Report

Non-Road Mobile Machinery Usage, Life and Correction Factors

Report to the Department for Transport

Report

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Executive Summary

The Department for Transport (DfT) commissioned **Netcen** to undertake research in order to assess the current status of the UK population of diesel-engined non-road mobile machinery (NRMM). This includes estimation of the size of the populations of a range of NRMM types, their typical usage rates in hours per year, their typical useful lifespan in years and average engine power. This information is in turn intended to permit estimates to be made of emissions to air from NRMMs in the UK atmospheric emissions inventories.

This study has derived estimates for the UK population, annual usage rates in hours per year, and average useful lifespan in years, for a number of specified types of non-road mobile machinery (NRMM) based on data supplied by stakeholders. There remain some machinery types relevant to the industry and construction sectors for which no data have been identified to date and therefore for which no estimates can be derived. In addition, confidence in the estimates derived is variable depending on the reliability of the source data used to derive them. In such cases, suitable stakeholders in the relevant sector should be consulted in order to attempt to improve on the estimates. In addition to clarifying uncertainties over population, usage and lifetime estimates, further consideration should be given to the validity and accuracy of fuel consumption factors, and of the loading factors used in the fuel-use cross checking procedure. In particular, the loading factors used in this study have been taken from work done in Finland, and may or may not necessarily be relevant to the UK situation.

This is the final report on the project and follows the draft report circulated among relevant stakeholders for consultation in August and September 2004, including those who had contributed to, or expressed interest in contributing to the work. It was hoped that the consultation exercise would lead to increased confidence by stakeholders in the estimates made, improve estimates where necessary, and be able to fill in remaining gaps in the dataset. The response received was small and generally limited to confirmation of the data and methods used, although in the case of agricultural machinery and rail locomotives some queries raised led to clarification or alteration of the datasets presented. Therefore, it is only in these areas that revisions have been made to the population and activity data presented in the draft report.

The limited response of the consultation process in the time available reflects how little centralised information exists on the population and usage of non-road mobile machinery in the UK. This is a diverse sector and although there is a reasonable amount of useful expert opinion to draw upon, there is generally little quantitative data to be obtained on a national basis. This will inevitably impose significant uncertainties in the atmospheric emission estimates for the sector. The study has considered the overall uncertainties in the UK population and activity estimates in the context of fuel consumption that can be calculated and used as a means of cross-checking the population and usage estimates made.

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1 Introduction

The Department for Transport (DfT) commissioned **netcen** to undertake research in order to assess the current status of the UK population of non-road mobile machinery (NRMM). This includes estimation of the size of the populations of a range of NRMM types (specified in Table 1.2 below), their typical usage rates in hours per year, their typical lifespan in years, and typical engine power ratings in kW. This information is in turn intended to permit more accurate estimates to be made of emissions to air from NRMMs in the UK's National Atmospheric Emissions Inventory.

1.1 NON-ROAD MOBILE MACHINERY (NRMM) IN THE UK

"Off road machinery" is one of the categories of emission sources considered in the UK National Atmospheric Emissions Inventory (NAEI). It comprises a wide range of vehicles and machinery powered by petrol or diesel whose primary function is not transport on public highways, as well as a wide variety of other mobile and portable machinery. NRMM is a subset of this off-road machinery sector in the NAEI. It includes machinery capable of moving, or being moved, on the ground with diesel engines between 18kW and 560kW power, and whose emissions, when new, are regulated by EU Directive 97/68/EC (see below). This machinery is used in a wide variety of industries including: agriculture, forestry, general industry, construction, mining and quarrying and aviation.

Further EU Directives regulate the emissions of agricultural tractors, portable generator sets, and engines used in garden machinery such as lawn mowers.

Other categories of machinery considered in the NAEI as "Other Transport" include diesel powered railway locomotives, shipping vessels and aircraft. Of these three, only railway locomotives are considered in this project.

Table 1.1 below indicates the estimated emissions from off-road machinery, plus rail locomotives in 2001, as included in the NAEI.

Table 1.1: Emissions from off-road machinery and rail locomotives in 2001 according to the National Atmospheric Emissions Inventory

		NOx	PM_{10}	NMVOCs	CO_2
Off road	emissions (ktonnes)	73.2	7.2	54.7	5614
	% all UK emissions	4.4%	3.9%	3.6%	1.0%
Rail locomotives	emissions (ktonnes)	10.3	0.68	1.40	1273
	% all UK emissions	0.6%	0.4%	0.1%	0.2%

Disparities between these figures and those of other EU member states have recently necessitated a review of the datasets and assumptions upon which the UK estimates are based, including the use of cross-checking against figures for red diesel (non-road gas oil or low tax diesel used for off-road sources) fuel use by the NRMM sector, for example. Emission inventories for other EU countries suggest a larger contribution to national emissions is made by NRMM than appears to be the case for the UK. However, it is not clear whether other countries perform any cross-checks of their data against fuel consumption or any other statistic. As part of that review, this study has re-examined the estimates of UK populations, usage and lifetimes used to derive emissions estimates for the UK.

1.2 LEGISLATION GOVERNING EMISSIONS FROM NRMM IN THE UK

The Non-Road Mobile Machinery (Emissions of Gaseous and Particulate Pollutants) Regulations 1999 implement EU Directive 97/68/EC in the UK, regulating emissions from compression ignition engines of net power 18kW-560kW and intermittent speed installed in NRMM. This legislation therefore enacts the European Tier I and Tier II standards for NRMM. Parallel standards for agricultural tractors are set in EU Directive 2000/25/EC.

Furthermore, the European Commission has now reached agreement on further new standards to reduce emissions for NRMM, to be implemented in three stages:

- Tier IIIa by 2005, requiring engine modification
- Tier IIIb by 2010, which will require the use of particle traps, and thereby low sulphur fuel, and
- Tier IV by 2013, which will require NOx abatement technology, and a new generation of engine technology.

These new forthcoming standards will need to be taken into account in future estimation of emissions for NRMM.

1.3 AIMS AND SCOPE OF THIS PROJECT

This study focused on the NRMM types specified in Table 1.2 below. These machinery types have further been categorised in order of priority, as specified by the DfT in the work specification. For each NRMM type, an estimate has been made of the likely UK population, typical usage pattern in hours/year, and the typical useful lifespan of the machinery. Periods of the typical lifespan during which the machinery remains little used or unused have been disregarded for the purposes of this study, as they would not lead to significant atmospheric emissions.

Table 1.2. Machinery types of interest and priority ratings

Priority	Machine Type
1	Portable Generator Sets 5-100kW, Portable Generator Sets 100-1000kW, Agricultural Tractors, Railcars, Rail locomotives, Refrigeration unit engines on HGVs
2	Forklifts, Rough Terrain Forklifts/Telescopic Handlers, Combines, Backhoe Loaders, Mini Excavators
3	Excavators, Access Platforms, Welding Equipment, Aircraft Ground Support Equipment (other than Terminal Tractors), Air Compressors, Wheeled Loaders
4	Terminal Tractors, Gas Compressors, Off-highway Trucks, Industrial Tractors, Cranes, Bulldozers
5	Concrete Pavers, Surfacing Equipment, Concrete Saws, Crawler Tractors, Shredders, Asphalt Pavers, Paving Equipment, Bore/Drill Rigs, Fellers/Bunchers, Skid-Steer Loaders, Crushing/Processing Equipment, Tracked Loaders, Other Materials Handling Equipment
6	Graders, Scrapers,

2 Methodology

The various machinery types of interest in this study were allocated to 5 broad economic sectors: industry and construction, agriculture, mobile refrigeration, aviation, and rail transport. The approach taken to obtaining data and for formulation of estimates varied depending on the sector in question. However, in all cases, relevant stakeholders were contacted to request copies of any available data and statistics which they held. Once initial estimates of population, annual usage and lifespan had been made, these were tested using a number of cross-checking methods.

2.1 DATA SOURCES CONSULTED

Stakeholders relevant to each sector were contacted asking whether they held any relevant data or statistics which might help with estimation of populations, usage and lifetimes. These included:

- Government Departments (e.g. DVLA, ONS)
- Trade associations (e.g. BITA, AMPS, ATOC)
- Manufacturers (e.g. JCB, FG Wilson)
- Plant Hire companies (e.g. A-Plant, Hewden Stewart)
- Machinery operators (e.g. UK airports)
- Market research organisations (e.g. Off Highway Research)
- Academics

In each case the stakeholder was sent a letter and proforma explaining the nature and purpose of the research, detailing the machinery types of interest and the statistics of interest, and asking the stakeholder if they would be prepared to share any data they might hold which would allow estimation of parameters.

Data received varied greatly in quantity and reliability, depending on the sector and machinery type in question. Once all responses had been received, the data was reviewed in order to derive the best estimate possible for each machinery type of interest. As considerable uncertainty surrounded figures provided in many cases, a range of estimates was generally derived, along with a best estimate.

A list of stakeholders contacted during the project, and who responded, is provided in Appendix 1. Stakeholders from whom significant data or guidance was received are mentioned in the relevant section of Chapter 3 of this report for each sector. A significant number of other organisations were contacted who provided no response.

2.2 CROSS-CHECKING OF ESTIMATES

For each machinery type of interest, the ranges and best estimates of population, annual hours of use and overall lifetime were further tested. Firstly estimates were used, along with typical fuel consumption factors to estimate overall fuel consumption across the entire NRMM sector. This total figure for NRMM gas oil (red diesel) consumption was then compared with independent estimates of red diesel consumption by the NRMM sector made by the UK Petroleum Industry Association (UKPIA) and one of their members as part of their own market research activities.

