Caltrain Electrification and Statewide Electrification Developments and Outlook

Rail Passenger Association of California and Nevada (RailPAC)

October 2024

Stadler Caltrain KISS Electric Multiple Unit

The Mercury News

Caltrain Electrification

- A milestone in the 160 years of SF Peninsula rail Service.
- State of the Art 25kV, 60 Hz Overhead Catenary System.
- Stadler KISS Electric Multiple Unit Trains.
  - Light-weight aluminum car bodies with a high-performance traction system.
  - Utilizing crash energy management, FRA compliant for mixed traffic routes.
  - Fully accessible and with capacity for large number of bicycles.
  - Over 1,145 cars produced and in-service in eleven countries.
- Replaces diesel locomotives meaning lower criteria pollutants, a reduction in noise and Greenhouse Gas Emissions.
- Provides a framework for future High-Speed Rail Service.
- New equipment, with faster more frequent service provides a critical foundation for the reimagining of Caltrain Service from commuter service to regional rail service.
- Transitions Caltrain from a service focused on the 9 to 5 commuter, to a service more attractive to hybrid workers, entertainment and sports travelers and shift workers outside the 9-to-5 schedule and weekend riders.

Caltrain Electrification Challenges

Mega-projects face many challenges in their construction – Caltrain's Electrification project was no exception

- No institutional foundation of megaproject management and expertise. Each agency is on a learning curve with limited staffing and expertise.
  - California's county-centric governance model exacerbates this issue.
- The lack of dedicated funding, resulting in stop and start project progress, adds to the project timeline and hinders the ability to build management staff and expertise.
- The long environmental, planning and permitting process adds time to the project.
  - The planning process overweight's the concerns of local stakeholders with no internal process to balance local concerns compared to regional benefits.
  - Politicization of projects to achieve macro policy goals outside of the project itself.
- Changes in scope, often to mitigate project impacts, partway through the planning process.
- The complex impact of construction inflation, original cost estimate vs. year of expenditure cost, on projects with decades long planning and construction timelines.
- Caltrain also faced additional challenges.
  - Contractor missteps
  - Seen as a proxy for High-Speed Rail it faced heightened political opposition.
  - Covid related supply chain material delays.

