

Report

Emission factors programme Task 8c – emissions from non- road mobile machinery in the lawn and garden sector

Report to the Department for Environment
Food and Rural Affairs; the National Assembly
of Wales; the Scottish Executive; and the
Department of Environment in Northern Ireland

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Executive Summary

This report has been prepared for the Department for the Environment, Food and Rural Affairs; the National Assembly of Wales; the Scottish Executive; and the Department of Environment in Northern Ireland by **netcen** (an operating division of AEA Technology plc) under the contract EPG 1/3/195 - Emission factors for air pollutants.

The Department for Environment Food and Rural Affairs (Defra), Air and Environment Quality (AEQ) Division is responsible for maintaining the UK National Atmospheric Emissions Inventory (NAEI). The NAEI is maintained by **netcen** on behalf of Defra. As part of the ongoing quality control of the NAEI the quantitative uncertainty in the national emission total of each component pollutant in the NAEI is reviewed annually. Based on the findings of this review, project EPG 1/3/195 aims to characterise and minimise uncertainty in the emission factors used in the compilation of the NAEI. The project objectives (Tasks) are set and reviewed annually; these comprise data collection and evaluation via literature review, personal contact with industrial representatives, direct source measurement and other means as appropriate.

Task 8c is a desk-based study into the quality of emission factors pertaining to non-road mobile machinery used in the lawn and garden sector. Obtaining data in this sector is particularly topical due to the introduction of EU Directive 2002/88/EC, which contains new emission limits for spark ignition internal combustion engines in non-road mobile machinery. As controls over emissions from other, larger, emission sources such as road transport increase, the overall contribution of the historically lower emitter sectors becomes increasingly important and demands greater attention.

The research included the gathering of information via telephone and e-mail contact with trade associations, manufacturers and government bodies, and small pieces of web based research. New data has been identified for:-

- Emissions factors for spark ignition engines
- Emission degradation factors for spark ignition engines

Gaps in new emission data were identified for certain types of machinery or specific pollutants. In addition to these gaps, there are still a number of areas where more research would be needed to identify any new data. This includes data characterising the activity statistics in the lawn and garden sector, such as machinery population, lifetime and hours of use.

From the data identified, changes have been recommended to emission factors in the NAEI model for current generations of non-road mobile machinery in the lawn and garden sector. The impact this has on predicted emissions for the sector has been calculated. The new emission factors are generally lower than ones currently used in the NAEI (especially for VOCs) and are assumed to apply to more modern equipment models. But further reductions in emissions from many of these machines will be required to meet more stringent EU standards, particularly VOC and CO emissions from 2-stroke equipment. The effect of the new emission factors and the future limit values on projected emissions from the UK garden machinery sector has also been modelled.

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1 Introduction

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Task 8c is a desk-based study into the quality of emission factors pertaining to non-road mobile machinery used in the lawn and garden sector. The aim of the task was to improve the confidence that an inventory user may place in the estimate of the mean emission factors within the NAEI for this sector. The work was undertaken via telephone and e-mail contact with trade associations, manufacturers and government bodies.

The improvement of the inventory data for this part of the non-road mobile machinery sector has been driven according to the five key aspects of inventory data quality: -

Transparency – investigating and summarising the assumptions and measurement methodologies upon which the source data are based.

Completeness – the search for new data for non-road mobile machinery in the lawn and garden sector and review of current inventory data has identified where emission factors for equipment types are unavailable or where the equipment to which data relates is uncertain.

Consistency – Regarding the consistency of inventory data compared to data from previous years, the cross-checking of data from a range of information sources provides a simple insight into the likely accuracy of emission factors pertinent to non-road mobile machinery in the lawn and garden sector. The review of information sources goes some way to ensuring that the assumptions and measurement methods used to generate emission factors are based on consistent criteria.

Comparability – The study has involved comparison of NAEI data with other international inventories and research findings such as EMEP-CORINAIR data and European Commission reports. The NAEI is already designed to utilise consistent standardised formats and assessment methodologies, and this study has continued to maintain this approach.

Accuracy – The inherent uncertainties in any emission factor must be assessed to allow a reasoned judgement of the usefulness of the data. The non-road mobile machinery in the lawn and garden sector has been identified as an area that requires further investigation because of the perceived uncertainties in historic NAEI data. This study has sourced new research reports that have been specifically tailored to developing a better

understanding of the values and variability of emission factors for engines used in this sector. By assessing these reports, some improvements to specific emission factors have been recommended. In addition, key areas have been identified that may require further research to improve accuracy of emission factors.

Obtaining data in this sector is particularly topical due to the introduction of EU Directive 2002/88/EC, which contains new emission limits for spark ignition internal combustion engines in non-road mobile machinery. As controls over emissions from other, larger emission sources such as road transport increase, the overall contribution of the historically lower emitter sectors becomes increasingly important and demands greater attention.

