



Best Foot Forward

Bringing sustainability down to earth

Determining the carbon footprint of the East Coast line and alternative transport modes

Report for National Express

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Determining the carbon footprint of the East Coast line and alternative transport modes

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Best Foot Forward

One of Europe's leading sustainability consultancies, Best Foot Forward (BFF) specialises in ecological and carbon footprint analysis offering consulting services, training and management tools.

Founded in 1997, BFF is widely credited with popularising the footprint concept in the UK following the award-winning *Island State* study of the Isle of Wight's economy, a guide on footprinting businesses, produced in 2001 for the Association of Chartered and Certified Accountants, and the publication, in 2000, of *Sharing Nature's Interest: ecological footprints as an indicator of sustainability*.

BFF's mission statement is 'to help organisations, regions and communities to reduce their footprint'.

Best Foot Forward has unrivalled experience and an enviable track record having helped over one hundred organisations and undertaken in excess of 300 footprint studies.

The company has advised on everything from reducing the supply chain impacts associated with African apple production and distribution to managing Greater London's ecological footprint.

Best Foot Forward's multinational team of analysts and consultants is based in Oxford, England. The company is also able to draw on a network of global partners and associates offering local knowledge, where appropriate, and additional sectoral expertise when required.

In 2005, Best Foot Forward was conferred the prestigious Queen's Award for Business in Sustainable Development. This 'corporate knighthood' specifically recognised BFF's contribution to corporate sustainability.



Summary

National Express Group have commissioned the production of this technical ‘white paper’ to inform and support an advertising campaign on the carbon benefits of travelling by train on the East Coast line.

The analysis investigates the greenhouse gas (GHG) emissions of different transport modes (car, train, air) for the specific routes (London to Peterborough, Leeds, Newcastle, and Edinburgh). These routes are served by the East Coast line train service provided by the National Express Group. The analysis therefore contrasts travelling by train with driving and flying.

Using the assumptions explained elsewhere in this report, Table 1 compares average emissions per passenger km expressed in terms of carbon dioxide equivalents from different transport modes for different routes. The results show that travelling by train produces the least amount of GHG emissions per passenger km of the three modes.

Table 1: Comparison of average emissions (gCO₂e) per passenger kilometre between different transport modes by destination (all from London)

	Leeds	Newcastle	Edinburgh	Peterborough
Train	42	42	42	42
Car	127	127	127	127
Air	304	153	144	/

As set out in Table 1, with average load factors a passenger travelling by train will emit around 42 gCO₂ equivalent emissions per km, while travelling by car will emit 127 g CO₂e per km. Travelling by air will emit between 144 g and 304 g CO₂e per km. The significant range in emissions by air is as a result of different load factors on the individual routes and because aircraft flying shorter distances generate more emissions per km because the fuel consumption during landing and take off cycle represents a bigger proportion of the total fuel use.

As a result an average train journey will generate a third of the emissions per passenger km than the average car journey. The average train journey will generate between a third and a seventh of total emissions per passenger than the average plane trip depending upon the route. Thus travelling by train represents a saving in greenhouse gas emissions of 67% over the car and between 71 and 86% of flying.

Table 2: Average total GHG emissions per passenger (kg CO₂e) for different transport modes and destination (all from London) All figures assume average occupancy.

	Leeds	Newcastle	Edinburgh	Peterborough
Train	12	18	27	5
Car	38	55	76	16
Air*	92	68	84	-

* Total emissions per passenger refer to the weighted average of emissions from all carriers flying from London to that destination.

Table 2 shows the total emissions by destination and mode. The absolute emissions from flying to Edinburgh are less than for driving, despite the aircraft emissions per km being higher, because the journey length by plane is less than the road route.

Note that the emissions associated with flying include only emissions arising from air travel from airport to airport. As airports are typically located outside of main conurbations, air travellers are more likely than train users and car drivers to require connecting travel at each end of their journey. These additional emissions have not been included in these calculations. If it is conservatively assumed these connecting journeys were by train it would add approximately 1.5 kg CO₂e per journey on to the air figures in Table 2. In practice many of these journeys will be by car.

