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CONFERENCE ON RAILWAY EXCELLENCE
Rail Transport for a Vital Economy RTSA
5-7 MAY 2014 ADELAIDE AUSTRALIA

FAST CHARGE BATTERIES AND IN ROUTE CHARGING – AN EMERGING OPTION FOR LOW COST FREIGHT ELECTRIFICATION

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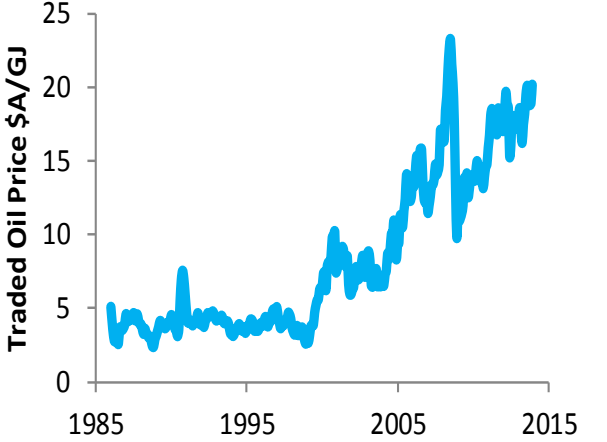
VARLEY ELECTRIC VEHICLES DIVISION

Pressures for Electrification



Oil import price for Australia – Data from http://www.indexmundi.com/commodities/

Energy and Economic Security

PM10 VOC CO_2e SO_x dB NO_x

Health, Safety, Environment and Social Licence

Performance

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Challenges for Electrification

Infrastructure Investment

Locomotive Investment

Branch Lines/ Sidings

The Battery Question

Can emerging commercial automotive battery technologies deliver a new approach that is compatible with the existing locomotive duty cycle?

Battery Locomotive Approaches

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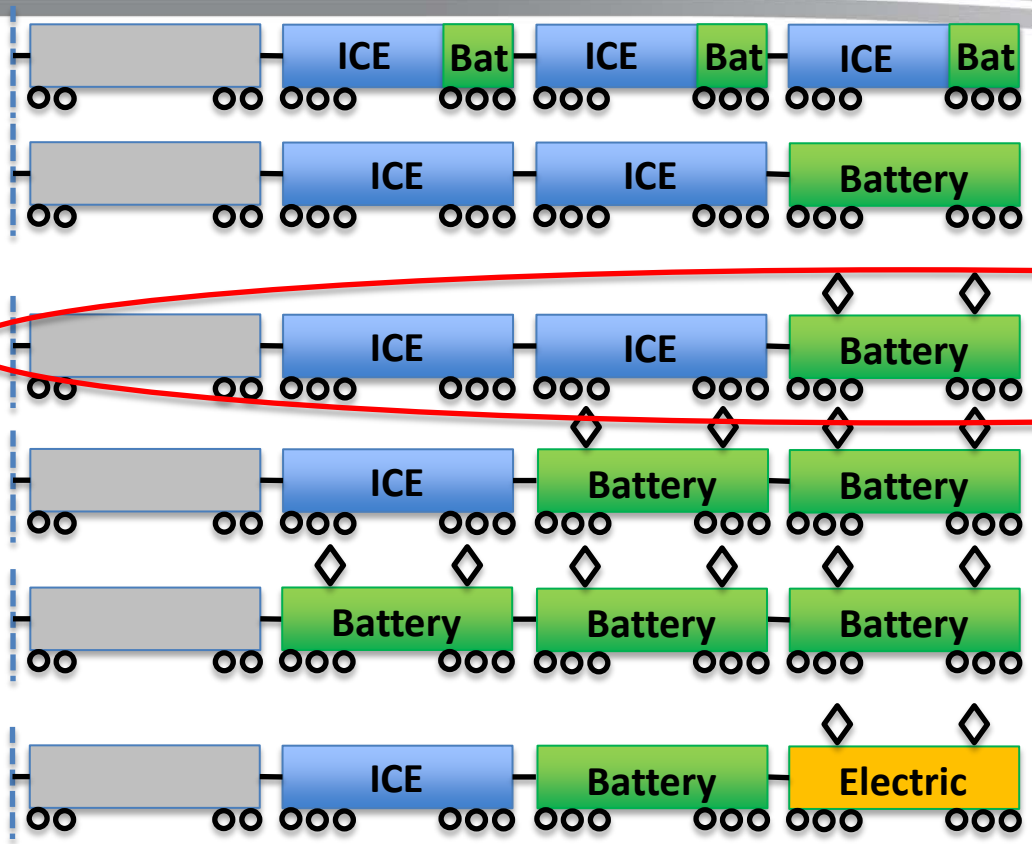

