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The need for freight rail electrification in Southern California - attachment

Additional submitted attachment is included below.

The Need for Freight Rail Electrification in Southern California

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There is a great need to electrify freight railroads in the United States. The most established way is installing overhead catenary wires over existing railroad tracks. While the up-front capital costs may be substantial, all-electric freight rail with overhead catenary is a tried-and-true technology that would pay for itself with significant reductions in emissions and transport energy costs. Used successfully all over the world for over a century, electric freight locomotives have many advantages. In particular, electric locomotives are:

- Zero-emissions
- More energy efficient than diesel-electric locomotives, and consume almost no power when idling.
- Capable of using regenerative breaking when going downhill to recover energy that can be stored on-board, used by other trains nearby, or returned as power to the grid.
- Capable of higher speed and pulling power than diesel-electric locomotives.
- Lower maintenance than diesel locomotives.
- Quieter than diesel-electric locomotives.
- Capable of being powered by renewably-generated electricity, further enhancing emissions benefits and reducing dependence on fossil fuels. Electrified rail corridors can also serve as electric transmission line routes, potentially accessing many renewable energy generation sites.

Southern California should be a national leader in freight rail electrification due to its need to reduce air pollution, and strong political support for clean technologies. The region once had an extensive electric rail network of passenger street car and interurban transit during the first half of the 20th century, and today has a rapidly growing network of all-electric subway and light rail lines. In the past decade, a number of studies have been commissioned by state and local government agencies on low- and zero-emissions freight rail in Southern California. These publicly-funded efforts were primarily due to interest in reducing air pollution in the South Coast Air Basin region, particularly for those living and working near the tracks. In addition to freight rail electrification with overhead catenary, other low and zero-emissions locomotive technologies evaluated in previous Southern California rail electrification studies included:

- Tier 4 diesel-electric locomotives with emissions after-treatment
- Dual-mode diesel-electric hybrid that can use diesel or overhead catenary
- Third-rail electric
- Compressed natural gas (CNG)
- Liquefied natural gas (LNG)
- Onboard all-battery electric or hybrid diesel-electric
- Diesel-electric locomotives with battery-tender cars
- PEM fuel cell (PEMFC)/battery hybrid
- Solid Oxide fuel cell-gas turbine (SOFC-GT) hybrid

However, all of these studies concluded that all-electric rail with overhead catenary is the only proven zero-emissions technology for heavy-rail freight movement over any distance.

In July 2015, Governor Jerry Brown issued Executive Order B-32-15, which "provides a vision for California's transition to a more efficient, more economically competitive, and less polluting freight transport system". The resulting California Sustainable Freight Action Plan has set a goal of transitioning to zero emissions technology in all freight- air, land and sea- by 2050. Released in July 2016, the plan called on the California Public Utilities Commission (CPUC), the California Energy Commission (CEC), the California Air Resources Board (CARB), and utilities to better plan for the electrification of the transportation sector.[1] In the spring of 2016, CARB released two reports evaluating clean freight rail technology for California[2]. While an admirable effort on behalf of the state, these two studies had significant shortcomings in evaluating electric freight rail, as discussed in the sections below.

The Port of Long Beach and the Port of Los Angeles have long been leaders in reducing emissions from port operations, and should continue this legacy by leading the way in electrified freight rail. The 2017 San Pedro Bay Ports Clean Air Action Plan (CAAP) is poised to continue this innovation in electric trucks, cranes, lifting equipment, and electrical plug-ins for ships. Freight rail electrification would build upon, and add value to, the large infrastructure investments that the ports are making to shift more freight from truck to rail. The 2017 CAAP calls for expanding the use of on-dock rail by investing in improvements to the port-wide rail network, with the long-term goal of moving 50% of all cargo leaving the ports by rail. The CAAP also calls for the continued exploration of short-haul rail. The 2017 CAAP draft discussion document, released in fall 2016, did call for the planning of the electrification of transportation sector and freight movement equipment in general, particularly drayage trucks. However, the plan did not mention rail electrification specifically.

The Alameda Corridor and the Pacific Harbor Line system around the ports could serve as a pioneering example of freight rail electrification. The Alameda Corridor is owned by the public, and it is in the public's interest to reduce air pollution electrifying the trains running through populated areas. The Alameda Corridor was built with enough vertical clearance for an overhead catenary wire over a double-container stacked train, along with other features designed in anticipation of future electrification. Electrification of the proposed short-haul rail service between the ports and the Inland Empire, currently under study, is an opportunity for using electric locomotives though the Alameda Corridor in the near- to medium-term. All-electric locomotives dedicated to the short-haul service could go back and forth along 80 miles or so of electrified track between San Pedro Bay and San Bernardino, while conventional non-electric line-haul freight trains could continue use the same tracks.

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[1] http://www.casustainablefreight.org

http://www.casustainablefreight.org/files/managed/Document/289/CSFAP_FINAL_07272016.pdf

California Air Resources Board, Rail Emission Reduction Program:
https://www.arb.ca.gov/railyard/railyard.htm

[2] *Draft Technology Assessment: Freight Locomotives.* California Environmental Protection Agency, Air Resources Board, Transportation and Toxics Division, April 2016.
https://www.arb.ca.gov/msprog/tech/techreport/freight_locomotives_tech_report.pdf

Transitioning to a Zero or Near-Zero Emission Line-Haul Freight Rail System in California Operational and Economic Considerations, Final Report. Prepared for State of California Air Resources Board by University of Illinois at Urbana-Champaign Rail Transportation and Engineering Center (RailTEC), Spring 2016. https://www.arb.ca.gov/railyard/docs/uoi_rpt_06222016.pdf

Next Steps for Freight Rail Electrification in Southern California

1. A comprehensive feasibility study on electrifying the Alameda Corridor, along with short-haul rail service from the Ports of Los Angeles and Long Beach to an 'Inland Port' or other types of intermodal facilities in the Inland Empire. This comprehensive study would include:

   - Preliminary design and cost estimation
   - Cost/benefit analysis
   - Environmental and social impact assessment of possible electrification alternatives.
   - Cost assessment of modifying/replacing existing infrastructure such as bridges and tunnels for overhead catenaries, impacts on rail operations and safety, impacts to regional power grids.
   - Operational impacts to existing freight and passenger rail service.
   - Carefully assess present and future patterns of truck and rail traffic from the Ports to the Inland Empire.
   - Further questions that must be addressed by such a study:
     - Match the electrified-Inland Port model with regional objectives
     - Are we trying to promote economic development?
     - Are we trying to relieve congestion?
     - Are we trying to gain market share?
     - Are we trying to reduce environmental impact?
     - Identify effective project "champions"

2. Increased research and development on all types of low-emissions or zero-emissions freight rail and truck technology, for railroad yards, intermodal shipping facilities, and ports. To compliment and build upon existing efforts in the region, a research program or center in Southern California should be established, dedicated to electric rail technology.

3. Construction in Southern California of a short, test track of overhead catenary at a freight rail yard or short-line freight railroad. This demonstration site could serve as a test bed to evaluate an all-electric locomotive such as modified Siemens ACS-64, a converted freight rail locomotive, a dual-mode locomotive such as a modified Bombardier ALP-45DP, a smaller all-electric switcher (yard) locomotive, or catenary hybrid/ battery tender/ZEBL technology (discussed below).

4. Demonstration site, at a freight yard or passenger train station/yard, with charging infrastructure for battery electric and hybrid locomotives, including emerging technologies such as wireless power transfer (WPT).

The electrification of the Alameda Corridor, and other rail lines in the region, is a major undertaking with a long development timeline, and could be started with a comprehensive feasibility study done by transportation professionals. This document attempts to outline what questions must be answered by such a study.

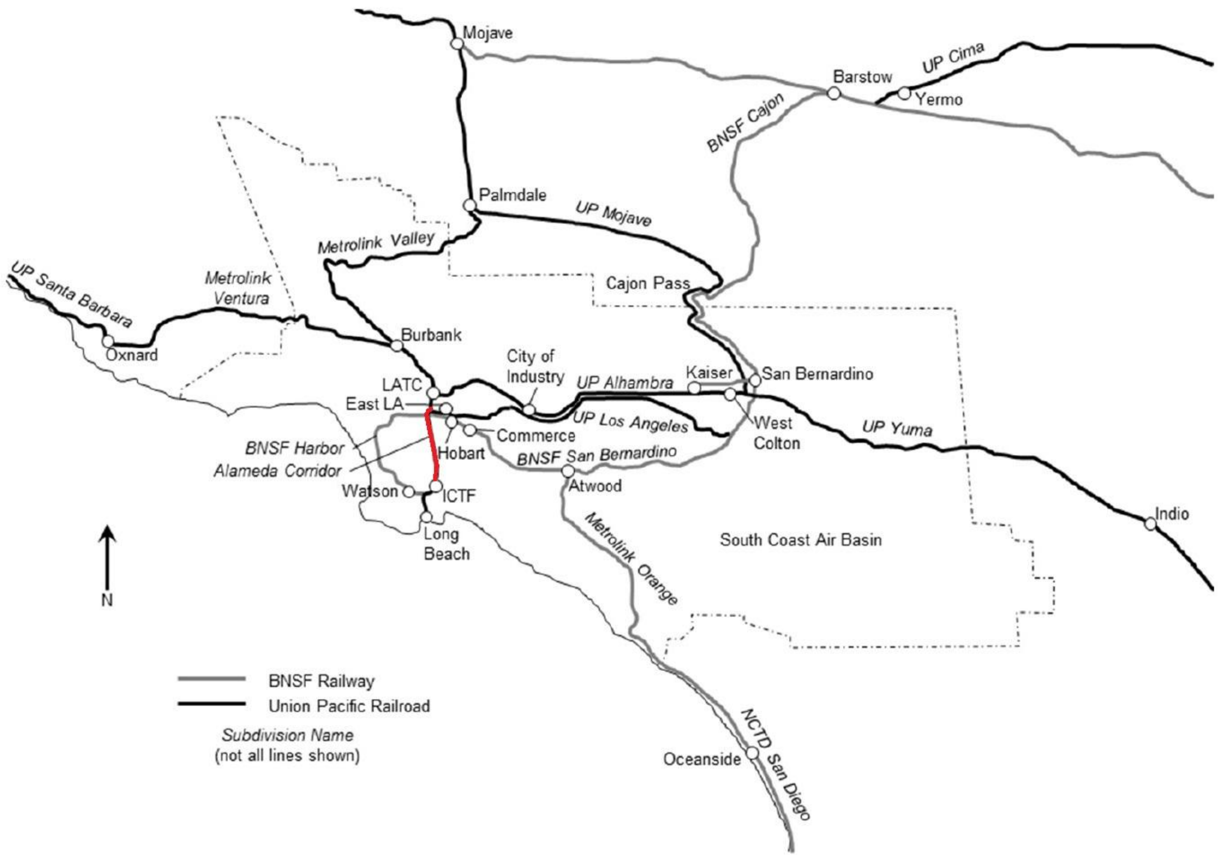
To successfully fund and implement an electric rail network in Southern California, a cooperative partnership must be forged between with the freight carriers (UP, BNSF, Pacific Harbor Line, trucking companies), and the government organizations listed below:

- Port of Long Beach
- Port of Los Angeles
- Alameda Corridor Transportation Authority
- Southern California Regional Rail Authority

- Cities along rail lines
- Counties of Los Angeles, Orange, San Bernardino and Riverside
- Southern California Association of Governments
- South Coast Air Quality Management District
- University transportation research centers (UTC San Bernardino, UTC Long Beach – METRANS, others)
- California Department of Transportation
- California Air Resources Board
- California Energy Commission
- California Public Utilities Commission

In addition, there is a need to build a broad base of support in the region for rail electrification from electric utilities, community organizations, environmental and public health public advocacy groups, along with local businesses, labor unions, trade associations and community activists. Local expertise from engineering, construction, and transit agency experience with electric rail transit could be applied to electrifying freight rail.

