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Air emissions from the refining sector. Analysis of E-PRTR data 2007-2011

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ABSTRACT

This report provides a review of the air pollutant emissions data submitted by national authorities for oil refineries in the E-PRTR from 2007 to 2011. Detailed analyses are given for five pollutants (SOx, NOx, NMVOCs, CO_2 and benzene).

Emissions of the five pollutants reviewed have decreased significantly between 2007 and 2011: SOx 37%, NOx 28%, NMVOCs 35%, benzene 44% and CO_2 9% even after taking into consideration the mass of crude processed which has declined by almost 10% over the same five year period, the percentage reductions in kt of reported emissions per Gt of crude processed reduced for the five pollutants: SOx 30%, NOx 19%, NMVOCs 28%, benzene 38%, CO_2 -1.4%.

KEYWORDS

E-PRTR, emissions, refineries, non-methane volatile organic compounds (NMVOC)

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SUMMARY

This report provides an overview of the European Pollutant Release and Transfer Register (E-PRTR) air pollutant data for oil refineries submitted by national authorities for the years 2007 to 2011. Detailed analyses are provided of the emissions of the five pollutants reported for the majority of refineries (SOx, NOx, NMVOCs, CO_2 and benzene). The changes in their reported emissions over the five year period are reviewed, as well as the significance of the oil refining sector in the overall reported E-PRTR inventories of these pollutants. The impact of incorrectly coded submissions is identified.

In this report an "oil refinery" has been defined as an installation where the main activity is the refining of crude oil as well as those considered as atypical refineries (bitumen and lube refineries). Within the 2011 set of air emissions data these are available for 112 oil refineries in 24 countries.

The facilities in the E-PRTR database are listed under both their "Industrial Activity" (IA) code from Annex I of the E-PRTR Regulation [4] and by their NACE code. In Annex I "mineral oil and gas refineries" are listed under the Energy Sector with an IA code of 1.(a). The NACE code for the "manufacture of refined petroleum products" is 19.20.

Under these codes there are a number of facilities reporting air emissions that do not meet the definition of oil refinery used in this report. In 2007 there were 20 such facilities (14% of the total) reporting to the E-PRTR under Annex I code 1.(a) and 10 under NACE code 19.20. The numbers in 2011 were 13 under IA 1.(a) and 9 under NACE 19.20. These facilities have a significant effect on the E-PRTR inventories for some pollutants e.g. contributing in 2011 92% of the HCFCs and 51% of the methane inventories. The analyses undertaken by Concawe for this report do not include the data submitted for those installations as they are not deemed to be oil refineries.

The total number of air pollutants reported for oil refineries on a pan-European basis in the E-PRTR between 2007 and 2011 has been 33, although the number of pollutants reported for individual refineries vary significantly. Refineries need to submit data for a pollutant if the emissions exceed the threshold value indicated in Annex II of the E-PRTR regulation. Exceeding this threshold on an individual pollutant basis depends on a number of factors, the main ones being the size of the refinery and the type of process plant installed.

Refineries are required to collate their pollutant release data and submit them on an annual basis to their relevant competent authority. The data are then compiled and quality checks undertaken. They are then provided, as part of the national return, to the EC and EEA before being uploaded by the latter onto the E-PRTR database. Due to the degree of data handling and transfer there is a risk, for example, of transcription errors occurring. It is therefore recommended that refineries check the E-PRTR database. Concawe cannot establish the accuracy of the emissions reported for each individual refinery. The data used in the analyses for this report are those that appear in the E-PRTR database on the EEA website.

Four of the five pollutants for which detailed analyses have been undertaken have reported reductions year on year. The exception is carbon dioxide which has seen an overall reduction since 2007 but with increases in one of the five years. However

the mass of crude processed, which has a direct impact on the air emissions from refineries, has also declined by almost 10% over the five year period. The emissions per unit of crude processed have therefore been determined to take this into account. The percentage reduction in kt of reported emissions per Gt of crude processed between 2007 and 2011 for the five pollutants are: SOx 30%, NOx 28%, NMVOCs 28%, benzene 38% and the CO_2 has slightly increased by 1.4%.

While the refining sector has reported significant reductions for four of the five pollutants, the emissions of these four pollutants reported for the other sectors contributing to the overall E-PRTR inventories have also reduced The result has been that the refining contributions to these inventories has been relatively stable. The refining sector is a major contributor to the 2011 E-PRTR inventories of benzene 41% and NMVOCs 27%. The contribution of the other three pollutants are less significant: SOx 11%, NOx 6% and CO_2 6%. It should be noted, however, that these inventories are for those industries submitting data under the E-PRTR Regulation and do not include major sources such as transport and domestic heating.

1. INTRODUCTION

The European Pollutant Release and Transfer Register (E-PRTR) was established by Regulation in 2006 [4] with the first reporting year being 2007. By May 2013 there had been a further four data sets added to the register, up to and including that for 2011.

The objectives of this report are:

- to review the changes in the emissions of the five air pollutants reported for the majority of refineries over the five years from 2007 to 2011;
- to understand the significance of the oil refining sector in the overall reported E-PRTR inventories of those pollutants;
- to identify the impact of incorrectly coded submissions.

Installations have to submit data to their competent authorities annually if i) they fall under at least one of the economic activities listed in Annex I of the Regulation, ii) are exceed a capacity threshold given in that Annex and iii) the quantities of pollutants released and/or waste transferred off-site exceed the thresholds specified in Annex II of the Regulation. From the submissions by the national competent authorities the data are compiled by the European Commission (EC) and the European Environment Agency (EEA) for dissemination on the E-PRTR website: http://prtr.ec.europa.eu. Data are available in the 2011 database for facilities within the 27 EU Member States as well as Iceland, Liechtenstein, Norway, Serbia and Switzerland.

In Annex I of the E-PRTR regulation “mineral oil and gas refineries” are listed under the Energy Sector with an industry activity (IA) code 1.(a); there is no capacity threshold provided.

The activities in the E-PRTR database are also reported using the NACE[1] (Revision 2) statistical classification of economic activities code [5]. Refineries have a NACE Code of 19.20 “manufacture of refined petroleum products”.

In this report a “refinery” is defined as an installation where the main activity is the refining of crude oil. This includes specialised refining installations, for example those producing bitumen or lubricating oils. Facilities where crude oil is not processed, such as lube oil blending plants, have been excluded from the data analyses. A Concawe data base of oil company installations was used to identify these facilities. Air emissions data for 112 refineries in 24 countries are available in the 2011 E-PRTR inventories.

In the E-PRTR database there are a relatively large number of facilities which are classified as undertaking activities 1.(a) and/or 19.20 but which fall outside of the definition of an oil refinery used in this report. The number of these is reviewed in section 2.1 and their impact on the reported total emissions in chapter 4.

In total there are 60 E-PRTR air pollutants. Concawe report 1/09 [1] provides the sector with recommended emission estimation methodologies for 24 of these pollutants. These pollutants were included in the report following a review of the emission sources that occur at the majority of refineries, the pollutants emitted, the methodologies available in the public domain for estimating these and the likelihood

[1] Nomenclature Générale des Activités Economiques dans l’Union Européen

that the emissions will exceed the E-PRTR reporting thresholds. It is the responsibility of refineries to review all sources of emissions to air and establish if there are other pollutants e.g. from chemical plant installed at the site, which may also require emission estimates to be made for E-PRTR reports. The total number of air pollutants, for which at least one submission has been made for a refinery between 2007 and 2011, has been 33. The numbers of pollutants reported, on a national basis, are reviewed in section 2.2.

The number of air pollutants individually reported by refineries to their national authorities vary significantly as only data on those estimated to be in excess of the specified threshold values have to be submitted. Five pollutants are reported for the majority of oil refineries. These pollutants are SOx, NOx, NMVOCs, benzene and CO_2.

The data within the E-PRTR database for these five pollutants are reviewed in detail in chapter 3. These pollutants include those listed in the National Emissions Ceiling Directive [2] (except for ammonia) and the main greenhouse gas emitted by refineries. To determine the significance of the refining industry, the emissions of these pollutants are compared to those reported for the other sectors under the E-PRTR Regulation.

There are two uploads of the E-PRTR database made each year (in mid and late year). The second upload provides corrections of any errors or omissions that may have occurred in the initial main upload. It should be noted that for this report the data for 2011 have been analysed using the database made available by the EEA in 2014 (E-PRTR v6.1).

2. OVERVIEW OF REPORTING

2.1. NUMBER OF SITES

The facility classification codes are not always applied correctly. There are a number of installations that are classified as Annex I activity code 1.(a) “mineral oil and gas refineries” or as NACE code 19.20 “manufacture of refined petroleum products” that are not refineries (as defined in this report).

On the other hand, some of the installations that are actually refineries are classified as other activities (e.g. manufacture of refractory products or manufacture of other organic basic chemicals).

In this report a “refinery” is defined as an installation where the main activity is the refining of crude oil and those considered as atypical refineries (bitumen and lube refineries). A cross-check of the E-PRTR database has been undertaken to identify the total number of installations that do not meet this definition of refinery and also the refineries that are classified under another category.

Table 1 summarises the total number of refineries (as defined above) for which air emissions have been reported to E-PRTR from 2007 to 2011.

Table 1 Total number of refineries for which air emissions have been reported to E-PRTR

	2007	2008	2009	2010	2011
Number of refineries reporting	121	119	115	116	112

Table 2 and **Table 3** show under which categories these refineries have been classified by Annex I and NACE activity names.

In general these different categorisations reflect the view taken by the site of its main activity. However, the mis-classification under the NACE activity 23.20 “manufacture of refractory products” is due to the revision of the NACE codes in 2006, as 23.20 originally was the code for oil refining.

Table 2 Classification of refineries in E-PRTR database by Annex I Activity Name

Annex I Activity Name / Code	2007	2008	2009	2010	2011
Mineral oil and gas refineries, 1.(a)	117	114	112	111	109
Chemical installations for the production on an industrial scale of basic organic chemicals, 4.(a)	1	2	1	1	1
Installations for the recovery or disposal of hazardous waste, 5.(a)	1	0	0	0	0
Installations for gasification and liquefaction, 1.(b)	1	1	1	1	1
Thermal power stations and other combustion installations, 1.(c)	1	2	1	2	1
Urban waste-water treatment plants, 5.(f)	0	0	0	1	0
Total	**121**	**119**	**115**	**116**	**112**

Table 3 Classification of refineries in E-PRTR database by NACE coding

NACE Main Economic Activity Name / Code	2007	2008	2009	2010	2011
Manufacture of refined petroleum products, 19.20	115	116	108	112	108
Manufacture of oils and fats, 10.41	0	0	1	1	1
Manufacture of other organic basic chemicals, 20.14	2	2	0	0	0
Manufacture of refractory products, 23.20	4	1	5	2	2
Wholesale of solid, liquid and gaseous fuels and related products, 46.71	0	0	1	1	1
Total	**121**	**119**	**115**	**116**	**112**

Table 4 compares the total number of sites for which air emissions have been reported to the E-PRTR which are classified as Annex I code 1.(a) or as NACE code 19.20. This shows that in 2007 there were 20 facilities (14% of the total) which did not meet the definition of refinery in this report but which were classified as Annex I code 1.(a) and 10 as NACE code 19.20. The numbers in 2011 were 13 as IA 1.(a) (10% of the total) and 9 as NACE 19.20.

Table 4 Total number of installations submitting air emissions data classified as Annex I Code 1.(a) or NACE Code 19.20 facilities

	2007	2008	2009	2010	2011
Number of refineries	121	119	115	116	112
Number of installations as 1.(a)	141	141	142	138	125
Number of installations as NACE 19.20	131	130	124	128	121

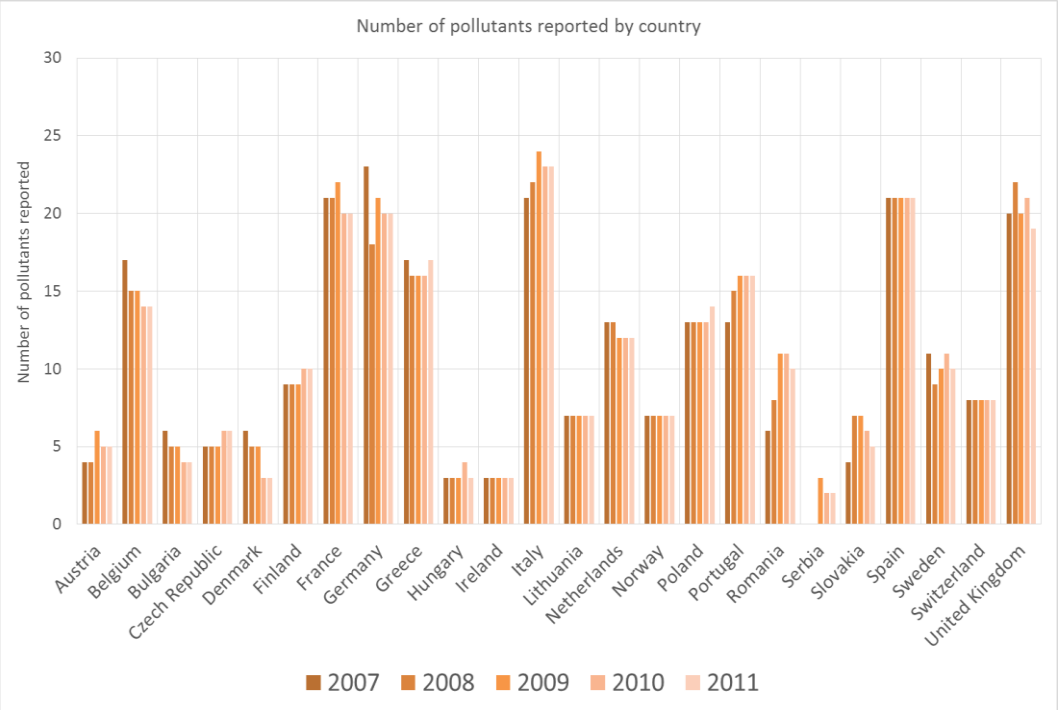
The analyses of the emissions included in this report have been undertaken on the data submitted for the refineries in Europe and does not include the emissions of those installations in the E-PRTR database which are not deemed to be oil refineries. An analysis of the impact of these latter installations is given in chapter 4.

2.2. POLLUTANTS

The number of air pollutants reported for refineries vary significantly due, for example, to the size of the refinery (which impacts on how many pollutants will be emitted in excess of the reporting thresholds), the type of process plant installed (in particular if the refinery incorporates petro-chemical production), etc.

