

# The Need for Freight Rail Electrification in Southern California

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May 13, 2018

## Executive Summary

Full electrification of freight trains is the only proven zero-emissions freight railroad technology. Electric rail propulsion can take several different forms, including locomotives powered by overhead catenary wire, on-board batteries, or more advanced concepts such as battery tender cars and linear synchronous motors. This white paper is largely a literature review of previous studies on electric freight rail in the Southern California region, with information compiled about existing electric freight rail locomotives and systems from around the world.

The two main benefits of freight rail electrification in the region would be reduced air pollution, and reduced consumption of diesel fuel for transportation. Electrification of freight rail in Southern California would reduce the public health impacts to local communities affected by diesel-powered freight transportation, and reduce greenhouse gas emissions of freight movement.

The main challenge for electric freight rail is the high capital costs of electric rail infrastructure, especially the overhead catenary wire over tracks. A variety of options for public and/or private financing of freight rail electrification need to be explored.

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 through the Alameda Corridor. Co-utilization of electric rail infrastructure planned for the California High Speed Rail project should also be studied.

To successfully fund and implement an electric rail network in Southern California, a cooperative partnership must be forged between the freight carriers (UP, BNSF, Pacific Harbor Line, trucking companies), transportation industry trade associations, locomotive and electrical manufacturers, electric utilities, community organizations, environmental and public health public advocacy groups, along with local businesses and labor unions. Electric utilities would benefit from the new business opportunity of supplying power to electrified rail corridors, as well as benefit from new electric transmission line routes and energy storage systems developed for railroads.

The last time that a regional, comprehensive rail electrification task force existed was in the early 1990s for the 1992 *Southern California Accelerated Rail Electrification Program* study. Such a regional task force should be created again, with committees for planning, engineering, analysis, operations & maintenance, environmental analysis, legislative funding, and regulatory requirements.

## Acknowledgements

Special thanks to Dave Cook (Rail Propulsion Systems) and Raphael Isaac (Ph. D. candidate at the UC Davis Institute of Transportation Studies) for their review and comments on the drafts of this white paper.

## 1. Introduction

There is a great need to electrify freight railroads in the United States. Railroad electrification is a proven form of zero-emissions freight transportation, and can take a variety of forms. The most established way to run trains on electricity is by overhead catenary wires over railroad tracks supplying power to the moving train's pantograph. 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 at point of use.
- More energy efficient than diesel-electric locomotives, and consume almost no power when idling.
- Capable of using regenerative braking 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.
- Quieter and lower maintenance than diesel 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.

Due to the unfamiliarity in the U.S. with electric freight rail, this technology is too often overlooked as a solution to many of the country's transportation needs, despite its proven track record of success in the rest of the world. Southern California should be a national leader in freight rail electrification due to its need to reduce air pollution, and strong longtime local political support for clean transportation technologies. The region once had an extensive electric rail network of passenger street car and interurban transit during the first half of the 20<sup>th</sup> century, and today has a rapidly growing network of all-electric subway and light rail lines. In the past three decades, 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 and without 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
- Paired diesel locomotives with all-electric locomotives (dual power trains)
- PEM fuel cell (PEMFC)/battery hybrid
- Solid Oxide fuel cell-gas turbine (SOFC-GT) hybrid

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

The San Pedro Bay Ports (Los Angeles and Long Beach) adopted their first Clean Air Action Plan in 2006<sup>1</sup>, and the Zero-Emissions Freight Collaborative was formed by Los Angeles County in 2012. 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.<sup>2</sup> In the spring of 2016, CARB released two reports evaluating clean freight rail technology for California<sup>3</sup>. 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.

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<sup>1</sup> <http://www.cleanairactionplan.org/about-the-plan/>

<sup>2</sup> <http://www.casustainablefreight.org>

[http://www.casustainablefreight.org/files/managed/Document/289/CSFAP\\_FINAL\\_07272016.pdf](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>

<sup>3</sup> *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](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](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: what lines are the best candidates for electrification?
  - Viable strategies for funding the high upfront costs of electrification.
  - 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.
  - Evaluation of Inland Port sites, in the Inland Empire, or further inland sites in the Victorville and Barstow areas.
  - Legal/legislative/regulatory actions needed to support rail electrification.
  - Further questions that must be addressed by such a study:
    - Match the electrified-Inland Port model with regional objectives
    - Best ways for more freight to be shifted from truck to rail, and to reduce truck VMT and highway congestion
    - Environmental impact of short-haul freight rail and related intermodal freight facilities
    - Economic development opportunities of short-haul freight rail
    - 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. Such a research program would partner with organizations such as the American Association of Railroad's Transportation Technology Center in Colorado, the University of Illinois at Urbana-Champaign Rail Transportation and Engineering Center (RailTEC), and other research centers located in other countries experienced with electric heavy freight rail.
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 in section 6). If at first such a test site could not be built in California, new electric freight rail locomotives could be tested on the existing electric rail test tracks of the Transportation Technology Center near Pueblo, Colorado.
4. Selection of an initial freight rail corridor in Southern California to electrify.
5. 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).
6. Explore co-deployment of electrification along corridors shared with passenger service trains of Metrolink, Amtrak, and California High Speed Rail.

7. Phasing-in of all-electric operations with existing fleet of diesel-electric locomotives, and opportunities for dual-power, or ‘mixed-unit’ trains pulled by both all-electric and diesel electric power.
8. Negotiated agreements between railroads and electric utility companies, and thorough analysis of the economic value and benefits to electric utilities from railroad-hosted transmission line routes and energy storage capacity.

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), transportation industry trade associations, locomotive and electrical manufacturers, electric utilities and the government organizations listed below:

- Port of Los Angeles
- Port of Long Beach
- 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 State Transportation Agency
- California Air Resources Board
- California High Speed Rail Authority
- California Energy Commission
- California Public Utilities Commission
- Federal Railroad Administration

In addition, there is a need to build a broad base of support in the region for rail electrification from community organizations, environmental and public health public advocacy groups, along with local businesses, labor unions, trade associations and community activists. Local engineering, construction, and transit agency experience with electric rail transit could be applied to electrifying freight rail. Global and national experts in electric rail should also be invited to Southern California. A regional rail electrification task force was created in the early 1990s for the 1992 *Southern California Accelerated Rail Electrification Program* study, with committees for planning, engineering, analysis, operations & maintenance, environmental analysis, legal/legislative funding, alternative fuels, and regulatory applications<sup>4</sup>. Such a regional task force should be created again for the 21<sup>st</sup> century.

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<sup>4</sup> *Southern California Accelerated Rail Electrification Program, Draft Executive Summary*. Prepared for Southern California Regional Rail Authority, February 10, 1992, pgs. ES-1, ES-2:

<http://libraryarchives.metro.net/DPGTL/Metrolink/1992-ExecSummary-SoCal-Accelerated-Rail-Electrification.pdf>

## 2. Benefits of Freight Rail Electrification

### *Emissions benefits-*

Even with conventional diesel locomotives, emissions per ton are several times less by rail when compared to truck. With electrification, the emissions directly emitted by locomotives drops to zero. Given the choice, rail is always a cleaner way to move freight than by truck. For example, Southern California's busiest truck corridor (Interstate 710) produces ten times more emissions than the region's busiest rail corridor.

Historically, efforts to advance electrification and other clean transportation technologies in the region have been driven primarily by a desire to reduce local air pollution. Many populated areas in Southern California regularly do not meet federal air quality standards, especially those near freight movement sites such as ports, rail yards and warehouses. The huge amount of freight movement activity in the South Coast Air Basin (SCAB) results in a massive amount of emissions from diesel-powered trucks and trains. Diesel exhaust around the San Pedro Bay ports and the region's railroad yards and freight facilities has been linked to cancer, asthma and many other ailments, as well as contributing to premature death, in nearby communities. Emissions from port-related goods movement, including levels of NOx, SOx and diesel particulate matter (PM), have declined significantly in the past decade due to stricter regulation and introduction of cleaner diesel engines. However, the public health impacts in the region caused by port-related goods movement industry still contribute to thousands of premature deaths and billions of dollars in health care costs each year<sup>5</sup>. The area around the San Pedro Bay ports has even been dubbed the "diesel death zone". In the Inland Empire, a hub of goods movement, logistics and warehousing, residents of San Bernardino and Riverside counties continue to suffer from some of the highest particulate and ozone pollution levels in the U.S.

Switching from a freight rail system that relies on diesel power to one that relies on electric power will have a substantial impact on emissions in Southern California. According the 2016 RailTEC report, if all line-haul freight rail locomotives in the SCAB were all-electric (and all electricity used from zero-emissions sources), compared to using a fleet of 100% Tier 2 diesel locomotives, the annual emissions reductions possible would be as follows<sup>6</sup>:

- 372,000 tons CO<sub>2</sub>
- 3,750 tons NOx
- 1,000 tons CO
- 200 tons hydrocarbons (HC)
- 140 tons particulate matter (PM)

The above figures do not include the region's freight yard/switcher or passenger locomotives. However, over 80% of locomotive emissions in the South Coast Air Basin are from line-haul freight trains. In addition to reducing emissions of pollution with local public health impacts, electrifying freight rail will also help meet the state's goals for reducing

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<sup>5</sup> Port of Long Beach & Port of Los Angeles, *San Pedro Bay Ports Clean Air Action Plan 2017, Draft Final Clean Air Action Plan Update*, July 2017, pgs. 16-20:

<http://www.cleanairactionplan.org/documents/clean-air-action-plan-2017-draft-document-final.pdf>

<sup>6</sup> *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. 52. [https://www.arb.ca.gov/railyard/docs/uoi\\_rpt\\_06222016.pdf](https://www.arb.ca.gov/railyard/docs/uoi_rpt_06222016.pdf).

greenhouse gas (GHG) emissions. If more freight and passenger traffic is shifted from road to rail in the future, the emissions benefits of electric rail would be more significant.

It is worth noting how the emissions reductions of fully electric locomotives are superior to other low emissions technologies. The 2016 RailTEC report also concluded that Tier 4 diesel freight locomotives with after-treatment (the report's preferred alternative), would not reduce CO<sub>2</sub> or CO emissions in the region. Also, diesel-LNG locomotives would decrease CO<sub>2</sub> emissions, but increase CO emissions. Locomotives powered by LNG using solid oxide fuel cell (SOFCs)-gas turbine hybrid systems were estimated to reduce CO<sub>2</sub> emissions by 57%<sup>7</sup>.

#### *Energy savings benefits-*

On a per-ton basis, a double-stack container rail car pulled by a conventional diesel-electric locomotive moves freight three to five times more fuel efficiently than a truck<sup>8</sup>. The overall energy efficiency of diesel-electric locomotive, or the proportion of energy diesel fuel converted to useful motive power, is approximately less than 40%. However, U.S. freight railroads have substantially improved their overall energy efficiency in the past several decades. According the Association of American Railroads, U.S. freight railroads moved one ton of freight an average of 468 miles per gallon of diesel fuel, up from 235 miles in 1980<sup>9</sup>.

The overall per-ton energy efficiency advantage of rail more than doubles with an all-electric locomotive, which converts over 80% of the electric energy captured from the overhead catenary wire into useful motive power<sup>10</sup>. The annual 'at wheel' energy consumption of all line haul freight rail locomotives operating in the SCAB, pulling an average of 130 line-haul freight trains per day, is presently about 435,000 MWh<sup>11</sup>.

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<sup>7</sup>*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. xiii. [https://www.arb.ca.gov/railyard/docs/uoi\\_rpt\\_06222016.pdf](https://www.arb.ca.gov/railyard/docs/uoi_rpt_06222016.pdf).

<sup>8</sup> Federal Railroad Administration, *Comparative Evaluation of Rail and Truck Fuel Efficiency on Competitive Corridors*, November 2009, pg. 9: <https://www.fra.dot.gov/eLib/details/L04317> .

<sup>9</sup> Association of American Railroads, *The Environmental Benefits of Moving Freight by Rail*, June 2017: <https://www.aar.org/BackgroundPapers/Environmental%20Benefits%20of%20Moving%20Freight%20by%20Rail.pdf>

<sup>10</sup> RailTEC, Spring 2016, pg. 49. [https://www.arb.ca.gov/railyard/docs/uoi\\_rpt\\_06222016.pdf](https://www.arb.ca.gov/railyard/docs/uoi_rpt_06222016.pdf).

<sup>11</sup>Ibid., pg. 48 and pg. xiii. [https://www.arb.ca.gov/railyard/docs/uoi\\_rpt\\_06222016.pdf](https://www.arb.ca.gov/railyard/docs/uoi_rpt_06222016.pdf).

### 3. Freight Rail in Southern California

With its deep-water ports and extensive network of railways and highways, Southern California has long been one of the country's most important hubs for freight movement. In 2014, the San Pedro Bay Ports handled about \$400 billion of international trade. Moving freight efficiently is vital to the region's economy. The freight movement sector directly involves the transportation, warehousing, trade, manufacturing, construction, agriculture, mining and utilities industries. In 2014, industries related to freight movement represented \$740 billion, or 32% of gross state product, and about 5 million jobs<sup>12</sup>.

