4 California Rail Scenarios to 2050

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RESEARCH QUESTION

Freight rail has been on an upward national trend over the last couple of decades (notwithstanding a recent, likely temporary dip in rail traffic). Reducing freight rail emissions will depend largely on fuel technologies (as with automobiles), and the pace of growth and new locomotive production are, to some extent, limiting factors. On the other hand, the freight rail industry has few actors, and rail movements are highly centralized, which would allow for high levels of coordination during any transition. This research aimed to examine some potential scenarios for emissions reduction in rail, looking at California rail movements only, looking forward to 2050.

FUELS BACKGROUND

Diesel-Electric: Currently powers approximately 87% of all domestic rail service (US DOE, 2013), >99% of freight rail operations.

Renewable Diesel – Biodiesel is a renewable biofuel that is blendable with diesel fuel in a range of applications and specifications. "Renewable diesel," typically produced using hydro-treating to upgrade oils, and which can be produced from a wide range of feedstocks, is one variant that is capable of 100% operation in any diesel engine (NREL, 2006).

- Drop-in diesel fuels made via gasification technologies are a potential future technology. These methods, which currently remain expensive and non-commercial, allow any biomass to be converted to long-chain hydrocarbons, via processes such as Fischer-Tropsch (F-T).
- In part due to the range of possible feedstocks and pathways, biodiesel and renewable diesel fuel emissions amounts are hard to pinpoint. Additionally, the CO_2 and other GHG emissions released during feedstock conversion and fuel production can be significant, as might be land use and soil carbon changes.

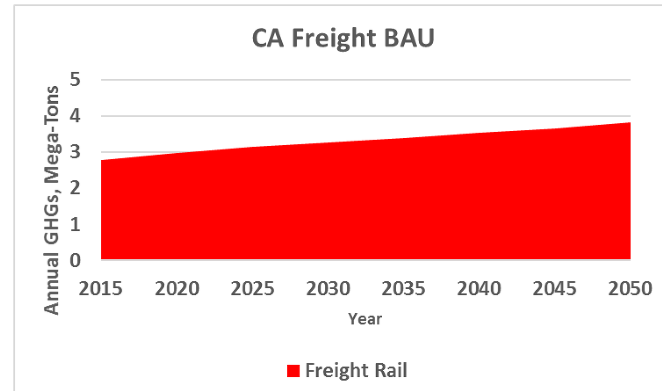
Hydrogen/Fuel Cell - Fuel cells produce zero pollutant or GHG emissions at the "tail pipe," and are more efficient than ICEs. This reduces the fuel requirement and, potentially, the cost - though hydrogen, where available, is currently not an inexpensive fuel.

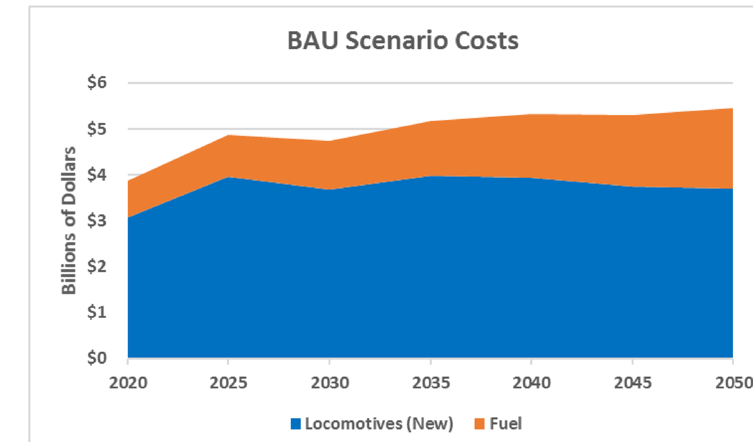
- HDV applications of fuel cells have been demonstrated in U.S. bus systems. In Europe, Alstom has partnered with Hydrogenics, and plans to have 40 passenger trains operating on compressed H2 in Germany by 2020.
- With a large enough distribution demand, H2 movement by dedicated pipeline is likely optimal (UC Davis, 2014); a pipeline could serve both rail facilities and other sources of demand, e.g. buses and trucks.
- Even in liquid form, hydrogen's per gallon energy density is much lower than diesel fuel. Fuel cell stack lifetime is another area of concern; however, one AC Transit (SF Bay Area) bus has a stack in operation that has required no major overhauls despite nearly 21,000 hours of operation.
- Emissions from hydrogen could vary tremendously depending on the source of the hydrogen (e.g. natural gas reformation predominating vs. a reliance on various renewable methods).

