Carbon brainprint case study

Improved delivery vehicle logistics

Cranfield
UNIVERSITY

Santander
UNIVERSITIES

HIGHER EDUCATION
FUNDING COUNCIL FOR ENGLAND
hefce

CARBON
TRUST

RESEARCH
COUNCILS UK

UNIVERSITY OF
CAMBRIDGE

University of
Reading

Centre for Environmental Risks and Futures
Building 42
Cranfield University
Cranfield
Bedford
MK43 9PB

www.cranfield.ac.uk
www.carbonbrainprint.org.uk
carbonbrainprint@cranfield.ac.uk

Carbon Brainprint Case Study

Improved delivery vehicle logistics

Analysis: David Parsons and Julia Chatterton
School of Applied Sciences, Cranfield University

Case study experts: Dr Mike Bernon and Dr Andrew Palmer
School of Management, Cranfield University

July 2011

Contents

Summary

Road transport accounts for about 20% of the total GHG emissions of the UK, and HGVs and LGVs are responsible for about one-third of these. The total direct GHG emissions from HGVs and LGVs in 2008 were about 40 Mt CO_2e.

Dr Andrew Palmer, a Cranfield University visiting fellow and former PhD student contributed to the transport recommendations for the food distribution industry following publication of The Food Industry Sustainability Strategy. These recommendations were taken up by IGD as part of the Efficient Consumer Response (ECR – UK) initiative and implemented with 40 leading UK brands. They reported that this initiative had taken off 124 million road miles (equivalent to 60 million litres of diesel fuel) from UK roads over three years (2007–2009) and 163 million road miles up to 2010, with a target of 200 million road miles by the end of 2011

The quoted reduction in vehicle use up to 2010 is equivalent to 250 kt CO_2e, but this cannot all be attributed to Cranfield University's carbon brainprint, because Dr Palmer was only one of the authors of the report and he was not an employee of the university at the time. We estimate the attributable brainprint to be 56 kt CO_2e with a 95% confidence range of 32–87. Assuming that this is maintained until 2020, and assuming a 1%/year increase in efficiency independent of this work, which will reduce the future brainprint, gives an estimate of 187 kt CO_2e (102–295) for the period 2007–2020.

General description

Road transport accounts for about 20% of the total GHG emissions of the UK, and HGVs and LGVs are responsible for about one-third of these. The total direct GHG emissions from HGVs and LGVs in 2008 were approximately 40 Mt CO_2e (NAEI, 2011). Dr Andrew Palmer, at the time a part-time PhD student and now a visiting fellow in the School of Management, contributed to the transport recommendations (Faber Maunsell, 2007) for the food distribution industry following publication of The Food Industry Sustainability Strategy (Defra, 2006). The other authors were Faber Maunsell (a subsidiary of AECOM) and Heriott-Watt University. Six options with a combined potential carbon-dioxide emissions reduction of 14.6% were identified: (1) computer vehicle routing and scheduling (CVRS) and telematics, (2) increased vehicle capacity, (3) collaboration between companies, (4) out of hours deliveries, (5) engine specification upgrades and (6) logistics system redesign. These recommendations were taken up by IGD as part of the Efficient Consumer Response (ECR – UK) initiative (IGD, 2011a) and implemented with 40 leading UK brands. They reported (IGD, 2011b) the following results for the first three years

> Through the Efficient Consumer Response (ECR) UK Sustainable Distribution initiative, food and grocery companies across the country have been partaking in innovative activities and taken off 124 million road miles from UK roads. This is the equivalent of removing 2000 lorries from Britain's roads and conserving 60 million litres of diesel fuel.

A similar result was obtained in the fourth year (IGD, 2011c)

> Last month, IGD announced that the food and grocery industry has saved 163 million HGV miles through a variety of sustainable distribution initiatives, making excellent progress towards its voluntary target of removing 200 million miles from the UK's roads by the end of 2011.

On the basis of these figures, there is potentially a substantial reduction in GHG emissions indirectly attributable to Cranfield's work.

System boundaries

The Carbon Brainprint procedures guidance (Parsons & Chatterton, 2011a) establishes the principle that emissions reductions included in the brainprint should be those that are directly attributable to the work of the university. The proportion that could be attributed to Cranfield was estimated by working back from the end point towards the university's contribution.