In Southern California, the industries of freight transportation and warehousing directly contribute over 300,000 jobs and about \$25 billion of gross regional product. Industries dependent on goods movement directly or indirectly represent nearly \$300 billion in gross regional product, and support about 3 million jobs<sup>13</sup>. Warehousing, distribution and logistics centers in Southern California boast about 1.2 billion square feet of storage space, representing 15% of the entire U.S. market, and 40% of the West coast market. Despite the status of Los Angeles as a global entertainment and media center, the regional economic importance of these industries is exceeded by those related to freight movement.

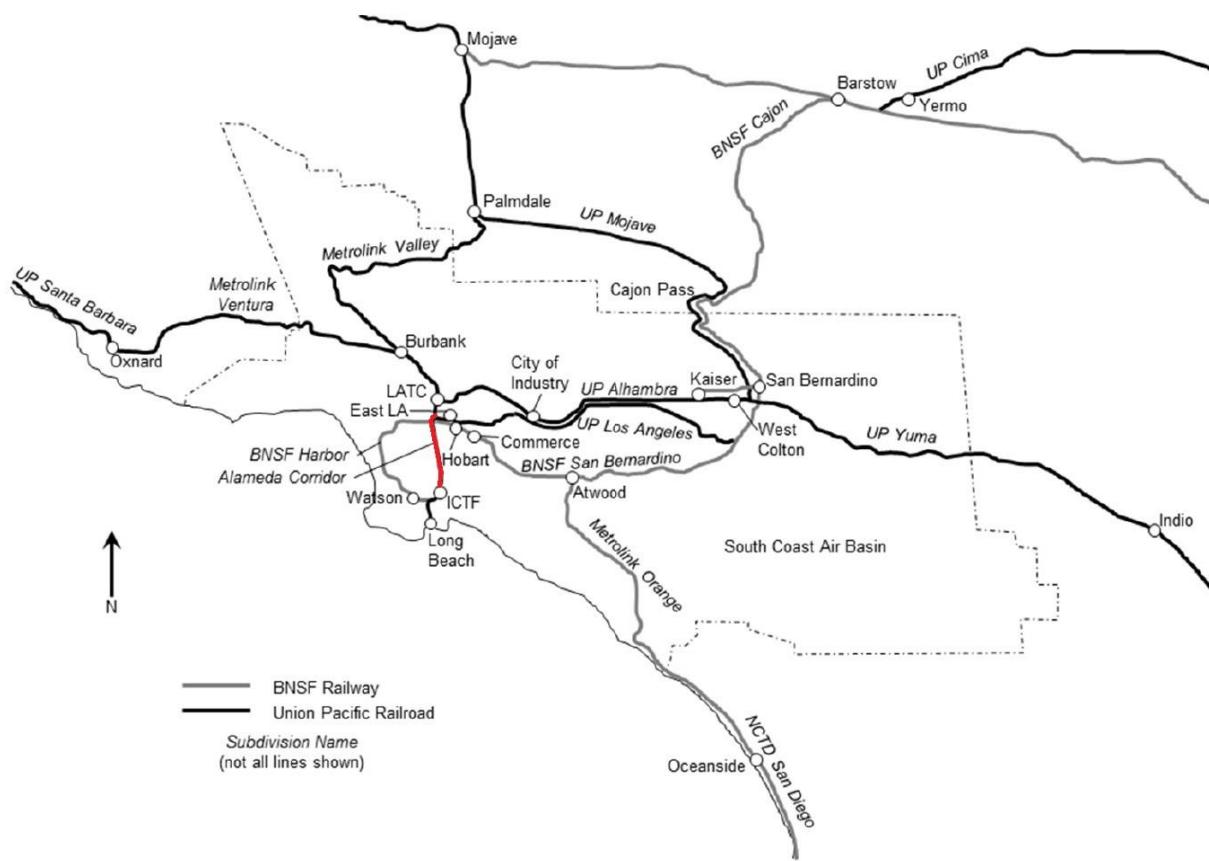
Manufacturing employs about 1.3 million in the state. While down from 2 million in 1980, this number is expected to stay at or above 1 million workers for the foreseeable future. The manufacturing industry is especially dependent on truck and rail transportation, and supports over 700,000 jobs in the Los Angeles-Inland Empire region alone. Southern California's manufacturing industry is heavily intertwined with international partners, especially in neighboring Mexico. Southern California's transport, warehousing and distribution infrastructure serves as a vital link between the large manufacturing industry of Baja California and the rest of North America.

The vast majority of California's rail freight traffic is carried by the two Class I railroads serving the state: Burlington Northern Santa Fe (BNSF) and Union Pacific (UP), which together operate about 130 line-haul freight trains each day in the SCAB. Trains originating or terminating in the South Coast Air Basin transport nearly 100 million tons of freight annually. A map of the region's major freight rail corridors, prepared for State of California Air Resources Board's 2016 zero-emissions rail report, is shown in Fig. 1 below.

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<sup>12</sup> State of California Employment Development Department, Labor Market Information by California Geographic Areas, <http://www.labormarketinfo.edd.ca.gov/geography/lmi-by-geography.html>, accessed March 21, 2016.

<sup>13</sup> Southern California Association of Governments, *2016-2040 Regional Transportation Plan/Sustainable Communities Strategy, Goods Movement Appendix*, April 2016, pg. 5:  
[http://www.freightworks.org/DocumentLibrary/2016RTPSCS\\_GoodsMovement.pdf](http://www.freightworks.org/DocumentLibrary/2016RTPSCS_GoodsMovement.pdf)



**Fig. 1. 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.

Southern California has some of the busiest railroad corridors in the U.S. For example the BNSF San Bernardino Subdivision between Los Angeles and Fullerton sees about 50 passenger trains and 40 long-haul freight trains per day, and 60 daily freight and 40 passenger trains between West Riverside and Colton. The BNSF Cajon Subdivision, over Cajon Pass, sees nearly 100 freight trains daily<sup>14</sup>. Both passenger and freight rail traffic is expected to increase in the years ahead. This increasing amount of rail traffic will make the zero-emissions benefits of electric trains even more important for trackside communities.

<sup>14</sup> Southern California Association of Governments, *2016-2040 Regional Transportation Plan/Sustainable Communities Strategy, Goods Movement Appendix*, April 2016, pg. 29:  
[http://www.freightworks.org/DocumentLibrary/2016RTPSCS\\_GoodsMovement.pdf](http://www.freightworks.org/DocumentLibrary/2016RTPSCS_GoodsMovement.pdf)

### *Ports of Los Angeles and Long Beach-*

The adjacent ports of Los Angeles and Long Beach, which share San Pedro Bay, combined are the busiest container port in North America. In overall tonnage, they rank as the third largest behind the ports of Houston and South Louisiana. Arguably the most important single international trade gateway on the continent, the Ports of Los Angeles and Long Beach together handle about 40% of all containerized U.S. imports. The majority of this freight is shipped by trucks and trains through the Los Angeles Basin to destinations outside of Southern California.

Rail cargo at the San Pedro Bay ports is about half intermodal containers, and half carload traffic. In 2015, 16 million twenty-foot-equivalent units (TEUs) of intermodal container traffic moved through the San Pedro Bay Ports. For shipping containers, intermodal transitions are an essential part of the North American freight system. In California, intermodal container traffic is growing faster than carload traffic. However, carload rail traffic of bulk commodities remains vital for California's agriculture, automobile, manufacturing, chemical and petroleum industries. In 2016, 28% of containerized import cargo moving through the San Pedro Bay ports left the docks by rail, and 72% by truck. In 2012, the San Pedro Bay Ports were responsible for approximately 55,000 direct daily regional truck trips, many of which are for moving containers. The trends of intermodal freight growth, such as ever-larger container ships, are leading to not only congestion of port facilities but also highways and railways. The San Pedro Bay Ports anticipate annual intermodal cargo volumes to increase about 3% per year, and to over 30 million TEUs annually by 2035.

The communities alongside San Pedro Bay live with some of the most polluted air in the nation, due to vehicle exhaust port operations, and heavy industries such as oil refineries. While much work remains to be done, the Ports of Los Angeles and Long Beach have been national leaders in reducing air pollution from ships, trains, and trucks. The ports pioneered "alternative marine power" (electrical plug-in for ships), and have introduced electric trucks, cranes, and lifting equipment, as well as restrictions on ship speed and port emissions. 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 and other at-berth pollution control technologies for ships.

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, and a near-term goal of 35%<sup>15</sup>. The CAAP also calls for the continued exploration of short-haul rail. The 2017 CAAP draft update, released in July 2017, did call for the planning of the electrification of transportation sector and freight movement equipment. The plan has the worthy goal of increasing the percentage of Port-related goods movement trips that use zero-emissions technology to at least 15% by 2025 and 25% by 2035<sup>16</sup>. The plan did not mention rail electrification specifically, but did say that in the future "the Ports will continue to seek opportunities with rail operators and technology developers to demonstrate and deploy locomotive technologies than can achieve zero-emissions track miles"<sup>17</sup>.

The Port of Long Beach and the Port of Los Angeles should continue their clean technology vision by leading the way in electrified freight rail. 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.

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<sup>15</sup> Port of Long Beach & Port of Los Angeles, *San Pedro Bay Ports Clean Air Action Plan 2017, Draft Final Clean Air Action Plan Update*, July 2017, pg. 56:

<http://www.cleanairactionplan.org/documents/clean-air-action-plan-2017-draft-document-final.pdf>

<sup>16</sup>Ibid., pg. 21.

<sup>17</sup> Ibid., pg. 57.

The majority of intermodal containers are transported by truck to and from the port. On-dock railyards offer the greatest opportunity to reduce the greatest reduction of truck miles per container, yet represents roughly 10% of the San Pedro Bay ports' intermodal freight traffic. The amount of containers transferred to on-dock rail is increasing, and transferring more containers from ship to rail is a goal of both ports. Both ports now have on-dock rail infrastructure at nearly all container terminals. The past decade has seen more than \$2 billion worth of port-area on-dock rail capacity improvements, and there is \$1 billion of proposed investment in near-dock rail infrastructure<sup>18</sup>.

Off-dock railyards, including near-dock facilities that are 5 miles or less away from the port, handle about 30% of the San Pedro Bay ports' intermodal freight traffic. The largest near-dock intermodal rail yard is UP's Intermodal Container Transfer Facility (ICTF) in Long Beach, astride the Alameda Corridor. UP's proposed expansion of ICTF, and BNSF's proposed near-dock Southern California International Gateway (SCIG) project along the Alameda Corridor in the Wilmington neighborhood of Los Angeles, have met significant community opposition largely due to air pollution concerns. Further inland, the off-dock intermodal facilities include BNSF's San Bernardino and Hobart (the busiest in the country) yards, and UP's LA Transportation Center (LATC) and City of Industry yards. Also important for freight movement in the region are transloading or transshipment facilities, where goods are typically taken out of 40' international containers arriving from the port, sorted, repackaged or placed in storage, then moved to a 53' container for domestic shipping to the rest of the U.S.

Electrification is possible for all land movements of a shipping container, from unloading off a ship with an electric crane, drayed by an electric truck to a nearby transshipment facility or intermodal yard, moved around at that facility with an electric forklift, and carried away on an electric train. By reducing GHG emissions and other air pollution per ton of intermodal freight, electrification would make the ports more environmentally competitive.

#### *Alameda Corridor-*

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<sup>19</sup>. 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, shown on the Pacific Harbor Lines map in Fig. 2 below. Completed in 2002 as a significant upgrade to an existing rail line, the Alameda Corridor was financed and built by the ACTA with over \$2 billion of public money. One of the project's main goals was shifting more freight to rail instead of truck. The line also includes a series of new grade-separated underpasses, overpasses to entirely separate the Alameda Corridor's tracks from automobile and pedestrian crossings.

