OFFICE FOR NATIONAL STATISTICS

ADJUSTMENTS TO THE UK'S ATMOSPHERIC EMISSIONS AND ENERGY ACCOUNTS TO BRING THEM ON TO A NATIONAL ACCOUNTS "RESIDENTS" BASIS

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Report by the Office for National Statistics

Abstract

The objective of this study is to explore methodologies for adjusting estimates of atmospheric emissions and energy use, which are based on fuel deliveries in the UK, onto a National Accounts "residents" basis. The study provides estimates of energy use and emissions from fuels purchased abroad by residents of the UK and from fuels purchased in the UK by residents of other countries. It shows that, for 1997,

- the adjustments are very significant for some sectors and some pullutants, in particular for emissions of carbon dioxide (CO_2) and the acidifying gases sulphur dioxide (SO_2) and oxides of nitrogen (NOx), from water transport, public administration defence activities and fishing
- at the national level, emissions of the last two gases (SO_2 and NOx) are significantly understated in the estimates of air emissions which are compared with national accounts economic aggregates.

The report assesses how sensitive the calculations are to the various assumptions made, and concludes that the adjustments are sufficiently robust to justify incorporating them in the main environmental accounts.

1. Introduction

Global warming knows no international boundaries: emissions of greenhouse gases from one part of the planet will have exactly the same effect as those from another part. Even where the emissions do not directly affect the local population, the citizens of the United Kingdom have some responsibility for the impact of their activities on the rest of the world. Attention is therefore increasingly focusing on who is responsible for the emissions rather than where they are coming from.

The primary source of information on emissions is, however, the national inventories, which are primarily based on estimates of the emissions from the deliveries and sales of fossil fuels within the national territory. Some of these sales will be made to residents of other countries, or may generate emissions outside the national territory, while fuels purchased in other countries may be brought into the national territory (by UK or by non-UK residents) or consumed in other countries by residents of the UK. It follows that if we want to know who is generating emissions, and how they relate to the production and consumption activities of the UK economy, we will need to make a number of adjustments to the territorial/deliveries-based inventories as they are currently compiled, and take into account emissions in international sea and air space as well.

Such adjustments are likely to be particularly important for countries with significant international freight and passenger transport sectors, or where there is a large difference in petrol and diesel prices between neighbouring countries. They will also be important for analyses which link the consumption of certain products with the associated energy use or emissions generated in the course of their final production and delivery (these elements are variously known as indirect or embedded emissions, ecological rucksacks or footprints, or food miles), and for sustainable development indicators which link the resource use and environmental impact of different industries with their economic performance.

1.1 The National Accounts "residents" basis

The National Accounts concept of "resident units"[1] is the basis used for accounting for the production and consumption activities of the UK economy; through the environmental satellite account, it also provides a convenient way of accounting for the environmental effect of these activities. The UK's National Accounts record the economic activities of resident units of the UK wherever they may be. Purchases of fuel in other countries by these units are recorded as imports, while fuels purchased in the UK by non-resident units are scored as exports.

Resident units are defined as institutional units (households, legal and social entities such as corporations, non-profit institutions and government) which

[1] See National Accounts Concepts, Sources and Methods for a full description of the accounting conventions.

have a centre of economic interest in the economic territory. A unit has a centre of interest in a country's economic territory when, from a location such as a dwelling, place of production or premises, it engages and intends to continue engaging in economic activities on a significant scale. Travellers, cross-border workers and crews of ships and aircraft from the UK are all UK resident units.

The objective of this study is therefore to explore the ways in which adjustments to the emission estimates from the UK inventory might be made in order to bring them onto a National Accounts "Residents" basis, and to assess the scale of these adjustments.

1.2 The National Atmospheric Emissions Inventory

The inventory used to monitor emissions in the UK is the National Atmospheric Emissions Inventory (NAEI)[2]. The emissions are estimated by applying emission factors[3] to the physical quantities of fuel[4] purchased within UK borders. The inventory also records emissions from non-fuel combustion sources.

It follows that the adjustment needed to bring the emissions inventory onto a National Accounts basis can be achieved by deducting the emissions relating to fuel purchases by overseas residents in the UK and by adding the emissions relating to fuel purchases by UK residents abroad (see Box 1).

Box 1 Adjustment from purchases in UK to UK residents' basis

Fuel use/emissions by:	UK resident units (R)	Overseas resident units (O)	
From purchases:			
delivered in the UK (d)	Rd	Od	Total from purchases in the UK = Rd + Od
abroad (a)	Ra		
	Total by UK residents = Rd + Ra		

Adjustment required: add (Ra - Od) or multiply by (Rd+Ra)/(Rd+Od)

[2] The NAEI is maintained and published by the National Environmental Technology Centre, AEA Technology, on behalf of the Department for Environment, Food and Rural Affairs.
[3] Emission factors are calculated by AEA Technology.
[4] Fuel deliveries and consumption are estimated by the Department of Trade and Industry and published in the Digest of UK Energy Statistics (DUKES).

The NAEI provides the UK air emissions data for submission to the United Nations Economic Commission for Europe (UN/ECE) and the United Nations Framework Convention on Climate Change (UNFCCC). The latter submission is used as a basis for monitoring the UK's progress against the targets agreed in the Kyoto protocol. These submissions are based on a subset of the emissions recorded in the inventory and hence a distinction needs to be made between the levels of emissions reported in the inventory and those reported on a UN/ECE or UNFCCC basis. The principal difference is that the UNFCCC basis excludes all emissions by international shipping and by aircraft on international flights. The emissions are reported as memorandum items, based on the fuels purchased in the UK by international aircraft and shipping operators (whether UK residents or not).