The structure of the report is detailed below :

Section 2 outlines the methodology followed by this research to focus the search for new information. From contact with trade associations, manufacturers and government bodies, and small pieces of web based research, new data has been identified for: -

- Emissions factors for spark ignition engines
- Emission degradation factors for spark ignition engines

From the data identified as a result of this research, changes are recommended to certain emission factors applied to particular equipment types in the lawn and garden machinery sector covered in the NAEI. These changes are detailed in **Section 3** where consideration is also given to the implications of the Directive 2002/88/EC on emission factors for future machinery used in the inventory. Within this new data there are still gaps in knowledge of emissions from certain types of machinery and these are identified in Section 3.

Section 4 shows the impact the changes to the emission factors has on calculated emissions for the sector and discusses these in the context of total UK emissions of VOCs, CO and NOx.

Section 5 provides conclusions of the research and recommends a number of areas where more research would be needed to further improve the inventory, particularly in areas covering the population and usage of machinery in the UK.

2 General Approach

2.1 SOURCING EXISTING DATA

The task included the gathering of information via telephone and e-mail contacts with trade associations, manufacturers and government bodies. At the start of the project, a number of research areas were identified, and these are detailed with associated key emissions. Before any new data could be compared with currently used data, the source of the current data within the inventory had to be confirmed. The files and reports believed to be the source of the data were checked against the inventory data with the following results.

2.1.1 Emission Factors

CORINAIR

The CORINAIR emission inventory guidebook (CORINAIR, 1996) has been identified as a significant source of inventory emissions data for non-road mobile machinery for the lawn and garden sector currently used in the NAEI. Matches between the two sets of figures are based on all engines being NADI (Natural Aspirated Direct Injection) and all spark ignition engine emission factors being based on uncontrolled emissions. The report was confirmed as the source of data for:

- Engine Design Weighting Factors for NO_x, CH₄, CO, particulate matter (hereafter referred to as PM) and NMVOC (hereafter referred to as VOCs) for compression ignition engines
- Emission degradation factors for all engine types for NO_x, CO, N₂O, VOCs and CH₄ (also PM for compression ignition engines)
- Baseline emission factors for all machinery types for NO_x, CO, N₂O and CH₄ (plus PM for compression ignition engines)
- Baseline emission factors for all machinery types for VOCs exhaust emissions except for:
 - o trimmers/edgers/bush cutters 2-stroke (hereafter referred to as 2sp)
 - o ride on machinery (domestic) 4-stroke (hereafter referred to as 4sp)
 - o lawn and garden tractors 4sp
 - o golf carts 4sp

Samaras

The source of the majority of CORINAIR figures appears to be a report by Samaras (1994), produced slightly earlier than the CORINAIR guidebook.

Additional, earlier (pre-1994 report) tables from Samaras have also been used for certain equipment types, despite being slightly less recent than the CORINAIR guidebook, due to greater certainty in the equipment types to which they applied, compared to the less prescriptive definitions of equipment provided by CORINAIR. The 2sp trimmers/edgers/bush cutters, and 4sp ride on machinery (domestic), lawn and garden tractors and golf carts are examples of this. A number of the VOC evaporation emission factors also match this earlier Samaras data.

Engine design weighting, or load factors for spark ignition engines were not an exact match with the Samaras data for all equipment types. There were matches for both

lawnmowers and chainsaws, but the form of the Samaras factors is unclear for lawn tractors and ride-on machinery.

2.1.2 Sales and Population

Research conducted in 1995 and 1998 by Precision Research International (PRI) is the current source of sales and population data in the inventory. The 1998 research provided more up to date figures for both two and four stroke engine lawnmowers and ride on lawnmowers and tractors.

2.1.3 Lifetime & Activity

The source of current activity data used in the NAEI was not identified but lifetimes, except those for lawnmowers were also provided by Precision Research International.

2.2 CONTACTS FOR NEW DATA

The research conducted by Precision Research International (PRI, 1995) included a list of organisations contacted in the lawn and garden machinery sector. This list formed the basis for the initial contact list for the current research (see Appendix 1).

2.2.1 General Requests

In this study, organisations were contacted by e-mail, with follow up calls made, to match the PRI methodology. The information request covered data for both spark ignition and compression ignition engines and all equipment types regarding: -

- Sales data
- Estimates of the population
- Emission factors
- Whether any abatement of emissions is applied to machinery now or is planned and resultant emission factors
- Degradation factors
- Estimates of lifetimes
- Estimates of the hours of usage/year
- Fuel consumption figures

There is a range of lawn and garden equipment in use. Though information on all types of equipment would have been useful, the research focused on obtaining data for lawnmowers and lawn and garden tractors as the current inventory showed these to be the most significant emitters among this group of machinery.

The pollutants of primary interest were VOCs, PM, NO_x and CO.

Following this initial list of contacts, additional organisations were contacted with more tailored requests.

2.2.2 Emission Factors

International Data

A potential source of emission data research on lawn and garden machinery (and other sources) is via the national programmes of other countries and co-operative international emission inventory work programmes at UNECE or EU level.

Contact was made with EUROMOT (The European Association of Internal Combustion Engine Manufacturers) and the UNECE (in particular the United Nations Environment, Energy and Industry Statistics Branch), which pointed towards the US inventory and data potentially available via the United States Environmental Protection Agency (USEPA). However there was no way to identify if the US data related to a similar type of machinery to those used in the UK, so emission data are of little use to development of the NAEI if the source measurements are for combustion technologies or fuels which are not employed in the UK. To improve inventory uncertainty, emission data should, wherever possible, be obtained from accredited test houses using recognised test protocols (for example EN or ISO Standards) and procedures on UK-representative machinery, engines and fuels.