This is reflected in the totals if reviewed on a national basis, as in **Figure 1.**

Figure 1 Number of pollutants to air reported by country



The total number of air pollutants reported for refineries on a pan-European basis in the E-PRTR between 2007 and 2011 has been 33. Note that this total number does not differentiate between the two ways of reporting CO_2 i.e. as a total and excluding biomass combustion.

For many of the reported pollutants the average emissions from a refinery are close to the threshold. **Table 5** provides a comparison between the median of the reported emissions data and the reporting threshold for ten pollutants. It can be seen that for the five air pollutants included in this report (SOx, NOx, NMVOCs, CO_2 and benzene), the median of the emissions reported for the majority of refineries in 2007 is at least an order of magnitude greater than the threshold value. The data for these five pollutants are reviewed in detail in chapter 3.

Table 5 Comparison between the reporting threshold value and the median of reported data for ten pollutants (2007)

Pollutant	Threshold kt/a	Median of reported data in 2007 kt/a	Ratio of median to threshold
SO_X	0.15	3.55	23.7
NO_X	0.1	1.26	12.6
NMVOCs	0.1	1.09	10.9
Benzene	0.001	0.02	15.8
CO_2	100	1165	11.6
Methane	0.1	0.27	2.7
PM_{10}	0.05	0.15	2.9
Nickel	0.0001	0.0014	14.0
Chromium	0.0001	0.00033	3.3
Cadmium	0.00001	0.000026	2.6

For the other pollutants the medians of the reported emissions are close to the threshold values. These pollutants are correspondingly only reported for a minority of sites.

3. POLLUTANT RELEASES TO AIR

This chapter presents detailed analyses of the emissions reported for refineries of five pollutants to air over the period 2007 to 2011. The five pollutants are SOx, NOx, NMVOCs, benzene and CO_2.

For each pollutant the following are provided:

1. Reported emissions for each year

The reported emissions from the European refineries are provided for each E-PRTR year thus enabling trends in emissions to be identified. However the mass of crude processed, which has a direct impact on the air emissions from refineries, had declined over the five year period. The emissions per unit of crude processed have therefore also been determined to take this into account.

The emission data from all the sectors reporting into E-PRTR are given, permitting a review of the refining contribution to the overall European PRTR inventories.

Concawe has not checked the accuracy of the emissions reported for each individual refinery. The data for each individual refinery are those that appear in the E-PRTR (v6.1) database in the EEA website.

2. Statistical analyses of submitted data

These provide the median, maximum and minimum values as well as the 5, 25 (first quartile - Q1), 75 (third quartile - Q3) and 95 percentiles of the pan-European refinery emissions data for each of the five pollutants. The number of outliers above the Upper Outliers Boundary (UOB) is also given. In this report the latter is calculated from Q3 + 2 x (Q3 – Q1).

3. Determination methods

For each pollutant the reporting facility must provide an indication how the value of the emission was determined. The EC guidance document for the implementation of the E-PRTR [3] provides three classes identified by code letters. Data classified as “M” are based on measurement. “C” means that the data are based on calculations using activity data, emission factors or mass balances. It is under this category that the estimation methodologies provided in Concawe report 1/09 would fall. The third category is “E” which includes “non-standardised” estimations (as defined in [3]), best assumptions, etc. Where the total release of a pollutant at a facility is determined by more than one method then the submitted report must indicate the code for the determination method with the greatest amount of release. For each of the pollutants the degree to which each of the three determination methods has been used to quantify the reported emissions is provided.

4. Comparison of emissions data on a national basis

The magnitude of emissions can vary widely between the refineries within a country. These differences can be caused by a number of factors e.g. the refinery capacity (more specifically throughput), the type of crude oils that are being processed and the complexity of the refinery as not every refinery has the same number and type of process-steps. For the various pollutants some more specific reasons for variations in the magnitude of emissions from refinery to refinery are given below:

- SOx: These emissions depend on the type/composition of the crude oil processed, the refinery throughput and complexity, the source of the energy used (steam and/or electricity can be produced either by the refinery or a third party), the type of fuel used in combustion units, the energy efficiency, the sulphur removal capacity, the type of Fluidised Catalytic Cracking Unit (FCCU) installed, the degree of sulphur abatement used in the process and combustion units, the quantity of sulphur containing streams flared due to incidents or turnarounds, etc.

- NOx: Dependent on the type of processes installed (in particular the FCCU), the source of the energy used (see SOx), the refinery throughput, the type of fuels used in combustion plants ,abatement techniques used, the energy efficiency etc.

- NMVOCs: Emissions depend on the amount and type of tankage and loading of volatile products and the type of abatement techniques installed, fugitive emission control programmes for process plant, the type of waste water treatment plants, etc.

- Benzene: Dependent on the type of crude oil processed, type of conversion steps used at the refinery including the presence of aromatic units, process operating conditions, type of abatement techniques used for point and area sources, degree of implementation of fugitive emission control programmes, the measurement and calculation methods used to determine the emissions from the above mentioned sources, etc.

- CO_2: Emissions depend on the refinery throughput, source of energy used (see SOx), type of fuel used in combustion plants, the energy efficiency, type of crude processed, refinery complexity, turn-around schedules, etc.

5. Comparisons of sectorial contributions

These provide the respective contributions of those Annex I sectors of activity under review for which emissions of the pollutant have been reported to the E-PRTR in the period 2007-2011.

It should be noted that no correction of any mis-classifications of installations has been carried out for any of the sectors and activities for these sectorial comparisons. The data included in this section, therefore, correspond directly to the information provided in the E-PRTR database.

3.1. OXIDES OF SULPHUR (SO_x/SO_2)

3.1.1. Emissions from European refineries

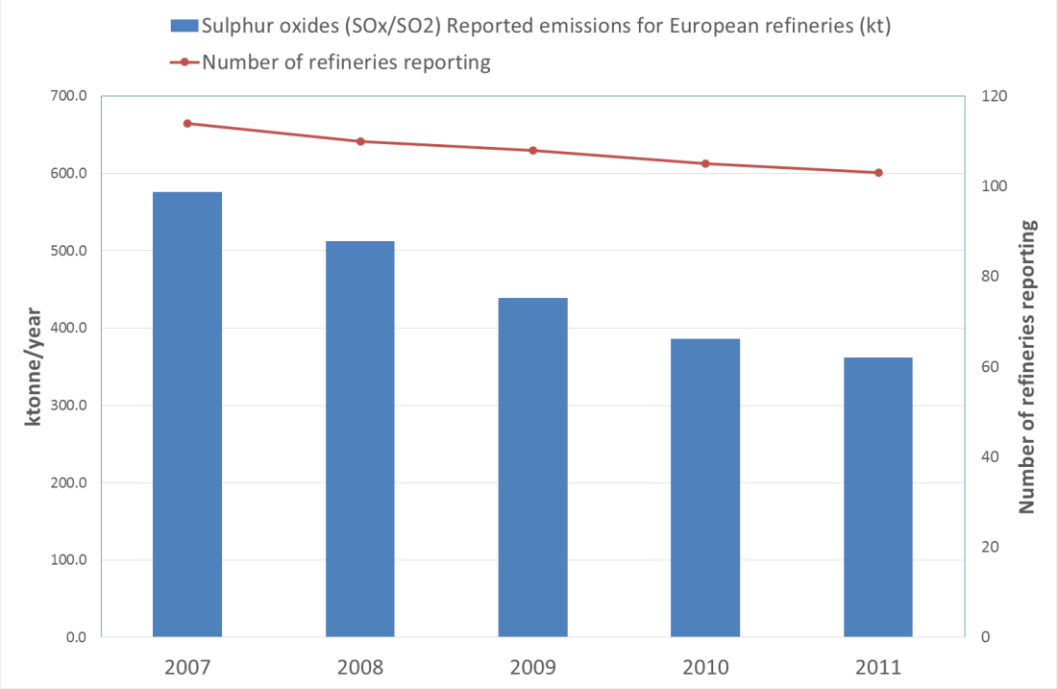
Table 6 summarises the reported emissions of oxides of sulphur to air from the European refineries. Since 2007, there has been a decrease in their overall reported emissions, year on year.

Figure 2 shows the trend observed for the years 2007 to 2011. The reported emissions in 2011 are 37% lower than those of 2007.

Table 6 Oxides of sulphur emissions reported for refineries

	2007	2008	2009	2010	2011
Reported emissions (kt)	576	512	439	386	362
Total reported emissions for all sectors (kt)	5652	4270	3792	3345	3332
Refineries contribution to total reported to E-PRTR	10%	12%	12%	12%	11%
Reported emissions per mass of crude oil transformed in refineries (kt/Gt)	885	784	728	641	618
Number of refineries reporting	114	110	108	105	103
Reporting threshold (kt)	0.15	0.15	0.15	0.15	0.15

Figure 2 Oxides of sulphur emissions from European refineries



3.1.2. Statistical analysis

Table 7 provides the median, maximum and minimum values of the data submitted for refineries for each reporting year. It also gives the values of the first and third quartiles, the 5 and 95 percentiles and the upper outlier boundary (UOB) and the number of outliers above the UOB. The analyses are represented graphically in **Figure 3** and **Figure 4**.

Table 7 Statistical analysis of oxides of sulphur data: emissions in kt/a

	2007	2008	2009	2010	2011
Minimum	0.16	0.16	0.18	0.15	0.18
Median	3.5	3.2	3.0	2.6	2.3
Maximum	21.0	20.4	21.0	22.4	21.0
5 percentile	0.2	0.4	0.3	03	0.3
25 percentile	1.4	1.4	1.1	1.1	0.8
75 percentile	7.4	6.4	5.5	4.8	4.6
95 percentile	16.2	13.6	12.0	11.1	11.6
Upper outlier boundary	19.3	16.3	14.3	12.2	12.1
Number of outliers	4	2	3	4	5

Figure 3 Statistical analysis of oxides of sulphur emissions from European refineries: first and third quartiles

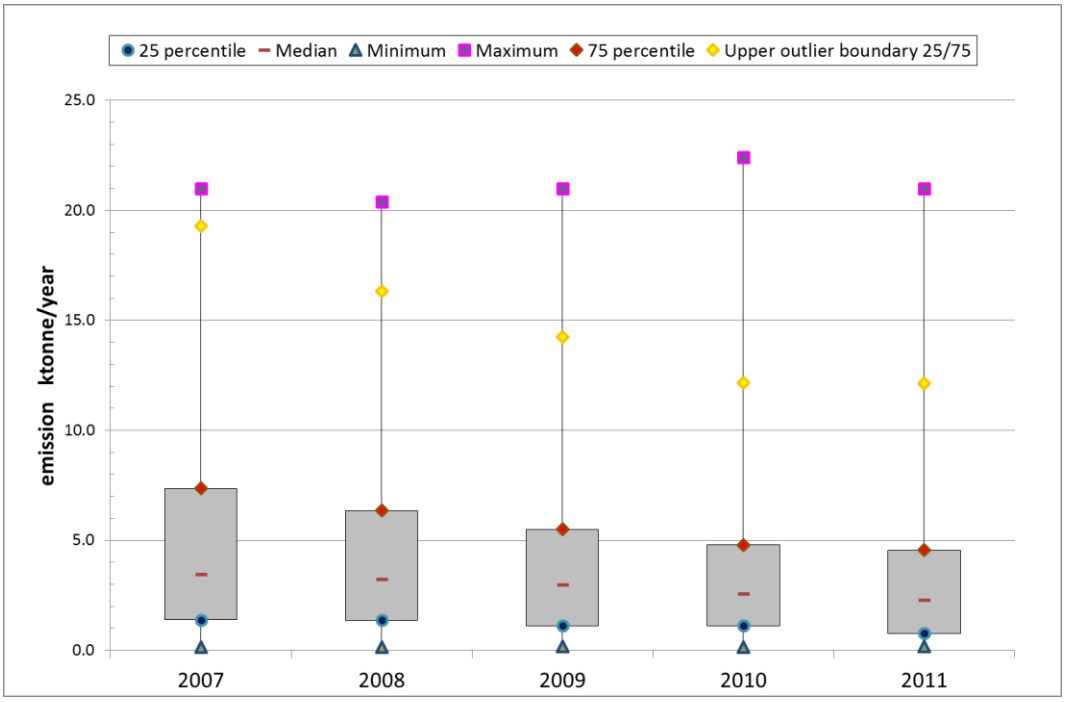
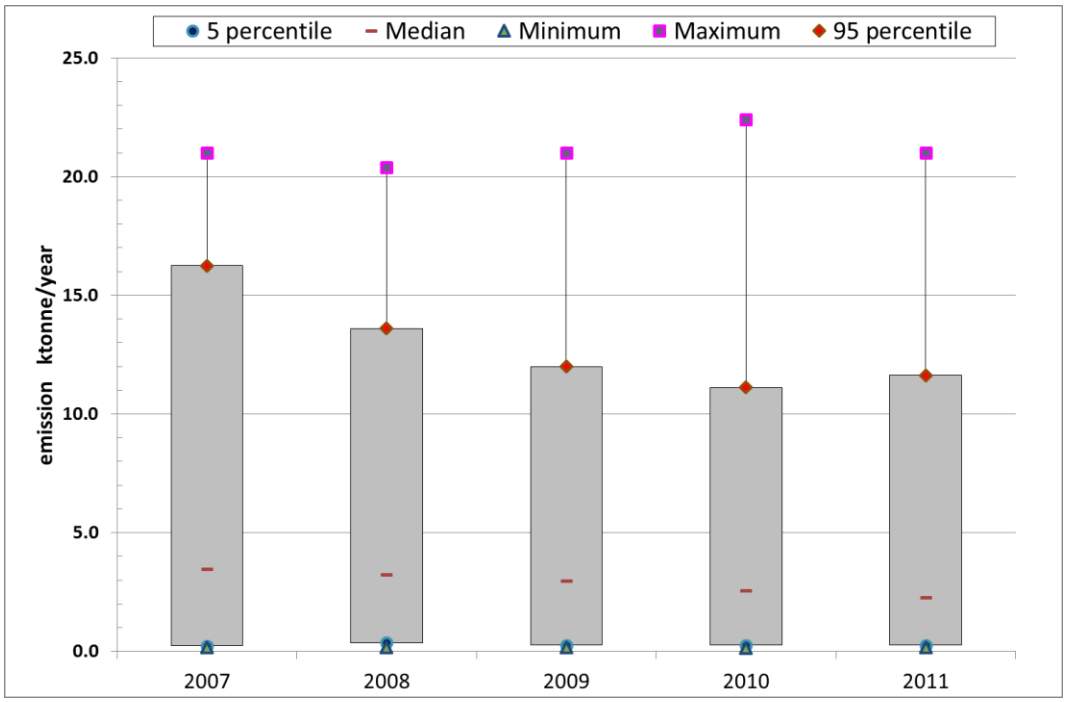


