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Air emissions from the refining sector. Analysis of E-PRTR data 2007-2017

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Air emissions from the refining sector.

Analysis of E-PRTR data 2007-2017

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ABSTRACT

This report is an updated version of the Concawe Report No 4/18 providing a review of the air pollutant emissions data submitted by national authorities for oil refineries in the European Pollutant Release and Transfer Register (E-PRTR) from 2007 to 2017. Detailed analyses are given for six pollutants of interest (SO_x, NO_x, NMVOCs, benzene, CO_2, and PM_{10}).

Emissions of all the six pollutants reviewed have decreased significantly between 2007 and 2017: SO_x by 65%, NO_x by 45%, NMVOCs by 38%, benzene by 50%, CO_2 by 20%, and PM_{10} by 65%. The mass of crude processed over the same eleven-year period has reduced by 9% (based on assumptions taken to determine the transformation input for 2017). When emissions are expressed as t per Mt of crude processed the reduction between 2007 and 2017 is: 61% for SO_x, 40% for NO_x, 32% for NMVOCs, 45% for benzene, 12% for CO_2, and 61% for PM_{10}.

KEYWORDS

E-PRTR, Emissions, Refineries, Sulphur oxides (SO_x/SO_2), Nitrogen oxides (NO_x/NO_2), Benzene, Carbon dioxide (CO_2), Non-methane volatile organic compounds (NMVOCs), Particulate Matter (PM_{10}).

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SUMMARY

This report updates Concawe Report No 4/18 [1] and 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 2017. Detailed analyses are provided for emissions of six pollutants reported for refineries (SO_x, NO_x, NMVOCs, benzene, CO_2, and PM_{10}). These pollutants include those listed in the National Emissions Ceiling Directive [4] and the main greenhouse gas emitted by oil refineries. The changes in reported emissions for each pollutant over the eleven-year period are reviewed, as is the contribution of the oil refining sector to the whole E-PRTR inventory. The impact of incorrectly coded submissions is also identified.

An "oil refinery" is defined in this report as an installation where the main activity is the refining of crude oil. Also included are specialised refineries for the production of bitumen and for the production of lubricants. Based on the 2017 data there were 96 "oil refineries" in 24[1] countries that reported air emissions.

The facilities in the E-PRTR database are listed under both their "Industrial Activity" (IA) code from Annex I of the E-PRTR Regulation [6] and by their NACE code[2]. There are a number of facilities using the refinery codes that do not meet the traditional definition of oil refinery (e.g., terminals, NGL plants, manufactures of industrial gases and/or chemicals, companies extracting natural gas). The facilities that do not meet the definition of oil refinery have a significant effect on the E-PRTR inventories for some pollutants (e.g. in 2017, they contribute almost 90% of the hydro-chlorofluorocarbons (HCFCs) and more than 50% of the carbon monoxide (CO) and methane (CH_4) inventories). The analysis undertaken by Concawe for this report excludes the data submitted for those installations as they are not deemed to be oil refineries. Additionally, there are also refineries that are classified as other activities in the E-PRTR database. In order to identify the total number of installations that do not meet Concawe's definition of refinery, as well as refineries that are classified under another category, a cross-check of the E-PRTR database with the Concawe refinery list was undertaken.

In total, between 2007 and 2017, refineries have reported emissions for 38 different air pollutants. 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 compiled and quality checks undertaken and they are then provided as part of the national return to the European Commission (EC) and European Environment Agency (EEA). The EEA uploads the data into the E-PRTR database. Due to the degree of data handling and transfer there is a risk, for example, of transcription errors occurring. For this reason, it is recommended that refineries check the E-PRTR database to validate the final submitted data. Concawe cannot establish the accuracy of the emissions

[1] In 2017, 80 refineries were operating in Europe (FuelsEurope (2018) Statistical Report 2018). The difference in the number of refineries that report air emissions is due to the fact that due to administrative changes some large sites previously operated as multiple entities and continue to report air emissions as separate E-PRTR installations.

[2] 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.

reported for each individual refinery. This analysis, therefore, is based on the published data.

Detailed analyses have been undertaken for emissions of six pollutants (SO_x, NO_x, NMVOCs, benzene, CO_2, and PM_{10}) reported for oil refineries over the period 2007 to 2017. The analysis indicates a clear downward trend of the reported air emissions from refineries for all the examined pollutants. The percentage of emissions reductions between 2007 and 2017 are: SO_x 65%, NO_x 45%, NMVOCs 38%, benzene 50%, CO_2 20%, and PM_{10} 65%.

