Greenhouse Gas Emissions from Inland Waterways and Recreational Craft in the UK

Task 25 of the 2010 DA / UK GHG Inventory Improvement Programme





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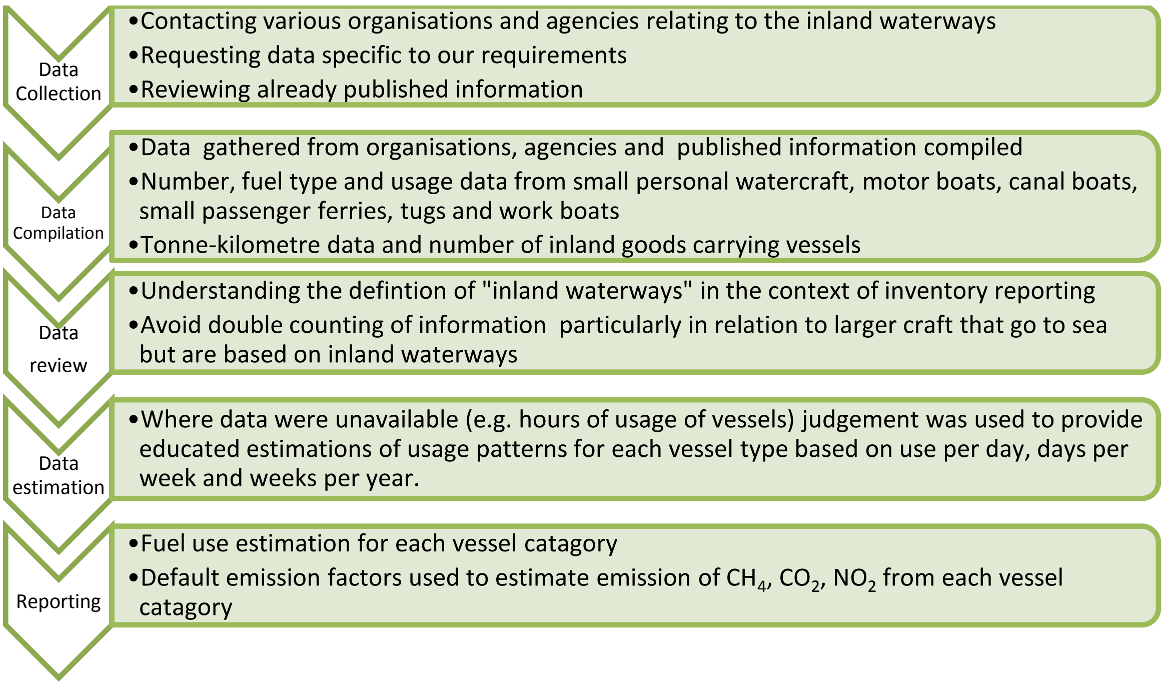
Executive summary

This report summarises the findings of Task 25: Inland Waterways, under the UK GHG inventory improvement programme. The work has focussed on investigating the availability of data to ascertain whether it is possible to estimate emissions from vessels operating on the UK's inland waterways, with a view to constructing a time series of fuel use and emissions for reporting in the Common Reporting Format (CRF) tables.

Emissions from vessels used on inland waterways are not currently reported in the UK Greenhouse Gas Inventory (GHGI). This is because there are no national fuel consumption statistics on the amount of fuel used by this sector. As all fuel consumed by all sources in the UK ***is*** captured by the inventory, it effectively means that emissions from inland waterways are also captured, but are being misallocated to other sectors using the same types of fuels.

This aim of this study was to reviews the possibility of estimating emissions from inland waterways on a national scale by means of alternative data sources on the population and annual usage of vessels. The figure below shows how the review was undertaken:



The approach used provides estimates of population and usage of each type of vessel. This led to an estimate of the total amount of each fuel consumed by the inland waterways sector. The estimates of fuel use and greenhouse gas emissions of CO_2, CH_4 and N_2O from each vessel category and vessels on the inland waterways as a whole (excluding the sea-going tugs and fishing vessels which may already be included in the shipping emissions inventory) are shown in Table 1.

The uncertainties in these emission and fuel consumption estimates have not been quantified but are expected to be very high, mainly because of the uncertainties in the hours of use figures. Overall, we believe the usage figures assumed and hence the fuel consumption and emissions derived from them are upper estimates. However, there is additional uncertainty that needs to be addressed on the type of diesel used for powering private recreational craft (i.e. whether road diesel or gas oil is used) which is important to the overall allocation of these fuels between sectors in the wider inventory.

Total GHG emissions of 0.72 Mtonnes CO_2 equivalent is estimated, excluding sea-going tugs and fishing vessels. This is 0.12% of total UK GHG emissions in 2008. If these sea-going vessels are included, the estimate is increased to 1.19 Mtonnes CO_2 equivalent, which is 0.19% of total UK GHG emissions.

It was estimated that roughly equal amounts of petrol and diesel are consumed by inland waterways, amounting to around 0.5% of total petrol and diesel consumption in the UK in 2008 on the basis of assumptions made on the use of road diesel for powering recreational craft.

A method has been proposed for backcasting emissions to 1990 based on a variety of proxy statistics appropriate for different types of inland waterway activities that are available over a consistent time-series.

Table 1: Summary of fuel usage and GHG emissions for each vessel category calculated in the core inventory where larger sea-going tugs and fishing vessels are excluded

Vessel category	Total Fuel usage /yr (ktonnes)	CO_2	CH_4	N_2O	CO_2e [a]	CO_2e [a]
		ktonnes	tonnes	tonnes	ktonnes	%
01. Sailing boats with auxiliary engines	1.8	5.8	0.09	0.15	5.9	1%
02. Motorboats / Workboats	186.0	588.2	95.45	14.88	594.8	
SUBTOTAL : ***Motorboats - inland waterways***	79.7	251.6	58.94	6.37	254.8	35%
SUBTOTAL: ***Motorboats – coastal***	91.4	289.2	35.77	7.32	292.3	41%
SUBTOTAL: ***Workboats*** [b]	14.9	47.4	0.74	1.19	47.8	7%
03. Personal watercraft i.e. jet ski	34.6	108.4	64.70	2.66	110.6	15%
04. Inland goods carrying vessels [c]	2.3	7.5	0.12	0.19	7.6	1%
TOTAL	**224.8**	**709.9**	**160.36**	**17.87**	**718.82**	100%
% of total UK emissions in 2008		**0.14%**	**0.01%**	**0.02%**	**0.12%**	

Notes: [a] Carbon dioxide equivalent emissions (CO_2e), calculated using GWP factors (GWP for CO_2 = 1; for CH_4 = 21; for N_2O = 310), consistent with reporting under the Kyoto Protocol (IPPC, 1996); [b] Vessel types sea-going tugs and fishing vessels EXCLUDED; [c] Shows averaged results from the two methodologies based on tonne-km factors for CO_2 and vessel population and usage data

It is recommended that:

- The estimates and assumptions are reviewed by external stakeholders to attempt to validate estimates and reduce uncertainty on the population and usage figures used;
- The assumptions made concerning the use of gas oil and DERV for powering recreational craft with diesel engines are confirmed by marine engine and fuel industry experts
- The findings on consumption of DERV, gas oil and petrol by inland waterways are assessed in the context of the consumption figures given in DUKES so that a re-allocation can be made across sectors including a re-allocation of petrol and DERV

consumption and hence emissions from the road transport to inland waterways sectors

- The method is further developed to provide a robust inventory time-series on UK emissions from inland waterways and for spatially disaggregating emissions and distributing emissions between each Devolved Administration country.

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1 Introduction

Emissions from vessels used on inland waterways are not currently reported in the UK Greenhouse Gas Inventory (GHGI). This is because there are no national fuel consumption statistics on the fuel used by this sector reported in DECC's *Digest of UK Energy Statistics* (DUKES). This does not mean that greenhouse gas emissions from this sector are not covered in the GHGI, but, because there is an overall fuel balance in the inventory, the emissions are effectively misallocated to other sectors which use the same fuels, mainly diesel in the form of gas oil or road diesel (DERV) and petrol which are used to drive the engines on inland waterway vessels.

Although their emissions are not omitted in the national inventory totals, the absence of inland waterways as a source in the inventory has been pointed out by external inventory review teams and by the Department for Transport (DfT). Including emissions from inland waterways would enable DfT and other policy makers in Government to make a more complete assessment of emissions from different transport sources and to develop and evaluate policies on intermodal shift, for example by switching movement of freight from road to waterways.

This study reviews the possibility of estimating emissions from inland waterways on a national scale by means of alternative data sources which reflect the levels of activity by vessels and therefore the amounts of fuel used. The study has focused on greenhouse gas emissions, but the issues and data sources assessed apply equally to inventories for air pollutant emissions which are also not currently included in the National Atmospheric Emissions Inventory (NAEI).

Inland waterways, like other off-road machinery sources of emissions, is a complex source to cover in an emissions inventory on a national scale because it is a diffuse source, involves a wide variety of vessels operating for a multitude of purposes (both commercial and recreational) with no centrally-held statistics on either the total amounts of fuel supplied or consumed by the sector or on the vessel population and usage patterns.

Consequently, it is necessary to estimate fuel consumption from estimates of the population and usage of vessels derived from information and expert advice held by users of vessels and regulators of inland waterway activities. The methodology used to estimate emissions from the sector follows that described in the EMEP/EEA Emissions inventory guidebook (EMEP, 2009a) where emissions from individual vessel types are calculated from an equation:

$$E = \sum_{i} N \times HRS \times HP \times LF \times EFi \qquad (1)$$

where:

E = mass of emissions of pollutant i during inventory period,

N = source population (units),

HRS = annual hours of use,

HP = average rated horsepower,

LF = typical load factor,

EFi = average emissions of pollutant i or fuel consumed per unit of use (e.g. g/kWh).

Emissions are calculated from the amount of fuel consumed derived from Equation (1) combined with g/kg fuel emission factors.

The method requires:

- a categorisation of the types of vessels;
- numbers for each type of vessel, together with the number of hours that each type of vessel is used;
- data on the average rated engine power for each type of vessel, and the fraction of this (the load factor) that is used on average to propel the boat;
- g/kWh fuel consumption factors and fuel-based emission factors.