Data from the CITEPA in France was a more likely match for UK machinery, but contact with them proved that they already feed the CORINAIR database so there was no new data from this source. A German study is underway on emissions from equipment at the Institute for Energy & Environmental Research (IFEU) and may provide information in the near future.

Department for Transport (DfT)

Contact was also made with the Department for Transport (DfT) in the UK. The Department are conducting a Regulatory Impact Assessment for EC Directive 2002/88/EC on emissions from non-road mobile machinery and it seemed reasonable that they would have needed to access emissions information for their work.

2.2.3 Sales & Population

The Office of National Statistics (ONS) was contacted for sales and population data and enquires into independent market research for new figures were also made, along with web searches for relevant data. Data in this area was also added to our request to the UK Department for Transport and contacts with industry (Appendix 1).

3 Analysis and Results

3.1 DATA FOR THE CURRENT INVENTORY

The majority of organisations contacted were unable to provide any new data and there appear to be no recent updates to the CORINAIR data set. A number of manufacturers and trade associations did however indicate the Agricultural Engineers Association (AEA) as a possible source of information. AEA provided an indication of the availability of the data and explained that it is currently dispersed, unavailable or commercially sensitive, making it impractical for anyone to organise data without significant additional funding.

The DfT provided two reports containing emission factors for certain machinery types. The first was a European Commission Report 'Emission Testing of Engines to be Installed in Non-Road Mobile Machinery' (EC, 1999). This report contained emissions data for a range of specified equipment types, including lawnmowers and chainsaws.

The second was Annex XXV 'Fuel Effects on Emissions from Non-Road Engines', an undated International Energy Agency – Advanced Motor Fuels (IEA/AMF) Interim Report (IEA-AMF). This report contained emissions data for two stroke spark ignition engine chainsaws, a four stroke spark ignition lawnmower engine and a diesel (compression ignition) engine. The Final Report was issued only days before the drafting of this report, excluding any additional findings from this particular study.

3.1.1 Emission Factors

The data from the two reports provided by DfT were used to produce new emission factors for certain equipment types and pollutants in the inventory. Unfortunately the diesel engine tested in the IEA/AMF report was manufactured in 1985 which means it is unlikely to represent the current population of machinery which has an estimated lifetime of ten or less years in the NAEI model. The engines tested also had a power rating of 70kW, compared to the estimated ratings of 5-10kW for the equipment represented in the current inventory. The significant difference in engine size this represents is the second factor that makes the diesel engine emission factor data from the IEA/AMF report unsuitable for the inventory. The decision was therefore taken to maintain the existing data in the inventory for diesel engines.

The emission factors for particulate matter emissions from spark-ignition engines given in the IEA/AMF report have also been excluded from use. The only PM data available was for a single engine for a chain saw and emissions seemed unrealistically high.

For NO_x, VOCs and CO emissions from petrol engined garden machinery, several emission factors from these two sources of data were adopted and these are shown in Table 3.1 in comparison with current values used in the NAEI. However, the "New" values shown were adopted only for machinery sold after 1995. This is an arbitrary date, but reflects the fact that the current values used in the inventory taken from CORINAIR and Samaras would have been based on tests on engines produced before this date, so the current factors were retained for pre-1995 machinery.

Table 3.1 Summary of revisions to NAEI emission factors based on the EC and IEA/AMF reports. New factors adopted for machinery types produced after 1995.

Equipment Type	Engine Type	Emission Factor g/kWh								
		VOC			NO _x			CO		
		Current	New	Source	Current	New	Source	Current	New	Source
Lawnmowers	2sp	355	165.4	A	1.02	0.7	A	643	658	A
	4sp	45.1	9.2	C	4	4.9	C	871	345	C
Ride on machinery (domestic)	4sp	28.7	8.8	C	4.02	5.4	C	567	316	C
Lawn and garden tractors	4sp	28.7	8.8	C	4.02	5.4	C	567	316	C
	2sp	270	136.9	A	1.05	0.6	A	460	432	A

A: European Commission Report 'Emission Testing of Engines to be Installed in Non-Road Mobile Machinery' (EC, 1999)

B: IEA/AMF 'Fuel Effects on Emissions from Non-Road Engines', Interim Report (IEA-AMF, undated)

C: Combination of reports A and B

The table shows that the new factors for VOCs in particular are significantly lower than existing values used. For NO_x and CO the new emission factors are either similar or again lower than the existing figures.

In order to make use of the data from the two reports certain assumptions and decisions had to be made and these are outlined below.