Hybrid Locomotive

Hybrid Train
(See Frank Szanto Tomorrow)

2E1B Plugin Hybrid Electric Train

1E2B Plugin Hybrid Electric Train

Battery Electric Train

Tri-Hybrid Electric Train

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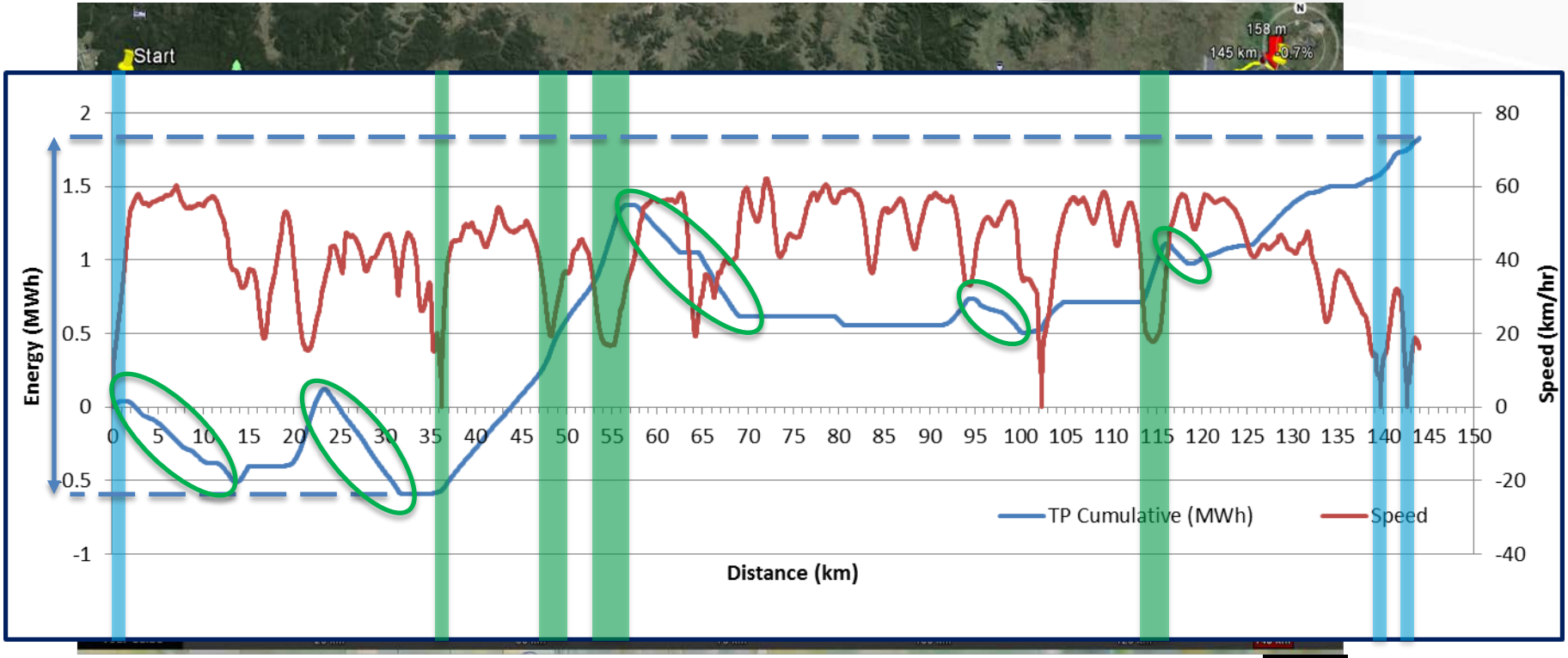
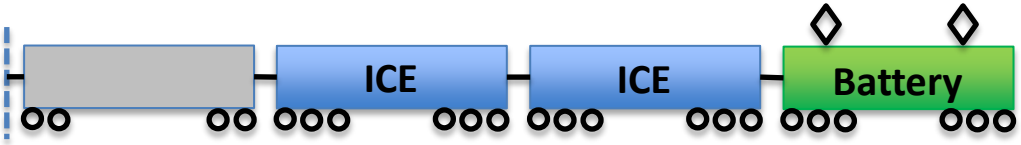
Tracking Energy and Power



