their likelihood to replace kerosene jet fuels are summarized below.

Cryogenic Fuels

Cryogenic fuel refers to fuel choices such as liquefied hydrogen (LH_2), methane, LPG, butane, or other petroleum gases. These fuels are viewed as possible aviation fuels in the distant future. The industry's current requirement to have fuels in liquid form presents unique storage, handling, and transfer issues for cryogenic fuels (Daggett 2006 and Daggett 2007), as cryogenic fuels are gases that require low temperatures or high pressure to be maintained in a liquid state. Today's aircraft fleets and airport fuel handling systems are not compatible with a fuel like LH_2. Entirely new engines, airframes and fuel systems would have to be constructed. Several technical challenges have to be solved before cryogenic fuels could become viable. LH_2 has a low volumetric heat of combustion, so larger quantities would be needed to meet the same performance level of conventional jet fuel. On shorter range flights, energy efficiency could be reduced by as much as 28 percent.

Larger fuel tanks with special insulation and pressurization requirements would be needed, precluding the current practice of storing fuel in the aircraft's wings. The larger fuel tanks would have to be engineered to be part of the fuselage. Currently, LH_2 fuel would also have a cost disadvantage as compared with kerosene jet fuels. LH_2 fuel is roughly two to four times more expensive than conventional jet fuel (Daggett 2006, Daggett 2007, and IPCC 1999).

From an air emissions standpoint, LH_2 does have some benefits. There are no CO_2 emissions from the combustion of LH_2 in the aircraft. However, CO_2 emissions from the production of LH_2 fuel are up to 3.5 times higher than similar emissions from crude oil-based jet fuels, depending on the means of production. CO_2 sequestration may be required to make this technology environmentally viable in the future. With regard to the emission of other pollutants, there are practically no PM, CO, sulfur compound, or unburned hydrocarbon emissions associated with use of LH_2.

For cryogenic fuels like LH_2 to be successful, hydrogen has to be obtained from sources other than fossil fuels. These other non-fossil energy sources include biomass and solar. Industry experts have indicated that this type of alternative fuel is decades away for the commercial aviation industry (Daggett 2006 and Chevron 2006).

Alcohol Fuels

Alcohol fuels include ethanol and methanol. Assessments made by the aviation industry show that these alternative fuels are not viable as replacements for conventional kerosene-based jet fuels. Both have poor mass and volumetric heat of combustion characteristics, requiring more fuel to provide the same performance as conventional jet fuel. Since more fuel would be needed, a much larger wing would be required causing weight increases of 20 percent. Aircraft engines would also have to have 50 percent more thrust to compensate for the greater weight of ethanol. Alcohols also have flash points that are half that of kerosene jet fuels, so they create a serious safety hazard. The combustion of alcohol fuels would yield unacceptable levels of acetaldehyde and formaldehyde, causing problems for both airport workers and passengers. Use of alcohol fuels would decrease CO_2 emissions, but NO_x emissions could be increased somewhat (*Air Safety Week* 2004; Daggett 2006; Daggett 2007; and Chevron 2006).

Alcohol fuels cannot be used as a total replacement for jet fuel, nor do they make suitable blending materials, as ethanol and methanol have significantly different chemical and physical properties from conventional jet fuel. Because of all these issues, alcohol fuels are not worth pursuing as a jet fuel alternative. It would be better to use these alcohol fuels as a substitute or blending agent in ground vehicles.

Biojet Fuels

As noted earlier, biofuels are combustible liquid fuels derived from renewable resources such as plant crops or animal fats. High oil content crops include soybeans, rapeseed, and sunflowers. Animal fats are obtained from large animal rendering and meat processing operations. At the current time, most of the available biofuels for jet aircraft are not capable of serving as total replacements for kerosene-based conventional jet fuels, as they do not meet the high-performance standards of commercial aviation fuels. Most biofuel use for jet aircraft is as a supplemental blending fuel. In order to meet commercial aviation performance specs, the biojet fuel would need to be further refined and processed beyond what is typical for biodiesel. The higher costs associated with this additional processing would make the fuel economically non-competitive (Daggett 2006). It has been speculated that biofuels' greatest application for aircraft may not be as a direct fuel substitute, but rather as biodiesel for ground vehicle fuels, which would free up more petroleum fuels for aviation purposes.

Because biojet fuels have nearly the same weight, volume, and energy characteristics as petroleum-derived jet fuel, they would be relatively easy to use and would not affect the design considerations of aircraft in use today (Daggett 2006). One of the most significant problems with biojet fuels for jet applications is their tendency to gel or freeze at temperatures associated with normal cruising altitudes. These problems limit the extent to which biojet fuels can be blended with conventional jet fuels. Various additives are being tested to address this problem, but concerns remain. The issue of freezing could be a major roadblock to acceptance and certification of biojet fuels for commercial aviation purposes.

One operational parameter that fuel researchers are investigating for biojet fuels is thermal stability. The higher carbon number and viscosity of biojet fuels has been shown to have some potential effect on the atomization and vaporization of biojet fuels in the engine combustion chamber (Chevron 2006). These issues could have an impact on engine performance and safety of operation. Engine modifications may be required to facilitate an equivalent level of performance with jet biofuels. Investigations into these issues are ongoing.

Another issue concerning jet biofuels is the potential availability of the fuels. Biomass derived fuels require sufficient land to sustainably grow the plant crops required for fuel production. Concerns exist on whether more industrialized nations have adequate arable land to grow the required feedstock crops (Daggett 2006) as discussed in earlier sections of this study. These issues are being investigated by such airlines as Virgin Atlantic. On February 24, 2008, Virgin Atlantic became the first airline in the world to operate a commercial aircraft on a biofuel blend. The Boeing 747 flew a short flight from London to Amsterdam, using a 20-percent biofuel/80-percent kerosene blend in one of its four engines. Virgin has invested $3 billion in biofuel research and development with the hope that aviation fuel needs can be met within the next decade using second generation biofuels made from sustainable feedstocks such as algae or waste biomass like woodchips.