Catalysts

No figures were used for equipment with catalysts as insufficient information was available to determine the emission factor. This in particular ruled out any new data on 2sp chain saws and trimmers from the European Commission Report (EC, 1999). There was also no information on how many equipment in the UK population are now fitted with catalysts

Averaging the Results

The emission factors available were measured over a number of test cycles. The following assumptions were made in averaging the figures: -

1. The EC report (EC, 1999) provided emission factors measured over different test cycles, all variations on the ISO 8178 standard. Based on the description in EC Directive 2002/88/EC of the types of equipment each cycle would normally be used for it was decided that results from test cycle ISO 8178 – 4, G2 were more applicable to equipment of a similar size to lawnmowers and test cycle ISO 8178 – 4, G1 for ride-on domestic and commercial lawnmowers and lawn and garden tractors. All chainsaws were tested under cycle ISO 8178 – 4, G3 and an average of results taken. The appropriate test results were subsequently selected for averaging in combination with appropriate IEA/AMF test results.
2. Figures from the IEA/AMF (undated) report did not specify the test cycles used, only that measurements were based on the ISO 8178 standard i.e. no indication of cycle G1, G2 etc. Rather than having to exclude new data from our calculations, they were used in the averages made for all relevant engine stroke and sizes rather than being distinguished as above.
3. Consideration was given to the power rating of the tested machinery which differed in the two studies.
4. Each test result was given an equal weight in averaging the results
5. The mid value was taken for any test result with a range.

Equipment Types

In order to apply new information as widely as possible this research has assumed that factors for 4sp spark ignition engine lawnmowers also apply to 4sp lawn and garden tractors and ride-on lawnmowers. The comparative size of the equipment has been taken into account by choosing the results from differing test cycles for averaging as described above.

3.1.2 Sales, Population & Lifetimes

Several organisations had data on the monetary amount spent on certain types of equipment each year, but sales by volume were unavailable. Although the Office of National Statistics did have some data in this regard it only had figures for net export and import of machinery for certain years, but with no indication of machinery that was produced and remained within the United Kingdom.

Again, the Agricultural Engineers Association (AEA) could be a potential co-ordinator of such information but are faced with the problems of disaggregated, unavailable or commercially sensitive data as described in Section 3.1 above.

Internet Research

Internet searches yielded individual pieces of data but these were insufficiently complete or consistent to warrant their use in the inventory. The data are included here for information only and have not been used in our update of the inventory.

DieselNet (www.dieselnet.com) gave 'useful lifetime estimates' for diesel engines of 3000 and 5000 hrs for engines at or below 37kW for constant/non-constant speeds, respectively. This is roughly twice the lifetime currently assumed in the inventory for commercial ride-on lawnmowers with diesel engines.

Various figures were also available for sales but it was impossible to separate out sales of electric from spark ignition or compression ignition engines, or gather a meaningful time series of numbers. The data are therefore shown below for information only, but does indicate that sales show significant variation between individual years: -

- Retailers sold (in monetary terms) 13% more lawnmowers in 1998, than 1997 (Office of National Statistics)
- In 2001, 17.7% less lawnmowers were sold in absolute terms than in 2000 (www.interconnectionresearch.com)
- 1.0 million lawnmowers were sold in Europe in 2001, the UK accounting for 22.7% of EU total

The inventory currently assumes constant sales and population data for garden machinery and this assumption will be retained until more definitive information can be found.

Market Research

Due to the low availability of data, market research was investigated. The organisation Report Finder, who advertised the Key Note series of reports, offered independent research for lawnmowers and chainsaws as they could not find any information in their standard sources, which also included the AMA Garden Products Distribution <http://www.the-list.co.uk/acatalog/am92012.html>.

3.2 IMPLICATIONS OF DIRECTIVE 2002/88/EC

Directive 2002/88/EC introduces emission limits for a range of spark ignition engines used in non-road mobile machinery manufactured and sold new over the next decade. Interpretation of the Directive allowed calculation of the emission factors that machinery will have to achieve in order to meet the Directive in the UK. The dates for the implementation of individual emission limits vary by equipment type and engine size, and are phased in two stages.

This section outlines the interpretation made of the Directive and the impact this will have on the emission factors for future machinery.

3.2.1 Interpretation of the Directive

The Directive loosely classifies engines into those used in "hand-held" and "non-hand-held" machinery. Based on examples given in Annex IV of the Directive, lawnmowers and most other equipment included in the inventory would be classed under "non-hand-held" while chainsaws and trimmers are classed as "hand-held". There is a further classification by engine size for non-hand-held machines into 4 ranges:

- <66cc
- 66-100cc
- 100-225cc
- >225cc

There are two stages of introduction of limit values for Type-Approval. For Stage I, the dates are the same for all engine types; for Stage II, introduction comes at different times according to engine size.

The Stage I implementation dates and limit values for non-hand held equipment are given in Table 3.2.

Table 3.2 - Stage I dates and limit values for non-hand held equipment

Engine Size	Date	CO (g/kWh)	HC + NOx (g/kWh)
<66cc	11 August 2004	519	50
66-100cc	11 August 2004	519	40
100-225cc	11 August 2004	519	16.1
>225cc	11 August 2004	519	13.4

The dates and limits for Stage II are summarised in Table 3.3.

