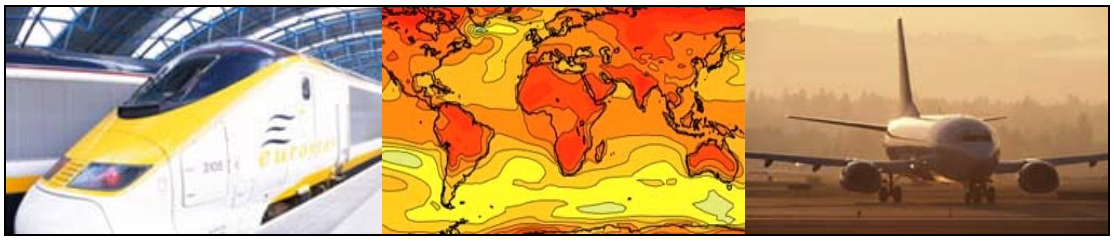
Update of Eurostar CO_2 Emissions using Energy Logging Train Data



Report to Eurostar

Independent research undertaken by:

Paul Watkiss Associates

February 2009

Executive Summary

The previous assurance study for Eurostar estimated the energy use and CO_2 emissions for journeys between London to Paris and London to Brussels. This information was used for estimating the carbon offsets as part of the 'tread lightly' campaign. The analysis is summarised on the Eurostar web-site.

This report updates the energy calculations, using measured electricity consumption data from the Eurostar energy logging train for journeys between London to Paris and London to Brussels. The report also updates the electricity generation and carbon emissions associated with energy use. The analysis of the metered data shows that:

- The measured electricity consumption is much lower (30% lower) than the previous estimated values. The previous values were based on a combination of aggregate measurements, engineering estimates and test data. The lower energy use leads to much lower carbon emissions for Eurostar.
- A statistical analysis of the measurement data shows that there are significant differences in the electricity consumption with route direction (outward vs. inward). There is also a correlation with energy use increasing slightly with the number of extra stops. However, no correlations are found between total energy use and passenger numbers, delays, or ambient temperatures.

The analysis has also used the measurement data to estimate energy and emissions for other Eurostar routes to Marne-La-Vallee (Disneyland resort, Paris), to Avignon, and to Bourg St. Maurice (the ski train).

The results per train journey are summarised for each train route below, as emissions per journey. The table also presents the previous values from the last offset assurance work. In interpreting these values we highlight that:

- In the previous assessment, the analysis of Eurostar emissions was undertaken using two approaches, first using the average generation mix in the UK, France and Belgium, and second using a UK supplier mix (based on BE supplied electricity for the UK, but using the average generation mix in France and Belgium). The second option was used for the estimation of offsets by Eurostar.
- In this phase, two approaches have also been used. The first updates the annual generation mix in the UK, France and Belgium. The second uses a UK/French/Belgium supplier mix (BE/ET/SNCF/ SNCB).
- The choice of which mix to use is the subject of a current debate. There is guidance in the UK and also in France, but this differs between the two countries:
    - In the UK, Defra has recently recommended that the UK average mix should be used in company reporting of emissions, rather than supplier mixes.
    - In France, the guidance from Ademe's Billan Carbone Guide Methodolique states that when the contracted supplier is known, and CO_2 coefficients are provided, it is correct to use them.
- As Eurostar journeys cross both two countries, there is an issue on which approach is most appropriate to use. To address this, the average generation and specific supplier values are both presented in the table below. Note that values are presented for the kg of CO_2 for an average single trip (based on the average of the return journey).