Many vessels on the inland waterways are used on an irregular or infrequent basis (e.g. recreational craft), while others may be used more frequently (e.g. small ferries). Some vessels may be equipped with more than one engine and fuels may be used for different purposes, mainly to propel the vessel, but also in auxiliary engines (e.g. on service vessels) and for heating. Although not relevant to this study, when estimating emissions of air pollutants, account would need to be taken of the age of the engine and emission standard the engine complied with when it was new. Emission standards for recreational craft are covered in EU Directive 2003/44.

The current study involved a survey of a number of stakeholders with particular interest in or regulation of activities associated with inland waterways and recreational craft. The study addresses:

- the fuel supplied for these craft and whether there may be alternative sources of fuel consumption data; and
- population and usage data for different types of craft in order to estimate fuel consumption and emissions using existing emission factors for engines and fuels typically used for vessels on inland waterways.

This report starts with a definition of inland waterways in an inventory context. Section 3 discusses the fuels used on inland waterways and how they are likely to be supplied. Section 4 provides a detailed description of the vessel population data acquired from various sources, the synthesis of the data and estimation of hours of use of each vessel category. Section 5 provides data on the average rated power for each type of vessel, and the fraction of this (the load factor) that is used on average, together with the fuel consumption and emission factors recommended for each vessel category. In Section 6, the information gathered in Sections 4 and 5 is combined to estimate the total fuel consumed by the UK inland waterways sector and emissions of CO_2, CH_4 and N_2O. The fuel consumption is put into context with total UK fuel consumption of each type of fuel to consider the implications to the other sectors where the fuel used by inland waterways is currently assigned, while the emissions are put into context with overall UK emissions.

The primary focus of the study is on fuel consumption and emissions from the sector in a recent year, but it will be necessary to make emission estimates for an inventory time-series extending at least as far back as 1990. While this issue is not considered in detail, the potential use of proxy data as indicators of activity in the inland waterways sector is briefly discussed in Section 7 as a means for estimating trends in fuel consumption in the time-series relative to recent levels.

Finally, Section 8 provides a summary and conclusions of the work.

2 Definition of Inland Waterways

The IPCC Guidelines (IPCC, 2006) for national greenhouse gas inventories indicate emissions from inland waterways are essentially a sub-set of the NFR category 1A3d Waterborne Navigation which also covers shipping. In the UK, all emissions from inland waterways would be included in domestic totals unlike in some other countries where some vessels on inland waterways could be classed as international as they pass between countries. The IPCC Guidelines specify that category 1A3d should include “not only fuel used for marine shipping, but also for passenger vessels, ferries, recreational watercraft, other inland watercraft, and other gasoline-fuelled watercraft”. The Guidelines recommend national energy statistics be used to calculate emissions, but if these are unavailable then emissions should be estimated from surveys of fuel suppliers, vessel movement data or equipment (engine) counts and passenger and cargo tonnage counts.

The IPCC Guidelines refer to more detailed information and methods for estimating emissions given in the EMEP/EEA Emissions Inventory Guidebook (EMEP, 2009a). In this, the simple Tier 1 and more detailed Tier 2 approaches are both based on the premise that quantities of fuel sold for these activities are available for the sector. Tier 2 involves making a split between engine type and technology assuming the availability of national information to do this or else using default values. The Tier 3 approach is more detailed and involves bottom-up estimates of fuel consumption and emissions using detailed vessel movement data and fuel consumption and emission factors given for a number of different petrol and diesel engine types and sizes associated with different vessel types, including sea-going vessels and recreational craft of different sizes.

The term ‘inland waterways’ is not used in the latest EMEP/EEA Emissions Inventory Guidebook (2009), rather emission factors are given a) for all vessels of different sizes and activity types which would be applicable for all non-recreational vessels (from sea-going ships to commercial vessels used on inland waterways) and b) for all recreational vessels of different engine types and vessel lengths. The factors are in g/kWh and the assumption is that there would be activity data to use in conjunction with these factors in terms of numbers of vessels, nominal engine power, load factors and hours of use. However, there is no direct way of associating a particular non-recreational inland waterway vessel type with engine type.

The earlier 2007 EMEP/EEA Emissions Inventory Guidebook (EMEP, 2007) does make specific use of the term “inland waterways” and divides this general class into four categories:

- Sailing Boats with auxiliary engines;
- Motorboats / Workboats – recreational motor boats, inland passenger boats, service boats (police, customs), tugs, commercial (swimming cranes);
- Personal Watercraft – small moped type craft with 2-stroke or 4-stroke engines, e.g. jet skis; and
- Inland Goods Carrying Vessels.

This Guidebook provides emission factors (including CH_4 and N_2O) for 2-stroke petrol and 4-stroke petrol engines and for diesel engines of different nominal engine power. The text in the Guidelines provides some indication of the engine sizes of the four categories.

The availability of emission factors in the Guidebook provides an indication of the vessel types which the study needed to focus on in terms of gathering activity data for the inventory of inland waterways and therefore which organisations to approach.

When contacting organisations, it became apparent that the UK has its own category system for defining different waters. These categories are:

- Category A: Narrow Rivers and canals where the depth of water is generally less than 1.5 metres;
- Category B: Wider rivers and canals where the depth of water is generally 1.5 metres **or more** and where the significant wave height could not be expected to exceed 0.6 metres at any time;
- Category C: Tidal rivers and estuaries and large, deep lakes and lochs where the significant wave height could not be expected to exceed 1.2 metres at any time;
- Category D: Tidal rivers and estuaries where the significant wave height could not be expected to exceed 2.0 metres at any time.

These categorisations determine which waters are not regarded as ‘sea’ for the purposes of regulations made, or treated as made, under Section 85 of the Merchant Shipping Act 1995.

DfT use a definition of inland waters devised for the survey of waterborne freight traffic (DfT, 2010). It uses two boundary definitions when measuring the amount of traffic. **Inland waters** are all waters within the outermost limit of Category D above. **Inland waterways** has a boundary much further upstream of the limit of Category D and covers all water areas available for navigation that lie inland of a boundary defined as the most seaward point of an estuary which might reasonably be bridged or tunnelled.

These definitions were helpful, but not restrictive in defining the definitions of vessels and movements covered in this study for the inland waterways emissions inventory. They were helpful because some organisations contacted talked in terms of these definitions. In order to understand and interpret some of the data obtained in the survey it was convenient also to think in terms of these definitions when deciding whether vessel numbers provided from different sources covered the same vessels and would lead to double-counting, whether there was at least some partial overlap (partial double-counting) or were completely independent (mutually exclusive).

Understanding the definitions also helped us decide whether vessel numbers and corresponding movements may already be included in the UK shipping inventory. This was a potential problem where certain vessels identified as inland waterway vessels spend some time at sea. The GHGI for domestic shipping was recently improved using the detailed inventory developed by Entec based on shipping movement data, but Entec acknowledged that movements of smaller vessels were not all covered and additional ports data were used to at least partially correct for this (Entec, 2010). The exact boundary between vessels covered in the shipping inventory and an inland waterways inventory could be unclear at the smaller end of the vessel size range of the shipping inventory and the larger end of the vessel size range of the inland waterways inventory. This might be the case for larger tugs, some passenger ferries and fishing vessels, for example, those that spend time in tidal estuaries, but occasionally go out to sea.

For the purpose of this study in defining the vessel numbers and usage to be used for an emission inventory of inland waterways, all vessels that were thought to remain in Categories A-D above were included as were small recreational craft that went out to sea and were definitely not included in the Entec shipping inventory. Larger commercial vessels that went out to sea from Categories C and D waters and were thought **unlikely** to be included in the Entec shipping inventory were not included in the core inventory estimates for inland waterways, but were taken account of in a sensitivity study to gauge the relative magnitude of their emissions.

On the basis of this definition, the vessels that were considered for the inland waterways inventory were as follows:

- Private, recreational craft used on rivers, canals and lakes;
- Commercial passenger craft used on rivers, canals and lakes;
- Service vessels (e.g. small tugs, floating excavators etc) used on rivers and canals;

- River barges and other freight carrying vessels going up wide river stretches and tidal estuaries;
- Private, recreational craft used on tidal rivers and estuaries, occasionally going out to sea, e.g. sailing yachts (with auxiliary engines), motor boats, cabin cruisers, small fishing vessels, speed boats, jet skis;
- Service boats used by port and harbour authorities, e.g. tugs;
- Small ferries crossing estuaries, but not going out to sea.

The study involved collecting information on the UK population of these vessels from various bodies as described in Section 4. These included:

- Port and harbour authorities;
- Environment Agency;
- Maritime and Coastguard Agency;
- British Waterways;
- Inland navigation authorities;
- DfT;
- Various boating associations.

Whilst a relatively large amount of information on numbers of vessels was gathered, obtaining information on hours of use of different vessel categories was much more difficult and in most cases had to be estimated on the basis of assumed usage patterns.

3 Fuel Used by Vessels on Inland Waterways

Vessels on inland waterways (as defined in Section 2) mainly have diesel engines. Some smaller vessels with outboard motors and equipment like jet skis use 4-stroke or 2-stroke petrol engines.

There are no centralised statistics on the amount of fuel used in the UK by vessels on inland waterways, but communications with HMRC and informal discussions with recreational boat owners were useful in understanding the current fuel duty system and the fuel purchasing behaviour of boat owners.

Two forms of diesel are used. All diesel used for commercial vessels would be gas oil. This has different physical properties to road diesel (DERV) and is paid for at a low rate of duty. It is often referred to as ‘red diesel’. The majority of private vessels with diesel engines are thought to run on a fuel which is essentially the same as road diesel. This fuel may also be available from suppliers at low duty rates with a red dye in it (so may also be called ‘red diesel’ even though it has different properties to gas oil used for commercial vessels), but since November 2008, fuel used for propulsion has to be paid for at the full rate of duty (HMRC, 2009). Fuel used for non-propulsion purposes on private boats (e.g. for heating, appliances), may be at the rebated duty rate. Boat owners therefore have to declare the amount of fuel used for propulsion and non-propulsion purposes when purchasing fuel from a red diesel supplier. Operators of private craft could therefore purchase ordinary road diesel (DERV) from their local filling station for propulsion purposes or buy their fuel at boat yards, marinas or filling points on rivers and estuaries and pay the excess duty. Either way, the fuel used for propulsion is the same fuel from the refinery stream as road diesel.