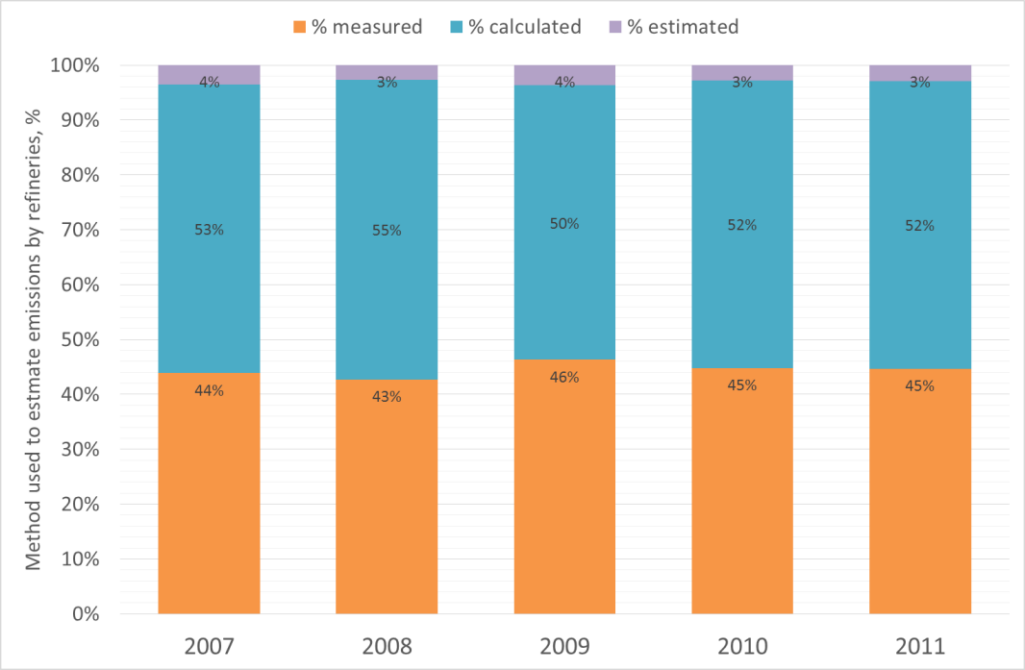
Figure 4 Statistical analysis of oxides of sulphur emissions from European refineries: 5 and 95 percentile



3.1.3. Methods used to determine the emissions

Figure 5 shows the degree to which the three different determination methods (as defined in reference 3] has been used to estimate SOx emissions. This shows that the use of approved estimation methodologies ("calculation") and measurement were used at virtually all installations.

Figure 5 Methods used to determine oxides of sulphur emissions



3.1.4. Sectorial Analysis

Figure 6 illustrates the contribution of those Annex I sectors of activity for which SOx emissions have been reported to E-PRTR in the period 2007 to 2011. It can be observed that the sulphur oxides emissions reported in the E-PRTR database are coming mainly from the energy sector (80-90%). From 2007 to 2011 the reported SOx emissions from the energy sector reduced by 45% (2.20 Mt). The energy sector is divided into five different economic activities. **Figure 7** shows the contribution of each of these to the total energy sector reported emissions. It can be seen that the main contributor to the emissions of the energy sector are the thermal power stations and other combustion installations (85-88%).

Figure 6 Oxides of sulphur emissions - sectorial distribution

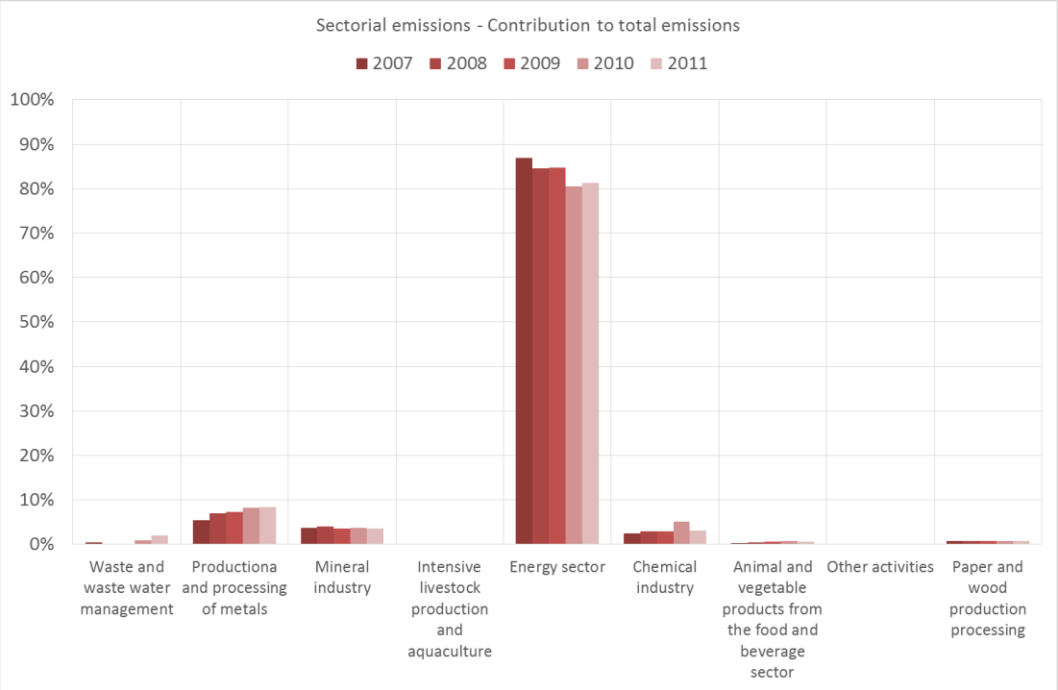
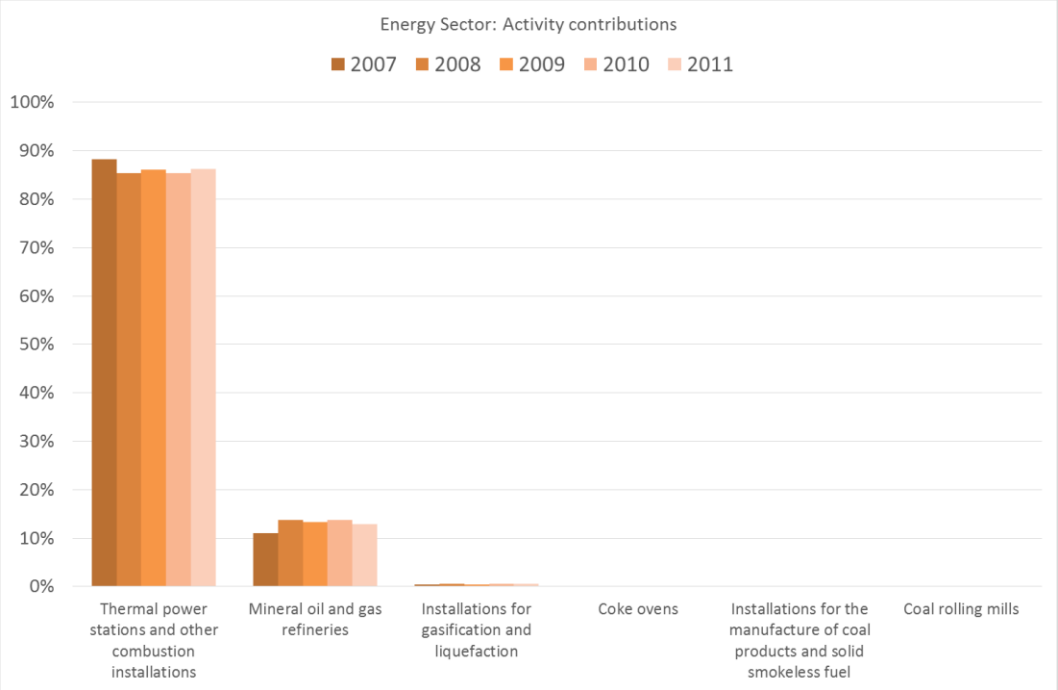


Figure 7 Oxides of sulphur emissions - distribution in energy sector



3.2. NITROGEN OXIDES (NO_X/NO_2)

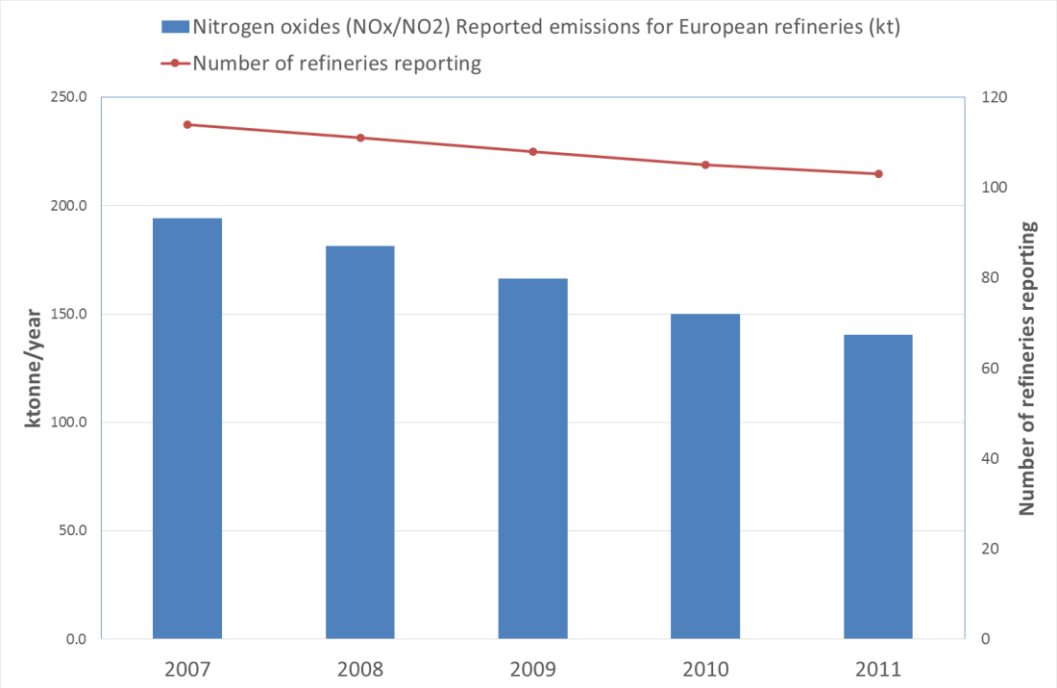
3.2.1. Emissions from European refineries

Table 8 summarises the reported emissions of nitrogen oxides to air from the European refineries. Since 2007, there has been a decrease in their overall reported nitrogen oxides emissions, year on year. **Figure 8** shows the trend observed in the years 2007 to 2011. The reported emissions in 2011 are 28% lower than those of 2007.

Table 8 Nitrogen oxides emissions reported for refineries

	2007	2008	2009	2010	2011
Reported emissions (kt)	194	182	166	150	141
Total reported emissions for all sectors (kt)	3450	3003	2648	2552	2509
Refineries contribution to total	6%	6%	6%	6%	6%
Reported emissions per mass of crude oil transformed in refineries (kt/Gt)	298	278	275	250	240
Number of refineries reporting	114	111	108	105	103
Reporting threshold (kt)	0.1	0.1	0.1	0.1	0.1

Figure 8 Nitrogen oxides emissions from European refineries



3.2.2. Statistical analysis

Table 9 provides the median, maximum and minimum values of the data submitted for refineries for each reporting year. It also gives the values of the first and third quartiles, the 5 and 95 percentiles and the Upper Outlier Boundary (UOB) and the number of outliers above the UOB. The analyses are represented graphically in **Figure 9** and **Figure 10**.

Table 9 Statistical analysis of nitrogen oxides data: emissions in kt/a

	2007	2008	2009	2010	2011
Minimum	0.10	0.10	0.11	0.11	0.11
Median	1.26	1.22	1.13	1.04	0.93
Maximum	7.47	6.82	7.12	8.46	8.03
5 percentile	0.18	0.18	0.21	0.18	0.15
25 percentile	0.53	0.55	0.54	0.54	0.45
75 percentile	2.45	2.16	2.11	2.06	1.95
95 percentile	4.81	4.36	4.16	3.83	3.56
Upper outlier boundary	6.30	5.38	5.24	5.10	4.95
Number of outliers	2	4	3	1	3

Figure 9 Statistical analysis of nitrogen oxides emissions from European refineries: first and third quartiles