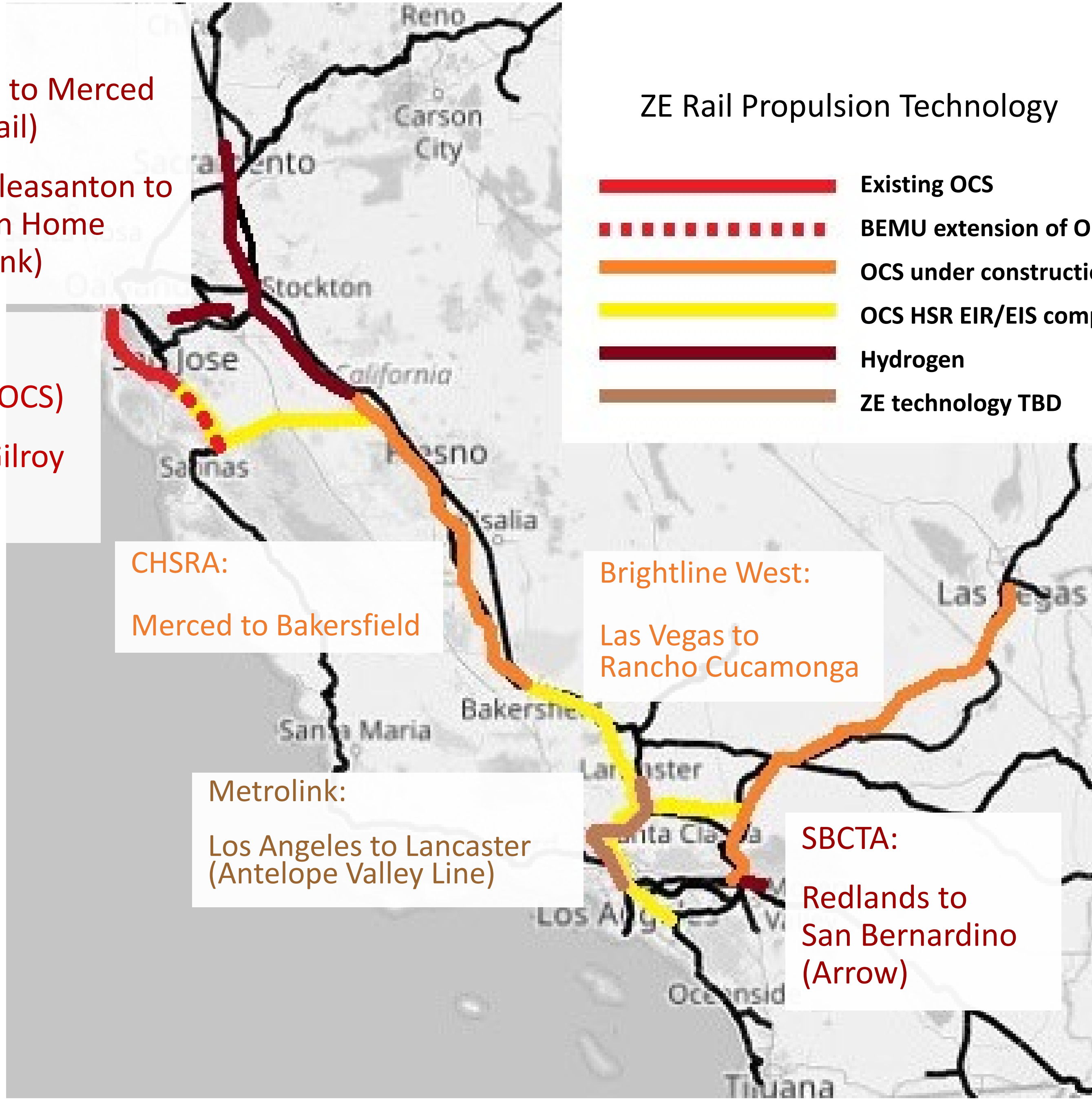
Current ZE Implementation Status

- The near-term goal is testing of Zero Emission (ZE) Rail Vehicle alternatives, making significant progress and achieving transition mileposts by 2035.
- The California Legislature has passed, and the Governor has signed Assembly Bill 2503 by Assembly Member Alex Lee, that exempts, until 1/1/2030, project (electrification) for passenger rail service, which will be exclusively used by zero-emission trains, located entirely within existing rail rights-of-way.
- Except for overhead catenary electrification, no alternative technology is currently available to meet operational requirements.
- Discontinuous/incremental electrification should be more fully explored as a ZE rail option.

Zero Emission Rail Vehicles - Looking Forward

- Work underway on testing ZE rail options on seven routes utilizing three technologies.
- Overhead Catenary Systems
  - CHSRA; Merced – Bakersfield, design and pre-construction.
  - Brightline West; Rancho Cucamonga – Las Vegas, design and pre-construction.
- Hydrogen/Battery
  - San Bernardino County Transportation Authority (SBCTA); Arrow-San Bernardino to Redlands-University, trainset delivered, construction of maintenance and fueling facility.
  - San Joaquin Regional Rail Commission (SJRRC); Valley Rail-Natomas to Merced and Valley Link-Dublin/Pleasanton (BART) to Mountain Home, trainsets under construction.
- Battery Electric Multiple Unit
  - Caltrain; San Jose to Gilroy, trainset under construction.
- Technological Options Under Study
  - Southern California Regional Rail Authority (SCRRA); Metrolink Los Angeles to Lancaster, options include hydrogen/battery or battery electric multiple unit combined with segments of overhead catenary.

Current Zero Emission Rail Initiatives



SJRRC:

Natomas to Merced (Valley Rail)

Dublin/Pleasanton to Mountain Home (Valley Link)

Caltrain:

SF-San Jose (OCS)

San Jose to Gilroy (BEMU)

CHSRA:

Merced to Bakersfield

Metrolink:

Los Angeles to Lancaster (Antelope Valley Line)

Brightline West:

Las Vegas to Rancho Cucamonga

SBCTA:

Redlands to San Bernardino (Arrow)

ZE Rail Propulsion Technology

- **Existing OCS**
- **BEMU extension of OCS**
- **OCS under construction**
- **OCS HSR EIR/EIS completed**
- **Hydrogen**
- **ZE technology TBD**

Brightline West Siemens HSR Trainset

- In May 2024 Brightline West signed a contract with Siemens to provide a fleet of ten “American Pioneer 220” (AP 220) train sets to be manufactured, delivered to Nevada and tested to support Brightline West’s timeline of initiating service in 2028.
- Power system 25kV/60 Hz OCS.
  - Maximum operating speed: 220 mph.
- The seven-car trains will carry between 434-450 passengers, depending on final configuration and can make the trip in less than two hours.

Stadler KISS Battery-Electric Multiple Unit

- Battery-electric multiple unit, equipped with a pantograph, that can operate as a fully electric EMU under catenary or operate on battery power on a route segment without catenary.
- Battery is charged during regenerative braking, while operating under catenary and during station layovers from overhead catenary.
  - Range; BEMU will have battery capacity to travel the 60-mile round-trip between Gilroy and San Jose.
- Power system 25kV/60 Hz OCS (with pantograph)
  - Maximum operating speed: 110 mph.
- The four-car trainset consists of bi-level trainset consist of three passenger cars and one battery/power systems/driving car. Fully accessible and includes bicycle parking spaces.
- Utilizing crash energy management, FRA compliant for mixed traffic routes.