On this basis, we have assumed in our analysis and for the purpose of the inventory calculations presented in this report that all privately owned vessels with diesel engines used for recreational purposes on a fairly infrequent basis use DERV, with the exception of canal boats which are assumed to use gas oil. Hire boats, charter boats, commercial passenger vessels, service boats (e.g. tugs), ferries, fishing vessels and all types of goods carrying vessels are all assumed to use gas oil.

Consumption of DERV and gas oil by inland waterways is not represented as such in DUKES, but is reflected in total fuel deliveries. This means that the fuel is currently misallocated to other sectors in the inventory and that a re-allocation will be necessary to account for the consumption by inland waterways leading to a reduction in fuel consumption and hence emissions from other sectors using gas oil and from the road transport sector in the case of DERV. The reallocation of DERV from the road transport sector is likely to be a very small fraction of the total amount of DERV currently assigned to road transport.

These assumptions made concerning the use of gas oil and road diesel by inland waterways require confirmation by talking with marine engine and fuel industry experts. Confirmation on how these fuels defined here by their physical properties relate to the definitions of road diesel and gas oil in DUKES is also required. This is pivotal to how the consumption of these two fuels and the resultant emissions are allocated between different source sectors in the inventory.

HMRC are themselves currently carrying out a review of the amount of diesel used by private leisure craft derived from the amount of fuel duty collected (HMRC, 2011). It is possible that this information could be made available for the inventory later in 2011, or at least as a means of verifying the estimates of fuel consumption made in the inventory approach discussed later in this report.

Petrol used by small recreational craft will most likely be purchased at local filling stations as this fuel is not generally sold in marinas, boat yards and along rivers. The fuel used by these vessels is therefore currently being captured by the road transport emissions inventory. Re-allocating this fuel to inland waterways will lead to a reduction in petrol consumption and hence emissions of CO_2 from the road transport sector, but the reduction is likely to be very small by comparison with the total amount of petrol assigned to road transport.

4 Population and Usage of Inland Waterway Vessels

4.1 Overview

From the initial assessment of how inland waterways should be defined for the purpose of the emissions inventory and the review of fuel used by vessels, it was concluded that at present the only means of estimating greenhouse gas emissions from this sector was through a bottom-up method using vessel population and hours of use data combined with emission factors for different craft and engine types.

Various organisations and agencies were contacted who were considered to have available data or at least the in-house expertise to make appropriate expert judgement. These included:

- The Environment Agency – for information on vessel numbers used on rivers and waters under their jurisdiction;
- British Waterways – for information on vessel numbers used on rivers and waters under their jurisdiction;
- Association of Inland Navigation Authorities (AINA) – this is the industry body in Great Britain for those authorities with statutory or other legal responsibility for the management and operation of navigable inland waterways;
- Maritime and Coastguard Agency – for information on vessel movements around rivers and estuaries;
- Royal Yachting Association – for information on private watercraft;
- DfT – for waterborne freight statistics;
- Port of London Authority – for information about vessel numbers and activity on the tidal Thames;
- Hoeseasons, Blakes and anglowelsh.co.uk – for information about boat holidays;
- Salters Steamers – for information about passenger boats e.g. operating on the Thames.

In addition, contact with DfT revealed that the International Vehicle Standards Division had recently collected similar information on **total numbers of engines** on vessels operating on Category A-D waters (DfT, 2011a). This was required for an assessment of the number of diesel engines on vessels that could potentially be affected by new fuel quality regulations. DfT were able to share the information that they had collected via surveys. This covered:

- Passenger Boat Association – fare paying passenger vessels;
- Cruising Association – recreational craft;
- Professional Boatmen's Association – Diving boats, fishing boats and other small charter boats;
- Commercial Boat Operators Association – commercial freight vessels and tugs not working to sea; and

- Port and harbour authorities – port operated tugs, patrol launches, pilot boats and work boats.

The information from DfT had the advantage of having the number of vessels in each vessel category with 1, 2 or 3 or more engines and in which category of water they would likely be operating (A-D) and whether they would be transiting through these waters out to sea.

It quickly became apparent that there was a reasonable amount of information on numbers of vessels, mostly from statistics held on numbers of licenses issued, memberships etc, or from expert opinion. However, the bigger challenge was finding any data on hours of use, so these would have to be estimated and would likely be the major source of uncertainty in the overall emission estimates.

The following sections describe in detail the vessel numbers collected and assumptions made in deriving the final population figures for each vessel category and specific issues with each data source. A major challenge was reconciling information on broadly the same vessel type from different sources. Differences may reflect the uncertainties in the data gathered by the relevant bodies or coverage in terms of geographical scale or vessel type. In some cases information from several sources were used. For example the data from one source might be considered more reliable or representative than data from a second source, but may not provide enough detail in terms of a breakdown by vessel type. The second source may provide a breakdown in vessel numbers by type and this would be used to disaggregate the total vessel numbers taken from the first source.

Another challenge was to understand the overlap in data received from different sources. The issue would be whether the different data sets were truly independent of each other, and could therefore be combined, or whether they partially captured the same population of vessels, and therefore would lead to a partial double-count if both were used.

Section 4.3 addresses the estimates of hours of use per year for each vessel type. This would be based on estimates of how many hours per day a vessel may be using its engine, over how many hours per week and weeks per year, capturing the different usage profiles associated with recreational activities concentrated during certain months of the year and days of the week and commercial activities occurring on a more regular basis throughout the year or specific parts of a year.

4.2 Population of vessels

4.2.1 Contacts

Initial contact was made with the following organisations with regards to potential sources of vessel numbers and activity on inland waterways in the UK:

- Associated British Ports – recommended contacting Port of London Authority;
- British Ports Association – no response as of 01/04/2011;
- British Waterways – provided information (see below);
- DfT, International Vehicle Standards – provided information (see below);
- DfT, Maritime Statistics Advisory Group (MSAG) – no response as of 01/04/2011;
- DfT, Ports General Enquiries – recommended contacting Maritime and Coastguard Agency;
- Environment Agency – provided information (see below);
- Inland Waterways Association – recommended contacting British Waterways;
- Maritime and Coastguard Agency (MCGA) – provided information (see below);
- Office for National Statistics (ONS) – relevant publications have been discontinued (Waterborne transport within the United Kingdom, http://www.statistics.gov.uk/CCI/nscl.asp?ID=8179; Pleasure boats licensed on canals and rivers, http://www.statistics.gov.uk/CCI/nscl.asp?ID=8071. Recommended contacting DfT Maritime Statistics Advisory Group;

- Port of London Authority – recommended contacting DfT;
- Ports and harbours of the UK – no response as of 01/04/2011;
- Rivers Agency Northern Ireland – recommended contacting Waterways Ireland;
- United Kingdom Major Ports Group Limited (UKMPG) – recommended contacting Port of London Authority;
- Waterways Ireland – provided information (see below);
- Hoeseasons, Blakes and AngloWelsh Waterway Holidays – no response as of 01/04/2011;
- Salters Steamers – provided estimations regarding fuel consumption and activity.

With regards to freight, the DfT's report on Waterborne Freight in the UK was utilised.

Table 4.1 summarises the data received from these organisations that was used in the subsequent vessel number and activity estimations.

Table 4.1 Summary of data received for estimation of UK inland waterway vessel numbers and activity

Organisation	Data provided
British Waterways	1. Inland Waterways Advisory Council (IWAC) report (2009); 2. Association of Inland Navigation Authorities (AINA) (2008) survey report.
DfT, International Vehicle Standards	Numbers of vessels operating on non-tidal (category A&B) and tidal (category C&D) waterways for DfT study on number of boats and engines affected by new fuel regulations 1. Passenger Boat association 2. Chamber of Shipping 3. National Work Boat Association 4. Cruising Association 5. Professional Boatmen's Association 6. Commercial Boat Operators Association 7. Commercial Fishing Vessels 8. Port & Harbour Authorities
Environment Agency	1. Craft registration figures for Environment Agency navigations
Maritime and Coastguard Agency (MCGA)	1. Number of passenger vessels carrying more than 12 passengers, operating on categorised waters – required to hold a Passenger Ship Safety Certificate; 2. “Ball-park" figures of commercially operating non-passenger vessels
Waterways Ireland	1. Number of vessels registered on the Erne System in Northern Ireland.

4.2.2 Vessel categories

The following four vessel categories were used to split the number of vessels, and subsequently the engine power and activity profiles (EMEP, 2007):

01. Sailing boats with auxiliary engines;
02. Motorboats / Workboats (e.g. dredgers, canal, service, tourist, river boats);
    a. recreational craft operating on inland waterways;
    b. recreational craft operating on coastal waterways;
    c. workboats;

03. Personal watercraft i.e. jet ski; and
04. Inland goods carrying vessels.

Some specific issues were identified when reviewing the data provided by stakeholders, some of which are described in the paragraphs below.

Data provided by DfT from a number of associations (DfT, 2011a) split vessels by category according to:

1. The number of engines (1, 2 or 3 or more); and
2. The number of these vessels operating predominantly in Category A and B waters or in Category C and D waters.

Where appropriate, these data were used directly, otherwise the fractional split was applied to alternative figures that were considered more complete. This allowed for vessels of one type to be assigned different engine sizes and activity profiles, and hence different emission factors.

The Environment Agency and British Waterways were contacted directly as they are the two biggest navigation authorities in the UK. The British Waterways manages 2,200 miles of Britain's canals and rivers, while the Environment Agency manages five navigations in the Anglian Region, the Great Ouse, Nene, Welland/Glen, Ancholme and Suffolk Stour. Data received from the Environment Agency covered only the geographical areas of England and Wales (EA, 2011). However, the Association of Inland Navigation Authorities report (AINA, 2008) covers a greater geographical region. The report contains boat numbers on 21 of AINA members' waterways, which between them have responsibility for 5,658 km of navigable inland waterways in England, Wales and Scotland.

Waterways Ireland provided the number of vessels by sub-category registered on the Erne System in Northern Ireland (Waterways Ireland, 2011). These data were added to the relevant sub-category.