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<sup>18</sup> Southern California Association of Governments, *2016-2040 Regional Transportation Plan/Sustainable Communities Strategy, Goods Movement Appendix*, April 2016, pp. 32-34:  
[http://www.freightworks.org/DocumentLibrary/2016RTPSCS\\_GoodsMovement.pdf](http://www.freightworks.org/DocumentLibrary/2016RTPSCS_GoodsMovement.pdf)

<sup>19</sup> Alameda Corridor Transportation Authority: <http://www.acta.org>

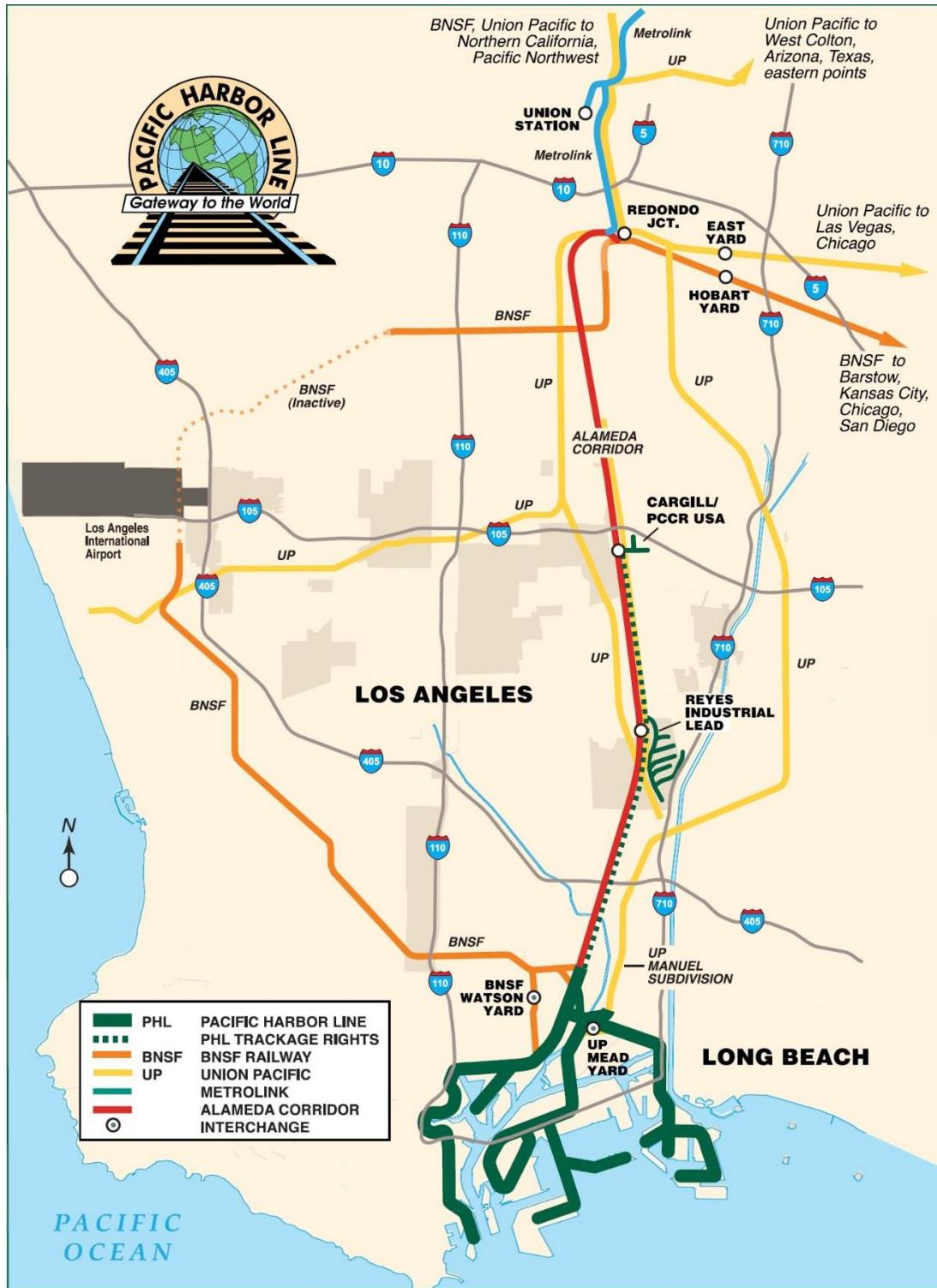


Fig. 2. Map of the Alameda Corridor, Pacific Harbor Line, and connecting freight rail lines.

Source: Anacostia Rail Holdings, <http://www.anacostia.com/sites/www.anacostia.com/files/assets/PHL-LA-LBTml-Map081414.pdf>

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. The Alameda Corridor's Mid-Corridor Trench, shown in the photo in Fig. 3 below, is a 33' deep, 10 mile-long, below-ground segment that allows the rail line to avoid more than 200 street-level railroad crossings. Currently used by about 40 trains per day, the Alameda Corridor has the capacity for about 150, making the corridor an underutilized resource. However, the corridor is still credited with reducing truck traffic congestion on the I-710 and other freeways. The Alameda Corridor Operating Agreement presently states that the ACTA cannot require the private railroads to use electric locomotives.



**Fig. 3. A section of the Alameda Corridor's mid-corridor trench in the city of Compton.**

Photo by Brian Yanity

### *Freight rail improvements-*

Freight transportation planning policy in Southern California in recent years has advocated the shifting of more freight from truck to rail, to reduce vehicle miles traveled (VMT) on the region's highways. The economic costs of highway congestion and delays affect timeliness and reliability of shipments, and waste fuel. Heavy trucks are also the greatest source of wear and tear on roads. Economic costs of delays are often passed on to consumers. The environmental costs of highway congestion include increased fuel use and pollution. Ongoing and proposed railroad capacity improvement projects in Southern California, to benefit both passenger and freight rail include:

- Grade separations
- Additional main line tracks to increase main line capacity
- Additional sidings, local unloading/loading tracks, and rail yard expansions
- Improved signal systems and Positive Train Control (PTC)
- On-dock rail capacity expansion at the San Pedro Bay Ports
- Locomotive upgrades, including introduction of cleaner Tier 4 diesel locomotives

The Southern California Association of Governments' *2016-2040 Regional Transportation Plan/Sustainable Communities Strategy, Goods Movement Appendix* in April 2016 proposed an \$11 billion package of regional rail improvement projects of the type listed above<sup>20</sup>.

Electrification would build upon the above-mentioned improvements to further enhance the reliability, capacity, and sustainability of the region's rail system. 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 by 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 operate along less than 100 miles of electrified track between San Pedro Bay and the Inland Empire, while conventional non-electric line-haul freight trains could continue use the same tracks.

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<sup>20</sup> Southern California Association of Governments, *2016-2040 Regional Transportation Plan/Sustainable Communities Strategy, Goods Movement Appendix*, April 2016, pp. 30-34:  
[http://www.freightworks.org/DocumentLibrary/2016RTPSCS\\_GoodsMovement.pdf](http://www.freightworks.org/DocumentLibrary/2016RTPSCS_GoodsMovement.pdf)

#### 4. Electric Rail Around the World

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, including 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. Nations from Chile to South Africa are investing in expanding or building new electrified rail lines, while China is in the middle of electrifying 20,000 km of existing track. As described by the *Solutionary Rail* book.<sup>21</sup>

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 underestimate 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 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.

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.

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<sup>21</sup> 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.

**Table 1: Railroad electrification around the world (as of 2016)<sup>22</sup>**

Country	Miles Electrified (approx.)	Percentage Electrified
Ethiopia/Djibouti	470	100%
Switzerland	3,200	99%
Belgium	1,900	85%
Sweden	7,600	76%
Japan	12,500	75%
Netherlands	1,400	72%
South Korea	1,600	70%
China	50,000	65%
Italy	8,200	65%
Spain	6,300	64%
Poland	7,400	62%
Austria	2,200	61%
Morocco	800	61%
Germany	12,400	60%
Finland	2,000	55%
France	9,400	52%
Russia	27,000	50%
South Africa	5,900	45%
India	14,700	35%
United Kingdom	3,300	33%

<sup>22</sup><https://www.cia.gov/library/publications/the-world-factbook/fields/2121.html>[http://uic.org/IMG/pdf/synopsis\\_2015\\_print\\_5\\_.pdf](http://uic.org/IMG/pdf/synopsis_2015_print_5_.pdf)[http://statbel.fgov.be/fr/statistiques/chiffres/circulation\\_et\\_transport/transport/ferroviaire/](http://statbel.fgov.be/fr/statistiques/chiffres/circulation_et_transport/transport/ferroviaire/)

## 5. Existing and Historical 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 20<sup>th</sup> 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 route 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<sup>23</sup>. The Pennsylvania Railroad had electrified nearly 2,700 miles of its track by the end of the 1930s<sup>24</sup>. The Sacramento Northern Railway, which ran between Oakland, Sacramento and Chico, ran electric freight locomotives until 1965<sup>25</sup>. 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 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<sup>26</sup>:

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

<sup>23</sup> Middleton, William D. (2001) [1974]. *When the Steam Railroads Electrified* (2nd ed.). Bloomington, IN: Indiana University Press, pgs. 226, 230.

<sup>24</sup> "Electrification History to 1948". *Pennsylvania Railroad Electrification*. [www.railsandtrails.com : http://www.railsandtrails.com/PRR/BOD1948/electric.htm#text](http://www.railsandtrails.com/PRR/BOD1948/electric.htm#text)

<sup>25</sup> <http://www.wrm.org/about/railroad-history/sacramento-northern-railway>

<sup>26</sup> *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](https://www.arb.ca.gov/railyard/docs/uoi_rpt_06222016.pdf)

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.

## 6. Electric Freight Locomotives

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<sup>27</sup>. There could be advantages in using an adapted, in 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 below) 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.

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/189,000 pounds starting tractive effort, 740 kN/166,000 pounds continuous) and EMD SD90MAC (890 kN/200,000 pounds starting tractive effort, 734 kN/165,000 pounds 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, 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/200,000 pounds of starting and 780kN/175,000 pounds continuous tractive effort). In general, locomotives in North America have three size classifications:

- Small, Freight Yard ‘Switcher’: 750 kW to 1.72 MW (1,000 to 2,300 horsepower)
- Medium-Power Locomotive: 1.72 to 2.8 MW (2,300 to 3,800 horsepower)
- Large ‘Line-Haul’ Locomotive: 2.8+ MW (3,800+ horsepower)

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 using a 25 kV catenary system. For the 535-mile Sishen–Saldanha Orex line, Transnet Freight Rail (formerly South African Railways/Spoornet) uses a 50 kV catenary system for hauling iron ore trains typically in excess of 40,000 metric tons (44,000 short tons), shown below in Fig. 4. More than double the weight of a typical U.S. line-haul freight train, these trains are pulled by up to nine all-electric Mitsui Class 15E locomotives in distributed configuration, not unlike their American counterparts.

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<sup>27</sup> *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](https://www.arb.ca.gov/railyard/docs/uoi_rpt_06222016.pdf)



**Fig. 4. South African Railways iron ore train on Sishen–Saldanha Orex line, pulled by electric locomotives under 50 kV catenary.**  
(Photo: Peter Ball collection, <http://www.theheritageportal.co.za/article/south-africas-world-record-breaking-train> )

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

Electric locomotive	Horsepower	Starting tractive effort (kN/pounds)	Est. cost per unit (US \$ millions)	Notes
CRRC Zhuzhou HXD1. <sup>28</sup>	19,300	1,140 / 256,000	unknown	The most powerful locomotive set 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 (similar HXD1 shown in Fig. 5 below).
TMH 4ES5K <sup>29</sup>	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 <sup>30</sup>	8,600	320 / 72,000	\$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 <sup>31</sup>	8,600	300 / 67,400	\$5.1	European electric passenger and freight locomotive.
Bombardier TRAXX <sup>32</sup>	7,500	300 / 67,400	\$4.3	European electric passenger and freight locomotive.
Bombardier IORE <sup>33</sup>	7,200	600 / 135,000	\$9	Version of TRAXX designed for hauling heavy iron ore trains, modified for greater tractive effort (shown in Fig. 6 below).
Mitsui Class 15E <sup>34</sup>	6,000	588 / 130,400	unknown	Operated by Transnet of South Africa using 50 kV catenary for hauling 41,000 metric ton (46,000 short ton) ore trains with distributed power.
Siemens 3800 <sup>35</sup>	5,400	525 / 118,000	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.

<sup>28</sup> <http://documents.epfl.ch/users/a/al/allenbac/www/HXD1.htm><sup>29</sup> [https://www.tmholding.ru/upload/journal/Transmashholding04\\_14\\_eng.pdf](https://www.tmholding.ru/upload/journal/Transmashholding04_14_eng.pdf)<sup>30</sup> <https://www.mobility.siemens.com/mobility/global/sitecollectiondocuments/en/rail-solutions/locomotives/customspecific-solutions/amtrak-acss64-en.pdf><sup>31</sup> <https://www.mobility.siemens.com/mobility/global/SiteCollectionDocuments/en/rail-solutions/locomotives/vectron/vectron-creating-corridors-technic-en.pdf><sup>32</sup> [http://www.bombardier.com/content/dam/Wbsites/bombardiercom/News/BT/BT\\_201704XX\\_Monthy%20Topic\\_Locomotive\\_TRA%20AC3%20Last%20Mile%20datasheet.pdf](http://www.bombardier.com/content/dam/Wbsites/bombardiercom/News/BT/BT_201704XX_Monthy%20Topic_Locomotive_TRA%20AC3%20Last%20Mile%20datasheet.pdf)<sup>33</sup> [http://www.br146.de/revisionen\\_daten/IORE%20Sweden\\_10286\\_LOC\\_Sept08\\_en.pdf](http://www.br146.de/revisionen_daten/IORE%20Sweden_10286_LOC_Sept08_en.pdf)<sup>34</sup> [https://www.toshiba.co.jp/sis/railwaysystem/jp/products/locomotive/pdf/15e\\_electricLocomotives.pdf](https://www.toshiba.co.jp/sis/railwaysystem/jp/products/locomotive/pdf/15e_electricLocomotives.pdf)<sup>35</sup> <https://www.mobility.siemens.com/mobility/global/SiteCollectionDocuments/en/rail-solutions/locomotives/customspecific-solutions/e40ac-en.pdf>



Fig. 5. China Railways HXD1 series freight locomotive set, under 25 kV overhead catenary wire

(Photo: <https://commons.wikimedia.org/wiki/File:HXD10004.jpg> )



Fig. 6. Bombardier IORE electric locomotive set hauling an iron ore train between Sweden and Norway

(Photo: David Gubler, 22.3.2011, <http://bahnbilder.ch/picture/7743?title=iore> )

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<sup>36</sup>:

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.