In terms of potential air emissions, CO_2 emissions from biojet fuels are estimated to be less than half of those associated with kerosene-based fuel (Daggett 2006 and Air Safety Week 2004). Emissions of PM are also expected to be less with jet biofuels; however, CO and hydrocarbons could be increased, especially under idle conditions (IPCC 1999). Emissions of organic acids and aldehydes may also be increased with biofuels as compared to conventional jet fuels. Emissions of sulfur oxides and nitrogen oxides from jet biofuels are expected to be less than comparable emissions from use of kerosene-based jet fuels (IPCC 1999).

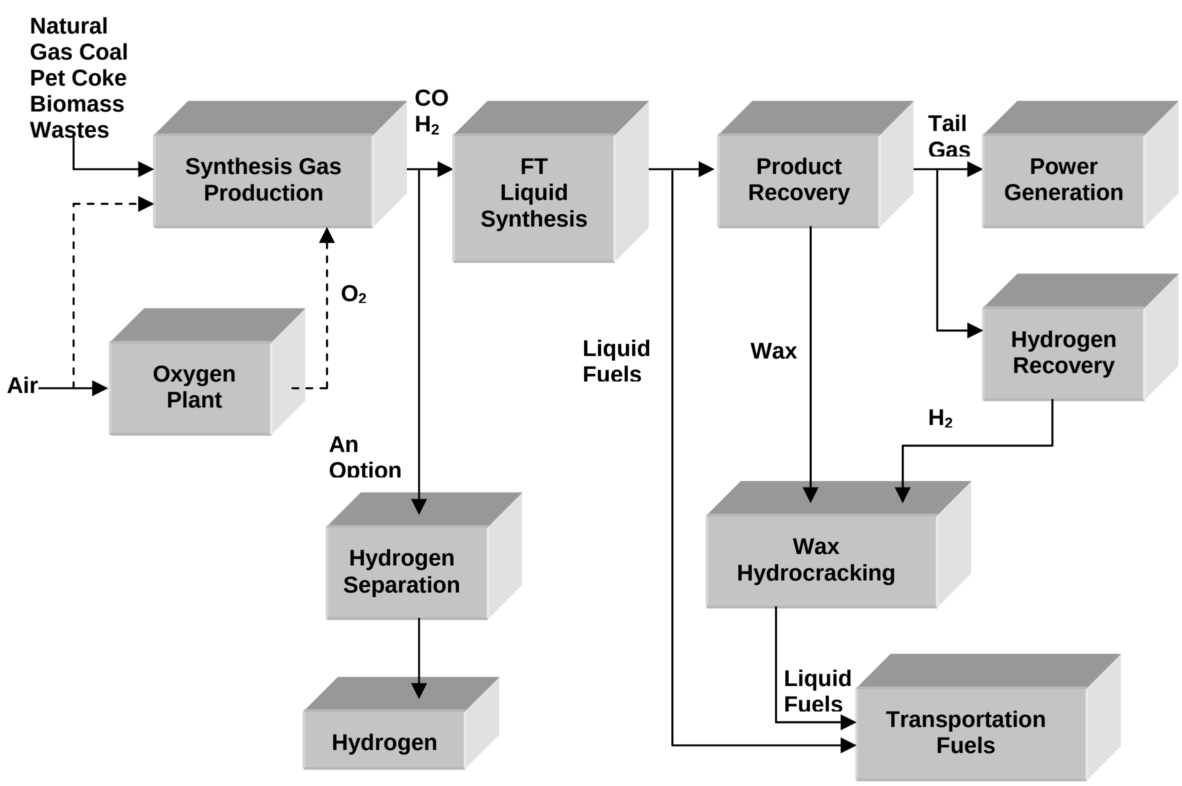
Synthetic Jet Fuels

Synthetic jet fuels refer to fuels derived from coal, natural gas, or other hydrocarbon-based feedstocks (see Figure 22). These fuels are synthesized primarily through use of the Fischer-Tropsch (FT) process, which is well demonstrated for this purpose. The FT process was developed in Germany during World War II and is currently the primary jet fuel synthesis process in use worldwide. According to current aviation industry literature, fuels produced by the FT process represent the only known "drop-in" alternative fuel for the commercial aviation industry, either as a supplement to kerosene-based fuels or as a total replacement (Daggett 2006 and Chevron 2006). One of the largest plants in the world currently producing synthetic fuels from natural gas and coal by the FT technology is the Sasol facility in South Africa. In addition to fossil fuel feedstocks, activities are also underway to produce synthetic jet fuels from vegetable oils, fats, and greases. The companies Tyson Foods and Syntroleum are building a facility for start-up in 2010 that will produce synthetic jet fuels and diesel fuels from vegetable oils and fats. The feedstocks will come from Tyson operations with Syntroleum providing the synthesis technology. The process known as "biofining" uses heat, hydrogen, and proprietary catalysts to make the synthetic fuels (Syntroleum 2007; Tyson 2007; and Gamino 2007).

The United States military has been a major leader in research efforts to develop and commercially produce synthetic jet fuels (Bezdek 2007, Blackwell 2007, Syntroleum 2007, Chevron 2006, and Shanker 2006). The military has partnered with both private groups and U.S. government groups like the National Energy Technology Laboratory (NETL) to investigate the production of liquid synthetic jet fuel (Bezdek 2007, Blackwell 2007, and NETL 2007). The U.S Air Force hopes to have 50 percent of its jet fuel requirements met by synthetic fuels by 2016 (Bezdek 2007 and Syntroleum 2007).