Table 3.3 - Stage II dates and limit values for non-hand held equipment

Engine Size	Date	CO (g/kWh)	NO _x (g/kWh)	HC + NOx (g/kWh)
<66cc	1 August 2004	610	10	50
66-100cc	1 August 2004	610	10	40
100-225cc	1 August 2007	610	10	16.1
>225cc	1 August 2006	610	10	12.1

Chainsaws and trimmers are classified as hand-held machines and have the values and implementation dates shown in Table 3.4. These assume an engine size >50cc.

Table 3.4 - Stage I and II dates and limit values for chain saws and trimmers

Engine Size	Date	CO (g/kWh)	HC (g/kWh)	NOx (g/kWh)	HC + NOx (g/kWh)
Stage I	1 August 2004	603	161	5.36	
Stage II	1 August 2011	603		10	72

1. This table assumes the chainsaws and trimmers in the NAEI model have an engine capacity of >50cc
2. The Stage II limit date of 2011 is due to a 3 year exemption from the general 'hand held' date of 1 August 2008.

The Stage II limits for all types of equipment are imposed in a different way to those for Stage I. The limits must be met after application of a deterioration factor to the emission factor of new equipment or by measurements made at the end of a defined emission deterioration period which is defined by the size of engine and the type of machinery the engine is used in.

For small volume manufacturers of non-hand held machinery, the deterioration factors in Table 3.5 are provided:

Table 3.5 - Deterioration factors

Engine Size	Side valve engine		Overhead valve engine	
	CO	HC + NOx	CO	HC + NOx
<66cc	1.1	2.1	1.1	1.5
66-100cc	1.1	2.1	1.1	1.5
100-225cc	1.1	2.1	1.1	1.5
>225cc	1.1	1.6	1.1	1.4

For all 2-stroke hand held equipment the degradation factor is 1.1 for HC, NO_x and CO.

Other manufacturers must calculate their own deterioration factor derived from emissions measured at the start and end of a defined durability period of the engine. The durability period (EDP) are summarised in Table 3.6. The manufacturer selects and must declare the EDP based on the engine size and its expected useful life, type of use etc.

Table 3.6 - Durability period

EDP category	1	2	3
	hours	hours	hours
<66cc	50	125	300
66-100cc	125	250	500
100-225cc	125	250	500
>225cc	250	500	1000

For the purpose of this research the deterioration factors provided for small volume manufacturers (shown in Table 3.5) have been used to assess the implications of the Directive on the emission factors within the inventory.

There are no limits on emissions of particulates from spark-ignition engines, but the Commission will report in 2004 on the costs, benefits and feasibility of reducing PM emissions from such engines, especially 2-stroke engines.

3.2.2 Implications for Emission Factors in the Inventory

These limits have been used to determine any changes that will be necessary in the emission factors used for future lawn and garden machinery in the inventory, in order to meet the implementation of the Directive. These changes and the process for their calculation are described below.

Stage I

The revised emission factors for current machinery shown in Table 3.1 were compared to the Stage I emission limits given in the Directive.

In addition to the assumptions made during the analysis of necessary changes to the factors for current machinery outlined in Section 3.1, certain assumptions were necessary in order to apply the information provided in the EC Directive to estimate factors for machinery meeting Stage I limits. First, it was assumed that unless emission factors for pre-Stage I machinery were already below Stage I limit values, they would be reduced to levels no lower than the Stage I limit values. The basis assumption is that manufacturers do no more than is necessary to meet the Stage I limit values. Furthermore, if emission factors for current machinery were calculated from test results from engines which covered more than one of the engine size ranges given in the Directive, the average of the limit values given for each relevant engine capacity range was adopted.

Stage II

To calculate the emission factors required of new equipment sold after the Stage II implementation dates, the Stage II limit values were divided by the degradation factors given in the Directive for small volume manufacturers. The same basic assumptions made for estimating factors for the Stage I machinery described above were made for Stage II, but in addition the side valve and overhead valve degradation factors given in the Directive were averaged for each engine capacity range to give one degradation factor as no information on the mix of the two types of equipment in the population was available.

The recommended emission factors for Stage I and Stage II machinery based on the interpretation of Directive 2002/88/EC are shown in Table 3.2.6 below, together with the values for pre-Stage I machinery taken from Table 3.1.

Volatile Organic Compounds (VOCs) & Nitrogen Oxides (NO_x)

The emission limits in the Directive (Tables 3.2 to 3.3) are based on HC (VOCs) and NO_x combined. There is a limit for NO_x of 10 g/kWh but all emissions are predicted to be within this value already.

Table 3.7 gives separate emission factors for HC and NO_x for existing and new equipment. For Stage II these figures represent emissions for new machinery either the result of dividing the emission limit in the Directive for Stage II by the degradation factors given as described above or is the emission factor for current machinery if that is lower.

As NO_x emissions are generally significantly lower than emissions of VOCs for 2sp engines, any necessary reductions in emissions are presumed to be achieved through reductions of VOCs. The same is not true for 4sp engines, and here proportionally equal

reductions have been calculated for the NO_x and VOC emissions factors. It is clear that in order to meet both Stage I and Stage II emission limits, large reductions in VOCs will need to be made in the emissions of two stroke spark ignition engines.

The results suggest the potential need for minor reductions in NO_x for 4sp equipment to meet Stage II limits.