As further discussed by the April 2016 CARB freight locomotive report<sup>37</sup>:

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

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<sup>36</sup> *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](https://www.arb.ca.gov/railyard/docs/uoi_rpt_06222016.pdf)

<sup>37</sup> *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](https://www.arb.ca.gov/msprog/tech/techreport/freight_locomotives_tech_report.pdf)

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<sup>38</sup>:

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<sup>39</sup>.

#### *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, could 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. While small, switcher-scale prototype battery locomotives have been built such as Norfolk Southern's NS999, battery-electric freight locomotives are expected to become more practical in the years ahead due to improvements in vehicle-scale battery technology. However, like electric automobiles, the current generation of battery locomotives have a limited range and have only a fraction of the power needed to pull a large freight train.

Battery-diesel hybrids are another possibility that could be well suited to medium and small locomotives. In the U.S., the first generation of prototype diesel-battery electric hybrid locomotives proved disappointing to railroads, such as

<sup>38</sup> 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.

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

<sup>39</sup> J.P. Baumgartner, *Prices and Costs in the Railway Sector*. Ecole Polytechnique Federale de Lausanne, 2001.

Railpower's Green Goat introduced in 2004, and GE's hybrid locomotive prototype introduced in 2007. Since 2014, more advanced Alstom Prima H3 and Prima H4 battery electric switcher locomotives, including both diesel-battery hybrids and battery-only versions, have been introduced into commercial service in Europe<sup>40</sup>.

The Zero Emissions Battery Locomotive (ZEBL) conceptual prototype developed by Rail Propulsion Systems could find application for switcher locomotives, or short-haul freight rail service. A 'hybrid ZEBL', battery electric locomotive with retractable overhead pantograph for receiving power from overhead catenary, could be used in freight yards or an electrified Alameda Corridor or other rail corridors in the region.

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<sup>40</sup> <http://www.alstom.com/products-services/product-catalogue/rail-systems/trains/products/prima-shunting-and-works-locomotives-/>

## 7. 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, with no change of locomotives. 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 is 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<sup>41</sup>:

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).

As described in the 2012 SCAG report<sup>42</sup> :

Key operations changes that may result from electrification include:

1. Increases in travel time from the L.A. region to other parts of the nation as a result of changing out locomotives at the “edge” of the electrified system, for example in Barstow, West Colton, or Indio... It is estimated by the railroads that nearly four hours could be added to a trip as a result of the “change-out” activity, per trip.
2. Changes in how railroads move and how logistics decisions are made in the regional and national network (for example, keeping a captive fleet of electric locomotives in the region) will change railroad fleet planning and potentially increase constraints on how locomotives can be utilized, which could have cost impacts; and

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<sup>41</sup> *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](https://www.arb.ca.gov/msprog/tech/techreport/freight_locomotives_tech_report.pdf)

<sup>42</sup> 2012 SCAG report, pgs. 4-5 to 4-6.

3. Operational impacts of not being able to run electrified catenary into major railyards and the Ports of Los Angeles and Long Beach.
4. Operational impacts of dealing with a shutdown to the electric mainline. In the event of an electric mainline shutdown, train traffic would need to be diverted to non-electric portions of the system. In this case, the railroads would have many idle full electric locomotives and a potential shortfall of diesel locomotives in order to move all of the goods into and out of the region.

The change out of locomotives on trains would require the construction of new dedicated siding tracks and other facilities to inspect, service, stage, and store both diesel and electric locomotives. The 2012 SCAG report concluded the locating the locomotive “switch out” locations at the end of the electrified segment of track, such as Barstow or Indio, would have the least impact on railroad operations<sup>43</sup>. Located in less-populated areas, such sites also have more opportunities and space for future expansion of track and facilities. Further out ‘stateline’ sites such as Needles (California), Yuma (Arizona) and Primm (Nevada) could also serve as ‘switch out’ locations.

The 2016 RailTEC report estimated that locomotive exchanging around the perimeters of the South Coast Air Basin, from zero-emissions to conventional diesel locomotives, would add significant costs and delays to rail freight<sup>44</sup>. The costs and delay were speculated to be great enough to make freight rail less competitive with truck, and cause a ‘mode shift’ of 12.5 million tons of freight from rail to truck each year. This amount would cost the railroads 10% or more of their regional market share. However, it is worth critically evaluating if such mode shift would be as significant as described in the RailTEC report, or be avoided entirely. What is left unsaid in RailTEC’s analysis is how much the estimated mode shift from rail to truck, due to locomotive exchange, would make highway congestion worse by adding potentially thousands of trucks to the roads. This would make trucks less competitive, incur delays and costs for all other highway users, and create additional environmental and economic costs to region as whole.

Possible ways of minimizing locomotive exchange delays need to be studied. Research is needed in collaboration with railroads operating in California, who best understand their operations, as well as bringing international expertise from electrified freight railroads outside the U.S. Potential solutions to the exchange point delay problem, which could be studied, could include:

- Computer simulations to model locomotive change-out, to find electrification strategies that have the least operational impacts.
- Evaluate locomotive change out of dual-mode diesel electric compared to that of all-electric locomotives, and if this would reduce change-out time.
- 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.

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<sup>43</sup>2012 SCAG report, pg. 4-28

<sup>44</sup> *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](https://www.arb.ca.gov/railyard/docs/uoi_rpt_06222016.pdf)), pgs. 90-103.

- Electric ‘helper’ locomotives carrying freight trains up and down up Cajon Pass, carrying ‘dead’ diesel-electric locomotives. There are different rules for adding ‘helper’ locomotives, as the air brake line is not broken between the locomotives and the cars, and the crew staying the cab of the original locomotive.
- For long-distance trains, the electrification could be phased in using dual-mode locomotives and electric-diesel mixed locomotive trains (discussed below in section 8). 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.

#### *Phasing out of existing diesel locomotive fleet-*

There are close to 30,000 operating line-haul freight diesel-electric locomotives in the U.S. Over 10,000 different line-haul freight locomotives operate within California on mainline freight operations each year. Short-line, terminal, industrial, and passenger railroads operate about 800 locomotives in California, most of which stay entirely within the state<sup>45</sup>. Given an average lifespan of diesel-electric locomotive of about 30 years, a phasing-in of electric locomotives will happen over several decades, while diesel locomotives also remain in service. Mixed operation of diesel and electric locomotives on the same train, described below, will be part of this process. Battery-electric slug or tender locomotives, coupled with conventional diesel-electric locomotives to form battery-hybrid pairs, could also be part of this phasing-in process.

#### *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 other possible track failures such was washouts, subgrade failures, or switch/signal system malfunctions. In California, freight railroads have also expressed concerns about electromagnetic interference to signaling systems, as well as 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 container cars. On India’s new electrified Dedicated Freight Corridors, an overhead catenary height of 7.47 m (24.5’) above ground level was chosen to allow for double-stacked container trains<sup>46</sup>.

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<sup>45</sup> *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](https://www.arb.ca.gov/railyard/docs/uoi_rpt_06222016.pdf)), pg. 24.

<sup>46</sup> [http://www.indianrailways.gov.in/railwayboard/uploads/directorate/rail\\_elec/downloads/1\\_DFC.pdf](http://www.indianrailways.gov.in/railwayboard/uploads/directorate/rail_elec/downloads/1_DFC.pdf)

## 8. 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. Even with electrification of main-line track, dual-mode locomotives could find application during electrification construction and maybe in non-electrified yards and sidings.

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 and power by carrying around the weight of one type of unused power plant (electric or diesel), while using the other.

There is limited experience around the world with dual-mode freight locomotives. 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<sup>47</sup>. 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.

### *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 on the Sishen–Saldanha Orex line<sup>48</sup>:

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, and.. 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.

In 1989, the Sishen–Saldanha line set a then-world record of heaviest and longest train using mixed electric and diesel locomotives. Nine electric and seven diesel locomotives pulled 660 fully-laden iron ore cars, in a train weighing 70,543 metric tons (77,760 short tons) with a length of 7.28 km (4.52 miles)<sup>49</sup>.

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<sup>47</sup> 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>

<sup>48</sup> [https://en.wikipedia.org/wiki/South\\_African\\_Class\\_15E](https://en.wikipedia.org/wiki/South_African_Class_15E)

<sup>49</sup> <http://www.theheritageportal.co.za/article/south-africas-world-record-breaking-train>

## 9. Electrification of Track

Overhead catenary wire has been used to power heavy electric freight trains for more than a century, and is tried-and-true technology. An overhead wire, 25 kV AC catenary electrification is a world standard for heavy freight and high-speed passenger rail. In California, a 25 kV AC catenary system is being installed for the Caltrain and California High Speed Rail passenger rail projects. 50 kV catenary, used on several heavy freight railroads around the world, offers the advantage of higher power capacity, and requires a smaller number of substations along the route. In Southern California, the steep grade of Cajon Pass would be better suited for 50 kV catenary due to the high power requirements and heavy freight traffic, as well as for long-distance sections. Fortunately, it is possible for electric locomotives to transition between 25 kV and 50 kV catenary at speed. Electrification of an initial pilot rail line, such as the Alameda Corridor, must be compatible with electrification standards that the rest of the North American rail system would follow.

The main drawback of rail 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 a 25-kV 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 \$26 million per route mile, not including the purchase of the new electric multiple unit (EMU) passenger trains<sup>50</sup>. 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<sup>51</sup>. 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.

Overhead catenary system maintenance costs were estimated by the 2016 CARB RailTEC report to be \$30,000 per route mile, per year<sup>52</sup>. The higher train frequency for a particular track segment, the more economical electrification will be. 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<sup>53</sup>:

[with social, environmental and economic benefits] combined, we see that it takes 21-29 bidirectional frequencies for benefits to match the costs of railroad electrification [for passenger rail].

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<sup>50</sup> <http://www.caltrain.com/Assets/Caltrain+Modernization+Program/Documents/PCEP+Quarter+4+2016+Report.pdf>

<sup>51</sup> *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](https://www.arb.ca.gov/msprog/tech/techreport/freight_locomotives_tech_report.pdf)

<sup>52</sup> *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](https://www.arb.ca.gov/railyard/docs/uoi_rpt_06222016.pdf)), pg. 20.

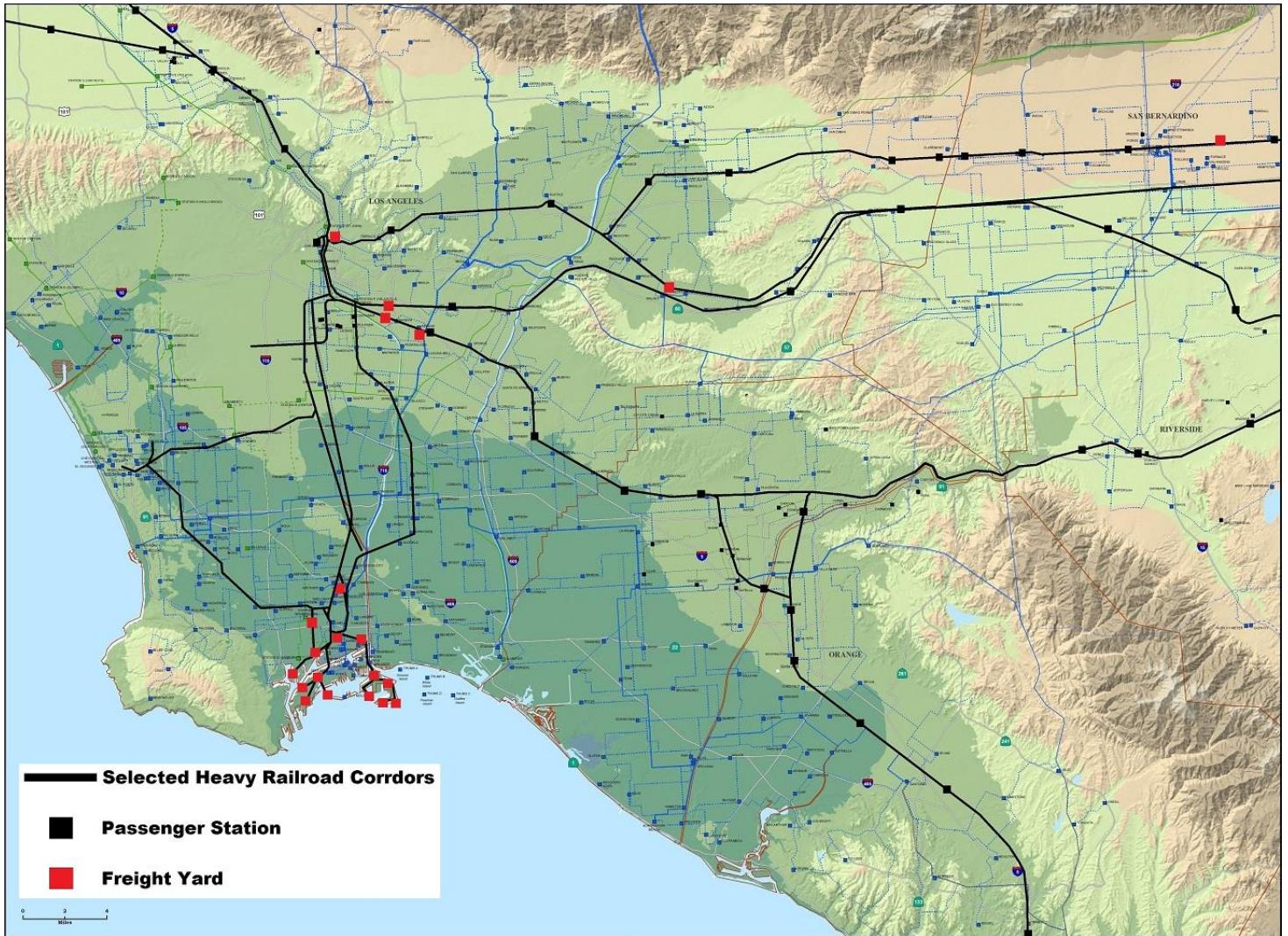
<sup>53</sup> Paul Druce, *Reason & Rail* blog, September 5, 2015:  
<http://reasonrail.blogspot.com/2015/09/a-cost-to-benefit-analysis-of-railroad.html>

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 construct or upgrade 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 needed to service electrified track in the Los Angeles area tends to be in industrial areas and alongside rail lines, as shown on the three maps below in Figs. 7, 8, and 9.