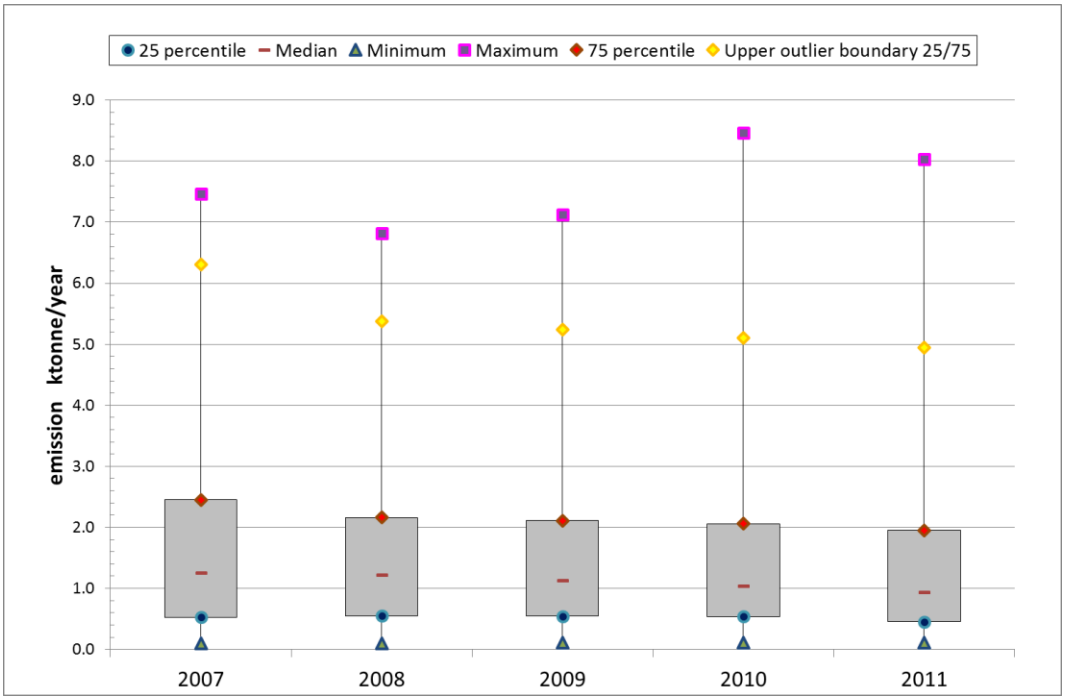
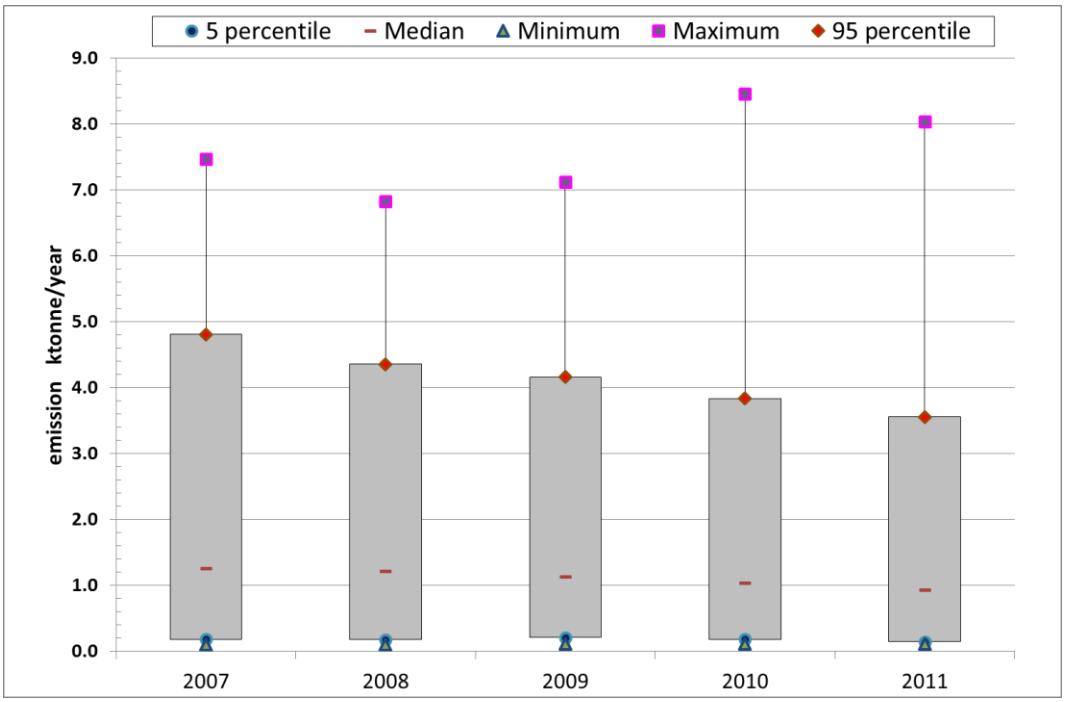


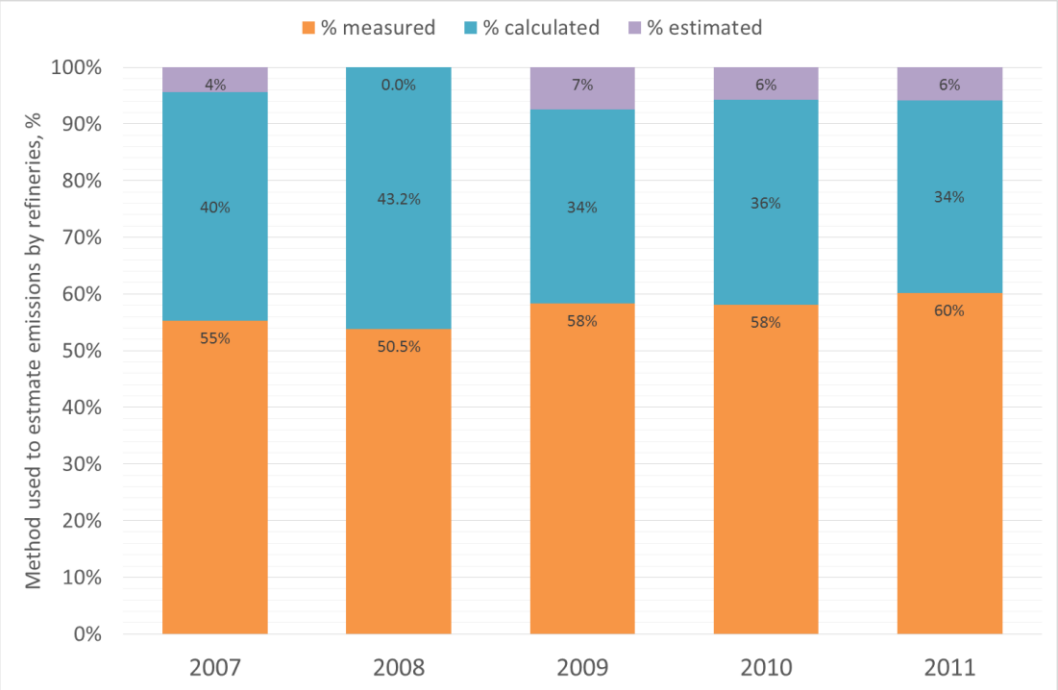
Figure 10 Statistical analysis of nitrogen oxides emissions from European refineries: 5 and 95 percentiles



3.2.3. Methods used to determine the emissions

Figure 11 shows the degree to which the three different determination methods (as defined in reference 3] has been used to estimate NOx emissions. This shows that the use of approved estimation methodologies ("calculation") and measurement were used at virtually all installations, with the majority of sites undertaking the latter.

Figure 11 Method used to determine emissions of NOx



3.2.4. Sectorial Analysis

Figure 12 illustrates the contribution of those Annex I sectors of activity for which NOx emissions are reported to E-PRTR in the period 2007 to 2011. It can be observed that the nitrogen oxides emissions reported in the E-PRTR database are coming mainly from the energy sector. From 2007 to 2011 the reported NOx emissions from the energy sector reduced by 27% (624 kt). The energy sector is divided into five different economic activities. **Figure 13** shows the contribution of each of these to the total energy sector reported emissions. It can be seen that the thermal power stations and other combustion installations are the major NOx contributors to the energy sector (90%).

Figure 12 Nitrogen oxides emissions - sectorial distribution

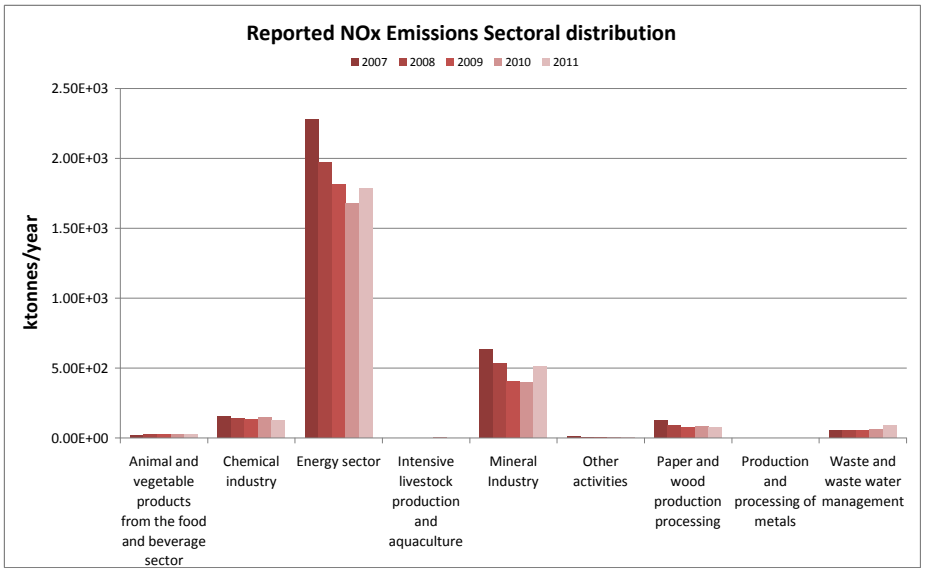
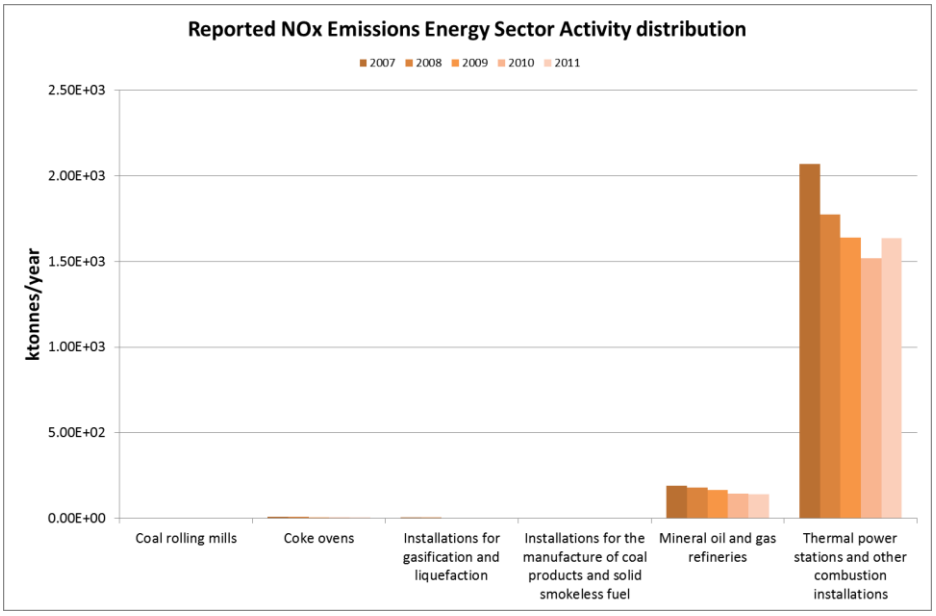


Figure 13 Nitrogen oxides emissions - distribution in energy sector



3.3. NON-METHANE VOLATILE ORGANIC COMPOUNDS (NMVOC)

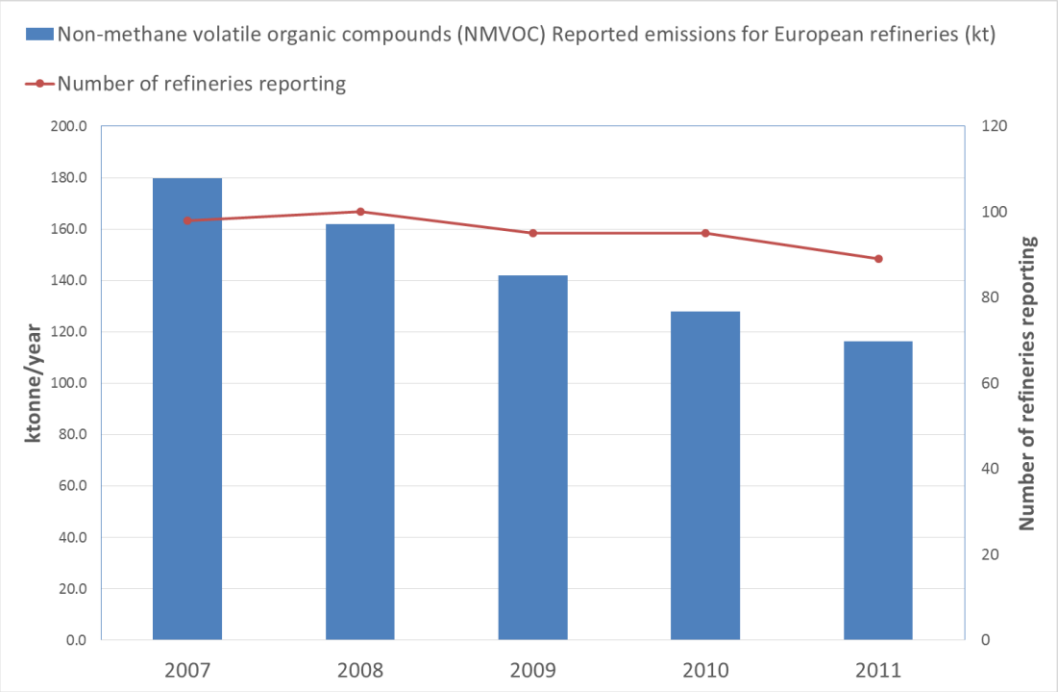
3.3.1. Emissions from European refineries

Table 10 summarises the reported emissions of non-methane volatile organic compounds (NMVOC) to air from the European refineries. Since 2007, there has been a decrease in their overall reported NMVOC emissions year on year. **Figure 14** shows the trend observed in the years 2007 to 2011. The reported emissions in 2011 are 35% lower than those of 2007.

Table 10 NMVOC emissions reported for refineries

	2007	2008	2009	2010	2011
Reported emissions (kt)	180	162	142	128	116
Total reported emissions for all sectors (kt)	712	603	510	485	438
Refineries contribution to total	25%	27%	28%	26%	27%
Reported emissions per mass of crude oil transformed in refineries (kt/Gt)	276	248	235	213	199
Number of refineries reporting	98	100	95	95	89
Reporting threshold (kt)	0.1	0.1	0.1	0.1	0.1

Figure 14 NMVOC emissions from European refineries



3.3.2. Statistical analysis

Table 11 provides the median, maximum and minimum values of the data submitted for refineries for each reporting year. It also gives the values of the first and third quartiles, the 5 and 95 percentiles and the upper outlier boundary (UOB) and the number of outliers above the UOB. The analyses are represented graphically in **Figure 15** and **Figure 16**.