1.3 Pollutants and sources of emissions covered in the study

The NAEI covers not only emissions of greenhouse gases, but a wide range of emissions of other atmospheric pollutants affecting air quality in the UK. Some of the emissions are generated by the combustion of fossil fuels, such as the main greenhouse gas carbon dioxide (CO_2) and the acidifying gases sulphur dioxide (SO_2) and oxides of nitrogen (NOx), but many others are generated in the process of industrial or agricultural activities unrelated to combustion. Since these activities are unlikely to be undertaken on a significant scale either by non-resident units in the UK or by resident units outside the UK, the gases covered by this study have been limited to the main gases from the combustion of transport fuels, namely CO_2, SO_2 and NOx[5].

The National Accounts make a distinction between the unit that is consuming the transport service and the unit that consumes the fossil fuel and is hence directly responsible for the generation of atmospheric emissions. Thus UK tourists who use public transport overseas may be held to be indirectly responsible for some of the related emissions, but as they do not consume the fuel directly, the energy use and emissions are attributed to the activities of the overseas rather than the UK economy. Similarly a UK company which hires road hauliers based in another country to carry goods across Europe is importing a public transport service, but the road haulier's emissions are recorded as having been generated by a resident unit of the overseas country.

On the other hand emissions generated by UK-based public transport operators providing coach tours to Europe would be included in the adjustment, as would the emissions abroad of any other UK-based owner of transport. The sources for which an adjustment is most likely to be significant are therefore

- purchases of fuels in overseas territories by UK resident units such as British tourists and business people driving abroad, UK-based road

[5] Consumption by UK residents is of course indirectly responsible for emissions generated in the course of producing goods for importing into the UK, such as agricultural produce, but these emissions would in the first instance be allocated to the relevant industrial sector in the country of origin.

hauliers and other road freight carriers, and (to a more limited extent) UK-based coach companies and tour providers;

- transport fuels used in international sea or air space by UK-based operators such as fishing fleets, military sea and air craft, international shipping and international passenger and freight aviation.

The following section sets out the general approach and basic data used in the study. Section 3 considers the adjustments required for international aviation, while sections 4 and 5 deal with international shipping and fishing respectively. Section 6 covers the use of private motor vehicles and section 7 deals with goods vehicles and Public Service Vehicles. Section 8 summarises the results of the study and assesses the reliability of the proposed adjustments, while section 9 concludes and makes recommendations.

2. General approach and basic data

The emissions recorded in the NAEI are based on the fuel consumption data published in the Digest of UK Energy Statistics (DUKES) by the Department of Trade and Industry. This data, which includes estimates of transport-related fuel consumption by transport category and by type of fuel, is based on deliveries of fuel in the UK territory. It includes estimates of deliveries of fuels to ocean-going vessels under international bunker contracts, which are known as marine bunkers. It also includes estimates of deliveries of aviation turbine fuel which are used for international aviation and sometimes referred to as air bunkers. Table 1 shows 1997 NAEI data on fuel consumption (in terms of tonnes of oil equivalent) by transport type and the resulting emissions in terms of the three pollutants covered in this study.

Table 1 Estimated fuel use and associated atmospheric emissions on a deliveries basis for specific fuels and sources for the UK, 1997

	Fuel use	*Emissions*		
	m toes	CO_2 Kt carbon	SO_2 Kt	NOx Kt
International aviation[1]				
- aviation turbine fuel	7.55	5,878	6.8	107.0
International shipping[2] **– gas oil**	0.84	665	15.1	44.2
– fuel oil	1.86	1,534	101.8	102.9
Military aviation - aviation turbine fuel	0.85	659	0.8	6.5
Military shipping - gas oil	0.41	326	7.4	21.7
Fishing vessels - gas oil	0.14	107	2.4	7.1
Private Vehicles[3] **– petrol**	23.09	17,592	14.5	517.9
– diesel	1.98	1,563	1.5	15.7
Goods Vehicles				
- HGV artic diesel	5.13	4,058	3.8	121.8
- HGV rigid diesel	3.40	2,686	2.6	103.9
- LGV diesel	3.55	2,802	2.7	25.5
- LGV petrol	1.46	1,115	0.9	34.0
Coaches - diesel	0.52	410	0.4	15.8
Total UK on a deliveries basis	203.93[4]	156,177	1,761.1	2,097.0

1. Aviation bunkers, excluding military use
2. Marine bunkers, excluding military use
3. Includes business use but excludes motorcycles
4. All energy use of fossil fuels

source: NAEI 2001, ONS

toes = tonnes of oil equivalent.
To convert CO_2 emissions from carbon equivalent to carbon dioxide equivalent multiply by 44/12.

The first step in adjusting these estimates onto a National Accounts basis is to estimate figures for the physical amount of fuel purchased in the UK and abroad, which are then multiplied by the relevant emission factors for each pollutant researched in the study, CO_2, SO_2, and NOx. The difference between total fuel purchases by UK residents (i.e. at home and abroad) and fuel purchases in the UK will then represent the adjustment to be made to the atmospheric emissions inventory.

The first source of information is the monetary transactions recorded in the National Accounts Balance of Payments estimates, since in general purchases abroad are recorded as imports and purchases in the UK by overseas units will be recorded as exports.

3. International and military aviation

As described above, the UNFCCC basis which is used to assess progress against Kyoto targets specifically excludes emissions from international

aviation, although they are noted as memorandum items. The estimates that are included in the memorandum items are based on aviation turbine fuel deliveries within the UK. Aviation spirit is not included as it is primarily used for smaller engines for domestic flights.

