Transition Marlborough
Transport Group

# Hants & Berks Line
# Newbury-Westbury Electrification
# Reduction in $CO_2$ emissions





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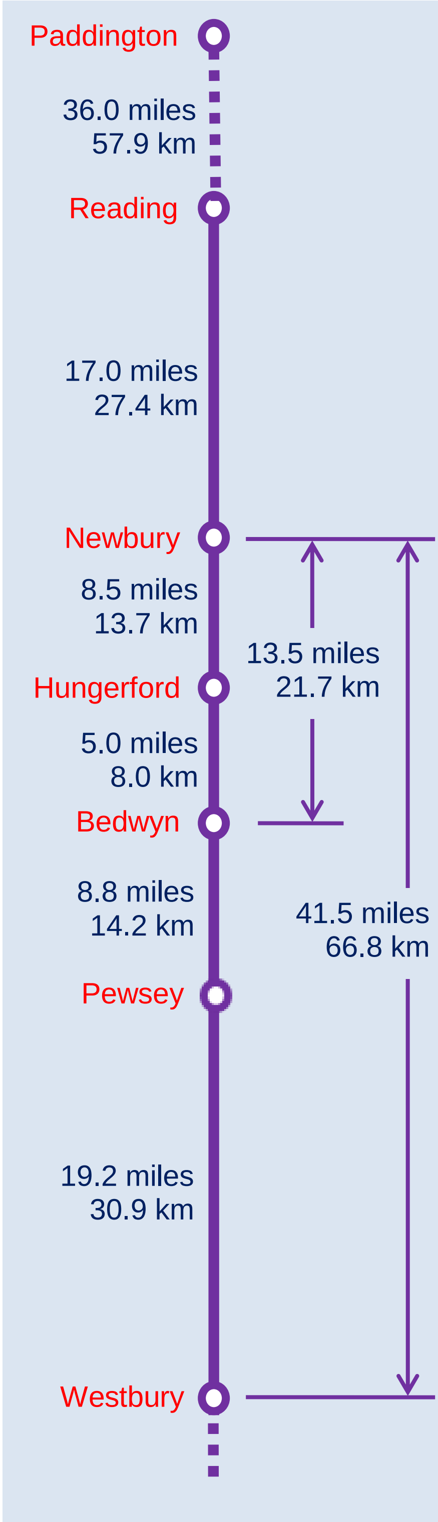
## PURPOSE

The purpose of this report is to estimate the reduction in carbon dioxide emissions associated with the proposed electrification of the Hants & Berks railway line between Newbury and Westbury.




## INTRODUCTION

The Berks & Hants Line currently operates diesel-powered trains between Newbury and Westbury. Electrification is already planned between Reading and Newbury. This report estimates the benefits of extending this electrification as far as Westbury. The emission benefits are quantified as tonnes of carbon dioxide saved per week.

## CARBON DIOXIDE EMISSIONS

Both diesel and electric trains produce carbon dioxide emissions.

### Diesel trains

The extracting of crude oil, its refining into diesel and the distribution of the finished fuel all involve carbon dioxide emissions. These are referred to as “well-to-tank” emissions. The subsequent burning of diesel fuel on board to power the train’s motion produces “tank-to-wheels” emissions. The sum of these two gives the “well-to-wheels” emissions.

### Electric trains

Running the train produces negligible emissions at the point of use. The various types of power station supplying the grid have different emissions characteristics. Fossil-fuel stations produce the most carbon dioxide. Nuclear and renewables produce very little. There are also emissions associated with the mining, extraction and delivery of fossil and nuclear fuels and with some of the renewables. These are referred to as “source-to-power station” emissions. “Source-to-power-station” and “power-station” emissions can added together to give a “Life Cycle Assessment” equivalent to the “Well-to-wheels” emissions for diesel.

## BASIS OF CALCULATIONS

### General

There are a number of different possibilities for future provision. Issues to be resolved include:

- alterations to the service patterns
- selection of rolling stock (with possible bi-mode operation)
- use of regenerative braking

This report aims at a “like-for-like” comparison. It assumes that:

- the present service pattern continues
- diesel rolling stock is replaced with currently available electric stock of roughly equivalent capacity (no bi-mode operation)
- regenerative braking is not used.