**Fig. 7. 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

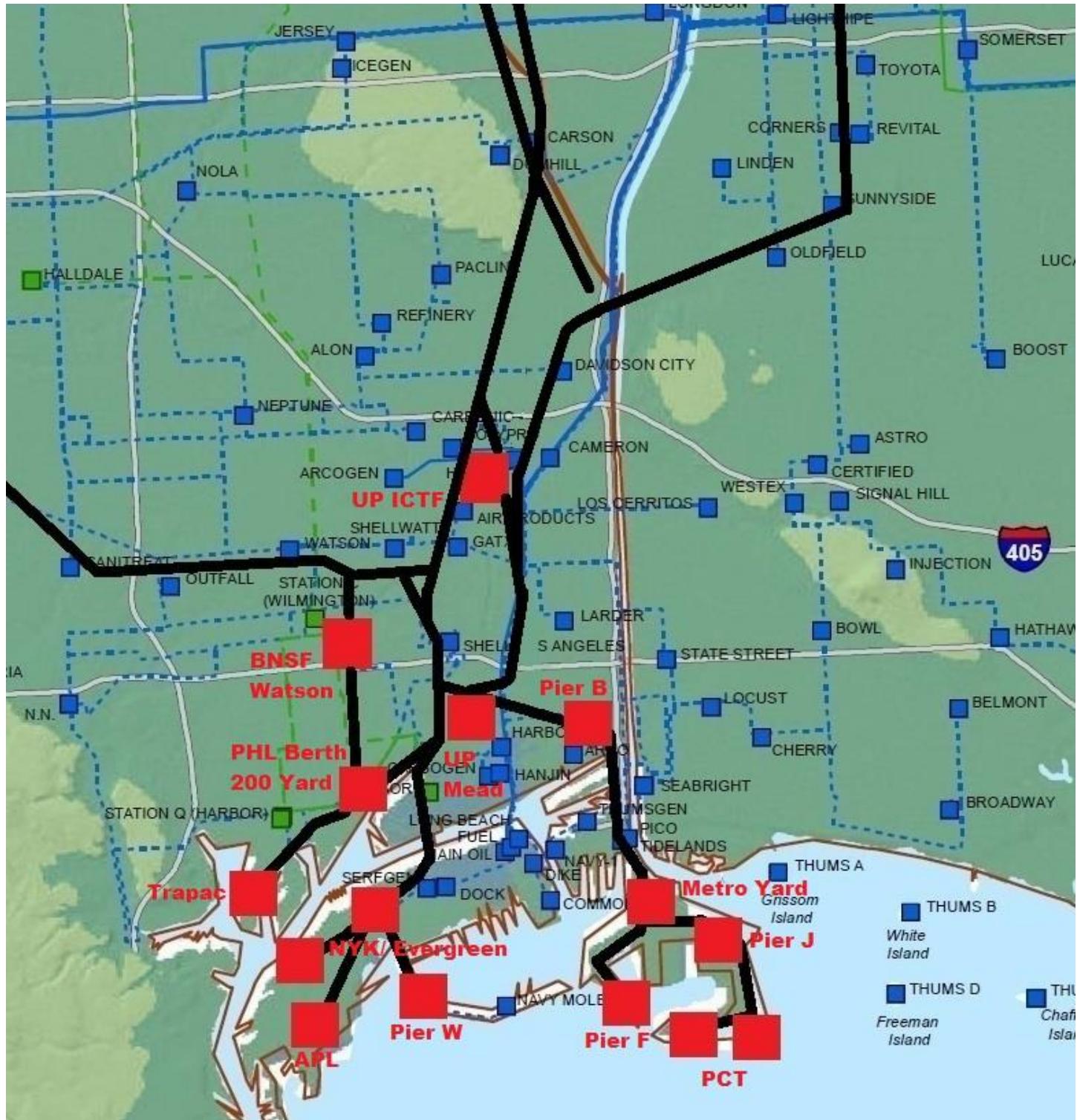
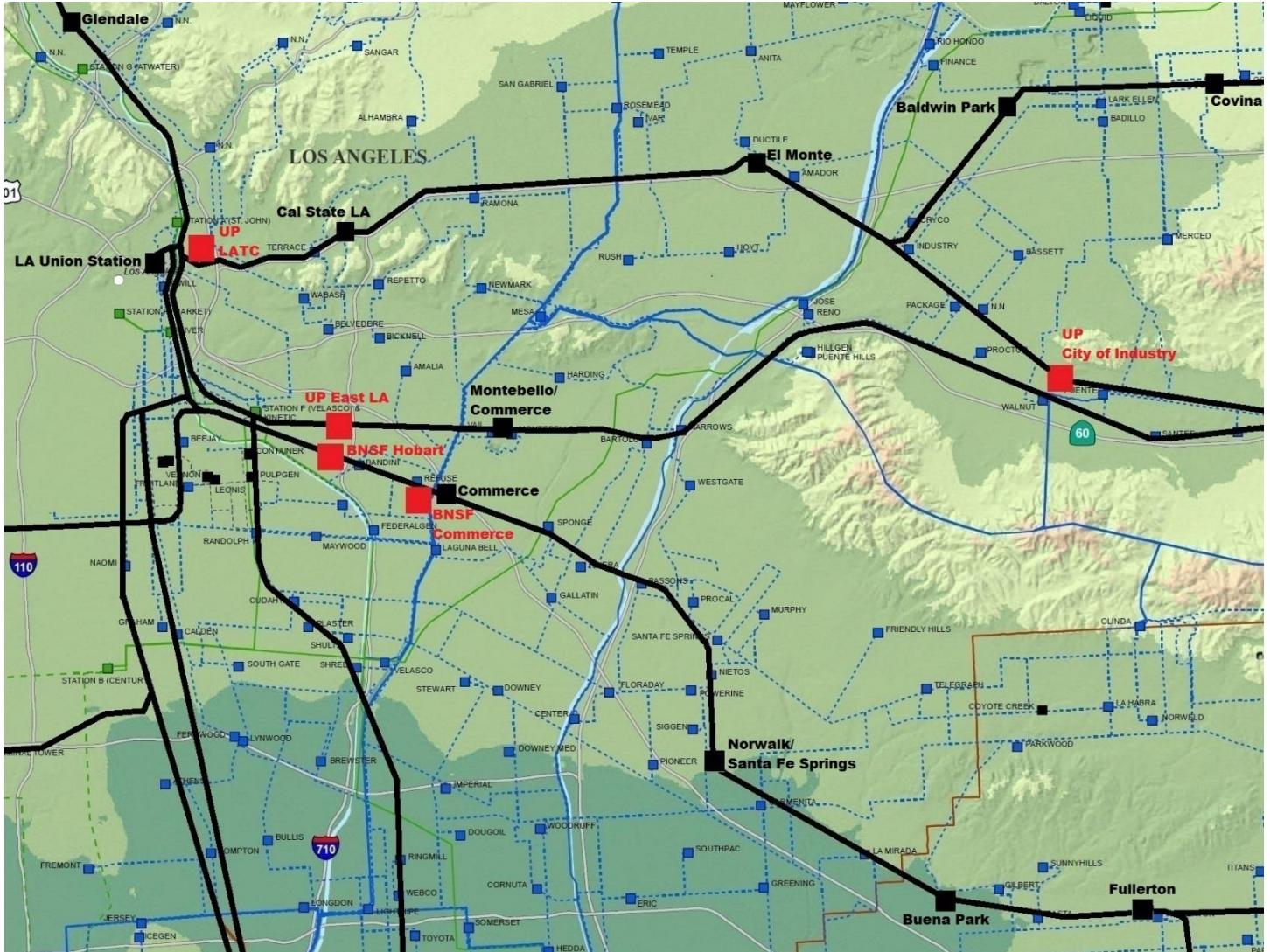


Fig. 8. Selected heavy rail corridors and freight yards (red squares)- San Pedro Bay harbor area, overlaid on map of existing electric utility transmission lines and substations.  
Port of Los Angeles on the left side of harbor, Port of Long Beach on the right.  
(Background map: California Energy Commission)



**Fig. 9. 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)**

**Table 3. Typical Electric Power Equivalent of Railroad Trains<sup>54</sup>**

Light Rail or Subway	1 MW or less
Commuter Trains	3 to 4 MW
High Speed, Intercity Passenger Trains	4 to 8 MW
Very High Speed Passenger Trains	8 to 20 MW
Long-Haul U.S. Freight Trains	18 to 24 MW

As shown in Table 3 above, a single large line-haul freight train can consume the equivalent of over 20 MW of electric power. 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

<sup>54</sup> B. Bhargava, *Railway Electrification Systems and Configurations*, SoCal Edison, Institute of Electrical and Electronics Engineers (IEEE), 1999.

average load<sup>55</sup>. 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 MWh/year by 2050 (114 MW average load)<sup>56</sup>. This amount of electricity consumption was described as a major disadvantage<sup>57</sup>:

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%. This level of loss is not 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 Southern California Edison (SCE) & Los Angeles Department of Water and Power (LADWP) service areas, as described below. 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 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 electricity consumption. Table 4 below shows the California Energy Commission's projected electric energy demand, by selected sector, for the designated utility planning area of SCE, which also includes municipal utilities surrounded by SCE's service area, and that of LADWP. As can be seen in Table 4, 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

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<sup>55</sup> *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](https://www.arb.ca.gov/railyard/docs/uoi_rpt_06222016.pdf)

<sup>56</sup> *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](https://www.arb.ca.gov/msprog/tech/techreport/freight_locomotives_tech_report.pdf)

<sup>57</sup> Ibid., pg. VIII-7.

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.

**Table 4: Present and projected 2026 electric energy demand in SCE and LADWP utility planning areas<sup>58</sup>**

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 2016, about 20 TWh of solar electricity was generated in California (not including roof-top solar projects on homes and small businesses), while wind generated about 13.5 TWh and geothermal contributed about 12 TWh<sup>59</sup>.

As a comparison, the total solar, wind and geothermal share of the electricity generated in 2016 within California, approximately 46 TWh, is *forty six 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 utility-scale solar energy development, with an installed generating capacity of about 10,000 MW in 2016<sup>60</sup>. At least 15,000 MW of solar energy capacity is in various stages of development in the state<sup>61</sup>. 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<sup>62</sup>. In the LADWP planning area, the peak output of customer self-generation by PV sources is projected to increase to as much as 340

<sup>58</sup> 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](http://docketpublic.energy.ca.gov/PublicDocuments/15-IEPR-03/TN207438_20160115T152222_California_Energy_Demand_20162026_Revised_Electricity_Demand_Fo.pdf)

<sup>59</sup> California Energy Commission, California Electrical Energy Generation statistics page:  
[http://www.energy.ca.gov/almanac/electricity\\_data/electricity\\_generation.html](http://www.energy.ca.gov/almanac/electricity_data/electricity_generation.html)

<sup>60</sup> [http://www.energy.ca.gov/renewables/tracking\\_progress/documents/installation\\_capacity.pdf](http://www.energy.ca.gov/renewables/tracking_progress/documents/installation_capacity.pdf)

<sup>61</sup> <https://www.seia.org/research-resources/major-solar-projects-list>

<sup>62</sup> California Energy Commission, January 2016, pg. 43.

MW by 2026, and as much as 240 MW for non-PV sources<sup>63</sup>. 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. A sufficient level of energy storage along a rail line could provide backup power in case of a local or regional power outage.