Furthermore, the reliability of the estimate ranges around the best estimate were also assessed, along with the potential impact of any uncertainty in fuel use estimates, using a statistical probabilistic approach. Based on the uncertainty ranges in the population, usage and engine power estimates, this gave an overall likely range in the estimates of fuel consumption which could be compared against estimates from the fuel supply chain provided by UKPIA.

Finally, contacts responsible for equivalent research in ten other EU Member States were contacted to ask if they had derived similar statistics for their own countries. Where such figures were provided, they were further used to assess the likely reliability of the estimates for the UK.

3 Results

In general, the data gathered has covered most of the NRMM types identified by DfT. A few gaps remain, but these are mainly in the lower priority categories 5 and 6. For these, no data were directly obtained from sources, nor were sufficiently unambiguous data available for estimates to be made. The most important gaps remaining are for industrial tractors and for welding equipment.

Tables 3.1-3.3 below detail the best estimates of population, usage and lifetime made for each machinery type of interest. The findings of the research are discussed below separately in more detail for each of the sectors considered, with an outline of how the estimates were derived.

Table 3.1 – Best estimates of parameters for industry, construction, agriculture and mobile refrigeration units

Machine Type	DfT Priority Class	Average Power rating (kW)	Population (units)	Annual usage, hours/year	Useful Lifetime (Years)
Industry and Construction					
Portable Generators 5-100kW	1	49	99802	844	6
Portable Generators 100-1000kW	1	194	21941	844	6
Forklift (non-RTF)	2	35	64006	844	6
Rough Terrain Forklifts (RTF)	2	56.25	6125	850	6.3
Telescopic Handlers	2	75	25200	1050	6.3
Backhoe Loaders	2	67.5	19950	1000	7.7
Mini Excavators	2	18.75	31500	1100	4.6
Excavators					
Wheeled excavators	3	100	2100	875	6.3
Crawler excavators	3	75	2975	1000	6.3
Access Platforms	3	17	1779	1400	5
Welding Equipment	3	ND	ND	ND	4
Air Compressors	3	30	12600	875	4.2
Wheeled Loaders	3	112.5	6475	1100	8.4
Industrial Tractors	4	ND	ND	ND	ND
Gas Compressors	4	30	6300	875	4.2
Off Highway Trucks					
Rigid dump trucks	4	712.5	945	1250	8.3
Articulated dump trucks	4	168.75	3640	875	7.7
Cranes	4	225	4690	1000	10.5
Bulldozers	4	135	1339	375	7.7
Concrete Pavers	5	ND	ND	ND	ND
Surfacing Equipment	5	ND	ND	ND	ND
Concrete Saws	5	ND	ND	ND	5
Crawler Tractors	5	ND	ND	ND	4
Asphalt Pavers	5	90	998	750	3.9
Paving Equipment	5	22.5	18900	500	8.8
Bore/drill rigs	5	ND	ND	ND	ND
Skid-Steer Loaders	5	33.75	6300	1000	4.2
Crushing/Processing Equipment	5	182.5	700	1350	ND
Tracked Loaders	5	120	367	500	9.5
Graders	6	150	123	375	12.3
Scrapers	6	341.25	88	500	14

Machine Type	DfT Priority Class	Average Power rating (kW)	Population (units)	Annual usage, hours/year	Useful Lifetime (Years)
Mobile Refrigeration Units					
Refrigeration unit engines on HGVs	1	11.5	47500	2500	9
Agriculture					
Agricultural Tractors	1	78	239344	812	11
Combines	2	75	12636	332	7
Shredders	5	ND	ND	ND	ND
Fellers/bunchers	5	ND	ND	ND	ND

ND-No data received or determined

Table 3.2 – Best estimates of parameters for rail industry

Machine Type	Priority Class	Average Power rating (kW)	Population estimate (number of engines)	Annual usage, hours/year	Useful Lifetime (Years)
Trains - Passenger					
Class 43 (HST)	1	1680	159	1,708	35
Class 142	1	172	95	1,805	29
Class 143	1	172	50	1,805	29
Class 144	1	172	56	1,805	28
Class 150	1	213	274	1,869	35
Class 153	1	213	70	1,869	32
Class 155	1	213	14	1,869	32
Class 156	1	213	228	1,869	32
Class 158	1	260	361	1,915	35
Class 158 (cambrian)	1	300	20	1,915	35
Class 159	1	300	66	1,915	33
Class 165	1	260	179	1,915	33
Class 166	1	260	63	1,915	31
Class 168	1	318	70	1,869	37
Class 170	1	318	352	1,949	41
Class 175	1	335	70	1,949	35
Class 180	1	559	70	2,333	33
Class 220	1	559	136	2,255	32
Class 221	1	559	216	2,255	31
Class 222	1	559	127	1,850	30
Trains - Freight					
Class 08	1	298	280	146	58
Class 09	1	298	36	146	54
Class 20	1	746	42	259	56
Class 31	1	1100	52	168	50
Class 33	1	1160	21	168	46
Class 37	1	1300	245	378	48
Class 47	1	1920	260	263	43
Class 56	1	2462	111	252	28
Class 57	1	1860	13	336	41
Class 57	1	2050	16	336	52
Class 59	1	2460	14	752	24
Class 60	1	2313	100	752	29
Class 66	1	2385	352	934	30
Class 67	1	2385	30	752	29
Class 73	1	448	37	57	40

Table 3.3 – Best estimates of parameters for aviation sector (airport machinery)

Machine Type	Priority Class	Average Power rating (kW)	Population (units)	Total annual hours operated (total unit.hours across all units)	Annual usage, hours/year	Useful Lifetime (Years)
Airports						
Air conditioning unit	3	20	11	5500	500	10
Airstart	3	450	61	12157	199	17.5
Cargo loader	3	40	11	16500	1500	15
Cabin heaters	3	10	11	15236	1385	17.5
Caterlift	3	20	22	22000	1000	15
Deicer	3	80	149	28563	192	12.5
Ambulift	3	20	33	60775	1842	17.5
Bus	3	30	88	1637546	18608	10
Ground power unit	3	150	436	1792119	4110	10
Steps	3	7.5	436	2074435	4758	15
Baggage conveyor	3	53	590	2624060	4448	12.5
Baggage tractor	3	74	502	3877453	7724	8.5
Baggage loader	3	20	160	240000	1500	ND
Buggy	3	20	50	50000	1000	ND
Dec loader	3	67	6	15164	2527	ND
Elevator	3	20	72	72000	1000	ND
Flatbed	3	20	50	50000	1000	ND
FMC platform	3	20	17	17000	1000	ND
Fuel bowser	3	20	121	427380	3532	ND
Griptester	3	10	11	5500	500	ND
Gritter	3	40	28	7000	250	ND
Heater	3	10	6	616	103	ND
Hilift	3	51	292	1739955	5959	ND
Hoist	3	10	6	6000	1000	ND
Hoselayer	3	10	6	3000	500	ND
Hydrant cleaner	3	10	6	3000	500	ND
Lift	3	20	17	17000	1000	ND
Lower deck loader	3	50	17	17000	1000	ND
Main deck loader	3	90	50	50000	1000	ND
Piler	3	50	6	6000	1000	ND
Pump	3	20	28	28000	1000	ND
Road sweeper	3	50	44	63488	1443	ND
Snow blower	3	50	28	2016	72	ND
Snow cutter	3	50	17	6562	386	ND
Snow equipment	3	50	166	45080	272	ND
Snow plough	3	50	28	2800	100	ND
Snow sweeper	3	50	105	10500	100	ND
Spreader	3	50	6	1500	250	ND
Tipper truck	3	50	6	6000	1000	ND
Toilet bowser	3	20	72	72000	1000	ND
Transporter	3	30	6	6000	1000	ND
Water bowser	3	20	50	50000	1000	ND
Mallaghan	3	20	11	11000	1000	ND
Pushback tug	3	183	425	1355122	3189	15
(Terminal) tractor	3	50	469	469000	1000	ND
Tug	3	50	717	717000	1000	ND

3.1 INDUSTRY AND CONSTRUCTION SECTOR

The majority of the NRMM types of interest in this study are used within the industrial and construction sectors. These are as listed in Table 3.1 above.
In order to assess the likely size of the UK populations, contact was made with trade organisations and with commercial companies operating within manufacturing, plant hire, and civil engineering professions (see Appendix 1). Population sizes are most likely to have been assessed as part of market research activities by manufacturers and plant hire companies, in order to assess the size of their markets. However, despite this, no significant datasets of population statistics were identified. Similarly, approaches to the above organisations to obtain information on usage patterns and lifetimes for machinery drew a mixed response. The best dataset of usage and lifetime estimates for this sector was provided by the Civil Engineering Contractors Association (CECA), who provided estimates for these parameters based on records kept by their members, and on expert knowledge of the field. Unfortunately CECA did not hold any records which enabled estimates to be made of UK population size for machinery types. The best estimates of UK population were provided by the market research organisation Off Highway Research (OHR).

In most cases, enquiries solicited a positive response and willingness to help, but time pressures and lack of currently available datasets made it difficult for organisations to respond within the timeframe of the project. The very limited response from organisations in this sector is likely to be the result of two factors: commercial sensitivity of marketing data, that is, a lack of willingness to release data which may prove useful to competitors, and time pressures on staff for whom provision of this data to **netcen** could have proved very time consuming if no such statistics are already available to hand. A number of commercial organisations had datasets and were willing to help with the research, but were unable to respond within the timeframe of the project.