Table 11 Statistical analysis of NMVOC data: emissions in kt/a

	2007	2008	2009	2010	2011
Minimum	0.11	0.10	0.10	0.10	0.12
Median	1.09	0.96	0.93	0.82	0.72
Maximum	11.40	11.10	9.71	9.44	9.59
5 percentile	0.16	0.16	0.15	0.15	0.16
25 percentile	0.51	0.41	0.43	0.35	0.33
75 percentile	2.57	2.21	2.07	1.66	1.70
95 percentile	5.22	5.00	4.49	4.29	4.06
Upper outlier boundary	6.69	5.81	5.35	4.27	4.45
Number of outliers	3	4	3	5	4

Figure 15 Statistical analysis of NMVOC emissions from European refineries: first and third quartiles

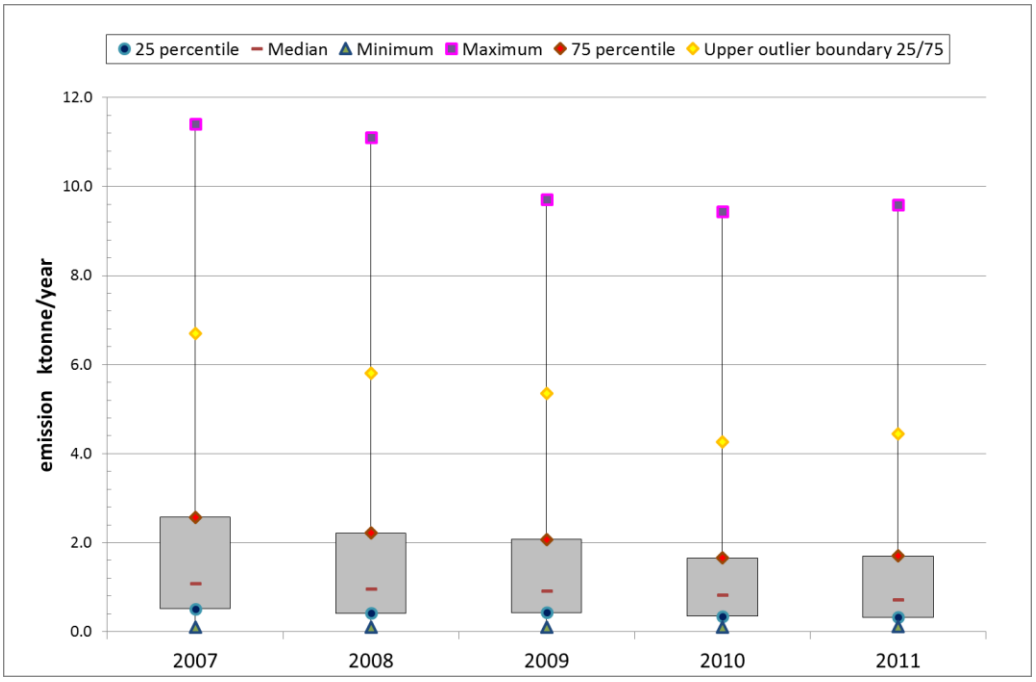
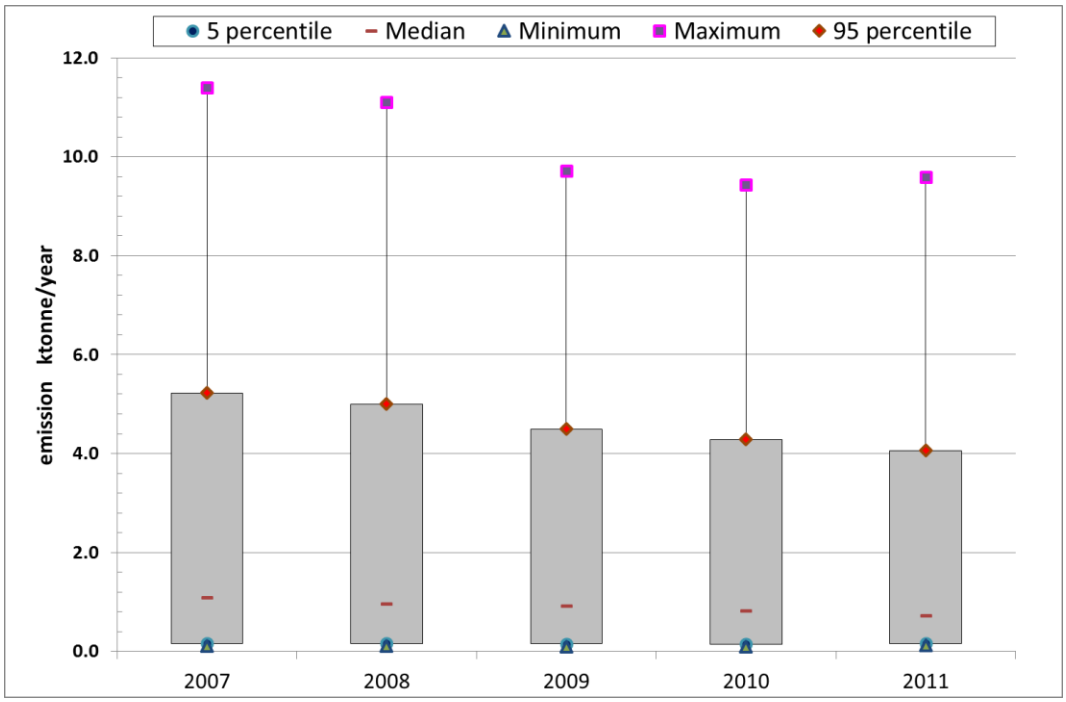


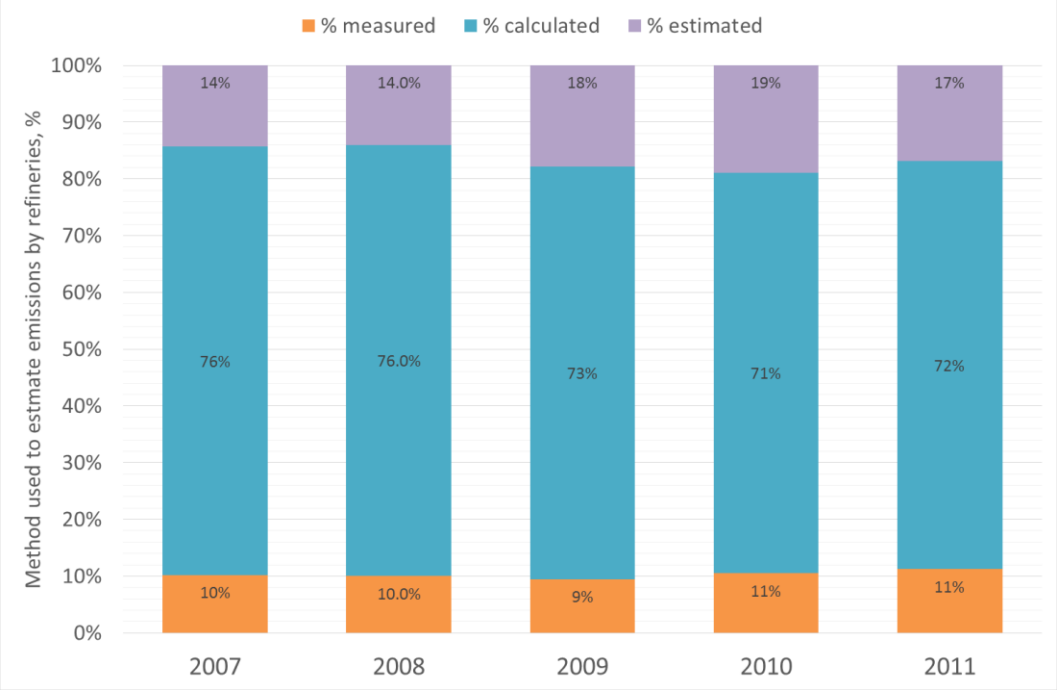
Figure 16 Statistical analysis of NMVOC emissions from European refineries: 5 and 95 percentiles



3.3.3. Methods used to determine the emissions

Figure 17 shows the degree to which the three different determination methods (as defined in reference 3] has been used to estimate NMVOC emissions. This shows that the use of approved estimation methodologies ("calculation") were used at more than 70% of sites, with measurement and other methods being used elsewhere.

Figure 17 Methods used to determine emissions of NMVOC



3.3.4. Sectorial Analysis

Figure 18 illustrates the contribution of those Annex I sectors of activity for which NMVOC emissions are reported to E-PRTR in the period 2007-2011. It can be observed that the NMVOC emissions reported in the E-PRTR database are coming mainly from the energy sector (around 40% of the total reported emissions to E-PRTR). From 2007 to 2011 the reported NMVOC emissions from the energy sector reduced by 42% (123 kt). The energy sector is divided into five different economic activities. **Figure 19** shows the contribution of these to the total energy sector reported emissions. It can be seen that Mineral oil and gas refineries contribute to 68-73% of the NMVOC emissions from the energy sector.

Figure 18 NMVOC emissions - sectorial distribution

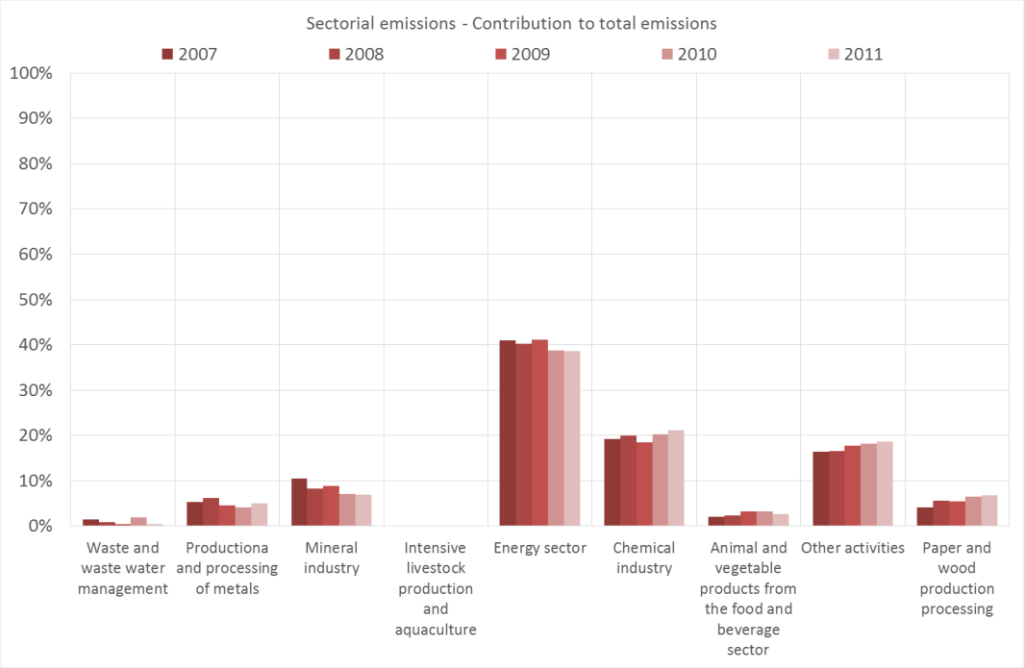
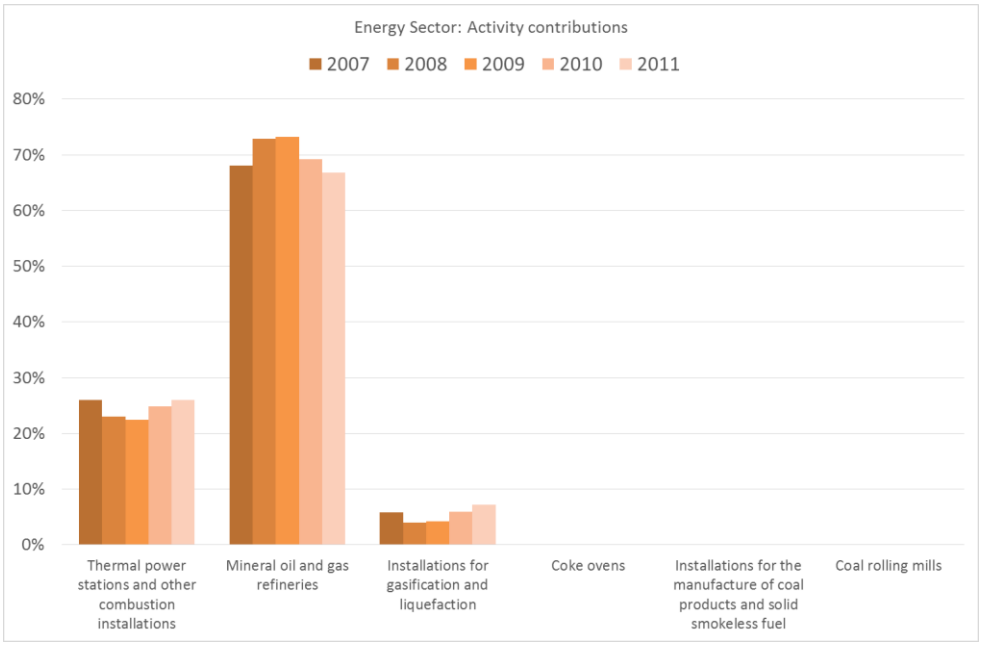


Figure 19 NMVOC emissions - distribution in energy sector



3.4. BENZENE

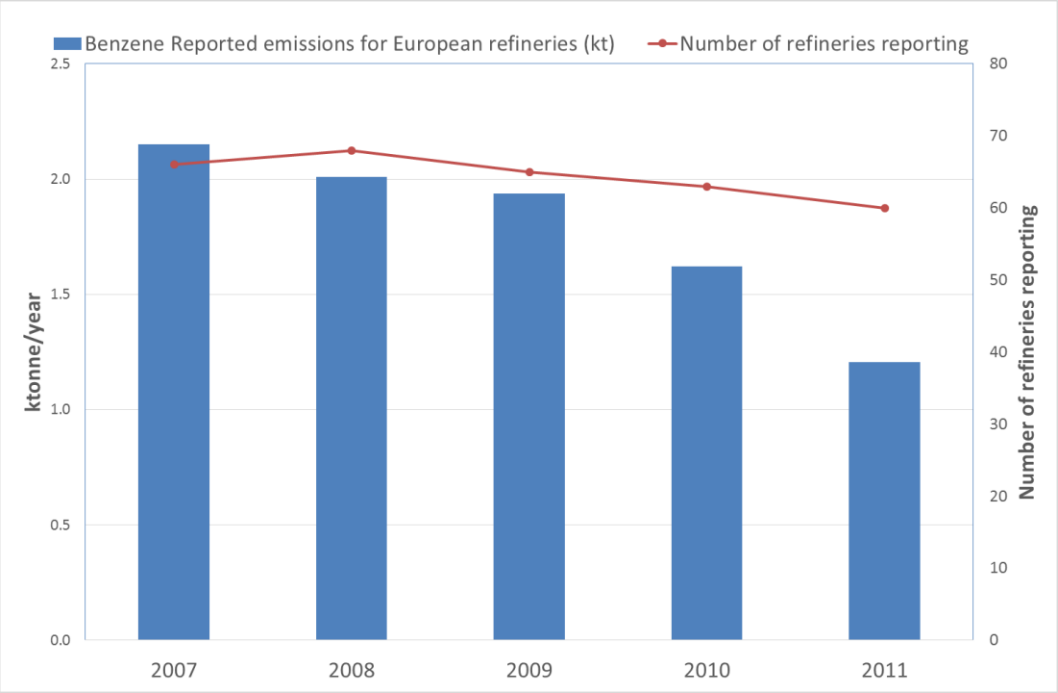
3.4.1. Emissions from European refineries

Table 12 summarises the reported emissions of benzene to air from the European refineries. Since 2007, there has been a decrease in their overall reported benzene emissions year on year. **Figure 20** shows the trend observed in the years 2007 to 2011. The reported emissions in 2011 are 44% lower than those of 2007.