Operating Plan

- The proposed service plan from San Jose to Gilroy will depend on the timeline for CHSRA's electrification of that line.
- The KISS BEMU will likely be tested in a number of different operating scenarios and temperature conditions.
  - San Jose – Gilroy
  - San Francisco – Gilroy
  - Gilroy - Salinas
- After testing it is likely that the KISS BEMU will replace one of the diesel shuttle trains. If the in-service performance is successful, additional KISS BEMUs will be ordered. This will allow the replacement of all San Jose – Gilroy diesel shuttle trains.
- A longer CHSRA construction timeline would likely see the BEMUs operating as a combination of shuttle trains (San Jose- Gilroy) and Regional Express trains from Gilroy to San Francisco (making local stops San Jose – Gilroy).
- A shorter CHSRA timeline for San Jose to Gilroy electrification would see the KISS BEMUs operating on selected Caltrain Regional Express Trains from San Francisco to Salinas.

Stadler FLIRT Hydrogen-Battery

(Photo: Keith Fender, *Trains* 9/21/22)

- Stadler's hydrogen/battery Flirt trainset, built for SBTA Arrow Service.
  - SBTA budget is $60 million for one trainset and one fueling facility.
- Similar trainsets a currently being built for SJRRC's new Valley Rail and Valley Link services.
- Hydrogen fuel cells produce electricity to charge batteries which then power the train.
  - Hydrogen fuel cell offers longer range than batteries alone but needs batteries for high power situations.
  - Does not require investment in overhead catenary, but investment in fueling facility required.
  - Risks around the volatility of hydrogen.
- Four car configuration has a top speed of 90 mph with 232 seats with a seat pitch of 32".
  - Trainset is fully accessible.
  - Utilizing crash energy management, FRA compliant for mixed traffic routes.

Operating Plan

- San Bernardino to Redlands University- Arrow, San Bernardino County Transportation Authority (SBCTA).
  - Frequent shuttle service between Redlands-University and San Bernardino Metrolink Station.
  - If the in-service performance is successful additional FLIRT Hydrogen-Battery trainsets could be ordered. This will allow the replacement of all FLIRT diesel trains.
  - The SBCTA FLIRT H2 trainset will likely be tested on other routes.
    - San Bernardino – Los Angeles
    - Los Angeles - Lancaster

- Natomas (Sacramento Airport) to Merced – Valley Rail, San Joaquin Regional Rail Commission (SJRRC)
  - Frequent Regional Rail Service connecting Valley cities utilizing the Union Pacific Railroad.
  - Connects with High-Speed Rail at Merced.
  - The SJRRA FLIRT H2 trainsets will likely be tested on other routes.
    - San Joaquin Merced to Oakland and Sacramento.
    - Coast Route San Jose to Santa Barbara.

- Dublin/Pleasanton BART station to Mountain House – Valley Link, San Joaquin Regional Rail Authority.
  - Frequent shuttle service from the San Joaquin Valley connecting to BART Regional Transit.
  - Future route extensions planned first to Lathrop, and then to Stockton.

Technological Options Pros and Cons

Hydrogen Fuel Cell (combined with Battery)

Pros
- Incremental phase-in of technology and hydrogen powered units
- Longer range than battery (only) trains.
- Promise of minimal operational changes (similar to diesel) due to shorter fueling time and one-for-one replacement of diesel locomotives.

Cons
- Technology is still under development.
- Lowest efficiency of any of the alternatives (under 40%) comparable to diesel.
- Source of hydrogen (currently most from fossil fuel), risk of “Greenwashed”. hydrogen
- Cost of carbon capture (Blue Hydrogen) and risk of leakage from carbon capture.
- Water supply an issue in the West for “Green Hydrogen” sourced from electrolysis.
- More costly and complex technology than other technologies – still requiring costly batteries.
- Reliability- the inherent complexity of hydrogen drivetrains means more potential points of failure
- Cost of hydrogen fuel is uncertain subject to market forces/international political tensions.
- Weight of fuel cell, hydrogen storage containers and batteries negatively impacting acceleration and schedule performance.
- Low energy density compared to other fuels.
- Safety risks of hydrogen leakage.

Technological Options Pros and Cons

Battery-only Technology

Pros

- Less technologically complex than hydrogen.
- Benefiting from auto experience, a more fully developed technology; less risk.
- Overall, a 75% - 80% efficiency more than double that of hydrogen.
- Incremental phase-in.
- No fundamental operational changes required.

Cons

- Cost of batteries and charging infrastructure.
- Cost of grid improvements to support high power demand at charging facilities.
- Higher operating and maintenance costs compared to catenary technology.
- Unit range lower and recharging time longer than alternative technologies.
- Weight of batteries reduces power to weight ratio negatively impacting. acceleration/schedule performance.
- Battery performance/range negatively impacted by high heat or severe cold conditions.
- Safety hazards (fires and chemical spills).