In the absence of data from commercial sources, three alternative sources of information were considered:

- Statistics from DVLA registration data for Great Britain and Northern Ireland;
- Annual UK net supply sales statistics from PRODCOM reports produced by the Office for National Statistics; and
- Statistics provided by Off Highway Research from their previous market research for this sector

For most of the NRMM types considered, very few are registered with the DVLA, as some of the types are not vehicles, and those that are, are unlikely to be required to use a public highway on a regular basis. Where a machinery type could be correlated with a DVLA vehicle bodycode the number of registered vehicles could be used as an indication of the population lower end estimate. This dataset proved more useful for the agricultural sector, less so for the other sectors. There was also not always a clear match between the priority NRMM categories specified by DfT and bodycodes used by DVLA, particularly as no clear definitions of the bodycodes are available.

Most estimates of population for this sector have therefore been based on the market research of Off-Highway Research. Where their work has not considered the machine type in question, Net UK Supply figures from the PRODCOM reports have been combined with assumed typical lifespan figures in years to provide a population estimate. Where significant uncertainty existed regarding lifespan, an upper and lower estimate were made and from this a population estimate range deduced. It is believed that there is considerable uncertainty in the population estimates based on PRODCOM sales data. The most significant machinery type for which this approach was required was for portable generators. This proved to be the most difficult NRMM type in the DfT Priority 1 category for which to obtain or estimate population and usage data. In addition, the PRODCOM sales data for generators did not distinguish between portable and non-portable units. Considerable uncertainty therefore surrounds the population estimates for portable generators and the following assumptions have been made:

- All generators rated less than 7.5kW were assumed portable;
- 75% of generators rated 7.5kW-100kW were assumed portable;
- 50% of generators rated 100kW-375kW were assumed portable;
- 10% of generators rated over 375kW were assumed portable;

In addition, OHR only provided population estimates for all compressors. In the absence of any guidance to the contrary, it has been assumed that one third of these are gas compressors and two thirds are air compressors.

The figures for lifespan and typical usage patterns have been estimated from the data provided by CECA and from discussions with plant hire companies and manufacturers.

3.1.1 Off Highway Research data

The market research organisation Off Highway Research (OHR) was contracted by **netcen** to provide population, usage and lifetime data for industrial and construction machinery specifically for this study. Off-Highway Research has undertaken a research programme over a period of 25 years to ascertain sales and population of certain types of construction equipment sold in the United Kingdom. Each year Off-Highway Research undertakes over 100 telephone and face to face interviews with UK manufacturers and overseas manufacturer's dealers and the relevant sales information has been gleaned during these interview. Further details of Off Highway Research's methodology are given below where relevant.

In their report provided with their data, OHR indicated in their report that individual companies do not keep records of their machines working in the UK. The population estimates provided by OHR were calculated by accumulating the sales to the UK market over the average life of the machine and subtracting the estimated number of machines scrapped or sold overseas during this period. To these figures OHR further applied judgement from their expert knowledge of the sector. OHR were unable to provide population, usage or lifetime estimates for the following machinery types:

- Portable generators
- Non rough-terrain forklifts
- Access platforms
- Welding equipment
- Industrial tractors
- Concrete pavers
- Surfacing equipment
- Concrete saws
- Crawler tractors
- Paving equipment
- Bore/drill rigs
- Crushing/processing equipment

It is therefore recommended that stakeholders in the construction and industry sector be consulted regarding the above uncertainties and data gaps.

3.1.2 Lifespan

From enquiries with stakeholders made during this project it became clear that most machines in the UK may be considered to have what are termed two or three working lives. The first working life is that with the original customer and, depending upon the machine, will be any period from 18 months to 6 years, during which the machine may be used very intensively. The second life is where the original purchaser sells the machine to a new customer. The onward sale is often in the UK but a significant number are sold overseas. The third life is often where the machine is very rarely used and consequently the machine is often in a state of disrepair and will eventually be scrapped. The backhoe loader used in agriculture for digging drainage ditches on farms is a prime example of this type of machine. For the purposes of this study, it is the first and second lifetimes which are of interest, the third lifetime having been discounted in considerations of lifetime and usage as it is considered that the usage is generally very limited and occasional.

The lifespan of off road equipment can often be very short. If used intensively on construction sites they can last less than 2 years for mid-range equipment (e.g. backhoe loaders/dumper trucks/skid steer loaders), perhaps on average 3 years for intensively used plant hire kit. They then may or may not be rebuilt or re-engined to original or latest specified standards, or scrapped.

In this study, for each machinery type, an estimate of the total lifetime has been made based on data provided by CECA and OHR. This has been split into first, second and third lifespans, assumed to be 30%, 40% and 30% respectively of the total lifetime. The average usage patterns were then considered for each working lifespan and for the overall lifespan of the machinery type.

3.1.3 Usage Patterns

Each machine working in the UK is unique. Depending upon the application, the number of hours worked will differ. Very few machines will be working eight hours per day, seven days per week. Some machines may be double shifted; some may only work a couple of hours in a day. OHR and CECA both provided estimates of the total number of hours which a piece of machinery might be expected to be used assuming that it is on an industrial or construction site 100% of the time. This may not be true for equipment from plant hire companies, which the hire company might expect to have on hire at sites perhaps 70% of the time. The remaining 30% or so of the time, it may remain idle. The project concludes that further consideration should be given to the proportion of each NRMM population which is hired out by plant hire firms, and to what proportion of the time typically the machine is on hire, as it is believed that for some NRMM types, perhaps 90% of machines are owned by plant hire firms.

OHR's estimates indicated that most machines work a normal period of five days per week, eight hours per day and 50 weeks per year, hence 2,000 hours. Those machines with a higher level are those primary machines where more than one shift per day is not unusual, and those working well under 2,000 hours are specialist machines working on specific applications and only used for short but very intense periods. The usage rates quoted by OHR are significantly greater than those cited by CECA. It has therefore been assumed for the purposes of this study that the annual hours of usage stated by OHR are in fact more representative of 'on site' times rather than actual active machine running times.

From this, actual machine running time per year has then been estimated. For the first lifetime it has been assumed that the machinery is on a site for the hours per year cited by OHR, with actual machine running time being 70% of this time, reducing to 35% for the second lifetime. It is assumed that annual usage is negligible and can be ignored for the third lifetime.

3.1.4 Nature of Market

The market for construction and industrial NRMMs is large and fragmented with a large number of manufacturers, plant hire firms and end users. There is also a significant second hand market, although a significant proportion of equipment sold second hand is exported. Lifespan and usage rates not only vary greatly with age of equipment as indicated above, but also according to the owner. It is believed that generally, approximately 10% of plant hire units are owned by large companies who buy new equipment, maintain high standards of maintenance, and sell on or scrap equipment after a short lifetime. The remaining majority of equipment is held by a large number of small operators with fleets of older equipment, often kept for many years, and sometimes subject to low standards of maintenance.

There remain therefore a number of machinery types for which currently little or no data exists on the UK population, typical lifespan and usage patterns. In particular a high priority is to improve characterisation of the data for portable generators. Population estimates are based on data derived from PRODCOM reports and contain considerable uncertainty. The PRODCOM data is also based on data for all generators, and it is not clear what proportion may be considered portable.

Further consideration for machinery types across the sector needs to be given to typical lifespan and usage patterns as it is considered that annual usage may have been overestimated for some machinery types. In particular, further expert opinion needs to be sought on typical loading factors. For example, a bulldozer may be rated at 100kW power, but at what power loading does it actually work most of the time? It may actually only work at a small fraction of this power rating most of the time. Figures provided from equivalent research undertaken in Finland have been used as estimates for the UK in this study. Consideration needs to be given as to whether these figures are relevant to the situation in the UK (see Section 4).

3.2 AGRICULTURAL SECTOR

For the purposes of this research the following equipment was taken to be primarily used for agriculture:

Priority 1: Agricultural tractors
Priority 2: Telescopic handlers, combines
Priority 5: Shredders, fellers/bunchers,

Backhoe loaders have been considered under the industry and construction sector.

Manufacturers of agricultural equipment were contacted and all regarded AEA (the Agricultural Engineers Association) to be the most promising source of information. AEA were subsequently contacted. However, after negotiations, it was not possible to obtain information for the purposes of the project.

UK Population estimates for the above machinery types were derived from data provided by:

- UK Net Supply figures from Office of National Statistics PRODCOM reports 29320 (Other Agricultural and Forestry Machinery) and 29310 (Agricultural Tractors)
- Department for Transport (DfT) statistics on vehicles licensed by propulsion (fuel) type
- DVLA vehicle licensing statistics for GB and Northern Ireland
- DfT reports on evasion of vehicle excise duty.

DfT data for vehicles licensed irrespective of taxation class was taken as the basis for a population estimate. Owing to gaps in the PRODCOM data for UK Net Supply, it was not possible to derive meaningful figures from this source.

All agricultural tractors, combine harvesters and other agricultural machinery that can move under its own power should be registered with the DVLA (the data source for the Dft datasets). Before January 2002 at least some of these had to pay a flat rate VED (Vehicle Excise Duty), but they are all now tax exempt. There is not an unusual jump in registered numbers between 2001 and 2002 however so it has been presumed that a high proportion of the entire UK population of agricultural machinery that is in regular use has been, and continues to be registered.

Usage figures and lifetimes for combines and agricultural tractors were derived by consideration of data provided in the “Farm Management Handbook” produced by Nix at Imperial College, London (Nix 2004). The National Farmers’ Union (NFU) recommended this as a source of statistical information for the project. This provides statistics on typical machine hours required per hectare per year of arable land and per head of livestock for different types of land use and livestock. Combination of this data with UK statistics (DEFRA 2003) for land use (hectares for different types of farmed land) and farming permitted calculation of the total number of tractor or combine hours per year in the UK. This in turn was combined with the UK machinery population estimates to estimate average machinery hours per year per unit. Appendix 2 provides further details of the methodology. The handbook also provided total lifetime hours for machinery which were used to calculate an estimated life expectancy for combines and tractors in years. Data derived in this way are presented in Table 3.1.

