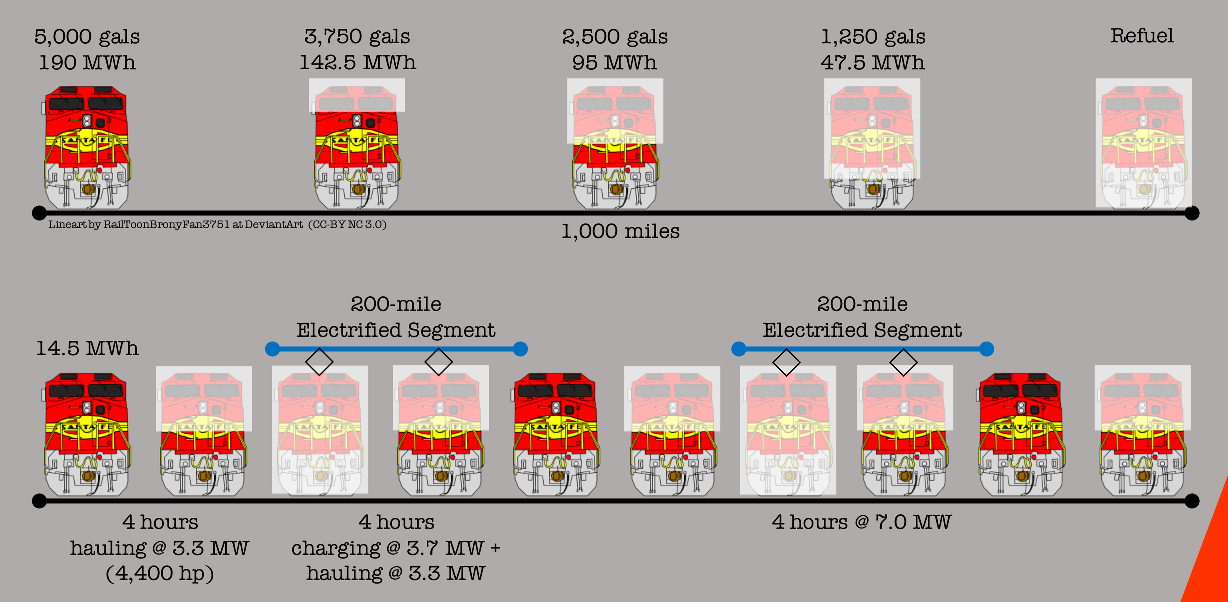
INTERMITTENT ELECTRIFICATION WITH BATTERY LOCOMOTIVES AND THE POST-DIESEL FUTURE OF NORTH AMERICAN FREIGHT RAILROADS

Alex Lu[1] John G. Allen[2] John P. Aurelius

A CARBON NEUTRAL FUTURE

Changing attitudes about fossil fuels are likely to lead freight railroads toward carbon-neutral technologies. Yet the alternatives to diesel-electric locomotives now being touted offer less promise than meets the eye toward carbon neutral rail freight operations. Rapidly emerging battery technology, however, offers the promise of battery-electric locomotives that can operate in conjunction with partial electrification covering about half of the route.



The promise of 7.2 megawatt-hour battery-electric locomotives (BELs), in combination with intermittent electrification, offers a new way of electrification for freight railroads. Today, a typical heavy-duty road diesel runs about 1,000 miles on a 5,000-gallon tank of diesel fuel. BELs should be able to operate comfortably with 200 miles under the wire, followed by another 200 miles off. Even at 40 mph, this implies five hours under the wire.

BELs should be able to fully recharge after 4 hours under the wire. At 14.5 MWh, a BEL plus a cableless booster should provide equivalent functionality to a high-powered road diesel. Energy demand varies dramatically by terrain, but averages out to about 100 kWh per mile for an 8,000-ton train.

Partial electrification allows railroads to electrify about half the route and still get full performance from BELs. Even in otherwise-electrified zones, railroads can have gaps in the electrification and run trains in battery mode through obstructions such as restricted-clearance drawbridges and tunnels.

Railroads can also leave mountainous areas unelectrified where building and maintaining electrification would be difficult. All that is needed is enough electrification in the foothills to make sure that trains have enough power to crest the summit.