The mass of crude processed, which has a direct impact on the air emissions from refineries, has also declined by almost 9% over the same period (2007-2017) (note: annual data are available until 2016, while for 2017 the transformation input is determined from the average of the previous years). The emissions per unit of crude processed have therefore been determined so that this is factored into the analysis. The percentage reductions in tonnes of reported emissions per Mt of crude processed between 2007 and 2017 for the six pollutants are: 61% for SO_x, 40% for NO_x, 32% for NMVOCs, 45% for benzene, 12% for CO_2, and 61% for PM_{10}.

1. INTRODUCTION

The European Pollutant Release and Transfer Register (E-PRTR) was established by Regulation in 2006 [6] with the first reporting year being 2007. By November 2019, there had been a further ten data sets added to the register, up to and including that for 2017.

The objectives of this report are:

- to review the changes in the emissions of six air pollutants (SO_x, NO_x, NMVOCs, benzene, CO_2, and PM_{10}) reported for refineries from 2007 to 2017;
- 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, and

ii) they 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.

After the submissions of the data to the national competent authorities, the data are compiled and they are then provided to 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 2017 database for facilities within the 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) and there is no capacity threshold provided. The activities in the E-PRTR database are also reported using the NACE[3] (Revision 2) statistical classification of economic activities code [7]. 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. Also included are specialised refining installations, for example those producing bitumen or lubricating oils. A Concawe database of oil refineries was used to identify these facilities. Based on the 2017 E-PRTR inventory there were 96 refineries in 24 countries that reported air emissions.

In total, there are 60 E-PRTR air pollutants. Concawe report 4/19 [2] provides the sector with recommended emission estimation methodologies for 25 of these pollutants. These pollutants were included in the report following a review of the emission sources that exist at the majority of refineries, the pollutants emitted, the methodologies available in the public domain for estimating these and the

[3] Nomenclature Générale des Activités Economiques dans l'Union Européen

likelihood 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 a 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 2017 is 38. The number 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 reporting is only required if values are in excess of the specified threshold. This report reviews the data for six pollutants reported for oil refineries: SO_x, NO_x, NMVOCs, benzene, CO_2 and particulate matter (in the form of PM_{10}). The data available in the E-PRTR database for these six pollutants are analysed in detail in Chapter 3. These pollutants include those listed in the National Emissions Ceiling Directive [4] (except for ammonia; the reported emissions from refineries in 2017 contribute only 0.2% of the total inventory) and the main greenhouse gas emitted by oil refineries. To determine the significance of the refining industry compared to other reported sources of emissions, the values for oil refineries are compared to those 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 emissions that may have occurred in the initial main upload. It should be noted that each version of the E-PRTR database may include additions, deletions and/or corrections of reported emissions not only from the latest but for historical years as well. For the analyses in this report the latest version of the E-PRTR database (E-PRTR v.17, published in October 2019, and last modified in November 2019) is used, which contains reported data from 2007 to 2017, and is recommended by EEA as the latest official database version for use.

2. OVERVIEW OF REPORTING

2.1. NUMBER OF SITES

The E-PRTR 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 (based on the definition given in this report). On the other hand, some of the installations that are actually refineries are classified as other activities (e.g. 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). In order to identify the total number of installations that do not meet Concawe's definition of refinery, as well as refineries that are classified under another category, a cross-check of the E-PRTR database with the Concawe refinery list was undertaken. **Table 1** summarises the total number of installations which meet Concawe's definition of refinery given in this report and for which air emissions have been reported to E-PRTR from 2007 to 2017.

Table 1 Total number of refineries[4] (which meet Concawe's definition) for which air emissions have been reported to E-PRTR during 2007-2017

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Number of refineries reporting air emissions[4]	122	118	115	117	115	111	106	105	99	96	96

Despite the fact that the installations in **Table 1** are considered as refineries, and therefore they should be classified in the E-PRTR database as Annex I activity code 1.(a) "mineral oil and gas refineries" or as NACE code 19.20 "manufacture of refined petroleum products", the E-PRTR classification is not correct for all of them. **Table 2** and **Table 3** show under which categories the above 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.

[4] In 2017, 80 refineries were operating in Europe (FuelsEurope (2018) Statistical Report 2018). The difference in the number of refineries that report air emissions is due to the fact that due to administrative changes some large sites previously operated as multiple entities and continue to report air emissions as separate E-PRTR installations.