Industry experts currently view synthetic jet fuel as the most near term and viable alternative fuel for commercial aviation. In most cases, synthetic jet fuels can be used directly in existing aircraft engines with no modifications required. These uses are as either a blend with conventional kerosene jet fuel or as a total replacement for conventional fuels. In addition, no other changes to the existing airframes are necessary. Also, the synthetic alternative fuels present no problem for the existing fuel distribution and handling systems (that is, pipelines, storage facilities, and fuel infrastructure systems). Their use at commercial airports would essentially be seamless (Syntroleum 2007; Daggett, 2006; Daggett, 2007; and Chevron, 2006).

Figure 22: Fischer-Tropsch (FT) process



Source: Fisher-Tropsch Archive (http://www.fischer-tropsch.org)

The synthetic jet fuels currently being produced are stable over a wide temperature range which makes possible the development of highly fuel-efficient engines (Blackwell 2007). Their mass and volumetric energy contents are on par with conventional jet fuels. Unlike biofuels discussed above, synthetic fuels also offer excellent low temperature properties so fuel freezing at high cruising altitudes is not a problem. Because these fuels have nearly the same weight, volume, and performance characteristics as petroleum-derived jet fuels, they are relatively easy to use and would not affect design considerations for aircraft in use today.

Synthetic jet fuels have several advantages over conventional jet fuels from an air emissions standpoint. Alternative fuels from the FT process using fossil fuels as feedstocks contain almost no sulfur species, no aromatics, and very little nitrogen oxide. Therefore, sulfur compounds emissions from combustion are essentially zero, and VOC emissions are extremely small.

Emissions of particulate matter are reduced 50 to 90 percent while combustion CO_2 emissions can drop by 2 to 4 percent (Blackwell 2007 and Chevron 2006). One of the primary air quality issues with FT synthetic jet fuels, however, is the overall net lifecycle increase in CO_2 that results unless emissions are somehow controlled or sequestered, since a large amount of energy is used (thereby generating CO_2) in the FT process (Daggett, 2006). Synthetic jet fuel from the Syntroleum "Biofining" process is reported to have a positive effect on GHG emissions because all of the carbon in the finished fuel originated in the atmosphere as CO_2. That CO_2 had been absorbed by plants that were turned into oils or fed to animals and converted into fats. Estimates indicate a 74 percent decrease in lifecycle GHG emissions with biofining as compared with conventional petroleum-based fuels (Syntroleum 2007 and Green Car Congress 2007).

Despite all the positives feature of synthetic fuels, there are some issues that need to be addressed before these fuels are made available for aviation applications. For example, since synthetic fuels produced by the FT process end up having no sulfur or aromatic content, turbine performance and maintenance activities can be affected. First, the absence of these materials lowers fuel density that is required in internationally accepted specifications. Second, with the lack of aromatics, elastomers used in aircraft fuel systems may not swell, causing fuel seals to leak (Chevron 2006 and Daggett 2006). Fuel leaks can cause any number of problems, some very serious. Synthetics can be blended with conventional jet fuel, mitigating the fuel leakage concern.

For the near term, the aviation industry and fuel manufacturers seem to agree that synthetic jet fuels represent the best option for reducing the use of kerosene-based jet fuels, based on reasons of compatibility with current engines, compatibility with current fuel handling and storage systems, performance levels, safety and maintenance concerns, and potential air emission impacts.

Advanced Technologies

Use of Composite Materials and Lean-Burn NO_x Combustors

The fundamental theory associated with current jet engines, has not changed significantly since the 1950s, though all of the engine manufactures such as GE, Rolls-Royce, and Pratt and Whitney, have refined the engine design using new light weight materials. For example, GE has recently come out with a new line of GEnx jet engines that delivers 10 and 15 percent better fuel consumption and has emissions up to 94 percent below 2008 regulatory limits. Pratt & Whitney is participating in NASA's Ultra-Efficient Engine Technology (UEET) program, which is developing an engine that will have a similar reduction in fuel consumption. The application of these engines on a typical Boeing 777 would reduce annual fuel costs by about $1 million per year and CO_2 emissions by about 11,700 metric tons.

In addition to being more fuel-efficient and having lower emissions, these engines are expected to be 30 percent quieter (Boeing 2007, Pratt and Whitney 2007, and Rolls Royce 2007).

These new engines take advantage of new materials like powdered metal alloys and carbon fiber composites to improve performance and reduce weight and maintenance activities. The engine's high pressure compressors reduce fuel usage and, when combined with lean burn combustors, reduce flame temperatures, which in turn reduce NO_x emissions (Boeing 2007 and Pratt and Whitney 2007).

The first GEnx engine was tested in 2006, with full certification scheduled for 2007. Boeing will use the new GEnx aircraft engines in Boeing's 747 and the new 787 Dreamliner and 747-8 (Boeing 2007).

Given the increasing cost of aviation fuel, it is anticipated that economics will be a very strong driving force for the introduction of these engines. These engines require no special maintenance or fuels and will be ideally suited for aircraft involved in the movement of 71,000 tons per year of cross border air cargo. Any programs that encourage the use of cargo aircraft equipped with these engines will yield a reduction in aviation fuel usage and emissions.