Min. Battery Specifications for Electrification



2E1B Plugin Hybrid Electric Train

Strategy	Battery Capacity (MWh)	Discharge Power (MW)	Charge Power (MW)	Volume (m^3)	Weight (t)
Whole Leg	>7.5	>9 (1.2C)	>11 (1.5C)	<28	<45
Regen + Recharge	>3	>9 (3C)	>11 (3.7C)	<28	<45

Li^+ Battery Chemistry Advances

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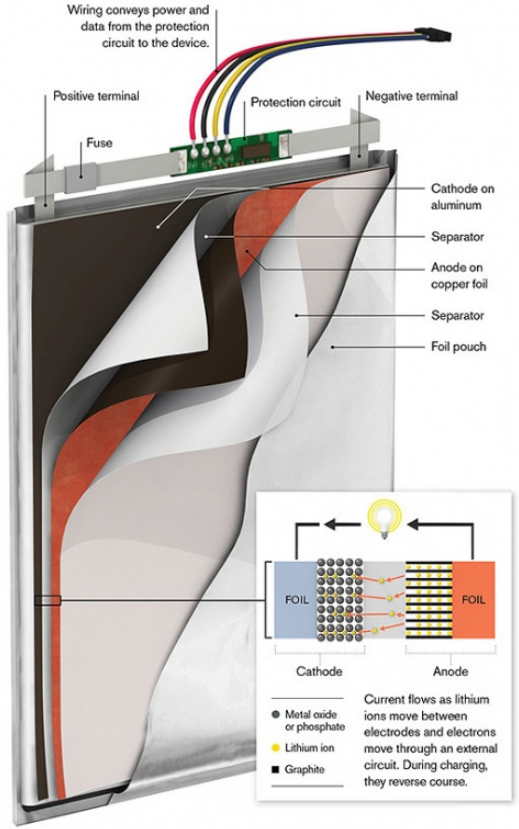

Cathode

Anode

$$LiCoO_2 \leftrightharpoons Li_{1-x}CoO_2 + xLi^+ + xe^- + xC_6 \leftrightharpoons xLiC_6 \quad \text{(LiPo)}$$

SEI Sensitive

Advanced Cathode

$$LiFePO_4 \leftrightharpoons Li_{1-x}FePO_4 + xLi^+ + xe^- + xC_6 \leftrightharpoons xLiC_6 \quad \text{(LFP)}$$

$$LiNi_aMn_bCo_cO_2 \leftrightharpoons Li_{1-x}Ni_aMn_bCo_cO_2 + xLi^+ + xe^- + xC_6 \leftrightharpoons xLiC_6 \quad \text{(NMC)}$$

$$LiNi_aAl_bCo_cO_2 \leftrightharpoons Li_{1-x}Ni_aAl_bCo_cO_2 + xLi^+ + xe^- + xC_6 \leftrightharpoons xLiC_6 \quad \text{(NCA)}$$

Advanced Anode

$$LiCoO_2 \leftrightharpoons Li_{1-x}CoO_2 + xLi^+ + xe^- + xLi_4Ti_5O_{12} \leftrightharpoons Li_{4x+x}Ti_{5x}O_{12x} \quad \text{(LTO)}$$

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Matching Batteries to Applications