Technological Options Pros and Cons

Overhead Catenary/Overhead Contact System (OCS)

Pros

- Proven technology, off the shelf commercial product in use worldwide in a range of services, operating demands – not impacted by severe heat or cold conditions.
- Highest efficiency greatly exceeding that of alternative technologies (90%+).
- Unlimited range.
- Lowest operating cost best of all alternatives, generating significant out year life-cycle savings.
- Proven resiliency, lowest operating and maintenance costs and long service life.
- No investment in fueling or static battery charging stations required.
- OCS efficiency factors yield the lowest life cycle costs of any technology.
- No out of service time for fueling or battery charging, equals more frequencies.
- High power to weight ratio enables faster acceleration, reduced schedules resulting in higher ridership and ticket revenue.

Cons

- Very large upfront capital cost.
- Service cannot begin until the entire route including ancillary tracks is electrified.
- Requires a change in operations. Electrified service limited to electrified lines; locomotive changes required
- Opposition from lineside stakeholders can delay the entire project for years.
- Limited manufacturer promotion in the US.

Technological Options Pros and Cons

Discontinuous Electrification: Battery combined with sections of Overhead Catenary

Pros

- Addresses the range limitation of batteries and the high upfront costs of overhead catenary electrification.
- High efficiency levels – 80% - 85% depending on miles of catenary (% of route with OCS)
- Lower operating and maintenance costs than hydrogen.
- Incremental phase-in; vehicle battery investment and catenary investment can be balanced to produce the optimum financial and operating performance.
- Avoids the high cost of grid upgrades for central battery charging facilities.
- Minimizes conflicts with lineside stakeholders with concerns over catenary.

Cons

- Complexity and costs of the mixing of technologies.
- Lack of economies of scale in the cost per mile for segments of overhead catenary.
- Other technologies benefit from complete vendor packages and promotion.
- Early phase-in pairing with diesel locomotives for reliability/range during testing may create a challenge with some stakeholders.
- Presence of on-board batteries increases maintenance costs and adds safety risks.
- Battery weight will negatively impact passenger train performance.

Overall Energy Efficiency of Technology Options

Technological Option	System Energy Input (MWh equivalent)	At Rail Energy Output	Energy Efficiency (range*)
Overhead Catenary	13 ~ 14 Megawatt Hours	10 Megawatt Hours	72 ~ 77%
Discontinuous Electrification	~14.5 Megawatt Hours	10 Megawatt Hours	70 ~ 74%**
Battery Only	14 ~ 18 Megawatt Hours	10 Megawatt Hours	56 ~ 71%
Hydrogen Battery	40 ~ 60 Megawatt Hours	10 Megawatt Hours	17 ~ 25%
Tier 4 Diesel	25 ~ 29 Megawatt Hours	10 Megawatt Hours	35 ~ 40%

Source: Mike Iden, "Freight Railroad Decarbonization & Energy Efficiency: The Dual Challenge for Railroads (Version 2)", UIUC Hay Seminar presentation, September 27, 2024: https://railtec.illinois.edu/wp/wp-content/uploads/UIUC-Hay-Seminar_Iden_20240927.pdf

* Adjusted for energy lost as a result of locomotive system transfer inefficiencies **RailPAC Estimate

- Overhead Catenary Electrification is the most efficient, Hydrogen Fuel Cell the least.
  - This has major implications for grid capital investment and long-term operating costs

“Zero Emissions” Rolling Stock Cost Europe comparison- All-Electric, Battery and Hydrogen

Compared to a typical new overhead catenary electrical multiple unit (EMU) passenger train in Europe…

- ***Battery trains are about 2 times more expensive*** **than a standard EMU:**

~ $5 million per ‘U.S.-length railcar’

[based on recent order of € 100 million for 11 ‘three-car’ Alstom battery trains in Germany]

- ***Hydrogen trains are about 4 times more expensive*** **than a standard EMU:**

~$11 million per ‘U.S.-length railcar’

[based on recent order of € 500 million for 27 ‘two-car’ Alstom hydrogen trains in Germany]

- This price differential is due to the cost of the batteries. These technologies also much more expensive to maintain and operate. Adding to the cost of these technologies is the cost of battery mid-life replacement and used battery disposal.

"Zero Emissions" Rolling Stock Cost California comparison- All-Electric and Hydrogen

- The two-car SBCTA Arrow hydrogen-powered Stadler FLIRT H2 has a published seating capacity of 116 passengers. Therefore, it follows that the four-car version of the FLIRT H2 would seat 232 passengers. If such a trainset costs Caltrans $21 million each, that would work out to approximately **$90,500 capital cost per passenger seat**.

- Caltrain's double-decker Stadler KISS EMU eight-car trainsets reportedly cost about $50 million each. A single trainset of eight double-decker KISS cars can carry about 800 people, which works out to **$62,500 capital cost per passenger seat**.