Population, usage and lifetime datasets were not available for shredders and for fellers/bunchers. The Forestry Commission indicated that they could provide information for forestry machinery but this was not available within the timescale of this project.

It should be noted that this method for estimating average activity on the basis of land-use data is common among emission inventory compilers when no other statistical information is available. In fact, it is usually the only method possible for diffuse emission sources (i.e. emissions from many individual sources over a wide area). The product of usage and population (e.g. tractor hours per year for the whole fleet of tractors) is the parameter directly linked to national emissions from the sector and will be more accurate than the average usage rates (hours/year) and lifetime calculated for an individual tractor. Therefore, the parameters population, usage rate and lifetime that are presented in Table 3.1 should not each be viewed in isolation, but together they form an internally consistent set of parameters for use in calculating emissions from the national population of tractors and combines.

Of course, there will be a significant number of tractors that are much older than the average lifetime figure shown here, but these would be expected to be used for fewer hours per year. Conversely, there will be younger tractors in the fleet used far more intensively than the average usage rate. It is also appreciated that usage of agricultural machinery is seasonal and may vary from year to year due to weather conditions. These figures presented in Table 3.1 reflect annual average usage rates for different farming practices based on Nix (2004). Errors in the emission calculations caused by applying a constant average lifetime and usage rate to the whole machinery fleet will tend to cancel out.

3.3 MOBILE REFRIGERATION UNITS

This section covers refrigeration units used on articulated and non-articulated good vehicles in the UK. These units are used by the temperature-controlled transport industry for the transport of frozen, refrigerated and chilled foodstuffs, liquids and other goods.

There is no central source of official statistics for this sector, and most trade association do not hold relevant information. There are therefore no official statistics that record the fleet size of refrigerated transport units. Although the Society of Motor Manufacturers and Traders (SMMT) does hold annual registration statistics for new refrigerated non-articulated vehicles, these do not include trailer units and also exclude the significant number of non-articulated vehicles converted for refrigeration post-registration. A number of UK trade associations were therefore contacted to determine whether suitable statistics were available, or an expert estimate of numbers able to be provided. The associations contacted directly, or on our behalf, included:

- The Chartered Institute of Logistics and Transport;
- The British Refrigeration Association;
- The Road Haulage Association;
- Temperature Controlled Storage and Distribution (a journal);
- Institution of Diesel and Gas Turbine Engineers; and
- Transfrigoroute UK

Of these, the first five were unable to supply any information or statistics. However, Transfrigoroute UK (a trade association specialist for transport of temperature-controlled foodstuffs and goods) were able to provide estimates of refrigeration unit numbers from expert knowledge.

Details of refrigeration unit numbers, power rating, annual hours of operation and fuel consumption are provided in Table 3.1.

The estimate provided of fuel consumption and annual hours of operation represent average values. In reality, both fuel consumption and the running time of units will vary according to which of the 3 basic operational modes the equipment is set to. These modes are:

- continual operation
- thermostatted operation
- ambient air flow for chilled loads

General fuel consumption is 3 l/hour when the unit is operational; across the 3 operating modes fuel consumption is estimated at 1.5-3 l/hr.

There is a relatively conservative 10% uncertainty in the population estimate of refrigerated unit numbers provided by the trade association. In reality, given the lack of concrete data on the numbers of such units, the uncertainty could certainly be higher e.g. *ca.* 15-20%. The uncertainty in numbers reflects the lack of official statistics and the varied nature of the refrigerated transport sector in the UK, with a large number of HGV vehicle operators having a corresponding wide range of fleet sizes making it difficult to obtain estimates of equipment numbers. As previously described, both the fuel consumption and the running time of units will also vary according to the operational settings used for the refrigeration units.

There were no sources of disaggregated data identified that could have provided a cross check of the estimates obtained for this sector.

3.4 RAIL SECTOR

To obtain information for the rail sector, AEAT Rail was commissioned to provide the population of different classes of diesel trains, their annual hours of use, their average lifetime, the average distance travelled and average engine power (kW). The population and average engine power were available from reliable published documents. However, annual hours of use, average lifetime and average annual distance travelled by each train class was deemed to be commercially sensitive information and therefore the estimates provided were derived from a group of expert's best judgement rather than from any sources of information available to AEAT Rail. AEAT Rail produced a report containing the data titled "Rail traction diesel engine data - Input to UK national emissions survey" (Draper 2004).

3.4.1 Passenger trains

In addition to the AEAT Rail Report, data were also obtained from the Association of Train Operating Companies (ATOC) for passenger trains. They provided information on the number of units in operation for each passenger train class and actual distance travelled. The average annual distance travelled data has been used in preference to the AEAT Rail data as it is based on actual data rather than estimates. AEAT Rail provided the number of engines whereas ATOC have provided the number of units. In simple terms a unit is a whole train, a vehicle is a wagon or a locomotive or any other wheeled item on the track (powered or not). Therefore depending on the type of train there may be a variation on the ratio of units to engines, and the AEAT Rail and ATOC data are therefore comparable. In Table 3.2 the number of engines in operation for each train class as provided by AEA Rail (consistent with the number of units as provided by ATOC) is shown as in the context of this piece of work it was felt that this would be the most useful.

Class 170 trains are increasing and therefore whilst the population shown was correct for 2003 this figure is subject to change. Class 222 trains are due to be introduced in 2004/5. Therefore the figures shown for this train class are indicative and all have been provided by AEAT Rail as no data were available from ATOC because these train types are not currently in service. For all passenger train classes, the annual average distance travelled has been calculated on a fleet weighted basis from ATOC's figures. The data obtained are summarised in Table 3.2.

3.4.2 Freight trains

Whereas for passenger trains the population and average engine power were available from published external sources, for freight trains, detailed information by Class was only available from the AEAT Rail Report. In this, annual hours of use, average lifetime and expected average annual distance travelled by each freight train Class were derived from a group of expert's best judgement. In addition, the rail freight company EWS have provided the total kilometres travelled annually by their fleet (which represented 31% of the total population) for years 2001-2004. The AEA Rail team provided details on the composition of the EWS fleet by individual Class. From these two data sources, the national freight fleet annual distance travelled by each Class was estimated. For each Class, the AEA Rail experts' average distance for that Class was scaled by a factor derived from the EWS total actual reported distance/the experts' estimate for the total

EWS population. For freight trains each locomotive (vehicle) contains an engine. This data provided by AEAT Rail and the annual average distance travelled calculated as above are shown in Table 3.2.

3.4.3 Fuel consumption

The lower the engine power the lower the fuel consumption. Since power per vehicle ranges from 172 - 559 kW, the fuel consumption varies from about 7 to 4.5 miles per gallon (mpg). The sub 100 mph classes (142 - 175) with their lower installed power and vehicle mass are in the range 7 - 5.5 mpg. The new class 180 and class 220/221 trains are relatively heavy and this in addition to their sustained use of high power to reach 125 mph, plus high auxiliary loads, leads to their worse consumption of around 4.5 mpg (~1 litre per mile). For freight locomotives, fuel used per mile varies considerably with trailing load and it is necessary to perform complex calculations in order to determine distance based fuel consumption.

ATOC have provided an estimate of gas oil consumption by passenger trains in 2003 of between 378 and 402 million litres. This compares reasonably with the 334,000 tonnes of gas oil used by the entire rail sector quoted in the Digest of UK Energy Statistics (Dti 2003).

3.4.4 Accuracy of data

There are a number of known un-quantified but small omissions. These are:

- track maintenance machines have not been included in the above data. However the numbers are small, possibly 2% of the number of "revenue" diesel powered vehicles, and their hours of operation are generally lower than revenue vehicles.
- "Heritage" and tourist locomotives have not been included. However the total contribution is minimal.
- Shunting locomotives used industrially rather than on the main network are not included.

3.5 AVIATION SECTOR

For this sector, two machinery types were specified as being of priority:

- Airport ground support equipment
- Terminal tractors

This sector was analysed in some detail. As activity occurs in a “contained” area (within airports), there were relatively good prospects of deriving good quality data at least using surrogate data associated with the use of NRMM, such as air traffic movements (ATMs).

Terminal tractors represent a specific item of NRMM equipment. However, airport support equipment encompassed a wide range of NRMM types of which terminal tractors are a subset. The various NRMM equipment types identified as used at UK airports are listed in Table 3.3. It should be noted that many vehicle types present airside at airports such as buses may be considered as NRMMs as they are special designs which are not roadworthy for the public highway. However, any airside vehicle which is or could be registered for the public road, such as the fire tenders or vans, has been excluded from the figures as not being an NRMM.

Population, usage and lifetime statistics for each of these machinery types was obtained from a survey of a representative sample of UK airports representing over 50% of UK aircraft movements. A strong correlation was observed between NRMM populations and annual usage, with the number of annual aircraft movements at a given airport. Population and usage figures for each machinery type were therefore scaled from the UK airports sampled, to national estimates using total UK aircraft movement figures.

There were 2,243,064 Air Transport Movements (ATMs) for the UK in 2003 (CAA 2003). The 63 airports in the UK were ranked by their 2003 ATMs in a cumulative frequency distribution. All 14 airports contributing to the first 75% of the ATMs were contacted. Nine of these (representing 51.9% of the ATMs) responded with data used in this review. For each of the subsequent 5% fractions, at least one airport in each fraction was contacted and responded. In total 28 airports representing 90.5% of the UK annual ATMs were contacted. Responses were received from 15 airports and were included in this review, representing 53.9% of the annual UK ATMs. From the population data provided for these airports and the correlation with ATMs, UK population estimates were deduced.