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LFP

LTO

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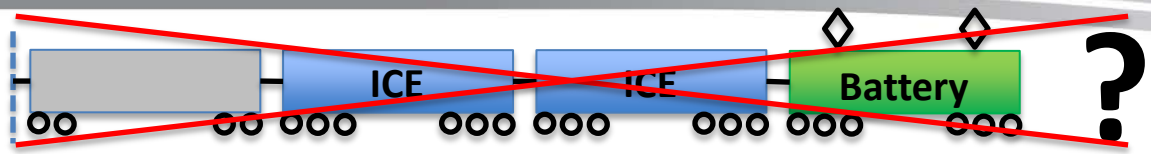
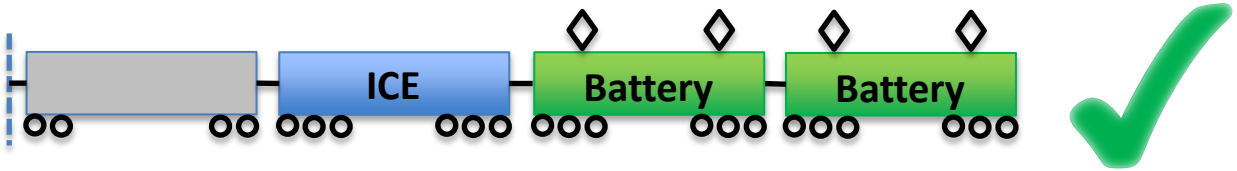
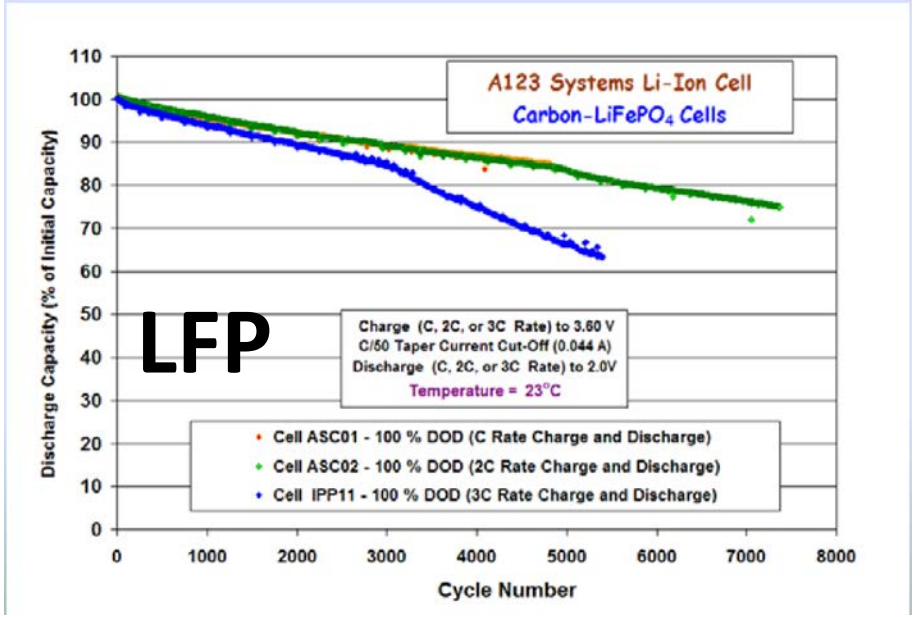
2E1B - Whole Leg?