Only passenger operations have been examined. No consideration is given to freight.

**Consumption rates**
The report makes extensive use of RSSB T618 – Traction Energy Metrics by Kemp (1). This gives diesel and electrical consumption figures for a selection of UK rolling stock. The Berks & Hants line's Class 165/166 diesels are assumed to have similar characteristics to the Class 170 Turbostar listed in T618. It is assumed that these would be replaced by Class 357 Electrostar EMUs.

In view of the number of stops between Newbury and Bedwyn, the consumption figures for the semi-fast services are probably optimistic. Actual figures would be higher. This would tend to amplify the benefits of electrification. Fast and semi-fast services have all been assumed to have the same consumption rates. It has been assumed that the Inter City 125s would be replaced by Inter-city 225s

**Well-to-tank emissions for diesel**
No well-to-tank figures were available for the rail industry. The figures used are from the EC JRC study (2) for European DERV.

**Tank-to-wheels emissions for diesel**
The energy value used is again for DERV from another EC JRC study (3). Emission rates are from Association of Train Operating Companies (4).

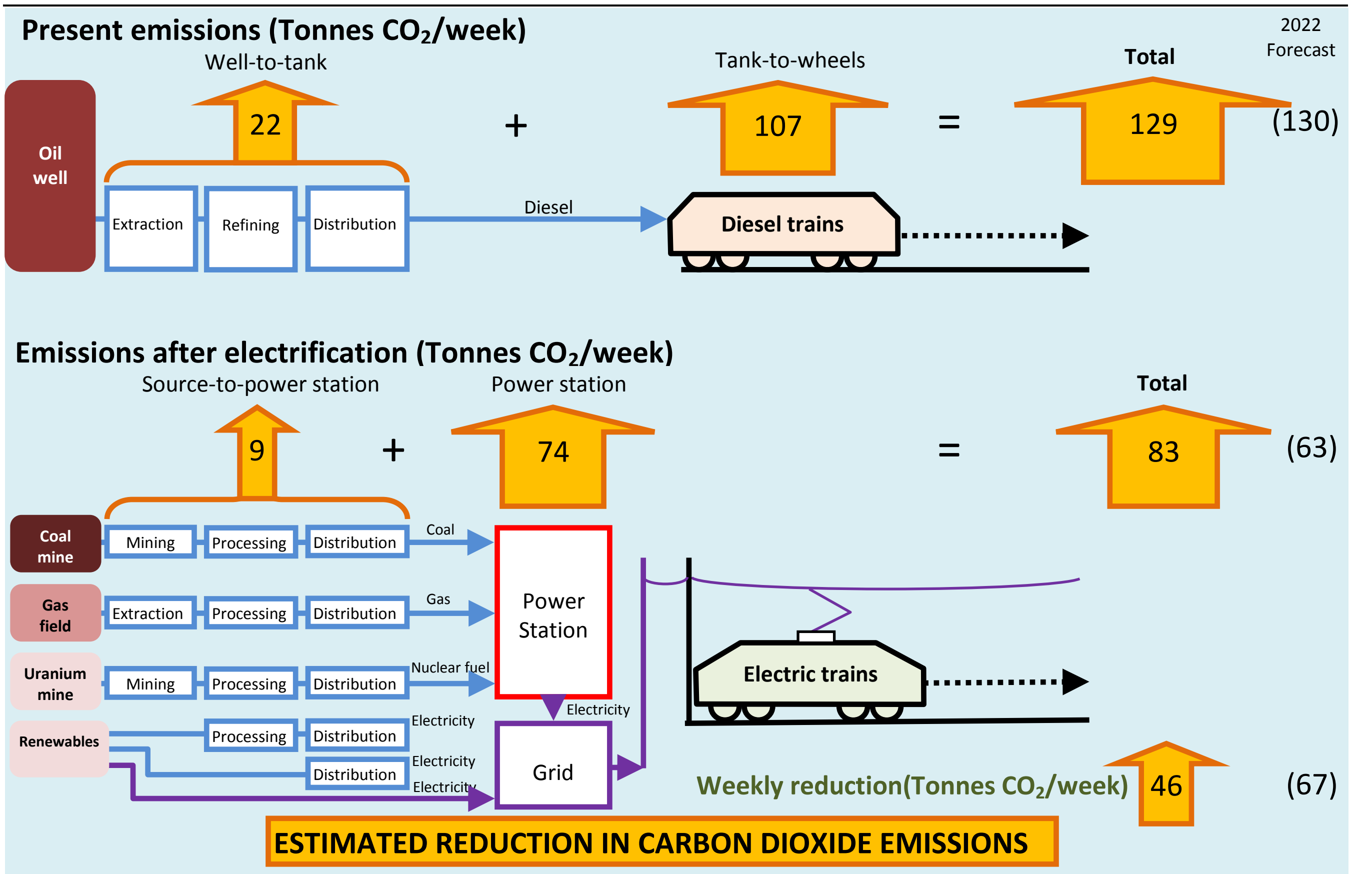
**Life Cycle Assessment Emissions**
LCA emissions figures for different types of power station are taken from the IPCC Special Report on Renewable Energy Sources (7) using 50$^{th}$ percentile values. These have been applied to the UK mix of power generation taken from DECC Digest of UK Energy Statistics (6)