Alameda Corridor

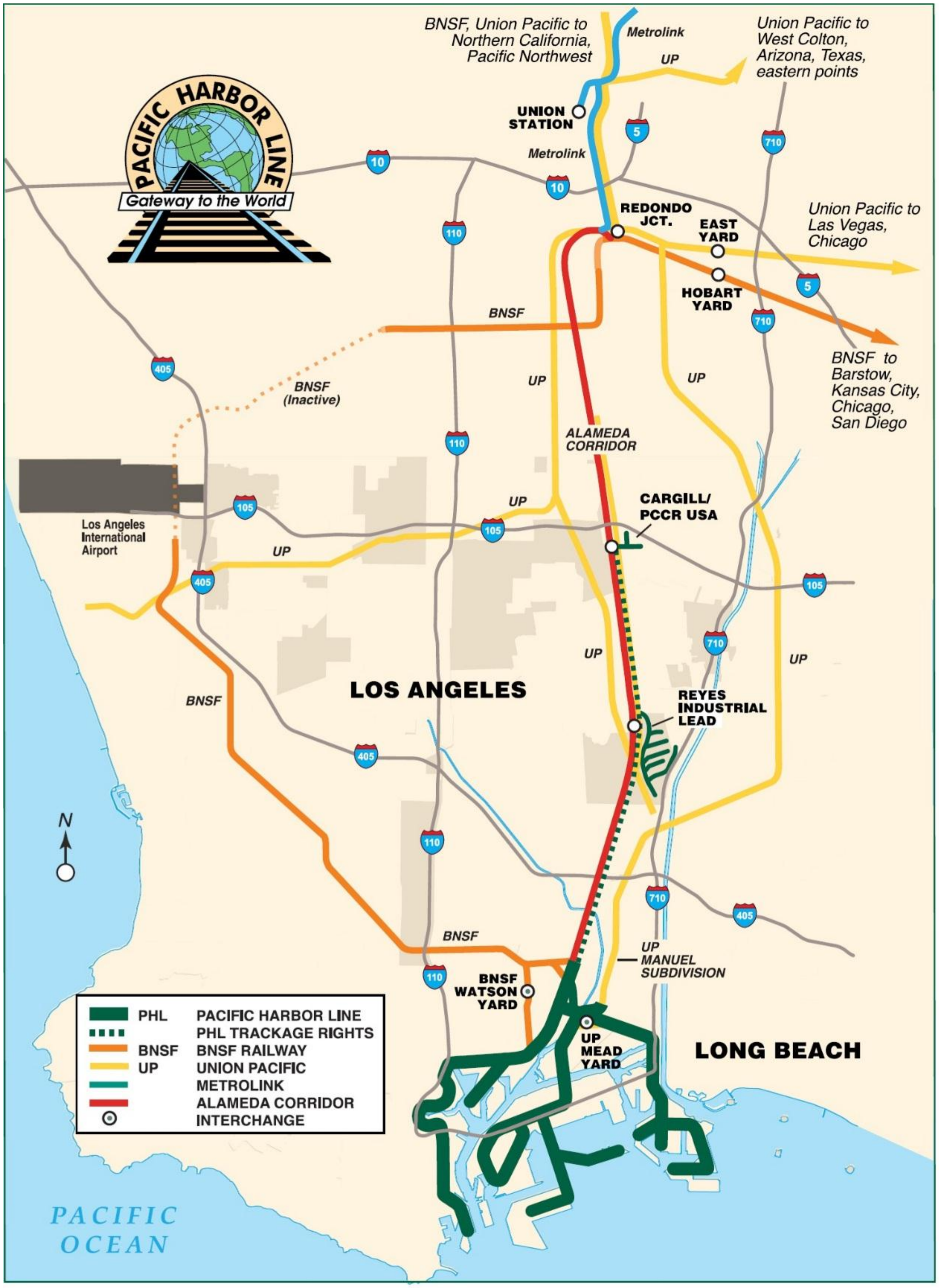


Map of line-haul freight rail network in the South Coast Air Basin (SCAB) of Southern California, highlighted to show the Alameda Corridor.

Source: Figure 3-2 from *Transitioning to a Zero or Near-Zero Emission Line-Haul Freight Rail System in California: Operational and Economic Considerations, Final Report.* Prepared for State of California Air Resources Board by University of Illinois at Urbana-Champaign Rail Transportation and Engineering Center (RailTEC), Spring 2016.

The Alameda Corridor is operated by the Alameda Corridor Transportation Authority (ACTA), a public joint powers authority formed by the cities of Long Beach and Los Angeles[3]. Union Pacific and BNSF both utilize the heavily-used route that connects the Ports of Long Beach and Los Angeles (both served by the Pacific Harbor Line), to the major railroad yards east of Downtown Los Angeles. Completed in 2002 as a significant upgrade to an existing rail line, the Alameda Corridor was financed and built by the ACTA mostly with over $2 billion of public money. The project’s main goal was the shifting more freight to rail instead of truck. The 20-mile, triple-tracked line was built with enough vertical clearance (25’ minimum) for an overhead catenary wire over a double-container stacked train, along with other features such as spaces for substations, which could be used for future electrification. Currently used by about 40 trains per day, the Alameda Corridor has the capacity for about 150, making the corridor an underutilized resource.

[3] Alameda Corridor Transportation Authority: http://www.acta.org



Map of the Alameda Corridor, Pacific Harbor Line, and connecting freight rail lines.
Source: http://www.anacostia.com/sites/www.anacostia.com/files/assets/PHL-LA-LBTml-Map081414.pdf

Electrification of the Alameda Corridor must be compatible with electrification standards that the rest of the North American rail system would follow when electrification is expanded. The Alameda Corridor Use and Operating Agreement limits the ability of the ports to impose zero emissions requirements on Class I locomotives that use the corridor.

Electric Locomotives

Most urban rail systems in the U.S. run on electricity, but electrification is sparse in the nation's intercity rail network. Amtrak runs electrified passenger service along the 457-mile Northeast corridor from Boston to Washington, and the Keystone Corridor from Philadelphia to Harrisburg, Pennsylvania. While electricity is now a major source of motive power for freight railroads in most advanced economies, the percentage of U.S. rail freight hauled using electricity is close to zero. Three lines totaling about 130 miles carry coal from mines to power plants in Arizona, Utah and New Mexico, while the Iowa Traction Railway runs 18 miles of electric line from Mason City to Clear Lake.

Outside of North America, electric freight trains are very common, as shown below in Table 1. Almost every industrialized country, nearly all of Europe and Japan, has an extensive network of electrified freight rail. Russia's Trans-Siberian Railway electrification was completed in 2002 - over 6,000 miles. Switzerland is all electric, except for one tourist line that has steam engines. Over one quarter of India's railways are electrified, and its first two freight-only electric rail lines are under construction in northern India, to carry double-stacked container under the wires. Chile and South Africa have electrified their main lines, while China is in the middle of electrifying 20,000 km. As described by the Solutionary Rail book:[4]

> AROUND A QUARTER OF THE WORLD'S RAIL LINES ARE ELECTRIFIED, 186,000 miles out of a total of 808,000. Western Europe leads with 53% of lines propelled by electricity, while North America trails with 1%. The global electrification market "continues to grow dynamically," particularly in Western Europe, Africa and the Middle East, SGI/Verkehr reports. Electricity's share in fueling rail is growing, up from 17% in 1990 to 36% in 2012, while oil has held steady at 58% and coal decreased from 25% to 6%....
>
> However, these figures understate the significance of electrification. Typically it is the more heavily used lines that are electrified. For example, though France is only 52% electrified, 85% of freight and 90% of passengers run on electrified lines.
>
> In Russia the Trans-Siberian, at nearly 6,000 miles the longest continuous rail line in the world, was fully electrified by the end of 2002. This is notable because it runs in one of the world's harshest environments and because reliable operation is critical to Russia's strategic control of its eastern regions. The rail line carries 30% of Russian exports. Overall, electric lines carry 70% of Russian freight, the equivalent in ton-miles of 80% of US rail freight... China's rail electrification has expanded rapidly. Concerted efforts have grown the percentage from only 5% in 1975 to over 40% today.
>
> Smaller economic powerhouse nations have largely electrified rail systems. Sweden grew electrification from 61% in in 1970 to 77% of its system in 2005. The Netherlands has increased its electrified network from 52% in 1970 to 73% in 2005. Switzerland is a global standout with a 100% electrification rate. That nation is in the midst of a major rail line improvement program, a central goal of which to move freight from trucks to electric rail. In 17 European nations the rail network is at least 40% electrified.
>
> Great Britain, which has lagged other European nations with only 33% of its rail network electrified, in 2007 announced a £1.1 billion effort to expand electrification. The Great Western Line linking London with Wales is slated for full electrification by 2017. Liverpool-Manchester, one of the world's oldest rail lines, was electrified in 2015.

[4] Bill Moyer, Patrick Mazza and the Solutionary Rail team (http://www.solutionaryrail.org/). *Solutionary Rail: A people-powered campaign to electrify America's railroads and open corridors for a clean energy future,* October 2016, pp.15-17.

Nations around the world that have recently expanded electrified rail or are engaged in significant efforts to do so include Chile, Taiwan, Malaysia, Iran, Israel, Saudi Arabia, Kazakhstan, Uzbekistan, Ethiopia, South Africa, Denmark, Norway, and New Zealand. Electrified rail is working around the world. It can work in the US again.

Table 1: Railroad electrification around the world

Country	Miles Electrified	Percentage Electrified
Switzerland	2,884	100%
Ethiopia/Djibouti	470	100%
Japan	12,160	72%
Italy	12,585	64%
Morocco	800	62%
France	18,417	52%
Germany	26,085	48%
Russia	54,157	46%
South Africa	6,045	46%
China	53,437	41%
United Kingdom	3,276	33%
India	39,741	30%

The weight of a long-distance, U.S. line-haul freight train ranges between 10,000 and 20,000 short tons. The most powerful diesel-electric locomotives used in U.S. freight service are the 6,000 hp GE AC6000CW (840 kN starting tractive effort, 740 kN continuous) and EMD SD90MAC (890 kN starting tractive effort, 734 kN continuous). However, U.S. freight railroads have moved away from such high-horsepower locomotives as they have found it more efficient to use multiple locomotives, of less than 5,000 hp each, as distributed tractive power in the front, middle and/or rear of a train. An example of a more typical large Tier 4 U.S. line-haul diesel-electric locomotive currently being manufactured is the EMD SD70ACe-T4 (4,600 hp, 890 kN of starting and 780kN continuous tractive effort).

An electric locomotive can be designed to match or exceed the performance specifications required by U.S. line-haul freight trains. In fact, the world's most powerful locomotives are all-electric, as shown below in Table 2. In China, a single HXD1 two-section, all-electric locomotive set pulls entire 20,000-ton coal trains. For the 535-mile Sishen–Saldanha Orex line, South African Railways uses a 50 kV catenary system for hauling 41,000 metric ton (46,000 short ton) ore trains. These trains are pulled by up to nine all-electric Mitsui Class 15E locomotives in distributed configuration, not unlike that of a U.S. line-haul freight train.