Conclusion

In this analysis of alternative fuels and technologies that can reduce fuel consumption and emissions for cross-border freight movements, technologies generally seem more likely to be implemented than alternative fuels, which typically require extensive infrastructure development in the United States and Mexico. Many of the technological recommendations rely upon systems and devices that make vehicles more aerodynamic, optimize fuel usage, or use engine technologies that are readily available and can be implemented in the near term. Most of the alternative fuel options require construction of processing plants and new infrastructure for fuel distribution and may require extensive engine modification or replacement.

The options evaluated in this study are summarized below for each of the transportation modes.

On-Road

For cross-border heavy-duty truck movements, it is important that low-sulfur diesel fuel be available in both Mexico and the United States to reduce SO_x and PM emissions. These fuels will allow for the use of advanced control technologies needed to reduce emissions of VOC and CO. However, low-sulfur fuels must be available in both markets to ensure that the advanced control devices do not get polluted by non-low sulfur fuels, rendering them ineffective.

In the near term, there are a number of technologies that will reduce fuel usage and emissions and should be encouraged, such as: construction of facilities equipped with truck stop electrification, use of auxiliary power units, low rolling resistance tires, and installation of airfoils and side skirts to enhance vehicle aerodynamics. For the most part however, the benefits of these technologies will be limited to long-haul freight movement.

In the medium term, programs should be considered that encourage the use of hybrid trucks; this would include electric hybrids for medium and long-haul operations, and hydraulic hybrids for drayage activities. Given the substantial incremental costs associated with introducing these technologies into a drayage fleet dominated by used vehicles, extensive subsidies will likely be required in this regard. Blended biofuels (B10 or B20) may also be possible in the medium term if agricultural constraints can be addressed and new processing plants built.

CNG, LNG, and ethanol should be considered longer term options as they require extensive infrastructure enhancements. For natural gas options, this would include development of Mexican natural gas fields, extending the natural gas pipelines, and construction of refueling stations. Ethanol requires a separate distribution system that uses corrosion-resistant materials, which would take considerable time and resources to develop. Ethanol blends (e-diesel) may be introduced earlier, as they require less infrastructure development.

Railroad

As with on-road vehicles, use of low-sulfur railroad engine fuels should be encouraged in the near term along with the use of aluminum rail cars, covered freight cars, and driving optimization systems. Near-term options also include use of hybrid engines for switching operations and genset locomotives for switching and short-haul applications. These near-term options should reduce fuel consumption and emissions without extensive changes to rail operations or fuel distribution.

Blended biodiesel may be a viable as a medium term option to reduce emissions, but additional studies are needed to more fully evaluate long-term impacts of biodiesel usage on engine components. Long-term options for railways include use of CNG for switching activities and LNG for switching and long-haul operations as these natural gas options require more extensive infrastructure enhancements.

Marine

Marine vessel diesel engines are able to burn a wide variety of fuels efficiently. The driving factor for shifting to alternative fuels is primarily fuel availability. In the near term, programs that encourage production and use of low-sulfur diesel, particularly on the Mexican side of the border, will have a significant impact in reducing emissions and complying with pending SECA regulations. The use of humid air motors could also be encouraged in the short term, to reduce NO_x emissions.

Blended biodiesel, though a cleaner option than low-sulfur diesel, is constrained by the availability of feedstock and processing plants. Synthetic fuels are also constrained by the lack of processing plants. In addition, the cost to construct these facilities is high, and they require advanced technical skills to operate. Both biodiesel and synthetic fuels should be viewed as medium-term options.

CNG and LNG should be considered a long-term option for short sea cargo shipments as they require significant changes to vessels and infrastructure, particularly on the Mexican side, where new gas fields need to be developed and gas pipeline infrastructure expanded.

Aviation

Unlike some of the other transportation modes, where the focus is on fuels that existing engines use with minimal modifications, the objective in aviation is to develop fuels or blends that are identical to existing fuels meeting international specifications such as safety requirements and require no engine or infrastructure changes. The international aviation community is actively considering potential alternative fuels with the leading medium-term candidate being synthetic fuel blends. To ensure sufficient supply of these fuels to meet the needs of cross border air cargo movements, synthetic fuel processing facilities need to be constructed in both Mexico and the United States. In the near term, fuel usage and pollutant emissions can be reduced through programs that promote use of new energy-efficient jet engines that take advantage of lightweight materials, improved compressor design, and use lean burn combustors. These engines operate on existing aviation fuel and therefore require no changes in fuel distribution and storage.

Table A-1: Alternative Fuel and Technology Options - Advantages and Disadvantages

(Note the information in this table summarizes the discussion in Chapter 4)

On-road		
Fuel/Technology Option	**Advantage**	**Disadvantage**
Low Sulfur Diesel Fuels	Reduction in PM and SO_x emissions Allows for use of advanced control technologies No engine modifications are required No modification to existing storage and distribution systems	Fuel availability in Mexico uncertain Fuel based on non-renewable resources Low sulfur fuel must be used in engines with advance control technologies Slight increase in engine maintenance possible Slightly lower energy content Slight increase in fuel cost above conventional diesel
Biodiesel	Reduction in CO, CO_2, PM, SO_x , and VOC, Emissions Allows for use of advanced control technologies Fuel based on renewable resources Spills biodegradable No engine modifications are required No modification to existing storage and distribution systems Improved lubricity over conventional diesel Can be blended with conventional diesel Lower volatility-safer to handle than conventional fuels	Slight increase in NO_x emissions possible Fuel availability in U.S. and Mexico limited at best Currently more expensive than conventional diesel Slightly lower energy content Slight increase in engine maintenance
Methanol/Methanol Blends	Reduction in SO_x and VOC emissions Fuel can be based on renewable resources	Fuel currently unavailable in U.S. and Mexico No recent studies on heavy duty trucks
Ethanol/Ethanol Blends	Reduction in CO,CO_2, NO_x, PM, SO_x, and VOC emissions Fuel based on renewable resources Non-toxic and biodegradable	Fuel availability in Mexico uncertain Currently heavy duty trucks not available Lower energy content Corrosive, requiring changes to fuel storage and distribution systems Increased maintenance
Natural Gas (compressed natural gas and liquefied natural gas)	Reduction in NO_x, PM, SO_x, and VOC emissions Reduction in maintenance	Increase in methane emissions Fuel based on non-renewable resources Lower energy content Requires engine replacement Significant and costly infrastructure development required