3.1 Data and methodology

Annual data on purchases of aviation turbine fuel in the UK is available both in physical and monetary terms[6]. The physical data is split into fuel use by domestic aviation, international aviation and the military; the monetary data is only available for total fuel deliveries in the UK.

In order to adjust the emissions accounts for the effects of overseas operators' fuel purchases in the UK and UK operators' fuel purchases abroad, a proxy for these respective purchases is needed. The Balance of Payments Division within ONS estimates imports and exports of aviation fuel on the basis of expenditure data supplied by the Civil Aviation Authority. The export and import data is only available in monetary terms, although for the purposes of estimating emissions data in physical terms is required.

As the focus is on the fuel used for international aviation, fuel for domestic use needs to be excluded from the calculations. Fuel for military use is attributed to a different industrial sector (public administration) and needs to be included but separately identified[7]. However, the information on military and domestic use is only available in physical terms, so the calculation requires that the monetary data is divided in the same proportions as the physical data. This involves the assumption that average prices are identical across these sectors.

A similar assumption is needed in order to convert Balance of Payments figures on imports into estimates of the physical quantities of fuel purchased. Contacts within the aviation industry in the UK have indicated that prices overseas will on average exceed those in the UK by up to 10%. For the purposes of this study we have assumed a difference of between 0% and 10%, with a central estimate of 5%.

3.2 Results

Table 2 sets out the calculations based upon these assumptions.

[6] Fuel use data is published by the Department of Trade and Industry.

[7] Purchases of aviation turbine fuel for military use is identified in the DTI statistics but no information is available about the proportion purchased by visiting forces.

Table 2 Calculation of adjustment for aviation turbine fuel use and related emissions for international and military flights, 1997

Purchases of aviation turbine fuel in UK - value	£1,210 m
- volume	8.41 mt
Implied price per tonne	£144
Exports: purchases by overseas operators	£458 m
Implied exports (volume) - assumed all for international flights[1]	3.19 mt
Assumed price differential overseas	+5%
Assumed average price overseas	£151/t
Imports: purchases overseas by UK operators	£572 m
Implied imports in volume terms	3.79 mt
Assume imports split between international and military use pro rata to purchases in the UK	
(ie international flights using UK-purchased fuels	6.84mt
military purchases of UK fuels	0.77mt)
Implied imports - international flight operators	3.41mt
- military use	0.38mt
Net adjustment - international flight operators	0.22mt (3%)
- military use[1]	0.38mt (50%)
Range based on alternative assumptions about relative price differentials - international flight operators	0.07-0.39mt
- military use	0.36-0.40mt

[1] Assumes purchase of fuel by visiting forces in the UK is negligible.

The emissions of air pollutants from aviation turbine fuel use depend upon a number of factors including the proportion of altitude cruising to take-off/landing activities. If we apply these adjustments, relating to the amount of aviation turbine fuel used, to the emissions of CO_2, SO_2 and NOx, we are implicitly assuming that the profile of flights using fuel purchased outside the UK is the same as those using fuels purchased inside the UK. Such an assumption is not likely to be unreasonable. Hence by estimating that fuel use by UK international flight operators is 3% more than that recorded in the NAEI, we are estimating that emissions of CO_2, SO_2 and NOx are also 3% higher than those recorded in the NAEI.

As might be expected, the adjustment for international flight operators is relatively small. In general international flights tend to be return trips from the UK and back (by UK-based operators) or to the UK and back (by overseas operators). Hence as roughly half of the UK air travel market is met by overseas operators it follows that they will undertake roughly 50% of fuel purchases in the UK, as the aircraft would be expected to re-fuel at the point of destination as often as they re-fuel within the UK. Some slight adjustment

might be expected for long-haul return flights, where the aircraft may re-fuel more than once.

The adjustment for military use is relatively more significant, because of the number of operations of the UK military forces that take place outside of the UK[8]. However, it is the adjustment for international flight operators which appears to be sensitive to assumptions about the relative price differentials between the UK and other countries.

4. International and military shipping

The UK is still a maritime nation, so it would seem likely that UK shipping operators purchase more fuel abroad than overseas operators purchase in the UK. This view is supported by the Balance of Payments figures, which show that in 1997 overseas operators spent £60 million on fuel in the UK, compared with purchases of £316 million in other countries by UK operators.

Fuels for international shipping are purchased from stocks known as marine bunkers, and are used by ships of any flag, including the UK. They are excluded from the energy balances shown in DUKES.

4.1 Data and methodology

Marine fuel is split into fuel oil and gas oil, which have different implications in terms of emissions, in that fuel oil has a much higher sulphur content. It is also necessary to distinguish military use from international shipping operators.

As with the adjustment for aviation, the available energy statistics give the total amounts of fuels purchased in the UK in physical and monetary terms, but the Balance of Payments import and export data is only available in monetary terms and assumptions about average prices need to be made. In the absence of any information to the contrary, it has been assumed that average prices in the UK are the same as those overseas.

Having estimated the quantity of fuels purchased abroad by UK operators (including those for military purposes), it is necessary to assume that the purchases are shared between shipping operators and naval shipping pro rata to their use of fuels purchased from UK bunkers.

4.2 Results

Table 3 sets out the calculations involved using these assumptions.

[8] The resident unit definition used within the National Accounts includes territorial enclaves such as military bases in Germany and Cyprus as part of the UK economic territory, but use of fuel by these units are not included in the energy statistics or the NAEI.