The 'Watersports and Leisure Participation Survey 2009' (BMF, 2009) is developed on an annual basis from household survey results. Some of the vessel ownership numbers quoted were considered to be very high compared with other data sources, most likely because the data acquired accounts for activity on the inland waterways *and* coastal areas. For example,

- the number of private watercraft (PWC) cited by BMF (2009) is 39,980, whereas RYA (2008) estimates that there are approximately 12,000 machines used in the UK – this gives a ratio of 0.30 relative to the BMF figure;
- BMF (2009) cites 50,615 Power Boats, 89,009 Motor Boats (Day or Other) and 13,128 Canal Boats (total = 152,752 vessels) compared with 72,331 vessels quoted in the AINA report for 2007 (AINA, 2008) – this gives a ratio of 0.47 relative to the BMF figure.

The BMF household survey was nevertheless useful because of the detailed breakdown it gives between vessel types. These data were used to break down total vessel numbers from other sources between vessel types. The number of canal boats on the inland waterways was taken directly from BMF (2009) as the majority of canal boat activity is undertaken on inland waterways and not coastal waters.

The average of the two ratios stated above, relative to the BMF figure, (0.39) was used to scale the number of yachts or sailing boats quoted by the household survey (53,205) to give 20,582 vessels.

More details regarding the methodology used to derive the number of vessels within each category are presented in Appendix 1. Table 4.3 gives the final vessel numbers used in the current study. In all cases, where data were available for several years, the most recent years' data were used.

Whilst Table 4.3 covers all vessels that could broadly be considered as falling within the inland waterways category, it was felt that movements of some of the vessels that go out to sea may already be captured in the recently updated shipping inventory (Entec, 2010) so including them in the inventory for inland waterways could lead to a double-count of their emissions. The vessels in this category are:

- Tugboats with 2 engines;
- Tugboats with 3 engines;
- Dive/Fishing/Charter vessels with 1 engine, that go to sea;
- Dive/Fishing/Charter vessels with 2 engines, that go to sea;
- Commercial fishing vessels.

There is considerable uncertainty in this potential overlap so it was decided to exclude these vessels initially from the core inventory calculations for inland waterways described in Section 6, but to include them in a sensitivity test to indicate the contribution they make towards UK emissions. This would indicate the importance of clarifying whether these vessels are already included in the shipping inventory.

The vessel population data were used in conjunction with usage data described in Section 4.3. However, for commercial freight moving vessels, it was apparent that two alternative sources of information found during the study could, in principle, be used to estimate emissions and were therefore worth comparing. The two types of information are:

1. the number of commercial freight vessels and tugs, from the Commercial Boat Operators Association (CBOA) (DfT, 2011c), shown in Table 4.3 could be used in the same manner as other vessel types in conjunction with estimates of hours of use, engine size and emission factors. A serious limitation of the data from CBOA is that it does not include vessels which operate on the Thames and Medway, nor in Scotland.

2. tonne-km data from the DfT's report on Inland goods carrying vessels (DfT, 2010) for non-seagoing, inland waters traffic only. This reflects both the population and usage of vessels combined and provides the potential for estimating emissions when used in conjunction with published emission factors expressed as kgCO_2/tonne.km.

Both the population and tonne.km figures for freight moving vessels on inland waterways are shown in Table 4.3 and the method used to derive emission estimates from both sources are described in Sections 5.2 and 6.

4.3 Vessel Usage

Almost no, or only very limited data regarding the usage of vessels operating on the inland waterways were found to be available. The default usage (number of weeks and days per annum) that each type of craft operates on the UK's inland waterways was set to equal those presented in the 2009 Inland Waterways Advisory Council publication, 'Climate Change Mitigation and adaptation: Implications for inland waterways in England and Wales', (IWAC, 2009). These data are presented in Table 4.2.

Expert judgement was used to amend the weekly and daily usage patterns where they were considered to under- or over-estimate vessel activity. An assumed hourly usage rate was then assigned to each type of craft in Table 4.2. The activity data used for each detailed vessel type are presented with the vessel numbers in Table 4.3.

The activity of each vessel type in hours per annum was used to calculate the energy consumed by the vessels per year (GWh/year). This is described in Chapter 5. No distinction was made with regards to the type of movement e.g. cruise, manoeuvring, hotelling.

Table 4.2 Activity data for vessels operating on the UK's inland waterways

Type of craft	Weekly usage (weeks/annum) [a]	Daily usage (days/week) [a]	Assumed hourly usage (hours/day) [b]
Powered	5	7	4
Trip / restaurant	42	6	3
Hire boat	25	6	2
Powered day boat	21	7	4
Work boats	50	5	7

Notes: [a] Default data, from IWAC, 2009. Where these were considered to over- or under-estimate activity, alterations were made (see Table 4.3); [b] Estimated for the purposes of this study.

4.4 Fuel Type

The fuel used by the majority of each type of vessel was also assigned on the basis of the following generalisations, as discussed in Section 3:

Coastal working boats	Gas oil
Other working and commercial boats	Gas oil
Private boats with inboard engines	Diesel
Vessels with outboard engines	Petrol (predominantly 4-stroke)
Personal water craft (PWC)	Petrol (predominantly 4-stroke, but 2-stroke for high performance stand-up craft.

In addition, some specific assumptions made included:

- RIBS, inflatables, sports boats and PWC use petrol;
- 10% of power boats operating on coastal waters were considered to be petrol vessels, and 90% diesel;
- On the inland waterways, 50% of power boats were assumed to use diesel, with the remaining 50% using petrol.

These assumptions lead to approximately 25% of all private and recreational boats operating on the UK's inland waterways running on petrol. This is consistent with assumptions used by the DfT (2011a).

The fuel type assumed for each vessel type is presented in Table 4.3.

Table 4.3 Summary of vessel numbers compiled for the inventory study

Type of vessel	Fuel type [a]	Number of vessels	Usage			
			Weeks/ year	Days/ week	Hours/ day	Product: Hours/ year
01. Sailing boats with auxiliary engines						
Sailing boats with auxiliary engines	D	20611	12	3	1	36
02. Motorboats / Workboats						
Motorboats - inland waterways	-	-	-	-	-	-
Inland waterways - Power boat (petrol, 50%)	P	10326	10	3.5	4	140
Inland waterways - Power boat (diesel, 50%)	D	10326	10	3.5	4	140
Inland waterways - Day motorboat	D	19496	10	3.5	4	140
Inland waterways - Other motorboat	D	12872	10	3.5	4	140
Inland waterways - Canal boat	GO	13166	10	3.5	4	140
Inland waterways - RIBS/Inflatables or sports boats	P	10223	10	3.5	4	140
Inland waterways - Trip/Restaurant boats, 1-engine, Category A&B waters	GO	656	26	6	3	468
Inland waterways - Trip/Restaurant boats, 2-engine, Category A&B waters	GO	285	26	6	3	468
Inland waterways - Hire boats	GO	1937	25	6	2	300
Inland waterways - Powered day hire boats	GO	1052	21	7	4	588
Inland waterways - Passenger vessels (>12 passengers) 3+engine, Category A&B waters	GO	41	50	6	4	1200
Motorboats - coastal	-	-	-	-	-	-
Coastal - Power boat (petrol, 10%)	P	2625	10	3.5	4	140
Coastal - Power boat (diesel, 90%)	D	23629	10	3.5	4	140
Coastal - Day motorboat	D	24784	10	3.5	4	140
Coastal - Other motorboat	D	16364	10	3.5	4	140
Coastal - RIBS/Inflatables or sports boats	P	12996	10	3.5	4	140
Coastal - Hire boats	GO	2462	25	6	2	300
Coastal - Powered day hire boats	GO	1337	21	7	4	588

Type of vessel	Fuel type [a]	Number of vessels	Usage			
			Weeks/ year	Days/ week	Hours/ day	Product: Hours/ year
Coastal - Trip/Restaurant boats, 1-engine, Category C&D waters	GO	342	26	6	3	468
Coastal - Trip/Restaurant boats, 2-engine, Category C&D waters	GO	514	26	6	3	468
Coastal - Passenger vessels (>12 passengers) 3+engine, Category C&D waters	GO	102	50	6	4	1200
Workboats	-	-	-	-	-	-
Tug, 1-engine	GO	151	50	5	3.5	875
Tug, 2-engine [b]	GO	412	50	5	3.5	875
Tug, 3-engine [b]	GO	40	50	5	3.5	875
Dive, Fishing, Charter, 1-engine, Category A&B waters	GO	22	21	7	4	588
Dive, Fishing, Charter, 2-engine, Category A&B waters	GO	24	21	7	4	588
Dive, Fishing, Charter, 1-engine, Category C&D waters	GO	60	21	7	4	588
Dive, Fishing, Charter, 2-engine, Category C&D waters	GO	120	21	7	4	588
Dive, Fishing, Charter 1-engine, To sea [b]	GO	530	21	7	4	588
Dive, Fishing, Charter 2-engine, To sea [b]	GO	1060	21	7	4	588
Fishing vessels – commercial [b]	GO	4823	50	5	3.5	875
Crane >12m	GO	40	50	5	3.5	875
03. Personal watercraft i.e. jet ski						
Stand-up machines: 2 stroke	P	1027	9	2	3	54
2 and 3-seater machines: 4-stroke	P	11816	9	2	3	54
04. Inland goods carrying vessels						
Non-seagoing inland goods carrying vessels [c]	GO	0.13 billion tonne-km				
Commercial freight vessels and tugs, 1-engine [c]	GO	140	50	5	3.5	875
Commercial freight vessels and tugs, 2-engine [c]	GO	60	50	5	3.5	875
Commercial freight vessels and tugs, 3-engine [c]	GO	10	50	5	3.5	875

Notes: [a.] Fuel type: P=Petrol, D=Diesel, GO=Gas Oil; [b] Vessels included for sensitivity tests only; [c] Two alternative activity data sources are considered for inclusion in category 04. Inland goods carrying vessels

5 Fuel Consumption and Emission Factors

5.1 Fuel consumption

The methodology used to generate this inventory is to use Equation 1, described in the EMEP/EEA Emissions inventory guidebook (EMEP, 2009a), to calculate the emissions from each vessel type, namely:

$$E = \sum_i N \times HRS \times HP \times LF \times EFi \quad (1)$$

Where:

E = mass of emissions of pollutant i during inventory period;

N = source population (units);

HRS = annual hours of use;

HP = average rated horsepower;

LF = typical load factor;

EFi = average emissions of pollutant i or fuel consumed per unit of use (e.g. g/kWh).