Liquefied Petroleum Gas	Reduction in CO, NO_x, PM, and VOC Readily available in U.S. and Mexico	Fuel based on non-renewable resources Currently heavy duty trucks not available Lower energy content Requires engine replacement
Electric Hybrids	Reduction in fuel consumption and emissions Can be coupled with ethanol or CNG fueled engines for further emission reductions Possible applications for long haul operations Can be introduced incrementally No infrastructure changes are required	Limited studies on heavy duty trucks Only one commercially available model at this time Replacement vehicles are costly, but possible repayment in fuel savings
Hydraulic Hybrids	Reduction in fuel consumption and emissions Possible applications for drayage operations Can be introduced incrementally No infrastructure changes are required	Limited studies on heavy duty trucks No models currently available, although extensive applications in demo fleets Replacement vehicles are costly, but repayment in fuel savings and extended engine life
Waste Heat Recovery	Utilization of energy from hot combustion gases Reduced fuel usage and emissions (5-10%)	Currently limited applications have been developed for U.S. market
Truck Stop Electrification	Modest reduction in fuel consumption and emissions Cost can be repaid relative to diesel/electric fuel cost differential Can be introduced incrementally	Limited number of facilities currently operating California – none in Mexico
Auxiliary Power Units	Modest reduction in fuel consumption and emissions Models are commercially available Cost can be repaid in fuel savings Can be introduced incrementally	Minor incremental cost increase for purchase and installation
Low Rolling Resistance Tires	Reduction in fuel consumption and emissions Requires little modification to existing vehicles Tires are commercially available Can be introduced incrementally Tire pressure monitor – improve vehicle safety	Limited availability of replacement tires, especially in Mexico Slight increase in cost, but quickly made up in fuel savings
Aerodynamic Improvements	Reduction in fuel consumption and emissions Kits are commercially available Can be introduced incrementally	Slight increase in cost, but quickly made up in fuel savings

Marine		
Fuel/Technology Option	**Advantage**	**Disadvantage**
Low Sulfur Diesel Fuels	Reduction in PM and SO_x emissions Allows for use of advanced control technologies No engine modifications are required No modification to existing storage and distribution systems Allows for compliance with pending SECA requirements	Fuel availability in Mexico uncertain Fuel based on non-renewable resources Low sulfur fuel must be used on engines with advance control Fuel cost significantly higher than conventional marine fuels
Biodiesel	Reduction in CO, CO_2, PM, SO_X, and VOC emissions Allows for use of advanced control technologies Fuel based on renewable resources Spills biodegradable No engine modifications are required No modification to existing storage and distribution systems Can be blended with conventional diesel Lower volatility-safer to handle than conventional fuels	Fuel availability in U.S. and Mexico limited at best Slight increase in NO_x emissions possible No studies of biodiesel being used on large cargo ships Currently more expensive than conventional marine fuels
Natural Gas (compressed natural gas and liquefied natural gas)	Reduction in CO_2, PM, SO_x, and VOC emissions Vessels commercially available Reduction in maintenance	Increase in methane emissions Uncertainty about NO_x emissions Fuel based on non-renewable resources Lower energy content Requires engine/vessel replacement Significant and costly infrastructure development required
Liquefied Petroleum Gas	Reduction in CO, NO_x, PM, and VOC emissions Readily available in U.S. and Mexico	Fuel based on non-renewable resources No data available on large commercial marine vessels Lower energy content Requires engine/vessel replacement Safety concerns about fugitive LPG build up in hull of the vessel Significant and costly infrastructure development required
Synthetic Fuels	Reduction in NO_x, PM, SO_x, and VOC emissions Fuels can be based on renewable resources Good long term storage stability Good thermal properties No engine modifications are required No changes in fuel distribution and storage required Fuels can be blended with existing marine fuels	Lubricity poor additives may be required New fuel refining facilities need to be constructed Fuel leakage may be a problem Significant CO_2 emissions from the manufacturing of the fuel
Humid Air Motor	Reduction in fuel consumption and emissions, particularly NO_x Cost effective relative to advance control devices	Space is needed for humidification units

Aviation		
Fuel/Technology Option	**Advantage**	**Disadvantage**
Cryogenic Fuels	No emission of CO, CO_2, PM, SO_x, and VOC	Extensive changes required to fuel storage and handling to ensure fuel remains in a liquid state Requires new airframe, engine, and fuel system Low energy content Currently, fuel is significantly more costly than current jet fuels Significant upstream emissions from the manufacturing of the fuel
Biofuels	Reduction in CO_2, NO_x, PM, and SO_X emissions Fuel based on renewable resources Spills biodegradable No modification to existing storage and distribution systems required Can be blended with conventional jet fuels Lower volatility-safer to handle than conventional jet fuels	Fuel gels at low temperatures typical of high altitudes Engine modifications may be required Increase in emissions of CO, VOC, organic acids, and aldehydes Jet grade fuel availability uncertain in U.S. or Mexico New biofuel refineries need to be constructed Currently more expensive than conventional jet fuel
Synthetic Fuels	Reduction in NO_x, PM, SO_x, and VOC emissions Fuels can be based on renewable resources Good long term stability Good thermal properties No engine modifications are required No changes in fuel distribution and storage required Fuels can be blended with existing jet fuels Fuel characteristics and energy content similar to existing jet fuels	New fuel refining facilities need to be constructed Fuel leakage may be a problem Significant CO_2 emissions from the manufacturing of the fuel
Alcohol Fuels	Reduction in CO_2 and SO_x emissions Fuel based on renewable resources	Requires new airframe, engine, and fuel system Fuel availability in Mexico uncertain Lower energy content Lower flash point, safety issue in handling the fuel Increased emissions of acetaldehyde and formaldehyde, possibly NO_x Does not mix with existing jet fuels
Improved Jet Engines	Reduced fuel consumption and emissions, particularly NO_x emissions No change in existing infrastructure required Can be implemented incrementally	Engine replacement is costly, but made up in fuel savings