Table 3 Calculation of adjustment for fuel oil and gas oil use and related emissions for international and military shipping, 1997

Purchases of marine fuel in UK - value	£280 m
- volume	2.96 mt
of which - fuel oil for international shipping (volume)	1.81 mt
- gas oil for international shipping (volume)	0.77 mt
- gas oil for military use	0.38 mt
Unit prices in UK based on DTI energy statistics - fuel oil	81 £/t
- gas oil	116 £/t
Exports: purchases of marine fuel by overseas operators	£60 m
Assumed (pro rata) purchases by overseas operators	
- fuel oil	£37 m
- gas oil[1]	£23 m
Implied exports in volume terms - fuel oil	0.46 mt
- gas oil[1]	0.20 mt
Imports: total value of purchases	£316 m
Assumed value of imports pro rata to use of UK fuels	
- fuel oil	£164 m
- gas oil (shipping)	£102 m
- gas oil (military)	£50 m
Implied volume of imports assuming no price differential	
- fuel oil (international shipping)	2.04 mt
- gas oil (international shipping)	0.88 mt
- gas oil (military use)	0.43 mt
Net adjustments to fuel/emission estimates	
- fuel oil (international shipping)	1.58mt (87%)
- gas oil (international shipping)	0.68mt (87%)
- gas oil (military use)[1]	0.43mt (113%)
Range based on alternative assumptions of 5% relative price differentials - international shipping operators	82% to 93%
- military use	107% to 119%

1. Assumes purchase of fuel by visiting forces to the UK is negligible.

This adjustment makes a significant difference to the estimates of the amount of energy used by, and emissions from, UK residents. The total adjustment amounts to 2.8 million tonnes of oil equivalent (not counting UK marine bunkers of 3.1 million toes, which are excluded from the UK energy balance aggregates, but are included within the NAEI), and increases the estimate of the total amount of NOx generated by UK activities by 7%.

These findings are not unexpected. According to contacts at the British Chamber of Shipping, a large part of the UK fleet rarely if ever visits the UK. The estimates do not appear to be particularly sensitive to different

assumptions about the relative price differentials of fuel purchased in the UK and overseas.

5. Fishing

The fishing industry purchased an estimated 125,000 tonnes of gas oil in the UK in 1997. This fuel is purchased by both UK and overseas operators. Since some of the UK fleet travels well beyond British waters, it is likely that some adjustment for fuels purchased in the UK by overseas operators, and for fuels purchased abroad by UK operators, will be necessary.

In the fishing industry an obvious proxy that can be used is the estimated amount of fish catches landed by vessels of UK and other nationalities. We can assume that vessels landing catches in a country other than their own would buy an amount of fuel at the place of the landings that is proportionate to the catches landed.

5.1 Data and methodology

According to DEFRA's Sea Fisheries Statistics, foreign vessels caught approximately 8% of the total catch landed in the UK. One possible assumption therefore is that 8% of fuel purchases allocated to the UK fishing industry are made by foreign vessels.

The Sea Fisheries Statistics also show that landings of fish catches abroad by UK vessels are equivalent to 44% of total landings in the UK, hence it can be assumed that these vessels buy a proportionate amount of fuel in the countries of the landings.

5.2 Results

This implies that of the total purchases in the UK of gas oil by the fishing industry of 125,000 tonnes, 8% or 10,000 tonnes are purchased by foreign vessels. UK vessels abroad are assumed to buy the equivalent of 44% of total purchases in the UK, which amounts to 55,000 tonnes of gas oil.

Hence, total purchases by UK vessels are estimated to be 170,000 tonnes, or 36.3% more than the amount recorded in the NAEI.

It is widely accepted that estimates of fish catches are not entirely reliable, and that there is a significant amount of illegal fishing. The sensitivity tests shown in table 4 assume that reported catches are under-recorded, but the estimates do not appear to be particularly sensitive to alternative assumptions.

Table 4 Calculation of adjustment for fuel use/emissions for the fishing industry, 1997

Landings of fish catch in the UK by - UK vessels	602.7 kt
- overseas vessels	51.1 kt
Landings of fish catch overseas by UK vessels	288.6 kt
Fuel (gas oil) purchased in UK for fishing purposes	0.13mt
Implied adjustment to fishing industry fuel use/emissions	0.05mt (36.3%)
Sensitivity tests	
Overseas landings understated by 50%:	0.04mt (31%)
UK vessels landings in UK understated by 10%; UK landings abroad understated by 20%:	0.05mt (41%)

In principle the monetary elements of these adjustments are included in the Balance of Payments calculations, but the amounts involved are small and they are not separately identifiable. It seems possible that these adjustments may still significantly understate the amount of fuel used by the UK fishing fleet, but there is no other information available on which to base an estimate.

6. Private motor vehicles

According to the NAEI, private car users[9] in the UK purchased 22.4 million tonnes of fuel in 1997. Petrol accounts for the bulk of this, with roughly 20.6 million tonnes, while 1.8 million tonnes of diesel were consumed. As there is no information on the type of fuel (petrol or diesel) or type of car (catalytic or non-catalytic) used by visitors to the UK or by UK residents abroad, it is assumed that the average emission coefficients for the mix of cars used in the UK will apply.

In 1997 pump prices of both petrol and diesel were lower in France than in the UK. The rationale for the adjustment is therefore that tourists travelling by car outside the UK will travel out with an empty tank and will buy fuel in other countries, both for the immediate purpose of travelling abroad, and in order to save on fuel costs when re-entering the UK. Visitors to the UK will also in general enter the UK with full tanks, but of course will need to buy fuel in the UK once their imported fuel has been used up. However, there is no easy way to find out how much fuel is bought by tourists whilst in another country, as the Balance of Payment figures do not disaggregate purchases by tourists sufficiently.