Carbon Monoxide (CO)

The Directive emission limits for CO do not vary with equipment size. Table 3.7 demonstrates that, based on the emission factors in the inventory, in order for both Stage I and Stage II limits to be met, reductions in CO emissions from most 2-stroke equipment will be required.

Table 3.7 - Summary of revisions to NAEI emission factors

Equipment Type	Engine Type	Emission Factor (g/kWh)											
		VOCs				NO _x				CO			
		Pre-Stage I (<1995)	Pre-Stage I (>1995)	Stage I	Stage II	Pre-Stage I (<1995)	Pre-Stage I (>1995)	Stage I	Stage II	Pre-Stage I (<1995)	Pre-Stage I (>1995)	Stage I	Stage II
Trimmers/edgers/bush cutters	2sp	300	300	161	64.5	1	1	1	1	1500	1500	603	603
Lawnmowers	2sp	355	165.4	15.4	8.2	1.02	0.7	0.7	0.7	643	658	519	519
Lawnmowers	4sp	45.1	9.2	9.2	5.5	4	4.9	4.9	2.94	871	345	345	345
Ride on (domestic)	4sp	28.7	8.8	8.8	5.3	4.02	5.4	5.4	3.24	567	316	316	316
Chain saws <4 bhp	2sp	660	660	161	64.5	1	1	1	1	1500	1500	603	603
Lawn and garden tractors	4sp	28.7	8.8	8.8	5.3	4.02	5.4	5.4	3.24	567	316	316	316
Lawn and garden tractors	2sp	270	136.9	15.4	8.2	1.05	0.6	0.6	0.6	460	460	460	460

The emission factors in Table 3.7 are proposed for inclusion in the NAEI to produce new emission estimates for lawn and garden machinery in the non-road mobile machinery sector in the future.

There are emission degradation factors defined in the new EC Directive 2002/88/EC for spark ignition engines. Although the way they are defined in the Directive makes use of them in the inventory difficult, they appear to be broadly consistent with degradation factors currently used. Hence, the degradation factors used in the NAEI are left unchanged.

3.3 COVERAGE OF MACHINERY TYPES IN THE NAEI

The new emission factors from the European Commission and IEA/AMF reports reviewed in this study covered the main classes of lawn and garden machinery included in the

NAEI, but not all of them. However, given the similarity in the engines and operational cycles of some of the other types of garden machinery, their emission factors were modified to be consistent with the main classes addressed in this study. Therefore, for the purpose of the inventory it was assumed:

- a) 4-stroke leaf blowers have the same emission factors as 4-stroke lawnmowers
- b) 2-stroke leaf blowers have the same emission factors as 2-stroke lawnmowers
- c) Commercial turf equipment, golf carts and 4-stroke ride-on machinery have the same emission factors as 4-stroke lawn and garden tractors

For other types of equipment included in the inventory, there was not such a strong basis for assuming new emission factors for the main machinery classes reviewed in this study should supercede those currently used in the inventory for these other types:

- 2-stroke tillers
- 2-stroke shredders
- 2-stroke wood splitters
- 2-stroke snow blowers
- 2-stroke wood chippers

However, consideration was given to the impact of the Directive on emission factors for these machinery types and the Stage I and II emission factors reduced accordingly.

4 UK Emission Estimates for Lawn and Garden Machinery

The effect of the new emission factors described in Section 3 on the inventory of emissions from the UK lawn and garden machinery sector from 1995 projected to 2010 was calculated using the NAEI model that combines emission factors with machinery activity data.

Using existing activity data on population, sales and lifetime of garden machinery in the UK, national emissions of NO_x, CO and NMVOCs were calculated using a) the original set of emission factors used in the NAEI; b) the new set of emission factors for machinery sold since 1995, but excluding the impact of the Directive limit values, i.e. assuming factors for all machinery remains at current levels (pre-Stage I (>1995) in Table 3.2.6); and c) the new set of emission factors for current machinery and including the effect of the Directives (i.e. using all the emission factors in Table 3.2.6).

The effect on emissions from 1995 to 2010 for each of these three cases is shown in Figures 1-3.

The new emission factors alone lead to a significant reduction in estimates of emissions of CO and NMVOCs from garden machinery in 2002, but little change in the estimates for NO_x emissions. On the other hand, it can also be seen that the Directive emission limit values will lead to reductions in NO_x and NMVOC emissions over the next decade, but little change in emissions of CO from garden machinery.

To put the garden machinery emissions into context, emissions of NO_x (0.9ktonnes) are 0.06% of the UK emission totals in 2002 and are virtually unchanged using the new emission factors. For CO, use of the new emission factors decreases the emission estimate from 94 to 75 ktonnes in 2002, and compares with 3238 ktonnes from all sources, i.e. 2.3% of total emissions. For NMVOCs, use of the new factors decreases the emission estimate from 29 to 17 ktonnes in 2002, and compares with 1364 ktonnes from all sources, i.e. 1.2% of total emissions.