**Power station emissions**
These have been taken from DECC DUKES (5)

**Source-to-power-station emissions**
These have been calculated indirectly by subtracting power station from LCA emissions. This has been done to separate these emissions (assumed to remain as they are) from future reductions in power station emissions.

**Present and future emissions**
It has been assumed that well-to-tank and tank-to-wheels emissions rates for diesel trains will continue at current rates. It has also been assumed that source-to-power-station emission rates will be unchanged. Power station emission rates have trended downwards for some years and this report uses a present rate of 443 $gCO_2$/kWh falling to Kemp's forecast of 320 $gCO_2$/kWh by 2022. Forecast future LCA emissions for the electrification option are calculated assuming that source-to-power-station emissions of 8.6 Tonnes $CO_2$/week continues, but that the power-station emissions fall to 74.7 x 320/443 = 53.9 Tonnes $CO_2$/week.

**CONCLUSIONS**
These are summarised in the following diagram. Electrification of the Newbury to Westbury section will show significant reductions in carbon dioxide emissions: some 46 Tonnes per week at present rising to 67 Tonnes per week by 2022.




| Hants & Berks Line - Newbury-Westbury Electrifiction - Reduction in $CO_2$ Emissions: Passenger services | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Present diesel provision** | | | | **Electrification option** | | | | |
| **Network services between Newbury and Bedwyn** | | | | **Network services between Newbury and Bedwyn** | | | | |
| Diesel consumption | | 1.362 | litre/train km | Energy consumption | | 7.410 | kWh/train km | |
| Distance | | 21.7 | km | Distance | | 21.7 | km | |
| Diesel used per train | | 29.6 | litre/train | Energy used per train | | 161 | kWh/train | |
| No of trains per week | (20x5)+18+8+(21x5)+18+8 | 257 | train/wk | No of trains per week | (20x5)+18+8+(21x5)+18+8 | 257 | train/wk | |
| Diesel used per week | | 7,596 | litre/wk | Energy used per week | | 41,325 | kWh/wk | |
| $CO_2$ emissions per litre of diesel | | 3.269 | kg $CO_2$/litre | $CO_2$ emissions per unit of electricity | | 0.494 | kg $CO_2$/kWh | |
| **$CO_2$ emissions per week** | | **24,829** | **kg $CO_2$/wk** | **$CO_2$ emissions per week** | | **20,420** | **kg $CO_2$/wk** | |
| | | | | | | | | |
| **Semi-fast services between Newbury and Bedwyn** | | | | **Semi-fast services between Newbury and Bedwyn** | | | | |
| Diesel consumption | | 4.189 | litre/train km | Energy consumption | | 16.6 | kWh/train km | |
| Distance | | 21.7 | km | Distance | | 21.7 | km | |
| Diesel used per train | | 90.9 | litre/train | Energy used per train | | 360 | kWh/train | |
| No of trains per week | (3x5)+2+0 + (4x5)+2+0 | 39 | train/wk | No of trains per week | (3x5)+2+0 + (4x5)+2+0 | 39 | train/wk | |
| Diesel used per week | | 3,545 | litre/wk | Energy used per week | | 14,057 | kWh/wk | |