Table 2 Classification of refineries (which meet Concawe's definition), for which air emissions have been reported to E-PRTR database during 2007-2017, by Annex I Activity Name

Annex I Activity Name / Code	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Mineral oil and gas refineries, 1.(a)	118	114	112	114	112	108	103	103	96	94	95
Chemical installations for the production on an industrial scale of basic organic chemicals, 4.(a)	1	2	1	1	1	1	1	1	0	0	1
Installations for the recovery or disposal of hazardous waste, 5.(a)	1	0	0	0	0	0	0	0	1	0	0
Installations for gasification and liquefaction, 1.(b)	1	1	1	1	1	1	1	0	0	0	0
Thermal power stations and other combustion installations, 1.(c)	1	1	1	1	1	1	1	0	1	1	0
Independently operated industrial waste-water treatment plants, 5.(g)	0	0	0	0	0	0	0	1	1	0	0
Chemical installations for the production on an industrial scale of basic inorganic chemicals, 4.(b)	0	0	0	0	0	0	0	0	0	1	0
Total	**122**	**118**	**115**	**117**	**115**	**111**	**106**	**105**	**99**	**96**	**96**

Table 3 Classification of refineries (which meet Concawe's definition), for which air emissions have been reported to E-PRTR database during 2007-2017, by NACE coding

NACE Main Economic Activity Name/Code	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Manufacture of refined petroleum products, 19.20	117	116	110	115	112	103	102	103	96	93	92
Manufacture of oils and fats, 10.41	0	0	1	1	1	1	0	0	0	0	0
Manufacture of other organic basic chemicals, 20.14	2	2	0	0	0	1	0	0	0	0	0
Manufacture of refractory products, 23.20	3	0	4	1	2	2	2	1	1	0	1
Treatment and disposal of non-hazardous waste, 38.21	0	0	0	0	0	3	0	0	0	0	0
Wholesale of solid, liquid and gaseous fuels and related products, 46.71	0	0	0	0	0	0	0	0	1	1	1
Manufacture of other chemical products n.e.c., 20.59	0	0	0	0	0	0	1	1	1	1	1
Raising of poultry, 1.47	0	0	0	0	0	1	0	0	0	0	0
Warehousing and storage, 52.10	0	0	0	0	0	0	1	0	0	0	0
Manufacture of coke oven products, 19.10	0	0	0	0	0	0	0	0	0	1	0
Trusts, funds, and similar financial entities, 64.30	0	0	0	0	0	0	0	0	0	0	1
Total	**122**	**118**	**115**	**117**	**115**	**111**	**106**	**105**	**99**	**96**	**96**

Table 4 compares the number of refineries that meet Concawe's definition and for which air emissions have been reported to the E-PRTR and classified as Annex I code 1.(a) or as NACE code 19.20, with the total number of installations for which air emissions have been reported to the E-PRTR and classified with the same Annex I and NACE codes. This shows that in 2007 there were 22 facilities (16% of the total) which did not meet the definition of refinery given in this report but were classified as Annex I code 1.(a). Similarly, there were 13 facilities that did not meet the definition of refinery which were classified as NACE code 19.20. In 2017, the facilities that did not meet the definition of oil refinery were 31 under IA 1.(a) and 15 under NACE 19.20.

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

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Annex I - 1.(a) Classification											
Total number of installations	140	140	142	140	137	136	138	134	126	136	126
Number of installations as 1.(a) which meet Concawe's definition of refinery	118	114	112	114	112	108	103	103	96	94	95
NACE 19.20 Classification											
Number of installations as NACE 19.20	130	128	123	129	124	117	116	117	109	108	107
Number of installations as NACE 19.20 which meet Concawe's definition of refinery	117	116	110	115	112	103	102	103	96	93	92