Chessie System fruit juice unit train running in battery mode through the Potomac River Tunnels at Mount Royal station, Baltimore, Maryland (top); Artist's conception by John G. Allen

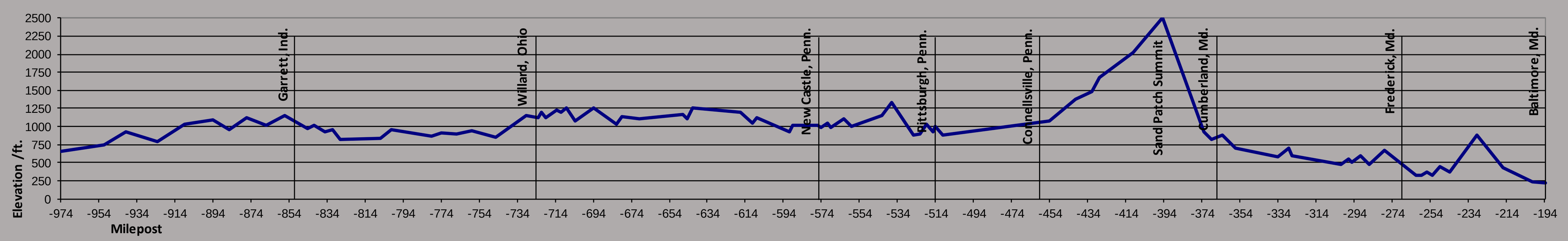
New York Central, Cuyahoga River restricted clearance Drawbridge, Cleveland, Ohio (bottom); Artist's conception by John G. Allen

Electrifying should be more straightforward in terrain where there are few overhead obstructions.

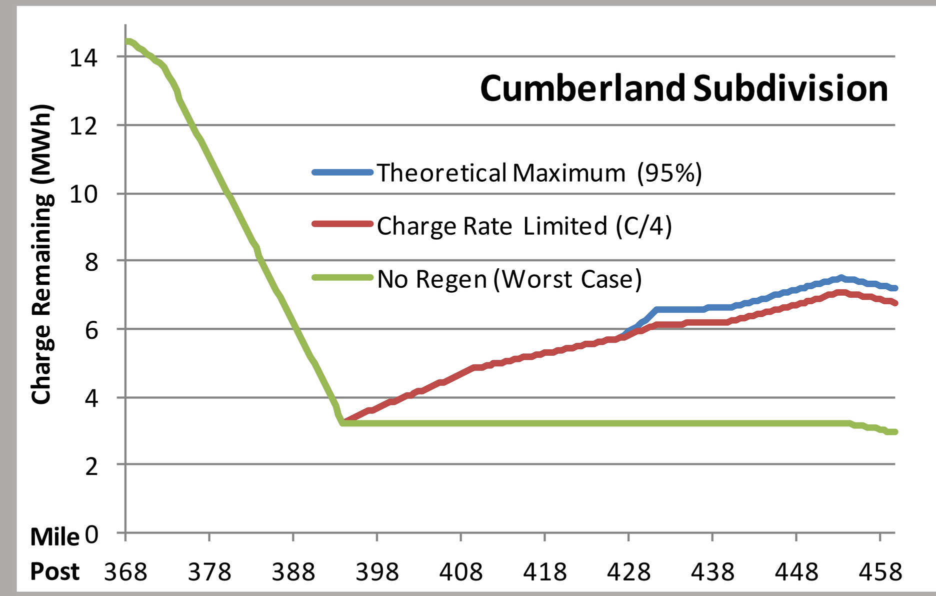
Chicago & North Western battery-electric locomotives charging through the prairies (right); Artist's conception by John G. Allen