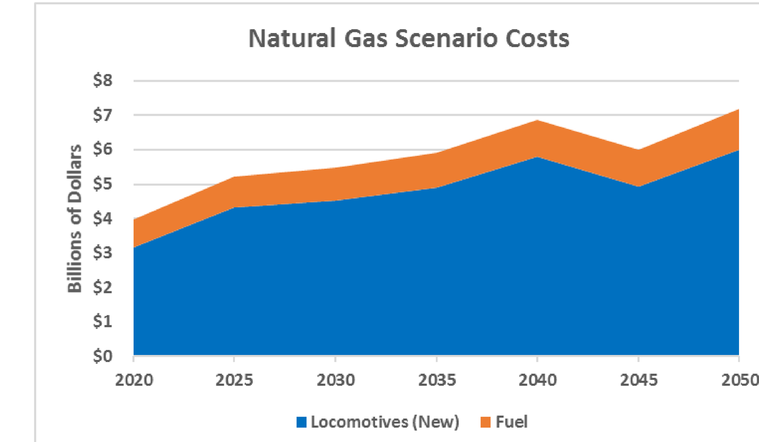
Natural Gas - At least one freight rail firm (as well as one passenger rail agency) is considering CNG as a potential rail fuel. While requiring a simpler system than LNG, CNG stores less energy per unit volume.

- Several freight rail firms are experimenting with LNG. Challenges include the low temperature at which it must be kept (roughly - 260 F), and that liquefaction is energy intensive and causes a loss in overall system efficiency compared to CNG. "Boil-off" is likely during refueling and on-board storage.
- With natural gas' lower energy density than diesel, tender cars will be required in most freight rail applications. Amount of methane leakage within the fuel supply change is under investigation, but likely has significant emissions implications.