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. California utilities should consult the experience of other countries with both extensive electric rail and high penetration of renewable energy generation, such as Germany and Spain. Both of these nations have populations greater than California's, meet more than one-third of their overall electricity needs from renewable sources (excluding large-scale hydroelectric), and have a rail system electrification rate of at least 60%.

#### *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, as described below.

For several years, the Los Angeles Metropolitan Transit Authority (Metro) has been testing both on-board energy storage systems, and wayside energy storage systems (WEES), to store energy produced by regenerative braking of subway trains<sup>64</sup>. At Metro's Westlake/MacArthur Park subway station, a 2 MW VYCON flywheel WEES system was installed in April 2014<sup>65</sup>. 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, 25 kV or 50 kV, 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 the existence of modern-day AC locomotives feeding power back to the overhead wire, the CARB 2016 RailTEC report was largely dismissive of regenerative braking<sup>66</sup>:

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<sup>63</sup> California Energy Commission, January 2016, pg. 108.

<sup>64</sup> 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](http://media.metro.net/about_us/sustainability/images/sustainable_rail_plan_final_clean_submitted.pdf)

<sup>65</sup> "LA Metro VYCON WEES 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>

<sup>66</sup> *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](https://www.arb.ca.gov/railyard/docs/uoi_rpt_06222016.pdf)

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.

The CARB report's assertion that a train's regenerated energy cannot be stored is incorrect. WESS systems under development around the world are proving the practical application of storing energy from a train's regenerative braking. 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.

#### *Grid-scale energy storage and electric rail-*

At a passenger train station or freight yard, the energy stored in a WESS could charge battery or hybrid locomotives in relatively brief, high-power 'pulses' during the day, with the WESS being charged by the utility grid at night. A trackside WESS could store energy recovered from a braking electric freight train using an overhead catenary, especially on long, steep grades such as Cajon Pass. A WESS could also provide voltage, frequency and reactive power support for an electric rail catenary system, and with smart utility-intertied inverters could provide such support (or ancillary services) for the grid itself. Another possible application would be to provide temporary backup power for a passenger train station or freight yard, allowing safe shut-down of equipment in the event of a major power outage.

The 2013 Transportation Research Board report *Advanced Wayside Energy Storage Systems for Rail Transit*, described the following WESS benefits for electric rail transit systems, all of which could be applied to electric heavy rail as well<sup>67</sup>:

- Electricity cost management
  - Time-based rate management
  - Demand charge management (peak demand reduction)
- Energy efficiency & resource optimization
  - Regenerative braking
  - Renewable energy optimization
  - Ramp-rate control for integration of intermittent renewable energy
- Power quality improvement
  - Voltage control
  - VAR control

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<sup>67</sup> Colette Lamontagne, Navigant Consulting, *Advanced Wayside Energy Storage Systems for Rail Transit*, Transit IDEA Project 66, Transportation Research Board, April 2013: <http://onlinepubs.trb.org/Onlinepubs/IDEA/FinalReports/Transit/Transit66.pdf>

- Phase balancing
- Reliability improvement
  - Backup power for rail facility

A large enough WESS, coupled with a micro-grid, could provide ‘island autonomy’ for a rail facility during a power outage, or serve as a ‘bridge’ to allow for a successful transfer to a temporary generator.

The storage of excess renewable energy generation is of great interest to California utilities. Train station and freight yard WESS sites could be charged when there is an excess of renewable energy generation on the local grid.

Research needs for grid-Integrated WESS for heavy freight and passenger rail include:

- Technical and economic study of how heavy-rail WESS could be a new business opportunity for electric utilities
- Strategies for rail WESS utility control with smart inverters- charging during off-peak hours, provide power to grid peak demand periods, providing ancillary services and aid integration of distributed renewable energy
- Construction of a heavy-rail WESS demonstration site, at a rail yard or passenger train station, to test charging infrastructure for battery electric and hybrid locomotives, including emerging technologies such as wireless power transfer (WPT).

#### *Routing of transmission lines along railroad rights-of-way-*

The routing of new transmission lines along freight railroad rights-of-way in Southern California is a concept worthy of study. This concept could be a new source of revenue for the railroads, increase the amount of renewable energy used in California, and improve power grid reliability.

A potential win-win for railroad and electric utility companies, installing overhead power transmission lines along rail lines has long been common around the world for electrified tracks. Such lines have overhead catenary wires used to power trains, along with high-voltage power transmission lines suspended further above the catenary. The use of a rail corridor for power transmission is possible whether or not the tracks themselves are electrified with overhead catenary, as shown below in Fig. 10. For electrified railways, support structures for the catenary wire can be combined with transmission line structures, as shown below in Fig. 11. Route-specific feasibility and design studies are needed to determine what size transmission lines could be safely accommodated on a particular railroad right-of-way. Potential benefits to electric utilities, as well as revenue opportunities for railroads hosting transmission lines and energy storage capacity need to be studied.



**Fig. 10: Existing Anaheim Public Utilities transmission and distribution lines, with voltages shown, sharing a section of the 100'-wide Los Angeles-San Diego Amtrak "Surfliner" LOSSAN double-track rail corridor**  
(Photo by Brian Yanity, 2/2/2017)



**Fig. 11. SEPTA train on Northeast Corridor, under catenary supported by structures which also carry overhead transmission lines**  
(Photo by jpmueller99, <https://commons.wikimedia.org/w/index.php?curid=4007886>)

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

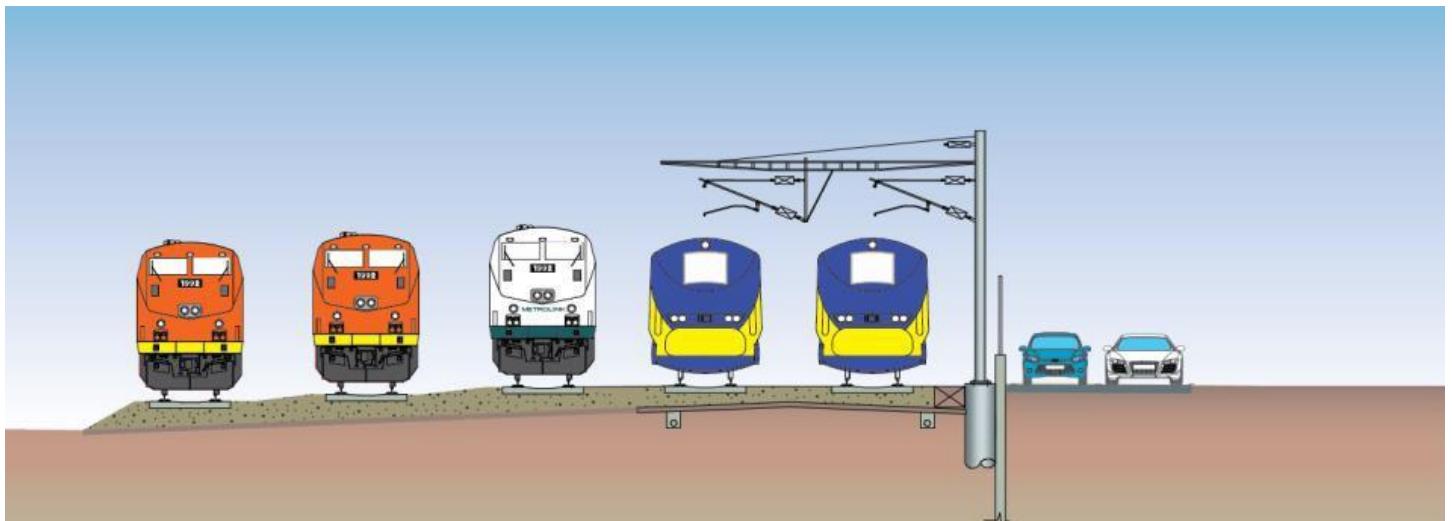
Many of California's busiest freight rail corridors share the tracks with commuter and intercity passenger trains. The co-utilization of electric rail infrastructure for both freight and passenger rail service should be studied. The California High Speed Rail Authority (CHSRA)'s investments could aid electrification of freight rail. CHSRA is planning "blended" electrified passenger service along the high speed line in urban/suburban areas at the two ends of the Phase I route between San Francisco and Anaheim, possibility of integrating with electrified "light express" or even conventional freight rail. In particular, California High Speed Rail presents interesting opportunities for sharing electrification on non-high speed segments, blending the high speed trains (going at non-high speeds) with other passenger trains on the corridor sections of San Francisco to San Jose (Caltrain) and Burbank-Los Angeles-Anaheim (Metrolink and Amtrak). On these two 'blended' electrified corridors that high speed trains would share with other passenger trains, conventional freight would be kept off the passenger tracks entirely. However, CHSRA has proposed the possibility lightweight "express" freight service on the normally 'passenger-only' tracks at night for hauling cargo such as FedEx parcels.

### 1. Caltrain- San Jose to San Francisco corridor:

Construction on Caltrain's electrification of the peninsular corridor route began in 2017. This corridor also currently used by up to several Union Pacific freight trains per day. Union Pacific has formally accepted electrification and plans to sell off its freight rights to the corridor, opening it for bid to a new third-party short-haul freight operator<sup>68</sup>. Perhaps this short-haul freight service between San Francisco and San Jose could be electrified along with passenger trains.

### 2. Burbank-Los Angeles-Anaheim-Irvine corridor:

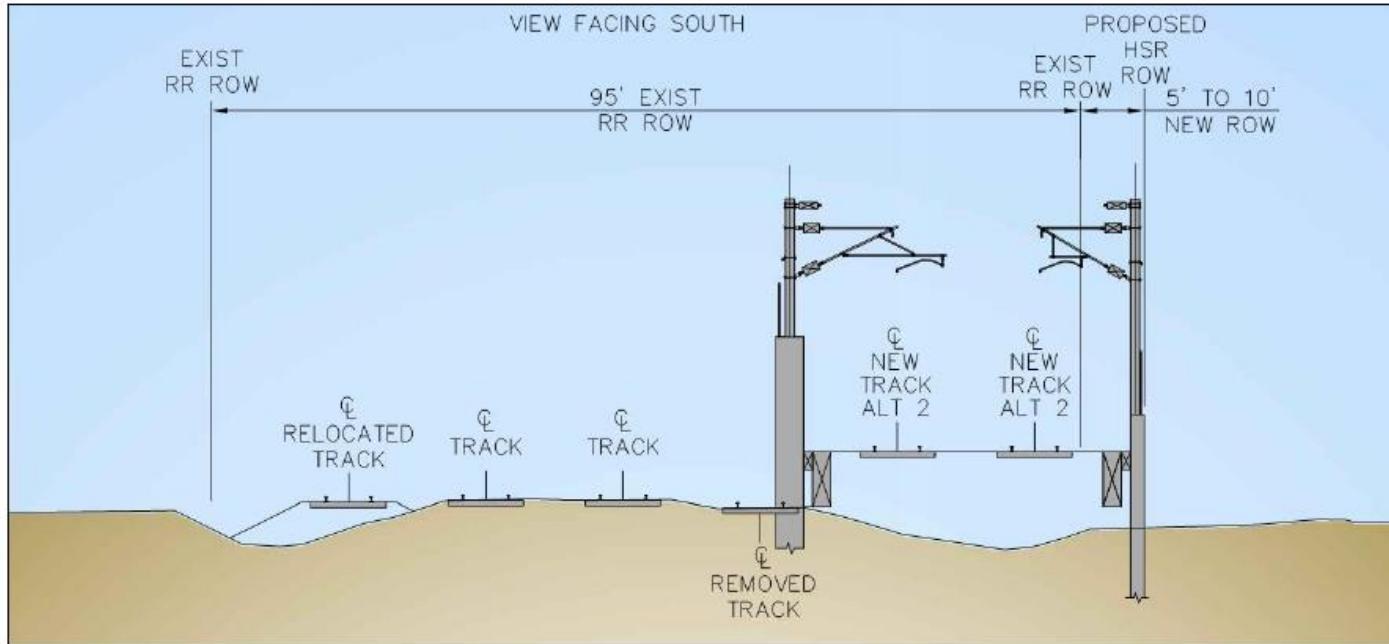
The early investment of High Speed Rail will improve upon and utilize the 'LOSSAN' corridor between San Luis Obispo and San Diego via Los Angeles. LOSSAN is used by both the Metrolink commuter rail and Amtrak's Surfliner, which is the second-busiest Amtrak route in the country after the Northeast Corridor between Washington, D.C. and Boston. CalTrans and BNSF have been working on the state-funded \$160 million, 17-mile triple-tracking project between Soto Junction (near Downtown LA) and Fullerton since the late 1990s. Presently the corridor is triple-tracked the entire 25 miles between LA and Fullerton, with the exception of one Rosecrans-Marquart road crossing which still has two tracks. This crossing will be upgraded to three or more tracks once a grade separation project is finished in 2021. All three tracks are owned by BNSF and shared by passenger ( $\approx$  50 trains per day) and freight ( $\approx$  40 trains a day). The Los Angeles-Fullerton segment has by far the most freight traffic of any corridor along the Phase 1 high speed route. This heavy amount of traffic leads to improved economics and higher utilization of electric rail infrastructure. North of LA Union Station, the passenger route is shared by only about 10 Union Pacific freight trains per day. CHSRA is proposing two electrified tracks on which all passenger service would run (electric or not), and three freight tracks<sup>69</sup>, for a total of five tracks between Los Angeles and Fullerton, as shown below in Fig. 12 and Fig. 13.