The procedures document advises that it is not necessary to reach an attribution between universities and clients, so all the reductions that arose directly from implementation of the recommendations in the report could be attributed among the authors. However it was necessary to consider the attribution between them.

Dr Palmer (personal communication) was the primary contributor to two of the six measures proposed: collaboration and improved logistics. We therefore attempted to identify the benefits arising from these and attribute them fully to Dr Palmer, on the basis that his contribution to the other recommendations was being omitted, so his overall contribution should not be overestimated. Of the reductions in all externalities predicted in the report, these two measures accounted for approximately 30% (Faber Maunsell, 2007, Table 26), so this factor was used to attribute the emissions reduction.

Dr Palmer's period of study at Cranfield provided the basis for his contribution to the recommendations and he remains linked to the university as a visiting fellow, so a substantial proportion of his contribution could be attributed to the university. An estimate of 75% was agreed with Dr Palmer.

When attempting to extrapolate the benefits into the future, three factors needed to be taken into account: further implementation of the recommendations, future demand for road haulage and other improvements in transport efficiency. Because of the difficulty of forecasting long-term demand, a medium-term (10 year) period was, in common with some of the other studies in this sector (e.g. McKinnon, 2009).

Data

There was very little primary data to work from, so the study relied on the information summarised in the general description and system boundaries.

Brainprint

Retrospective brainprint

The results reported on IGD's web site (IGD, 2011b) gave two pieces of information from which emissions reductions could be estimated: a reduction of 124×10^6 vehicle miles (200×10^6 km) and a saving of 60 Ml of diesel fuel. It is likely that one of these was primary data and the other was derived from it by assuming the fuel consumption was 0.3 l/km.

At the time it was accessed, there was a small error on the web page, which said "60 million litres of diesel fuel per year." IGD have confirmed (Karen Chalmers, personal communication) that both figures were totals for the three year period ending in 2009.

IGD further reported (IGD, 2011c) 163×10^6 vehicle miles (262 Gm) or 80 Ml of diesel saved since then, with a target of 200×10^6 vehicle miles (322 Gm) by then end of 2011. For convenience, although it is not explicitly stated on the IGD web site, these periods were treated as whole calendar years.

The emission factor for GHGs from diesel fuel including indirect emissions is 3.1787 kg CO_2e/l (AEA, 2010), giving an emissions reduction of 191 kt CO_2e from a saving of 60 Ml. The emissions reduction based on an activity reduction of 200 Gm depends on the assumption made about the types of vehicles used (Table 1) and there is considerable variation within each class depending on size and loading.

Table 1. Estimates of emissions reductions from activity reduction of 200 Gm based on vehicle types using UK average loads (AEA, 2010)

Vehicle type	Emission factor, kg CO_2e/km	Emissions reduction, kg CO_2e
Van/light commercial	0.30026	60
Rigid HGV <7.5 t	0.68105	136
Rigid HGV 7.5–15 t	0.90350	181
Rigid HGV >17 t	1.18533	237
All rigid HGV	0.99887	200
All articulated	1.16819	234
All HGV	1.07897	216

The estimate for the medium rigid HGV and the rigid HGV average were both close to the emissions reduction obtained from the fuel saving, showing that the two estimates were consistent. The value of 191 kt CO_2e derived from the fuel saving was therefore used as the starting point.

As discussed in the system boundaries, 30% of this, 57 kt CO_2e, was attributed to Dr Palmer, of which 75%, 43 kt CO_2e was attributed to Cranfield as the carbon brainprint to the end of 2009.

Similarly, the emissions reduction to the end of 2010 was 250 kt CO_2e, giving a brainprint of 56 kt CO_2e.

Prospective brainprint

If the target for 2011 is met, the total activity reduction will be 322 vehicle Gm over 5 years, with a total emissions reduction of 307 kt CO_2e and a Cranfield brainprint of 69 kt CO_2e.

Assuming that the average activity reduction of 65 vehicle Gm/year is maintained until 2020, the total emission reduction for the period 2007–2020 will be 867 kt CO_2e with a Cranfield brainprint of 195 kt CO_2e.