Annual usage figures in hours per year were again provided by a sample of UK airports (Heathrow, Gatwick, Luton and Birmingham), and again these were scaled in line with national total aircraft movements to estimate UK annual hours of use of each type of airport support vehicle in all UK airports. It should be noted that this data only covers the support vehicles (i.e. those actively engaging the aircraft and not ancillary equipment such as runway sweepers, fire equipment, snow equipment and grounds maintenance). Further data from other airports allowed estimation for some of these types of airport equipment types.

Data on engine power was principally received from only 2 airports (Gatwick and Coventry) and for a limited amount of machinery. For many generic types of equipment there are a range of engines available and the power varies over a wide range. The variability is particularly true for pushback tugs as the size of aircraft they are designed for determines their engine power. Smaller airports will tend to operate smaller aircraft and hence smaller pushback tugs. For example Gatwick reported 37 pushback tugs in the range 65-300 kW, Exeter has 2x 265 kW tugs plus one smaller unit and Coventry has 2 units, 90 and 135 kW each. Additional information on air starts and ground power units (GPUs) was obtained from the manufacturers.

Data on equipment age was received from Birmingham (134 units) and Gatwick (446 units). Age of units in operation is probably being affected by environmental policies at UK airports. For example Heathrow Operational Safety Instruction OSI 11/03 requires that new vehicles shall conform to the latest European emission regulation for that class of vehicle, e.g. Euro III for On Highway Vehicles, and 97/68/EG Step II for Non-Road Mobile Machinery. Also, these vehicles must be less than 5 years of age. The maximum age for any NRMM operating at Heathrow is 15 years unless fitted with abatement technology where the limit is extended to 20 yrs. Manufacturers/sales indicate lifespan of GPU and airstarts at 15-20 yrs. Lifespans for other equipment was obtained by questioning airside equipment suppliers in the UK. These were Falcon Airside, Owen Holland and Airside Airport Equipment. Frequently the lifespan of individual pieces of equipment is limited by factors other than the operational life of the equipment. For example at BAA airports there are limits on the age of airside NRRM (see age above). For some equipment e.g. de-icers technology improvements render the equipment useless prior to the end of its normal operational life.

The detailed individual equipment types shown in Table 3.3 were assigned to categories of either ‘Airport ground support equipment’ or ‘Terminal tractors’ to match the machinery classes specified by DfT for this study and to match the emission factor classification used in the NAEI. Emission factors are not available for these individual classes of airport machinery. A weighted average for power rating, annual usage, lifetime, fuel consumption and load factor was obtained by weighting the individual equipment types by the total hours operated for all units. These summary figures are given in Table 3.4.

Table 3.4: Population and activity data for groups of airport machinery derived from data for detailed classes of machinery weighted by hours of use.

Category	Average Power rating (kW)	Population (units)	Total annual hours operated (total unit.hours across all units)	Annual usage, hours/year	Useful Lifetime (Years)	Fuel consumption rate	load factor
Airport support	59	3827	15186905	3968	11	260	0.40
Terminal tractor	120	1622	2552122	1573	15	260	0.38

4 Cross-Checking of Estimates

4.1 COMPARISON WITH DATA FROM OTHER EU MEMBER STATES

Research institutions responsible for undertaking inventory studies similar to the present project in 10 other EU member states were contacted to ask whether they had undertaken similar work to obtain information on how off-road (NRMM) emissions inventories are compiled in other countries (see Appendix 1). In particular, information was sought on:

- What is the general approach taken by other countries in estimating emissions from these categories?;
- What the source of the activity data (equipment numbers and usage, equipment specific fuel consumption etc) used by other countries is (i.e. specialist survey, trade associations, national statistics, expert estimates etc), and how often is this updated?;
- Whether countries perform any cross checking procedures and if so, how?

An informal questionnaire was sent out to inventory experts from 10 existing and new EU Member States. Four replies were received in the time available for this task (one from Finland, one from France and two from Germany).

A useful overview of work done in these three countries was provided. It is clear that Finland, France and Germany use fundamentally the same approach as the NAEI in calculating national emissions from the off-road sector, but in varying degrees of machinery detail and with varying prospects for cross-checking. Finland uses engine population estimates based on sales and survival rates using a 'median life' assumption – the engine age where half of the engines have been scrapped. Activity data are broken into two parts: an active first phase and a less active latter phase assuming usage rates of half of the annual usage hours of the active phase. This is a 'bottom up' method, but no mention was made of any cross-checking against national fuel use statistics.

France uses a 'top-down' approach to split fuel consumption in major categories (e.g. industry, agriculture, domestic etc.) into sub-categories including machinery. The allocation of fuel consumption to machinery is on the basis of 'fleet' statistics, but not at a detailed equipment level. A regular survey is carried out for agricultural machinery, but for other machinery no statistics are available and estimates of the fleet are made from expert advice.

Germany uses a detailed 'bottom-up' approach based on population, usage, engine load factor and engine power. Most data sources are national statistics, surveys, expert opinion and data from manufacturers. The most detailed information is available for the agriculture and construction sectors. Data gaps in population are filled using sales figures. Usage and engine power data are taken from trade associations and specifications. Germany has fuel consumption data for non-taxed diesel used by the agricultural sector and finds this consistent with fuel consumption calculated with this bottom-up approach based on population. Fuel data for other machinery sectors are not available for cross-checking purposes.

The Finnish contact provided data with which to compare the estimates made in the present study. Finnish data on machinery population sizes was rescaled to give a "UK equivalent" population with which to compare the estimates made in this study. This was achieved by scaling the Finnish data in line with the ratio between the UK and Finnish GDP, population figures, or in the case of agriculture, according to the two countries' relative extents of agricultural and forestry land.

Comparison of the estimates made in this study with the Finnish estimates indicated that some parameters may have been underestimated, whilst other may have been overestimated by a significant margin. As regards population estimates, the comparison suggest that the present study may have significantly overestimated the UK population of portable generators, telescopic handlers and compressors, whilst underestimating the populations of excavators, wheeled loaders and graders. Estimates of the UK population of agricultural tractors and combines appeared disproportionately low compared with Finnish figures, but this could be due to differences in the agricultural sectors in the two countries. There may also be differences in the industry and construction sectors between the two countries making comparisons difficult.

As mentioned above, a key variable in estimating fuel use by NRMM is the assumed loading factors for each type of machinery. It is necessary to know on average what proportion of maximum power a piece of machinery is usually used at. Typically it is found that machinery such as generators which run at fairly constant speeds for much of the time normally operate at a high percentage loading, perhaps 50%-70%. In contrast machinery used at highly variable machine speeds often works on average well below maximum rated power, perhaps only 20%-30%. The NAEI has generally used loading factors of around 50% for all machinery. The Finnish work uses lower values for many machine types.

The Finnish work provided useful estimates of loading factors which have been used in this study. It is therefore recommended that consideration be given to whether the Finnish estimates of typical loading rates are relevant to the situation in the UK. Whereas machinery designed to operate at a fairly constant loading for a high proportion of its usage time, such as generators, were assumed to operate at average loadings of over 50%, other machinery such as construction site equipment which operate at variable loading, were assumed on average to operate at much lower loading rates of, for example, 30%.

As regards the average power rating, annual usage rates and lifetimes, it is not clear to what extent the Finnish data will be comparable with the UK situation. No major disparities were identified between average power ratings quoted for the Finnish fleet, and the annual usage rates in hours per year estimated in this study fell within the ranges quoted by the Finnish sources. However, the lifetimes quoted by Finnish sources were significantly longer than those estimated in this study.

Insufficient evidence is currently available to assess whether these parameters are likely to be similar in Finland and the UK.

4.2 FUEL USE CROSS CHECK

Once best estimates and estimate ranges had been determined for the UK population, typical annual usage and average lifespans for as many equipment types as possible, the estimates were tested by cross-checking them against fuel use figures supplied by the oil industry. For each machinery type, estimates of population, average power rating, load factors and annual usage figures were combined with fuel consumption factors in g/kWh to derive estimates of total annual UK consumption of red diesel for each machinery type. These totals in turn were summed to provide an overall estimate of UK annual consumption of red diesel across all NRMM types. A range and best estimate of overall fuel consumption was derived, and the uncertainty of the estimates tested using a probabilistic Monte Carlo-type software tool.

The fuel consumption factors used in this analysis are those used for the NAEI and are based on European emission inventory data sources including CORINAIR (1999) and Samaras (1996). Estimates of fuel consumption for some types of machinery not covered in the NAEI category 'off-road sources' were also included.

Appendix 4 summarises the assumed fuel consumption factors and loading factors used in this assessment.

4.2.1 Assessment of likely range of fuel consumption figures

The impact of uncertainty on the calculated fuel consumption by non-road mobile machinery was investigated using risk analysis software (@Risk™). This approach involved the use of probability distribution functions to describe input parameters in the calculation of fuel consumption rather than discrete values. The probability distribution functions were chosen from a selection of generic types (e.g. triangular or rectangular) but all types require the minimum value and maximum value for a given parameter to be defined, together with some other measure or measures such as the mean or mode of the distribution.

The software tool then performed a calculation by sampling individual data values from each of the probability distributions on the basis of probability density and entered these values into the fuel consumption calculation. The resulting fuel consumption estimate is recorded and then this process is repeated many times (20,000 iterations were used for the analysis) in order to build up an output distribution of the estimated fuel consumption.