The analysis is therefore based on estimates of the number of visits by tourists in private vehicles and assumptions about the distance driven whilst in another country and the extent to which they fill up with fuel before entering

[9] For the purposes of this analysis, consumption by motor cycle users is ignored.

the UK. This ignores fuels for cars which tourists hire (without hiring a driver) in other countries, which in principle should also be included in the adjustment.

6.1 Data and methodology

The ONS International Passenger Survey (IPS) compiles figures on overseas visitors to the UK and UK residents travelling abroad. As part of this survey, the number and origin of those travelling in private vehicles in each direction is obtained. A separate survey (the Vehicle Occupancy Survey) gives information on the average number of travellers in each car.

In 1997, 870,000 foreign visitors brought private vehicles into the UK, while 2.75 million UK residents took their cars abroad. Because the distances driven by these two groups cannot be assumed to be equal, further information on the destinations of the tourists was sought.

Using IPS information on the areas of the UK visited by foreign tourists, approximate distances were calculated, based on the distance between the county capital and the most popular port, Dover, and an allowance for additional distance driven whilst at the chosen location. This resulted in an average distance of 650 kilometres per foreign visitor. This is similar to a result obtained in a small sub-sample of the IPS, which included information on distances.

For cars driven by UK residents, the IPS gives information on the number of visits made to each European country. From this information, the distances can be judged very roughly. Again, an assumption has to be made about the distances driven. It was assumed that, on average, all drivers will drive to the capital of the respective country and back. This resulted in an estimate of the average distance driven of 819 kilometres per UK resident abroad. The average distance takes account of the fact that 27% of all visits abroad were daytrips to France, where a much shorter total distance travelled was assumed.

In order to calculate the fuel used for this distance, an assumption about fuel use per kilometre is also needed. The Department of Transport, Local Government and the Regions' (DTLR) National Travel Survey (NTS) of the UK provides data that is used as the basis for the adopted assumption.

According to the NTS, passenger vehicles in the UK drove a distance of 379 billion kilometres in 1997, which corresponds to the estimate of 22.4 million tonnes of fuel used. On the basis of this information, the amount of fuel used per kilometre can be calculated as 0.00006 tonnes per kilometre. This rate of fuel use is taken as applying to all categories of cars considered, foreign or UK, diesel or petrol.

The adjustments for the amount of fuel brought into the UK (by both UK and overseas residents) are based on the estimates of vehicle numbers, as well as on assumptions about available tank capacity, the specific density of the

fuels, and the take-up rate (the proportion of drivers engaging in the practice of crossborder shopping for petrol - also known as tank tourism). Some downward adjustment to the calculated allowance needs to be made for short trips to the UK, where the distance travelled in the UK will be not be enough to use up all the fuel which the visitor brought in to the UK.

6.2 Results

In order to split the fuel use between petrol and diesel, the proportions of these types of fuel sold in the UK market are used. Overall, the adjustment made to estimates based on the NAEI is 0.8%. That means that UK residents consume about 0.8% more fuel than is sold in the UK. Table 5 sets out the relevant calculations.

Table 5 Calculation of adjustment for petrol and diesel use and related emissions for private cars, 1997

	Overseas visitors to the UK	UK visitors overseas
Fuel used by travellers		
Visits by car: estimated distance travelled	566 mkm	2,273 mkm
Average tonnes per kilometre	0.00006	0.00006
Total fuel used - petrol	0.03 mt	0.13 mt
- diesel	0.00 mt	0.01 mt
Fuel purchased abroad and brought into the UK		
Number of visits	0.9m	2.8m
% take-up	80%	80%
Available capacity	40L	40L
Specific density - petrol	0.74	0.74
- diesel	0.83	0.83
Amount brought in to UK - petrol	0.02 mt	0.06 mt
- diesel	0.00 mt	0.01 mt
Net adjustment for cars - petrol	0.01 mt	0.19 mt
- diesel	0.00 mt	0.02 mt
		Overall change
Total adjustment for cars - petrol		0.17 mt (0.8%)
- diesel[1]		0.02 mt (0.9%)

[1] The slightly different percentage change for diesel is a result of applying a different specific density in order to convert litres to tonnes.

The calculation shown in Table 5 involves a number of assumptions - about the distances travelled, the proportion of cars which fill up before entering the UK, and the available capacity of these cars. Varying these assumptions gives a possible range of between 0.7% and 1.0%, compared to the central estimated adjustment of 0.8%.

These estimates are slightly below the levels implied by a Customs and Excise report on duty lost through cross-border shopping in 2000, which

suggested that about 0.23 million tonnes of petrol, or about 1% of total use in the UK, was lost through through this legitimate activity. The report also gives a similar estimate for duty losses from petrol brought across the border into Northern Ireland, which has not been taken into account in this study. In addition to these legitimate duty free imports of fuel for private car use, it is possible that there is a certain amount of smuggling across the border into Northern Ireland from the Republic of Ireland for private car use. The assumption made in this study is that smuggling primarily relates to diesel purchased abroad for use in goods vehicles, and not to petrol for private car use. The issue is dealt with in more detail in Section 7.3 below.

7. Goods vehicles and coaches

The rationale for this adjustment is the same as that for private motor vehicles, ie that most cross-border goods vehicles will enter the UK with full tanks and leave the UK with empty tanks. Generally speaking, drivers of goods vehicles and coaches are more likely to seek to maximise the financial benefits of buying cheap fuel in other countries, both because of the greater fuel capacities of their vehicles and because the price differential for diesel is greater than that for petrol. However, the analysis is more complex for goods vehicles because of the different types of lorries involved and the wide range of fuel capacities.