| $CO_2$ emissions per litre of diesel | | 3.269 | kg $CO_2$/litre | $CO_2$ emissions per unit of electricity | | 0.494 | kg $CO_2$/kWh | |
| **$CO_2$ emissions per week** | | **11,588** | **kg $CO_2$/wk** | **$CO_2$ emissions per week** | | **6,946** | **kg $CO_2$/wk** | |
| | | | | | | | | |
| **Long distance with Westbury stops** | | | | **Long distance with Westbury stops** | | | | |
| Diesel consumption | | 4.189 | litre/train km | Energy consumption | | 16.6 | kWh/train km | |
| Distance | | 66.8 | km | Distance | | 66.8 | km | |
| Diesel used per train | | 279.8 | litre/train | Energy used per train | | 1,110 | kWh/train | |
| No of trains per week | (8x5)+5+6 + (7x5)+7+9 | 102 | train/wk | No of trains per week | (8x5)+5+6 + (7x5)+7+9 | 102 | train/wk | |
| Diesel used per week | | 28,542 | litre/wk | Energy used per week | | 113,174 | kWh/wk | |
| $CO_2$ emissions per litre of diesel | | 3.269 | kg $CO_2$/litre | $CO_2$ emissions per unit of electricity | | 0.494 | kg $CO_2$/kWh | |
| **$CO_2$ emissions per week** | | **93,297** | **kg $CO_2$/wk** | **$CO_2$ emissions per week** | | **55,923** | **kg $CO_2$/wk** | |
| | | | | | | | | |
| | | | Present | | | | Present | Forecast |
| | | | | | | | | for 2022 |
| Well-to-tank | | **22.8** | **Tonnes $CO_2$/wk** | Source-to-power station | | **8.6** | **Tonnes $CO_2$/wk** | 8.6 |
| Tank-to-wheels | | **106.9** | **Tonnes $CO_2$/wk** | Power station | | **74.7** | **Tonnes $CO_2$/wk** | 53.9 |
| **WELL-TO-WHEELS EMISSIONS** | | **129.7** | **Tonnes $CO_2$/wk** | **LIFE CYCLE ASSESSMENT EMISSIONS** | | **83.3** | **Tonnes $CO_2$/wk** | 62.6 |
| | | | | **SAVING** | | **46.4** | **Tonnes $CO_2$/wk** | 67.2 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Basis of calculations** | | | | | | | | | |
| **Emissions from present diesel provision** | | | | | **Emissions from electrification option** | | | | |
| **Diesel consumption (1)** | | | | | **Energy consumption (1)** | | | | |
| Network services assumed Class 170 Turbostar 3-car DMU (164 seats). | | | | | Network services assumed Class 357 Electrostar 3-car EMU (200 seats approx) | | | | |
| Diesel consumption | | 0.454 | litres / veh km | | Engy cnsmptn(avg of 2 "all stations" trains) | | 2.47 | kWh/veh km | |
| | | 3 | veh / train | | | | 3 | veh / train | |
| Therefore diesel consumption | | **1.362** | litres / train km | | Therefore energy consumption | | **7.410** | kWh/train km | |
| | | | | | | | | | |
| Semi-fast & long distance services assumed IC 125 2+8 (617 seats) | | | | | Semi-fast & long dist services assumed IC 225 (554 seats) loco+9+DVT=11 veh | | | | |
| Diesel consumption - ATOC study of ECML | | 1,260 | ,000 litres | | Energy consumption ATOC study of ECML | | 1.510 | kWh/veh km | |
| | distance run | 300,788 | km | | | Vehicles | 11 | veh/train | |
| Therefore diesel consumption | | **4.189** | litres / train km | | Therefore energy consumption | | **16.610** | kWh/train km | |