Table 2: Examples of notable all-electric locomotives currently manufactured or in-use:

Electric locomotive	Horsepower	Starting tractive effort (kN)	Est. cost per unit (US $ millions)	Notes
CRRC Zhuzhou HXD1	19,300	1,140	unknown	The most powerful locomotive currently used in the world, used for hauling 20,000 metric ton (22,000 short ton) coal trains in China, under 25 kV overhead catenary.
TMH 4ES5K	17,400	unknown	unknown	The four-section locomotive is designed to haul 7,100 metric ton (7,800 short ton) freight trains on Tayshet – Taksimo section of Russia's Baikal-Amur Mainline route without needing additional locomotives, or 9,000 metric ton (9,900 short ton) trains on less steeply-graded routes.
Siemens ACS-64	8,600	320	$8.6	The highest-horsepower locomotive operating in the U.S., used for fast passenger service on the Northeast Corridor and the Keystone Corridor, PA. Manufactured near Sacramento, Siemens has sold 70 ACS-64 electric locomotives to Amtrak starting in 2014 and 13 to SEPTA. Based on Siemens European electric locomotives EuroSprinter and Vectron.
Siemens Vectron	8,600	300	$5.1	European electric passenger and freight locomotive.
Bombardier TRAXX	7,500	300	$4.3	European electric passenger and freight locomotive.
Bombardier IORE	7,200	600	$9	Swedish version of TRAXX for hauling iron ore trains, modified for greater tractive effort.
Mitsui Class 15E	6,000	580	unknown	Operated by South African Railways using 50 kV catenary for hauling 41,000 metric ton (46,000 short ton) ore trains with distributed power.
Siemens 3800	5,400	525	unknown	Used by three railroads in Australia for hauling heavy coal and ore trains; can operate on both 25 kV and 50 kV catenary systems.

European freight locomotives tend to be less powerful than their U.S. counterparts, which leads to a common misconception that all-electric locomotive technology is not powerful enough for U.S. freight rail. As described by the Spring 2016 CARB Railtec report[5]:

> One-for-one replacement of conventional diesel-electric locomotives with electric locomotives is conceptually possible if a new generation of purpose-built electric line-haul freight locomotives are developed for the North American market. Current European designs develop sufficient horsepower but lack the number of axles, axle loads and adhesion required to match the tractive effort of a North American line-haul diesel-electric locomotive.

[5] *Transitioning to a Zero or Near-Zero Emission Line-Haul Freight Rail System in California Operational and Economic Considerations, Final Report.* Prepared for State of California Air Resources Board by University of Illinois at Urbana-Champaign Rail Transportation and Engineering Center (RailTEC), Spring 2016, pg. 20. https://www.arb.ca.gov/railyard/docs/uoi_rpt_06222016.pdf

As further detailed by the April 2016 CARB freight locomotive report[6]:

> An all-electric freight line haul locomotive would be powered solely by electrified catenary. Currently, all -electric freight line haul locomotives operate in other parts of the world (e.g., Europe, China, and Russia). However, these locomotives are typically built for greater speeds, to reduce slowdowns for high speed passenger trains that share the same rail electrification system. Therefore, all-electric freight locomotives have significantly less pulling power (i.e., up to two-thirds less –though they are typically higher horsepower for speed) than U.S. diesel-electric freight interstate line haul locomotives.
>
> …U.S. freight railroad electrification requires power levels ranging between 18 to 24 MW for per freight train, compared to 6 to 10 MW for freight trains in Europe The U.S. freight train power level is much higher and will require strong utility networks, traction substations, and catenaries.
>
> The major differences in freight rail electrification in Europe and other countries are the power needs and system design. In most cases around the world, railroad electrification has been built for speed, to support high speed passenger trains. In other parts of the world, all-electric freight locomotives are typically built for speed (i.e., with high horsepower) to reduce congestion and delays for the high speed passenger trains sharing the same electric rail system. This is typically at the expense of pulling power.
>
> For comparison, European all-electric freight trains typically pull about ten times less tonnage (i.e., about 1,000 to 2,000 tons) than U.S. diesel-electric freight trains (i.e., 10,000 to 20,000 tons). A typical European all-electric freight locomotive has about 70,000 pounds of force of pulling power or tractive effort, whereas U.S. diesel-electric freight locomotives can approach 200,000 pounds of force of tractive effort.
>
> Greater catenary heights and clearances to allow for double stack containers carried by U.S. freight trains may create clearance issues, especially under bridges and tunnels. In the U.S., the railway electrification systems would require higher catenary clearances (23.5 feet) from rails, and could necessitate lowering tracks or raising bridges to provide adequate clearances.

The 2016 CARB reports seem to use the example of fast, lighter electric freight trains in Europe as the only type of all-electric freight train. What is not discussed are the heavy all-electric freight trains used in China, Russia, Australia and South Africa, which are more appropriate electrification examples for U.S. freight rail. In fact, the heaviest all-electric ore and coal trains in these countries are much heavier than U.S. line-haul freight trains.

Europe's relatively small freight train sizes are due to reasons particular to that continent's railroad network, and not due to the limitations of electric locomotive technology. European freight train length and weight are limited by the infrastructure they run on, and limited in distance travelled due to still-remaining differences in rail standards between European countries. To allow for a higher volume of passenger traffic, European freight and passenger trains sharing the same track operate at similar speeds, and braking distances are similar for all trains. Consequently, European freight cars have lower limits on axel weight and drawbar strength compared to their U.S. counterparts. Despite these fundamental differences with U.S. freight rail operations, European all-electric locomotive technology can still serve as a basis for U.S. electric freight locomotives. As described by the 2012 SCAG freight rail electrification study[7]:

[6] *Draft Technology Assessment: Freight Locomotives.* California Environmental Protection Agency, Air Resources Board, Transportation and Toxics Division, April 2016, pg. VIII-3 to VIII-6. https://www.arb.ca.gov/msprog/tech/techreport/freight_locomotives_tech_report.pdf

[7] *Task 8.3: Analysis of Freight Rail Electrification in the SCAG Region (Final Technical Memorandum)*, prepared by Cambridge Systematics, Inc. for Southern California Association of Governments, April 2012, pg. 2-5.

> A variety of… high horsepower electric freight locomotives [are] in operation in Europe, such as the DB Schenker EG3100 (8,837 hp), or the Bombardier Swiss Class 482 Traxx Locomotive (7,614 hp). However, in their present configurations, these units do not offer sufficient starting tractive effort to move typical high-tonnage trains up the critical mountain passes that must be crossed to enter or leave the L.A. region (i.e., the Cajon Pass on BNSF/UP and Beaumont Hill on the UP).
>
> For purposes of this analysis, the assumed locomotive type will be one with similar specifications to the Bombardier IORE, due to its relatively high tractive effort (which is necessary to get long and heavy U.S. freight trains moving), six-axle design, high horsepower, and its potential adaptability to the U.S. freight railroad operating environment. While some adjustments would be necessary to prepare these locomotives for U.S. operations (such as additional weight to increase tractive effort), they should be relatively minor.

In addition to reduced energy costs, electric locomotives require less maintenance than diesel-electric locomotives. Due to their decreased mechanical complexity, electric locomotive maintenance costs are 40%-50% lower than those of a comparable diesel-electric locomotive fleet, and have longer operating lives[8].

Existing and historical all-electric freight railroads in North America-

There are only four all-electric freight railroads currently in operation in the United States. Three of the existing U.S. all-electric freight railroads are dedicated and isolated lines to haul coal between a mine and a coal-fired power plant. These are the Black Mesa & Lake Powell Railroad (78 mile length, completed 1973) in Arizona, the Deseret Power Railroad (39 mile length, completed 1984) between Utah and Colorado, and the Navajo Mine Railroad (14 mile length, electrified 1984) in New Mexico. All three lines use GE E60C all-electric freight locomotives built in the 1970s and 80s, which utilize 25 kV or 50 kV overhead catenary. The GE E60Cs are rated at 6,000 horsepower, but with 333 kN of starting tractive effort, have about one-third the pulling power of typical U.S. diesel-electric freight line- haul locomotives. The fourth existing U.S. electric freight railroad is the Iowa Traction Railway, which runs 18 miles of electric line from Mason City to Clear Lake, and can interchange freight cars with a Class I railroad network. The Iowa Traction Railway's four small Baldwin-Westinghouse electric locomotives are nearly 100 years old and still operating.

Several notable, pioneering electric freight rail lines existed in the U.S. during the first half of the 20th Century, particularly for steep mountain grades. In the Washington Cascades, the Great Northern Railway electrified its Cascade Tunnel in 1909. The longest lasting of the large U.S. freight rail systems were those of Pennsylvania's Keystone Corridor and the Milwaukee, St. Paul and Pacific Railroad (commonly referred to as the Milwaukee Road). The Milwaukee Road electrified 645 miles of its Pacific Extension in two long sections of the Rocky and Cascade mountain ranges between 1914 and 1920, the longest electric railroad in the world at the time. The Pennsylvania Railroad had electrified nearly 2,700 miles of its track by the end of the 1930s. The Milwaukee Road electrification ended in 1974, and in Pennsylvania the last electric freight trains (then run by Conrail) ran in 1981. Elsewhere in North America, Mexico ran electric freight rail for about 140 miles between Mexico City and Queretaro between 1994 and 1997, using GE E60 locomotives. In

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http://www.freightworks.org/DocumentLibrary/CRGMSAIS%20-%20Analysis%20of%20Freight%20Rail%20Electrification%20in%20the%20SCAG%20Region.pdf

[8] J.P. Baumgartner, *Prices and Costs in the Railway Sector.* Ecole Polytechnique Federale de Lausanne, 2001.

Canada, BC Rail used all-electric locomotives on an 85-mile line to a coal mine between 1984 and 2000. As further described by the Spring 2016 CARB RailTEC report[9]:

> The most significant electrified mainline line-haul freight operation in the United States, and last to remain in service, was the route between New York, Philadelphia and Harrisburg, Pennsylvania, last operated by Conrail and now part of Norfolk Southern. Previous electrified networks operated by the Milwaukee Road and Norfolk & Western were removed from service in 1974 and 1962, respectively. Part of the reason for the longevity to the Harrisburg electrification is that it operated between two major gateway terminals at one extreme end of the Conrail network. Harrisburg was the location of Enola Yard, one of the largest hump classification yards in North America. The majority of trains traversing the electrified territory operated between an origin on the Philadelphia-New York electrified territory and Enola Yard for reclassification. With both origin and destination on the electrified territory, the trains did not need to make a mid-route locomotive change (Bezilla, 1980). The two other major electric operations that were discontinued years earlier were all located in the middle of train routes and away from major terminals, leading to locomotive changes, delay and logistical issues (Marchinchin, 2013).
>
> In British Columbia, Canada, 84.5 miles of new mainline constructed by BC Rail to reach two new coal mines were electrified in 1984. This route segment operated with electric locomotives until 2000. Coal trains serving the mines executed a locomotive change at an exchange point located at the southern end of the electrification. The electric locomotives transported the empty trainsets to the mine for loading and return to the exchange point. During this process, the diesel-electric locomotives were staged in a siding track. The locomotive exchange facility was not placed at a crew change point; as crews completed the locomotive exchange, they continued their run with the new motive power. Since the volume of traffic never exceeded three loaded trains per day, logistical issues at the exchange point were minimized. The commodity being transported, coal for overseas export to Japan, was also not particularly sensitive to delays associated with the locomotive exchange operation. Electrified operations were terminated in 2000 as coal production at the mines was scaled back and BC Rail, previously operating as a government-owned corporation, was privatized through a lease to Canadian National.
>
> In Mexico, a 154-mile segment of freight mainline between Mexico City and Queretaro was electrified with operations commencing in 1994. The electrification had originally been planned to extend to the major terminal in San Luis Potosi with fast, frequent shuttle train service between the two end points. Due to financial difficulties, the electrification was terminated in Queretaro, a location that was neither an existing locomotive servicing point nor a crew change point for through trains. The need for a mid-route locomotive change created delays and logistical issues with balancing motive power. When the route was privatized in 1997, electric operations were immediately terminated in favor of run-through diesel-electric locomotives.
>
> In each case, maintenance of the overhead catenary system, and the capital cost of replacement or refurbishment at the end of its service life, is often cited as the primary reason for discontinuing electric operations. However, improved locomotive utilization and elimination of delay from locomotive changes were also significant factors.