London to Leeds

In absolute terms the average journey to Leeds by train would generate 12 kg CO₂e emissions, while the equivalent journey by car would produce three times more emissions (38 kg CO₂e) and flying seven times more than the train at 92 kg CO₂e per passenger. Travelling by train from London to Leeds therefore represents a saving of 68% over driving and 86% over flying.

London to Newcastle

Travelling to Newcastle by train will generate 18 kg CO₂e emissions. Equivalent journey by car would produce three times as many emissions (55 kg CO₂e) and flying 68 kg CO₂e. Travelling by train from London to Newcastle therefore represents a saving of 67% over driving and 73% over flying.

London to Edinburgh

As a consequence of the longer distance and high load factors flying to Edinburgh produce 11% more emissions (84 kg CO₂e) per passenger than travelling by average car, which would generate 76 kg CO₂e emissions. However, travelling by train produces a third of the emissions (27 kg CO₂e). Travelling by train from London to Edinburgh therefore represents a saving of 65% over driving and 68% over flying.

London to Peterborough

A train journey to Peterborough would generate 5 kg CO₂e emissions whilst covering the same distance by car will generate 16 kg CO₂e emissions. There are no flights between London and Peterborough.

Detailed Calculations by Mode

Train

Assumption and Calculations

Table 3 provided detailed data on train emissions for different routes served by National Express trains (East Coast line). Data sources used for the calculations are presented below.

Table 3: Train emissions (kg CO₂e) for different routes

	Leeds	Newcastle	Edinburgh	Peterborough
Track distance (km)	299	433	632	122
Train energy consumption (kWh/km)	16.15	16.15	16.15	16.15
Train energy consumption including loss in the railway electric transmission network (6%)	16.48	16.48	16.48	16.48
Total electricity consumption (kWh)	4,926	7,134	10,413	2,010
Fuel consumption (litres of diesel per km)	4.16	4.16	4.16	4.16
Total fuel consumption (litres of fuel)	1,244	1,801	2,629	508
Total train emissions (electric - UK average mix 2007)	2,747	3,978	5,806	1,121
Total train emissions (diesel)	3,428	4,964	7,245	1,399
Load factor	0.44	0.44	0.44	0.44
Total number of seats (diesel train)	529	529	529	529
Total number of seats (electric train)	539	539	539	539
kg CO ₂ e per passenger (average energy mix)	12	17	25	5
kg CO ₂ e per passenger (diesel)	14	21	31	6
Electric train emissions (kg CO ₂ e per pass km; average energy mix)	0.039	0.039	0.039	0.039
Diesel train (kg CO ₂ e per pass km)	0.048	0.048	0.048	0.048
Average emissions per passenger km (gCO ₂ e)	42	42	42	42
Average total emissions per passenger (kg CO ₂ e)	12	18	27	5
Average fleet				
Electric	75%	72%	68%	74%
Diesel	25%	28%	32%	26%

The results show that the average journey to Peterborough would produce 5 kg CO₂e emissions per passenger. The journey to Leeds would generate 12 kg CO₂e emissions, while travelling to Newcastle and Edinburgh will produce 18 and 27 kg CO₂e, respectively. These estimates are based on the average train emissions that stand at 42 gCO₂e per passenger km.

Trains are able to source electricity from different energy providers who can have very different carbon intensity as a consequence of the proportion generated from, for instance, nuclear power or renewable generation. . Using energy from these sources may significantly reduce carbon footprint of train journeys.

British Energy generates most of its electricity from nuclear power and consequently has a much lower intensity of GHG emissions compared to average UK grid electricity. Sourcing electricity exclusively from British Energy would produce 10 g CO₂e emissions per passenger km for a train journey as opposed to 39 g CO₂e per passenger km calculated above and based on average UK electricity mix.

If electricity for trains were sourced from 100% renewable energy, the carbon footprint from a train journey would become very low.