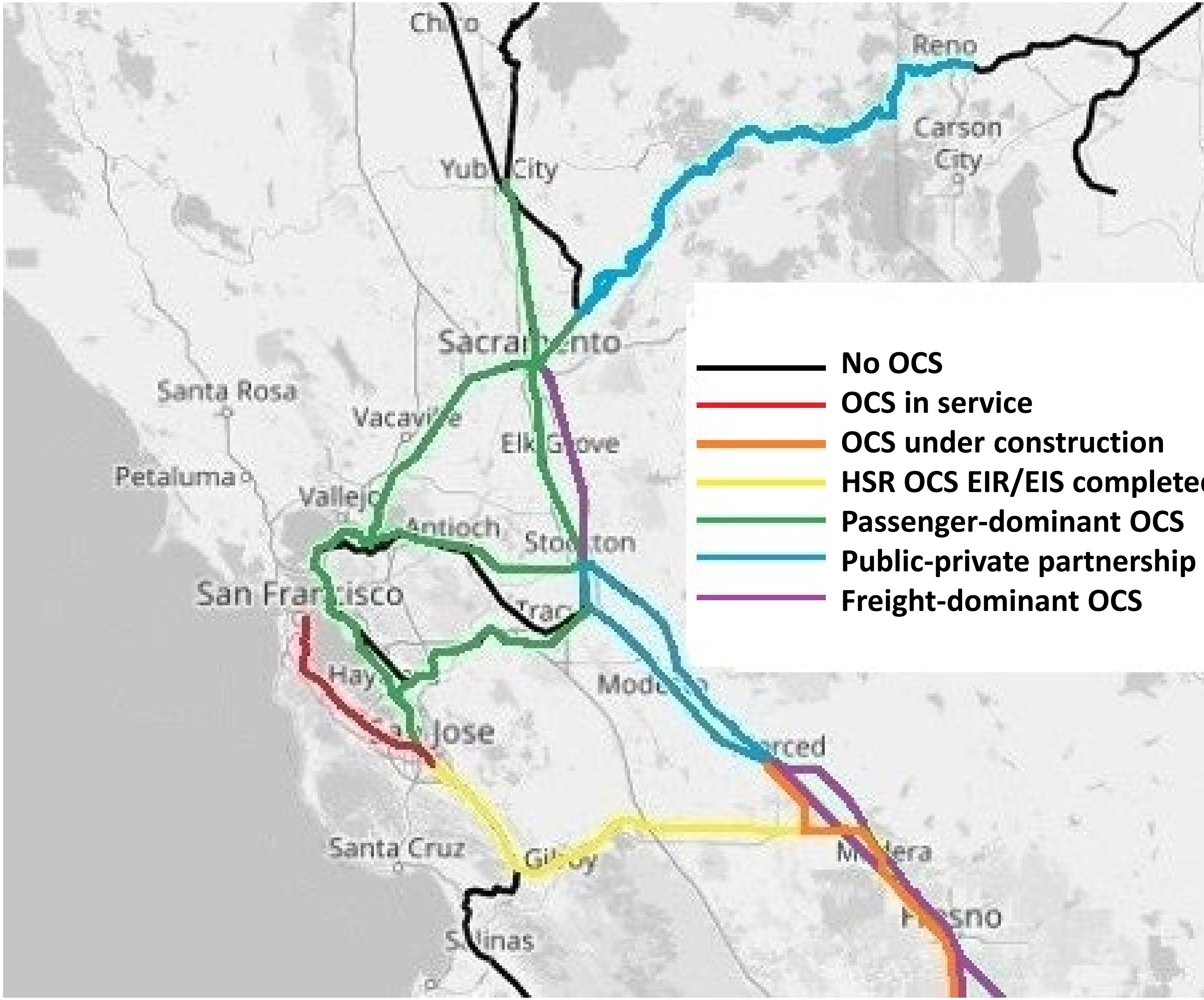
Note: These figures are only for the upfront capital cost of rolling stock, and do not take into account the per-passenger costs of other required capital costs such as OCS/electric power or hydrogen or supply infrastructure and fueling systems, nor the O&M costs of the trains.