Table 12 Benzene emissions reported for refineries

	2007	2008	2009	2010	2011
Reported emissions (kt)	2.2	2.0	1.9	1.6	1.2
Total reported emissions for all sectors (kt)	4.7	4.1	3.5	3.4	2.9
Refineries contribution to total	46%	49%	55%	48%	41%
Reported emissions per mass of crude oil transformed in refineries (kt/Gt)	3.3	3.1	3.2	2.7	2.1
Number of refineries reporting	66	68	65	63	60
Reporting threshold (kt)	0.001	0.001	0.001	0.001	0.001

Figure 20 Benzene emissions from European refineries



3.4.2. Statistical analysis

Table 13 provides the median, maximum and minimum values of the data submitted for refineries for each reporting year. It also gives the values of the first and third quartiles, the 5 and 95 percentiles and the upper outlier boundary (UOB) and the number of outliers above the UOB. The analyses are represented graphically in **Figure 21** and **Figure 22**.

Table 13 Statistical analysis of benzene data: emissions in kt/a

	2007	2008	2009	2010	2011
Minimum	1.0E-03	1.1E-03	1.0E-03	1.0E-03	1.0E-03
Median	1.6E-02	1.4E-02	1.3E-02	1.3E-02	9.3E-03
Maximum	3.3E-01	3.4E-01	3.0E-01	2.9E-01	2.4E-01
5 percentile	2.1E-03	1.3E-03	2.2E-03	1.4E-03	1.2E-03
25 percentile	5.7E-03	4.9E-03	4.6E-03	4.6E-03	4.1E-03
75 percentile	3.4E-02	2.8E-02	2.5E-02	2.5E-02	2.5E-02
95 percentile	1.1E-01	9.4E-02	1.2E-01	7.7E-02	6.3E-02
Upper outlier boundary	9.0E-02	7.4E-02	6.6E-02	6.5E-02	6.7E-02
Number of outliers	4	5	7	6	3

Figure 21 Statistical analysis of benzene emissions from European refineries: first and third quartiles

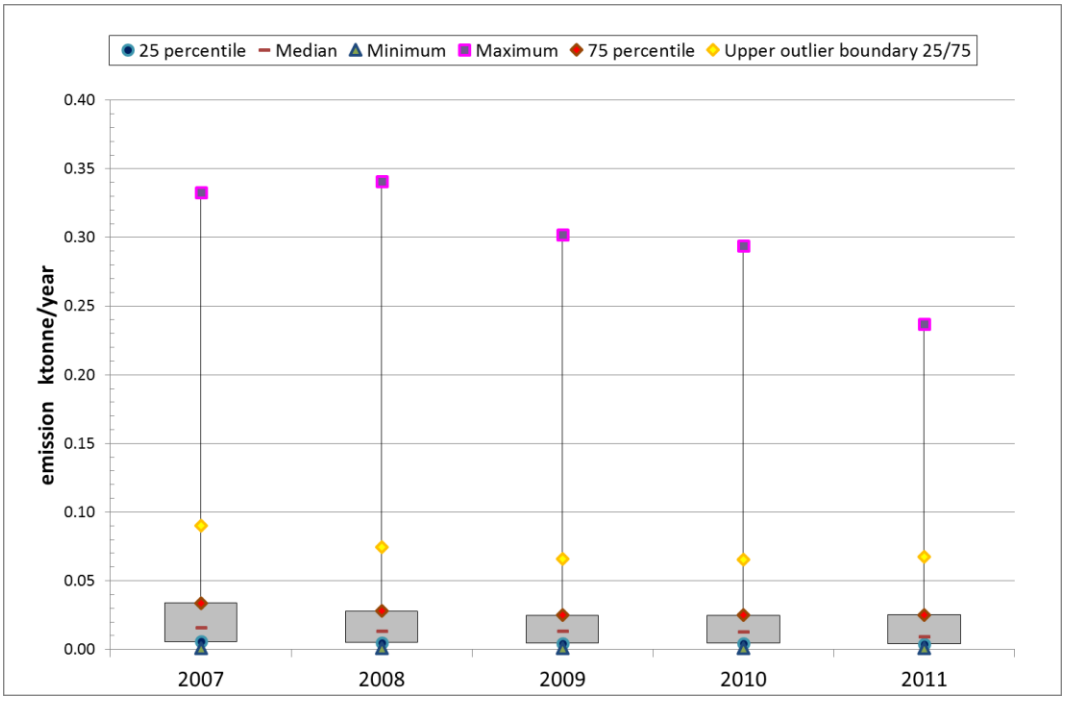
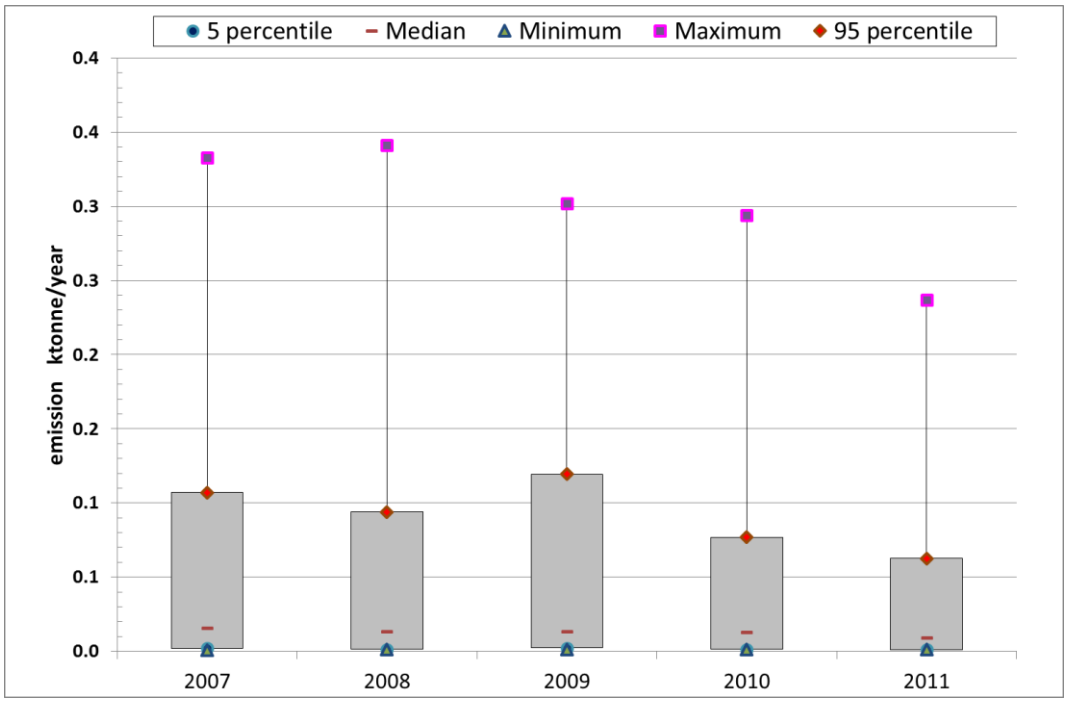


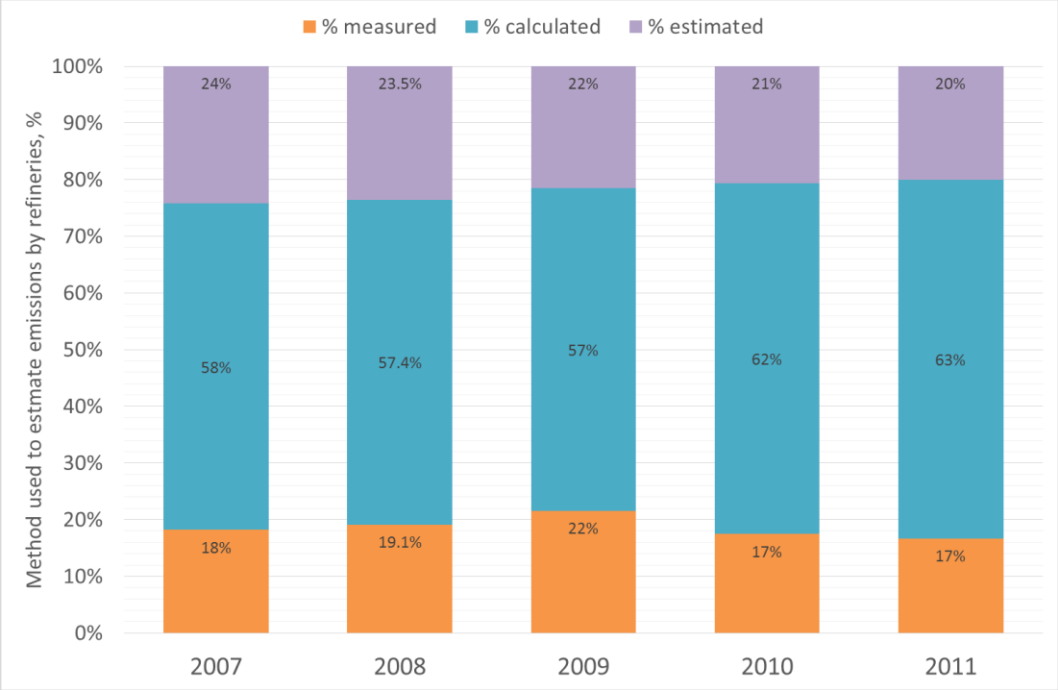
Figure 22 Statistical analysis of benzene emissions from European refineries: 5 and 95 percentiles



3.4.3. Methods used to determine the emissions

Figure 23 shows the degree to which the three different determination methods (as defined in reference 3] has been used to estimate benzene emissions. This shows that the use of approved estimation methodologies ("calculation") and measurement were used at approximately 80% of sites, with other "non-standardised" estimation methods (as defined in [3]) used elsewhere.

Figure 23 Methods used to determine emissions of benzene



3.4.4. Sectorial Analysis

Figure 24 illustrates the contribution of those Annex I sectors of activity for which benzene emissions are reported to E-PRTR in the period 2007-2011. It can be observed that the benzene emissions reported in the E-PRTR database are coming mainly from the energy sector (45-60%). From 2007 to 2011 the reported emissions of benzene from the energy sector reduced by 38% (871 t). The energy sector is divided into five different economic activities. **Figure 25** shows the contribution of these to the total energy sector reported emissions. It can be seen that Mineral oil and gas refineries contribute to 73-87% of the NMVOC emissions from the energy sector.

Figure 24 Benzene emissions - sectorial distribution

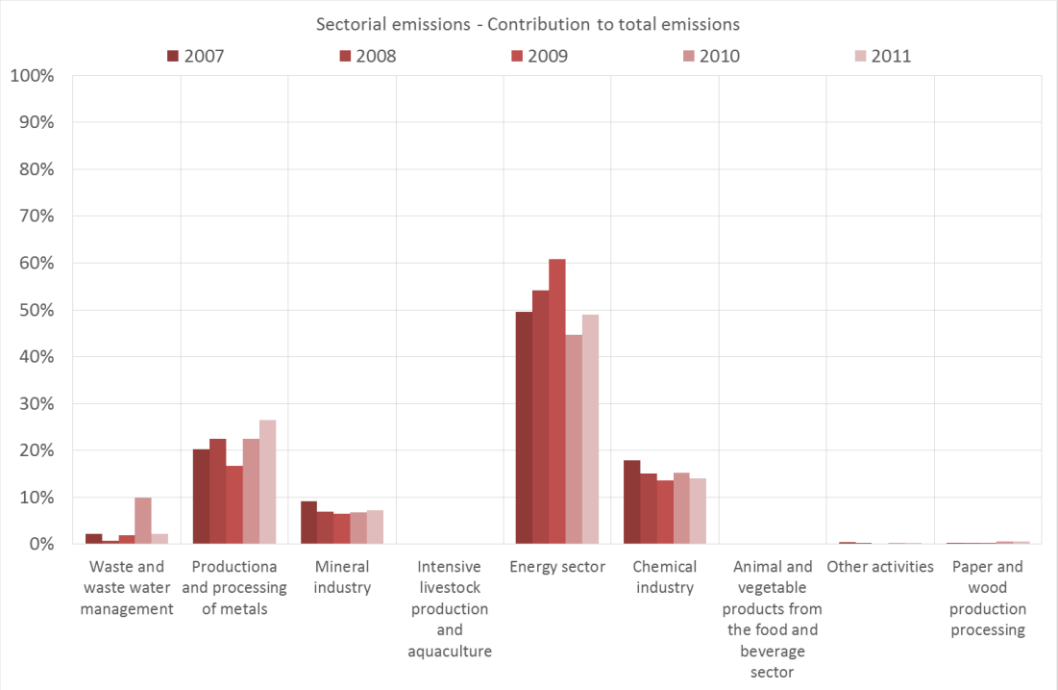
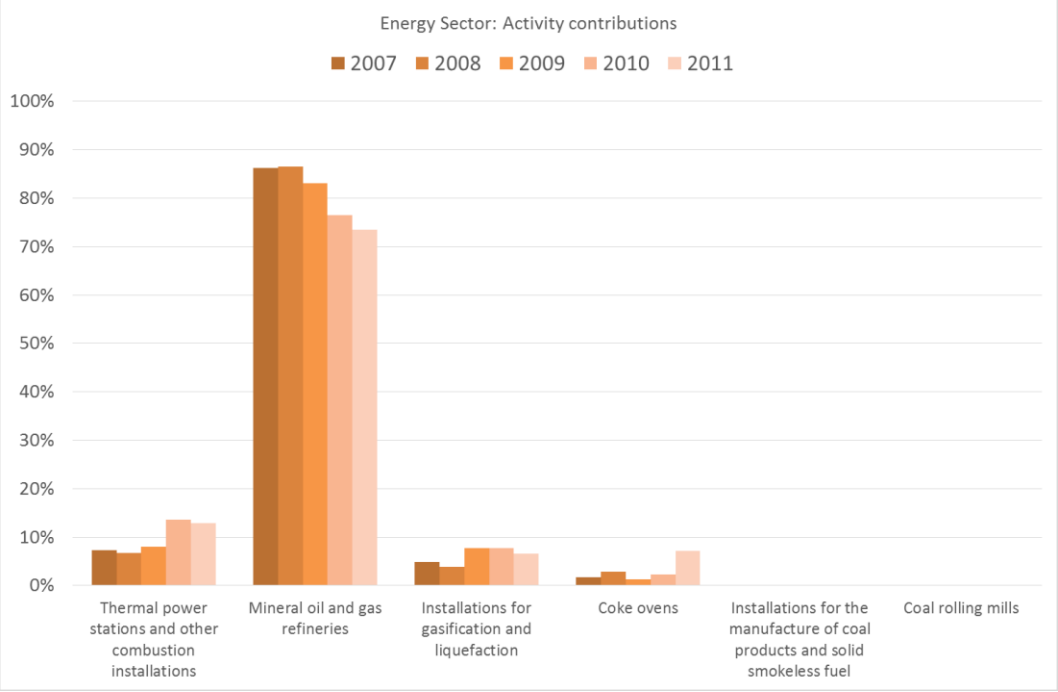