Emissions are actually calculated from the amount of fuel consumed derived from Equation (1) combined with g/kg fuel emission factors.

Numbers of the different types of vessels and estimates of their hours of use per year were derived in the previous chapter and shown in Table 4.3. This section considers the following parameters for the different vessel types required for the calculations:

- the average weighted horsepower (kW) of the engines;
- typical load factors;
- the specific fuel consumption figures (g of fuel per kWh energy produced).

From these, the fuel used annually by each type of vessel is estimated. Section 5.2 contains information on the emission factors in units of mass of pollutant per mass of fuel used.

5.1.1 Weighted average engine power

Average rated engine power (HP) for different classes of vessels were derived from:

- Information within the EMEP/EEA Emissions inventory guidebook (EMEP, 2009a,b);
- Details from sale advertisements for used vessels;
- Specifications for new vessels;
- Expert judgement.

Rated powers range from vessels such as sailing boats, canal boats and day motor boats with small engines estimated at 22.5 kW (30 h.p.) through passenger vessels to large, three-engined tugs. For tugs, the EMEP/EEA guidebook (EMEP, 2009b) gives the average power in the 2010 fleet as 2,000 kW (2,700 h.p.). In this study our research has indicated appropriate values are:

- 1 engined tugs (151 vessels) average rated power 940 kW (1,250 h.p.);
- 2 engined tugs (412 vessels) average rated power 1,875 kW (2,500 h.p.);
- 3 engined tugs (40 vessels) average rated power 3,300 kW (4,400 h.p.).

Another type of vessel that was subsequently found to contribute more than 10% of all power generated by inland waterway vessels is passenger vessels capable of carrying >12 passengers on tidal rivers and estuaries (category C & D waters). These range for example, from lower powered conventional "steamers", similar to those operating on the UK's larger, non-tidal rivers and lakes, to the high powered Thames clippers. Vessels' rated powers range from around 130 kW (170 h.p.) for the former to 1,440 kW (1,920 h.p.) for the latter. A vessel usage weighted average of 500 kW has been estimated.

5.1.2 Typical load factors

The algorithm used to estimate the power produced by vessels annually considers the number of hours use per year, the rated power, and also the average fraction of the rated power (the load factor, LF) used. This will vary for different groups of vessels and will be dependent upon:

- the type of vessel and its "genre", e.g. sports use for personal water craft, or cruising for canal boats;
- the pattern of usage, e.g. high intensity when used, e.g. for personal water craft and sports power boats, to a role which involves cruising and then waiting, e.g. for a passenger vessel, or manoeuvring/towing for tugs.

Expert judgement has been used to derive the load factors. These vary from 40% for some hire boats and trip boats to 75% for personal water craft (jet skis), with the majority around 50%.

The data above, plus the vessel numbers, and hours of use for each type of vessel enable the total amount of power (e.g. in GWh) per year to be estimated for each type of vessel.

Table 5.1 summarises the rated power and load factor for each vessel type appearing in Table 4.3.

Table 5.1 Summary of vessel fuel type, rated power and load factor used in the current inventory study

Type of vessel	Fuel type [a]	Rated power (kW)	Load factor (%)
01. Sailing boats with auxiliary engines			
Sailing boats with auxiliary engines	D	22.5	40%
02. Motorboats / Workboats			
Motorboats - inland waterways	-	-	-
Inland waterways - Power boat (petrol, 50%)	P	75	50%
Inland waterways - Power boat (diesel, 50%)	D	75	50%
Inland waterways - Day motorboat	D	22.5	40%
Inland waterways - Other motorboat	D	37.5	50%
Inland waterways - Canal boat	GO	26.3	40%
Inland waterways - RIBS/Inflatables or sports boats	P	22.5	75%
Inland waterways - Trip/Restaurant boats, 1-engine, Category A&B waters	GO	112	40%
Inland waterways - Trip/Restaurant boats, 2-engine, Category A&B waters	GO	225	40%
Inland waterways - Hire boats	GO	37.5	40%
Inland waterways - Powered day hire boats	GO	22.5	40%
Inland waterways - Passenger vessels (>12 passengers) 3+engine, Category A&B waters	GO	500	50%
Motorboats - coastal	-	-	-
Coastal - Power boat (petrol, 10%)	P	75	50%
Coastal - Power boat (diesel, 90%)	D	75	50%
Coastal - Day motorboat	D	22.5	40%
Coastal - Other motorboat	D	37.5	50%
Coastal - RIBS/Inflatables or sports boats	P	22.5	75%
Coastal - Hire boats	GO	37.5	40%
Coastal - Powered day hire boats	GO	22.5	40%
Coastal - Trip/Restaurant boats, 1-engine, Category C&D waters	GO	112	40%

Type of vessel	Fuel type [a]	Rated power (kW)	Load factor (%)
Coastal - Trip/Restaurant boats, 2-engine, Category C&D waters	GO	225	40%
Coastal - Passenger vessels (>12 passengers) 3+engine, Category C&D waters	GO	500	60%
Workboats	-	-	-
Tug, 1-engine	GO	937	50%
Tug, 2-engine [b]	GO	1875	50%
Tug, 3-engine [b]	GO	3300	50%
Dive, Fishing, Charter, 1-engine, Category A&B waters	GO	56	50%
Dive, Fishing, Charter, 2-engine, Category A&B waters	GO	112	50%
Dive, Fishing, Charter, 1-engine, Category C&D waters	GO	56	50%
Dive, Fishing, Charter, 2-engine, Category C&D waters	GO	112	50%
Dive, Fishing, Charter 1-engine, To sea [b]	GO	56	50%
Dive, Fishing, Charter 2-engine, To sea [b]	GO	112	50%
Fishing vessels – commercial [b]	GO	112	50%
Crane >12m	GO	75	40%
03. Personal watercraft i.e. jet ski			
Stand-up machines: 2 stroke	P	101	75%
2 and 3-seater machines: 4-stroke	P	161	75%
04. Inland goods carrying vessels			
Non-seagoing inland goods carrying vessels [c]	GO	n/a[c]	
Commercial freight vessels and tugs, 1-engine [c]	GO	150.0	50%
Commercial freight vessels and tugs, 2-engine [c]	GO	225.0	50%
Commercial freight vessels and tugs, 3-engine [c]	GO	300.0	50%

Notes: [a.] Fuel type: P=Petrol, D=Diesel, GO=Gas Oil; [b] Vessels included for sensitivity tests only; [c] Two alternative data sources are considered for inclusion in category 04. Inland goods carrying vessels

5.1.3 The specific fuel consumption for vessels

The amount of fuel required to provide the total amount of power for each vessel type is derived from the specific fuel consumption factor (SFC). The values of SFC expressed as grammes of fuel per kWh are provided in Table 5.2 for the three types of fuels used by inland waterway vessels.

Table 5.2 Specific Fuel Consumption (SFC) for the fuels used by vessels on the inland waterways

Fuel	SFC (g/kWh)	Evidence
Gas oil	215	Gas oil is used in larger, coastal craft, and Table 3-10 of the EMEP/EEA guidebook (EMEP, 2009b) gives SFC of 203 g/kWh for cruising and 223 g/kWh for manoeuvrings
Diesel	275	This is the figure given in Table 3-11 of the EMEP/EEA guidebook (EMEP, 2009b) for diesel recreational craft, e.g. motor boats
Petrol (4-stroke)	425	This is the figure given in Table 3-11 the EMEP/EEA guidebook (EMEP, 2009b) for all petrol recreational craft listed

From the amount of power (in GWh) per year estimated for each type of vessel, multiplication by the specific fuel consumption figures above give the total annual fuel used for each type of vessel according to:

$$\begin{aligned} &Fuel\ consumed\ (tonnes/year) \\ &\qquad = Annual\ power\ requirement\ (GWh) \times SFC\ (tonnes/GWh, or\ g/kWh) \end{aligned}$$

5.2 Emission Factors

Emissions are derived from the amount of fuel consumed (Equation 1) and fuel-based emission factors in g/kg fuel appropriate for the type of fuel and engine type.

The emission factors are given in Table 5.3.

Table 5.3 Greenhouse gas emission factors by fuel type (g/kg fuel)

Fuel	CO_2	CH_4	N_2O
Petrol (2-stroke)	3135	5.0	0.02
Petrol (4-stroke)	3135	1.7	0.08
Diesel (DERV)	3164	0.05	0.08
Gas Oil	3190	0.05	0.08

The factors for CO_2 are the default factors used in the GHGI for each type of fuel on the basis of fuel carbon content (MacCarthy et al, 2010).

The factors for CH_4 and N_2O for diesel and gas oil are the factors used in the GHG inventory for shipping vessels using gas oil (MacCarthy et al, 2010). These are consistent with the shipping factors given in the EMEP Emissions Inventory Guidebook (EMEP, 2007). Note that the same guidebook provides different factors for these pollutants emitted from inland waterways, but these look unrealistically high and so preference has been given to the factors for shipping. The factors for 2-stroke and 4-stroke petrol engines are taken from the EMEP Emissions Inventory Guidebook for inland waterways (EMEP, 2007).

Section 4.2.2 highlighted that an alternative way of calculating emissions of CO_2 from the movement of freight is to use the Defra/DECC GHG Conversion Factors for Company Reporting (Defra, 2010). In Annex 7 on “freight transport” there are data in Table 7g for converting tonne-km data to CO_2 emissions for movement of freight by shipping vessels. For the smallest vessels, figures vary from 0.045 kg CO_2 direct emissions per tonne-km for a products tanker, to 0.0198 kg CO_2 emissions per tonne-km for a general cargo vessel. A mid-range figure, 0.028 kg CO_2 emissions per tonne-km used in this study, can be multiplied by the tonne-km figure, such as that given in DfT Transport Statistics (DfT, 2010), and shown in Table 4.3, to obtain a CO_2 emissions figure for freight movements on inland waterways.