Viewing the Path Forward

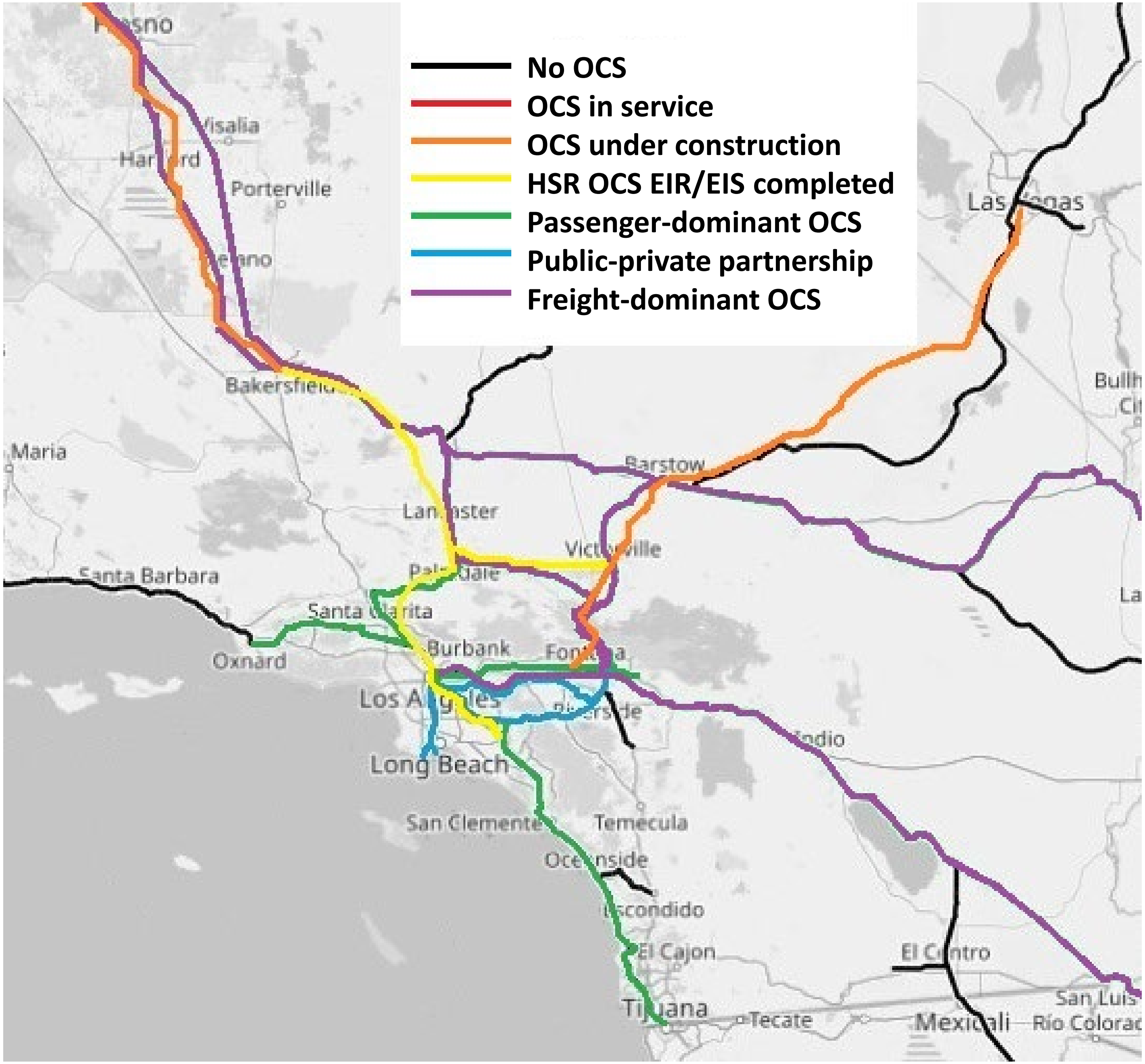
By measures of train frequency (passenger), gross tons of freight per year, gradient profile and life cycle Return on Investment, key California rail routes (both freight and passenger) exceed the Return on Investment threshold for Overhead Catenary System electrification.

- The choice should be the alternative that transitions to Zero Emissions and generates a strong life-cycle return on investment.
- When reviewing Northern and Southern California maps, consideration should be given to increased interest in container shuttle trains from the Ports of Los Angeles/Long Beach to Inland ports at Las Vegas, Sparks/Fernley, NV and Salt Lake City. Adding this tonnage to these routes will likely allow the market financed installation of OCS on these lines.

Northern California High-Volume Trunk Lines



Southern California High-Volume Trunk Lines



Freight Rail Concerns

- High initial capital cost of Overhead Catenary Systems negatively impacting cash flow, stock price, financial position and increasing overall financial risk during any potential traffic downturn.
- Operating challenges as a result of a mix of locomotive technologies.
- Double-stack clearance issues and heavy-haul power issues.

Double-stack train under wire in Penns.   Norway-Sweden heavy haul electric train

Electric Freight Rail

Electric train carrying double-stack containers under 25 kV wire in India

China Railways HXD1 series 12,900 hp freight locomotive set, under 25 kV overhead catenary wire pulls 20,000 ton coal trains

Addressing Freight Rail Issues

- Given the rebuilding of a substantial percentage of older locomotives, the freight railroads face a substantial capital expense in the 2035-45 period even for in-kind locomotive technology replacement.
- All the proposed Zero Emission alternatives involve a substantial capital outlay.
- During the transition period, all proposed Zero Emission alternatives will result in operational challenges (i.e. more frequent enroute power change-outs, power for lower volume lines, etc.).
- Several railroad sponsored studies on heavy-haul routes over the last few decades have shown a strong financial payback from the investment in overhead catenary systems.
- The option of Discontinuous Electrification brings a new flexible option to the analysis – technological adoption, operational impact and financial impact.