| **$CO_2$ emissions from diesel** | | | | | **$CO_2$ emissions from electrical generation** | | | | |
| DERV well-to-tank emissions (2) | | 16 | g$CO_2$/MJ | | Source-to-p-s emissions (= 0.494 - 0.443) | | 0.051 | | |
| Lower Heating Value for diesel (3) | | 43.1 | MJ/kg fuel | | Power station emissions (current mix) (1) | | 0.443 | | |
| Therefore DERV well-to-tank emissions | | 0.690 | kg$CO_2$/kg fuel | | LCA emissions 2011 power station mix | | **0.494** | **kg $CO_2$/kWh** | |
| Diesel density (3) | | 0.832 | kg fuel/litre | | Source-to-power station emissions | | 0.051 | | |
| Therefore DERV well-to-tank emissions | | 0.574 | kg$CO_2$/litre | | Power station emissions - 2022 mix (1) | | 0.320 | | |
| Diesel tank-to-wheels emissions (4) | | 2.695 | kg$CO_2$/litre | | Forecast emissions 2022 | | **0.371** | **kg $CO_2$/kWh** | |
| Therefore diesel well-to-wheels emissions | | **3.269** | **kg$CO_2$/litre** | | | | | | |
| | | | | | **UK Electrical Generation Mix : Life Cycle Assessment** | | | | |
| | | | | | | Mix of UK power station types-2011 (6) | 50th percentile LCA emissions (7) | **weighted emissions** | |
| | | | | | **Power station types** | | g $CO_2$/kWh | g $CO_2$/kWh | |
| | | | | | Coal | 30% | 1,001 | **300** | |
| | | | | | Gas | 40% | 469 | **188** | |
| | | | | | Nuclear | 19% | 16 | **3** | |
| | | | | | PV/wind/other | 11% | 29 | **3** | |
| | | | | | | 100% | | **494** | |
| | | | **EMISSIONS SUMMARY** | | | | | | |
| **Diesel** | | | | F'cast 2022 | **Electrification** | | | | F'cast 2022 |
| **Well-to-tank emissions g$CO_2$/litre** | | **0.57** | **18%** | 0.57 | **Source-to-power stat emissions g$CO_2$/kWh** | | **51** | **10%** | 51 |
| **Tank-to-wheels emissions g$CO_2$/litre** | | **2.70** | **82%** | 2.70 | **Power station emissions g$CO_2$/kWh** | | **443** | **90%** | 320 |
| **Well-to-wheels emissions g$CO_2$/litre** | | **3.27** | **100%** | 3.27 | **Life Cycle Assessment g$CO_2$/kWh** | | **494** | **100%** | 371 |

## References

(1) Kemp R. J. T618 Traction Energy Metrics, Rail Safety & Standards Board, Dec 2007
(2) Edwards R., Larivé J-F., Beziat J-C. - Well-to-Tank Report, European Commission Joint Research Centre, 2011 - Fig 4.2-2
(3) Edwards R., Larivé J-F., Mahie V., Rouveirolles P. - Tank-to-Wheels Report, European Commission Joint Research Centre, 2007 - Table 2.1
(4) ATOC Baseline energy statement - energy consumption and carbon dioxide emissions on the railway, 2007 - Table 3
(5) Dept for Energy and Climate Change Digest of United Kingdom Energy Statistics - 2012 - Chapter 5 Table 5A
(6) Ibid - Chart 5.2 - Figures are for the year 2011
(7 ) Intergovernmental Panel on Climate Change - Special Report on Renewable Energy Sources and Climate Change Mitigation - 2012 - Annex II Table A.II.4

**Acknowledgement**
Title page: Bottom three photographs are copyright Rail Safety and Standards Board –T618 Traction Energy Metrics