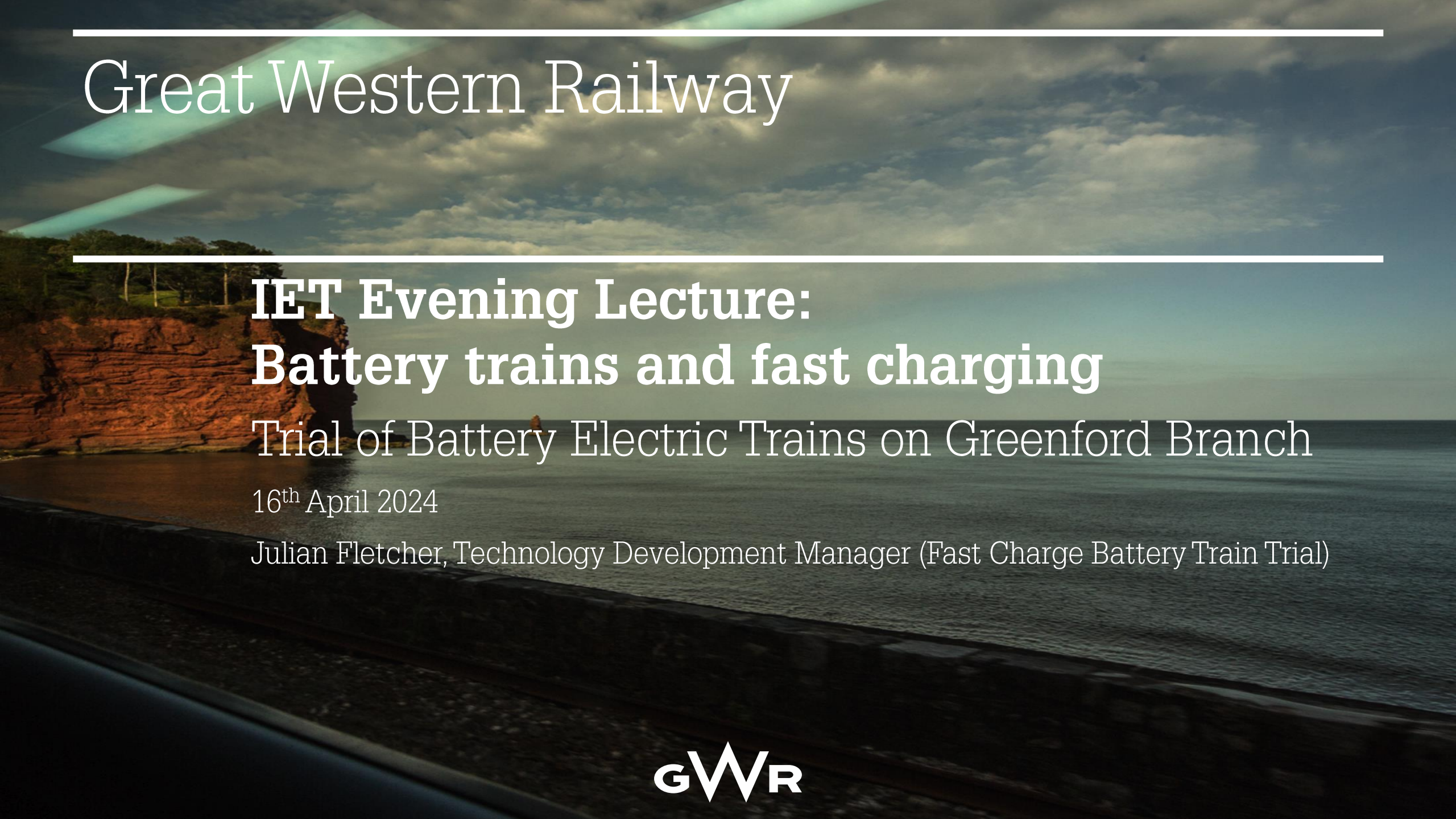


Great Western Railway

IET Evening Lecture: Battery trains and fast charging

Trial of Battery Electric Trains on Greenford Branch

16th April 2024

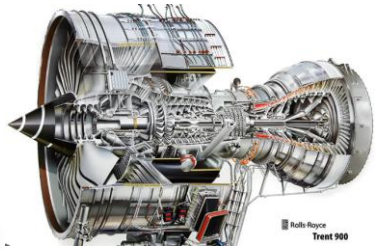
Julian Fletcher, Technology Development Manager (Fast Charge Battery Train Trial)

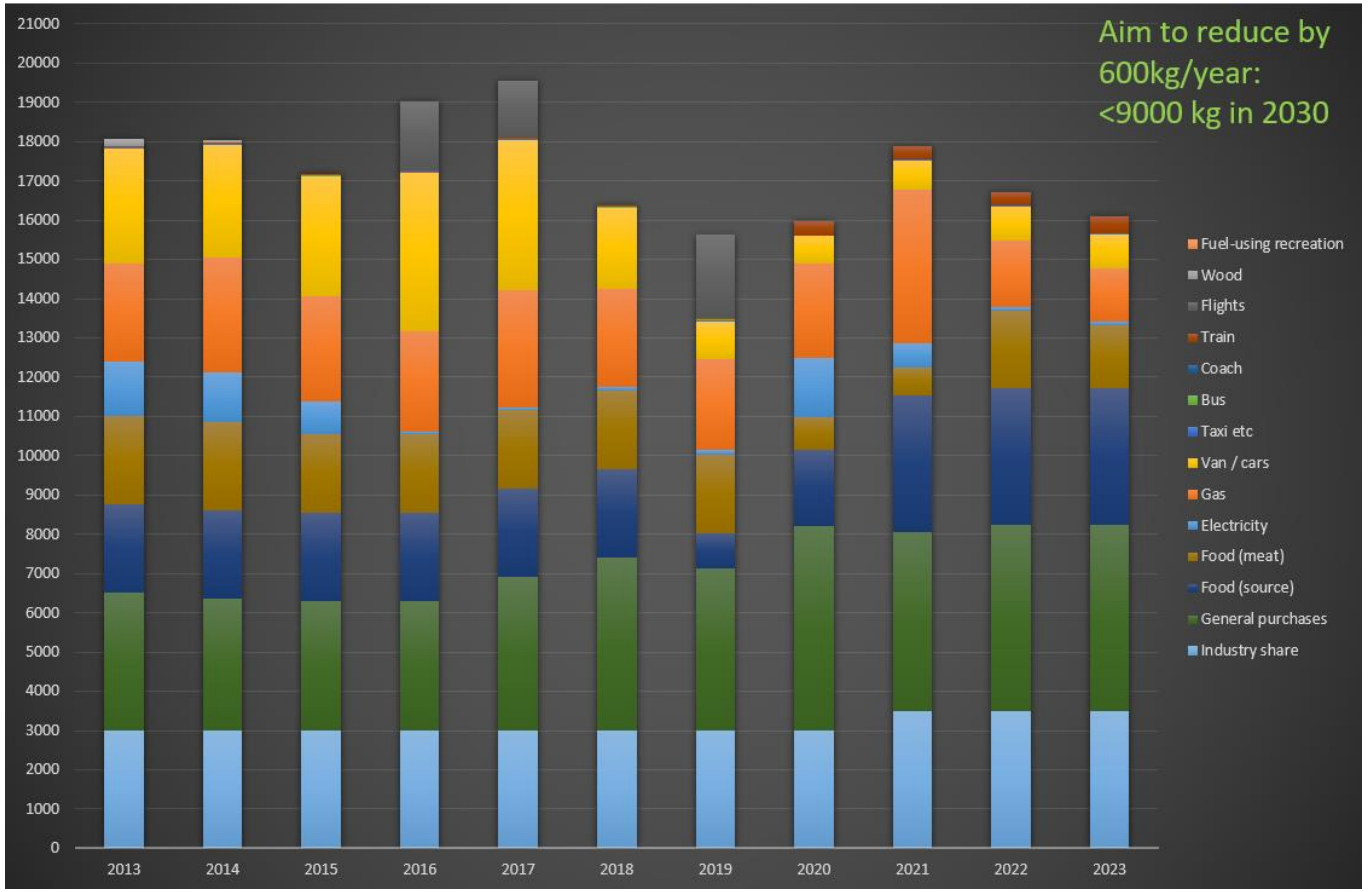
GWR

Agenda

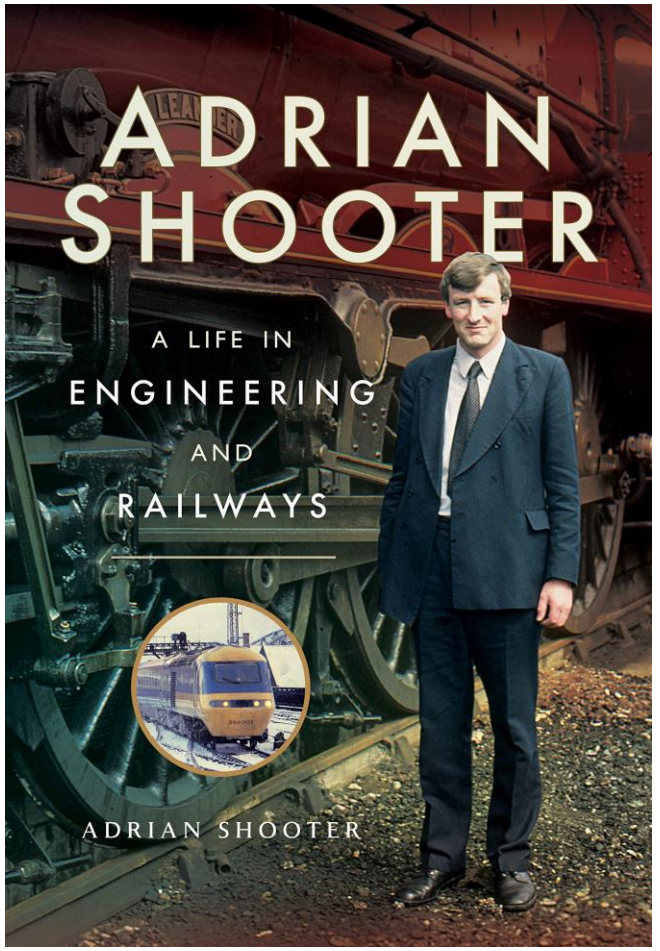
- Personal background and project history
- The train
- The Fast Charge project
- Where are we now?
- What next?
- Q&A