Source: Authors

Table A-2: Mexican Heavy Truck Emissions Standards

<table>
<tr><th rowspan="2">Mexico Dates</th><th rowspan="2">U.S. Dates</th><th colspan="5">U.S. Standards</th><th colspan="5">Euro Standards</th></tr>
<tr><th>CO g/bhp-hr</th><th>NO_x g/bhp-hr</th><th>HC g/bhp-hr</th><th>PM g/bhp-hr</th><th>Useful Life</th><th>CO g/bhp-hr (g/Kwh)</th><th>NO_x g/bhp-hr (g/Kwh)</th><th>HC g/bhp-hr (g/Kwh)</th><th>PM g/bhp-hr (g/Kwh)</th><th>Useful Life</th></tr>
<tr><td>2006 – June 2008</td><td>1998</td><td rowspan="4">15.5</td><td>4.0</td><td>1.3</td><td rowspan="2">0.10</td><td></td><td>4.1 (5.4)</td><td>3.73 (5.0)</td><td>0.58 (0.78)</td><td>0.12 (0.16)</td><td></td></tr>
<tr><td>July 2008 - 2011</td><td>2004</td><td>2.5</td><td>0.5</td><td rowspan="3">435,000 Miles Max.</td><td rowspan="3">3.0 (2.0)</td><td>2.61 (3.5)</td><td rowspan="3">0.41 (0.55)</td><td rowspan="3">0.022 (0.03)</td><td rowspan="3">300,000 Miles Max.</td></tr>
<tr><td rowspan="2">2011 & Beyond</td><td>2007</td><td>1.2</td><td rowspan="2">0.14</td><td rowspan="2">0.01</td><td rowspan="2">1.5 (2.0)</td></tr>
<tr><td>2010</td><td>0.20</td></tr>
</table>

Source: Authors

CHAPTER 5: Recommendations

The purpose of this analysis was to understand how energy and emissions considerations can inform, and benefit from, policies and investments to improve the flow of goods across the California-Baja California border. There are major issues of economic development and security associated with development of the border region, and energy considerations, while not minor, are unlikely to drive the discussion. At the same time, agencies grappling with energy, climate change, petroleum consumption, and air quality issues in the States of California and Baja California can provide a perspective that will broaden discussion of cross-border transportation investment, which to date has focused primarily on reducing delays at, and in the immediate vicinity of, the border.

Alternative Modes

There is a large amount of information available on transportation issues in the border area, resulting from federal data collection programs and several binational efforts to assess and improve the flow of people and goods in the area. These efforts have focused largely on improvement of traffic flow at the border and in its immediate vicinity. They have produced several detailed reports containing information on traffic volumes and levels of service on border region highways and border delay times, as well as transportation improvement programs to address areas of congestion. By and large, however, they have not considered alternative modes of transportation, technology, or fuel options.

For a broader assessment of the border region's transportation needs, including consideration of the full range of solutions to meet the needs of desired future growth patterns, it will be essential to have consistent, binational data about cross-border trade. Origin/destination information at the municipal level on both sides of the border, for instance, will be needed, with special attention to distinctions between transshipment points and final destination.

SANDAG and Caltrans District 11 have conducted surveys to gather exactly these kinds of information. With increased sample size, periodic updates, and thorough analysis and dissemination of findings, these surveys could be extremely useful in formulating a comprehensive plan for improving the region's transportation infrastructure.

Federal data collection yields detailed records and interactive databases relating to the flow of goods across the border. This data has a variety of limitations, however, chief among them the paucity of detail on the Mexican side, including the lack of state-of-origin information for northbound shipments. In addition, the federal data does not provide tonnage for southbound shipments, complicating the already difficult task of associating goods volumes with vehicle volumes.

Similarly, information on goods arriving at maritime ports and other ports of entry is inadequate. The final destination of a given container, for instance, that may arrive at Los Angeles and be sent by rail to San Bernardino before being loaded on a truck to Tijuana, is apparently not consistently collected in any publicly available database. While this information may not be crucial to planning for highway expansion projects, an analysis of rail or other trucking alternatives will certainly require it.

This particular analysis was hampered especially by a shortage of data regarding two activity generators of great interest, namely maquiladora operations and maritime ports. There is undoubtedly substantial private data on trips serving these operations, but compiling this data in such a way as to create a coherent picture of the goods flows in and through Southern California and northern Baja California is essential to forward-looking transportation planning in the region.

Recommendation 1: Expand data collection efforts to better understand trends that influence border region transportation patterns, trends and opportunities.

- Support the work of Caltrans and border area associations of governments to update and analyze origin-destination data for cross-border truck trips, including full detail on trip ends on the Mexican side.
- Investigate the feasibility of expanding the Transborder Freight Data collection to include state of origin for northbound trips.