Data sources

National Express group provided data for the railway track distances, average train load factors, total number of seats in trains and the structure of an average fleet. National Express also provided data for the train energy consumption.

Conversion factors for electricity and diesel were obtained from Best Foot Forward’s internal database based on the rolling average as reported by Defra (2007) and adjusted for greenhouse gases).

Losses in the railway network were assumed to be 6% (ATOC 2007).

The carbon intensity of the electricity is conservatively based upon the current UK grid average. The East Coast railways currently source their electricity from British Energy, which actually has lower carbon intensity than the UK grid average as it sources most of its electricity from nuclear.

Table 4: Data sources used in the analysis

Data	Source
Track distance (km)	National Express, 2008
Train energy consumption (kWh/km)	National Express, 2008
Train energy consumption including loss in the railway electric transmission network (6%)	ATOC, 2007
Fuel consumption (litres of diesel per km)	National Express, GNER 2008;
Conversion factor for electricity (kg CO ₂ e/kWh)UK average generation mix (2007)	Defra, 2007, Best Foot Forward, 2008
Conversion factor for diesel fuel (kg CO ₂ e/litre)	Defra, 2007, Best Foot Forward, 2008

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Load factor	National Express, 2008
Total number of seats in a train	National Express, 2008
Average fleet	National Express, 2008

Air

Assumptions and Calculations

Table 5 sets out the data and assumptions used to calculate the emissions from aviation.

Due to the fact that London has five airports from which it is possible to travel to the selected destinations the emissions are calculated as a weighted average of flights leaving London airports.

Table 5: Emissions from Flight

	Distance			Load factor	Emissions (kg CO ₂ e)			
	km	9 % uplift	% of flights		Total	Per seat	Per seat km	Per psg km
London to Edinburgh								
Heathrow	533	581	0.37	0.74	8368	57	0.099	0.132
Gatwick	573	625	0.20	0.77	8786	60	0.096	0.125
City	542	591	0.22	0.58	1849	62	0.104	0.181
Luton	494	538	0.11	0.63	7977	55	0.101	0.162
Stansted	509	555	0.11	0.77	8135	56	0.100	0.130
weighted average								0.144
London to Newcastle								
Heathrow	405	441	0.460	0.82	7057	48	0.109	0.134
Gatwick	443	483	0.204	0.46	7464	51	0.106	0.231
City	409	446	0.008	0.35	1239	43	0.096	0.276
Luton	363	396	0.002	0.79	6649	46	0.115	0.147
Stansted	373	407	0.326	0.69	5291	36	0.089	0.128
weighted average								0.153
London to Leeds								
Heathrow	278	303.02	0.999	0.43	5796	40	0.131	0.304

Average flight emissions from London to Edinburgh will equal to 144 g CO₂e per passenger kilometre, while flight from London to Newcastle will produce 153 g CO₂e emissions per passenger km. A passenger flying from London to Leeds will produce 304 g CO₂e emissions per passenger km.

Table 6: Total emissions per passenger (kg CO₂e) from flying to a particular destination

	Leeds	Newcastle	Edinburgh
Emissions*	92	68	84

*Total emissions per passenger refer to the weighted average of emissions from all carriers flying from London to that destination.

Note that the emissions associated with flying include only emissions arising from air travel from airport to airport. As airports are typically located outside of main conurbations, air travellers are more likely than train users and car drivers to require connecting travel at each end of their journey. . These additional emissions have not been included in these calculations. If it is conservatively assumed these connecting

journeys were by train it would add approximately 1.5 kg CO₂e per journey on to the air figures in Table 2. In practice many of these journeys will be by car.

Other aircraft emission calculations

The calculated aircraft emissions were contrasted to updated Defra (2008) conversion factors and to results obtained by using SAS emission calculator.