Some personal background



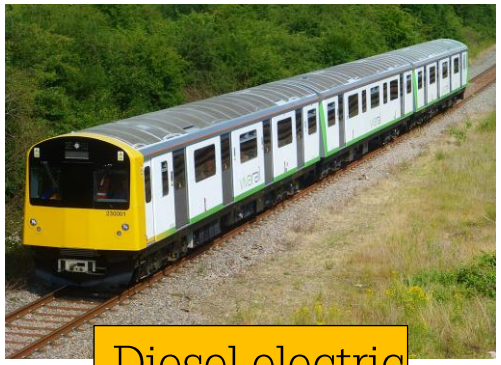


Brief history of the Class 230 project



Brief history of the Class 230 project

D78 stock
London Underground



Diesel electric
Prototype

Diesel electric
West Midlands Trains

Diesel battery hybrid
Transport for Wales

3rd rail electric
Isle of Wight

Battery (1st gen)
USA export

Battery (2nd gen)
COP26 / GWR

Battery (2nd gen + Fast Charge)
GWR Greenford branch trial

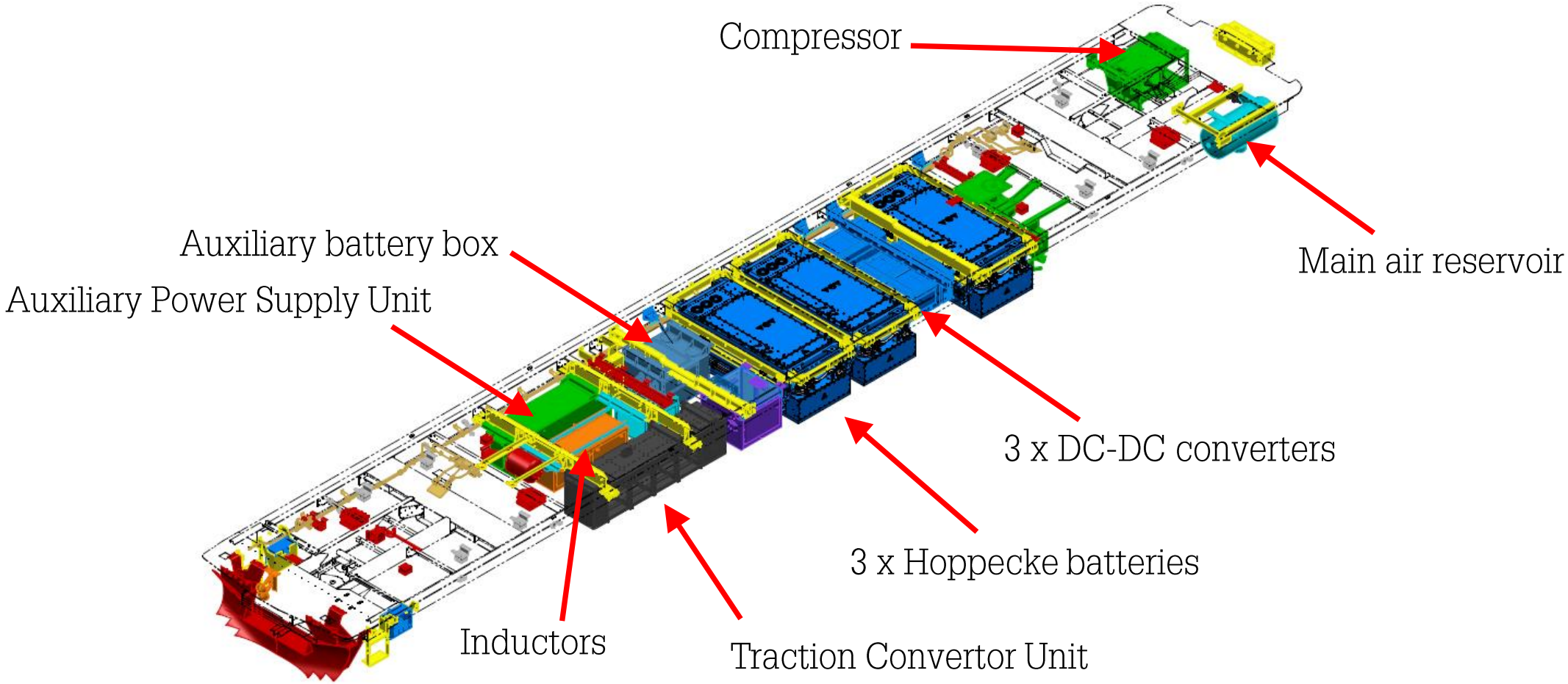
The key ingredients

People

Train

Charging system

The Train: 230001 – COP26 configuration

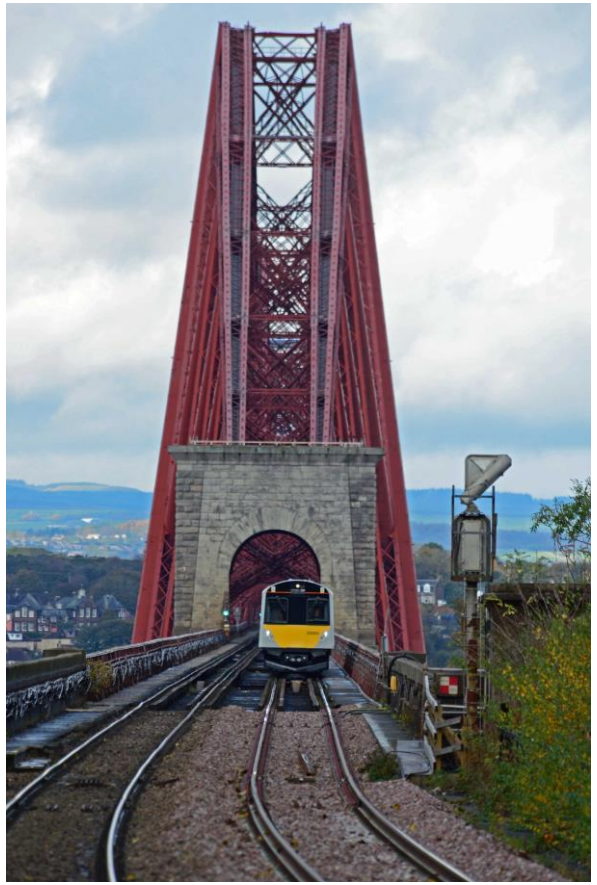


The Train: mass

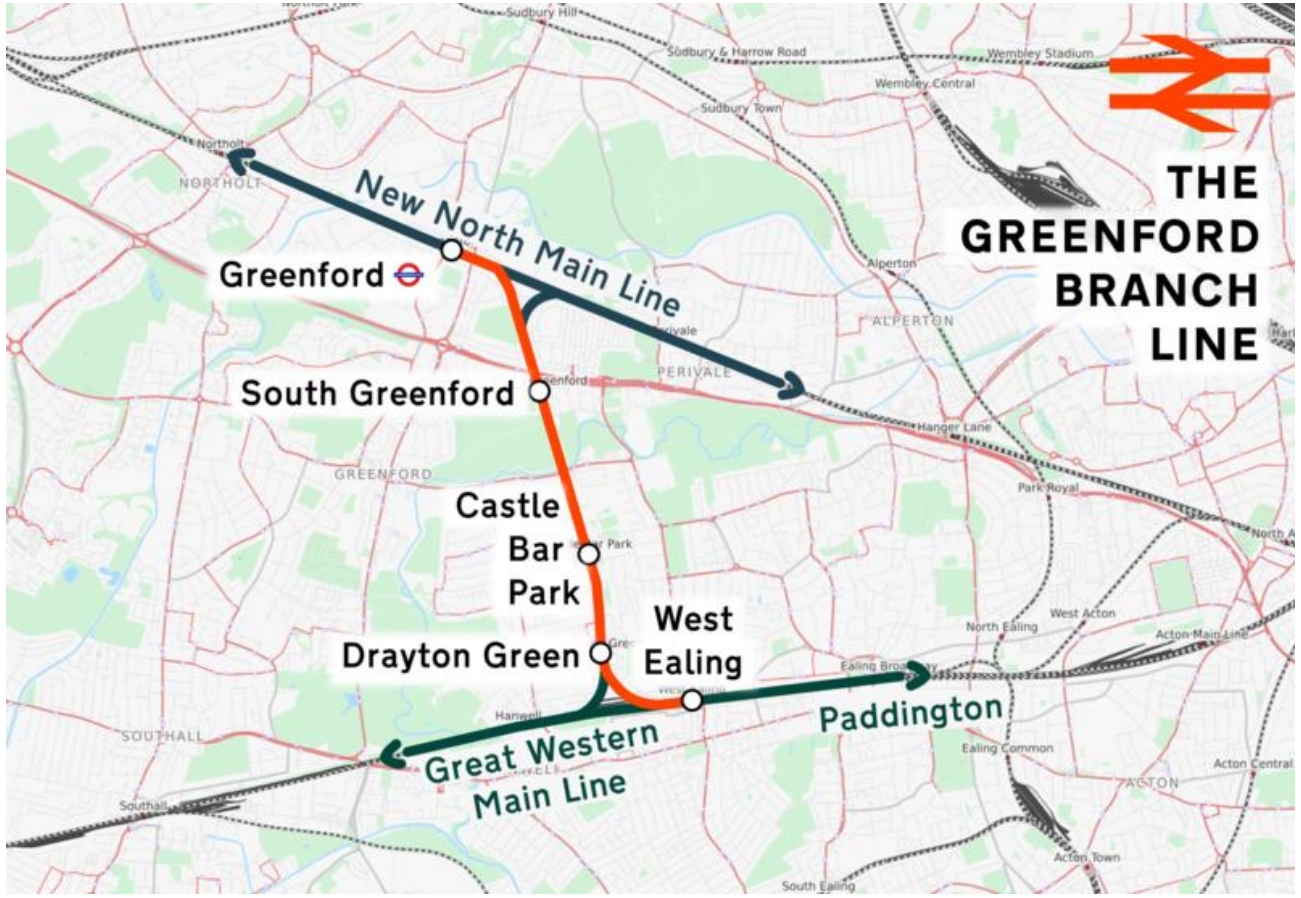
Parameter	Value	Comment
Tare mass	95 t	COP26 configuration – any changes considered negligible. Approx 8 tonnes (8.5%) more than diesel
Fully seated mass	105 t	138 seats.
Crush loaded mass	135 t	138 seats + 62 m^2 standing area.