However, the emission factor used is likely to be at the low end of the “real” emission factor spectrum for water-borne freight because there are significant economies of scale, with the emissions (per tonne-km) being smaller for transport by larger vessels. Those used on inland waterways tend to be small relative to the vessels which go to sea. The former may be around 500 – 1000 tonnes deadweight, whereas the lightest range in the Defra/DECC GHG Conversion Factor tables are typically for vessels of 0 – 4,999 dwt.

The gas oil CO_2 emission factor given in Table 5.3 is used to convert emissions calculated in this manner into the mass of fuel used and from this, CH_4 and N_2O emissions can be calculated.

Chapter 6 discusses the findings using the methodologies described above.

6 Estimates of Fuel Consumption and Emissions from Inland Waterways

The table in Annex 2 shows the total amount of fuel consumed and emissions of CO_2, CH_4, N_2O and total CO_2 equivalent emissions from each vessel category.

There are two estimates made of the emissions from category 04 'Inland goods carrying vessels'. One is based on the population and estimated usage of these vessels combined with g/kWh fuel consumption and emission factors (Method A). The second uses DfT's tonne-km figures for inland goods carrying vessels combined with an average factor for CO_2 emissions in $kgCO_2$/tonne.km (Method B). Method A leads to 3.53 ktonnes fuel consumption by inland goods carrying vessels while Method B leads to 1.17 ktonnes fuel consumed. Method A would be expected to give less fuel consumption than Method B because the population data used in Method A does not include vessels which operate on the Thames and Medway, nor in Scotland. However, the reverse seems to be the case. The reason for this discrepancy is unclear but probably reflects considerable uncertainty in the key assumptions made in both methods.

For Method A it is possible that the fuel consumption estimates are high because the usage figures assumed are too high. It is assumed that these vessels operate for 3.5 hours per day, 5 days per week and 50 weeks per year. Method B on the other hand, may be using a $kgCO_2$/tonne.km factor which is too small. Since the factor used is based on the average of factors for small sea going vessels the possibility remains that the smaller vessels operating on inland waterways operate less efficiently due to either the design of the vessels and their usage patterns or due to their loading being less well optimised. The factors in the GHG Conversion Factors for Company Reporting for ships do cover a wide range from 0.0025 $kgCO_2$/tonne.km for large bulk carriers to 0.057 $kgCO_2$/tonne.km for small vehicle transporters.

This is an area that needs further investigation and in the absence of further information, the mean of the two calculations of fuel consumption and emissions for inland goods carrying vessels was used in our analysis, i.e. a value of 2.35 ktonnes fuel. This is around 5% of all the gas oil estimated to be used by inland waterways.

As stated earlier, there is some uncertainty in the potential overlap between the larger inland waterway vessels counted for in this study and the small vessels included in the shipping inventory. A **core inventory** was therefore calculated that excluded these vessels and an **alternative inventory** was also developed which included these vessels. This would show the sensitivity of the inland waterways inventory to decisions made about vessel coverage at the boundary of the inland waterways-shipping vessel categories.

6.1 Fuel Consumption by Inland Waterways

Table 6.1 summarises the total amount of petrol, diesel and gas oil consumed by inland waterways for the core inventory scenario and for the alternative scenario which includes the sea-going tugs and fishing etc vessels that may be included in the shipping inventory. The results are also shown as a fraction of total UK consumption of these fuels.

It can be seen that roughly equal amounts of petrol and diesel are consumed by inland waterways. Moreover, these are about 0.5% of total petrol and diesel consumed in the UK in 2008. This indicates the amount of fuel that would have to re-allocated from the road transport to inland waterways sectors, reducing CO_2 emissions from UK road transport by the

Table 6.1 Estimated fuel consumption by inland waterways in the UK

	Core		Alternative inc sea vessels	
	ktonnes	% All UK consumption in 2008	ktonnes	% All UK consumption in 2008
Petrol	86.8	0.52%	86.8	0.52%
Diesel	87.3	0.42%	87.3	0.42%
Gas oil	50.6	0.78%	196.2	3.01%

same amount, i.e. 0.5%.

Around 51 ktonnes gas oil are estimated to be consumed by commercial inland waterway vessels with diesel engines in the core scenario, excluding the sea-going tugs and fishing vessels. This represents about 0.8% of total UK gas oil consumption. However, this figure is almost quadrupled if the larger sea-going tugs and fishing vessels are included. Moreover, the total amount of gas oil consumption for the alternative scenario represents around 50% of all the gas oil used by domestic shipping. This emphasises the need to determine the coverage of the shipping inventory and whether the additional gas oil consumption of 146 ktonnes is a sub-set of the figure in the shipping inventory.

The estimate of gas oil consumption is the amount that would have to be re-allocated from other emission sources in the inventory that use this fuel.

6.2 Emissions of Greenhouse Gases from Inland Waterways

Table 6.2 is a summary of fuel consumption and emissions of CO_2, CH_4 and N_2O for each of the four main EMEP categories for inland waterways. The figures in this table refer to the core inventory when the larger sea-going tugs and fishing vessels are excluded. The CO_2 equivalent emissions of all the GHGs are also shown.

The motorboats/workboats dominate emissions, being responsible for 83% of all inland waterway GHG emissions. Inland goods carrying vessels are responsible for only 1% of all inland waterways GHG emissions. The majority of the emissions are from private leisure and passenger craft in coastal waters (41%); the contribution of these craft on waterways further inland is around 35%.

Table 6.2 also shows the contribution that these emissions make to total UK emissions of GHGs from all sources, based on the emissions reported for 2008 in the 2009 version of the GHGI. Overall, consumption of fuels by inland waterways contributes to around 0.1% of total UK GHG emissions.

Table 6.3 shows the corresponding figures for the alternative scenario when the larger sea-going tugs and fishing vessels are included. If these vessels are not already included in the shipping inventory and so would need to be included in the inventory for inland waterways, then the domination of motorboats/workboats increases. Moreover, the workboats category (in which these vessels are included) becomes the dominant source of GHG emissions (43%) overall, with emissions from private leisure and passenger craft in coastal waters contributing to 25% and the contribution of these craft on waterways further inland around 21%. In this scenario, consumption of fuels by inland waterways including these larger sea-going vessels would contribute to around 0.2% of total UK GHG emissions in 2008.

Table 6.2 Summary of fuel usage and GHG emissions for each vessel category calculated in the core inventory where larger sea-going tugs and fishing vessels are excluded

Vessel category	Total Fuel usage /yr (ktonnes)	CO_2	CH_4	N_2O	CO_2e [a]	CO_2e [a]
		ktonnes	tonnes	tonnes	ktonnes	%
01. Sailing boats with auxiliary engines	1.8	5.8	0.09	0.15	5.9	1%
02. Motorboats / Workboats	186.0	588.2	95.45	14.88	594.8	
SUBTOTAL : ***Motorboats - inland waterways***	79.7	251.6	58.94	6.37	254.8	35%
SUBTOTAL: ***Motorboats - coastal***	91.4	289.2	35.77	7.32	292.3	41%
SUBTOTAL: ***Workboats*** [b]	14.9	47.4	0.74	1.19	47.8	7%
03. Personal watercraft i.e. jet ski	34.6	108.4	64.70	2.66	110.6	15%
04. Inland goods carrying vessels [c]	2.3	7.5	0.12	0.19	7.6	1%
TOTAL	**224.8**	**709.9**	**160.36**	**17.87**	**718.82**	100%
% of total UK emissions in 2008		**0.14%**	**0.01%**	**0.02%**	**0.12%**	

Notes: [a] Carbon dioxide equivalent emissions (CO_2e), calculated using GWP factors (GWP for CO_2 = 1; for CH_4 = 21; for N_2O = 310), consistent with reporting under the Kyoto Protocol (IPPC, 1996); [b] Vessel types sea-going tugs and fishing vessels EXCLUDED; [c] Shows averaged results from the two methodologies based on tonne-km factors for CO_2 and vessel population and usage data

Table 6.3 Summary of fuel usage and GHG emissions for each vessel category calculated in the alternative inventory scenario where larger sea-going tugs and fishing vessels are included

Vessel category	Total Fuel usage /yr (ktonnes)	CO_2	CH_4	N_2O	CO_2e [a]	CO_2e [a]
		ktonnes	tonnes	tonnes	ktonnes	%
01. Sailing boats with auxiliary engines	1.8	5.8	0.09	0.15	5.9	0%
02. Motorboats / Workboats	331.5	1,052.5	102.73	26.52	1,062.8	
SUBTOTAL : ***Motorboats - inland waterways***	79.7	251.6	58.94	6.37	254.8	21%
SUBTOTAL: ***Motorboats - coastal***	91.4	289.2	35.77	7.32	292.3	25%
SUBTOTAL: ***Workboats*** [b]	160.4	511.7	8.02	12.83	515.8	43%
03. Personal watercraft i.e. jet ski	34.6	108.4	64.70	2.66	110.6	9%
04. Inland goods carrying vessels [c]	2.3	7.5	0.12	0.19	7.6	1%
TOTAL	**370.3**	**1,174.2**	**167.64**	**29.52**	**1,186.86**	100%
% of total UK emissions in 2008		**0.22%**	**0.01%**	**0.03%**	**0.19%**	

Notes: [a] Carbon dioxide equivalent emissions (CO_2e), calculated using GWP factors (GWP for CO_2 = 1; for CH_4 = 21; for N_2O = 310), consistent with reporting under the Kyoto Protocol (IPPC, 1996); [b] Vessel types sea-going tugs and fishing vessels INCLUDED; [c] Shows averaged results from the two methodologies based on tonne-km factors for CO_2 and vessel population and usage data

7 Inventory Time-Series

The figures quoted so far refer to a recent year when the surveys or other information on vessel population were gathered by different organisations. The data were mainly reported in years between 2007 and 2009. The figures are therefore assigned to the year 2008.

In addition to an inventory covering this year, a time series backcasting the inventory for previous years will be required if the data is to be included in future updates of the GHGI. Whilst undertaking this is outside the scope of the current study, it is appropriate that some consideration is given to possible approaches that could be used to backcast emissions.