The principal justification for investment in major non-highway infrastructure to transport goods across the border lies in its ability to shape this fast-growing region in a more sustainable pattern, rather than to serve current goods movement patterns. This case is hard to make using conventional transportation analysis.

Identifying alternatives to trucking is increasingly part of the U.S. transportation agenda, however, as the federal government, states, municipalities, and the private sector seek solutions to problems of growing congestion, driver shortages, high fuel prices, and GHG emissions. Federal initiatives to promote short-sea shipping and intermodal rail have been proposed, but have not yet risen to a high level of visibility or implementation.

As a leader on climate issues, California should play a special role in reshaping the goals of transportation policy and planning in the United States. As California develops strategies to combat global warming through, for example, its Assembly Bill 32 (AB 32) (Núñez, Chapter 488, Statutes of 2006) compliance plan, its approach to transportation will necessarily include a new look at non-highway modes for both passenger and freight transportation. There are likely to be ambitious proposals to expand the state's rail system, for example that could include the cross-border rail projects discussed in this report.

Recommendation 2: Integrate border-region freight transportation planning into statewide and binational climate, economic, and environmental planning.

- Work with Baja California agencies and maquiladora associations to develop a coherent picture of what characteristics a transportation system must have to meet the transportation needs of the region for the next 20 years.
- Add transportation to the agenda of the cross-border energy working group.

With the release of the California Goods Movement Action Plan and the Clean Air Plan for the Ports of Los Angeles and Long Beach, substantial resources will be devoted to reducing congestion on major freight routes and ensuring that vehicles serving the ports will have emissions greatly reduced from today's levels. These plans thus far have very little to do with reducing fuel consumption, however, so an important opportunity to address these issues in concert may be missed. In addition, the border region could greatly benefit from integration into port planning, given that congestion and dray truck issues are similar at the border and at the ports.

Recommendation 3: Integrate consideration of alternative modes for the border region and elsewhere into state goods movement and port planning.

The specific alternative mode options that were evaluated in Chapter 3 vary widely with respect to likelihood of public and private support and time frame for possible implementation, but at least some of them warrant further attention at this time. Rail in the Tijuana corridor has a head start on other options in that there is already considerable interest in the project, and elements consistent with the rail service analyzed above are programmed, albeit for the long term, in regional transportation plans.

In the Calexico corridor, by contrast, lower levels of activity in the area and the apparent lack of a proponent for upgrading rail service make it a relatively low priority for major investment. Should growth accelerate in Mexicali or plans for Punta Colonet materialize, options for this line should be revisited.

Recommendation 4: Revisit planned projects in the Los Angeles-Tijuana corridor with the aim of creating a convenient, high-speed rail service for both shipments to and from the Midwest, and shipments from the Ports of Los Angeles and Long Beach.

- Investigate the interest of businesses in locating in the border region in a scenario in which high-quality rail service is available.
- Support SANDAG projects to upgrade Los Angeles – San Diego – Tijuana freight rail infrastructure and service.

Full rehabilitation and expansion of the SD&AE appears to be a promising option only if other infrastructure developments precede or accompany it. These include expanded capacity and connectivity of the rail line in the Tijuana corridor and expansion of the Ports of San Diego and/or Ensenada.

Recommendation 5: Proceed with modest upgrades to the Mexico and Southern Line segments of the San Diego and Eastern Railway; reconsider major upgrades upon completion of Tijuana corridor improvements.

Whether Punta Colonet is constructed will be determined largely by forces and interest outside of the border region, with the exception of the state of Baja California, which supports the project. Should the port move forward, however, there could be new opportunities to expand transportation options in the border region that focus on energy-efficient and non-polluting transportation modes, as discussed in earlier chapters.

Recommendation 6: Should Punta Colonet proceed to construction, develop and pursue a plan to take advantage of new opportunities for rail and shipping options serving the border region.

A state-sponsored initiative on short-sea shipping could greatly increase the likelihood of developing a cross-border barge service, given that one of the primary feasibility issues associated with a cross-border operation is that it would be affordable only as part of a multi-route operation.

Recommendation 7: With public and private parties interested in pursing short-sea shipping operations serving California and Baja California ports, form a collaborative to design and evaluate a system that allows shared intermodal infrastructure, vessels, and economies of scale to reduce energy consumption and emission of GHG and other air pollutants.

Emissions and Technologies

In the near term, programs that encourage production and use of low-sulfur diesel for all freight modes, particularly on the Mexican side of the border, will have a significant impact in reducing emissions and complying with pending SECA regulations.

Recommendation 8: Ensure the availability of low- or reduced-sulfur diesel fuel on both sides of the border.

Reducing the level of sulfur in diesel fuels results in direct reductions in PM emissions and can enable the adoption of additional exhaust controls (for example, oxidation catalysts for NOx reduction). In the absence of low-sulfur diesel, fuel with the lowest available sulfur content should be promoted. In addition, a proactive approach would be active sampling by state officials of fuels at retail sites to ensure that ULSD fuels for onroad vehicles and locomotives are in fact sold. With respect to marine SECA regulations, low-sulfur marine fuel consistent with current ARB regulations should be made available in both California and Baja California to help ensure cross- border consistency. Further inroads can be made by encouraging biodiesel availability at retail fuel outlets. In addition, strategies designed to accelerate fleet turnover will take fuller advantage of the co-benefits of low-sulfur fuel introduction.

In addition, CNG, LNG, and ethanol should be considered longer term options as they require extensive infrastructure enhancements. For natural gas options, this would include development of Mexican natural gas fields, extending the natural gas pipelines, and construction of refueling stations. Long-term options for railways include use of CNG for switching activities and LNG for switching and long-haul operations as these natural gas options require more extensive infrastructure enhancements. CNG and LNG should be considered a long-term option for short sea cargo shipments as well.