The train: interior

The Train: under its own power at COP26



Greenford branch Fast Charge Battery Train trial



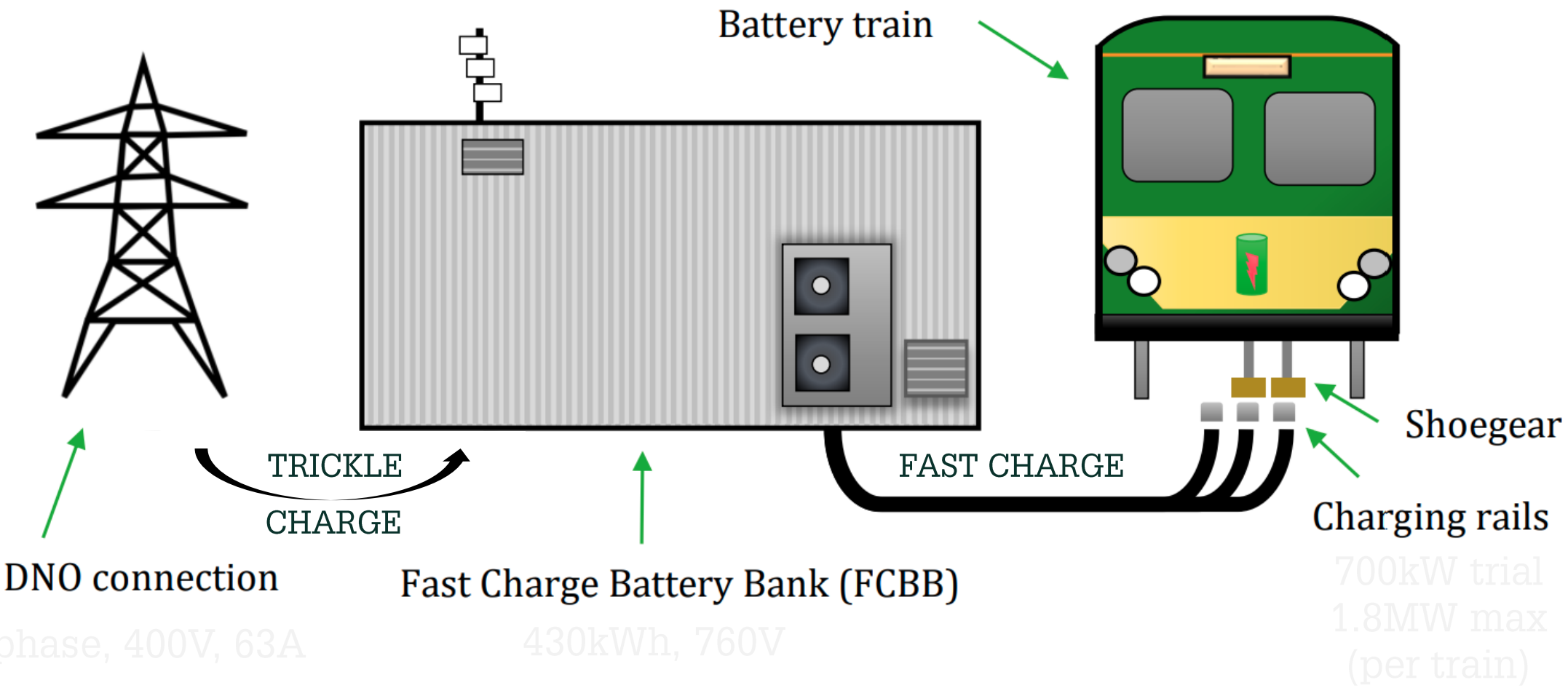
vivarail

Department for Transport

GWR

NetworkRail

Fast Charge: system overview



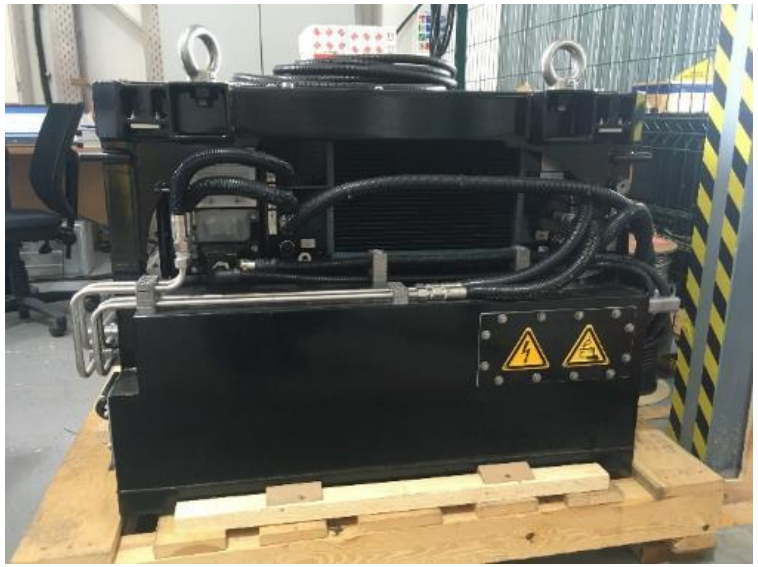
Fast Charge: How it works

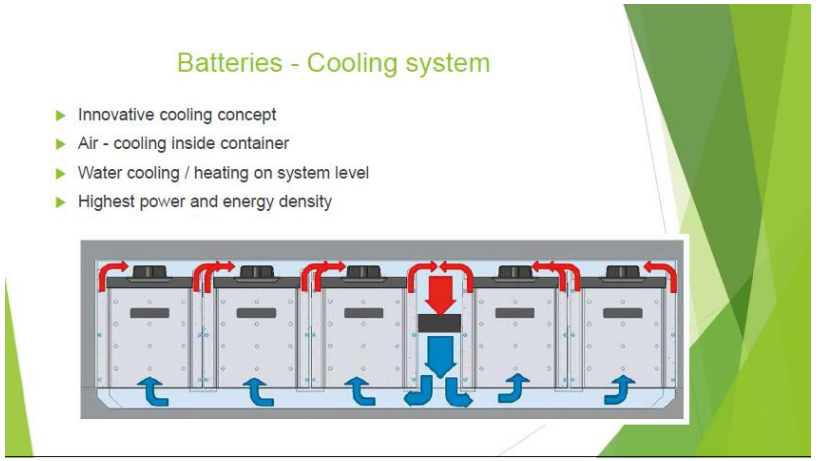
"station confirmation"

"lower the shoes"

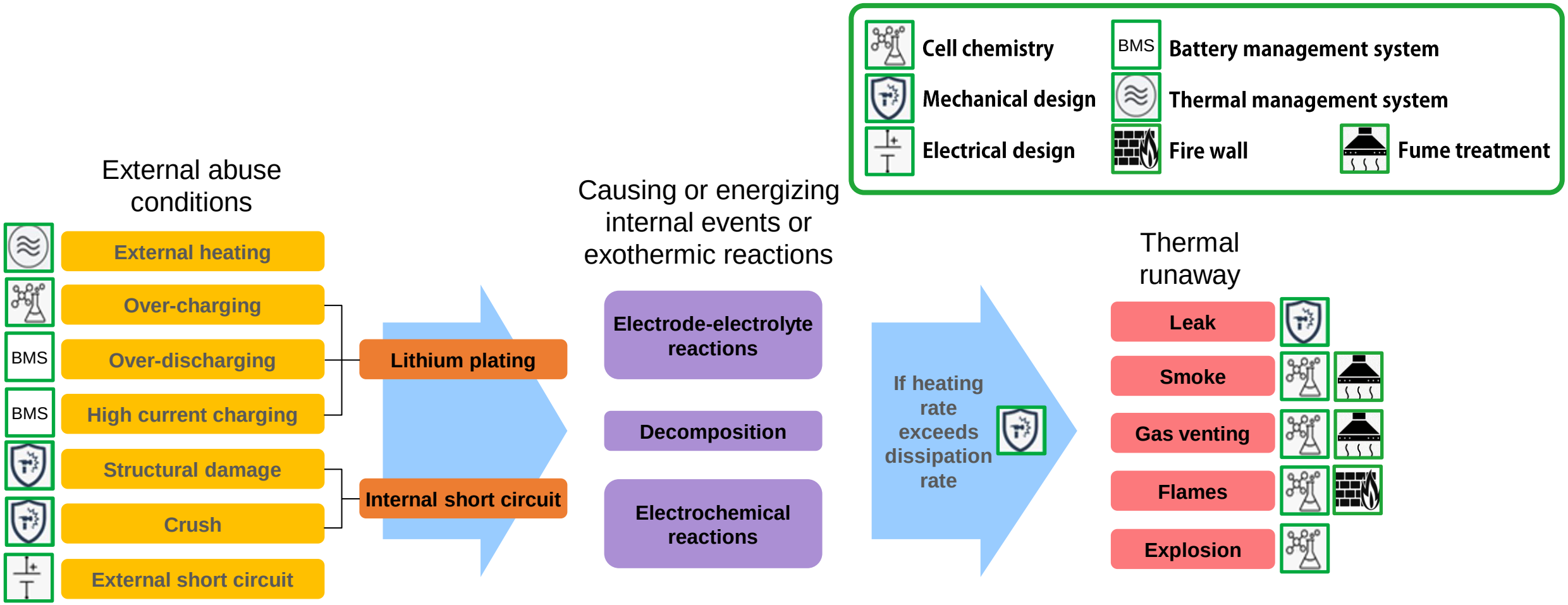
"initiate fast charge"

Automatic charging a.k.a. “Fast Charging”



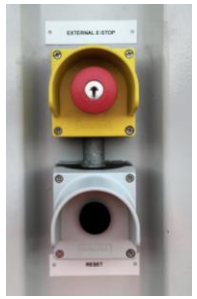


Fire safety: traction batteries

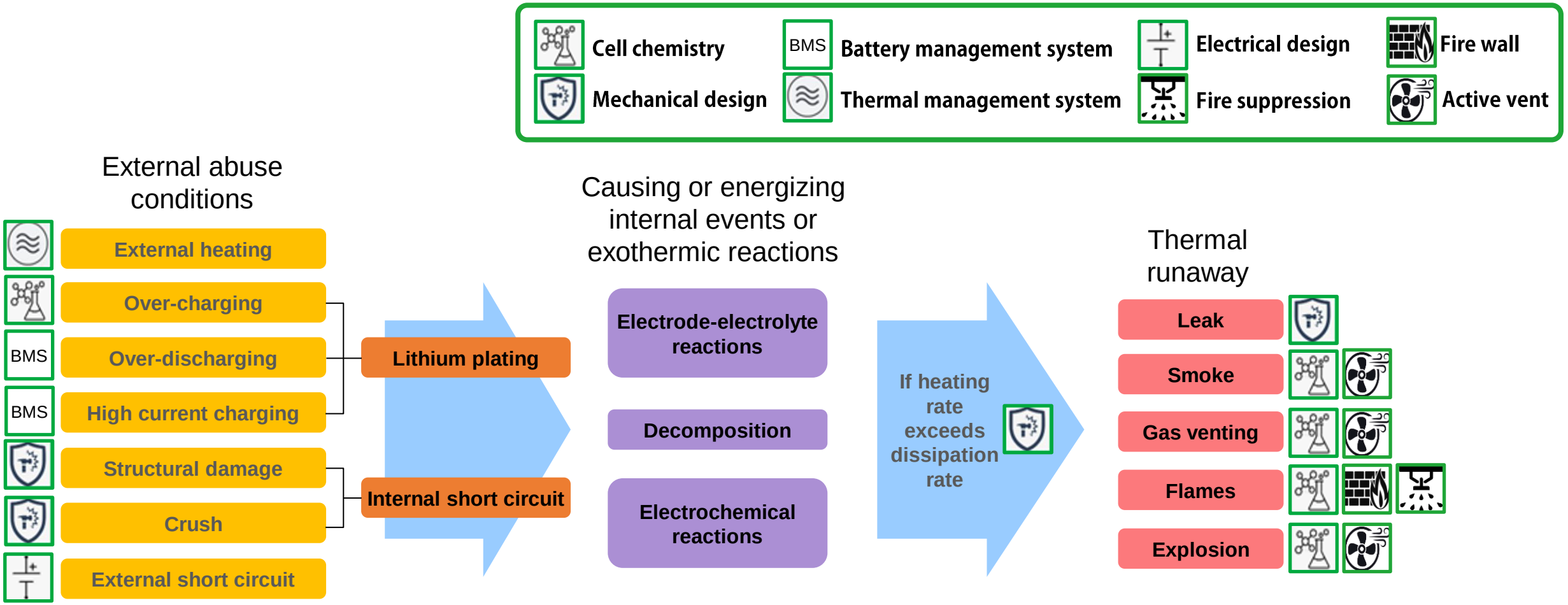


Data source: National Renewable Energy Laboratory and Warwick Manufacturing Group