The probability distribution functions for each parameter were chosen either to reflect the variation in the available data or by expert judgement. For example, if two estimates are available for the annual usage rate for a particular machinery type, the lower value might be used as a minimum value, the other value taken as the maximum value, with the mean of the two estimates used as the mean of the probability distribution. In many cases, only a single estimate has been obtained for a parameter, and, in general, this estimate has been taken as the mean of a triangular distribution, with the minimum and maximum values assumed to be a fixed percentage lower and higher than the mean (usually a figure of 30% is used).

The mean value for the calculated fuel consumption was recorded, as well as the 95% confidence limits i.e. the fuel consumption at the 2.5% cumulative probability and the 97.5% cumulative probability. The results are tabulated below:

	Fuel consumption, Mtonnes		
	2.5 percentile	Mean	97.5 percentile
Total, excluding railway locomotives	3.27	3.80	4.37
Total, including railway locomotives	3.62	4.16	4.76

4.2.2 Comparison with fuel use statistics

Having determined the likely range and best estimate of fuel consumption by NRMM, this was compared to figures independently estimated by the oil industry prior to this study. The petroleum industry's trade association UKPIA (UK Petroleum Industry Association) and one of its members, a petrochemical company believed to represent approximately 15% of the UK market share in fuel sales, had both conducted their own market research into the likely quantities of red diesel consumed annually in the UK by the off-road machinery sector. Both these studies were based on a limited survey of a representative sample of their customers. Both surveys independently concluded on a likely approximate figure of 2 million tonnes of red diesel being consumed in the UK per year by off-road machinery. It is understood that this figure excludes consumption by the rail industry. It is not known how up-to-date this research is. However, it is believed that it was undertaken within the last 5 years.

Comparison of this figure with the fuel consumption estimates made in this study (mean consumption of 3.8 million tonnes per year, (excluding rail)) indicate that the population and activity data arising from this study leads to an overestimate in the fuel consumption of red diesel by the UK NRMM sector by a factor of up to 2. The petroleum industry estimate is also below the lower end of the estimate range of 3.3Mt.

Given the uncertainties in many of the estimates made during this study, any of the parameters estimated in Tables 3.1-3.3 could have been overestimated. The population estimates have generally been based on figures provided by official government records, trade association records or operator databases. It is therefore unlikely that the uncertainty in the population figures is of such a large order of magnitude in most cases.

It is however possible that significant errors in estimation of average power rating of equipment, average power loading (percentage of maximum power) during use, in annual usage rates and lifetimes could have compounded to give this large disparity. For example, a 20%-30% overestimation of all 4 of these parameters systematically across all machinery types can lead to an overall 2-fold overestimation of fuel consumption. Further to this there are likely to be errors in the population figures and in the average fuel consumption factors. This therefore highlights the need to minimise the uncertainties as much as possible for as many machinery types as possible.

It should be noted that the NAEI has previously used fuel consumption estimates provided by Dti for specific NRMM sector groups to adjust fuel consumption and emission estimates based on population and usage data for off-road machinery. On a sectorial basis the Dti figures were from 2-50 times lower than the NAEI-calculated fuel consumption estimates prompting a corresponding scaling down in the calculated emission estimates on the basis that the Dti figures were reliable. However, discussions with Dti during this project revealed that they have little confidence in their sectorial split in the provision of gas oil to different industries and other user groups. The Dti sectorial breakdown is based on a very old survey. It is therefore recommended that the NAEI no longer cross-check estimated fuel consumption based on population and usage or adjust emissions for sector groups using the Dti data, but further surveys of the quantities of gas oil (red diesel) used in the UK specifically for off-road machinery is recommended.

4.3 DISTIBUTION CHAIN FOR NON-ROAD GAS OIL (RED DIESEL) IN THE UK

Accurate data for annual consumption of low-tax diesel for off-road purposes (commonly referred to in the UK as red diesel, or non-road gas oil) were not possible to identify owing to the fact that the distribution networks for road diesel and red diesel are entirely separate following production at the oil refinery. Road diesel is required to have a lower sulphur content than red diesel, and therefore the two fuels are formulated as separate products from crude oil at the refinery. Road diesel is generally produced from oil distillates from which it is easiest to remove any sulphur. Red diesel can also be produced from the same distillate fractions, but is more usually made from other distillate products from which it is harder to remove the sulphur, and which are produced from the cracking of heavier distillate.

Once the fuels have been formulated in the refinery, the red diesel is dyed red to ensure it is not confused with higher quality road diesel, and the duty to be paid to Customs and Excise is then established on the basis of a higher duty rate for road diesel and a lower rate for red diesel. Duty is levied on the fuel leaving the refinery, with road diesel then being distributed via a network of approximately 50 distribution depots, whilst red diesel is distributed through a separate chain of a very large number of outlets. As red diesel has a variety of uses other than for NRMM, such as for heating systems, and since the outlets do not keep records of the end-use, nor the end-user of the fuel, it is extremely difficult to establish accurately the quantities of red diesel consumed by the NRMM sector.

Furthermore, there are also examples of post-distribution cross-over between the two fuels. This would include, for example, fuel sold from 5 locations in the UK which are permitted to sell road diesel as red diesel at the appropriate duty rate, for use for example by Eurotunnel maintenance vehicles. Conversely, there are also understood to be local agreements with Customs and Excise at a number of locations, such as airports, where it has been permitted to use red diesel as fuel in non-DVLA registered road-worthy airside vehicles. However, it is understood that these uses represent a small proportion of the total quantities of either fuel used.

5 Conclusions and Recommendations

5.1 GENERAL CONCLUSIONS AND RECOMMENDATIONS

This study has derived estimates for the UK population, annual usage rates in hours per year, engine power and average useful lifespan in years, for a number of specified types of non-road mobile machinery (NRMM), based on data supplied by stakeholders. There remain some machinery types relevant to the industry and construction sectors for which no data has been identified to date and therefore for which no estimates can be derived. In addition, confidence in the estimates derived is variable depending on the reliability of the source data used to derive them. Specific data gaps and uncertainties requiring further work are detailed below. In such cases, suitable stakeholders in the relevant sector should be consulted in order to attempt to improve on the estimates. In addition to clarifying uncertainties over population, usage and lifetime estimates, further consideration should be given to the validity and accuracy of fuel consumption factors, and of the loading factors used in the fuel-use cross checking procedure. In particular, the loading factors have been taken from work done in Finland, and may or may not be relevant to the UK situation.

A number of leads could be followed up which there was insufficient time to pursue within this project. The project covered a diverse range of machinery types, all with unique usage patterns, making it impossible to analyse in detail. Any further work should focus on specific machinery sectors (e.g. construction).

5.2 SECTOR-SPECIFIC CONCLUSIONS AND RECOMMENDATIONS

5.2.1 Industry and Construction

There remain a number of machinery types for which currently little or no data exists on the UK population, typical lifespan and usage patterns. In particular a high priority is to improve characterisation of the data for portable generators. Population estimates are based on data derived from PRODCOM reports and contain considerable uncertainty. The PRODCOM data is also based on data for all generators, and it is not clear what proportion may be considered portable.

Further consideration for machinery types across the sector needs to be given to typical lifespan and usage patterns as it is considered that annual usage may have been overestimated for some machinery types. In particular, further expert opinion needs to be sought on typical loading factors. For example, a bulldozer may be rated at 100kW power, but it may actually only work at a small fraction of this power rating most of the time. Figures provided from equivalent research undertaken in Finland suggest that this may be the case.

Further consideration should also be given to the proportion of each NRMM population which is hired out by plant hire firms, and to what proportion of the time typically the machine is actually on hire.

A wide range of possible leads could be pursued with more time, which might lead to further information which would assist in better characterisation of the estimates made in this project. For example, commercial organisations such as JCB offered to provide help and information, but were unable to respond during the timescale for reporting on this current work. Other possible further sources of useful information include:

- Highways Agency
- Port Authorities
- Utility companies
- Mining and quarrying associations
- Maintenance and servicing records, part suppliers and warranty providers for NRMM
- Quantity surveyors
- VOSA (formerly vehicle inspectorate)
- Local authority planning applications, fleets and licences to operate

5.2.2 Agriculture

Reasonably robust datasets have been sourced for both agricultural tractors and combine harvesters for all three variables of population, usage and lifetime estimates. The parameters presented in this report should not each be viewed in isolation, but together they form an internally consistent set of parameters for use in calculating emissions from the national population of tractors and combines.

Less data were available for other agricultural machinery types within the timescale of this project, but opportunities to gather further data for these and tractors and combines may be possible in future. The next DEFRA farm survey will be carried out in 2005 which may be a prime opportunity to gather data on many agricultural equipment types. Should additional resources be made available to the Agricultural Engineers Association there is a possibility that more detailed information could be obtained from this source.

5.2.3 Mobile Refrigeration Units

There is only limited availability of data for this sector. An expert estimate of activity levels, fuel consumption etc was obtained from one of the main UK trade association in the field of transport of temperature-controlled foodstuffs and goods.

It is probable that a more precise estimate of refrigeration unit numbers could be obtained were a fuller survey to be performed. This could for instance involve approaching the main fleet operators, maintenance and installation firms, and refrigerant providers who supply the transport sector to obtain firmer estimates on activity. However, given the large number of operators in the sector, any questionnaire process could not be comprehensive, and it is likely that a significant degree of uncertainty would still remain in any revised estimate obtained.

5.2.4 Rail

It has not been possible to verify the annual average distance travelled (for freight only), useful lifetime and annual hours of use. However the figures have been compiled from experts that work in the rail industry and so it is likely that the figures are reasonable estimates. However it should be noted that the kilometre figures provided by AEAT Rail for passenger trains were not in all cases very similar to the data provided by ATOC which was based on TOCs' actual data.