While latest available figures released by Defra report average domestic emissions per passenger km to be 160.1 g CO₂, SAS calculator enables calculation of a route specific emissions from using a specific aircraft. The data for the most efficient aircraft available on a specific destination show that a journey between London and Edinburgh would produce 130 g CO₂ per passenger km, 142 g CO₂ per passenger km would be released on a flight between London and Newcastle and 242 g CO₂ per passenger km for a flight from London to Leeds. SAS emission figures are calculated for a distance based on Great Circle Distance (shortest distance between two points), which leads to a lower fuel consumption and thus emissions compared to the figures presented in the report, which takes into account 9% increase in distance due to the IPCC recommendations. SAS results do not provide figures for fuel consumption making estimation of other GHG more difficult.

For commercial reasons there is limited data available for other airlines by route. However, Easyjet publish the most information. They consistently have some of the highest occupancy rates and seats per plane and a modern fleet. Using their webpage calculator a flight from Stansted to Edinburgh would produce 60 kg CO₂ per passenger. This is equivalent to 0.108 kg CO₂ per passenger km based on a distance of 556 km. This figure is 25% lower than the figure obtained by the 'average' calculations in this report which are based on all airlines flying those routes (17% lower when comparing average emissions per passenger km between Stansted and Edinburgh).

Data Sources

The primary data source for fuel consumption was the EMEP/CORINAIR Emission Inventory Guidebook – 2006. It provides fuel consumption data for individual aircrafts for the Landing and Take Off Cycle and for the Cruise Cycle. This split is important because fuel consumption and consequently emissions from the first phase are very much similar for all the journeys, irrespective of their distance. Fuel consumption during cruise depends on the distance travelled and is very much similar (per km flown) for all flight types. This is the principal reason why short distance flights produce higher emissions per seat kilometre than long haul flights.

Fuel consumption data for the most representative aircrafts serving particular route were also taken from Corinair database.

Load factors for the year 2007 have been provided by CAA, which lists number of passengers as well as estimated number of seats for all journeys between analyzed airports.

Flights between London City and Newcastle, Luton and Newcastle and all flights to Leeds from London airports except for Heathrow were excluded from the analysis due to the low passenger traffic. Flight distances include 9% uplift factor, which takes into account indirect routing/delays (Defra, 2007).

Calculation of emissions rests on the conversion factor produced by Defra (2008), which is adjusted for other greenhouse gases that are produced from burning fuel on the ground.

Considerable uncertainty surrounds the use of a multiplier (referred to as the Radiative Forcing Index or RFI) to reflect the climate change impact of flying - which extends beyond that from carbon dioxide emissions alone. RFI values of between 1.9 and 4 have been commonly applied to the carbon emissions. However, some research suggests that the global warming potential of flying may be as little as 20% greater than the impact of carbon dioxide (REF PAPER). No multiplier is used in the calculations presented here – this gives a conservative estimate of the impact of flying.

Table 7: Data sources

Data	Source
Emission factor for aviation fuel	Defra, 2008, Best Foot Forward, 2008
Fuel consumption data	Corinair, 2006
Distance uplift factor	Defra, Passenger Transport Emission Factors, June 2007
Distances	http://www.world-airport-codes.com
Load factors	CAA, 2007

Car

Assumptions and calculations

The Table 8 below portrays GHG emissions (by route) produced by an average petrol car. Emissions depend on the distance and the car occupancy level.

Table 8: Car emissions (kg CO₂e) for individual journeys

	Leeds	Newcastle	Edinburgh	Peterborough
Single occupancy	61	87	120	26
Average occupancy	38	55	76	16
Full occupancy	15	22	30	6

An average car with average occupancy rate 1.58 passengers per vehicle would emit 38 kg CO₂e when driven to Leeds. Average emissions to Newcastle would equal 55 kg CO₂e, while emissions to Edinburgh and to Peterborough would be equal to 76 and 16 kg CO₂e, respectively.