These would overestimate the benefits if the fuel efficiency of vehicles increased over the same period. A recent study (McKinnon, 2009) found no evidence of such an increase in the period 1998–2009, but reported that a Delphi survey of 100 specialists followed by focus groups forecast that "...fuel efficiency was expected to rise by around 5% by 2020 and carbon intensity per litre of fuel to drop by 5%." Modelling the combined effect as a 1%/year reduction in the emission factor over the period 2011–2020 reduced the total brainprint for 2007–2020 to 187 kt CO_2e.

The potential indirect effects are much larger than this brainprint. The members of ECR are responsible for about half of all grocery mileage (IGD, 2011a). Having demonstrated the benefits, similar changes might be possible in other companies in the grocery sector and in road haulage generally. However, indirect benefits are excluded from the definition of the carbon brainprint (Parsons & Chatterton, 2011a).

Uncertainties

The main sources of uncertainty in the brainprint estimate were the activity data (vehicle miles saved), the extrapolation to 2020 and the attribution. The carbon brainprint guidance (Parsons & Chatterton, 2011a) suggests uncertainties of 2% and 10% for distances and fuel use per km respectively. As the data appear are based on distances and fuel consumption rate, with some rounding, we used a normal distribution with a coefficient of variation (CoV) of 15%. A similar distribution was used for the future activity. A CoV of 15% is suggest in the guidance for expert judgement when moderately familiar with the circumstances. The attribution of the benefits between the authors of Faber Maunsell (2007) was a judgement based on information in the report and communicated by Dr Palmer, so again a normal distribution with a CoV of 15% was used. A similar uncertainty was applied to the attribution to Cranfield by using a triangular distribution with a range of ±30% of the mid point (75%), because a normal distribution would have exceeded 100% occasionally. No uncertainty was applied to the annual reduction in the emission factor representing fuel efficiency and carbon intensity of the fuel, because it was small enough to have a negligible effect.

The Monte-Carlo simulation was carried out in R (R Development Core Team, 2007) using 10,000 trials. The results (Table 2) inevitably showed large uncertainties; there was a slight positive skew and the means were very close to the deterministic calculations. The total retrospective brainprint to 2010 had a 95% confidence range of 32–87 kt CO_2e, and the prospective brainprint to 2020 had a range of 102–295 kt CO_2e under the assumption that efficiency will increase from 2011 onwards, or 107–309 kt CO_2e without this assumption.

Table 2. The results of the uncertainty analysis on the brainprint

To year	Deterministic	Mean	Standard deviation	Median	2.5%	97.5%
2009	43	43	11	42	25	66
2010	56	56	14	55	32	87
2011	69	69	17	68	40	107
2020	187	186	50	181	102	295
2020*	195	195	52	190	107	309

* Assuming no change in efficiency in future

References

AEA (2010). 2010 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting. Produced by AEA for the Department of Energy and Climate Change (DECC), Version 1.2.1 FINAL, Updated: 06/10/2010

Defra (2006). Food Industry Sustainability Strategy. Department for Environment, Food and Rural Affairs, 116 pp.

Faber Maunsell (2007). Reducing the external costs of the domestic transportation of food by the food industry. Report to Defra, Department for Environment, Food and Rural Affairs

IGD (2011a). ECR UK - Sustainable Distribution (06/04/2011). http://www.igd.com/index.asp?id=1&fid=5&sid=43&tid=59

IGD (2011b). The road to success (accessed 06/04/2011). http://www.igd.com/index.asp?id=1&fid=1&sid=3&tid=41&folid=0&cid=1440

IGD (2011c). Sustainable distribution: miles better (accessed 01/06/2011). http://www.igd.com/index.asp?id=1&fid=1&sid=3&tid=41&folid=0&cid=2002

McKinnon, A. (2009). Transport challenges and opportunities: briefing paper on the freight transport sector. Heriot-Watt University, Edinburgh, Prepared for the Commission for Integrated Transport

NAEI (2011). National Airborne Emissions Inventory (accessed 10/03/2011). http://www.naei.org.uk/

Parsons, D. J.; Chatterton, J. (2011a). Guidance for the calculation of carbon brainprints of higher education institution activities. Cranfield University, Report for HEFCE project LDSHE43

R Development Core Team (2007). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, 409 pp.