Summary of Results – Data for Offsets and Assurance Statement – Single Trip

	Kg CO_2 per train journey (single trip)	Kg CO_2 per train journey (single trip)
Route	**Updated phase**	**Previous analysis**
London to Paris		
Average mix 2006 (CTRL 1)	3,355	
Average mix 2007 (CTRL 2)	3,590	4,540
Average mix 2008 (CTRL 2)	3,210	
Average mix 2010 (CTRL 2)	3,184	4,496
Supplier mix 2006 (CTRL 1)	2,240	
Supplier mix 2007 (CTRL 2)	2,364	2,409
Supplier mix 2008 on (CTRL 2)	1,684	
London to MLV		
Average mix 2006 (CTRL 1)	3,362	
Average mix 2007 (CTRL 2)	3,597	
Average mix 2008 (CTRL 2)	3,217	
Average mix 2010 (CTRL 2)	3,192	
Supplier mix 2006 (CTRL 1)	2,248	
Supplier mix 2007 (CTRL 2)	2,372	
Supplier mix 2008 on (CTRL 2)	1,692	
London to Brussels		
Average mix 2006 (CTRL 1)	3,529	
Average mix 2007 (CTRL 2)	3,732	4,803
Average mix 2008 (CTRL 2)	3,321	
Average mix 2010 (CTRL 2)	3,208	4,574
Supplier mix 2006 (CTRL 1)	2,235	
Supplier mix 2007 (CTRL 2)	2,230	2,672
Supplier mix 2008 on (CTRL 2)	1,642	
London to Avignon		
Average mix 2006 (CTRL 1)	5,213	
Average mix 2007 (CTRL 2)	5,533	
Average mix 2008 (CTRL 2)	5,240	
Average mix 2010 (CTRL 2)	5,386	
Supplier mix 2006 (CTRL 1)	4,508	
Supplier mix 2007 (CTRL 2)	4,632	
Supplier mix 2008 on (CTRL 2)	3,952	
London to Bourg St. Maurice		
Average mix 2006 (CTRL 1)	5,162	
Average mix 2007 (CTRL 2)	5,480	
Average mix 2008 (CTRL 2)	5,184	
Average mix 2010 (CTRL 2)	5,326	
Supplier mix 2006 (CTRL 1)	4,446	
Supplier mix 2007 (CTRL 2)	4,570	
Supplier mix 2008 on (CTRL 2)	3,890	

* Based on the previous PWA assurance analysis. Note that the values on the web-site have been updated with new values.
** Note for 2005 supplier numbers, only the UK segment was supplier mix. For overseas, the average grid mix was used. These values are not directly comparable with the new supplier mix values, which have supplier mix in UK and France.

Summary of Modal Comparison

The study has also updated the previous air vs. rail comparison. Note that in presenting these estimates, the same issues are raised as above in relation to:

- Average vs. supplier mix.

There are also some additional issues.

- The values for gCO_2/passenger km in the previous phase were based on the carbon emissions per actual km travelled, not the straight line distance. Train tracks do not follow a straight line, and the same applies to a lesser extent to aircraft. Strictly speaking, any modal comparison between destinations should compare on a like for like basis, and therefore the most direct, accurate and fair analysis is to compare kg CO_2 per passenger trip. This is therefore used here. A sensitivity analysis reporting gCO_2/passenger km is included in the main report.
- The values in the table below are reported as Kg CO_2 passenger trip for a single trip, not a return. This is because most comparative modal studies, and also the web based carbon calculators, cite values for single trips. In the previous report, values for return values were reported, and we have found that some people have misinterpreted this data (and confuse Eurostar return with single trip values).

Results – $kgCO_2$/passenger trip

The results are shown below for Eurostar, for the average, and supplier mix.

Eurostar results – emissions per passenger journey (single trip)

	kg CO_2 per passenger SINGLE TRIP			
Route)	**Average Mix**			
Estimated	**CTRL1 2006**	**CTRL2 2007**	**CTRL2 2008**	**CTRL2 2010**
London to Paris	6.8	7.0	6.3	6.2
London to MLV	6.9	6.8	5.6	5.3
London to Brussels	10.5	10.6	8.4	7.6
London to Avignon	12.9	15.7	8.6	9.2
London to B.St.M (Ski train)	12.5	11.1	9.3	9.4

Route)	**Supplier Mix**			
Estimated	**CTRL1 2006**	**CTRL2 2007**	**CTRL2 2008**	**CTRL2 2010**
London to Paris	4.5	4.6	3.3	3.3
London to MLV	4.6	4.5	2.9	2.8
London to Brussels	6.6	6.5	4.1	3.9
London to Avignon	11.1	13.1	6.5	6.8
London to B.St.M (Ski train)	10.8	9.3	7.0	6.9

These can be compared against the equivalent values by air. In this phase of the work, we use the International Civil Aviation Organization (ICAO) emission calculator. This has the advantage of being an aviation industry calculation tool. However, it assumes a constant 67% load factor on all European flights. To investigate this assumption, we have also run a sensitivity analysis where the ICAO outputs are adjusted with route and airport specific load factors from the CAA (Civil Aviation Authority). Therefore, two

sets of results are presented below - the centre column presents the output from the ICAO tool directly – the right hand column adjusts these value using specific load factors from the CAA. In some cases the load factors are lower than 67% and in some cases they are higher.