Ethanol requires a separate distribution system that uses corrosion-resistant materials, which would take considerable time and resources to develop. Blended biofuels (B10 or B20) may also be possible in the medium term if agricultural constraints can be addressed and new processing plants built. Blended biodiesel, though a cleaner option than low sulfur diesel, is constrained by the availability of feedstock and processing plants. Synthetic fuels are also constrained by the lack of processing plants.

Recommendation 9: Pursue opportunities to expand availability of alternative fuels.

- Investigate opportunities to develop Mexican natural gas fields, extend pipelines, and construct refueling stations.

- Consider CNG for switch locomotive activities and LNG for switch and long haul railroad operations; in the long term, consider CNG and LNG for short-sea shipping operations.
- Evaluate lifecycle costs and benefits associated with ethanol production for various feedstocks and conventional fuel cost scenarios.
- Pending lifecycle analysis results, consider introduction of ethanol blends (e-diesel) with sustainable feedstock to border-area filling stations.
- In the medium to long term (5 to 20 years), consider construction of biodiesel processing plants if sustainable feedstocks are available.
- Evaluate long-term impacts of biodiesel usage on locomotive engine components.

In the near term, there are a number of technologies that will reduce fuel usage and emissions and should be encouraged, such as: truck stop electrification, auxiliary power units, low rolling resistance tires, and airfoils and side skirts to enhance vehicle aerodynamics. For the most part, the benefits of these technologies will be limited to long-haul freight movement.

Fuel usage and pollutant emissions in aircraft can be reduced through programs that promote use of new energy-efficient jet engines that take advantage of lightweight materials, improved compressor design, and use lean burn combustors.

Recommendation 10: Provide incentives for the adoption of efficiency technologies.

- Promote electrification of truck stops and cold ironing for vessels while dockside.
- Incentivize the use of auxiliary power units, low rolling resistance tires, and airfoils and side skirts to enhance vehicle aerodynamics.
- Provide incentives for hybrid technologies, including idle-off and hydraulic hybrids for dray trucks and hybrid-electrics for both dray and long-haul trucks.
- Incentivize use of hybrid engines for switching operations and genset locomotives for switching and short-haul applications.
- Encourage the use of humid air motors to reduce NO_x emissions.
- Create programs that facilitate the use of energy-efficient jet engines using lightweight materials, improved compressor design, and lean burn combustors.

Policies and Practices

Recommendation 11: As feasible, remove legal, regulatory, and other obstacles to improved efficiency and alternative freight modes at the border.

- Review possibility to streamline rail car cleaning process at Calexico crossing.
- Establish remote border inspection stations for freight rail to allow processing at the point of embarkation.
- Pursue the Federal Highway Administration pilot project on through trucks to the extent that safety and security concerns can be addressed.
- Pursue standardization of container sizes.

- Promote the cross-border harmonization of vehicle emissions requirements.
- Explore elimination of requirements that maquiladora products return to parent companies for shipping.

Railroads today are investing far more in system rehabilitation and expansion than they have for decades because there is a very clear demand for more service. One should not expect however that the Class I railroad companies will lead the way to a new freight transportation infrastructure that will support the public priorities of sound land use planning, reduced petroleum dependence, and lower emissions of GHGs. Consequently, the government will need to play a role in funding, and convening private sector stakeholders to fund, innovative large-scale freight projects.

Recommendation 12: Explore and promote an array of financing mechanisms for funding alternative transportation modes that serve the border region.

Glossary

AASHTO	American Association of State Highway and Transportation Officials
APU	Auxiliary power unit
ARB	California Air Resource Board
BNSF	Burlington Northern-Santa Fe Railroad
BTS	Bureau of Transportation Statistics (U.S. Department of Transportation)
Btu	British Thermal Unit
Caltrans	California Department of Transportation
CIRIS	California Inter-Regional Intermodal System
CNG	Compressed natural gas
CO	Carbon monoxide
CO_2	Carbon dioxide
CZRY	Carrizo Gorge Railway
DOT	Department of Transportation
EPA	Environmental Protection Agency
FDA	Food and Drug Administration
FAST	Free and Secure Trade
FIRE	Foundation for Intermodal Research & Education
FHWA	Federal Highway Administration
FT	Fischer-Tropsch
GHG	Greenhouse gas
GRT	Gross registered tonnage
HCAS	Highway Cost Allocation Study
HPDI	High-pressure direct injection
IVAG	Imperial Valley Association of Governments
KCS/KCSM	Kansas City Southern/Kansas City Southern de Mexico Railroad
LAX	Los Angeles International Airport
LH_2	Liquefied hydrogen
LNG	Liquefied natural gas

LPG	Liquefied Petroleum Gas
MARAD	U.S. Maritime Administration
MARPOL	Marine Pollution
NAFTA	North American Free Trade Agreement
NOAA	National Oceanic and Atmospheric Administration
NO_x	Oxides of nitrogen
PEMEX	Petróleos Mexicanos
POE	Port of entry
PM	Particulate matter
RO-RO	Roll on-roll off
RTP	Regional Transportation Plan
SANDAG	San Diego Association of Governments
SD&AE	San Diego and Eastern Railway
SDIY	San Diego and Imperial Valley Railroad
SECA	SO_x Emission Control Areas
TEU	Twenty-foot-equivalent unit
TSE	Truck stop electrification
UEET	Ultra-Efficient Engine Technology
UP	Union Pacific Railroad
UPS	United Parcel Service
ULSD	Ultra-low-sulfur diesel
USDA	U.S. Department of Agriculture
VOC	Volatile organic compound

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