Figure 25 Benzene emissions - distribution in energy sector



3.5. CARBON DIOXIDE (CO_2)

3.5.1. Emissions from European refineries

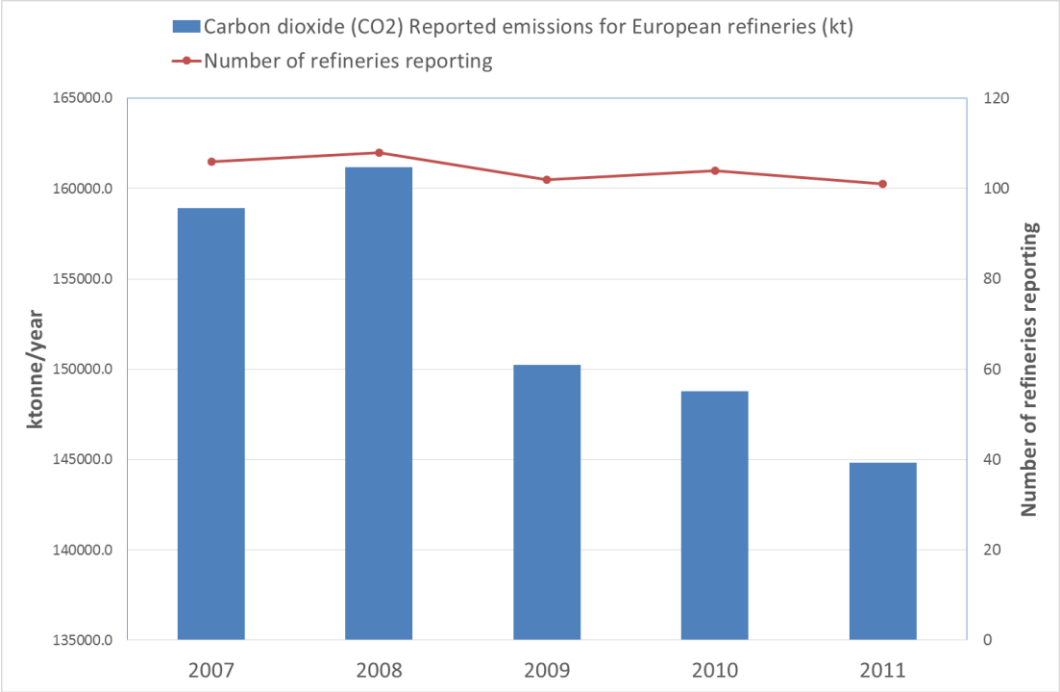
Table 14 summarises the reported emissions of "total" carbon dioxide to air from the European refineries. E-PRTR also provides reported data on CO_2 emissions due to biomass combustion. **Figure 26** shows that the reported emissions in 2011 were 9% lower than those in 2007. However, the mass of crude processed, which has a direct impact on the air emissions from refineries, also declined by almost 10% over the five year period. As shown in **Table 15** there was little change in the annual reported emissions per unit of crude processed during the period 2007 to 2011.

Table 14 Carbon dioxide emissions reported for refineries

	2007	2008	2009	2010	2011
Reported emissions (kt)	1.59E+05	1.61E+05[1]	1.50E+05	1.49E+05	1.45E+05
Total reported emissions for all sectors (kt)	2.65E+06	2.55E+06	2.31E+06	2.43E+06	2.37E+06
Refineries contribution to total	6%	6%	6%	6%	6%
Reported emissions per mass of crude oil transformed in refineries (kt/Gt)	2.44E+05	2.47E+05	2.49E+05	2.47E+05	2.47E+05
Number of refineries reporting	106	108	102	104	101
Reporting threshold (kt)	100	100	100	100	100

[1] In Concawe report 1/13 R the CO_2 emissions for the sector are considered to be 151 Mt, which indicates a difference of 10 Mt with the CO_2 appearing in E-PRTR database after correction for mis-classification. It should be considered that the figure reported in 1/13 excludes CO_2 emissions from integrated petrochemical plants.

Figure 26 Carbon dioxide emissions from European refineries



3.5.2. Statistical analysis

Table 15 provides the median, maximum and minimum values of the data submitted for refineries for each reporting year. It also gives the values of the first and third quartiles, the 5 and 95 percentiles and the upper outlier boundary (UOB) and the number of outliers above the UOB. The analyses are represented graphically in **Figure 27** and **Figure 28**.

Table 15 Statistical analysis of carbon dioxide data: emissions in kt/a

	2007	2008	2009	2010	2011
Minimum	151	133	146	106	109
Median	1 165	1140	1 170	1 120	1 140
Maximum	6 240	6 160	6 130	6 350	6 230
5 percentile	250	265230	307	187	152
25 percentile	582	643	632	552	537
75 percentile	2035	2028	1968	1908	1970
95 percentile	3858	3818	3778	3665	3690
Upper outlier boundary	4941	4797	4640	4618	4836
Number of outliers	3	3	2	2	2

Figure 27 Statistical analysis of CO_2 emissions from European refineries: first and third quartiles

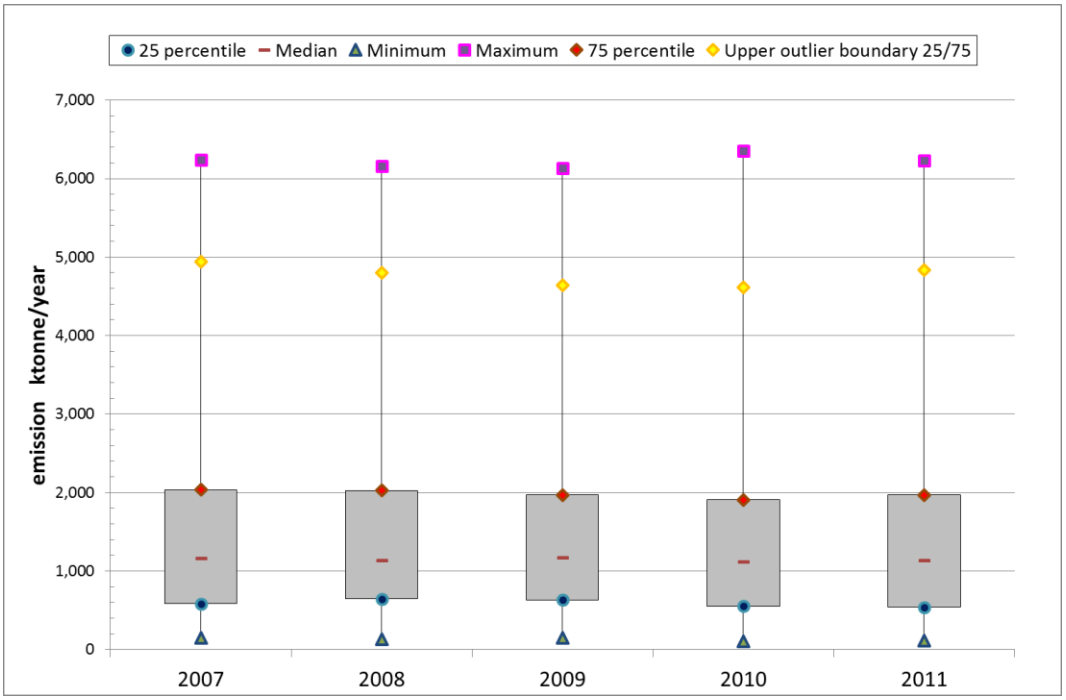
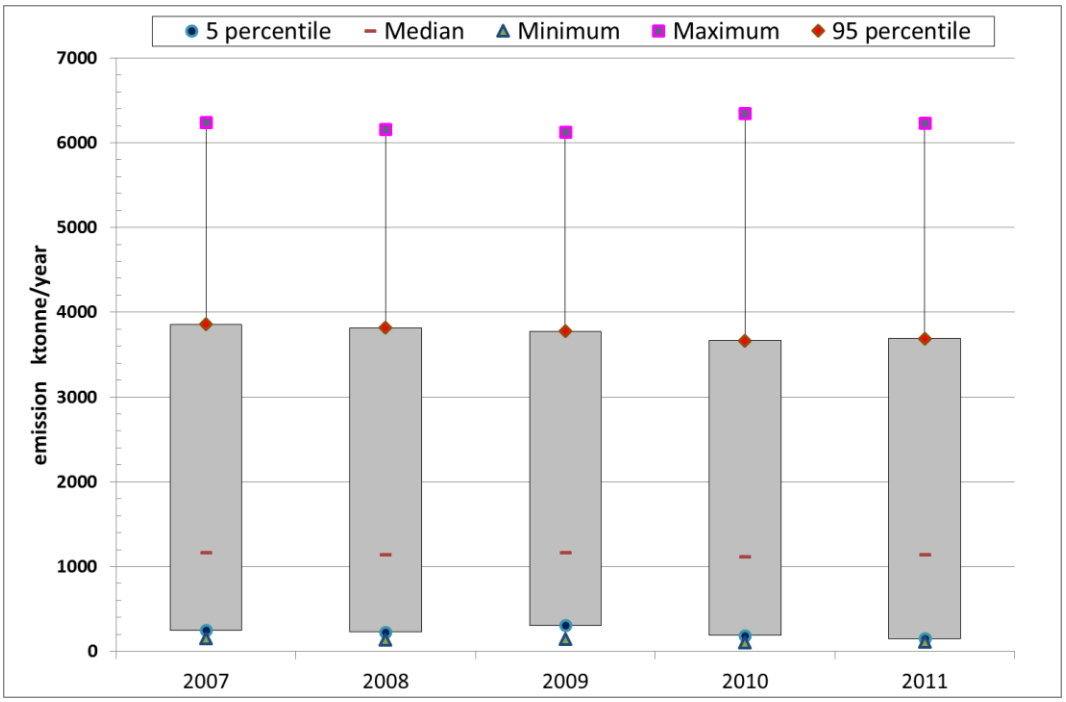


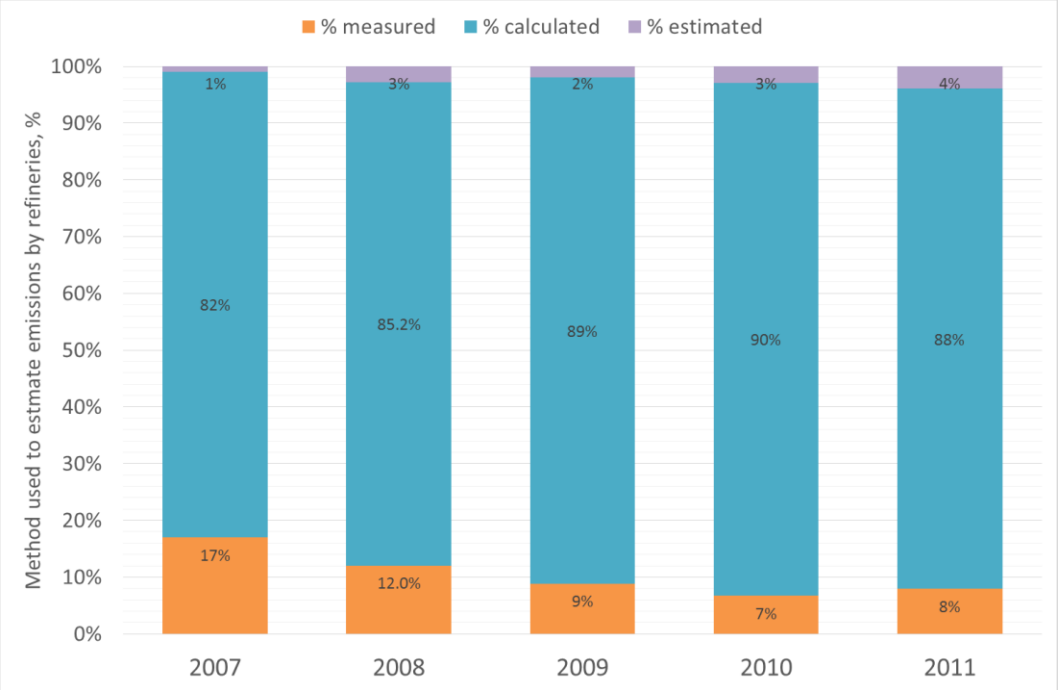
Figure 28 Statistical analysis of CO_2 emissions from European refineries: 5 and 95 percentiles



3.5.3. Methods used to determine the emissions

Figure 29 shows the degree to which the three different determination methods (as defined in reference 3] has been used to estimate carbon dioxide emissions. This shows that the use of approved estimation methodologies ("calculation") and measurements were used at virtually all refineries.