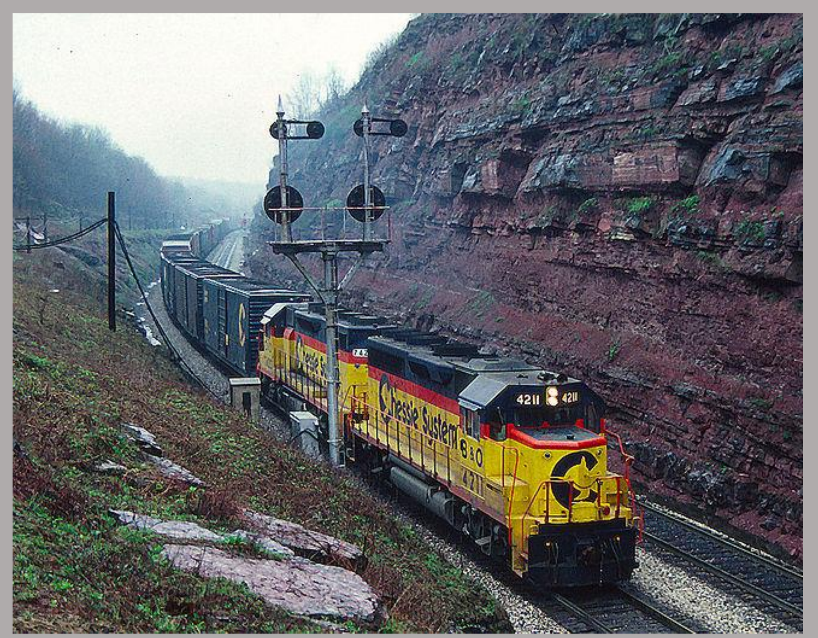
PERFORMANCE SIMULATIONS

We performed Train Performance Calculations (TPCs) using standard industry formulas to show how BELs would perform in a major service lane between Chicago and Washington over the Sand Patch grade.



With diesel-electrics, the energy transferred from traction motors to resistor grids when moving downgrade is lost. With battery-electrics, that energy can be used to recharge. Nevertheless, our simulation shows that even in a worst-case scenario without regenerative braking (green line), BELs should still perform quite well, cresting the summit westbound at Sand Patch and then traveling another 65 miles.



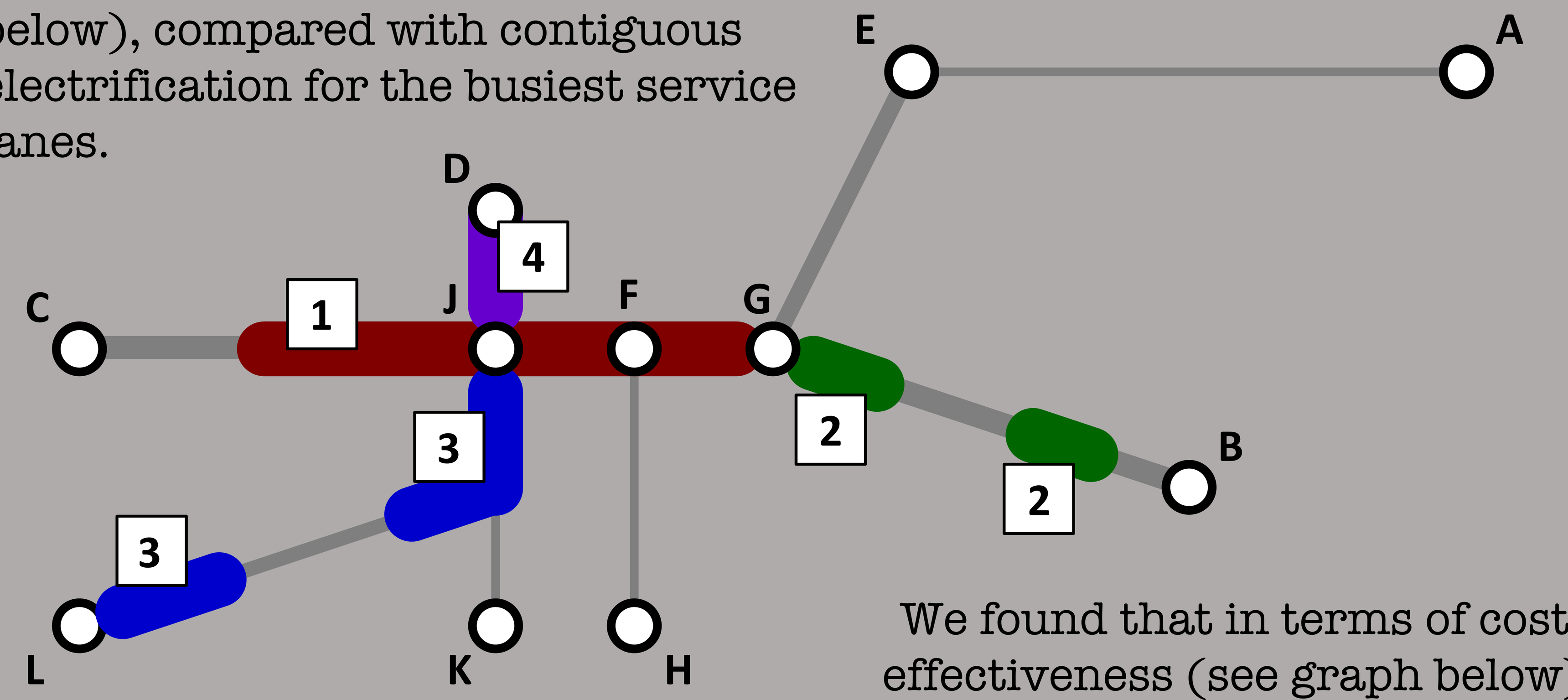


Sand Patch Grade, Pennsylvania, 1987, Bruce Fingerhood photo (CC BY 2.0)