**Fig. 12. At-grade alignment of electrified passenger rail tracks alongside three freight tracks, as proposed for the Los Angeles to Fullerton corridor.**  
(Diagram from California High Speed Rail Authority)

<sup>68</sup> <http://www.greencaltrain.com/2017/01/union-pacific-accepts-electrification-plans-to-open-bids-for-peninsula-freight-service/>

<sup>69</sup> CAHSR website about the Los Angeles to Anaheim corridor:  
[http://www.hsr.ca.gov/Programs/Statewide\\_Rail\\_Modernization/Project\\_Sections/losangeles\\_anaheim.html](http://www.hsr.ca.gov/Programs/Statewide_Rail_Modernization/Project_Sections/losangeles_anaheim.html)



Source: STV, 2015 (Figure not to scale)

**Figure 3.4-15 Alternative 2 Typical At-Grade Cross-Section - Fullerton**

**Fig. 13. Electric catenary infrastructure proposed by California High Speed Rail Authority at Fullerton, on Los Angeles-Anaheim section along BNSF San Bernardino Subdivision.**

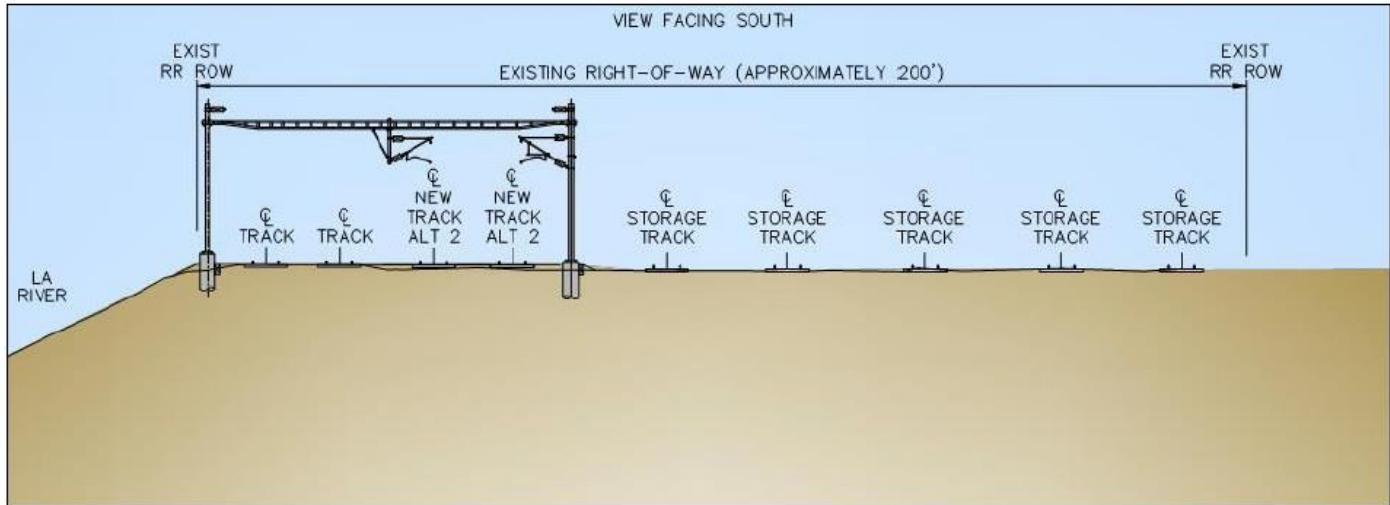
(Diagram from California High Speed Rail Authority, *Los Angeles to Anaheim Project Section: Supplemental Alternatives Analysis Report*, April 2016<sup>70</sup>)

The 25 miles between Los Angeles and Fullerton that overlap with the San Bernardino Subdivision of the BNSF Southern Transcon, which is the only major transcontinental freight rail segment that will share a corridor with Phase I of the CAHSR project. South from Fullerton, the CAHSR would leave the BNSF Southern Transcon and continue to Anaheim and points further south along the double-tracked (both electrified) LOSSAN corridor. Between Fullerton and San Diego, there are only several BNSF freight trains per day on the LOSSAN corridor.

The CAHSR 25-kV overhead catenary system could be designed to support catenary wire over the freight tracks in the future. A 25-kV overhead catenary electrification system is powerful enough to pull heavy freight trains, as demonstrated by existing electric freight railroads around the world. In downtown Los Angeles, the planned CAHSR catenary structure over the tracks along the West Bank of the Los Angeles River is already planned to span over most of the freight tracks as well, as shown below in Fig. 14.

<sup>70</sup> California High Speed Rail Authority, *Los Angeles to Anaheim Project Section: Supplemental Alternatives Analysis Report*, April 2016, pg. 57.

[http://www.hsr.ca.gov/docs/brdmeetings/2016/brdmtg\\_041216\\_Item9\\_ATTACHMENT\\_LA\\_to\\_Anheim\\_Supplemental\\_Alternative\\_s\\_Analysis.pdf](http://www.hsr.ca.gov/docs/brdmeetings/2016/brdmtg_041216_Item9_ATTACHMENT_LA_to_Anheim_Supplemental_Alternative_s_Analysis.pdf)



Source: STV, 2015 (Figure not to scale)

**Figure 3.4-10 Alternative 2 – Typical Cross-Section -- LA River West Bank: Approaching Redondo Junction**

**Fig. 14. Electric catenary infrastructure proposed for Los Angeles River West Bank by California High Speed Rail Authority, on Los Angeles-Anaheim section south of LA Union Station**

(Diagram from California High Speed Rail Authority, *Los Angeles to Anaheim Project Section: Supplemental Alternatives Analysis Report*, April 2016<sup>71</sup>)

The ‘blended’ CAHSR Burbank-Los Angeles-Anaheim corridor could serve as a catalyst for the Electrolink electric regional rail concept for Southern California, proposed by the Rail Passenger Association of California and Nevada. The Electrolink proposal would start with electrifying the 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.

<sup>71</sup> California High Speed Rail Authority, *Los Angeles to Anaheim Project Section: Supplemental Alternatives Analysis Report*, April 2016, pg. 53:

[http://www.hsr.ca.gov/docs/brdmeetings/2016/brdmtg\\_041216\\_Item9\\_ATTACHMENT\\_LA\\_to\\_Anheim\\_Supplemental\\_Alternative\\_s\\_Analysis.pdf](http://www.hsr.ca.gov/docs/brdmeetings/2016/brdmtg_041216_Item9_ATTACHMENT_LA_to_Anheim_Supplemental_Alternative_s_Analysis.pdf)

## 10. Short-Haul Freight 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 intermodal freight railroad yards known as 'inland ports'. In recent decades, the business model of Class I freight railroads such as UP and BNSF has focused on long-haul bulk shipments over 500 miles, and not short-haul trains that would compete more directly with truck. However, the decline of bulk commodity shipments of coal and oil in the past several years have made U.S. freight railroads more open to exploring new business opportunities such as short-haul rail.

The 'Inland Empire' region, consisting of San Bernardino and Riverside counties, has emerged as a major warehousing, distribution, logistical and transshipment center, due to available land and its strategic location along major rail and highway networks. The majority of freight passing through the San Pedro Bay ports also travels through the Inland Empire. About a third of all containerized imports that move through the San Pedro Bay ports go by truck to warehouses and distribution centers in San Bernardino and Riverside counties.

Increased road congestion, particularly near the Ports of Los Angeles and Long Beach, has renewed 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 counties combined. According to the study, 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<sup>72</sup>. The inland terminal locations studied included Mira Loma, Ontario and Victorville.

From the ports, many shippers have historically found that trucking containers to the Inland Empire for transloading from 40' international containers to 53' domestic containers to be cheaper than paying the fee to use the Alameda Corridor. However, in recent years drayage trucking costs have increased due to highway congestion, tightened port security, higher driver wages and other factors. A 2017 analysis by the American Transportation Research Institute estimated that road congestion in the Los Angeles area costs the trucking industry greater than \$1 billion per year in added operational costs, the most of any metropolitan area in the nation<sup>73</sup>. The ports' Clean Air Action Plan will also increase trucking costs by requiring newer, cleaner trucks and eventually fees for non-zero emissions vehicles<sup>74</sup>.

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

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<sup>72</sup> *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](http://tiogagroup.com/docs/Tioga_Grp_SCAGInlandPortReport.pdf)

<sup>73</sup> <http://atri-online.org/2017/05/16/cost-of-congestion-to-the-trucking-industry-2017-update/>

<sup>74</sup> Port of Long Beach & Port of Los Angeles, *San Pedro Bay Ports Clean Air Action Plan 2017, Draft Final Clean Air Action Plan Update*, July 2017, pg. 62:  
<http://www.cleanairactionplan.org/documents/clean-air-action-plan-2017-draft-document-final.pdf>

of new intermodal distribution facilities located in the Inland Empire<sup>75</sup>. The study is motivated by the need to reduce truck congestion at the ports and on highways by shifting of more freight from truck to rail<sup>76</sup>:

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. [economist John] 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.

...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 is uncertain.

The Ports' 2017 Clean Air Action Plan update stated that the Ports are continuing to pursue a detail review of the short-haul freight shuttle concept, and that further study is necessary to ensure that potential impacts are not just being shifted to a new location<sup>77</sup>. 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<sup>78</sup>:

<sup>75</sup> "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](http://www.joc.com/port-news/us-ports/port-los-angeles/la-lb-ports-revisit-short-haul-rail-beat-congestion_20151222.html)

<sup>76</sup> "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](http://www.joc.com/rail-intermodal/shippers-await-short-haul-rail-option-la-lb-ports_20160427.html)

<sup>77</sup> Port of Long Beach & Port of Los Angeles, *San Pedro Bay Ports Clean Air Action Plan 2017, Draft Final Clean Air Action Plan Update*, July 2017, pg. 62: <http://www.cleanairactionplan.org/documents/clean-air-action-plan-2017-draft-document-final.pdf>

<sup>78</sup> *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](http://tiogagroup.com/docs/Tioga_Grp_SCAGInlandPortReport.pdf)

*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.

*Choose 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. Success for private rail companies, shippers and distribution companies is necessary for public goals of a cleaner, more efficient freight transportation system.

#### *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, 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 options, or phases, of freight rail electrification in the region, shown on the map in Fig. 15 below<sup>79</sup>:

- Option I: 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 [51 track miles].
- Option II: LATC to West Colton yard (UP), Hobart to San Bernardino (BNSF), sharing catenary with electric passenger trains [422 track miles].
- Option III: Ports to Barstow/Yermo/Indio/Chatsworth/San Fernando [863 track miles].

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<sup>79</sup> 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>

**Figure 4.3 Regional Electrification Options and the SCAB Boundary**



**Fig. 15. Freight rail electrification scenarios in the South Coast Air Basin, as proposed by 2012 SCAG report.**

(Source: 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. 4-24.

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

Freight car switching on either end of electrified track segments could be performed by zero emissions battery-electric switcher locomotives, which would not require overhead catenary. Phase 1 could also involve electrification of the Pacific Harbor Line, more likely with battery -electric switcher locomotives than with overhead catenary, a scenario shown on the map below in Fig. 16. As discussed above, overlap with passenger rail electrification infrastructure could make freight rail electrification between the ports and the Inland Empire more economic. GRID Logistics has proposed 137-mile “Freight Pipeline”, a subterranean pipeline using an electrified robot train. If feasible such a Freight Pipeline would be a possible future variation on short –haul electric freight rail to move containers between the Ports and local destinations<sup>80</sup>.

<sup>80</sup> <http://www.gridinc.biz/thegridproject/>



**Fig. 16. Possible operating scenario of Alameda Corridor electrification using catenary/battery hybrid locomotives, overlaid on map of existing electric utility transmission lines and substations.**

(Background map: California Energy Commission)

*Deep Inland Ports (Victorville, Barstow, Indio)-*

If “deep inland” undeveloped desert areas near Victorville, Barstow, Indio or even further-inland sites such as Needles or Yuma turn out to be the only available Inland Port sites, this could justify an initial rail electrification effort encompassing all three electrification phases listed above in the 2012 SCAG study. These inland facilities could also serve as locomotive exchange points for long-distance freight trains.

The Cajon Pass between San Bernardino and Victorville represents a particularly important opportunity for energy and emissions savings through freight rail electrification. The steep grade between San Bernardino (1,053' elevation) to Cajon Pass (3,777' elevation) climbs over a track length of less than 30 miles. Such a grade is well-suited to an electric locomotive's many advantages in mountainous terrain, including better adhesion, greater power at low speeds, and regenerative braking. The two rail subdivisions through the Cajon Pass, UP Mojave and BNSF Cajon, together represent 256,000 MWh annually of ‘at-wheel’ locomotive energy, or about 60% of all energy consumed by freight locomotives in Southern California<sup>81</sup>. An average of about 90 freight trains per day traverse Cajon Pass, making it the rail section in California which would have greatest emissions and energy-use reductions with electrification. In addition, routing new electric transmission lines along railroad corridors to the desert, such as Cajon Pass, would provide more transmission corridors between solar energy development areas and the Los Angeles Basin.