Addressing Freight Rail Issues

- The perception of the freight railroads as a declining business with the focus on the near-term maximization of cash flow/stock price to investors, clouds long-term investment decisions.
- For overhead catenary systems the barrier is not technology but the development of a viable financial package that de-risks the initiative.
  - Required is an off-balance sheet financial package such as low interest loans, tax credits, partnerships with utilities, etc. that facilitate both long-term investment with continued strong near-term rail company financial performance.
- Freight railroads and their stakeholders need to develop a solid business case of how electrification can reduce Operating and Maintenance costs while improving throughput/performance, especially on mountain grades.

Railroad electrification around the world (both passenger and freight combined, as of 2022)

Over 30% of the world's railroad track is electrified (electrified trackage is growing every year) the US should join the trend

Country	Miles Electrified (approx.)	Percentage Electrified
Ethiopia/Djibouti	470	100%
Armenia	435	100%
Switzerland	3,200	99%
Laos	256	98%
Belgium	1,900	85%
India	34,300	83%
Georgia	800	82%
Italy	8,200	79%
South Korea	2,300	78%
Sweden	7,600	76%
Netherlands	1,400	76%
Japan	12,500	75%
Taiwan	800	73%
Bulgaria	1,800	71%
Portugal	1,100	71%
Austria	2,400	69%
North Korea	2,400	68%
Norway	1,600	68%
Spain	6,900	68%
China	62,000	67%
Poland	7,500	65%
Azerbaijan	790	60%
Bosnia and Herzegovina	350	56%
Germany	14,000	55%
Finland	2,000	55%
France	9,700	54%
Russia	27,200	51%
Morocco	630	49%
South Africa	5,900	47%
Ukraine	5,800	47%
Slovakia	1,000	44%
Turkey	3,400	43%
Uzbekistan	1,600	39%
United Kingdom	3,800	38%
Israel	155	18%
Iran	1,400	17%
United States	**1,500**	**< 1 %**

Appendix One

Exhibit 8-10: Southern California rail line capacity by subdivision, 2022

Corridor	Freight trains per day	Passenger trains per day	Total trains per day	Minimum # of tracks	Trains per track	Signaling	Practical capacity (trains per day)	LOS grade
Alameda Corridor	31	0	31	3	10.3	CTC	163	A
BNSF San Bernardino, LA to Fullerton	56	46	102	3	34.0	CTC	148	C
BNSF San Bernardino, Fullerton to San Bernardino	56	26	82	2	41.0	CTC	90	E
BNSF Cajon	66	2	68	2	34.0	CTC	99	C
BNSF Needles	62	2	64	2	32.0	CTC	99	C
BNSF Mojave	21	0	21	1	21.0	CTC	48	C
UPRR Los Angeles	16	11	27	1	27.0	CTC	39	C
UPRR Alhambra	9	1	10	1	10.0	CTC	45	B
UPRR Mojave	10	0	10	1	10.0	CTC/ABS	25	C
UPRR Cima	13	0	13	1	13.0	CTC	48	B
UPRR Yuma	21	1	22	1	22.0	CTC	47	C
Metrolink San Bernardino	4	36	40	1	40.0	CTC	45	C
Metrolink Antelope Valley, LA to SC	8	60	68	2	34.0	CTC	96	D
Metrolink Antelope Valley, SC to Lancaster	9	22	31	1	31.0	CTC	41	D

Below capacity   Near capacity   At capacity

Source: National Rail Freight Infrastructure Capacity and Investment Study, prepared by Cambridge Systematics for the Association of American Railroads, September 2007; FRA grade-crossing data; Oliver Wyman analysis

From: Dec. 2023 Oliver Wyman short-hail rail study for Pacific Harbor Lines

Discontinuous Electrification Phase In

- Phase One – Proof of Concept
  Battery electric locomotives with a test group of existing trainsets utilizing a 15-mile segment of catenary, paired with a diesel locomotive for reliability.
  Test in motion pantograph nesting with catenary at speed, range of battery electric locomotive with enroute, in-motion electric power supply.
  Utilize actual operating data to determine optimum catenary segments and their length.
- Phase Two – Implementation Battery Electric Service
  Construct additional segments of catenary, if required, and equip all trainsets with battery locomotives.
  Implementation starts to minimize lineside emissions and maximize GHG Savings.
  Test maximum in-service range of battery electric locomotive with protect diesel locomotive to assure reliability under all conditions to expand the number of frequencies with the same number of trainsets.
- Phase Three – Extend Overhead Catenary
  With ridership growth, increase in frequencies, desire for faster schedules, in conjunction with re-fleeting with EMU’s, transition to full OCS electrification if appropriate.