The analysis is once again based on proxies because estimates of the amount of fuel purchased abroad for use in UK vehicles and fuel purchased in the UK by overseas visitors are not available. The figures for the numbers of UK lorries driving abroad and foreign lorries coming to the UK are again taken from the IPS, which also provides some information on coach trips.

7.1 Data and methodology - goods vehicles

The amount of fuel purchased in the UK for use in goods vehicles amounted to 12.4 million tonnes in 1997. Roughly 8 million tonnes of this was diesel fuel consumed by heavy goods vehicles (HGVs), the rest was both petrol and diesel use by Light Goods Vehicles (LGVs). Coaches accounted for a further 0.5 million tonnes of diesel.

For visitors to the UK, the average distance driven was estimated to be 950km. This is based on another small sub-sample of the IPS, but was roughly confirmed by other calculations based upon information on the origin and destination of UK transported goods taken from a DTLR survey on Goods Transport in the UK, which was used to gauge the distances driven by drivers of goods vehicles.

In the case of UK goods vehicle drivers going abroad, figures obtained from a DTLR survey on International Road Haulage were used to estimate the distances driven. This particular survey collects data on tonne-kilometres and tonnes of goods transported, hence the average distance can be readily

calculated. For UK drivers abroad, the average distance is estimated to be 2,100 kilometres per trip.

The estimates of the number of these trips, and the distances travelled, need to be split between the different types of lorries, because the emissions, fuels and tank capacities vary significantly. The IPS gives numbers of lorry passengers travelling abroad, broken down by LGV and HGV. It was assumed that the average occupancy of each lorry type was 1.1, that the bulk (90%) of HGVs were articulated lorries and that 60% of LGVs were diesel-powered. It was also assumed that HGVs on average travelled further than LGVs. These assumptions resulted in the following estimates of the shares of trip numbers and mileages between the four different types of lorries:

	Trips by overseas residents		Trips by UK residents	
	Numer of trips (%)	Mileage (%)	Number of trips (%)	Mileage (%)
HGVs articulated lorries, diesel	72	86	51	78
HGVs, rigid, diesel	8	10	6	9
LGVs, diesel	12	3	26	8
LGVs, petrol	8	2	17	5
All goods vehicles	100	100	100	100

To obtain the fuel consumption per kilometre, the NTS data mentioned above is used again. Here, different fuel consumption values were calculated for LGVs and HGVs.

The adjustments for the amount of fuel brought into the UK by UK and non-UK operators are again based on the estimated vehicle numbers and an assessment of the available tank capacity, with some allowance for the possibility that operators may have to return to the continent without having travelled the distance required in order to use up all the fuel that they brought into the UK in the first place.

Adjustments for smuggling and coaches are considered in Sections 7.3 and 7.4 respectively.

There is no information available on purchases in other countries of petrol and diesel for military use (or of purchases in the UK by visiting forces) and no allowance for this consumption has been made in this study.

7.2 Results for goods vehicles

Table 6 shows the results of applying these assumptions.

Table 6 Calculation of adjustment for diesel and petrol use and related emissions for goods vehicles, 1997

	Overseas visitors to the UK	UK visitors overseas
Fuel used by travellers		
Visits by lorry: estimated distance travelled	391 m km	1571 m km
Average tonnes per kilometre - HGVs	0.00029 t/km	0.00029 t/km
- LGVs	0.0001 t/km	0.0001 t/km
Total fuel used - HGVs articulated lorries, diesel	0.10 mt	0.36 mt
- HGVs rigid lorries, diesel	0.01 mt	0.04 mt
- LGV diesel	0.00 mt	0.01 mt
- LGV petrol	0.00 mt	0.01 mt
Fuel purchased abroad and brought into the UK		
Number of visits	0.41 m	0.75 m
% take-up	85%	85%
Available capacity - HGVs articulated lorries	850 L	850 L
- HGVs rigid lorries	350 L	350 L
- LGV diesel	45 L	45 L
- LGV petrol	35 L	35 L
Specific density - diesel	0.83	0.83
- petrol	0.74	0.74
Amount brought into UK - HGVs articulated lorries	0.18 mt	0.23 mt
- HGVs rigid lorries	0.01 mt	0.01 mt
- LGV diesel	0.00 mt	0.01 mt
- LGV petrol	0.00 mt	0.00 mt
Net adjustment for lorries - HGVs articulated lorries	0.00 mt	0.58 mt
- HGVs rigid lorries	0.00 mt	0.05 mt
- LGV diesel	0.00 mt	0.02 mt
- LGV petrol	0.00 mt	0.01 mt
		Overall change
Total adjustment for lorries - HGVs articulated lorries		0.66 mt (14.0%)
- HGVs rigid lorries		0.05 mt (1.5%)
- LGV diesel		0.02 mt (0.6%)
- LGV petrol		0.01 mt (0.9%)

There are a number of assumptions involved in making these calculations. The most important ones concern the proportion of lorries which are articulated HGVs, their estimated mileage travelled abroad, and the extent to which the operators engage in the practice of leaving the UK with empty tanks and returning with full tanks.

The estimates are reasonably sensitive to alternative assumptions, and may possibly overstate the amounts of fuel involved. However, the adjustment for smuggling (see section 7.3 below) suggests that the estimates are more likely to be on the low side. Using a combination of alternative assumptions, the adjustment to the NAEI estimate of the total amount of diesel used by goods

vehicles appears to be in the range 5.0% to 10.4%, with a central estimate of 5.8%.