*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 served by short haul rail, could be designed from the ground up as all-electric, utilizing both electric trucks and electric trains along with electric freight movement equipment. 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. Intermodal facilities could also investigate large-scale energy storage and WEES, as discussed above.

Electric drayage truck demonstration projects are part of the San Pedro Bay Ports Clean Air Action Plan, and several large electric trucks have begun service at the ports. In June 2016, the California Air Resources Board recently awarded \$9 million funds came from the California Climate Investments program for electric trucks, including for two BNSF railroad yards in Commerce and San Bernardino<sup>82</sup>:

...“At BNSF, we believe it is good business and good citizenship to minimize our impact on the environment and to contribute to the long-term sustainability of our business. We welcome the opportunity to participate in this demonstration project to test the viability and effectiveness of using zero-emission trucks inside two of our Southern California facilities,” said Mark Kirschinger, BNSF general manager operations California Division.

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<sup>81</sup>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](https://www.arb.ca.gov/railyard/docs/uoi_rpt_06222016.pdf)

<sup>82</sup> <https://www.arb.ca.gov/newsrel/newsrelease.php?id=824>

The two types of trucks funded by this grant are the most common at every major freight location in the U.S., providing a model for truck electrification that could be scaled to any facility. The project will demonstrate 23 battery-electric 80,000-pound (GVWR) Class 8 yard trucks, also known as “yard goats,” which are used to move heavy freight containers short distances within freight yards, warehouses, distribution centers and port terminals. The project also demonstrates four 16,100-pound (GVWR) Class 5 medium-duty service trucks. BNSF Railway will operate the trucks at two of its intermodal rail yards in the cities of San Bernardino and Commerce; Daylight Transport will also operate the trucks at its new truck freight transfer facility in Fontana.

The grant is part of a larger statewide investment in low-carbon transportation projects that are pivotal to meeting California’s ambitious goals to reduce greenhouse gas emissions, improve air quality and reduce petroleum dependency by accelerating the development and deployment of advanced vehicle technologies. The project also supports the Governor’s Executive Order (B-32-15) to “upgrade freight vehicles and infrastructure” utilizing “technologies, energy sources, and fuels that enable greater transportation efficiency while reducing community and environmental impacts.” The draft California Sustainable Freight Action Plan, required under the Executive Order, was made public last month.

The fully electric trucks will be designed and manufactured by BYD in Lancaster, California.

It should be noted that Berkshire Hathaway owns a 10% stake in China-based BYD, which has its North American headquarters in downtown Los Angeles and its electric truck factory in Lancaster, northern Los Angeles County.

## 11. Electrification of Intrastate and Short-line Freight Rail Lines

Short-line railroads could serve as good demonstration sites for overhead catenary electric or battery-powered switcher locomotives. 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<sup>83</sup>. Notable urban Southern California short lines include the Pacific Harbor Line that operates in and around the Ports of LA and Long Beach, the Los Angeles Junction Railway which provides switching locomotives for the freight yards and industrial facilities east of downtown Los Angeles, the Ventura County Railway that serves Port Hueneme, and the San Diego and Imperial Valley (SD&IY) Railroad described below.

Short line freight railroads in rural Southern California, such as the Baja California Railroad/San Diego & Arizona Eastern Railway Desert Line, the Arizona & California Railroad, and the Trona Railway could offer opportunities to be electrified before long-haul routes of the Class I railroads. The operational nature of these short-haul railroads, with short engine districts, largely avoids the need for locomotive exchanges.

### *San Diego & Arizona Eastern (SD&AE) Railway/ Baja California Railroad (BJRR)-*

The San Diego & Arizona Eastern (SD&AE) Railway was originally completed in 1919, connecting San Diego via Mexico to the Imperial Valley. The only rail line connecting the San Diego-Tijuana metropolitan area to the East, the line has been dormant for most of the past three decades. Reopening the line would add much-needed freight rail capacity for the largest bi-national U.S.-Mexico conurbation, which is presently served by only one freight rail line. The Class III San Diego and Imperial Valley (SD&IY) Railroad, connects 13 miles north from the international border at San Ysidro to the BNSF yard at the Port of San Diego. Freight rail capacity on the BNSF San Diego Subdivision, which connects to the BNSF Southern Transcon in Orange County, is constrained due to sharing of the track with a large number of passenger trains.

In Mexico, the Baja California Railroad (BJRR) runs along the SD&AE route for 44 miles from the San Ysidro Port of Entry in Tijuana to the border near Tecate (Mexico) and Campo (U.S.). The railroad continues as the SD&AE Desert Line for 70 miles to Plaster City. The Desert Line is publicly-owned by the San Diego Metropolitan Transit System (SDMTS). In June 2016, the Tijuana-based BJRR entered into a sublease for most of the Desert Line from the Pacific Imperial Railroad (PIR), a company which previously leased the tracks from the SDMTS. Between \$60 and \$70 million in repairs on 70 miles of track are needed to the Desert Line, including on 57 bridges and 17 tunnels, before any freight can be moved again on the line. The two rail companies will pay for the renovations.<sup>84</sup> Due to BJRR's upgrade and repair efforts, service was recently restored for the entirety of the line's route in Mexico.

Mexico is California's number one international market, consuming about \$25 billion, or 15% of the state's exports. The manufacturing industries of California and Mexico are closely intertwined. About 98% of all freight movement between California and Mexico is by truck, with 1.6 million truck border crossings per year, or about 4,400 per day. The remaining 2% of freight moved across the border by rail by the SD&IY interchanging with BJRR at San Ysidro, and on the UP Calexico sub, interchanging with Ferromex railroad at Mexicali. The poor air quality near border crossings, both in the

<sup>83</sup> 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](https://www.arb.ca.gov/msprog/tech/techreport/freight_locomotives_tech_report.pdf)

<sup>84</sup> "Border rail line to connect U.S., Mexico", *San Diego Union-Tribune*, June 9, 2016:

<http://www.sandiegouniontribune.com/business/sdut-desert-line-gets-new-operator-repairs-starting-2016jun09-story.html>

San Diego-Tijuana metropolitan area and the Imperial Valley, could be improved by shifting freight from truck to electric rail.

San Diego officials estimate that over \$6 billion in regional economic activity lost annually due to trucks delayed crossing the border<sup>85</sup>. Tijuana is Mexico's fifth-largest metropolitan area, and one of North America's major manufacturing centers. Shifting of more freight from truck to the BJRR rail line would ease congestion and reduce air pollution from the region's three Ports of Entry at San Ysidro (the world's busiest land border crossing), Otay Mesa and Tecate. As described by BJRR's website for the Desert Line project<sup>86</sup>:

The Desert Line rehabilitation will be an opportunity for the maquiladora industry in the region regarding transportation logistics. The reopening of this old route will become a new alternative for freight movement to the East Coast of the United States.

The Desert Line has a length of 70.06 miles from Tecate to Plaster City, consisting of 57 bridges that go from 9 feet to 650 feet tall, and 17 tunnels with a length from 174 feet up to 2,602 feet long, all clearing up a height from 21'7" to 24'11".

In the agreement, BJRR will have the responsibility to operate, maintain, and rehabilitate the existing railroad track from Tecate Mexico/ Tecate Mile Post to Coyote Wells, while PIR will rehabilitate the from Coyote Wells to Plaster City, connecting with one of the main railroad systems in the United States [UP Sunset Corridor].

..The Desert Line will be a new freight route that increases the freight capacities offering more logistical opportunities, reducing truck traffic in Mexico and the United States.

Facts to consider:

- Daily there is a trade of \$ 2.1 million dollars between San Diego and Tijuana.
- 135,000 cars and 6,200 truck cross from Mexico to the United States daily at the San Ysidro, Otay Mesa and Tecate Port of Entry, with an estimate of a 2-hour border wait.
- An estimated 6 billion dollars are lost annually due to border delays of trucks carrying freight.

PIR intends to build an intermodal facility near Coyote Wells in Imperial County to load freight and provide space to assemble the 100+-car trains that can be delivered to the Union Pacific main line network.

#### *Trona Railroad-*

Trona Railway is a 30.5 mile short-line railroad owned by Searles Valley Minerals, which Interchanges at Searles with the UP Lone Pine Subdivision. UP Lone Pine Subdivision travels north from Mojave to connect to the Trona Railway.

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<sup>85</sup> "MTS cheers deal to rebuild Desert Line railway for Tijuana link", *Times of San Diego*, 9 June 2016:

<http://timesofsandiego.com/business/2016/06/09/mts-cheers-deal-to-rebuild-desert-line-railway-for-tijuana-link/>

<sup>86</sup> <http://bajarr.com/eng/news/joint-venture-between-baja-california-rail-road-and-pacific-imperial-railroad-provides-boost-to-regional-growth-2/>

*Southwest Portland Cement Railroad-*

Southwest Portland Cement Railroad, owned by CEMEX, is a 14-mile short-line railroad between Black Mountain quarry to the BNSF Cajon Subdivision in Victorville.

*Electrification of Intrastate line-haul freight lines operating within California-*

Intrastate freight rail, trips typically less than 500 mile between regions within California, has been largely ignored by Class I railroads to reasons similar to short-haul rail. Of California intrastate freight traffic, 98% of ton-miles is by truck and only 2% by rail. Each year, about 160 million tons (8.5 million truckloads) of freight travels between various subareas of California. Increasing the amount of intrastate freight shipped by rail would reduce air pollution, fuel consumption and reduce North-South truck traffic on Interstate 5 and State Route 99 in the Central Valley.

A 2017 article by Michael Setty in *California Rail News* proposed electrifying a new freight rail line over Tejon Pass, paralleling Interstate 5<sup>87</sup>. In order to be competitive with truck for distances less than 500 miles, intrastate trains would be have to be much faster than a conventional U.S. line-haul freight train. Electric intrastate freight trains can be faster than truck over mountain grades such as Tejon Pass, due to the higher tractive effort of electric locomotives. Light, fast and relatively short (10 to 50 car) trains carrying intermodal container or roll on/off trailers, similar to those in Europe, could share electrified passenger tracks.

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<sup>87</sup> Michael Setty, "'Electric fast freight' in California? Moving short-distance truck freight to rail", *California Rail News*, May-September 2017: <http://www.calrailnews.org/wp-content/uploads/2017/06/crn0617h-web.pdf>

## 12. 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:<sup>88</sup>

### 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 to its major yard at Clovis, about 1,000 track miles east from Los Angeles would be 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 electrification between California and the Southeastern U.S.

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<sup>88</sup> *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](https://www.arb.ca.gov/railyard/docs/uoi_rpt_06222016.pdf)

### 13. Strategies for Financing Rail Electrification in Southern California

The capital cost of electric catenary infrastructure is the number one reason that U.S. freight railroads have resisted electrification. Freight railroads are among the most capital-intensive industries in the world, combined with historically low rates of return. U.S. freight railroads have thus traditionally been highly risk-adverse. The large amounts of capital required for installing catenary wire over track, could otherwise be spent by a railroad company on 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 largely 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 to the ongoing 'Alameda Corridor East' improvement projects<sup>89</sup> 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 (SCRRRA) and the electric utility SCE<sup>90</sup>:

SCENARIO ONE: 100% Rate Based: SCE Customer Paid

SCENARIO TWO: 40% Rate Based: SCE Customer Paid

SCENARIO THREE: 40% Rate Based: SCRRRA 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: SCRRRA Funded
- 10% Freight Railroad Participation.

The RAIL Solution organization and the Solutionary Rail campaign have proposed a Steel Interstate Development Authority (SIDA) infrastructure bank, a nonprofit corporation financed with low-interest, government-subsidized loans

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<sup>89</sup> <http://www.theaceproject.org/>

<sup>90</sup> *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>

to fund electrification infrastructure along a rail corridor that traverses multiple cities, counties or states<sup>91</sup>. 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 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 Southern California utilities already familiar with electric passenger rail systems. The SIDA would negotiate with right-of-way owners to site infrastructure, and the same owners would make commitments to use it.

Possible funding sources for clean freight projects in California, described by the California Sustainable Freight Plan include<sup>92</sup>:

- Goods Movement Emission Reduction Program
- Trade Corridors Improvement Programs
- Carl Moyer Memorial Air Quality Standards Attainment Program
- California Infrastructure Revolving Fund Program
- Alternative & Renewable Fuel and Vehicle Technology Program
- California Pollution Control Financing Authority
- California Alternative Energy & Advanced Transportation Financing Agency
- Low Carbon Transportation Investment and Air Quality Improvement Program
- National Corridor Planning & Development Program
- Coordinated Border Infrastructure Program

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<sup>91</sup> 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, pgs. 56-58.

<sup>92</sup> California Sustainable Freight Plan, pgs. 6-20 to 6-27

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