Fig.1 Emissions of NOx from garden machinery

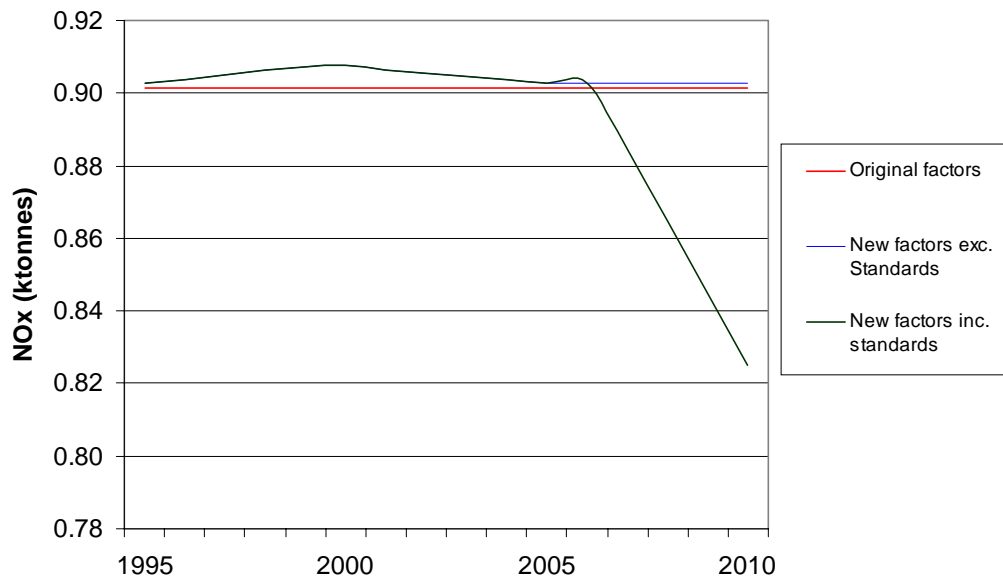


Fig.2 Emissions of CO from garden machinery

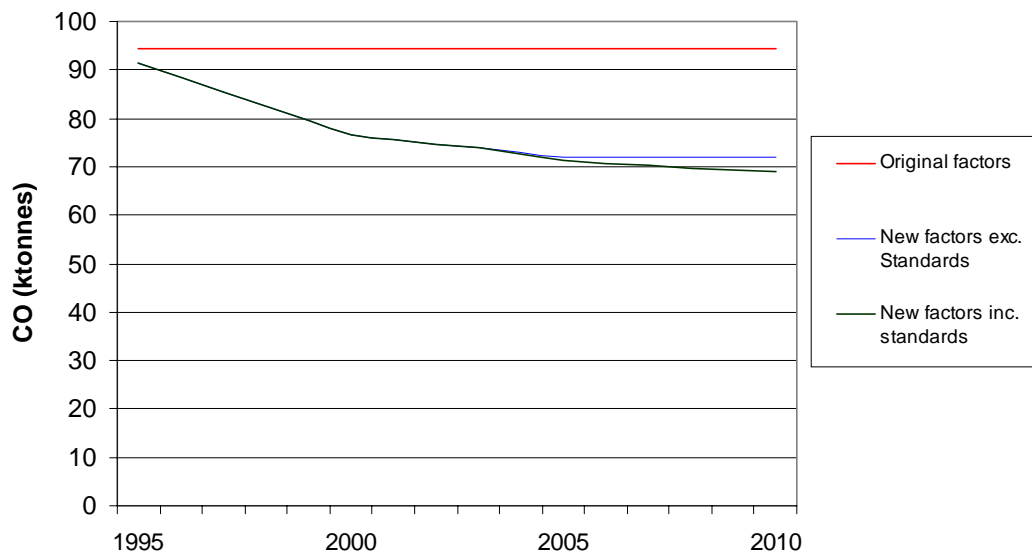
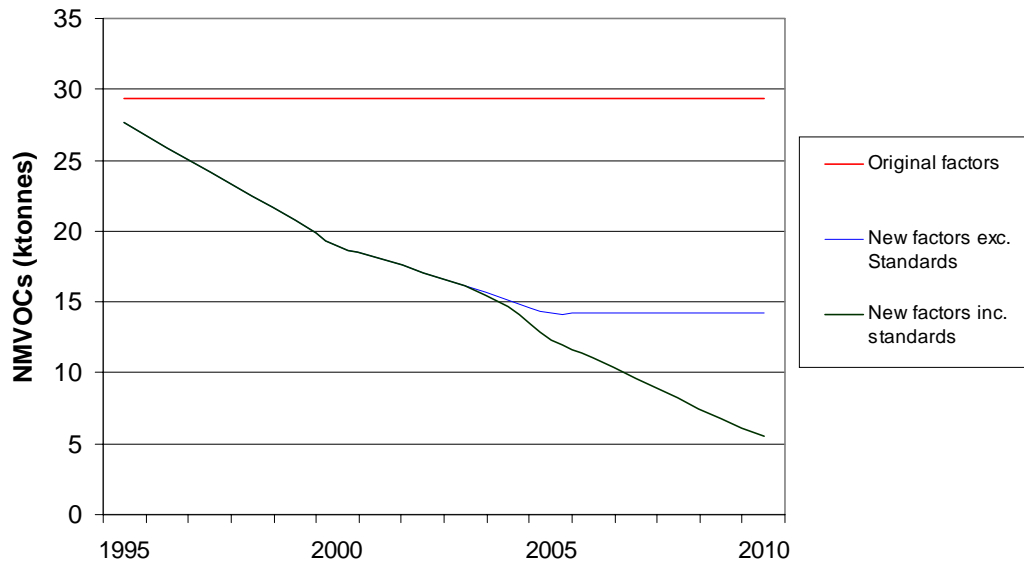


Fig.3 Emissions of NMVOCs from garden machinery



5 Conclusions

This Task focused on the emission factors and activity data for off-road mobile machinery used in the lawn and garden sector. The study covered machinery such as lawn mowers, lawn and garden tractors, chainsaws and trimmers.