Fast Charge system - Fast Charge Battery Banks



Fire safety: Fast Charge Battery Banks



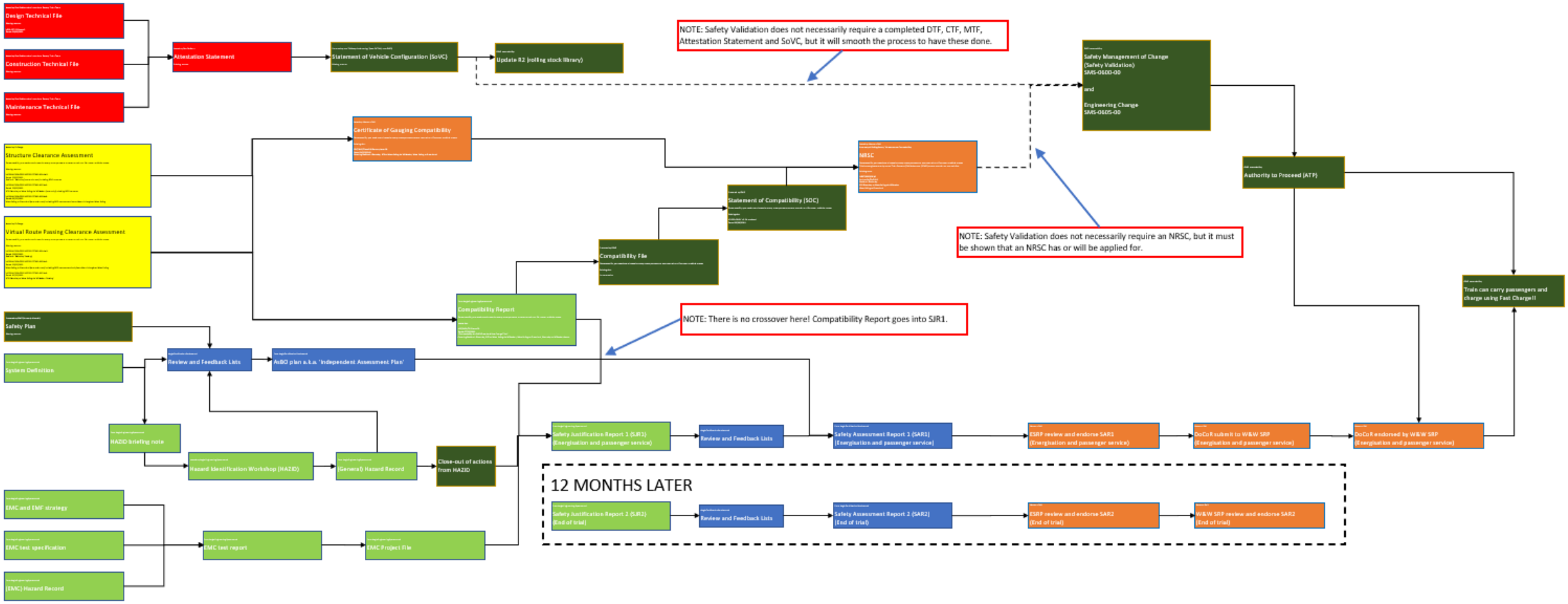
Data source: National Renewable Energy Laboratory and Warwick Manufacturing Group

Fast Charge system – shoegear

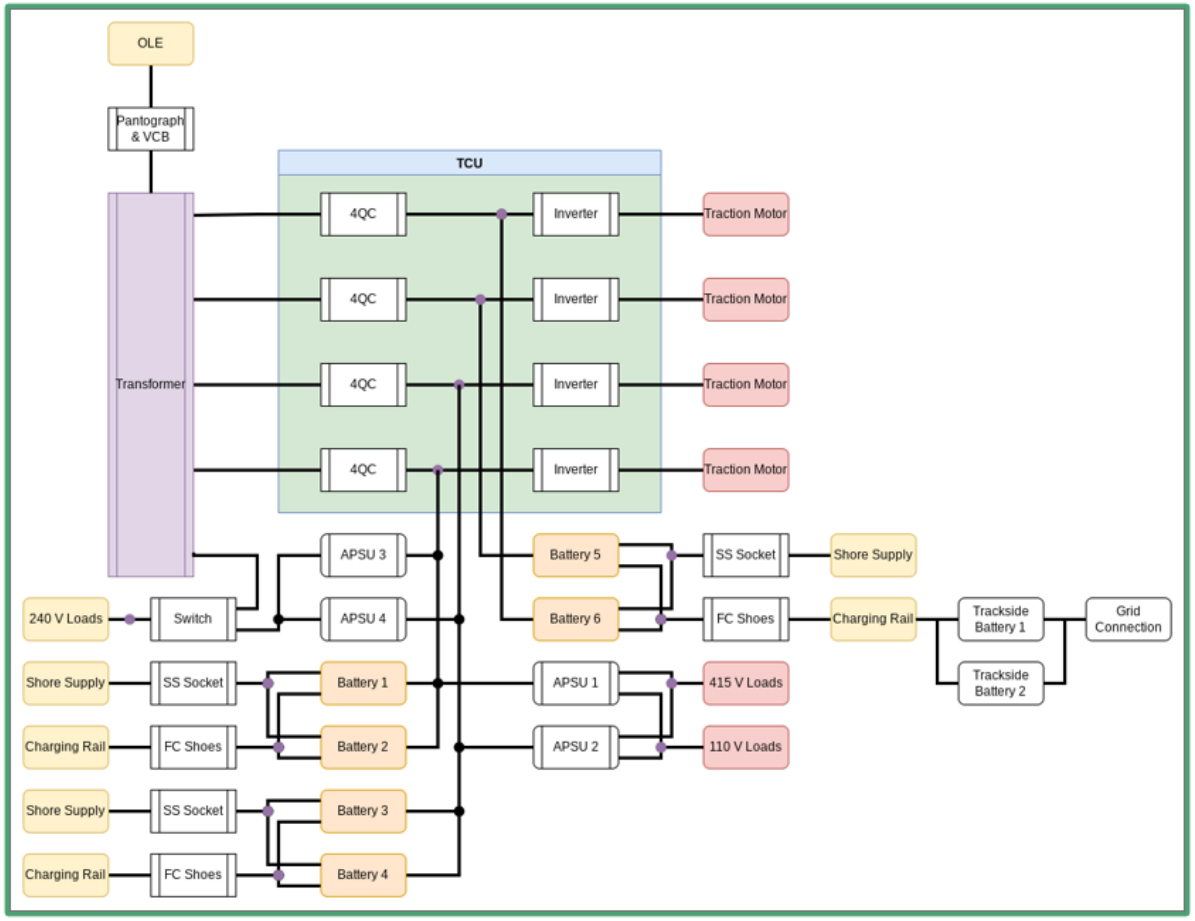
Fast Charge system - shoegear /charge rails

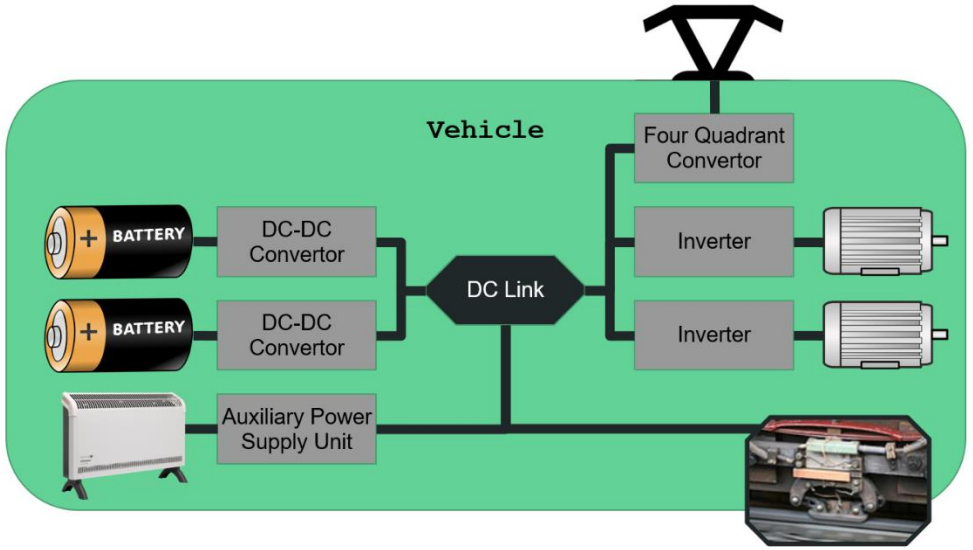
Fast Charge system - shoegear /charge rails

Approvals

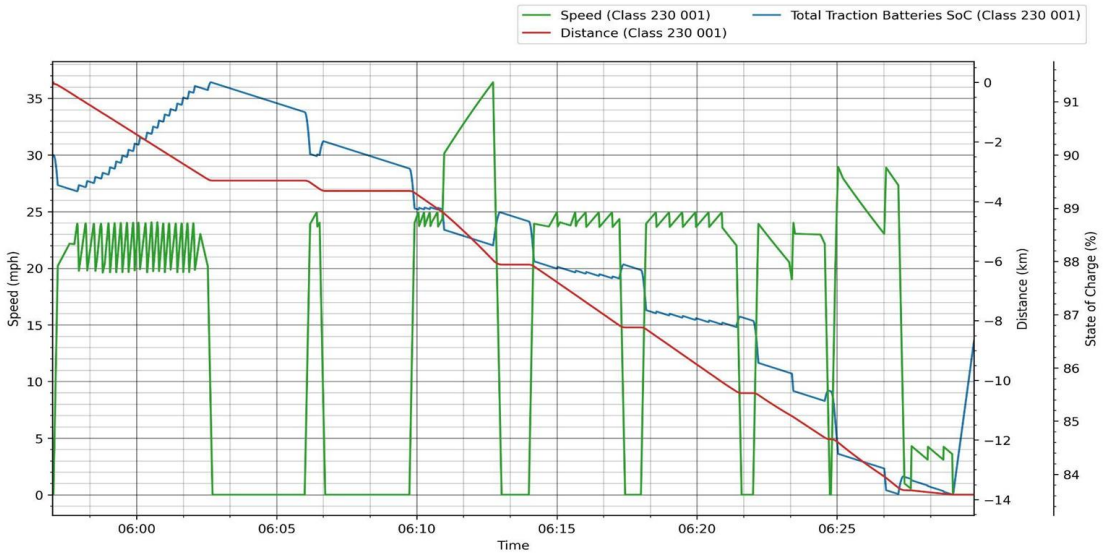

Design Technical File
Construction Technical File
Maintenance Technical File
Attestation Statement
Statement of Vehicle Configuration (SoVC)
Update RZ (rolling stock library)
NOTE: Safety Validation does not necessarily require a completed DTF, CTF, MTF, Attestation Statement and SoVC, but it will smooth the process to have these done.
Safety Management of Change (Safety Validation) SMS-0600-00
and
Engineering Change SMS-0605-00
Certificate of Gauging Compatibility
Structure Clearance Assessment
Virtual Route Passing Clearance Assessment
NRSC
Statement of Compatibility (SOC)
Compatibility File
Authority to Proceed (ATP)
NOTE: Safety Validation does not necessarily require an NRSC, but it must be shown that an NRSC has or will be applied for.
Train can carry passengers and charge using Fast Charge!!
Compatibility Report
NOTE: There is no crossover here! Compatibility Report goes into SJR1.
Safety Plan
System Definition
Review and Feedback Lists
AsBO plan a.k.a. 'Independent Assessment Plan'
HAZID briefing note
Hazard Identification Workshop (HAZID)
(General) Hazard Record
Close-out of actions from HAZID
Safety Justification Report 1 (SJR1) (Energisation and passenger service)
Review and Feedback Lists
Safety Assessment Report 1 (SAR1) (Energisation and passenger service)
ESRP review and endorse SAR1 (Energisation and passenger service)
DoCoL submit to W&W SRP (Energisation and passenger service)
DoCoL endorsed by W&W SRP (Energisation and passenger service)
12 MONTHS LATER
Safety Justification Report 2 (SJR2) (End of trial)
Review and Feedback Lists
Safety Assessment Report 2 (SAR2) (End of trial)
ESRP review and endorse SAR2 (End of trial)
W&W SRP review and endorse SAR2 (End of trial)
EMC and EMF strategy
EMC test specification
(EMC) Hazard Record
EMC test report
EMC Project File