For widespread freight rail electrification to work again on a large scale in the U.S., there is a need for a new generation of all-electric locomotives designed specifically for the U.S. freight market. The 2016 CARB Railtec report estimated the cost of a new all-electric U.S. line-haul freight locomotive to be roughly $5 million/unit, compared to average price of $3 million/unit for a comparable Tier 4 diesel-electric locomotive [10]. There are advantages in using an adapted, in

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[9] *Transitioning to a Zero or Near-Zero Emission Line-Haul Freight Rail System in California Operational and Economic Considerations, Final Report.* Prepared for State of California Air Resources Board by University of Illinois at Urbana-Champaign Rail Transportation and Engineering Center (RailTEC), Spring 2016, pg. 30. https://www.arb.ca.gov/railyard/docs/uoi_rpt_06222016.pdf

[10] *Transitioning to a Zero or Near-Zero Emission Line-Haul Freight Rail System in California Operational and Economic Considerations, Final Report.* Prepared for State of California Air Resources Board by University of Illinois at Urbana-Champaign Rail Transportation and Engineering Center (RailTEC), Spring 2016, pg. 58. https://www.arb.ca.gov/railyard/docs/uoi_rpt_06222016.pdf

production electric locomotive for a small order for the short-haul freight service in the Alameda Corridor, or between the ports and the Inland Empire. Perhaps the Bombardier IORE freight or the Siemens ACS-64 passenger locomotives (see Table 2 above) could be modified for Southern California short-haul freight rail service, pulling lighter and faster trains than an interstate line-haul freight train. It is also possible for an existing line-haul freight locomotive, with its higher weight, tractive effort and six-axle chassis, to be converted to all-electric by replacing the diesel engine with a catenary pantograph and transformer system.

Electrification of freight yard switcher and short-line locomotives-

In addition to large line-haul electric locomotives, smaller all-electric locomotives such as medium-sized or small switcher units, should be developed for short-haul and freight yard switching service. All electric versions of small 'switcher' (1,000 to 2,300 hp, 130 to 450 kN tractive effort) and medium-sized (2,300 to 4,300 hp, 350 to 700 kN tractive effort) locomotives could be utilized by short-line railroads and freight railyards in Southern California. Short-line railroads, such as the Pacific Harbor Line that operates in and around the Ports of LA and Long Beach, could serve as a good demonstration site for a demonstration electric (with overhead catenary) or battery-powered switcher locomotive. California as a whole has about 26 Class III short-haul railroads, operating about 135 locomotives, along with smaller military and industrial freight rail operations consisting of about 75 smaller locomotives[11].

The Zero Emissions Battery Locomotive (ZEBL) conceptual prototype for switcher locomotives, short-haul rail service, or 'hybrid ZEBL', battery tender with retractable overhead pantograph for receiving power from overhead catenary, could be used in freight yards or the Alameda Corridor before other rail corridors in the region.

Potential for freight fail service to benefit from passenger rail electrification-

The co-utilization of electric rail infrastructure for both freight and passenger rail service should be studied. As part of the California High Speed Rail project, for example, it is proposed that passenger rail electrification of the Los Angeles to Anaheim corridor, which happens to be along the first section of the BNSF Southern Transcon between the ports and the Inland Empire. The Electrolink electric regional rail concept for Southern California has been proposed by the Rail Passenger Association of California and Nevada. The Electrolink proposal would start with electrifying existing shared Amtrak/Metrolink route between northern Los Angeles and southern Orange County, and then expand to the rest of the LOSSAN (Los Angeles to San Diego), or Surfliner passenger rail corridor.

[11] *Draft Technology Assessment: Freight Locomotives.* California Environmental Protection Agency, Air Resources Board, Transportation and Toxics Division, April 2016, pgs .1-11 – 1-12.
https://www.arb.ca.gov/msprog/tech/techreport/freight_locomotives_tech_report.pdf

Performance Limitations of Electric Locomotives

Aside from the capital cost of electric catenary systems, the main disadvantage of electric locomotives is operational flexibility. Conventional electric locomotives must remain on tracks with overhead catenary wire, while diesel locomotives can go on any track.

Delays caused by exchange of locomotive type-

The business model of U.S. Class I freight railroads such as UP and BNSF is to minimize the number of trains run by maximizing the weight, length and distance travelled by each train. The Class I railroads prefer to run freight trains for a minimum of 500 miles. The U.S. railroads typically run locomotives extremely long distances, often literally coast to coast. The costs from time-delay of the engine change and additional locomotive facilities a disadvantage that has been cited by U.S. railroads as a reason not to electrify. As described by the April 2016 CARB freight locomotive report[12]:

> UP and BNSF currently operate high priority intermodal unit trains that can leave the West Coast and make the trip to Chicago (>2,000 track-miles) in 48 to 72 hours. Freight interstate line haul locomotives, with about 5,000 gallon fuel tanks, have a refueling range of about 1,000 miles. On the trip from Chicago to Los Angeles, a typical freight train will refuel twice: once in Kansas City, Kansas and then either at Belen, New Mexico or Santa Teresa, New Mexico and then to California.
>
> An isolated freight electrification system in California could create a number of challenges for UP and BNSF operations on the North American freight rail system including:
>
> - Maintenance of two separate types of locomotive technologies – all-electric in California and diesel-electric for the rest of North American freight rail system;
>
> - Delays in operations by having to stop freight trains at an exchange point, just outside the South Coast Air Basin or California border, to switch all-electric to diesel-electric operations (these delays could take anywhere from 2 to 6 hours, depending on the configurations of the trains, and based on price and time, could potentially lead to a mode shift to trucks or ships).

Possible ways of speeding up, or mitigating the impact, or locomotive exchange delays need to be studied. Potential solutions to the exchange point delay problem could include electrifying short-haul rail service as first phase of electrification, with later expansion in stages to entire long-haul corridors such as the Southern Transcon or the Sunset Corridor. For long-distance trains, the electrification could be phased in using dual-mode locomotives and electric-diesel mixed locomotive trains (discussed below). The short-haul freight train service could also begin with dual-mode. When there is a sufficient amount of regional track electrified, commuter passenger rail and short-haul freight services would switch to straight electric, and the dual mode locomotives moved to long-haul freight service. The locomotive types could also be switched where crews are changed, and where diesel-electrics are already refueled and inspected, to reduce costs and delays.

Electrification impacts on rail system reliability/resilience to disruption-

From a reliability perspective, the failure of an electric catenary system is an additional 'single point of failure', along with track failures such was washouts, subgrade failures, switches/signal system malfunctions. In California, freight

[12] *Draft Technology Assessment: Freight Locomotives.* California Environmental Protection Agency, Air Resources Board, Transportation and Toxics Division, April 2016, pg. VIII-4.
https://www.arb.ca.gov/msprog/tech/techreport/freight_locomotives_tech_report.pdf

railroads have also expressed concerns about electromagnetic interference to signaling systems, overhead clearance for double-stacked container cars. However, other electric railroads around the world, such as Pennsylvania's Keystone Corridor, for decades have successfully shared catenary tracks with non-electric freight trains, including those with double-stacked containers cars.

Dual Mode/Diesel- Electric Hybrid Locomotives and Mixed Operation

A dual-model diesel-electric locomotive has two separate power plants: diesel electric and all-electric. This gives the flexibility to use all-electric mode with pantograph on track with an overhead catenary, and also operate in diesel-electric mode on track with no electric catenary. The main disadvantages of dual-mode locomotives are that they are more expensive to build and mechanically more complex, resulting in higher maintenance costs. They also lose some energy efficiency by carrying around the weight of one type of unused power plant (electric or diesel), while using the other.

Existing dual-mode locomotives designed for passenger service include the Bombardier ALP 45 DP and the EMD DM30AC. The 2012 SCAG freight rail electrification study concluded that the Bombardier ALP-45DP was the existing dual-mode locomotive that could most easily be converted to freight operation in North America[13]. These dual-mode electrics were built for New Jersey Transit and Montreal's Agence Metropolitaine de Transport. In all-electric operation the unit has a maximum power of 4,000 kW (over 5,000 hp) and a starting tractive effort of 316 kN, while in diesel mode power is reduced to about 3,100 kW (4,200 hp). The ALP-45DP units, at over $10 million each, were more expensive than a comparable all-electric or diesel-electric locomotive, and have spent a lot of time in the maintenance shop with "teething troubles". There is limited experience around the world with freight dual-mode locomotives. Despite having more limited fuel capacity than a regular diesel-electric locomotive, even with electrification of main-line track, dual-mode locomotives could find application during electrification construction and maybe in non-electrified yards and sidings.

Mixed diesel-electric and all-electric locomotive operation-

Another possibility for diesel and electric hybrid operation is sharing traction power between all-electric and diesel-electric locomotives. Mixed-unit trains are operationally more flexible, and potentially more efficient than dual-mode locomotives. The concept should be studied for California freight rail. The Milwaukee Road developed a way to power trains with a shared configuration all-electric and diesel locomotives and used it regularly in the last few years of electric operation before 1974. A particularly interesting example is the South African use of mixed diesel and electrics for heavy freight rail[14]:

> On the Sishen–Saldanha Orex line, GE Class 34 series and Class 43-000 diesel-electric locomotives run consisted to Class 9E and Class 15E electric locomotives to haul the 342-wagon iron ore trains. Each wagon has a 100-ton capacity and the trains are at least 3.72 kilometres (2.31 miles) in length, powered by mixed consists of Class 9E and Class 15E electric, GE type U26C Classes 34-000, 34-400, 34-500 and 34-900 and, from 2012, GE type C30ACi Class 43-000 diesel-electric locomotives. In South Africa mixed electric and diesel-electric consists are unique to the Orex line, necessitated by the huge voltage drops which can occur as a result of the long distance between some of the sub-stations along the route.

[13] *Task 8.3: Analysis of Freight Rail Electrification in the SCAG Region (Final Technical Memorandum)*, prepared by Cambridge Systematics, Inc. for Southern California Association of Governments, April 2012, pg. 2-7. http://www.freightworks.org/DocumentLibrary/CRGMSAIS%20-%20Analysis%20of%20Freight%20Rail%20Electrification%20in%20the%20SCAG%20Region.pdf

[14] https://en.wikipedia.org/wiki/South_African_Class_15E

Electrification of Track

The main drawback of electrification is the high capital cost of installing overhead catenary wire. The costs for electrification of track must be evaluated on a case-by-case basis, with route-specific cost assessment of the needs to modify or replace existing infrastructure such as bridges and tunnels for overhead catenaries, impacts on rail operations and safety, impacts to regional power grids. Typical low-end costs cited for rail line electrification in rural areas are around $2 million per route mile for single track, and $2.5 million for double track. The California High Speed Rail Authority has estimated an electrification cost of $5 million per route mile for rural areas in the Central Valley. However, in urban and suburban areas, the cost is much higher. The Caltrain electrification costs between San Francisco and San Jose are about $40 million per route mile, which perhaps is the most expensive rail electrification project in the world. Using the Caltrain construction cost estimates as a basis, the April 2016 CARB freight locomotive report estimated that freight rail electrification capital costs in the South Coast Air Basin would be about $50 million per route mile [15]. However, these costs were rough estimates, and not based on a detailed analysis of existing rail routes. A comprehensive engineering design study and cost estimate of freight rail lines in the South Coast Air Basin needs to be conducted.