7.3 Smuggling

It is also desirable to make an allowance for smuggling, which is believed to be primarily across the border into Northern Ireland from the Republic of Ireland. By its nature the adjustment is subject to a wide range of uncertainty. It is possible to base an estimate on a report by Customs and Excise on smuggling and fraud in 2000. This report noted that while the bulk of an estimated £230 million losses of duty on diesel was the result of legitimate own use of diesel by cross-border traffic, a "large element" related to the smuggling of fuel from the Republic of Ireland for sale or use in the North. A possible calculation of the amounts involved is shown in Table 7.

Table 7 Calculation of adjustment for the effect of smuggling of diesel on estimates of diesel use and related emissions by UK residents, to be applied to 1997

Estimated duty losses relating to diesel use in Northern Ireland, 2000	£230 m
Assumed proportion relating to smuggling of diesel	10%
Duty on diesel in 2000	£0.52 /L
Implied litres smuggled each year	44.4 m
Specific density of diesel	0.83
Implied tonnes of diesel smuggled	0.04 mt (0.3%)
Assumed share by lorry type (pro rata to overall UK usage)	
- HGVs articulated lorries	0.02 mt (0.3%)
- HGVs rigid lorries	0.01 mt (0.3%)
- LGV diesel	0.01 mt (0.3%)
Range based on alternative assumptions about the proportion of duty lost resulting from smuggling	
- assuming smuggling accounts for 5% of £230 m lost	0.2%
- assuming smuggling accounts for 15% of £230 m lost	0.5%

The adjustments involved are not large on a national scale, and are reasonably straightforward to implement. It is worth noting that if the remaining 90% of duty losses were attributed entirely to legitimate cross-border traffic, the estimate of the amount of diesel brought into Northern Ireland would amount to 0.3 million tonnes, which is more than the total amount of diesel for the UK as a whole which we estimated (see Table 6) to have been brought into the UK by UK residents.

7.4 Coaches

The IPS also gives information on the number of people travelling to and from the UK by coach, and the average occupancy rate of the coaches. The overall amount of fuel used by coaches is not large, but the adjustment makes

a significant difference to the estimate of the total emissions and fuel use of the public road transport sector. The calculation follows the same methodology as for other motor vehicles.

First, the total milage needs to be estimated, based on the estimated numbers of coaches involved. It was assumed that coaches visiting the UK on average travelled the same distance as lorries, but that UK-operated coaches travelling abroad on average travelled 200 kilometres less than lorries. Second, assumptions about the available fuel capacity and take-up rates were required. On this basis purchases of fuel brought into the UK by overseas operators exceeded the estimated amount used within the UK, so instead a small allowance for those coaches travelling large distances within the UK was made. Table 8 gives the details of the calculations for UK residents only.

Table 8 Calculation of adjustment for diesel use and related emissions for coaches, 1997

Number of trips by UK coaches going overseas	0.67 m
Average distance travelled	950 km
Total distance travelled	127 m km
Fuel use rate	0.00022 t/km
Total diesel used overseas	0.03 mt
Number of coaches returning to the UK with full tanks	0.67 m
Available capacity	450L
Take-up rate	85%
Specific density of diesel	0.83
Implied amount of diesel brought into UK by coaches	0.02 mt
Total diesel bought by UK residents	0.05 mt
As percentage of purchases in the UK	10%

8. Summary of findings

8.1 The effect on national totals

Overall, the adjustments are estimated to increase energy use figures for 1997 based on the NAEI by 2.3%, while emissions of carbon dioxide increase by 2.4%, sulphur dioxide by 6.4% and nitrogen oxides by 9.0%.

Table 9 Summary of adjustments required to bring the NAEI figures on to a National Accounts residents' basis

	Fuel use	*Emissions*		
	m toes	Kt Carbon	Kt SO2	Kt Nox
International aviation - aviation turbine fuel	0.24 (3%)	190	0.2	3.5
International shipping – gas oil	0.73 (87%)	581	13.2	38.7
– fuel oil	1.63 (87%)	1,341	88.9	89.9
Military aviation - aviation turbine fuel	0.42 (50%)	328	0.4	3.2
Military shipping - gas oil	0.47 (113%)	368	8.3	24.5
Fishing vessels - gas oil	0.05 (36%)	39	0.9	2.6
Private Vehicles – petrol	0.19 (1%)	149	0.1	4.4
– diesel	0.02 (1%)	14	0.0	0.1
Goods Vehicles - HGV artic diesel	0.74 (14%)	583	0.6	17.5
- HGV rigid diesel	0.06 (2%)	49	0.1	1.9
- LGV diesel	0.03 (1%)	26	0.0	0.2
- LGV petrol	0.01 (1%)	10	0.0	0.3
Coaches - diesel	0.05 (10%)	41	0.0	1.6
Total UK adjustment	4.64	3,708	112.7	188.1
As % of total NAEI figure	(2.3%)	(2.4%)	(6.4%)	(9.0%)

Figures in brackets show the adjustment as a percentage of the estimate given in the NAEI.
toes = tonnes of oil equivalent.
To convert CO_2 emissions from carbon equivalent to carbon dioxide equivalent multiply by 44/12.

The adjustments for certain individual industrial sectors are of course more significant. The sectors particularly affected are for water transport, public administration (defence activities) and fishing (see Table 10).