Data sources

It was assumed that the average car consumes 7.62 litres of petrol per 100 kilometres. This is equivalent to 201 gCO₂ equivalent emissions per vehicle kilometre. At average occupancy levels 1.58 passengers (Travel Survey, 2007) this equates to 127 gCO₂e per passenger kilometre. A fully loaded car (assuming 4 people in a car) would produce only 50 gCO₂e emissions per km.

Table 9: Emissions for an average petrol car

	Fuel consumption	Emissions (kg CO ₂ e per km)		
	l/100km	Single occupancy	Average occupancy	Full occupancy
Average car	7.62	0.201	0.127	0.050

Distances between cities were calculated by the means of the Michelin route calculator, while data on fuel conversion factors were taken from Best Foot Forward's database. These are essentially factors from Defra 2007 adjusted to include all GHG emissions.

Table 10: Data sources

Data	Source
Conversion factors for petrol and diesel fuel	Defra, 2007, Best Foot Forward, 2008
Fuel consumption	Defra 2007
Split of the car parc (total number of cars in use)	SMMT, 2008
Average occupancy	Travel survey, 2007
Distance calculators	http://www.viamichelin.com/viamichelin/gbr/dyn/controller/route-planner#

Uncertainty

Load Factors

The headline figures provided in this report are based on ‘average’ consumption data. In practice emissions per passenger km by mode can vary significantly with variability depending on type of fuel used, load factors and distance travelled. There are other methodological considerations including, for example, whether a Radiative Forcing Index is included. In this section the variability of results within each mode is explored.

Table 11 explores the impact of varying load factor. Fully loaded cars emit twice the mass of GHG emissions than fully loaded trains, while travelling by a fully occupied flight will create five times more emissions than travelling by fully occupied train. Using low load factors (30% for trains, 25% for cars – one person, 43% for air) produces even greater variability of emissions across transport modes.

Table 11: Comparison of variability of emissions per pass km (kg CO₂e) across transport modes

Mode	100% load	Low load factor
Train	0.017-0.021	0.058-0.071
Car	0.031-0.055	0.124-0.220
Air	0.102-0.135	0.231-0.306

Train – detailed calculations

The main variability in train emissions comes from load (as described above), train model and, to a lesser extent, fuel type. To account for variability in emissions load factor of 30% (National Express 2006) was used to denote low utilization of the network, while 100% load factor was used to allow comparison across fully utilized transport alternatives.

A fully loaded train produces a third of the emission per passenger (18 g CO₂e per passenger km) than 30% loaded train.

Diesel trains emit just over 10% more emissions than electric train.

Table 12: GHG emissions of trains based on different load factors and fuel type

Train type	Train emissions per pass km (kg CO ₂ e)	
	100% load	30% load
Electric train	0.017	0.058
Diesel train	0.021	0.071
Average train	0.018	0.061

Car – detailed calculations

Variability in the emissions of cars is dependent on factors such as load factor, fuel type and vehicle model. For example, an average diesel car emits 10 per cent less GHG emissions than the average petrol car. A medium hybrid electric car produces 30 % less emission than an average petrol car. These values are based on Defra 2007 figures which take into account all cars in use in the UK. New cars are typically more efficient than the models they replace.

Table 13: Variability of car emissions

	Car emissions (kg CO ₂ e per km)		
	Single occupancy	Average occupancy	Full occupancy (4 passengers)
Average petrol	0.205	0.130	0.051
Average diesel	0.181	0.115	0.045
Hybrid - medium	0.124	0.078	0.031
Hybrid - large	0.220	0.139	0.055

Air – detailed calculations

Emissions per passenger km for flights depend on the load factors, aircraft type, distance and on the multiplier used to express the non-CO₂ climate changing impacts. Short flights generates more emissions per passenger km than longer flights. For this reason flying to Edinburgh, when flight is 100% loaded, will produce 30% less emissions per passenger km than flying to Leeds.

Table 14: Variability of air emissions

	Air emissions per pass km (kg CO ₂ e)	
	Fully loaded	Low occupancy (43%)
Edinburgh	0.99	0.232
Newcastle	0.102	0.234
Leeds	0.131	0.305