Both the 1992 Southern California rail electrification[16] and April 2016 CARB freight locomotive[17] reports, recommend an overhead catenary voltage of 50 kV for electric freight rail in Southern California. Overhead catenary system maintenance costs were estimated by the 2016 CARB RailTEC report to be $30,000 per route mile, per year[18]. Factoring in the social benefits of reduced pollution, electrification for several key Southern California freight and passenger lines was economically favorable according to a cost-benefit analysis done by Paul Druce in 2015[19]:

> Considering just the social benefits, maintenance is paid for with 3.5-4.5 daily frequencies. This alone does not justify electrification in most corridors, however, as it would require 55 frequencies, five times the current level of the Pacific Surfliner, to justify solely on environmental grounds. As we established earlier, however, electric propulsion is quite a bit cheaper than diesel propulsion; for a corridor intercity or commuter train with consumption of 22 kWh per train-mile, we can expect a cost of $2.42 per train-mile, $5.18-7.46 cheaper than diesel.

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[15] *Draft Technology Assessment: Freight Locomotives.* California Environmental Protection Agency, Air Resources Board, Transportation and Toxics Division, April 2016, pg. VIII-10 to VIII-11. https://www.arb.ca.gov/msprog/tech/techreport/freight_locomotives_tech_report.pdf

[16] *Southern California Accelerated Rail Electrification Program, Draft Executive Summary.* Prepared for Southern California Regional Rail Authority, February 10, 1992: http://libraryarchives.metro.net/DPGTL/Metrolink/1992-ExecSummary-SoCal-Accelerated-Rail-Electrification.pdf

[17] *Draft Technology Assessment: Freight Locomotives.* California Environmental Protection Agency, Air Resources Board, Transportation and Toxics Division, April 2016, pg. VIII-6. https://www.arb.ca.gov/msprog/tech/techreport/freight_locomotives_tech_report.pdf

[18] *Transitioning to a Zero or Near-Zero Emission Line-Haul Freight Rail System in California Operational and Economic Considerations, Final Report.* Prepared for State of California Air Resources Board by University of Illinois at Urbana-Champaign Rail Transportation and Engineering Center (RailTEC), Spring 2016 (https://www.arb.ca.gov/railyard/docs/uoi_rpt_06222016.pdf), pg. 20.

[19] Paul Druce, *Reason & Rail* blog, September 5, 2015: http://reasonrail.blogspot.com/2015/09/a-cost-to-benefit-analysis-of-railroad.html

Again, maintenance is very quickly paid for: 2-3 frequencies will pay for the maintenance, but construction costs require rather more: 32-47 frequencies. Combined, we see that it takes 21-29 bidirectional frequencies for benefits to match the costs of railroad electrification.

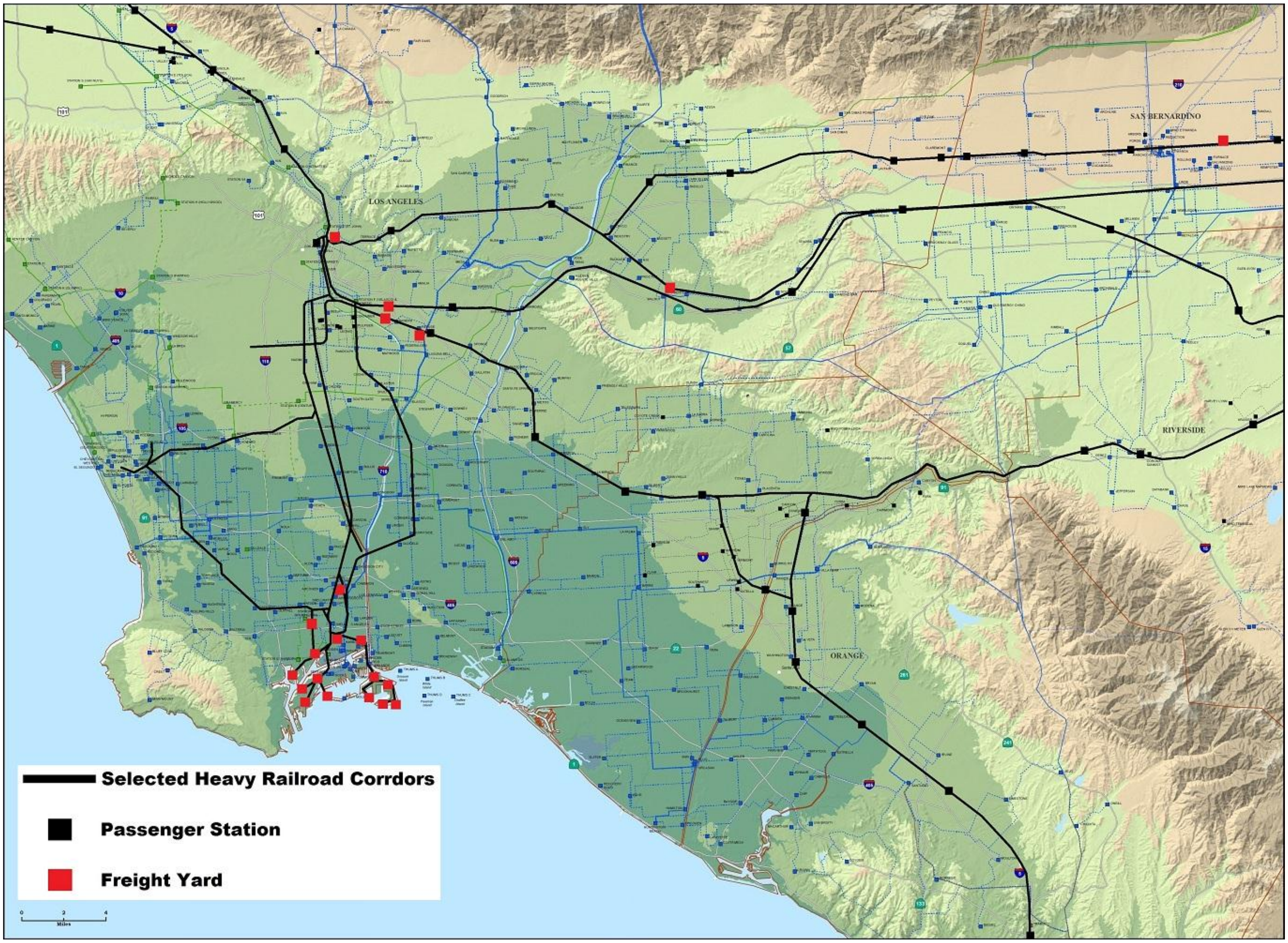
	Frequencies to break even	Social benefit per frequency	Cost savings per frequency
Class 222	29	$2,638.51	$3,781.40
Amtrak	25	$3,034.29	$4,613.60
Metrolink	21	$3,430.06	$5,445.80

In California, this would indicate that it would be justified to electrify Caltrain between San Jose and San Francisco. With increased service, electrification would also be justified on Metrolink's San Bernardino Line as well as LOSSAN between Burbank and Irvine (Metrolink and Pacific Surfliner) and Oceanside and San Diego (Coaster and Pacific Surfliner).

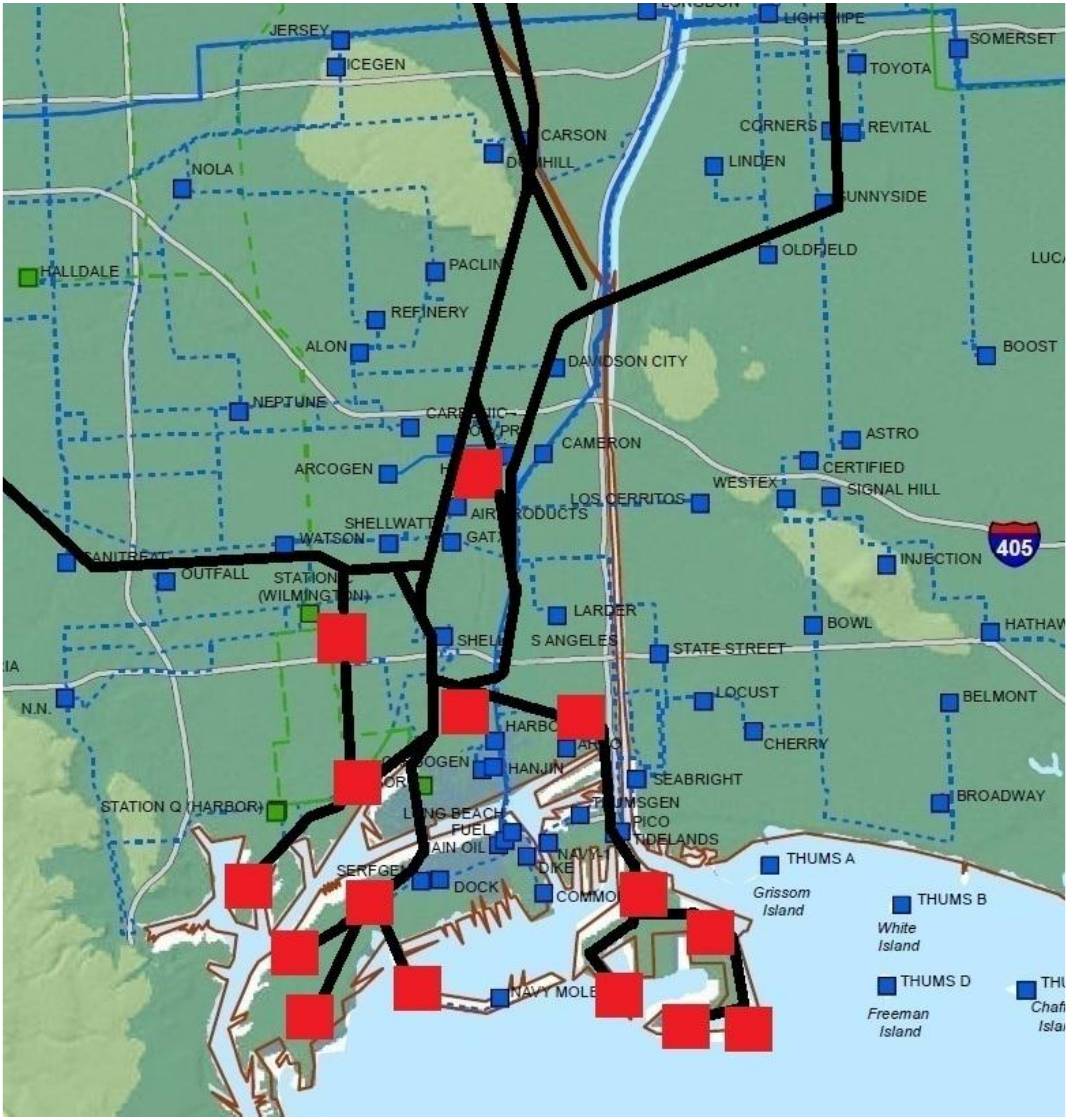
For freight trains, the decreased fuel costs play a much larger role, and more importantly, the only one that the board of directors actually care about, resulting in break even at fewer frequencies. From the 2014 STB R-1 reports, we see that, for the Class I railroads, there is an average consumption of 6.92 gallons per train-mile; a comparable figure for electric traction would be 86.5 kWh per train-mile. Because of the significantly greater fuel consumption, the pay off is much quicker: Only 9 trains per day are needed in each direction with social benefits included or 15.4 when only considering fuel costs. Of course, private companies aren't going to be using Federal discount rates and will likely be seeking money on the open market. While this will be more expensive, it won't be enormously so. Union Pacific recently sold 40 year bonds at 3.875%; if I've done the math correctly, this would come out to $212,374 per mile of track, pushing the break even points to 10 and 17.3 frequencies. In Southern California, this would justify the electrification of the Alameda Corridor, Sunset Corridor, and Southern Transcon.