Aviation results – emissions per passenger journey (single trip)

Estimated	ICAO* kg CO_2 per pass. SINGLE TRIP	ICAO with route load factors CAA** kg CO_2 per pass. SINGLE TRIP
London to Paris / MLV		
London City to Paris CDG	75.6	219.8
London City to Paris Orly	78.6	124.7
London Gatwick to Paris Orly	58.0	n/a
London Heathrow to Paris CDG	55.0	53.9
London Luton to Paris CDG	62.3	51.4
London Stansted to Paris CDG	58.4	n/a
London to Brussels		
London City to Brussels	50.5	69.9
London Gatwick to Brussels	67.0	101.1
London Heathrow to Brussels	56.1	70.3
London Stansted-Brussels Charleroi	58.7	n/a
London to Avignon		
Southampton (SOU) to Avignon t	118.3	n/a
London (LTN) to Nimes	114.9	n/a
London (STN) to Toulon-hyeres	123.7	n/a
London (LCY) to Nice	169.0	237.7
London (LGW) to Nice	108.0	92.8
London (LHR) to Nice	108.9	93.9
London (LTN) to Nice	124.3	108.3
London (STN) to Nice	101.8	91.7
London (LGW) to Montpellier	94.0	90.2
London (STN) to Montpellier	115.1	n/a
London (LGW) to Marseilles	114.0	n/a
London (LHR) to Marseilles	98.3	98.6
London (STN) to Marseilles	119.1	109.6
London to Geneva		
London Heathrow to Geneva	133.0	132.6
London Gatwick to Geneva	90.4	78.0
London City to Geneva	85.3	102.8
London Luton to Geneva	100.2	86.1
London Stansted to Geneva	85.4	73.9

* The output from the ICAO tool. This assumes a standard load factor of 67% on all routes.
** The results above adjusted for actual load factors as reported by the CAA for these specific routes. 2007 data.
n/a. Data for 2007 from CAA either not requested, or not available due to new routes.

Most routes have load factors that are fairly close to the 67% assumed in the ICAO database. The exceptions are flights from London City airport, which tends to have low load factors, and flights to Brussels, which also tend to have lower load factors than the European average. The low cost airlines, and routes to the South of France, tend to have slightly higher load factors than the European average.

The results for rail and air are compared below for a selection of routes, using 2007 data. The analysis also compares how much higher air emissions are compared to Eurostar, presented as a factor that air is greater than the Eurostar average and supplier mix.

The main routes to Paris and Brussels are first shown. The average and supplier mix values for Eurostar are presented. The values for the air are presented for the original ICAO results, and with the values which adjust with CAA route and airport specific load factors.

Comparative emissions between Eurostar and Air for passenger journey – selective (main) air routes to Paris and Brussels for 2007

Trip/Mode	kg CO_2 per passenger trip - single (2007)	2007 Factor Air>Rail (average mix	2007 Factor Air>Rail (supplier mix
London-Paris			
Eurostar - Paris			
Average mix (2007 HS2) *	7.0		
Supplier mix (2007 HS2) *	4.6		
Air: Heathrow- Paris			
ICAO	55.0	7.9	12.0
ICAO (CAA Load Factor)	53.9	7.7	11.7
Air - Luton- Paris			
ICAO	62.3	8.9	13.5
ICAO (CAA Load Factor)	51.4	7.3	11.2
London-Brussels			
Eurostar - Brussels			
Average mix (2007 HS2) *	10.6		
Supplier mix (2007 HS2) *	6.5		
Air - Gatwick- Brussels			
ICAO	67.0	6.3	10.3
ICAO (CAA Load Factor)	101.1	9.5	15.6
Air - Heathrow- Brussels			
ICAO	56.1	5.3	8.6
ICAO (CAA Load Factor)	70.3	6.6	10.8
London to MLV			
Eurostar - MLV			
Average mix (2007 HS2) *	6.8		
Supplier mix (2007 HS2) *	4.5		
Air	**As for Paris above**		