RESULTS

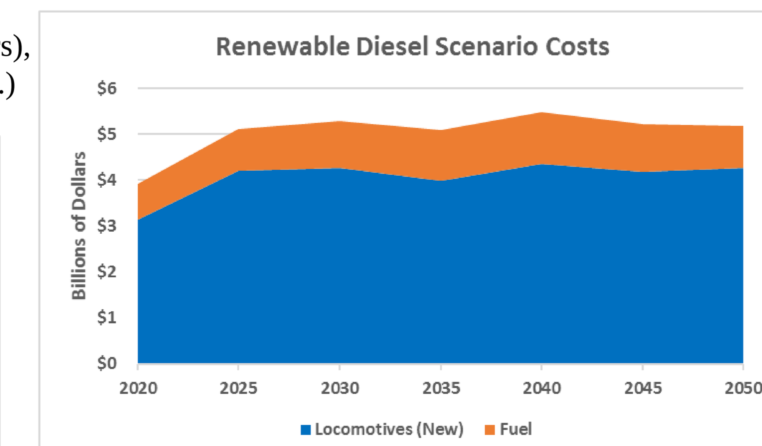


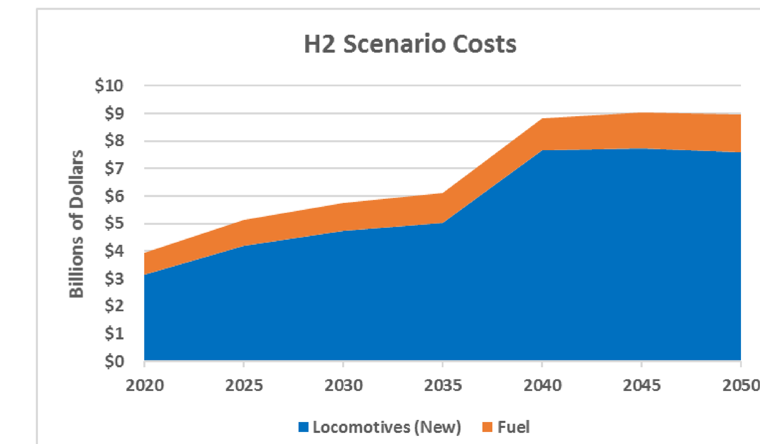


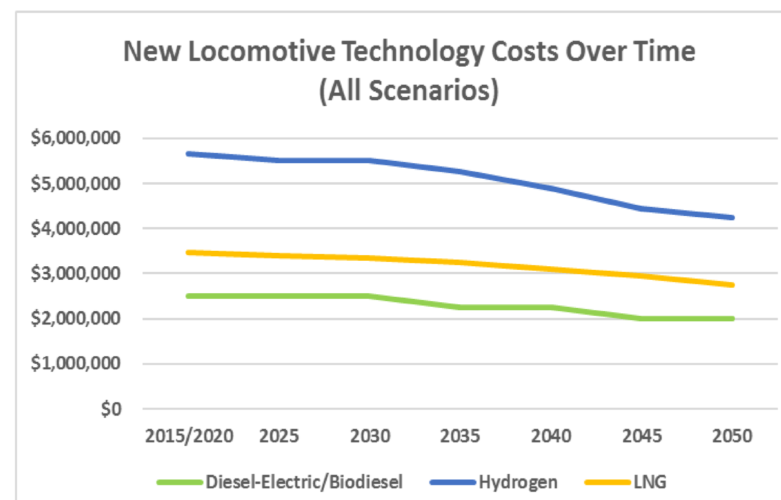


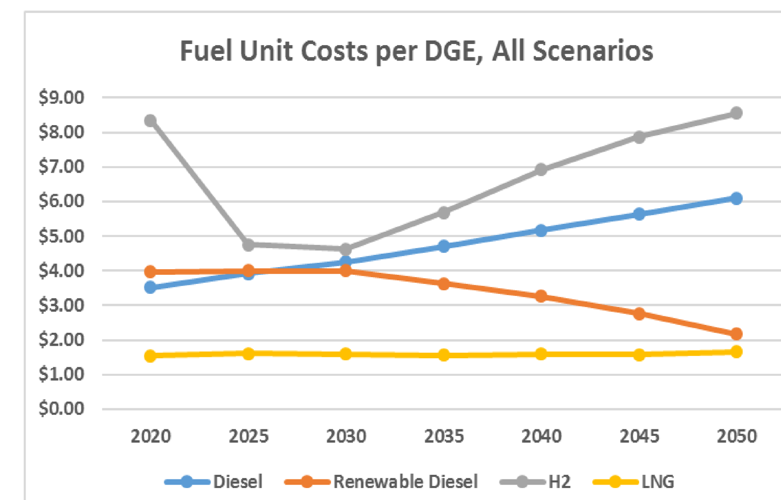
Best Case and Worst Case Emissions Reductions Scenarios*

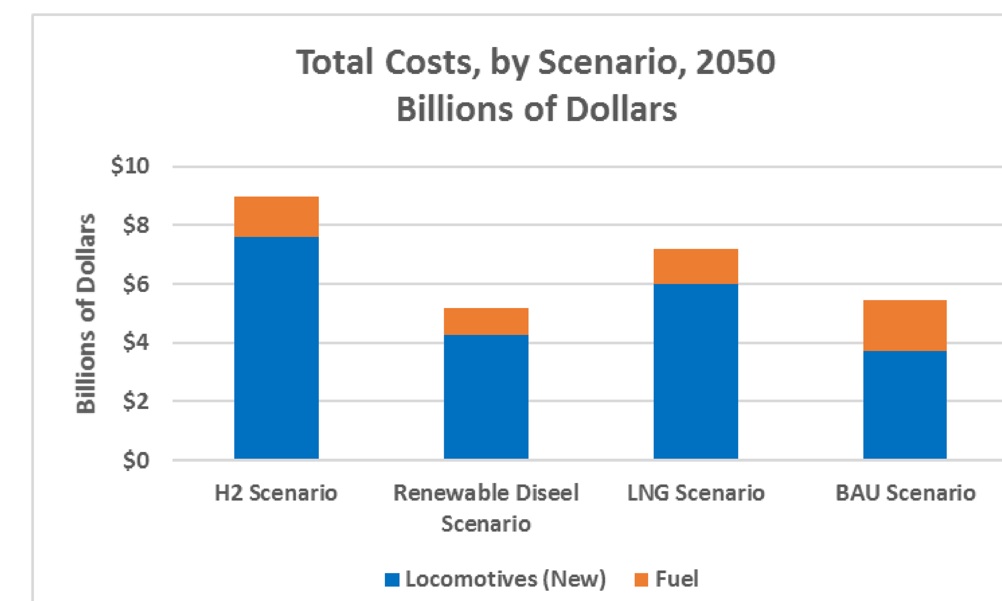
*(Note: Reductions in best case limited by H2 technology timeline in freight context, long lifetime of locomotives (approx. 30 years), and limited rate of new locomotive production. (Recent data show ~12.5% of fleet composed of vehicles produced in last 5 years.)

