Passenger Rail Fuel Alternatives for the 2020’s and Beyond

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Domestic passenger rail has been on the upswing (APTA/Amtrak). As this mode of travel continues to thrive, reducing total emissions from rail will depend largely on innovative fuel technologies. The research presented here looked at some of these potential technologies and is also relevant to other domestic passenger rail routes. The following powertrains were modeled: “Benchmark” diesel-electric vehicle that uses both mechanical and dynamic (though “rheostatic”) braking, diesel-electric and hydrogen fuel cell powertrains that rely on dynamic braking, and, finally, each of these prime mover options hybridized via batteries (so as to fully take advantage of regenerative braking).

**Fuels Background**

**Diesel-Electric** - Currently powers approximately 99% of domestic non-transit rail operations (US DOE)

**Electricity (via Catenary)** – Approx. 2.3% of track over which passenger rail operates in the United States is electrified (Amtrak); however, due to the density of passenger rail traffic in the ‘Northeast Corridor,’ passenger rail operational energy is currently split at 74% diesel, 26% electric. (US DOE, 2017). Exact CO\(_2\) emissions varies by region, depending on the fuel mix of electricity generation at the producing power plants.

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

- Several freight firms experimented with LNG earlier in the decade. 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 likely be required in many freight applications. Amount of methane leakage within the fuel supply change is under investigation, but likely has significant emissions implications.

**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 rather expensive.

- 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. (Gaseous or liquid tenders will likely be required for freight rail.) 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.
- H2 fuel cell emissions vary tremendously depending on the source of the hydrogen (e.g. natural gas reforming predominating vs. a focus on renewable energy sources).

**Hybridization** - A hybrid vehicle has a primary power source and an on-board energy storage device.

- Primary power source/power-plant: E.g. Combustion engine (diesel) combined with electric generator, Fuel cell
- Storage device: E.g. Batteries, Flywheels, Supercapacitors
- Benefits: i) Capture regenerative braking energy
  ii) Operate prime mover (especially an engine) in its optimal zone(s)
  iii) Opportunity to downsize the prime mover

**Research Next Steps**

- Examine three different train types on U.S. mainline freight route
- Analyze CO\(_2\) and pollutant impacts over fuel lifecycle

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