On a strict like for like comparison:

- When using the average generation mix, Eurostar is not a factor of ten lower, in terms of emissions per passenger trip (Kg CO_2/trip), with factors of around 6 to 9.
- However, when the supplier generation mix is used, then in nearly all cases, Eurostar is a factor of ten lower than air.

The comparison for the other routes is shown below. Again, the average and supplier mix values for Eurostar are presented. The values for the air are presented for the original ICAO results, and with the values which adjust with CAA route and airport specific load factors.

Comparative emissions between Eurostar and Air for passenger journey – selective (main) air routes to South of France and the Alps for 2007

Trip/Mode	kg CO_2 per passenger trip - single (2007)	2007 Factor Air>Rail (average mix	2007 Factor Air>Rail (supplier mix
London to Avignon			
Eurostar			
Average mix (2007 HS2) *	15.7		
Supplier mix (2007 HS2) *	13.1		
Air: Heathrow - Marseilles			
ICAO	98.3	6.3	7.5
ICAO (CAA Load Factor)	98.6	6.3	7.5
Air: Luton - Nice			
ICAO	124.3	7.9	9.5
ICAO (CAA Load Factor)	108.3	6.9	8.3
Air: Gatwick -Montpellier			
ICAO	94.0	6.0	7.2
ICAO (CAA Load Factor)	90.2	5.7	6.9
Air: Stansted- Nice			
ICAO	101.8	6.5	7.8
ICAO (CAA Load Factor)	91.7	7.0	7.0
London to Bourg St. Maurice			
Eurostar			
Average mix (2007 HS2) *	11.1		
Supplier mix (2007 HS2) *	9.3		
Air: Gatwick - Geneva			
ICAO	90.4	8.1	9.7
ICAO (CAA Load Factor)	78.0	7.0	8.4
Air: Heathrow- Geneva			
ICAO	133.0	12.0	14.3
ICAO (CAA Load Factor)	132.6	11.9	14.3
Air: Luton- Geneva			
ICAO	100.2	9.0	10.8
ICAO (CAA Load Factor)	86.1	7.8	9.3
Air: Stansted- Geneva			
ICAO	85.4	7.7	9.2
ICAO (CAA Load Factor)	73.9	7.9	7.9

The results are slightly different for these two longer routes. On a strict like for like comparison:

- When using the average generation mix, Eurostar is not a factor of ten lower, in terms of emissions per passenger trip (Kg CO_2/trip), with factors of around 6 to 8 for the South of France, and 7 to 9 for the ski train (though one airport route is higher than this).
- When the supplier generation mix is used, Eurostar is not a factor of ten lower, in terms of emissions per passenger trip (Kg CO_2/trip), with factors of around 7 to 9 for the South of France. There is more variation for the comparison with the ski train, with factors from 8 to 10 depending on the airport and carrier (though again, one route is higher than this).

In general, there are lower relative CO_2 benefits for Eurostar over air for these longer distances. This is expected, because the longer flight distances reduce the relative contribution of the landing and take-off (LTO) emissions (noting the LTO emissions always occur, but for a longer flight, they are a lower

proportion of total emissions for the journey). As distances increase, the relative benefits of Eurostar over air will decrease slightly – this is an important conclusion.

The values above are for 2007. There are two important differences that would occur with a 2008 analysis.

- The Eurostar emissions for the supplier mix falls significantly in 2008, due to the switch to French supplied electricity by Eurotunnel, which reduces the average mix emissions by around 10%, and the supplier mix emission by around 30%. This does not change the overall message on the main routes to Paris and Brussels, but it does mean that the advantage on the ski train and South of France trips are more favourable towards Eurostar (i.e. the factors above will increase)/
- The load factor for the South of France Eurostar route dramatically improved in 2008 (from 47% to 81%). This has a dramatic change on the relative performance of this route, such that Eurostar is a factor of ten greater. The data are shown below (noting there is no CAA data for 2008).