Energy consumption of electric rail, utility participation-

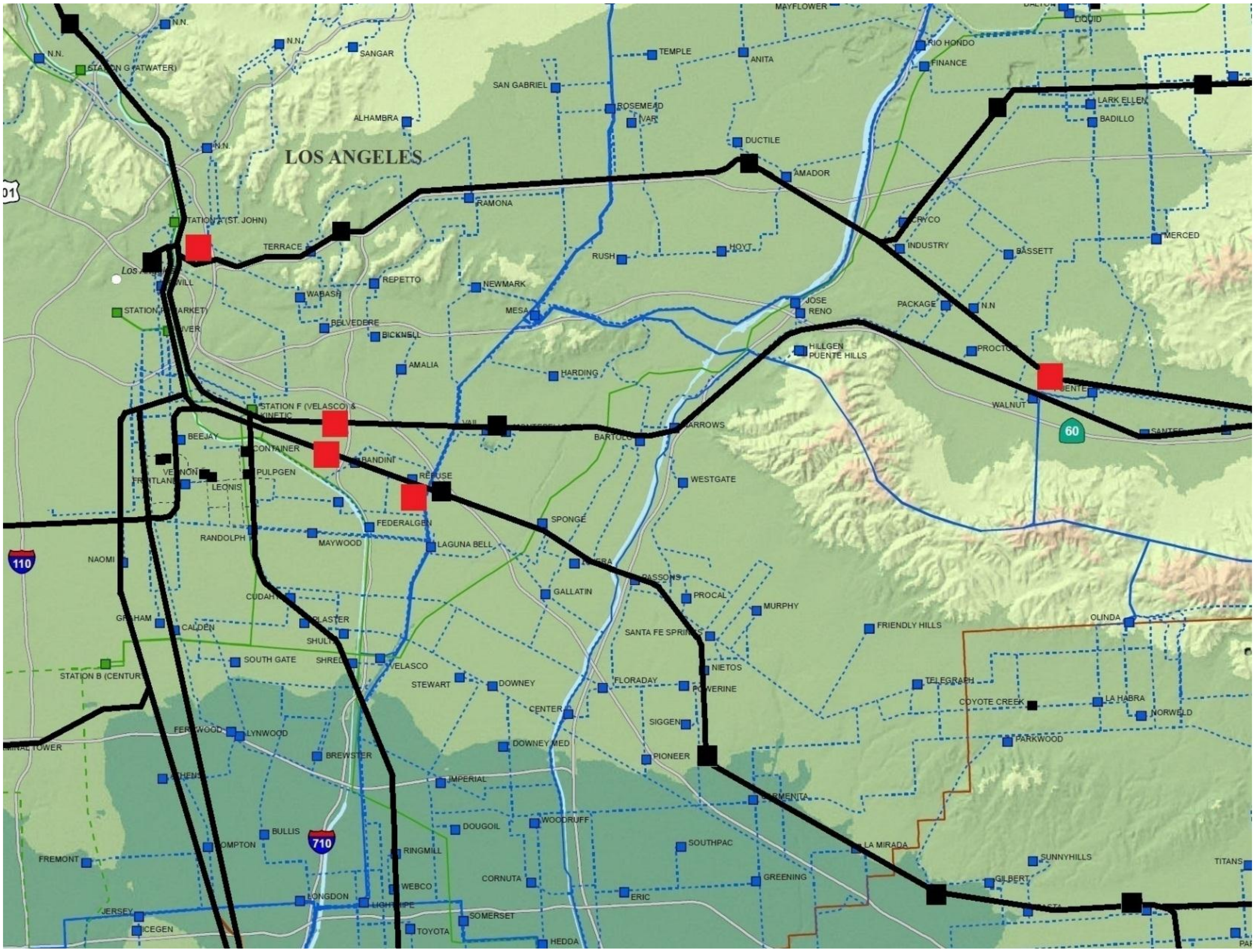
Electric utilities must be involved in planning for rail electrification from the outset. It is the electric utilities who will provide the electric energy, build up new substation infrastructure to service electrified track, and any new distribution and transmission lines. While there would be a need to construct new electric power infrastructure to serve electrified freight rail lines, electric utilities could see the new loads from freight trains as a business opportunity. In fact, the region’s utilities are concerned about losing revenue from more and more customers, particularly large industrial and institutional ones, investing in distributed self-generation projects such as rooftop solar. Utilities also would benefit from being able to transmit or distribute power via rail rights-of-way. Existing transmission and distribution grid infrastructure in the Los Angeles area tends to be in industrial areas and alongside rail lines, and could be used to service electrified track, as shown on the three maps below.



Selected heavy rail corridors, passenger stations and freight yards in the Los Angeles basin, overlaid on map of existing electric utility transmission lines and substations.
Background map: California Energy Commission



Selected heavy rail corridors and freight yards (red squares)- San Pedro Bay harbor area, overlaid on map of existing electric utility transmission lines and substations.
Background map: California Energy Commission



Selected heavy rail corridors, passenger stations (black squares) and freight yards (red squares)- central Los Angeles and east, overlaid on map of existing electric utility transmission lines and substations.
Background map: California Energy Commission

The 2016 CARB RailTEC report estimated that UP and BNSF locomotives operating in the South Coast Air Basin, about 130 line-haul freight trains per day, currently consume the equivalent of 435,000 MWh/year, or about 50 MW average load[20]. The 2016 CARB studies estimated that powering all line-haul freight locomotives with electricity would require just over 400,000 MWh of electricity per year (45 MW average load) at present rail traffic levels, and 1,000,000

[20] *Transitioning to a Zero or Near-Zero Emission Line-Haul Freight Rail System in California Operational and Economic Considerations, Final Report.* Prepared for State of California Air Resources Board by University of Illinois at Urbana-Champaign Rail Transportation and Engineering Center (RailTEC), Spring 2016, pg. 48.
https://www.arb.ca.gov/railyard/docs/uoi_rpt_06222016.pdf

MWh/year by 2050 (114 MW average load)[21]. This amount of electricity consumption was described as a major disadvantage[22]:

> To meet future freight electrification power demands in the South Coast Air Basin of up to one million MWh by 2050, five 50 MW power plants would be required (assuming those plants operate at 50 percent of capacity on an annual basis).
>
> Finally, it would be critical to build the electricity generating power plants as close to the freight rail operations as possible. The further away the electricity is generated from the rail operations, significant electricity transmission losses can occur, reducing the overall efficiency of the system. Therefore, with transmission losses from electricity generated from power plants outside the South Coast Air Basin or California, more power plants may need to be built.
>
> Current freight diesel-electric freight locomotives can achieve efficiency levels about 40 percent or more. Significant electrical transmission losses, and the use of non-renewable power sources like coal, could reduce the overall efficiency of the rail electrification system to less than 30 percent. This loss in efficiency could potentially offset any gains from fuel savings.

The authors of the 2016 CARB freight locomotive report provide no estimates of transmission losses, or their costs. Such power transmission losses are typically around 5%, and are not currently considered a significant problem for new natural gas and renewable generation projects, across Southern California region and neighboring states, to serve the LA basin electricity market. Also, the choice of five 50 MW power plants of 50% capacity factor, of unspecified type, seems to have been chosen arbitrarily as a source of 1,000,000 MWh/year, or 1 TWh/year. However, 1 TWh a year is well under 1% of the present-day annual consumption of the combined SCE & LADWP service areas. While 1 TWh is not an insignificant amount of energy, it could easily be accommodated in the Southern California grid with advanced planning, and sourced from renewable energy instead of fossil-fuel generating plants. Even fossil fuel power generating plants, with the possible exception of coal, are cleaner than mobile diesel-fueled sources such as locomotive engines. Also, the power for electric locomotives can come from zero-emissions sources, including geothermal power, hydroelectric power, nuclear power, solar power and wind turbines. The authors of CARB 2016 report mention coal as an energy source, which is rapidly being phased out by utilities in Southern California. The authors also provide no analysis of how overall energy efficiency of a rail electrification system could be as low as 30%.

The projected future loads from electric freight trains needs to be put in perspective of the greater Los Angeles region's overall future electricity scenario. Table 3 below shows the California Energy Commission's projected electric energy demand, by selected sector, for the designated utility planning areas of Southern California Edison (SCE), which also includes municipal utilities surrounded by SCE's service area, and that of the Los Angeles Department of Water and Power (LADWP). As can be seen in Table 3, the present combined industrial annual electricity demand for the SCE and LADWP planning areas of 24 TWh is projected to stay flat or increase only slightly by 2026. The utilities would likely treat electrified freight rail as a large industrial load. The utilities are already planning for electric vehicle demand, not including electric rail, which is projected to increase to 4 TWh/year by 2026 in the combined SCE and LADWP planning areas. In fact, electric transportation (automobiles and rail) is the only load type that California utilities expect to increase significantly, as energy efficiency and customer self-generation is expected to slow the growth of electric utility load for most other uses.

[21] *Draft Technology Assessment: Freight Locomotives.* California Environmental Protection Agency, Air Resources Board, Transportation and Toxics Division, April 2016, pg. VIII-6.
https://www.arb.ca.gov/msprog/tech/techreport/freight_locomotives_tech_report.pdf

[22] Ibid., pg. VIII-7.

Table 3: Present and projected 2026 electric energy demand in SCE and LADWP utility planning areas[23]

Designated utility planning area	2015 estimated annual total electricity demand (TWh)	2015 estimated annual industrial electricity demand (TWh)	2026 Maximum projected annual total electricity demand (TWh)	2026 Maximum projected annual electricity savings from energy-efficiency programs (TWh)	2026 Maximum projected annual electricity consumption from non-rail electric vehicles (TWh)
SCE	110	20	122	32	3
LADWP	25	4	28	8	1
Total SCE + LADWP	135	24	150	40	4

Both LADWP and SCE have goals of meeting 33% of total electric energy demand from renewables by 2020, and 50% by 2030, reflecting the state of California's goal as a whole. LADWP has pledged to completely phase out coal-generated electricity by 2025. In 2015, over 15 TWh of solar electricity was consumed in California, while wind and geothermal each contributed about 12 TWh.[24] As a comparison, the total solar, wind and geothermal share of the state's 2015 electricity demand, 39 TWh, is nearly *forty times* the 2050 projected freight rail electric energy consumption for the South Coast Air Basin described by the 2016 CARB studies. The share of renewable energy in the state's electricity mix is growing rapidly. California leads the nation in solar energy development, with an installed electric generating capacity of 12,000 MW as of mid-2016. More than 20,000 MW of solar energy capacity is in various stages of development in the state. A typical solar power plant has an overall capacity factor of 20%. In theory, this would indicate that about 570 MW of solar power generation capacity would be needed to produce 1 TWh of annual electric energy.