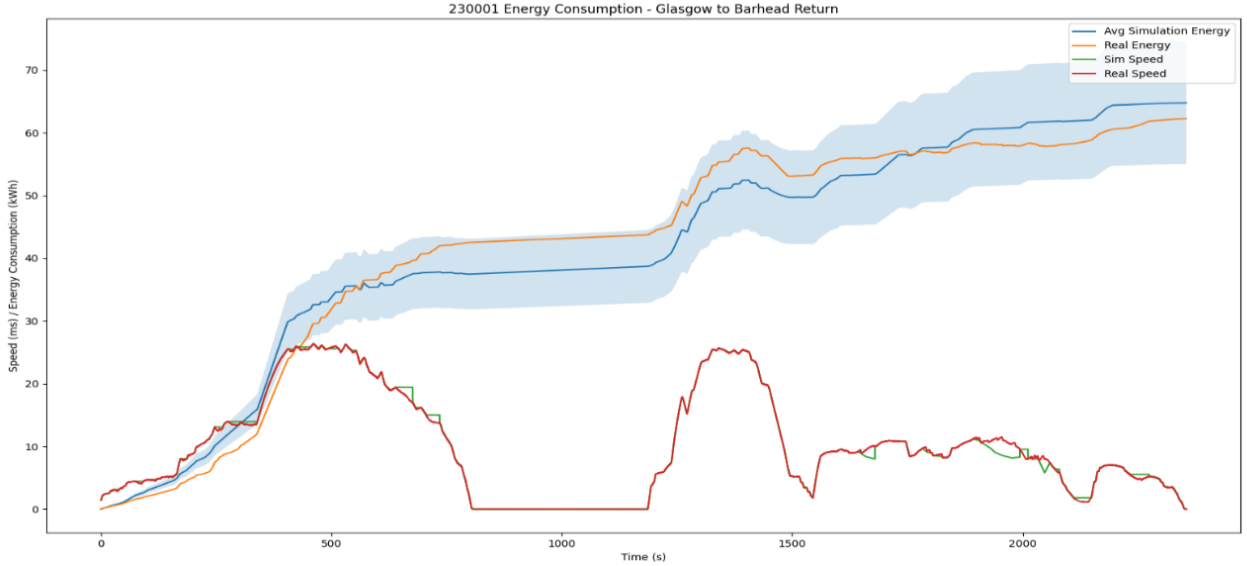
Energy simulations





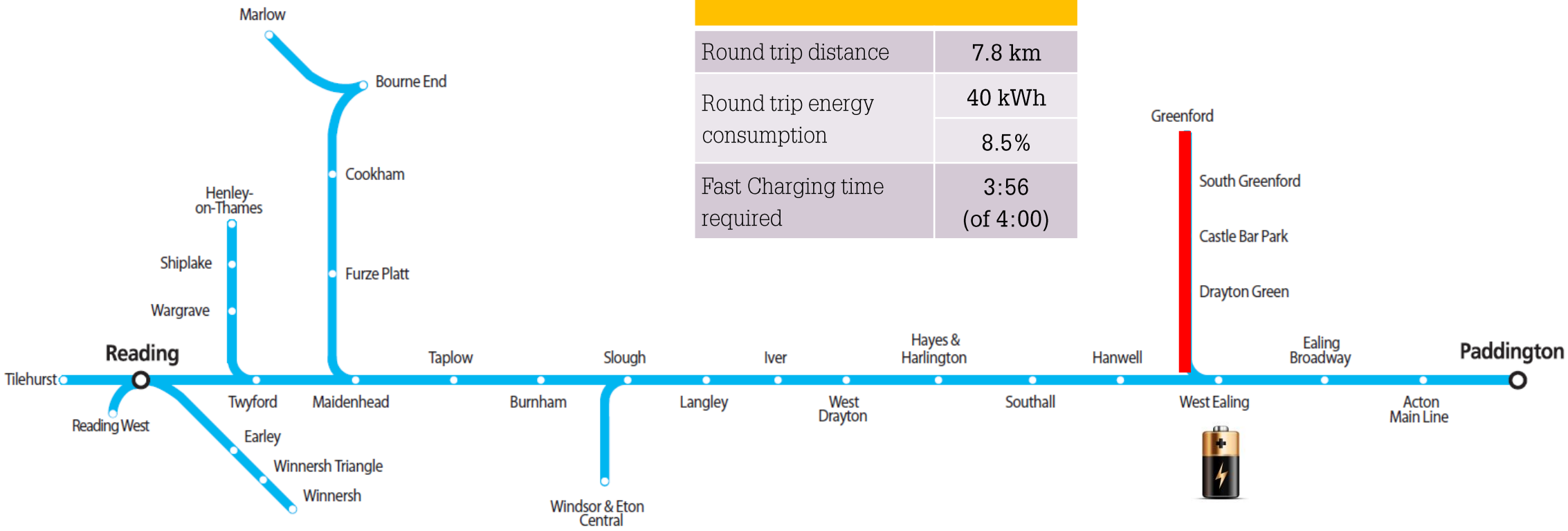
Energy simulations – typical outputs





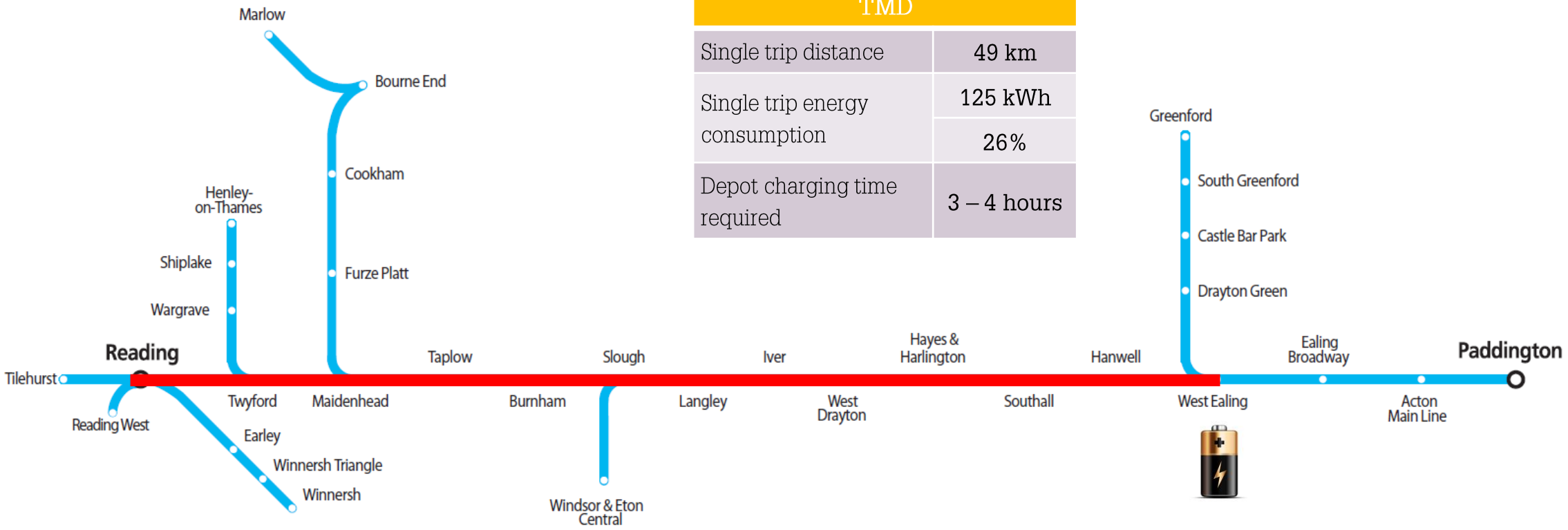
Energy simulation: round trip consumption (typical)

Greenford branch	
Round trip distance	7.8 km
Round trip energy consumption	40 kWh
	8.5%
Fast Charging time required	3:56 (of 4:00)

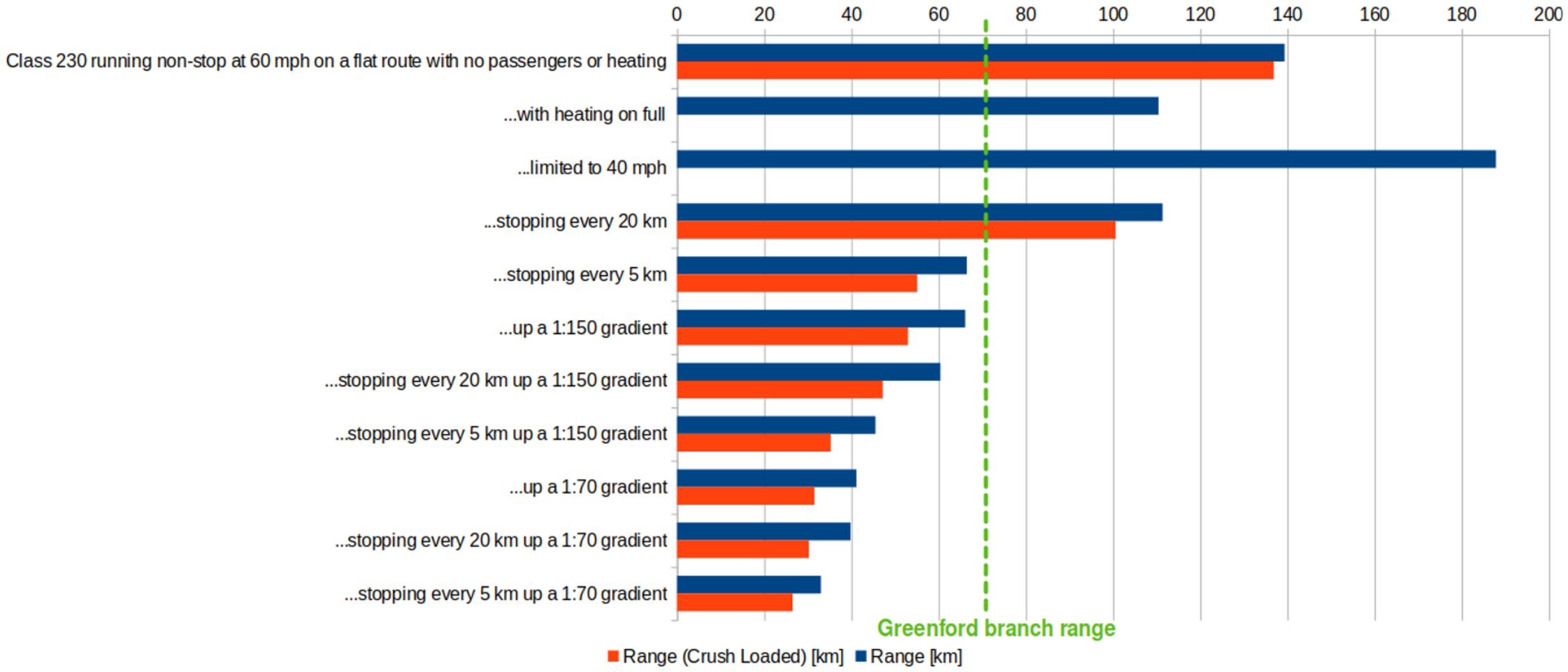


Energy simulation – getting to Reading depot (ECS), typical

West Ealing FCBB to Reading TMD	
Single trip distance	49 km
Single trip energy consumption	125 kWh
	26%
Depot charging time required	3 – 4 hours



How far will it go?



