Rail Technology Assessment Summary of Results (Draft, 08/26/14)

	Technology	Performance (rel to Tier 2)	Cost	Operational Considerations	Status	Next Steps	Key Challenges
Tier 2/3		**5.5 g/hp-hr NOx, 0.1-0.2 g/hp-hr PM (SCAB is Tier 2 avg today)**	~$2.3M/unit	**Compatible with national fleet**	**Full-Scale Commercial Production**	**Already in full production.**	**Nat'l standards, engine tech advances were necessary to bring Tier 2 to commercial introd.**
Tier 4	Combustion improvements, enhanced cooling, and Exhaust Gas Recirculation	75-85% NOX and PM reductions	~$3M/unit for enhanced combustion, cooling & systems integration	Compatible with national fleet	GE: Support field service testing of 20 pre-commercial production units	Full-scale commercial introduction anticipated in 2017	
LNG	dual fuel (60-80% NG) retrofits for Tier 2/3 or HPDI for Tier 4	Same as Tier 2 for retrofits, 75-85% NOx/PM reductions for Tier 4, No DPM when using NG	Locomotive +$1M for each tender, but fuel costs 50% less	Need for tender, NG fueling infrastructure	4 linehaul prototypes w/tender, 2 MHP prototypes	Cost-benefit analysis. Industry may pursue NG if cost-benefit works.	NG energy density (and potential tender operational impacts), cost-benefit?
Tier 4+	SCR for NOX, DOC and DPF for PM	90% reduction , 70% NOx/PM reductions beyond Tier 4	~$4M/unit. Possible maintenance cost increases for after-treatment.	Compatible with national fleet, will require maintenance & supply for urea	Concept phase	Policies and funding for R&D	Engine compartment space, and policies/investments to get technology to commercial introduction.
On-Board Battery Hybrid	On-board batteries to power locomotives	Up to 10% NOx and PM additional reductions, due to reduced fuel consumption	$~5M for Tier 4 locomotive with on-board batteries. Costs should go down as production levels increase.	Compatible with national fleet	Conceptual phase, with prototype.	Policies and funding for R&D	Engine compartment space

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Battery Tender	Battery tender connected to locomotive. Could potentially be connected to T2-T4+ locomotives.	Zero emission miles	Locomotive +$5M for each tender. Costs should go down as production levels increase and electricity cheaper than diesel.	Compatible with national fleet if there's a national charging infrastructure, otherwise potential operational impacts	Concept	Policies and funding for R&D	Overcoming potential operational impacts (ARB funded UofI Study)
Catenary	Electric power provided from catenary lines	Zero tailpipe, upstream emissions for power generation	Range of ~$30 to ~$300 million per mile but would be amortized over many years.	Compatible with national fleet if there's a national catenary system	Technology used in U.S., Europe, Russia, China and other parts of the world.	Policies and funding needed for capital costs and research and development.	Capital costs of infrastructure. Studies needed on system design, electric power plants, and existing infrastructure modifications.
Fuel Cell	Proton Exchange Membrane (PEMs), Solid Oxide Fuel Cell (SOFC)/Gas Turbine	Zero tailpipe, upstream emissions for hydrogen generation	Not available	Compatible with national fleet if there's a national fueling system	PEMS: Conceptual phase, with BNSF small prototype switcher locomotive. (BNSF 1205: Green Goat converted to fuel cell) SOFC/GT: Concept Paper	Policies and funding needed for research and development.	