Energy storage, as well as SCE and LADWP's self-generation incentive programs, are also changing their utility business model. In the SCE planning area, the peak output of customer self-generation by solar photovoltaic (PV) sources is projected to increase to as much as 2,500 MW by 2026, and as much as 1,300 MW for non-PV sources[25]. In the LADWP planning area, the peak output of customer self-generation by PV sources is projected to increase to as much as 340 MW by 2026, and as much as 240 MW for non-PV sources[26]. California's largest utilities are also now required to procure progressively larger amounts of energy storage capacity in the years ahead. Energy storage connected to electric rail catenary, and trackside charging systems for locomotives with batteries, could be located at passenger train stations and along freight railroads. These rail energy storage systems could be a new business opportunity for electric utilities. Under utility control, these distributed energy storage systems could be charged at off-peak hours, provide power to the local distribution grid during periods of peak demand, and provide ancillary services such as voltage and frequency support, reactive power, or aid integration of distributed solar energy systems

[23] *California Energy Demand 2016-2026 Revised Electricity Demand Forecast, Volume 2: Electricity Demand by Utility Planning Area*, California Energy Commission, January 2016: http://docketpublic.energy.ca.gov/PublicDocuments/15-IEPR-03/TN207438_20160115T152222_California_Energy_Demand_20162026_Revised_Electricity_Demand_Fo.pdf

[24] California Energy Commission, California Electrical Energy Generation statistics page: http://www.energy.ca.gov/almanac/electricity_data/electricity_generation.html

[25] Ibid., pg. 43.

[26] Ibid., pg. 108.

Regenerative braking-

Significant among the benefits of electric locomotives on mountain grades, such as the Cajon Pass north of San Bernardino, is regeneration of power from braking. This recovered power can be used to power other trains nearby on the same line, or be fed back to the power grid via bi-directional substations. There are potential benefits to utilities from electric rail regenerative braking. From a utility perspective, an electric locomotive feeding power back to the grid would basically be serving as distributed generation source. SCE and LADWP not only have much experience serving the expanding network of passenger electric rail lines, but are already investigating harvesting energy fed back into the grid from the regenerative breaking of electric transit trains.

For several years, the Los Angeles Metropolitan Transit Authority (Metro) has been testing both on-board energy storage systems, and wayside energy storage systems (WESS), to store energy produced by regenerative braking of subway trains[27]. At Metro's Westlake/MacArthur Park subway station, a 2 MW VYCON flywheel WESS system was installed in April 2014[28] . Metro's electric rail transit vehicles are DC-powered, with relatively low voltages, making feeding regenerated power back to the grid more difficult. Electric freight locomotives would use much higher voltage AC power, reducing line losses. The feeding of power back to the grid from an electric locomotive's regenerative braking dates back to at least 1909, on the first AC-powered electric trains on the Great Northern Railway in the Washington Cascades. Despite these facts, the CARB 2016 RailTEC report was largely dismissive of regenerative braking[29]:

> Like the battery tender concept, regenerative braking offers the potential to further decrease electrical energy consumption and source emissions. The catenary traction power distribution system can be used to transfer energy from electric locomotives in dynamic braking to electric locomotives on other trains that are consuming traction power. Unlike the battery tender concept, however, the regenerated energy cannot be stored. Regenerated power can only be used if there is a nearby train in the same power district to absorb the energy. In Europe, where mainline electrification is common and short passenger trains tend to operate on more frequent headways, train schedules are carefully choreographed to maximize use of regenerated energy (van der Meulen, 2013). Obtaining similar levels of regeneration within the study area is likely to be difficult due to the longer headways between heavy freight trains and the greater schedule flexibility of freight train operations. Due to the substantial daily variation in freight train operating patterns, this study does not consider regeneration in its evaluation of electrification.

It is simply not true that a train's regenerated energy cannot be stored, as WESS systems under development around the world are proving. In addition, a number of electric transit vehicles in use around the world store energy from regenerative braking with on-board batteries and capacitors. WESS installations could be coupled with smart inverters that could benefit electric utility operations, as described above. The value of regenerated energy, to not only reduce train energy consumption, but also to be of value to the power grid as a whole, must be studied for Southern California rail electrification.

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[27] Los Angeles County Metropolitan Transportation Authority (METRO), *Sustainable Rail Plan*, May 2013, pgs. 10-17: http://media.metro.net/about_us/sustainability/images/sustainable_rail_plan_final_clean_submitted.pdf

[28] "LA Metro VYCON WESS system saving energy", *Railway Age*, November 4, 2014: http://www.railwayage.com/index.php/passenger/rapid-transit/la-metro-vycon-wess-system-saving-energy.html?channel

[29] *Transitioning to a Zero or Near-Zero Emission Line-Haul Freight Rail System in California Operational and Economic Considerations, Final Report.* Prepared for State of California Air Resources Board by University of Illinois at Urbana-Champaign Rail Transportation and Engineering Center (RailTEC), Spring 2016, pg. 19: https://www.arb.ca.gov/railyard/docs/uoi_rpt_06222016.pdf

Strategies for financing rail electrification in Southern California-

The capital cost of electric catenary infrastructure is the number one reason that U.S. freight rail railroads have resisted electrification. The large amounts of capital required for installing catenary wire over track, could otherwise be spent by a railroad company in investing in other capital projects that would expand capacity. To avoid these opportunity costs, capital should ideally originate from sources outside the railroad companies.

Because of the substantial public benefit to be realized by modernizing and electrifying major rail corridors, it makes sense for the public to partner with private railroads to make these improvements financially feasible. Railroads in other industrialized nations have been able to make the investments because they are publicly owned. Electric catenary infrastructure could also be publicly financed and owned, while the existing track will remain privately owned by the railroad companies. A variety of financing mechanisms and public-private partnerships should be studied.

The Alameda Corridor Transportation Authority (ACTA) and other local government agencies in Southern California could collaborate to fund and own rail electrification infrastructure. A regional electrification effort could expand upon the existing ACTA model of a mixture of revenue bonds and federally-backed loans, similar the ongoing 'Alameda Corridor East' improvement projects[30] on Union Pacific tracks in the San Gabriel Valley.

The 1992 Southern California rail electrification study proposed three different funding scenarios for passenger and freight rail electrification in the region, involving the Southern California Regional Rail Authority (SCRRA) and the electric utility SCE[31]:

SCENARIO ONE: 100% Rate Based: SCE Customer Paid

SCENARIO TWO: 40% Rate Based: SCE Customer Paid

SCENARIO THREE: 40% Rate Based: SCRRA PAID

Scenarios Two and Three allocate funding shares as follows:

• 40% SCE: Rate Based

• 30% State and Federal Funding

• 10% Local Transportation Agencies: Cash Contribution

• 10% Local Municipality/JPA Financed: SCRRA Funded

• 10% Freight Railroad Participation.

The Solutionary Rail campaign has proposed a Steel Interstate Development Authority (SIDA) infrastructure bank, a nonprofit corporation financed with low-interest, government-subsidized loans to fund electrification along a rail corridor that traverses multiple cities, counties or states. It would be chartered with the authority to raise funds for electrified rail infrastructure investment on both publicly and privately owned rights of way, and take advantage of lower cost of capital available through public financing. Under this scenario, funds would be raised from private markets

[30] http://www.theaceproject.org/

[31] *Southern California Accelerated Rail Electrification Program, Draft Executive Summary.* Prepared for Southern California Regional Rail Authority, February 10, 1992, pg. ES-22: http://libraryarchives.metro.net/DPGTL/Metrolink/1992-ExecSummary-SoCal-Accelerated-Rail-Electrification.pdf

and federal loan funds. The system would be self-financing through user fees paid by railroads drawing energy from the lines and utilities transmitting electricity. Electrification infrastructure would be publicly owned, overcoming the property tax disadvantage railroads face. The electrification could be operated on a leased basis by utilities already familiar with such systems. The SIDA would negotiate with right-of-way owners to site infrastructure, and the same owners would make commitments to use it.

Electrification of interstate line-haul freight lines originating in Southern California (BNSF Southern Transcon and UP Sunset Route)-

For long-haul freight rail, taking a multi-state corridor approach to electrification could help avoid the 'mode shift' costs and delays of locomotive exchanges needed for 'captive California electric fleet' approach. The Spring 2016 RailTEC report to the California Air Resources Board describes this corridor approach:[32]

> 3.3.4 Regional versus Corridor-based Fleets
>
> A 2014 report [by the National Cooperative Freight Research Program] addressing sustainability strategies and air emissions of supply chains acknowledged that rail freight transportation in the United States is likely to cross multiple jurisdictions each with the ability to set their own air quality regulations (NCFRP, 2014). The report indicated that supply chain efficiency issues can arise where there are differences in the air emissions standards and the regulations applied between geographies. Dual standards or regulations can increase manufacturer costs and risks, and may cause difficulties for rail carriers. The report suggested that a corridor-based approach to freight transportation air emissions management can provide an effective way of planning, financing, and regulating freight movement. Consistent approaches allow optimal supply chain operations, keeping costs down, and maintaining certainty. The EU Green Freight Corridors concept is an example of this approach (NCFRP, 2014). Instead of regional regulations, the EU applies certain efficiency targets on specific cross-jurisdictional corridors with concentrations of freight traffic moving between major hubs. In terms of mainline freight railway emissions in California, instead of applying new locomotive technology to all trains traversing the air basin, the corridor-based approach would apply new locomotive technology to a select number of long-distance trains operating between major terminals on a particular corridor. While such an approach would alleviate the need for locomotive exchanges, the emission benefit would be global in scale along the entire route and not concentrated in the South Coast basin.

The Southern Transcon is the main line of the BNSF Railway between Los Angeles and Chicago. Almost entirely double-tracked for its 2,200 miles, the route traverses California, Arizona, New Mexico, Texas, Oklahoma, Kansas, Missouri, Iowa and Illinois. UP's Sunset Corridor runs about 800 miles from Los Angeles to El Paso, Texas across California, Arizona and New Mexico. For BNSF, electrification from Los Angeles to its major yard at Clovis, about 1,000 track miles east from Los Angeles would a logical 'halfway mark' to electrifying to Chicago. For UP, electrifying from Los Angeles to its major El Paso yard would be a halfway step for 'coast-to-coast' electrification.

[32] *Transitioning to a Zero or Near-Zero Emission Line-Haul Freight Rail System in California: Operational and Economic Considerations, Final Report.* Prepared for State of California Air Resources Board by University of Illinois at Urbana-Champaign Rail Transportation and Engineering Center (RailTEC), Spring 2016. https://www.arb.ca.gov/railyard/docs/uoi_rpt_06222016.pdf

Short Shuttle Service between the Ports and Inland Empire

In addition to electrification, the railroad lines of Southern California could be configured to accommodate fast, frequent short-haul freight trains, sharing tracks with passenger and the bulk line-haul trains. New types of rail freight service must be explored for the region. There are a number of European innovations in intermodal rail freight which could serve as an example for California. These include fast, more nimble, freight trains designed to be competitive with highway trucking for distances less than 500 miles. Many major ports around the world, including several in the U.S., have dedicated short-haul rail service from the docks to special long-haul freight railroad yards known as 'inland ports'.

Increased road congestion around the Ports of Los Angeles and Long Beach has increased interest in short-haul freight rail service to the Inland Empire, which previous studies (the most recent being 2008) had concluded to be uneconomic. According to the 2008 Inland Port Feasibility Study for SCAG, there were at the time about 3,500 daily truck trips between the Ports and Riverside and San Bernardino Countries combined. Two daily round trip intermodal trains could divert a maximum of about 35% of these trips. Regional truck vehicle miles travelled (VMT) was predicted to decline, but truck VMT within the Central Inland Empire was predicted to increase. There was predicted to be a noticeable increase in truck traffic in the immediate vicinity of the inland port terminal[33]. The inland terminal locations studied included Mira Loma, Ontario and Victorville. From the ports, shippers have historically found that trucking containers to the Inland Empire for transloading from 40 foot international containers to 53 foot domestic containers to be cheaper than paying the fee to use the Alameda Corridor. However, this is changing with increasing highway congestion.