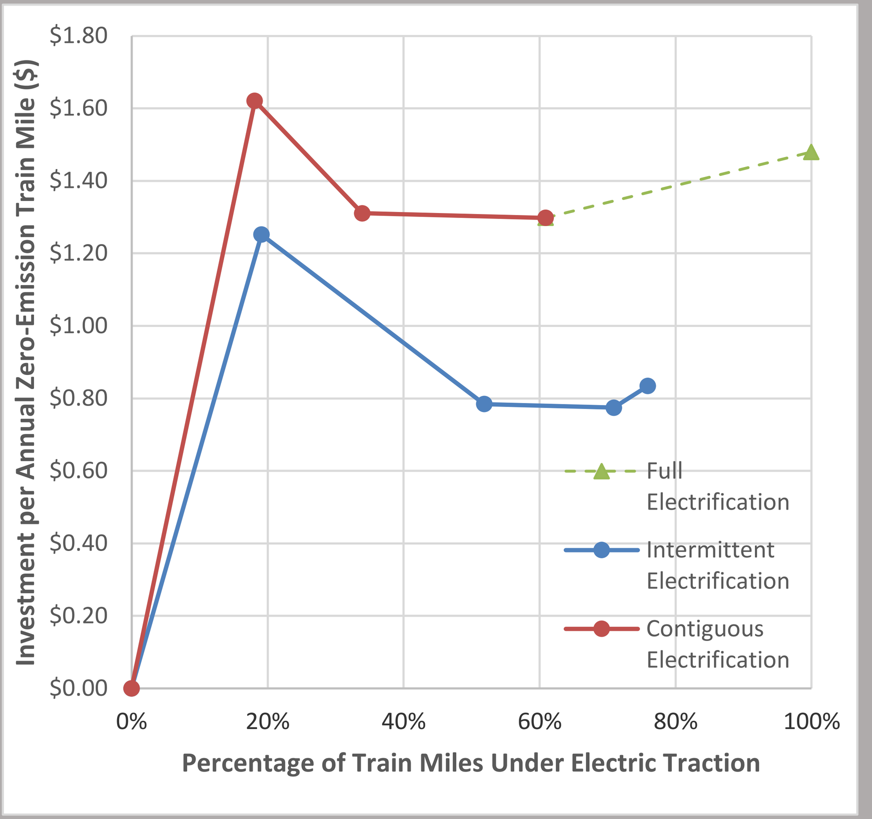
Regardless of the specific locomotive configurations used, 14.5 MWh is sufficient to power an 8,000-ton train for more than 200 miles under typical operating conditions. We estimate that a typical 200-mile charging island will require five supply substations rated at 125 MW each – only slightly larger than those typically used in heavy-duty passenger electrification.

HYPOTHETICAL CLASS ONE ELECTRIFICATION STUDY

We examined a hypothetical east-west Class One railroad with 2,195 main line miles, assuming 8,000-ton trains and up to four daily departures in busier service lanes. We examined the economics of intermittent electrification, to be installed in four stages (see map below), compared with contiguous electrification for the busiest service lanes.



We found that in terms of cost-effectiveness (see graph below) and other measures (investment capital, operational complexity, and relationship to maintenance-of-way costs), intermittent electrification outperformed the continuous electrification alternative.



We also analyzed life cycle costs, which show that if society seeks to reduce greenhouse gas emissions from freight trains, some sort of financial help will be needed. Yet even so, even if 76% of train-miles operated with BELs under intermittent electrification, the increase in life cycle cost is only 7.6%.

CONCLUSION

Freight railroads are understandably concerned about the cost of finding alternatives to diesels. But if public policy moves North America's railroads toward non-emitting propulsion technologies, intermittent electrification with BELs is a doable approach with technological promise and high cost-effectiveness.

For more information, please visit: http://lexciestuff.net/bel/

Contact emails: [1] lexcie@gmail.com [2] jgatransit@2200.com