Where are we now: main line testing

Where are we now: Routine Fast Charging

Full timetable operation, passenger carrying

WEST EALING TO GREENFORD

MONDAYS TO FRIDAYS

London Paddington ⊖	d	**0544**	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
London Paddington El ⊖	d	.	0609	0639	0706	0736	0808	0838	0908	0936	1006	1054	1124	1154	1224	1254	1324	1354	1424	1454	1524	1554	1624	
Ealing Broadway ⊖	d	**0553**	0618	0648	0719	0748	0818	0848	0918	0948	1018	1103	1133	1203	1233	1303	1333	1404	1434	1504	1533	1603	1633	
Heathrow Terminals 2 & 3 ⊖ ✈	d	0536	0606	0636	0706	0736	0806	0836	0906	0936	1006	1051	1121	1155	1225	1255	1325	1355	1425	1455	1525	1555	1625	
Hayes & Harlington	d	0542	0612	0642	0712	0742	0812	0842	0912	0942	1012	1057	1127	1202	1232	1302	1332	1402	1432	1502	1532	1602	1632	
Southall	d	0545	0615	0645	0715	0745	0815	0845	0915	0945	1015	1100	1131	1200	1230	1301	1330	1400	1430	1500	1530	1600	1630	
West Ealing	d	**0556**	**0628**	**0657**	**0730**	**0800**	**0830**	**0900**	**0930**	**1000**	**1030**	**1110**	**1140**	**1215**	**1245**	**1315**	**1345**	**1415**	**1445**	**1515**	**1545**	**1615**	**1645**	
Drayton Green	d	**0558**	**0630**	**0659**	**0732**	**0802**	**0832**	**0902**	**0932**	**1002**	**1032**	**1112**	**1142**	**1217**	**1247**	**1317**	**1347**	**1417**	**1447**	**1517**	**1547**	**1617**	**1647**	
Castle Bar Park	d	**0600**	**0632**	**0701**	**0734**	**0804**	**0834**	**0904**	**0934**	**1004**	**1034**	**1114**	**1144**	**1219**	**1249**	**1319**	**1349**	**1419**	**1449**	**1519**	**1549**	**1619**	**1649**	
South Greenford	d	**0603**	**0635**	**0704**	**0737**	**0807**	**0837**	**0907**	**0937**	**1007**	**1037**	**1117**	**1147**	**1222**	**1252**	**1322**	**1352**	**1422**	**1452**	**1522**	**1552**	**1622**	**1652**	
Greenford ⊖	a	**0608**	**0640**	**0709**	**0742**	**0812**	**0842**	**0912**	**0942**	**1012**	**1042**	**1122**	**1152**	**1227**	**1257**	**1327**	**1357**	**1427**	**1457**	**1527**	**1557**	**1627**	**1657**	

London Paddington ⊖	d	.	.	.	.	.	.
London Paddington El ⊖	d	1654	1725	1755	1825	1854	1924
Ealing Broadway ⊖	d	1703	1735	1805	1835	1903	1933
Heathrow Terminals 2 & 3 ⊖ ✈	d	1655	1725	1755	1825	1855	1925
Hayes & Harlington	d	1702	1734	1802	1832	1902	1932
Southall	d	1702	1730	1801	1831	1901	1930
West Ealing	d	**1715**	**1745**	**1815**	**1845**	**1915**	**1945**
Drayton Green	d	**1717**	**1747**	**1817**	**1847**	**1917**	**1947**
Castle Bar Park	d	**1719**	**1749**	**1819**	**1849**	**1919**	**1949**
South Greenford	d	**1722**	**1752**	**1822**	**1852**	**1922**	**1952**
Greenford ⊖	a	**1727**	**1757**	**1827**	**1857**	**1927**	**1957**

SATURDAYS

London Paddington ⊖	d	**0543**	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
London Paddington El ⊖	d	.	0624	0654	0724	0754	0824	0854	0924	0954	1024	1054	1124	1154	1224	1254	1324	1354	1424	1454	1524	1554	1624	
Ealing Broadway ⊖	d	**0552**	0633	0703	0733	0803	0833	0903	0933	1003	1033	1103	1133	1203	1233	1303	1333	1403	1433	1503	1533	1603	1633	
Heathrow Terminals 2 & 3 ⊖ ✈	d	0536	0621	0651	0721	0751	0821	0851	0921	0951	1021	1051	1121	1155	1225	1255	1325	1355	1425	1455	1525	1555	1625	
Hayes & Harlington	d	0542	0627	0657	0728	0757	0827	0857	0927	0957	1027	1057	1127	1202	1232	1302	1332	1402	1432	1502	1532	1602	1632	
Southall	d	0545	0630	0700	0731	0800	0830	0900	0930	1000	1030	1100	1131	1200	1230	1301	1330	1400	1430	1500	1530	1600	1630	
West Ealing	d	**0555**	**0645**	**0715**	**0745**	**0815**	**0845**	**0915**	**0945**	**1015**	**1045**	**1115**	**1145**	**1215**	**1245**	**1315**	**1345**	**1415**	**1445**	**1515**	**1545**	**1615**	**1645**	
Drayton Green	d	**0558**	**0647**	**0717**	**0747**	**0817**	**0847**	**0917**	**0947**	**1017**	**1047**	**1117**	**1147**	**1217**	**1247**	**1317**	**1347**	**1417**	**1447**	**1517**	**1547**	**1617**	**1647**	
Castle Bar Park	d	**0600**	**0649**	**0719**	**0749**	**0819**	**0849**	**0919**	**0949**	**1019**	**1049**	**1119**	**1149**	**1219**	**1249**	**1319**	**1349**	**1419**	**1449**	**1519**	**1549**	**1619**	**1649**	
South Greenford	d	**0602**	**0651**	**0721**	**0751**	**0821**	**0851**	**0921**	**0951**	**1021**	**1051**	**1121**	**1151**	**1221**	**1251**	**1321**	**1351**	**1421**	**1451**	**1521**	**1551**	**1621**	**1651**	
Greenford ⊖	a	**0607**	**0657**	**0727**	**0757**	**0827**	**0857**	**0927**	**0957**	**1027**	**1057**	**1127**	**1157**	**1227**	**1257**	**1327**	**1357**	**1427**	**1457**	**1527**	**1557**	**1627**	**1657**	

London Paddington ⊖	d	.	.	.	.	.	.
London Paddington El ⊖	d	1654	1724	1754	1824	1854	1924
Ealing Broadway ⊖	d	1703	1733	1803	1833	1903	1933
Heathrow Terminals 2 & 3 ⊖ ✈	d	1655	1725	1755	1825	1855	1925
Hayes & Harlington	d	1702	1732	1802	1832	1902	1932
Southall	d	1700	1730	1800	1830	1900	1930
West Ealing	d	**1715**	**1745**	**1815**	**1845**	**1915**	**1945**
Drayton Green	d	**1717**	**1747**	**1817**	**1847**	**1917**	**1947**
Castle Bar Park	d	**1719**	**1749**	**1819**	**1849**	**1919**	**1949**
South Greenford	d	**1721**	**1751**	**1821**	**1851**	**1921**	**1951**
Greenford ⊖	a	**1727**	**1757**	**1827**	**1857**	**1927**	**1957**

GREENFORD TO WEST EALING

MONDAYS TO FRIDAYS

Greenford ⊖	d	**0614**	**0643**	**0715**	**0745**	**0815**	**0845**	**0915**	**0945**	**1015**	**1054**	**1125**	**1200**	**1230**	**1300**	**1330**	**1400**	**1430**	**1500**	**1530**	**1600**	**1630**	**1700**	
South Greenford	d	**0618**	**0647**	**0719**	**0749**	**0819**	**0849**	**0919**	**0949**	**1019**	**1058**	**1129**	**1204**	**1234**	**1304**	**1334**	**1404**	**1434**	**1504**	**1534**	**1604**	**1634**	**1704**	
Castle Bar Park	d	**0620**	**0649**	**0721**	**0751**	**0821**	**0851**	**0921**	**0951**	**1021**	**1100**	**1131**	**1206**	**1236**	**1306**	**1336**	**1406**	**1436**	**1506**	**1536**	**1606**	**1636**	**1706**	
Drayton Green	d	**0622**	**0651**	**0723**	**0753**	**0823**	**0853**	**0923**	**0953**	**1023**	**1102**	**1133**	**1208**	**1238**	**1308**	**1338**	**1408**	**1438**	**1508**	**1538**	**1608**	**1638**	**1708**	
West Ealing	d a	**0625**	**0654**	**0726**	**0757**	**0826**	**0856**	**0926**	**0956**	**1026**	**1105**	**1136**	**1211**	**1241**	**1311**	**1341**	**1411**	**1441**	**1511**	**1541**	**1611**	**1641**	**1711**	
Southall	a	0642	0711	0741	0811	0841	0911	0941	1011	1041	1111	1156	1226	1256	1326	1356	1426	1456	1526	1556	1626	1656	1726	
Hayes & Harlington	a	0645	0714	0744	0814	0844	0914	0944	1014	1044	1114	1152	1223	1253	1322	1353	1422	1452	1522	1552	1623	1653	1722	
Heathrow Terminals 2 & 3 ⊖ ✈	a	0652	0721	0751	0821	0851	0921	0951	1021	1051	1121	1159	1230	1300	1329	1400	1429	1459	1529	1559	1630	1700	1729	
Ealing Broadway ⊖	a	0637	0707	0737	0807	0837	0907	0937	1008	1037	1111	1141	1222	1252	1322	1352	1422	1452	1523	1552	1622	1652	1722	
London Paddington El ⊖	a	0650	0720	0748	0818	0848	0920	0950	1018	1047	1121	1151	1232	1303	1333	1402	1433	1502	1533	1602	1632	1705	1735	
London Paddington ⊖	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	

Greenford ⊖	d	**1730**	**1800**	**1830**	**1900**	**1930**	**2000**	**2030**	**2100**	**2131**	**2203**
South Greenford	d	**1734**	**1804**	**1834**	**1904**	**1934**	**2004**	**2034**	**2104**	**2135**	**2207**
Castle Bar Park	d	**1736**	**1806**	**1836**	**1906**	**1936**	**2006**	**2036**	**2106**	**2137**	**2209**
Drayton Green	d	**1738**	**1808**	**1838**	**1908**	**1938**	**2008**	**2038**	**2108**	**2139**	**2212**
West Ealing	d a	**1741**	**1811**	**1841**	**1911**	**1941**	**2011**	**2041**	**2111**	**2142**	**2215**
Southall	a	1756	1826	1856	1926	1956	2026	2056	2126	2156	2226
Hayes & Harlington	a	1752	1822	1852	1922	1952	2023	2052	2123	2152	2229
Heathrow Terminals 2 & 3 ⊖ ✈	a	1800	1830	1900	1929	1959	2030	2059	2130	2159	2236
Ealing Broadway ⊖	a	1752	1822	1852	1922	1952	2022	2052	2122	2152	**2219**
London Paddington El ⊖	a	1805	1832	1902	1932	2002	2032	2102	2132	2202	.
London Paddington ⊖	a	.	.	.	.	.	.	.	.	.	**2231**

Travelling to London Paddington

Trains to London Paddington will use the National Rail station or the nearby Elizabeth line station. The stations are shown as two separate lines in the timetable. Please check which station your service arrives at.