In addition to investing in more on-dock rail access, the Ports of Long Beach and Los Angeles announced in late 2015 that they were launching a joint feasibility study of short-haul rail service to move containers from the ports to a cluster of new intermodal distribution facilities located in the Inland Empire[34]. The study is motivated by the need to reduce truck congestion at the ports by shifting of more freight from truck to rail[35]:

> The concept has been studied periodically over the past two decades, but the economics always fell short and the logistical challenges could not be overcome. However, growing port congestion the past two years, increased drayage costs and a desire by beneficial cargo owners in Southern California's Inland Empire to avoid sending their truckers to the harbor offer financial encouragement. Shippers in the Inland Empire will have the advantage of sending their trucks only a short distance to the new rail hub rather than all the way to the harbor and back.
>
> The key to success may be held by the importers that operate warehouses in the sprawling Inland Empire east of Los Angeles who would ultimately pay for the service through their freight rates. Husing has been talking to the shippers, and he said they are "quite enthused." Warehouses in the Inland Empire would significantly reduce the distance trucks would have to travel if a short-haul service was established there from the ports. Also, there are a number of shippers with operations in Phoenix and Las Vegas that would be much happier sending their trucks to the Inland Empire rather than to the harbor, Husing said.

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[33] *Inland Port Feasibility Study, Project No. 06-023 Final Report*, Prepared by the Tioga Group Inc., Railroad Industries, Inc. and Iteris for the Southern California Association of Governments, August 2008, pg. 1: http://tiogagroup.com/docs/Tioga_Grp_SCAGInlandPortReport.pdf

[34] "LA-LB ports revisit short-haul rail to beat congestion", *Journal of Commerce*, December 22, 2015: http://www.joc.com/port-news/us-ports/port-los-angeles/la-lb-ports-revisit-short-haul-rail-beat-congestion_20151222.html

[35] "Shippers await short-haul rail option to LA-LB ports", *Journal of Commerce*, April 27, 2016: http://www.joc.com/rail-intermodal/shippers-await-short-haul-rail-option-la-lb-ports_20160427.html

> …developing short-haul rail in Southern California will require support from the UP and BNSF railroads, which own the tracks and much of the rolling stock and equipment in the region. The railroads could work out an agreement with Pacific Harbor Line, which performs switching in the harbor on behalf of the railroads, to pull the trains to the Inland Empire, but that would be a new venture for PHL in its relationship with UP and BNSF.
>
> UP spokesperson Justin Jacobs said the railroad is in early discussions with the various parties about opportunities that exist for on-dock and short-haul rail at the ports, but any project that moves forward must “make sense from a commercial and business perspective.” BNSF spokesperson Lena Kent noted that historically there has not been a compelling business case for a short-haul rail service to the Inland Empire. Therefore, BNSF has concentrated its efforts on attempting to secure environmental clearance for construction of its proposed near-dock Southern California International Gateway five miles from the harbor, which would provide sufficient staging acreage for trains that cannot be built on dock. However, a California court recently found the SCIG environmental impact report to be inadequate, so the future of the near-dock facility isuncertain.

There is a great need to evaluate the market demand of beneficial cargo owners and shippers in the Inland Empire for short-haul container rail service from the ports, who would see an economic benefit by avoiding losses from highway congestion. There is also a need to carefully evaluate localized VMT impacts of a new Inland Port located in the Inland Empire, so that truck traffic and its resulting pollution is not merely shifted from the port area to a new location. The 2008 SCAG study identified some necessary implementing steps for an inland port/rail shuttle system, each with significant barriers to overcome[36]:

> *Target Markets*- The primary near-term market identified in the 2008 study is the Mira Loma area in the Inland Empire, due the large number of existing distribution and transshipment facilities in the area which receive cargo trucked from the Ports. The Barstow and Victorville markets are developing and would likely be candidates for future logistics parks served by inland ports.
>
> *Chose and Secure Terminal Sites*- The study identified a small number of candidate sites for Inland Empire terminals serving Mira Loma, as well as the Southern California Logistics Airport in Victorville and an open area west of the BNSF yard in Barstow. Locating new intermodal facilities in populated areas have proven to be extremely difficult for freight railroads, due to local community opposition over pollution, traffic and noise concerns.
>
> *Provide Port-Area Rail Capacity*- Substantial improvements to the port-area rail network would be required.
>
> *Rail Service Agreement*- The railroad(s) would agree to operate a fixed schedule of rail shuttle trains, or allow a contractor to do so, in return for operating payments and capacity funding. This arrangement would be similar to existing agreements with Amtrak and Metrolink passenger rail in the region.

In the history of Inland Port developments, most project failures have been market failures, so there is a need to make a realistic appraisal of the regional shipping market and purpose[37]. Success for private rail companies, shippers and distribution companies is necessary for public goals of a cleaner, more efficient freight transportation system.

[36] *Inland Port Feasibility Study, Project No. 06-023 Final Report*, Prepared by the Tioga Group Inc., Railroad Industries, Inc. and Iteris for the Southern California Association of Governments, August 2008, pg. 2: http://tiogagroup.com/docs/Tioga_Grp_SCAGInlandPortReport.pdf

[37] Ibid.

Electrification of short-haul freight rail from the Ports of Long Beach and Los Angeles to the Inland Empire-

The economic feasibility of Port-to-Inland Empire short haul freight rail service is beyond the scope of this paper, but if such a service proves to be economically viable it would be a logical first phase of freight rail electrification. All-electric locomotives dedicated to the short-haul service could go back and forth along 80 miles or so of electrified track between San Pedro Bay and San Bernardino, with while conventional non-electric line-haul freight trains could continue to use the same tracks. Electrified freight shuttles could also utilize the same overhead catenary used by electric passenger trains.

The 2012 SCAG report proposed three phases of freight rail electrification in the region[38]:

- Phase 1: Alameda Corridor, electrification from the ICTF (UP) yard, located just north of the port, to LATC (UP) and Hobart (BNSF) yards east of downtown LA.
- Phase 2: LATC to West Colton yard (UP), Hobart to San Bernardino (BNSF).
- Phase 3: Ports to Barstow/Indio/Chatsworth/San Fernando

If “deep inland” undeveloped desert areas near Barstow or Indio turn out to be the only available Inland Port sites, this could justify an initial rail electrification effort encompassing all three phases listed above.

Electric trucks and electric trains, both serving an ‘all-electric’ intermodal facility or Inland Port-

A new intermodal facility, such as BNSF’s proposed Southern California International Gateway (SCIG) project, or a proposed Inland Port that could be served by short haul rail, could be all-electric, utilizing both electric trucks and electric trains. The local community and environmental opposition to the SCIG or Inland Port site could be mitigated if the facility would be required to utilize a significant fraction, or even entirely, all-electric trucks and all-electric shuttle and long-haul freight trains. Perhaps a solution to the current SCIG impasse could be found in the form of a 21st century intermodal facility based entirely on electrified modes of transport- both trains and trucks. The several miles between the port docks and the proposed SCIG site in Wilmington would be easily managed by battery-powered electric container drayage trucks that exist today. BNSF has already started testing electric trucks at its Southern California intermodal facilities.

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[38] *Task 8.3: Analysis of Freight Rail Electrification in the SCAG Region (Final Technical Memorandum)*, prepared by Cambridge Systematics, Inc. for Southern California Association of Governments, April 2012, pgs. 3-1 to 3-6. http://www.freightworks.org/DocumentLibrary/CRGMSAIS%20-%20Analysis%20of%20Freight%20Rail%20Electrification%20in%20the%20SCAG%20Region.pdf

References

California Environmental Protection Agency, Air Resources Board, Transportation and Toxics Division, *Recent studies concerning freight rail electrification in Southern California: Draft Technology Assessment: Freight Locomotives,* April 2016:
https://www.arb.ca.gov/msprog/tech/techreport/freight_locomotives_tech_report.pdf

University of Illinois at Urbana-Champaign Rail Transportation and Engineering Center (RailTEC) for the State of California Air Resources Board, *Transitioning to a Zero or Near-Zero Emission Line-Haul Freight Rail System in California Operational and Economic Considerations, Final Report.* Spring 2016.
https://www.arb.ca.gov/railyard/docs/uoi_rpt_06222016.pdf

California Energy Commission, *California Energy Demand 2016-2026 Revised Electricity Demand Forecast, Volume 2: Electricity Demand by Utility Planning Area*, January 2016: http://docketpublic.energy.ca.gov/PublicDocuments/15-IEPR-03/TN207438_20160115T152222_California_Energy_Demand_20162026_Revised_Electricity_Demand_Fo.pdf

Cambridge Systematics, Inc. for Southern California Association of Governments, *Task 8.3: Analysis of Freight Rail Electrification in the SCAG Region (Final Technical Memorandum)*, April 2012:
http://www.freightworks.org/DocumentLibrary/CRGMSAIS%20-%20Analysis%20of%20Freight%20Rail%20Electrification%20in%20the%20SCAG%20Region.pdf

Kenneth James, *Evaluating the Feasibility of Electrified Rail at the Port of LA/LB*, College of Engineering, California State University Long Beach. for METRANS Project 07-323306, June 2011.

Los Angeles County Metropolitan Transportation Authority (METRO), *Sustainable Rail Plan*, May 2013:
http://media.metro.net/about_us/sustainability/images/sustainable_rail_plan_final_clean_submitted.pdf

Bill Moyer, Patrick Mazza and the Solutionary Rail team (http://www.solutionaryrail.org/). *Solutionary Rail: A people-powered campaign to electrify America's railroads and open corridors for a clean energy future,* October 2016.

Electrifying the Alameda Corridor, Issue Briefer, prepared for the Natural Resources Defense Council by Marissa Blunschi, Noah Verleun, Tamim Ayuby, and Edward Ng, July 2011:
http://priceschool.usc.edu/files/enews/july11/NRDC_Briefer.pdf

Tioga Group Inc., Railroad Industries, Inc. and Iteris for the Southern California Association of Governments, *Inland Port Feasibility Study, Project No. 06-023 Final Report*, August 2008:
http://tiogagroup.com/docs/Tioga_Grp_SCAGInlandPortReport.pdf

"LA-LB ports revisit short-haul rail to beat congestion", *Journal of Commerce*, December 22, 2015:
http://www.joc.com/port-news/us-ports/port-los-angeles/la-lb-ports-revisit-short-haul-rail-beat-congestion_20151222.html

"Shippers await short-haul rail option to LA-LB ports", *Journal of Commerce*, April 27, 2016:
http://www.joc.com/rail-intermodal/shippers-await-short-haul-rail-option-la-lb-ports_20160427.html

Could Short-Haul Rail Speed Up the Supply Chain?", Port of Long Beach press release, April 4, 2016:
http://www.polb.com/news/displaynews.asp?NewsID=1542

Southern California Regional Rail Authority, *Southern California Accelerated Rail Electrification Program, Draft Executive Summary*, February 10, 1992:
http://libraryarchives.metro.net/DPGTL/Metrolink/1992-ExecSummary-SoCal-Accelerated-Rail-Electrification.pdf

California High Speed Rail Authority, Los Angeles to Anaheim Section reports:
http://www.hsr.ca.gov/Programs/Statewide_Rail_Modernization/Project_Sections/losangeles_anaheim.html

URS and Cambridge Systematics, *Technical Memorandum- I-710 Railroad Goods Movement Study*. Prepared for Los Angeles County Metropolitan Transportation Authority, February 3, 2009:
http://media.metro.net/projects_studies/I710/images/710_dr_rgms.pdf