Appendix Two

Comments/Talking Points

- Slide 4 – **Caltrain Electrification Challenges;**
  - (2nd bullet) The result is a reliance on consultants.
  - (5th bullet) The inability to articulate to the general public regarding construction cost inflation when weighing value of Dollars at the Alternatives Analysis point vs. the value of Dollars at the year or expenditure, the real cost is the same.
- Stakeholders are generally involved in only one Mega-Project perceiving it as unique.
- Slide 7 – **Current Zero Emission Initiatives (Map);**
  - Almost 400 route miles of OCS high-speed rail is under design and construction
  - Note: LA-Anaheim HSR OCS EIR/EIS is nearly completed, but not yet formally approved.
- Slide 9 **– Stadler KISS Battery-Electric Multiple Unit**
  - The range under ideal temperature conditions, speed and grades may be approximately 90 miles.

Comments/Talking Points

- Slide 13 – **Hydrogen Pros**;
  - No operational changes/adjustments required
  - Potentially lower upfront costs or costs borne by others (fuel companies)

  Hydrogen Cons;
  - Technology and its capabilities still under development, high number of unknowns
  - Efficiency under 40%
  - Poor performance in cold weather
  - Range, while better than battery only trains, is only a fraction of diesel trains
  - Technology is inherently very complex, leading to higher costs and more points of failure
  - Many potential external costs which will be reflected in fuel costs
  - Cost of hydrogen production, cost of carbon capture, cost of fuel transport and storage and cost of fueling facilities
  - Battery development running apace with hydrogen improvements yielding little net gain for hydrogen.

Comments/Talking Points

- Slide 14 – **Battery Only Pros**;
  - Potentially lower upfront costs or costs borne by others (power companies)
  - One-for-one unit replacement
  - 77% efficient

  Battery Only Cons;
  - Battery technology with the capability to deliver range and schedule turn times still under development, increased risk
  - Long charging time will require more trainsets than alternative technologies
  - Cost of grid improvements provided by others reflected in higher electricity costs
  - Higher electricity (fuel) costs as battery only trains are less efficient than Overhead Catenary trains

Comments/Talking Points

- Slide 15 – **Overhead Catenary Pros**
  - 90% Efficient
  - Almost unlimited peak time power available for critical short-time operational requirements
  - Cost of fuel (electricity) is less than equivalent diesel or hydrogen fuel
  - No refueling or battery charging time means less trainsets required
  - Because OCS divides its trainset power draw over multiple utility substations spread along its route, the requirement for power grid upgrades is potentially less than for battery only technology with its static charging locations
  - Combination of agency owned behind-the-meter solar and battery storage facilities can provide an opportunity to substantially reduce operating costs (power) along with an upside revenue potential from power sales to the grid during grid peak power demand
  - With fewer moving parts, OCS electric trains are more reliable resulting in lower maintenance costs than alternative technologies

  OCS Cons
  - Entire route including key sidings, station, yard and service tracks required to be electrified for service to begin
  - Limited manufacturer/promotion, all costs are borne within an agency's budget

Comments/Talking Points

- Slide 16 – **Discontinuous Electrification – Pros**
  - 80 – 85% efficiency depending on the percentage of track miles with catenary
  - During transition can integrate with existing equipment and power consists
  - Investment timeline for further catenary investments can match service requirements and the level of grant awards
  - Can be incremental first step to full overhead catenary electrification by allowing electric operations to begin before the entire route is wired

  Discontinuous Electrification – Cons
  - Like full OCS electrification all costs are borne within the rail budget. No trade-off of vendor borne capital costs shifted to out-year power/fuel costs
  - No vendor offers a complete turn-key package. Agency will have to develop and manage the mix of the two technologies
  - Discontinuous Electrification is an unknown concept not well understood by grant awarding entities.
  - Like full OCS electrification all costs are borne within the rail budget (unless partnered with a utility). There is no trade-off of vendor borne capital costs shifted to out-year fuel costs

Comments/Talking Points

- Slide 22 – **Southern California High-Volume Trunk Lines (Map);**
  - Note: LA-Anaheim HSR OCS EIR/EIS is nearly completed, but not yet formally approved.

Comments/Talking Points

- Slide 30 – **Discontinuous Electrification Proof of Concept**
  - Test for seamless transfer of motive power from diesel to electric and electric to diesel
- Slide 30 – **Discontinuous Electrification Implementation Battery Electric Service**
  - To assure reliability at service launch limit frequency growth and build in additional turn time for full charging
  - For highest utilization trainsets pair with diesel locomotive to assure reliability
- Slide 30 – **Discontinuous Electrification Extend Overhead Catenary**
  - Balance mix of catenary, critical segments without catenary, frequencies the number of batteries in the new equipment
  - Generate increased ridership and ticket revenue, lower emissions and GHG savings from customer mode switch