London Paddington for the National Rail station

London Paddington El for the Elizabeth line station

SATURDAYS

Greenford ⊖	d	**0610**	**0700**	**0730**	**0800**	**0830**	**0900**	**0930**	**1001**	**1030**	**1100**	**1130**	**1200**	**1230**	**1300**	**1330**	**1400**	**1430**	**1500**	**1530**	**1600**	**1630**	**1700**	
South Greenford	d	**0613**	**0703**	**0733**	**0803**	**0833**	**0903**	**0933**	**1004**	**1033**	**1103**	**1133**	**1203**	**1233**	**1303**	**1333**	**1403**	**1433**	**1503**	**1533**	**1603**	**1633**	**1703**	
Castle Bar Park	d	**0616**	**0706**	**0736**	**0806**	**0836**	**0906**	**0936**	**1007**	**1036**	**1106**	**1136**	**1206**	**1236**	**1306**	**1336**	**1406**	**1436**	**1506**	**1536**	**1606**	**1636**	**1706**	
Drayton Green	d	**0618**	**0708**	**0738**	**0808**	**0838**	**0908**	**0938**	**1009**	**1039**	**1108**	**1137**	**1208**	**1238**	**1308**	**1338**	**1408**	**1438**	**1508**	**1538**	**1608**	**1638**	**1708**	
West Ealing	d a	**0621**	**0711**	**0741**	**0811**	**0841**	**0911**	**0941**	**1012**	**1042**	**1111**	**1141**	**1211**	**1241**	**1311**	**1341**	**1411**	**1441**	**1511**	**1541**	**1611**	**1641**	**1711**	
Southall	a	0641	0726	0758	0826	0856	0926	0956	1026	1056	1126	1156	1226	1256	1326	1356	1426	1456	1526	1556	1626	1656	1726	
Hayes & Harlington	a	0644	0729	0759	0822	0852	0922	0952	1022	1052	1122	1152	1222	1252	1322	1352	1422	1452	1522	1552	1622	1652	1722	
Heathrow Terminals 2 & 3 ⊖ ✈	a	0651	0736	0806	0829	0859	0929	0959	1029	1059	1129	1159	1229	1259	1329	1359	1429	1459	1529	1559	1629	1659	1729	
Ealing Broadway ⊖	a	0637	0722	0752	0822	0852	0922	0952	1022	1052	1122	1152	1222	1252	1322	1352	1422	1452	1522	1552	1622	1652	1722	
London Paddington El ⊖	a	0647	0732	0802	0832	0902	0932	1003	1032	1102	1132	1202	1232	1302	1332	1402	1432	1502	1532	1602	1632	1702	1732	
London Paddington ⊖	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	

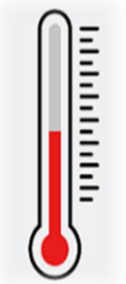
Greenford ⊖	d	**1730**	**1800**	**1830**	**1900**	**1930**	**2000**	**2030**	**2100**	**2130**	**2204**
South Greenford	d	**1733**	**1803**	**1833**	**1903**	**1933**	**2003**	**2033**	**2103**	**2133**	**2207**
Castle Bar Park	d	**1736**	**1806**	**1836**	**1906**	**1936**	**2006**	**2036**	**2106**	**2136**	**2210**
Drayton Green	d	**1738**	**1808**	**1838**	**1908**	**1938**	**2008**	**2038**	**2108**	**2138**	**2212**
West Ealing	d a	**1742**	**1811**	**1841**	**1911**	**1941**	**2011**	**2041**	**2111**	**2141**	**2214**
Southall	a	1756	1826	1856	1926	1956	2026	2056	2126	2156	2226
Hayes & Harlington	a	1752	1822	1852	1922	1952	2022	2052	2122	2152	2229
Heathrow Terminals 2 & 3 ⊖ ✈	a	1759	1829	1859	1929	1959	2029	2059	2129	2159	2236
Ealing Broadway ⊖	a	1752	1822	1852	1922	1952	2022	2052	2122	2152	**2218**
London Paddington El ⊖	a	1802	1832	1902	1932	2002	2032	2102	2132	2205	.
London Paddington ⊖	a	.	.	.	.	.	.	.	.	.	**2228**

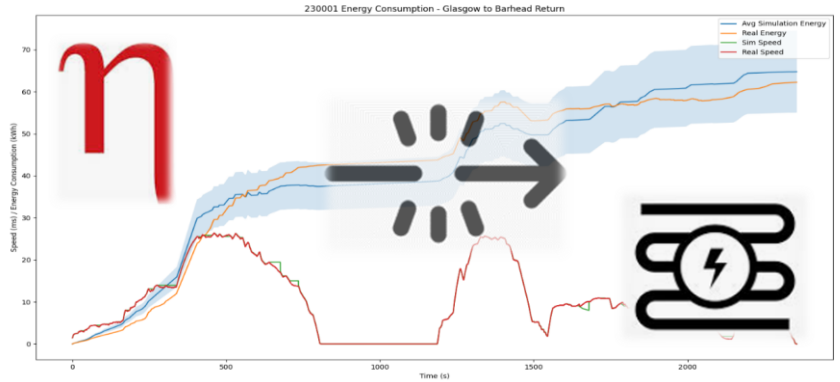
Changes to our timetables

The times shown in this timetable are a guide to our services. Train times may change late at night or at weekends to allow maintenance work to be done. You should always confirm your train times online, less than 24 hours prior to travelling at **GWR.com/check**

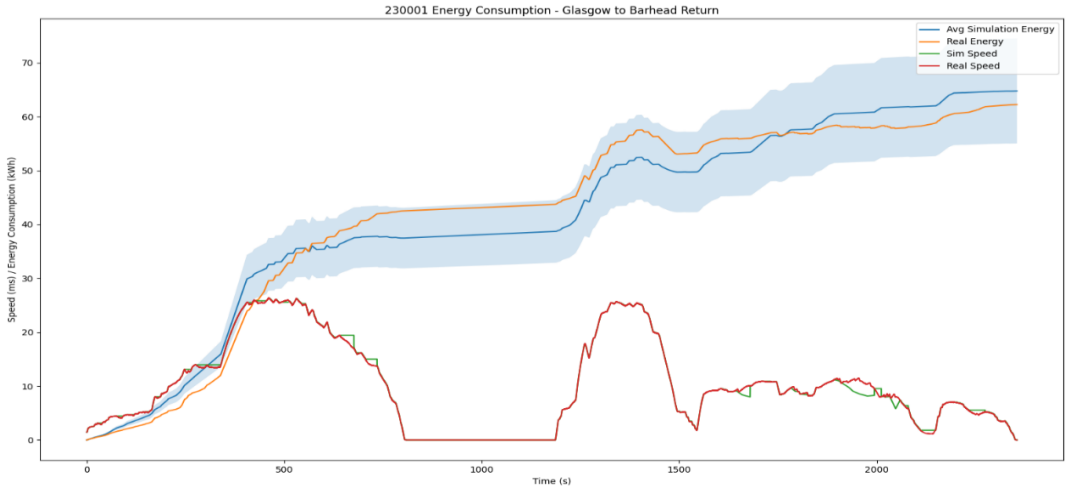
There is no service on this route on Sundays