Where possible, an inventory time-series should be developed from annually collected activity data sets. This is not possible for all vessel types included in inland waterways because neither fuel usage nor other activity data sets such as vessel population are collected on an annual basis. This problem exists for other sources included in the inventory, for example off-road machinery which cover a very diverse range of activities. For that source, surrogate statistical data are used as proxies to indicate likely changes in levels of activity (the product of machinery population and usage rates) that reflect changes in fuel consumption. This approach seems appropriate for inland waterways and this section considers potential data that could be used as suitable proxies for backcasting fuel consumption to 1990 and forward casting in future inventory years.

It was noted in the introduction that emissions from inland waterways are complex because it comprises a diffuse source. It involves a wide variety of vessels operating for a multitude of purposes (both commercial and recreational) with no centrally-held statistics on either the total amounts of fuel supplied or consumed by the sector or on the vessel population and usage patterns. Therefore it is unlikely that a single data indicator will be appropriate to represent all inland waterways activity; rather a combination of factors is likely to be required.

The recommended approach is to assign each vessel type to one of the following categories which are likely to have distinct activity drivers and to find appropriate proxy data as drivers for each:

- Private leisure craft;
- Commercial passenger/tourist craft;
- Service craft – tugs etc.;
- Freight.

Characteristics required for potential proxy data include:

- It should be a relevant proxy;
- It should provide an appropriate time series, e.g. from 1990 if possible, i.e. data should be collected using the same, or similar, methodology over a number of years;
- It should use accepted statistical methods and be appropriately quality assured.

Some potential sources of information for the four categories above are given in Table 7.1. The next steps would be to critically evaluate the suitability of these potential sources.

Table 7.1 Potential sources of proxy data which could be used to generate a time-series in activities by inland waterways for use in the UK inventory

Type of inland waterways vessels	Potential proxy data for generating a time series
Private leisure craft	1. ONS data Product Sales Report, PRA 35120 "Product sales and trade: Pleasure and sporting boats". Data from 1998 2. Relevant statistics on leisure activities or tourism
Commercial passenger/tourist craft	No DfT inland waterways passenger data found. 1. Visit England: "Visitor attractions trend in England" reports. Data from 1989 2. Relevant tourist statistics
Service craft – tugs etc	1. Maritime statistics on overall numbers of visits of vessels to ports
Freight	1. DfT Transport Statistic GB: Inland and coastal waters data tables - Domestic waterborne freight transport. Data from 1990

8 Summary and Conclusions

This study has considered the possibility of estimating an inventory of greenhouse gas emissions from vessels used on inland waterways in the UK. This source has not previously been reported in the UK's Greenhouse Gas Inventory because there have not been any centralised statistics on amounts of fuel consumed by this sector. The overall fuel balance that underpins the inventory ensures that emissions *have* been covered, but they have not been reported explicitly as a source and have been misallocated to other sources using the same types of fuels.

Inland waterways is a complex and diverse sector involving a wide variety of vessels operating for a multitude of purposes, both commercially and for recreational use. A review of the sector confirmed that there are no centrally held data on fuel consumption nor on numbers of vessels so that developing an inventory would require a Tier 3 approach based around a survey on the population and usage of each type of vessel. A survey of this sort on a national scale has never before been undertaken.

Vessels used on inland waterways run their engines on petrol, road diesel and gas oil. All service craft and large vessels used for commercial purposes with diesel engines will use gas oil, but the situation is less clear for privately owned vessels used for recreational purposes. These craft are prohibited from using diesel for propulsion purposes at the low duty rate (red diesel) and are unlikely to be using gas oil even if the excess duty is paid. It is assumed that all diesel fuel used by privately owned vessels is road diesel (DERV). This has implications on the re-allocation from other sectors using these fuels to the inland waterways sector and the assumptions require confirmation by talking with marine engine and fuel industry experts. Confirmation on how these fuels defined here by their physical properties relate to the definitions of road diesel and gas oil in DUKES is also required.

A detailed survey was carried out with various organisations and agencies connected with the inland waterways sector and from the information provided it was possible to compile a relatively large and complete set of data on the UK population of different types of vessels. The vessels ranged from small personal watercraft such as jet skis to motor boats, canal boats, small passenger ferries to larger tugs, work boats and inland goods carrying vessels.

Interpretation of the data collected required a thorough understanding of the definition of inland waterways. A challenge was to understand the overlap in data received from different sources so as to avoid any double-counting and also the potential for any overlap with vessels already captured in the shipping inventory, particularly for large vessels such as tugs and fishing vessels that spend a lot of time in tidal rivers and estuaries, but occasionally go out to sea.

The study found virtually no data on hours of use of vessels. These had to be estimated by considering the different modes of use of recreational craft, freight vessels and commercial craft and work boats. We consider this as a major source of uncertainty in the emission estimates. Data are available on tonne-kilometres of freight moved on inland waterways providing an alternative approach to estimating emissions from this category of vessels.

Combining estimates of population and usage of each type of vessel led to estimates on the total amount of fuel consumed by the inland waterways sector. Roughly equal amounts of petrol and diesel are consumed by inland waterways, amounting to around 0.5% of total petrol and diesel consumption in the UK in 2008. This indicates the amount of fuel that would have to re-allocated from the road transport to inland waterways sectors, reducing CO_2 emissions from UK road transport by the same amount, i.e. 0.5%.

A core inventory estimate of 51 ktonnes was made on the consumption of gas oil consumed by excluding the activities by large sea-going tugs and fishing vessels as there was concern that at least some of these activities could be included in the shipping inventory. This represents about 0.8% of total UK gas oil consumption. As a sensitivity test, an alternative estimate of 196 ktonnes was made when these vessels were included. This represents a large proportion of the total gas oil consumption by the domestic shipping sector and emphasises the need to determine the coverage of the shipping inventory and whether the additional gas oil consumption of 145 ktonnes is a sub-set of the figure in the shipping inventory.

Using default emission factors with the fuel consumption data it was possible to estimate emissions of CO_2, CH_4 and N_2O from inland waterways. Excluding the sea-going tugs and fishing vessels leads to an estimate of total greenhouse gas emissions from inland waterways of 0.72 Mtonnes CO_2 equivalent, which is 0.12% of total UK GHG emissions. The majority of the emissions are from private leisure and passenger craft. When these sea-going vessels are included, the estimate is increased to 1.19 Mtonnes CO_2 equivalent, which is 0.19% of total UK GHG emissions.

A method has been proposed for backcasting emissions to 1990 based on a variety of proxy statistics appropriate for different types of inland waterway activities that are available over a consistent time-series. The same method could be used to forward cast emissions from the current to future inventory years.

The uncertainties in these emission and fuel consumption estimates have not been quantified but are expected to be very high mainly because of the uncertainties in the hours of use figures. Overall, we believe the usage figures assumed are upper estimates. This means that the emission and fuel consumption estimates in this report are likely to be, if anything, overestimated, but the uncertainty range is expected to be large. A more rigorous appraisal of the uncertainties in the parameters used in the emission calculations would need to be undertaken for a full uncertainty analysis of the inventory alongside a sensitivity analysis to highlight the key assumptions made whose detail markedly influences the total result obtained. This may benefit from having the assumptions checked by stakeholders to help reduce the levels of uncertainty.

Recommendations

Stakeholder consultation on population and hours of use

The estimates and assumptions on population and hours of use made in this study should be reviewed by external stakeholders to help reduce the levels of uncertainty. This consultation may also be used to identify additional sources of data, such as activity or surrogate data which may be used to backcast the time series to 1990.

Stakeholder consultation on use of fuels

The patterns of use of gas oil and road diesel (DERV) for recreational craft with diesel engines and the assumptions made in this study need confirmation from marine engine and fuel industry experts. Further confirmation is also required on how these physically distinct fuels relate to the definitions of gas oil and road diesel in DUKES. This clarification should be extended to the wider use of diesel (whether road diesel or gas oil) used by off-road machinery engines (e.g. agricultural machinery).

Time series

Following external review, we propose using the methods described in this report to provide a complete inventory time series in UK emissions from inland waterways back to 1990. Further work will be required to provide a robust time series for emissions from inland waterways in the next inventory submission.

Subsequently, the amount of petrol and diesel fuel estimated to be used by the inland waterways vessels should be re-allocated from the road transport to inland waterways sectors, thus reducing CO_2 emissions from UK road transport by the same amount.

Spatial disaggregation

A method for spatially disaggregating emissions and distributing emissions between each Devolved Administration country has not been considered. However, we believe that sufficient data has been collected (for example vessel registrations in different river and sea areas), that, combined with sea port and harbour activity data would enable a method to be devised for spatially distributing emissions around the river and canal networks and coastal areas of the UK.

Emissions of air pollutants

The study has not considered the inventory for air pollutant emissions. These could be quantified in the same manner using appropriate emission factors, but an additional consideration would need to be given to the impact of recent European regulations on emissions from new vessel engines and the proportion of engines in the fleet made to different emission standards.

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ONS

Salters Steamers Ltd (Liam Challis)

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Appendices

Appendix 1 – Derivation of vessel numbers

Data sources

Data were collected from the following sources:

Reference	Reference Title	Organisation
AINA, 2008	Number of boats on the Inland Waterways. Report of the 2008 AINA survey	AINA Association of Inland Navigation Authorities
BMF, 2009	Watersports and Leisure Participation Survey 2009	BMF, MCA, Lifeboats, RYA, ybw.com
DfT, 2010	Transport Statistics Bulletin, Waterborne Freight in The United Kingdom 2009. DfT, November 2010.	DfT
DfT, 2011a	Personal Communication (07/03/2011)	DfT
DfT, 2011b	Port & Harbour Authorities	Through communication with DfT (DfT, 2011)
DfT, 2011c	Commercial Boat Operators Association	Through communication with DfT (DfT, 2011)
DfT, 2011d	Professional Boatmen's Association	Through communication with DfT (DfT, 2011)
DfT, 2011e	Passenger Boat Association	Through communication with DfT (DfT, 2011)
EA, 2011	Personal Communication (28/02/2011)	Environment Agency
EMEP, 2007	EMEP/CORINAIR air pollutant emission inventory guidebook — 2007	EMEP/EEA
IWAC, 2009	IWAC Climate Change Mitigation and Adaptation Implications for Inland Waterways in England and Wales April 2009 report	IWAC
MCGA, 2011	Personal Communication (07/02/2011)	Maritime and Coastguard Agency
RYA, 2008	Managing Personal Watercraft a guide for local and harbour authorities	RYA
Waterways Ireland, 2011	Personal Communication (01/04/2011)	Waterways Ireland

Methodology

The number of vessels was principally split according to EMEP/EEA 2007 Emission Inventory Guidebook (EMEP, 2007) suggested subsectors:

01. Sailing boats with auxiliary engines
02. Motorboats / Workboats (e.g. dredgers, canal, service, tourist, river boats).
    a. recreational craft on inland waterways
    b. recreational craft on coastal waterways
    c. workboats
03. Personal watercraft i.e. jet ski
04. Inland goods carrying vessels

The following sections describe how the number of each vessel type was derived from the acquired data.