It is recommended that actual annual freight train kilometre figures be obtained from freight operators. The annual hours of use were compiled by AEAT Rail from estimated duty cycles and % of time in use. Whilst these estimates are thought to be reasonable, ideally actual figures would be obtained from the passenger and freight train operating companies.

5.2.5 Aviation

Estimates have been made of the UK populations, lifetimes and annual usage rates of a wide variety of airport support equipment. Population figures for all equipment types, and usage rates for support equipment have been made on the basis of data supplied by UK airports representing over 50% of UK annual aircraft movements. Further confidence in the figures could be provided by a more extensive and detailed survey of airports covering the majority of movements. This would also allow greater characterisation of the differences between larger airports and smaller ones.

In addition, greater uncertainty exists in the figures for ancillary and maintenance vehicles. Nevertheless, the 'contained' nature of the machinery used at airports gives relatively high confidence in the figures at a national level compared with any other machinery types. It also suggest good prospects for attaining a more accurate assessment via targeted surveys.

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The project team was:

Martin Adams (mobile refrigeration units)
Clare Collier (airports)
Geoff Dollard
Chris Dore (agriculture)
Kate Haigh
Melanie Hobson (rail and industry)
Jim McGinlay
Tim Murrells
Neil Passant (industry)
Sue Powditch
Ian Roberts (agriculture)
Susan Wood (agriculture)

Appendices

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Appendix 1 Stakeholders consulted during the project
Appendix 2 Methodology for calculation of annual usage and lifetime for agricultural machinery
Appendix 3 Rail Statistics
Appendix 4 Data for fuel use cross-checking

Appendix 1
Stakeholders

CONTENTS

Appendix 1 List of stakeholders contacted during the course of the research

Appendix 1 – Stakeholders Consulted during this Study

UK Government Bodies

DEFRA
Department for Trade and Industry Dti – Fuels Group
Department for Transport (DfT)
DRDNI
DVLA
Highways Agency
HM Customs and Excise (HMCE)
HSE
Office of National Statistics (ONS)

EU Member State Research Institutes

The following EU research agencies were contacted and provided information for this project:

Finnish Environment Institute
Umweltbundesamt - German Federal Environmental Agency
IFEU Institute for Energy and Environmental Research - Germany
CITEPA:Centre Interprofessionnel Technique d'Etudes de la Pollution Atmosphérique, France

In addition the following other EU research agencies were contacted:

Directorate General - Instituto do Ambiente - Portugal
Mininsterio de Medio Ambiente - Spain
National Environmental Research Institute - DK.
Estonian Environment Information Centre
Swedish Environmental Protection Agency
Umweltbundesamt- Austrian Federal Environmental Agency
Norwegian Pollution Control Authority

Market Research Companies

Off Highway Research

Industry and Construction

A-Plant
AMPS
British Compressed Air Society (BCAS)
British Industrial Truck Association (BITA)
Civil Engineering Contractors Association (CECA)
CNH
FG Wilson
Hewden
JCB
Major Contracting Group
National Specialist Contractors Council
Swan Generators
UKPIA (UK Petroleum Industry Association)
Woodland Generators

Agriculture

AGCO Ltd (Massey Ferguson)
Agricultural Engineers Association (AEA)
Dr John Nix, Imperial College, London – Wye Campus, Kent
Forestry Commission
John Deere Ltd
National Farmers Union (NFU)

Mobile Refrigeration Units

The Chartered Institute of Logistics and Transport;
The British Refrigeration Association;
The Road Haulage Association;
Temperature Controlled Storage and Distribution (a journal);
Institution of Diesel and Gas Turbine Engineers; and
Transfrigoroute UK

Rail

AEA Rail
Association of Rail Operating Companies (ATOC)
EWS

Aviation

British Airports Authority (BAA)

Airports contacted and from whom responses were received were:

Birmingham Airport
Blackpool Airport
Bristol Airport
Cambridge Airport
Cardiff Wales Airport
Coventry Airport
Exeter Airport
Glasgow Airport
Glasgow Prestwick Airport
Guernsey Airport
London City Airport
London Gatwick Airport
London Heathrow Airport
Luton Airport
Newcastle Airport

Airside Equipment suppliers contacted included:

Airside Airport Equipment
Falcon Airside
Owen Holland

Appendix 2
Agriculture

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Appendix 2	Methodology for calculation of annual usage and lifetime for agricultural machinery.

Illustration of Methodology for Average Agricultural Tractor Usage and Lifetime in the UK

The following methodology was used to calculate average tractor and combine usage hours and lifetimes in the UK. Unfortunately, data for the other machinery types covered in the agricultural area were not calculated due to lack of available data.

The source data for both tractors and combines drew on the set of data provided by Nix (2004) and from DEFRA ("Agriculture in the UK 2003" tables 3.1 UK agricultural land use, 3.2 UK crop areas and livestock numbers).

To calculate total useful lifetimes for both tractors and combines in the UK, the total number of tractor or combine hours required per year was initially calculated for each farming task based on land use data. This figure was then divided by the total UK population of tractors or combines to give the average machine hours of use per year per tractor or combine. This figure was then used to decide average lifetime for each machine type by checking against tables of "Estimated Useful Life" in Nix (2004) (years of power operated machinery in relation to annual use).

More detailed methodologies used for tractor and combines are split into two sections below as they differ slightly. For example, Nix provided actual machine hours per annum per hectare of different crops for tractors, and only labour hours per annum per hectare for combines which required additional work to extract combine hours per annum per hectare.

Tractors

The annual hours of use of a tractor was calculated by using "Agriculture in the UK 2003" from DEFRA and Nix (p158). The total tractor hours spent attending livestock plus the total tractor hours spent on arable land resulted in the average tractor working hours being 812 hours a year per tractor.

For this machine group it was calculated that the useful lifetime of an average tractor is 11 years. This figure is based on tables in Nix (p162) showing the estimated useful life in relation to annual use (hours). The annual use was based on an average tractor working 812 hours a year.

The following Steps illustrate how the above figure of 812 hours was calculated and therefore a lifetime of 11 years were arrived at. Please note that various assumptions about the data had to be made where there was either missing data or a specific problem in aligning the data from Nix and DEFRA.

1) For each ***UK crop type*** the total tractor years was calculated as follows:

For example Nix provides an average 9 hours spent per hectare per year on cereal crops, and the "Agriculture in the UK 2003" shows 3,059,000 hectares of cereal crop area in the UK in 2003. Therefore multiplying both total area and average hours spent per hectare for cereals results in a figure of 27,531,000 tractor hours worked on cereals. This process was then repeated for other crops to give total average tractor years for arable land, which was 8,923 years.

2) For each ***UK livestock category*** the total tractor years was calculated as follows:

For example, Nix provides an average 6 hours spent per head of dairy cow per year and the "Agriculture in the UK 2003" shows 2,192,000 heads of dairy cows in the UK in 2003. Therefore multiplying both total number of livestock and average hours spent per head for diary cows results in a figure of 13,152,000 tractor hours worked on diary cows. This process was then repeated for other livestock to give total average tractor years for farming livestock, which was 13,131 years.

3) The total tractor hours for arable and livestock farming were then combined to give the total number of tractor years spent by tractors tending UK agriculture in 2003 (13,131+8,923 = 22,054 tractor years). This figure was then divided by the total number of tractors in the UK which is 237,865 giving the average figure of 812 hours per year for each tractor.

Combines

For this machine group it was calculated that the useful lifetime of an average combine is 7 years. This figure is based on Nix (p162) and the estimated useful life in relation to annual use. The annual use was based on an average combine working 332 hours per year.

The annual hours of use of a combine was calculated using "Agriculture in the UK 2003" from DEFRA and Nix (p131-143).

The following Steps illustrate how the above figure of 332 hours was calculated and therefore a lifetime of 7 years were arrived at. Again, various assumptions about the data had to be made where there was either missing data or a specific problem in aligning the data from Nix and DEFRA.

1) Nix only provided data on man labour hours per hectare for different crops which include operations involving combines along with other seasonal tasks such as barn work and carting grain, rather than providing exact combine machine hours. The number of labour hours per hectare covering all seasonal operations on a given crop was divided equally among all the operations involved on the crop. For example, the average labour hours per hectare on winter cereals was 2.5 hours and involved 3 seasonal operations. It was assumed therefore that one-third of this time was spent on combine work, equivalent to 0.83 hours per hectare of combine work on winter cereals. The average for all cereals was 0.82 hours per hectare.

2) For each ***UK crop type*** the total combine years was calculated

For example, Nix provides an average 0.82 hours spent per hectare per year on cereal crops, and the "Agriculture in the UK 2003" shows 3,059,000 hectares of cereal crop area in the UK in 2003. Therefore multiplying both total area and average hours spent per hectare for cereals results in a figure of 2,508,000 combine hours worked on cereals. This process was then repeated for other crops to give total average combine years for arable land, which was 479 years.

3) The figure of 479 combine years was then divided by the total number of combines in the UK which is 12,630 giving the average figure of 332 hours per year for each combine.

Appendix 3
Rail

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Appendix 3	Statistics for passenger and freight trains

Table A3.1: Passenger train statistics.