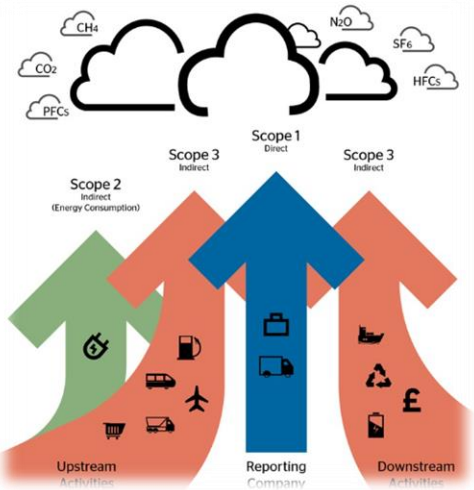
Ongoing evaluation

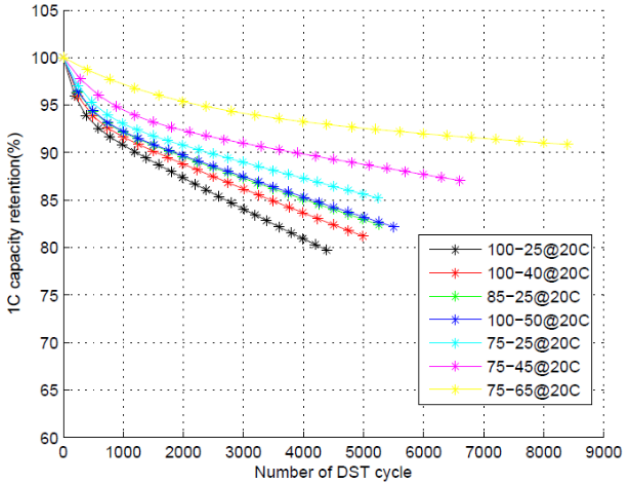




Data – based deliverables



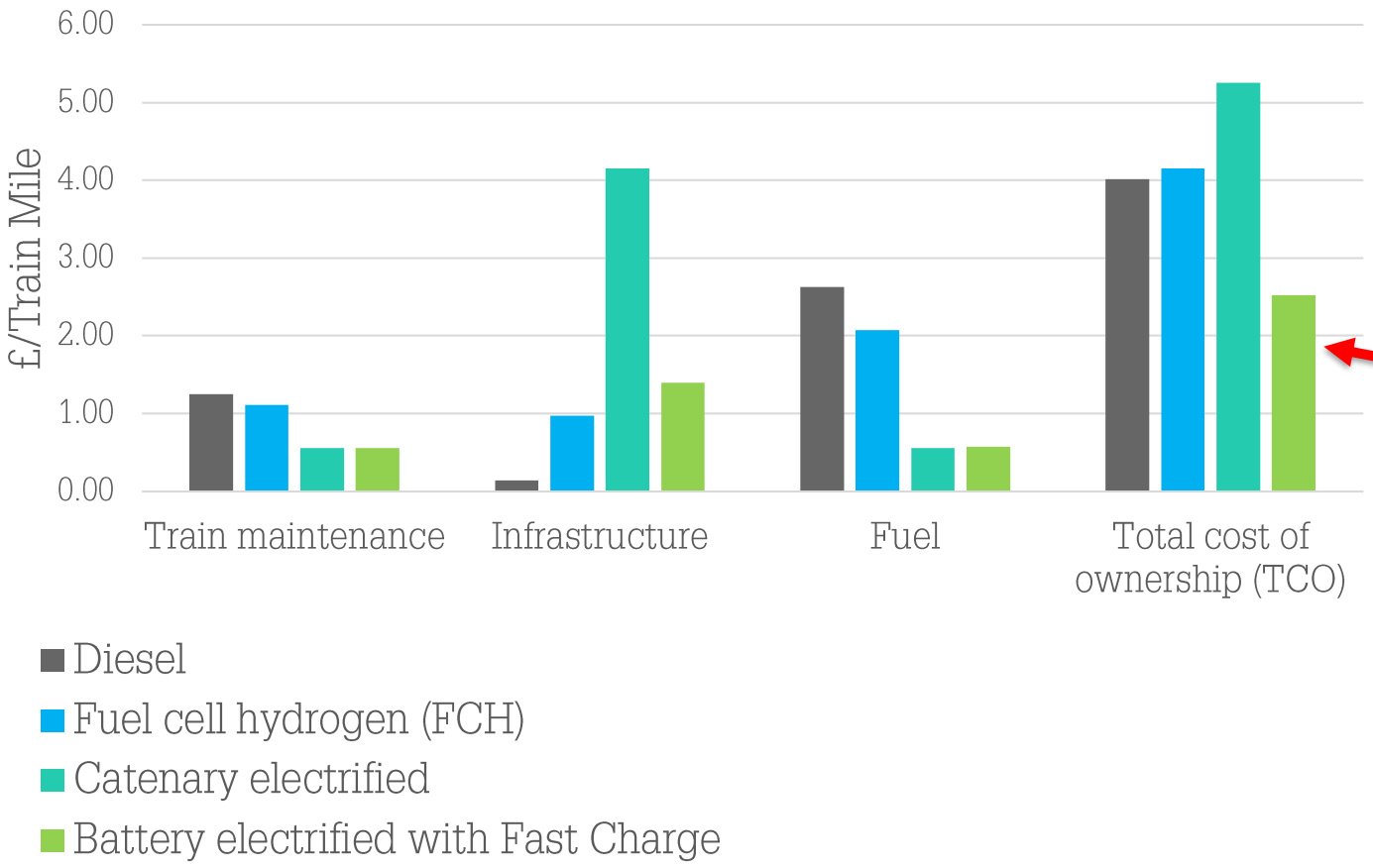


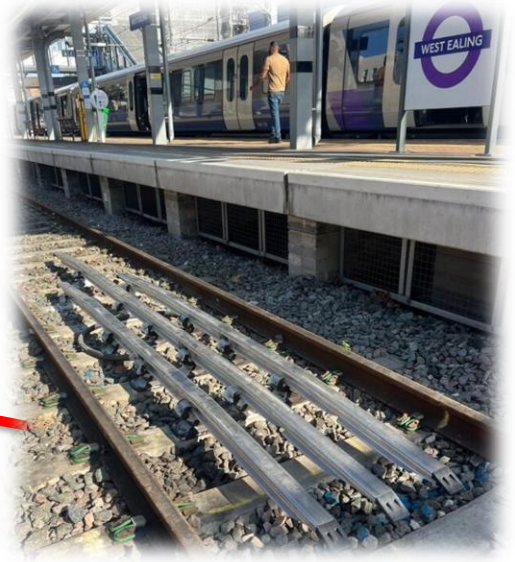


Cost of ownership

Source data: Study on the use of fuel cells & hydrogen in the railway environment: REPORT 1: State of the art & business case and market potential. EU Shift2Rail Joint Undertaking and Fuel Cells and Hydrogen Joint Undertaking, 2019. Figure 12. https://www.fch.europa.eu/sites/default/files/Report%201.pdf

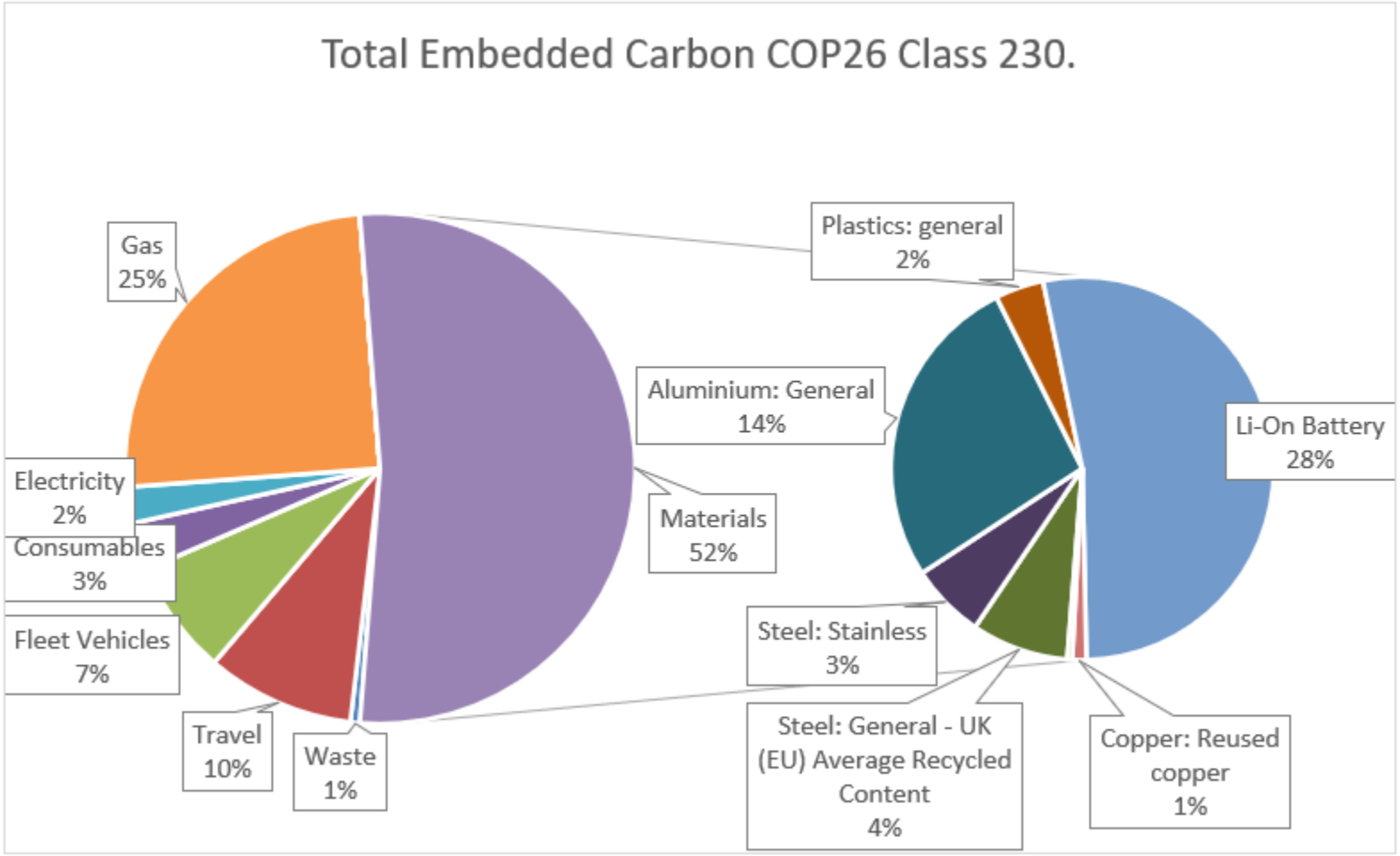
Battery case added by GWR Fast Charge Battery Train Team.



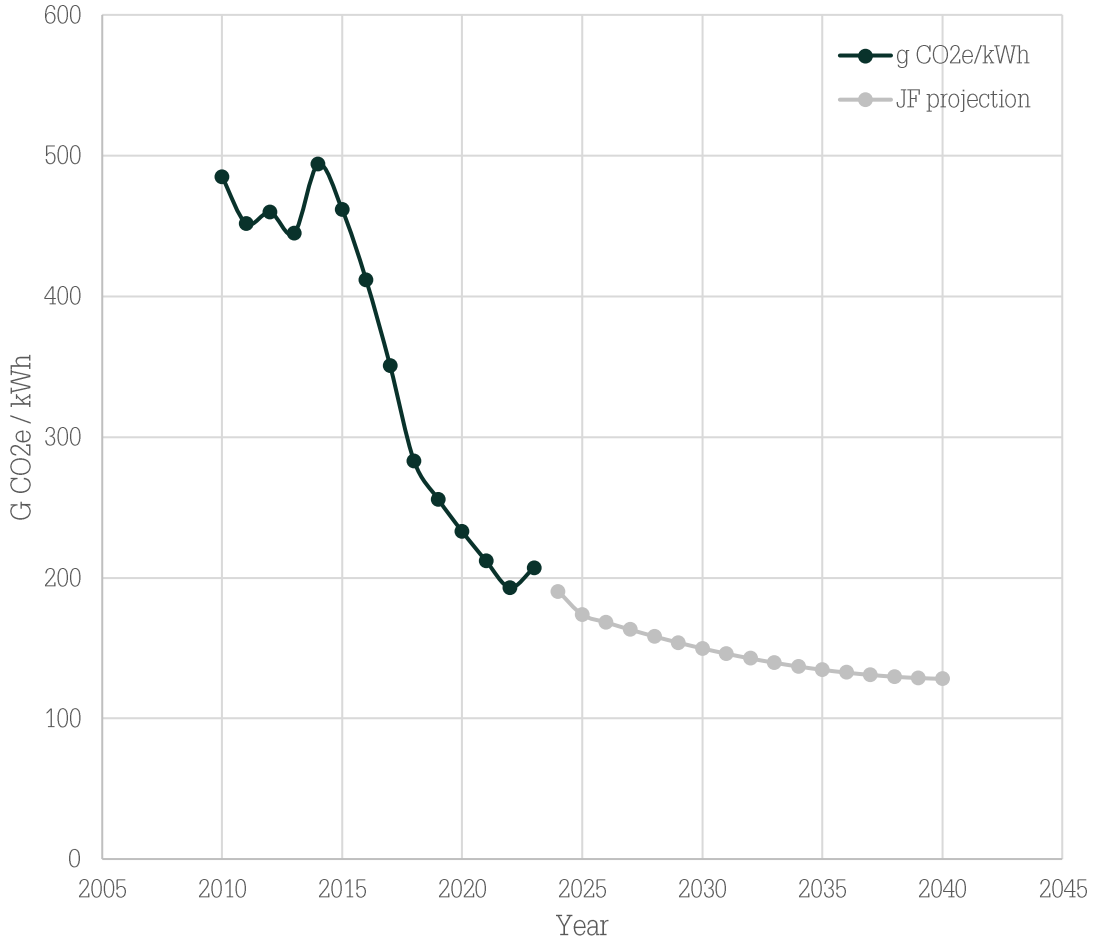


Embodied carbon: COP26 configuration

COP26 config: 255 tonnes total embodied carbon



Cumulative emissions



FAQs

“Everything you always wanted to know about Fast Charge battery trains*

*But were afraid to ask”

Thank you