01. Sailing boats with auxiliary engines

Initially the figure of 53,205 was taken from BMF, 2009;
This figure from a leisure survey was considered to be very large, and was therefore scaled using data from 2 additional sources. This gave 20,582 vessels using the averaged ratio of the following (0.39, 2dp):

- Number of PWC (RYA, 2008/ BMF, 2009) (0.30, 2dp);
- Number of Motorboats (AINA, 2008/ BMF, 2009) (0.47, 2dp).

The number of sailing yachts registered on the Erne System in Northern Ireland was added to the GB total (Waterways Ireland, 2011).

02. Motorboats / Workboats

a. Recreational craft on inland waterways

The total number of Powered boats was taken from AINA, 2008. The number of canal boats given by BMF (2009) was used directly and subsequently removed from the total number of powered boats. This was split to give the number of the following vessel types using the split between vessels given in BMF, 2009:

- Power boat (50% petrol, 50% diesel);
- Day motor boat;
- Other motor boat;
- RIBS/Inflatables or sports boats.

The numbers of motor, power and canal boats registered on the Erne System in Northern Ireland were added to these GB totals (Waterways Ireland, 2011).

The total number of Trip/Restaurant vessels was taken to be 1,798 taken from AINA, 2008. This was further split to 1 or 2 engine and category A/B waters using data from DfT, 2011e.

The number of hire boats and powered day hire boats were taken from AINA, 2008.

The total number of passenger vessels (>12 passengers) with 3+ engines was taken as:

- The number of passenger ferries from MCGA (2011), minus the number of Trip/Restaurant boats given in AINA (2008);
- This was subsequently split according to water categories (DfT, 2011e).

b. Recreational craft on coastal waterways

The total number within this category was estimated to be twice the number of berths in the UK (DfT, 2011a) minus the number of Personal Watercraft (RYA, 2008), minus the number of Trip/Restaurant and Passenger vessels operating on category C/D waters (derived from inland waterways methodology, above):

$$= (2 \times 49{,}000) - 12{,}000 - 958 = 85042$$

- This was subsequently subdivided between the categories below, using the split defined in *a. Recreational craft on inland waterways*:

1. Power boat (10% petrol, 90% diesel);
2. Day motor boat;
3. Other motor boat;
4. RIBS/Inflatables or sports boats;
5. Hire boats;
6. Powered day hire boats.

c. Work boats

The number of tugs with 1 engine was taken from DfT, 2011b. The number of 2 and 3+ engined vessels, from DfT (2011b), was used only as a sensitivity test.

The number of Dive, Fishing & Charter vessels was taken directly from DfT, 2011d for 1 and 2 engined vessels and those operating in category A/B and C/D waters. The number of work boats registered on the Erne System in Northern Ireland was added to the GB total (Waterways Ireland, 2011).

The number of commercial fishing vessels was taken from a DfT (2011a) survey of active fishing vessels – this found that 4823 of the 6500 registered vessels were active. This was used only as a sensitivity test.

The number of cranes was taken from the MCGA 'ball-park' figures (MCGA, 2011).

03. Personal Watercraft (PWC)

The number of PWC was split between stand-up machines and 2&3 seater machines using data directly from RYA, 2008. Approximately 1,200 new machines are sold in the UK annually, and it is estimated that there are a total of 12,000 machines used in the UK, 92% of which are two and three seater machines (assumed to be 4-stroke), and 8% are stand-up vessels (assumed to be 2-stroke). The number of PWC registered on the Erne System in Northern Ireland was added to the GB total (Waterways Ireland, 2011).

04. Inland goods carrying vessels

Data regarding 'goods moved' were taken from DfT, 2010. Billion tonne-km undertaken on UK inland waters were used to derive emissions of CO_2, fuel usage and power per annum, assuming a CO_2 emission factor of 0.028 kg/per tonne-km of freight. This figure was estimated from the DECC/Defra GHG Company Reporting Guidelines (DECC, 2010).

An alternative method for inland freight used the number of commercial freight vessels and tugs with 1, 2 and 3+ engines from DfT, 2011c.

Appendix 2 – Summary of vessel fuel type, power, fuel usage and GHG emissions

Summary of vessel fuel type, fuel usage and GHG emissions calculated in the current inventory study

Type of vessel	Fuel type [a]	Fuel useage (kt/year)	CO_2	CH_4	N_2O	CO_2e [d]
			Emissions, (tonnes/year)			
01. Sailing boats with auxiliary engines						
Sailing boats with auxiliary engines	D	1.8	5810.4	0.09	0.15	5857.8
02. Motorboats / Workboats						
Motorboats - inland waterways	-	-	-	-	-	-
Inland waterways - Power boat (petrol, 50%)	P	23.0	72232.2	39.17	1.84	73626.1
Inland waterways - Power boat (diesel, 50%)	D	14.9	47170.8	0.75	1.19	47556.2
Inland waterways - Day motorboat	D	6.8	21374.1	0.34	0.54	21548.7
Inland waterways - Other motorboat	D	9.3	29399.8	0.46	0.74	29640.0
Inland waterways - Canal boat	GO	4.2	13274.0	0.21	0.33	13381.5
Inland waterways - RIBS/Inflatables or sports boats	P	10.3	32180.2	17.45	0.82	32801.2
Inland waterways - Trip/Restaurant boats, 1-engine, Category A&B waters	GO	3.0	9481.2	0.15	0.24	9558.1
Inland waterways - Trip/Restaurant boats, 2-engine, Category A&B waters	GO	2.6	8244.5	0.13	0.21	8311.4
Inland waterways - Hire boats	GO	1.9	5978.2	0.09	0.15	6026.7
Inland waterways - Powered day hire boats	GO	1.2	3818.3	0.06	0.10	3849.2
Inland waterways - Passenger vessels (>12 passengers) 3+engine, Category A&B waters	GO	2.6	8410.8	0.13	0.21	8478.9
Motorboats - coastal	-	-	-	-	-	-
Coastal - Power boat (petrol, 10%)	P	5.9	18365.0	9.96	0.47	18719.4
Coastal - Power boat (diesel, 90%)	D	34.1	107938.5	1.71	2.73	108820.4
Coastal - Day motorboat	D	8.6	27171.8	0.43	0.69	27393.8
Coastal - Other motorboat	D	11.8	37374.5	0.59	0.94	37679.9
Coastal - RIBS/Inflatables or sports boats	P	13.0	40909.1	22.18	1.04	41698.5
Coastal - Hire boats	GO	2.4	7599.8	0.12	0.19	7661.4
Coastal - Powered day hire boats	GO	1.5	4854.0	0.08	0.12	4893.3
Coastal - Trip/Restaurant boats, 1-engine, Category C&D waters	GO	1.6	4946.7	0.08	0.12	4986.8

Type of vessel	Fuel type [a]	Fuel useage (kt/year)	CO_2	CH_4	N_2O	CO_2e [d]
			Emissions, (tonnes/year)			
Coastal - Trip/Restaurant boats, 2-engine, Category C&D waters	GO	4.7	14840.2	0.23	0.37	14960.4
Coastal - Passenger vessels (>12 passengers) 3+engine, Category C&D waters	GO	7.9	25232.3	0.40	0.63	25436.8
Workboats	-	-	-	-	-	-
Tug, 1-engine	GO	13.3	42477.2	0.67	1.07	42821.4
Tug, 2-engine [b]	GO	72.7	231795.9	3.63	5.81	233674.2
Tug, 3-engine [b]	GO	12.4	39607.8	0.62	0.99	39928.8
Dive, Fishing, Charter, 1-engine, Category A&B waters	GO	0.1	249.5	0.00	0.01	251.6
Dive, Fishing, Charter, 2-engine, Category A&B waters	GO	0.2	544.4	0.01	0.01	548.8
Dive, Fishing, Charter, 1-engine, Category C&D waters	GO	0.2	680.5	0.01	0.02	686.0
Dive, Fishing, Charter, 2-engine, Category C&D waters	GO	0.9	2722.1	0.04	0.07	2744.2
Dive, Fishing, Charter 1-engine, To sea [b]	GO	1.9	6011.4	0.09	0.15	6060.1
Dive, Fishing, Charter 2-engine, To sea [b]	GO	7.5	24045.6	0.38	0.60	24240.4
Fishing vessels – commercial [b]	GO	51.0	162808.5	2.55	4.08	164127.8
Crane >12m	GO	0.2	720.1	0.01	0.02	726.0
03. Personal watercraft i.e. jet ski						
Stand-up machines: 2 stroke	P	1.8	5613.5	8.95	0.04	5812.6
2 and 3-seater machines: 4-stroke	P	32.8	102810.0	55.75	2.62	104794.1
04. Inland goods carrying vessels						
Non-seagoing inland goods carrying vessels [c]	GO	1.2	3732.7	0.06	0.09	3762.9
Commercial freight vessels and tugs, 1-engine [c]	GO	2.0	6301.2	0.10	0.16	6352.3
Commercial freight vessels and tugs, 2-engine [c]	GO	1.3	4050.8	0.06	0.10	4083.6
Commercial freight vessels and tugs, 3-engine [c]	GO	0.3	900.2	0.01	0.02	907.5

Notes: [a.] Fuel type: P=Petrol, D=Diesel, GO=Gas Oil; [b] Vessels included for sensitivity tests only; [c] Two alternative data sources are considered for inclusion in category 04. Inland goods carrying vessels; [d] Carbon dioxide equivalent emissions (CO_2e), calculated using GWP factors (GWP for CO_2 = 1; for CH_4 = 21; for N_2O = 310), consistent with reporting under the Kyoto Protocol (IPPC, 1996).

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