The results are shown below.

Comparative emissions between Eurostar and Air for passenger journey – selective (main) air routes to Paris and Brussels for 2008

Trip/Mode	kg CO_2 per passenger trip - single (2007)	kg CO_2 per passenger trip - single (2008)	2008 Factor Air>Rail (average mix)	2008 Factor Air>Rail (supplier mix
London-Paris				
Eurostar - Paris				
Average mix (2007 HS2) *	7.0	6.3		
Supplier mix (2007 HS2) *	4.6	3.3		
Air: Heathrow- Paris				
ICAO		55.0	8.7	16.7
Air - Luton- Paris				
ICAO		62.3	9.9	18.9
London-Brussels				
Eurostar - Brussels				
Average mix (2007 HS2) *	10.6	8.4		
Supplier mix (2007 HS2) *	6.5	4.1		
Air - Gatwick- Brussels				
ICAO		67.0	8.0	16.3
Air - Heathrow- Brussels				
ICAO		56.1	6.7	13.7

The use of 2008 data does not change the overall message for the main routes, i.e. only Eurostar supplier mix is a factor of ten greater than air for the Paris and Brussels routes.

It does, however, change the relative comparison for the other routes, particularly for the South of France. For 2008, these changes lead to a factor of ten advantage for Eurostar over air for average and supplier mix for both routes (with one exception for a low cost flight to Geneva).

Comparative emissions between Eurostar and Air for passenger journey – selective (main) air routes to South of France and the Alps for 2008

Trip/Mode	kg CO_2 per passenger trip - single (2007)	kg CO_2 per passenger trip - single (2008)	2008 Factor Air>Rail (average mix)	2008 Factor Air>Rail (supplier mix
London to Avignon				
Eurostar				
Average mix (2007 HS2) *	15.7	8.6		
Supplier mix (2007 HS2) *	13.1	6.5		
Air: Heathrow - Marseilles				
ICAO		98.3	11.4	15.1
Air: Luton - Nice				
ICAO		124.3	14.5	19.1
Air: Gatwick -Montpellier				
ICAO		94.0	10.9	14.5
Air: Stansted- Nice				
ICAO		101.8	11.8	15.7
London to Bourg St. Maurice				
Eurostar				
Average mix (2007 HS2) *	11.1	9.3		
Supplier mix (2007 HS2) *	9.3	7.0		
Air: Gatwick - Geneva				
ICAO		90.4	9.7	12.9
Air: Heathrow- Geneva				
ICAO		133.0	14.3	19.0
Air: Luton- Geneva				
ICAO		100.2	10.8	14.3
Air: Stansted- Geneva				
ICAO		85.4	9.2	12.2

In future years, there is a trend towards greater renewables and lower carbon intensity in the electricity generation mix of all European countries, which will become even more significant over the next decade (towards the new EU 2020 targets). These trends would increase the performance of Eurostar in future years. However, there would also be improvements in the air fleet, as more modern aircraft enter the fleet, and thus both modes would improve – more detailed analysis would be needed to investigate the relative speed of improvement in both modes to assess the relative long-term trends.

Notes and caveats

We are aware that the information in this report could be used to update the information on comparative emissions on the Eurostar web-site. The issue of whether to report the average or supplier mix for Eurostar is highlighted above. This report does not make recommendations on which is more appropriate, but a considered approach might be to report both. For air, Eurostar would need to consider whether it was appropriate to use the ICAO values. This would require a strict consideration of the terms and conditions of the ICAO tool. This report has not investigated these issues. There is also an issue whether the load factor adjusted ICAO values should be used. While we believe the use of actual load factors is more accurate, the adjustment of ICAO values might be more controversial, especially in relation of the terms and conditions for using the ICAO tool. An alternative would be to generate a set of 'own estimates' using the previous CORINAIR methodology. This has been undertaken for the main Paris and Brussels routes. This does not lead to very different values from the analysis above.