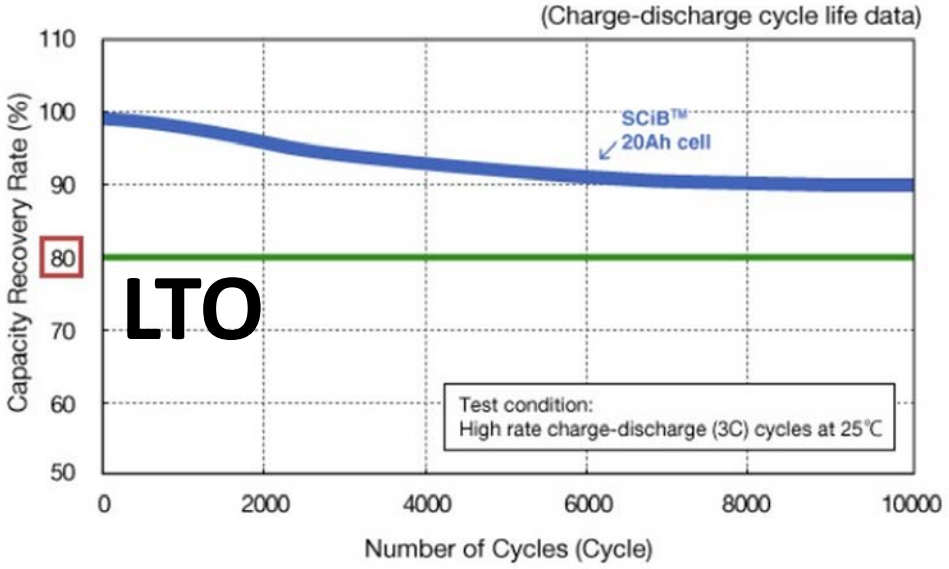


Strategy	Battery Capacity (MWh)	Discharge Power (MW)	Charge Power (MW)	Volume (m^3)	Weight (t)
Whole Leg	>7.5	>9 (1.2C)	>11 (1.5C)	<28	<45
LFP,NMC,NCA	7.5	75	11 (1.5C)	34	75
LTO	7.5	75	22.5 (3C)	39	83



2E1B – Regen + Recharge?

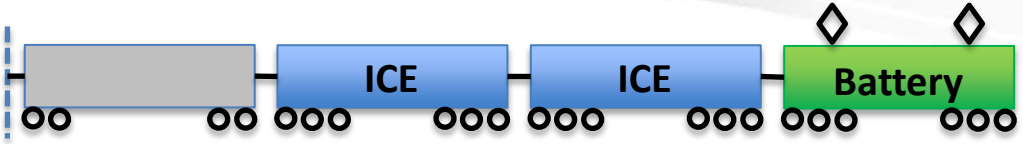




The 2E1B Enabling Question

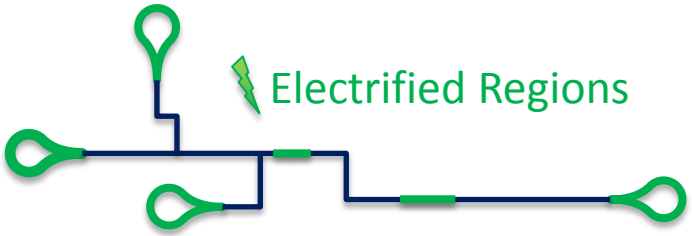
Plugin Hybrid Train

(Locomotive Investment ↓
+ Branch Line Interoperability)



Deliberately Discontinuous Electrification

(Electrification Infrastructure Investment ↓
+ Cost Effective Branch Line Electrification)



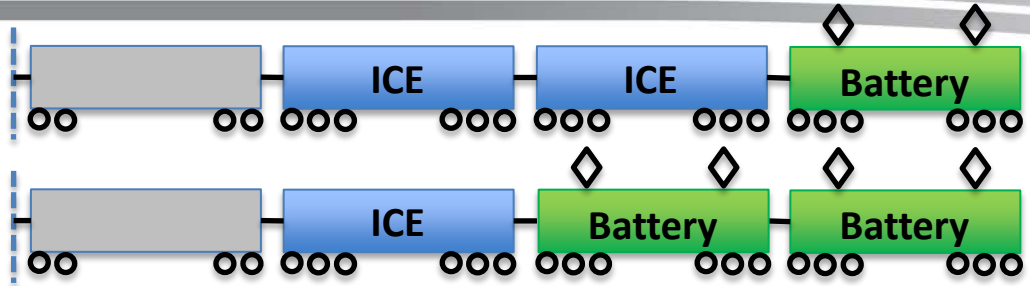
How to fast charge without adding weight to the locomotive?

Adaptive DC Supply

Sup
e.g

di
el
ail

Battery Electrification Looks Technically Possible



Infrastructure Investment

Locomotive Investment

Branch Lines

Conclusions

- New commercially available battery technologies suggest the emergence of a fundamentally new path for freight rail electrification – but you need to know your tech
- Fast charge is a key enabler for reducing battery size
- Deliberately Discontinuous Electrification and Adaptive DC Supply are a key enablers of the 2E1B hybrid plugin train

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