Table 10 Adjustments (absolute and %) to estimates for different sectors, from the atmospheric emissions accounts 1997

	Fuel use	*Emissions*		
	m toes	**Kt Carbon**	**Kt SO2**	**Kt Nox**
Air transport	0.24 (3%)	190 (1%)	0.2 (3%)	3.5 (4%)
Water transport	2.36 (72%)	1,922 (20%)	102.1 (80%)	28.6 (108%)
Public administration (defence activities)	0.89 (19%)	696 (7%)	8.7 (43%)	27.7 (109%)
Fishing	0.05 (36%)	39 (10%)	0.9 (36%)	2.6 (52%)
Other land transport[1]	0.69 (7%)	542 (2%)	0.5 (7%)	16.8 (10%)
Domestic sector[2]	0.21 (0%)	162 (0%)	0.1 (0%)	4.5 (1%)
National totals[3]	4.64 (2.3%)	3,708 (2.4%)	112.7 (6.4%)	188.1 (9.0%)

Source: ONS

[1] Assumes that the adjustment to goods vehicles energy use and emissions is shared between public hire road hauliers and own account operators in the same proportions as the unadjusted estimates. Also assumes that none of the purchases relating to LGV use are for private (domestic) purposes.
[2] Assumes all of the private car adjustment is in respect of the domestic sector.
[3] Includes adjustment in respect of own account goods vehicle operators.

toes = tonnes of oil equivalent.
To convert CO_2 emissions from carbon equivalent to carbon dioxide equivalent multiply by 44/12.

8.2 The effect of different assumptions

The estimated adjustments involve a substantial element of judgement and a number of assumptions. For the estimates of energy use and carbon dioxide emissions, however, the results are not particularly sensitive to variations in these assumptions. In the unlikely event that all the assumptions made were viewed as being on the high side (in terms of their effect on the size of the adjustment), energy use might alternatively be calculated as 2.0% higher than NAEI figures, rather than the 2.3% currently estimated. Conversely, if all the assumptions made were viewed as being on the low side, it would be possible to obtain an alternative estimate with energy use being 2.8% more than the unadjusted figure. This range suggests that the adjustments are reasonably robust despite the large element of judgement involved. Table 11 gives details of the effect of varying the assumptions upon the estimated fuel use and emissions of CO_2, SO_2 and NOx.

Table 11 Range of adjustments to NAEI national totals, using various alternative assumptions, 1997

	Fuel use	*Emissions*		
	m toes	**Mt Carbon**	**Kt SO2**	**Kt Nox**
Unadjusted NAEI national total	203.9	156.2	1,761	2,097
Adjusted total (low estimate)	208.0	159.4	1,867	2,269
% change	2.0%	2.1%	6.0%	8.2%
Adjusted total (high estimate)	209.7	160.8	1,882	2,318
% change	2.8%	2.9%	6.9%	10.5%
Adjusted total (central estimate)	208.6	159.9	1,874	2,285
% change	2.3%	2.4%	6.4%	9.0%

toes = tonnes of oil equivalent
To convert CO_2 emissions from carbon equivalent to carbon dioxide equivalent multiply by 44/12.

9. Conclusions and recommendations

There is a wide range of assumptions used in estimating the size of the adjustment required to bring the estimates of energy use and atmospheric emissions from the NAEI on to a National Accounts residents' basis. These assumptions will doubtless be subject to modification in the light of further consideration, and improvements are likely to the underlying data used in the calculations. Nevertheless, initial testing of the various assumptions suggests that adjustments to the energy use and carbon dioxide emissions for 1997, of between 2.0% and 2.9%, would be justified, with corresponding adjustments to the sulphur dioxide (of between 6.0% and 6.9%) and nitrogen oxides estimates (of between 8.2% and 10.5%).

By applying the adjustments at the level of the NAEI source/fuel combination, there will also be some, less significant, amendments to the estimated emissions of other pollutants from transport fuels and road use.

The NAEI data which is used in the atmospheric emissions accounts covers the period 1990 to 1999, so there is little point in simply amending the figures for one year. The procedures for applying the methodologies described in this research will vary depending upon the source of the emission and the available data. For the air and water transport industries and for the associated military fuel use, it is probably sufficient to apply the percentage change from this report to the fuel use for other years as recorded in the NAEI.

For fishing, an analysis of the proportions of fish catch landed abroad and in the UK during the 1990s could be used to provide figures for the relevant adjustment for other years.

For diesel purchases, the general assumption that travellers sought to minimise costs by purchasing fuel outside the UK probably held true throughout the decade, when diesel prices were consistently lower in Fance. However, the adjustment will need to reflect changes in the number of vehicles leaving and entering the UK, for which IPS data for the other years will be required. This data will also reflect changes resulting from the opening of the Channel tunnel in the early 1990's.

For tourists using petrol driven cars, the adjustments for other years need to allow both for changes in the numbers of vehicles (for which the IPS provides a source) and for changes in relative pump prices. In particular, a much lower take-up rate will need to be assumed for years when fuel prices were not significantly different in France.

As far as smuggling is concerned, the amounts of fuel involved will depend both upon relative fuel prices and the actions of Customs and Excise to combat the problem. But because there is no other information available on which to base an estimate, a reasonable default assumption might be to assume a fixed amount of smuggling throughout the 1990s so as not to distort any trends that would otherwise be apparent.

Further consideration will need to be given to the extent of cross-border business use of private cars and private use of LGVs. At the moment the adjustment for private car energy use and emissions has been allocated to the domestic sector, while the whole of the adjustment for energy use and emissions from LGVs has been allocated to the non-domestic sector.

Once these adjustments have been implemented, it is intended to include them in a more complete summary of the differences between the amounts reported under UNFCCC guidelines and the estimates of emissions on a National Accounts basis.

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