The research examined new sources of emission factors for machinery equipped with spark-ignition petrol engines (2-stroke and 4-stroke), considered to be more applicable to newer designs of equipment. It has also reviewed the EU Directive 2002/88/EC which set emission limits for spark ignition engines used in non-road mobile machinery and considered the impact on emission factors for types of garden machinery used in the NAEI. A new set of emission factors for different garden machinery types was developed and recommended for use in the NAEI. Within this new data there are still gaps for certain types of machinery or specific emissions and further research would be needed to fill these gaps.

The research also examined the availability of activity data for this sector. These included population, lifetimes and hours of use per year of specific types of machinery. Unfortunately, potential sources of such information that were contacted were unable to provide the data required within this study.

There are a number of areas where further research is needed to identify any new data to improve or confirm the accuracy of the inventory: -

- Sales of equipment by volume
- Activity data i.e. hours of use per year
- Lifetimes and populations of equipment
- Current methods of or plans for future abatement of emissions
- Fuel consumption figures.

The impact of changing to the new set of emission factors was calculated in the inventory model using existing activity data. The impact on UK emissions of NO_x, NMVOCs and CO from garden machinery was calculated.

For 2002, the new emission factors leaves NO_x emissions from garden machinery almost unchanged, but leads to a decrease in CO emissions of 21% and NMVOC emissions of 42% compared with estimates using the original emission factors. Emissions of all three pollutants are projected to fall with penetration of newer, lower emitting machinery into the population when compared with previous forecasts.

6 References

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PRI (1995) Market research commissioned by Department of Transport 'Off Road Vehicle Emissions: Equipment Ownership and Usage. Precision Research International (1995 & 1998).

Samaras, Z., Andrias, A. and Zierock, K.H. (1994). "The Estimation of the Emissions of 'Other Mobile Sources and Machinery' Subparts 'Off-Road Vehicles and Machines', 'Railways', and 'Inland Waterways' in the European Union". European Union. Also, Samaras (1993) data tables sent to AEA Technology pre-publishing of the 1994 report.

Appendices

CONTENTS

Appendix 1 Organisations Contacted During This Research

Appendix 1

Organisation Contact List

ORGANISATIONS CONTACTED DURING THIS RESEARCH

Organisation	Contact Name and/or Number	E-mail Address
<i>Contacted by PRI for their earlier research (new contact names/no.s found):</i>		
Agricultural Engineers Association (AEA)	Jake Vowles (MD) 01733 371381	
British Hardware Federation	0121 4466688	Information@bhfgroup.co.uk
British Lawn Mower Manufacturers Association	Could not find contact details	
DTI	General enquiries 020 7215 5000	dti.enquiries@dti.gsi.gov.uk
Engine Control Systems	Peter Howell 01752 891360	info@westerntydens.co.uk
Federation of British Hand Tool Manufacturers	0114 266 3084	light.trades@virgin.net
Garden Industry Manufacturers Association	Secretary 0121 446 5213	info@gima.org.uk
Institute of Agricultural Engineers	The Secretary 01525 861096	secretary@iagre.org
The British Agricultural and Garden Machinery Association	0870 205 2834	info@bagma.com
<i>Other Organisations Contacted (not on the original PRI list):</i>		
CITEPA		infos@citepa.org
CORINAIR		Jytte.Boll.Illerup@dmu.dk
Dft	Chris Parkin	
Electrolux	Ken Goodman 01325 302256	
EUROMOT	Dr Harmut Mayer	euromot@vdma.org
HTA	Lee Appleyard 0118 930 3132	
IFEU – Institute for Energy & Environmental Research (Germany)	Udo Lambrecht	udo.lambrecht@ifeu.de
Office of National Statistics (ONS)	0845 601 3034	
Trade Magazine – Lawn and Garden Equipment	Chris Biddle General number on web-site	
UNECE		envstats@un.org
USEPA		hq.foia@epa.gov
<i>Selection of manufacturers (selection from list on www.classic-lawns.co.uk):</i>		
Hayter	01279 723 444 Sales Office ext: 2250	sales@hayter.co.uk
Lawn-King	Tel: 01889 566183	enquiries@trenchex.com
GGP/Mountfield Unlimited	Anne Jones	Anne.jones@ggp-group.com (same for Stiga)
Stihl		www.stihl.co.uk postmaster@stihl.co.uk
Viking		www.viking.co.uk enquiry@bir-int.com