Figure 29 Methods used to determine emissions of carbon dioxide



3.5.4. Sectorial Analysis

Figure 30 illustrates the contribution of those Annex I sectors of activity for which CO_2 emissions are reported to E-PRTR in the period 2007-2011. It can be observed that the CO_2 emissions reported in the E-PRTR database are coming mainly from the energy sector (56-76%). From 2007 to 2011 the reported emissions of CO_2 from the energy sector decreased by 12% (234 Mt). The energy sector is divided into five different economic activities. **Figure 31** shows the contribution of these to the total energy sector reported emissions. It can be seen that thermal power stations and other combustion installations contribute to 88-91% of the CO_2 emissions from the energy sector.

Figure 30 CO_2 emissions - sectorial distribution

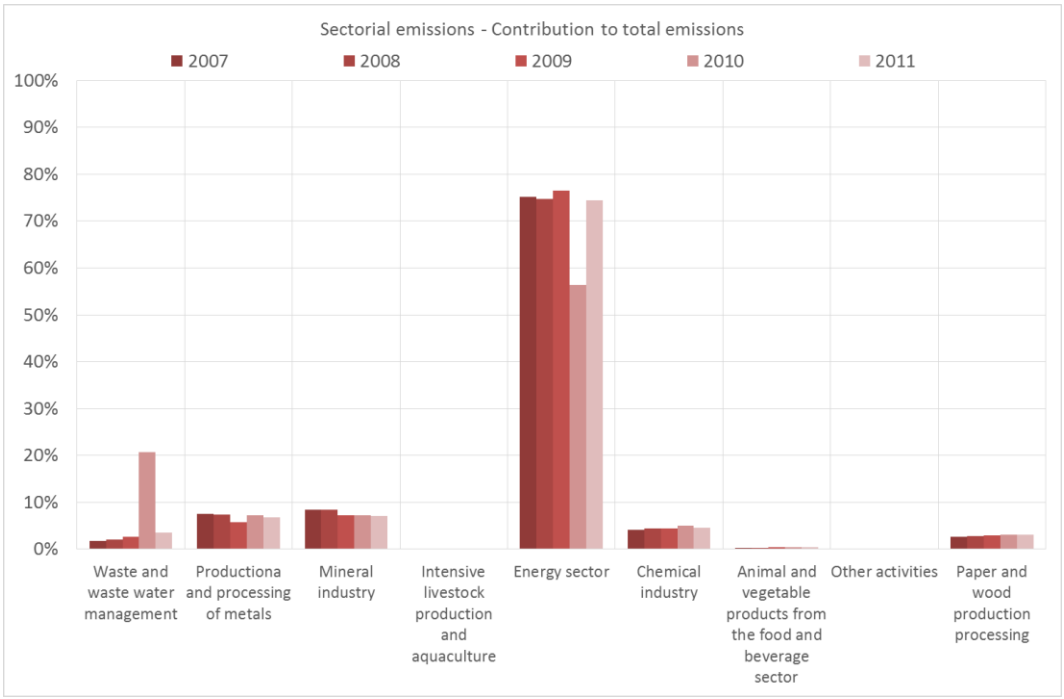
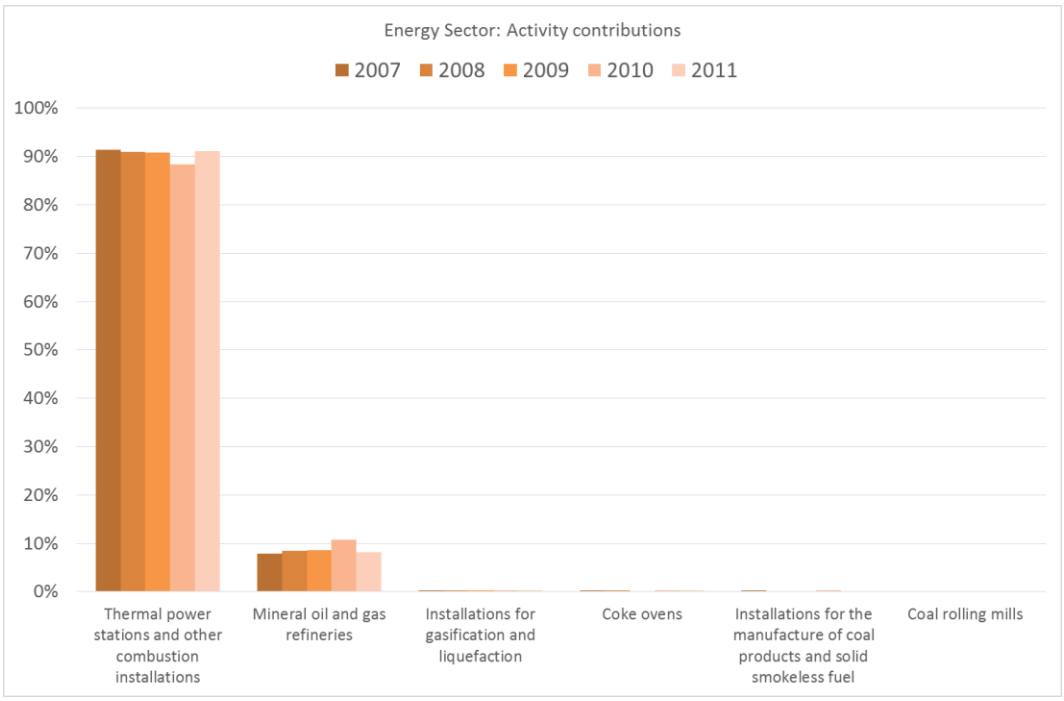


Figure 31 CO_2 emissions - distribution in energy sector



4. NON-REFINING SECTORIAL CONTRIBUTION

4.1. GENERAL

Table 16 provides the number of installations for which emissions to air have been reported that are not oil refineries, as defined in this report, but which are coded as such, either as Annex I, 1.(a) and/or NACE code 19.20.

Table 16 Number of non-refineries for which emissions to air have been reported but coded as IA code 1.(a) or NACE code 19.20

	2007	2008	2009	2010	2011
Total number of installation that are not refineries but that are reported as IA 1(a): *Mineral oil and gas refineries*	20	22	27	22	13
Total number of installation that are not refineries but that are reported as NACE 19.20: *Manufacture of refined petroleum products*	10	11	9	12	9

4.2. CONTRIBUTION OF NON-REFINING INSTALLATIONS TO EMISSION INVENTORIES

Table 17 shows the contributions reported for installations which are not oil refineries but coded as Annex I, activity 1.(a) which have exceeded 5% of the total reported emissions by oil refineries in one of the 2007 to 2011 reporting years.

Table 17 Contribution by non-refineries to Industrial Activity 1.(a) inventories

	2007	2008	2009	2010	2011
CO	16.2%	16.7%	25.5%	0	0
HCFCs	0	0	41.7%	59.6%	91.2%
HFCs	98.7%	65.6%	35.9%	0	0
Methane	54.4%	60.3%	48.8%	52.9%	51.0%
NMVOCs	9.4%	8.3%	7.8%	1.8	0

This table shows, for example, that in the 2011 E-PRTR database, under Annex I activity 1.(a) “Mineral oil and gas refineries” the contribution by refineries to the E-PRTR methane inventory is only 49%, the balance being from other facilities coded as such.

In addition, the NACE mis-classification of installations significantly impacts the annual emission inventories of naphthalene and in less degree the emission inventories of PM_{10} (2010) and dioxins and furans (2009). The contributions for such installations wrongly coded are shown in **Table 18.**

Table 18 Contribution by non-refining installations to NACE 19.20 inventories

	2007	2008	2009	2010	2011
CO	13.4%	18.5%	21.0%	26.8%	21.9%
HCFCs	22.5%	8.2%	0	40.6%	87.6%
Methane	5.7%	10.0%	8.2%	9.9%	17.1%
Naphthalene	24.3%	43.3%	100.0%	13.7%	33.2%
Particulate matter (PM_{10})	0	0	0	6.7%	0
PCDD + PCDF (dioxins + furans) (as Teq)	0	0	13.7%	0	0

5. DISCUSSION

This report provides a review of the emissions of air pollutants for oil refineries located in 24 European countries submitted to E-PRTR for the years 2007 to 2011. Within that period the number of refineries for which air emissions data have been submitted has reduced from 121 to 112.

The facilities in the E-PRTR database are listed under both their “Industrial Activity” (IA) code from Annex I of the E-PRTR Regulation [1] and by their NACE code. There are a number of sites classified in the E-PRTR under Annex I code 1.(a) or under NACE code 19.20 but which do not meet the definition of oil refinery used in this report. In 2007 there were 20 such facilities (14% of the total) for which air emissions were reported to the E-PRTR under Annex I code 1.(a) and 10 under NACE code 19.20.The respective numbers in 2011 were 13 under IA 1.(a) and 9 under NACE 19.20.

These incorrectly coded facilities have a significant effect on the Annex I activity 1(a) methane, HCFC and HFC inventories, and on the NACE inventory for naphthalene, e.g. contributing in 2011 91% of the HCFCs and 58% of the methane 1(a) inventories.

The total number of air pollutants reported for oil refineries on a pan-European basis in the E-PRTR between 2007 and 2011 has been 33 (of the 60 E-PRTR air pollutants). The number of pollutants reported for individual refineries vary significantly as data for a pollutant only have to be submitted if the emissions exceed a threshold value.

Detailed analyses have been undertaken of the emissions of the five pollutants to air reported for the majority of oil refineries over the period 2007 to 2011. These pollutants are SOx, NOx, NMVOCs, CO_2 and benzene.

It is reported that the emissions data for SOx, NOx and CO_2 have been determined using calculation or measurement methods at virtually all facilities. By contrast, “non-standardised” methodologies (as defined in [3]) have been used for NMVOCs and benzene at 15% and 20% respectively of sites in 2011. It is not known, what effect the use of these methodologies has on the uncertainty of the reported emissions.

Refineries are required to collate their pollutant release data and submit them on an annual basis to their relevant competent authority. The data are then compiled and quality checks undertaken. They are then provided, as part of the national return, to the European Commission and EEA before being uploaded by the latter onto the E-PRTR database. Due to the degree of data handling and transfer there is a risk, for example, of transcription errors occurring. It is therefore recommended that refineries check the E-PRTR database. Concawe has not established the accuracy of the emissions reported for each individual refinery. The data used in the analyses for this report are those that appear in the E-PRTR database (v.6.1) on the EEA website.

Four of the five pollutants reviewed have reported reductions year on year. The exception is carbon dioxide which has seen an overall reduction of 9% since 2007 but with increases in one of the five years. The percentage emissions reductions between 2007 and 2011 for the other four pollutants are: SOx 37%, NOx 28%, NMVOCs 35% and benzene 44%.

However the mass of crude processed, which has a direct impact on the air emissions from refineries, has also declined by almost 10% over the same five year period The emissions per unit of crude processed have therefore been determined to take this into account. The percentage reductions in kt of reported emissions per Gt of crude processed between 2007 and 2011 for the five pollutants are shown in **Table 19**.

Table 19 Variations in reported emissions in kt/Gt crude processed between 2007 and 2011

Pollutant	Reported emissions for oil refineries kt/Gt of crude processed		Reduction %
	2007	2011	
SOx	885	618	30
NOx	298	240	28
NMVOCs	276	199	28
Benzene	3.3	2.1	38
CO_2	243,900	247,300	-1.4

Although for the refining sector significant reductions have been reported for four of the five pollutants, the other sectors contributing to the overall E-PRTR inventories have also reported reduced emissions. The result has been that the refining contributions to these inventories has been relatively stable. **Table 20** provides an indication of the oil refining percentage contribution to the E-PRTR inventories of the five pollutants in both 2007 and 2011.

Table 20 Refining contribution to E-PRTR inventories: 2007 and 2011

Pollutant	Refining contribution to E-PRTR inventory %	
	2007	2011
SOx	10	11
NOx	6	6
NMVOCs	25	27
Benzene	46	41
CO_2	6	6

The refining sector is a major contributor to the E-PRTR inventories of benzene and NMVOCs. It must be recognised that these inventories are for those industries submitting data under the E-PRTR Regulation and do not include major sources such as transport and domestic heating.

6. ANNEX 1 CRUDE OIL TRANSFORMATION INPUT IN REFINERIES

Table 21 Crude oil transformation input in refineries, thousands of tonnes (from [6])

COUNTRY	YEAR				
	2007	2008	2009	2010	2011
Austria	8,548	8,666	8,306	7,749	8,298
Belgium	32,963	33,725	31,324	33,283	29,777
Bulgaria	7,096	7,146	6,247	5,475	5,083
Czech Republic	7,394	8,249	7,376	7,901	7,098
Denmark	7,798	7,782	7,805	7,246	6,811
Finland	10,844	11,097	10,940	10,511	11,212
France	82,350	83,667	72,131	65,424	65,401
Germany	109,395	107,427	100,903	95,388	93,439
Greece	19,169	17,957	17,210	19,575	16,490
Hungary	7,087	6,967	6,324	6,389	6,596
Ireland	3,389	3,272	2,812	2,905	2,949
Italy	92,770	86,944	80,348	83,284	78,158
Lithuania	4,742	9,241	8,407	8,985	9,007
Netherlands	49,883	50,356	48,424	51,845	50,410
Norway	15,207	13,915	13,829	12,895	14,374
Poland	20,113	20,804	20,304	22,843	24,001
Portugal	12,314	12,046	10,406	11,297	10,275
Romania	13,006	12,981	11,210	10,050	9,675
Serbia	3,249	3,164	2,880	2,857	2,359
Slovakia	5,955	5,847	5,700	5,453	5,991
Spain	57,704	58,610	52,651	52,794	52,316
Sweden	18,363	20,663	19,638	20,226	18,645
Switzerland	4,674	5,021	4,748	4,488	4,733[1]
United Kingdom	75,707	75,844	70,716	68,711	70,691
TOTALS	669,720	671,391	620,639	617,574	603,789

Table Note 1: No data for 2011 provided in reference 6. Transformation input for that year determined from the average of the previous four years.

7. GLOSSARY

CH_4	Methane
EEA	European Environment Agency
E-PRTR	European Pollutant Release and Transfer Register
FCCU	Fluidised Catalytic Cracking Unit
HCFCs	Hydrochlorofluorocarbons
IA	Industrial Activity
NACE	Nomenclature Générale des Activités Economiques dans l'Union Européen
NECD	National Emission Ceiling Directive
NMVOC	Non-methane Volatile Organic Compound
NOx	Oxides of nitrogen
NO_2	Nitrogen dioxide
SOx	Oxides of Sulphur
SO_2	Sulphur dioxide
UOB	Upper Outliers Boundary

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