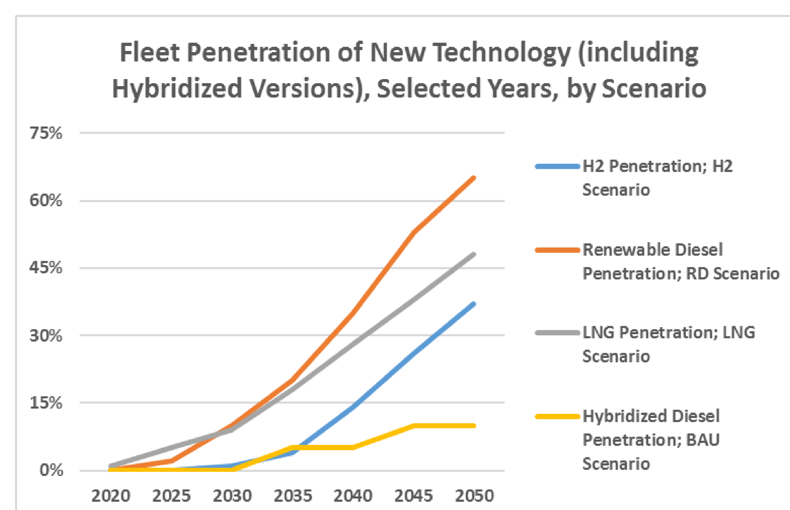


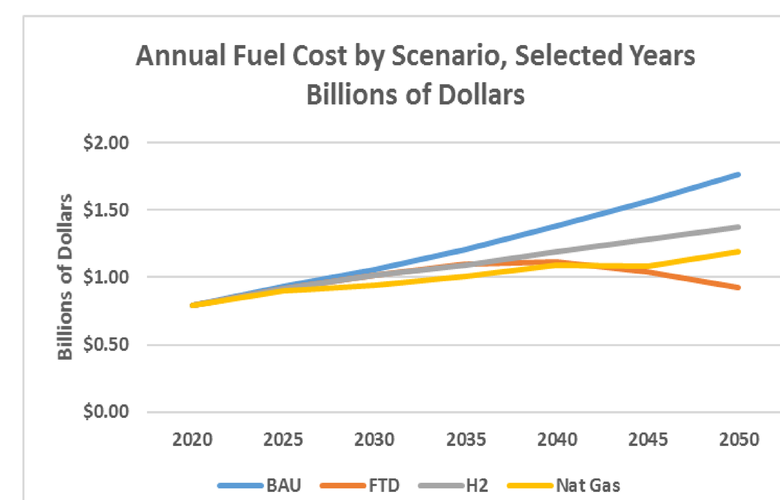


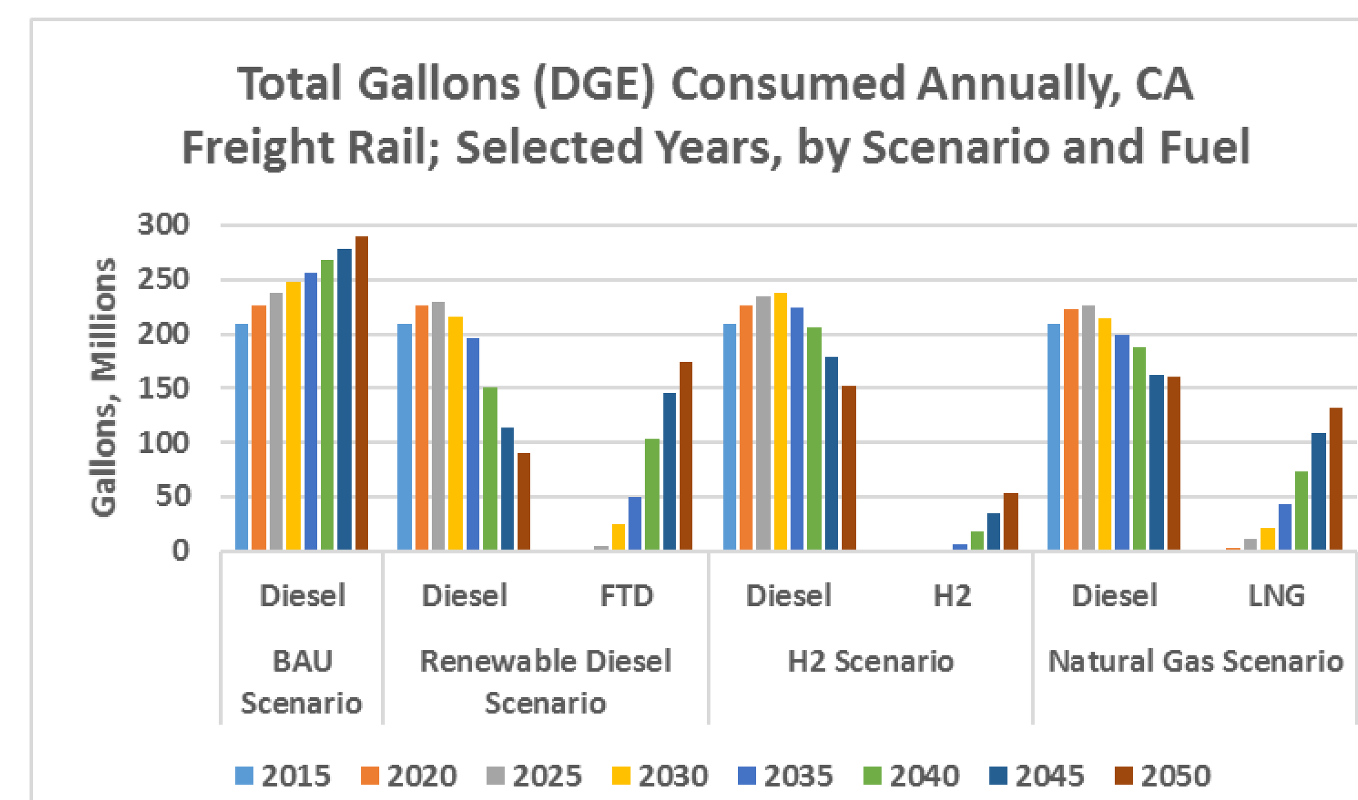












ANALYSIS ASSUMPTIONS

Four scenarios were developed:

A) "Business as Usual" (BAU) scenario assumes little to no specific push towards a change from the status quo. Hybridization of the current diesel-electric powertrain with batteries, where helpful (e.g. switcher locomotives), is assumed to begin towards the end of the period, partly as a result of an expected parallel technology push in passenger locomotives, which make frequent stops.

B) Biodiesel/Fischer-Tropsch Diesel scenario assumes significant investment into and resulting successful development, over time, of advanced biofuels, including Fischer-Tropsch diesel (and some concomitant battery hybridization). Integration into rail proceeds fairly smoothly between now and 2050, with sales proceeding via a roughly S-shaped growth curve (with stock trailing by a bit behind growth).

C) High H2 scenario assumes significant investment into and resulting successful development, over time, of hydrogen-based powertrains (i.e. H2-only powertrains and H2-dominant powertrains hybridized with batteries). After a slight delay due to lingering technological challenges, integration into freight rail proceeds fairly smoothly between 2030 and 2050, and proceeds via a roughly S-shaped growth curve.

D) Natural Gas (LNG) scenario assumes that price incentives drive freight firms to increase the penetration of LNG vehicles and fuels) in their fleets. The increase in sales resembles an S-shaped growth curve between now and 2050. Compression ignition implies same efficiency as diesel (though the limited amounts of diesel fuel required for start-up not included in calculations).

i) Ton-miles data based on ARB/Vision II model data for gallons consumed, 2011 and AAR national average freight fuel consumption data, with future projections based on national projections for freight rail tonnage from the Freight Analysis Framework (USDOT).

ii) Projected emissions values based on combination of GREET (DOE) model and modelling by UC Davis (Yang et al., 2016).

iii) Fuel cost estimates also based on research by Yang et al., and locomotive technology cost projections based on previous research by the author (e.g. Isaac & Fulton, 2015)

RESEARCH NEXT STEPS

- Add additional scenarios, including hybridized powertrains
- Examine costs of different scenarios
- Expand beyond California-only
- Refine projections vis-a-vis freight ton-mile increases

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