Train type	Power rating (kW)	Population estimate (number of engines)	Annual average distance travelled (km)	Useful lifetime (years)	Annual hours of use
Class 43 (HST)	1680	159	251,480	35	1,708
Class 142	172	95	106,355	29	1,805
Class 143	172	50	92,164	29	1,805
Class 144	172	56	90,944	28	1,805
Class 150	213	274	111,600	35	1,869
Class 153	213	70	111,860	32	1,869
Class 155	213	14	115,904	32	1,869
Class 156	213	228	120,567	32	1,869
Class 158	260	361	167,226	35	1,915
Class 158 (cambrian)	300	20	158,857	35	1,915
Class 159	300	66	206,957	33	1,915
Class 165	260	179	122,535	33	1,915
Class 166	260	63	171,646	31	1,915
Class 168	318	70	117,438	37	1,869
Class 170	318	352	174,772	41	1,949
Class 175	335	70	290,125	35	1,949
Class 180	559	70	109,380	33	2,333
Class 220	559	136	229,205	32	2,255
Class 221	559	216	241,787	31	2,255
Class 222	559	127	200,000	30	1,850

Note Data for HSTs (High Speed diesel trains) are highly uncertain.
Sources of information: Power rating and population: Data obtained from AEAT Rail using 'British Railways Locomotives and Coaching Stock, 2003' Platform 5 Publishing Ltd.
Distance travelled - information provided by the ATOC, apart from for Class 222 (see above).
Useful lifetime & annual hours of use - information supplied by AEAT Rail based on their best judgment.

Table A3.2: Freight train statistics.

Train type	Power rating (kW)	Population estimate (number of engines)	Annual average distance travelled (km)	Useful lifetime (years)	Annual hours of use
Class 08	298	280	5,860	58	146
Class 09	298	36	5,860	54	146
Class 20	746	42	63,292	56	259
Class 31	1100	52	11,721	50	168
Class 33	1160	21	11,721	46	168
Class 37	1300	245	82,045	48	378
Class 47	1920	260	46,883	43	263
Class 56	2462	111	82,045	28	252
Class 57	1860	13	93,766	41	336
Class 57	2050	16	93,766	52	336
Class 59	2460	14	82,045	24	752
Class 60	2313	100	82,045	29	752
Class 66	2385	352	93,766	30	934
Class 67	2385	30	93,766	29	752
Class 73	448	37	469	40	57

Sources of information: Power rating & population: Data obtained from AEAT Rail using 'British Railways Locomotives and Coaching Stock, 2003' Platform 5 Publishing Ltd.
Other information supplied by AEAT Rail based on their best judgment.

Appendix 4
Cross-Checking Data

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Appendix 4	Loading factors and fuel use factors used in estimating total annual red diesel consumption by NRMM in the UK

Table A4 - Loading factors and fuel use factors used in estimating total annual red diesel consumption by NRMM in the UK

Machine Type	Class	Fuel consumption rate (g/kWh)	Loading factor		
			Best	Low	High
Industry and Construction					
Portable Generators 5-100kW	1	269	50%	35%	65%
Portable Generators 100-1000kW	1	254	50%	35%	65%
Forklift (non-RTF)	2	265	30%	21%	39%
Rough Terrain Forklifts (RTF)	2	265	30%	21%	39%
Telescopic Handlers	2	260	27.5%	19.25%	35.75%
Backhoe Loaders	2	260	32.5%	22.75%	42.25%
Mini Excavators	2	269	40%	28%	52%
Wheeled excavators		260	30%	21%	39%
Crawler excavators		260	32.5%	22.75%	42.25%
Access Platforms	3	269	30%	21%	39%
Air Compressors	3	265	60%	42%	78%
Wheeled Loaders	3	269	30%	21%	39%
Gas Compressors	4	265	60%	42%	78%
Rigid dump trucks		254	30%	21%	39%
Articulated dump trucks		254	30%	21%	39%
Cranes	4	254	20%	14%	26%
Bulldozers	4	260	37.5%	26.25%	48.75%
Asphalt Pavers	5	265	35%	24.5%	45.5%
Paving Equipment		269	70%	49%	91%
Skid-Steer Loaders	5	260	25%	17.5%	32.5%
Crushing/Processing Equipment		269	50%	35%	65%
Tracked Loaders	5	260	35%	24.5%	45.5%
Graders	6	260	35%	24.5%	45.5%
Scrapers	6	254	30%	21%	39%
Mobile Refrigeration Units					
Refrigeration unit engines on HGVs	1	260	60%	42%	78%
Agriculture					
Agricultural Tractors	1	265	30%	21%	39%
Combines	2	265	57.5%	40.25%	74.75%
Trains - Passenger					
Class 43 (HST)	1	260	40%	28%	52%
Class 142	1	260	40%	28%	52%
Class 143	1	260	40%	28%	52%
Class 144	1	260	40%	28%	52%
Class 150	1	260	40%	28%	52%
Class 153	1	260	40%	28%	52%
Class 155	1	260	40%	28%	52%
Class 156	1	260	40%	28%	52%
Class 158	1	260	40%	28%	52%
Class 158 (cambrian)	1	260	40%	28%	52%
Class 159	1	260	40%	28%	52%
Class 165	1	260	40%	28%	52%
Class 166	1	260	40%	28%	52%
Class 168	1	260	40%	28%	52%
Class 170	1	260	40%	28%	52%

Machine Type	Class	Fuel consumption rate (g/kWh)	Loading factor		
			Best	**Low**	**High**
Class 175	1	260	40%	28%	52%
Class 180	1	260	40%	28%	52%
Class 220	1	260	40%	28%	52%
Class 221	1	260	40%	28%	52%
Class 222	1	260	40%	28%	52%
Trains - Freight					
Class 08	1	260	40%	28%	52%
Class 09	1	260	40%	28%	52%
Class 20	1	260	40%	28%	52%
Class 31	1	260	40%	28%	52%
Class 33	1	260	40%	28%	52%
Class 37	1	260	40%	28%	52%
Class 47	1	260	40%	28%	52%
Class 56	1	260	40%	28%	52%
Class 57	1	260	40%	28%	52%
Class 57	1	260	40%	28%	52%
Class 59	1	260	40%	28%	52%
Class 60	1	260	40%	28%	52%
Class 66	1	260	40%	28%	52%
Class 67	1	260	40%	28%	52%
Class 73	1	260	40%	28%	52%
Airports					
Air conditioning unit	3	260	60%	42%	78%
Airstart	3	260	50%	35%	65%
Ambulift	3	260	30%	21%	39%
Baggage conveyor	3	260	50%	35%	65%
Baggage loader	3	260	30%	21%	39%
Baggage tractor	3	260	30%	21%	39%
Buggy	3	260	40%	28%	52%
Bus	3	260	40%	28%	52%
Cabin heaters	3	260	50%	35%	65%
Cargo loader	3	260	30%	21%	39%
Caterlift	3	260	30%	21%	39%
Dec loader	3	260	30%	21%	39%
Deicer	3	260	50%	35%	65%
Elevator	3	260	50%	35%	65%
Flatbed	3	260	40%	28%	52%
FMC platform	3	260	50%	35%	65%
Fuel bowser	3	260	40%	28%	52%
Griptester	3	260	50%	35%	65%
Gritter	3	260	40%	28%	52%
Ground power unit	3	260	50%	35%	65%
Heater	3	260	50%	35%	65%
Hilift	3	260	30%	21%	39%
Hoist	3	260	30%	21%	39%
Hoselayer	3	260	40%	28%	52%
Hydrant cleaner	3	260	50%	35%	65%
Lift	3	260	30%	21%	39%
Lower deck loader	3	260	30%	21%	39%
Main deck loader	3	260	30%	21%	39%

Machine Type	Class	Fuel consumption rate (g/kWh)	Loading factor		
			Best	Low	High
Mallaghan	3	260	30%	21%	39%
Piler	3	260	50%	35%	65%
Pump	3	260	50%	35%	65%
Pushback tug	3	260	40%	28%	52%
Road sweeper	3	260	40%	28%	52%
Snow blower	3	260	40%	28%	52%
Snow cutter	3	260	40%	28%	52%
Snow equipment	3	260	40%	28%	52%
Snow plough	3	260	45%	31.5%	58.5%
Snow sweeper	3	260	40%	28%	52%
Spreader	3	260	40%	28%	52%
Steps	3	260	50%	35%	65%
Tipper truck	3	260	30%	21%	39%
Toilet bowser	3	260	40%	28%	52%
(Terminal) tractor	3	260	30%	21%	39%
Transporter	3	260	40%	28%	52%
Tug	3	260	40%	28%	52%
Water bowser	3	260	40%	28%	52%
	3				
Other NRMM Categories from NAEI					
Leaf blowers/vacuums	d	271	50%	35%	65%
Ride on (commercial)	d	271	40%	28%	52%
Lawn and garden tractors	d	271	30%	21%	39%
Commercial turf equipment	d	271	40%	28%	52%
Pumps	d	271	50%	35%	65%
Welding equipment	d	269	50%	35%	65%
Pressure washers	d	271	50%	35%	65%
Sweepers/ scrubbers	d	271	40%	28%	52%
Other general industrial equipment	d	271	50%	35%	65%
Concrete pavers	d	265	40%	28%	52%
Paving equipment	d	269	40%	28%	52%
Surfacing equipment	d	269	40%	28%	52%
Signal boards		260	50%	35%	65%
Bore/drill rigs	d	254	50%	35%	65%
Concrete /industrial saws	d	269	50%	35%	65%
Cement & mortar mixers	d	271	50%	35%	65%
Crawler tractors	d	260	35%	24.5%	45.5%
Off highway tractors	d	265	25%	17.5%	32.5%
Agricultural mowers*	d	271	40%	28%	52%
Sprayers	d	271	40%	28%	52%
Balers*	d	271	40%	28%	52%
Tillers > 5 bhp	d	271	40%	28%	52%
Swathers	d	271	40%	28%	52%
Hydro-power units	d	271	50%	35%	65%
Other agricultural equip	d	271	40%	28%	52%
Shredders > 5 bhp	d	269	50%	35%	65%
Skidders	d	265	40%	28%	52%
Fellers/bunchers	d	269	40%	28%	52%