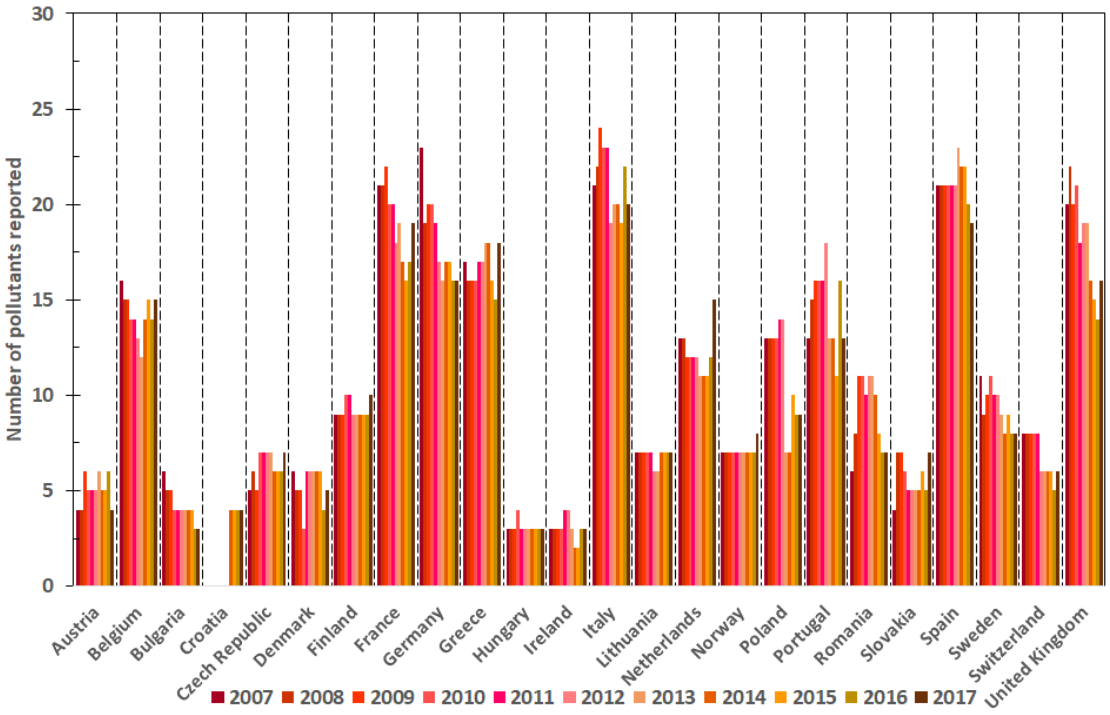
The analyses of the emissions included in this report have been undertaken on the data submitted for the refineries in Europe and exclude the emissions of those installations in the E-PRTR database which are not deemed to be oil refineries.

An analysis of the impact of all non-refining emissions is provided in Chapter 4, where the contribution of the installations which do not meet the definition of refinery given in this report to the total reported air emissions of pollutants is discussed.

2.2. POLLUTANTS

The number of air pollutants reported for refineries can vary significantly due to a number of factors. For example, the size of the refinery impacts how many pollutants will be emitted in excess of the reporting thresholds. Additionally, the type of process plant installed can also impact the number of pollutants in particular if the refinery incorporates petro-chemical production. This is reflected in the totals if reviewed on a national basis, as in **Figure 1**.

Figure 1 Number of air pollutants reported for refineries in each European country



The reported pollutants might differ from year to year. In total, between 2007 and 2017, refineries have reported emissions for 38 different air pollutants.

3. REFINERIES EMISSIONS SUMMARY

This Chapter presents detailed analyses of the emissions of six pollutants to air that are reported for European refineries over the period from 2007 to 2017. For each pollutant the following are provided in the analysis:

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, has declined over the eleven-year period. The emissions per unit of crude processed have therefore also been determined to take this into account.

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 latest E-PRTR database (v17) on the EEA website.

2. Statistical analyses of submitted data

These include the median, maximum and minimum values as well as the 5^{th}, 25^{th}, 75^{th}, and 95^{th} percentiles of the pan-European refinery emissions data for each of the six pollutants. These values give the range of the reported emissions in each data set, as well as an indication of the percentage of the refineries that report emissions below a particular value. These values are also used to identify any outliers in the datasets. The number of outliers above the Upper Outliers Boundary (UOB) is also given. In this report the latter is calculated from $75^{th} + 2 \times (75^{th} - 25^{th})$.

3. Determination methods

For each pollutant, the reporting facility must provide an indication how the emission value was determined. The EC guidance document for the implementation of the E-PRTR [5] provides three classes identified by code letters:

- "M" means the emissions 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 4/19 would fall.
- "E" which includes "non-standardised" estimations (as defined in [5]), 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. Comparisons of emissions by sector

These provide the respective contributions of those Annex I sectors of activity [6] for which emissions of the pollutant have been reported to the E-PRTR in the period 2007-2017. 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 comparisons of emissions by sectors. 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 5 summarises the reported emissions of oxides of sulphur to air from the European refineries. The reporting threshold for emissions of oxides of sulphur to air is 0.15 kt/a. Since 2007, there has been a decrease in their overall reported emissions, year on year.

Figures 2 and 3 show the trend observed for the years 2007 to 2017. The reported emissions in 2017 are 65% lower than those in 2007 **(Figure 2)**. When emissions are expressed per unit of crude processed (see data in **Appendix 1**), the reduction is 61% **(Figure 3).**

Table 5 Oxides of sulphur emissions to air reported for refineries in the E-PRTR database during 2007-201.

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Reported emissions for refineries (kt)	576	511	438	392	368	309	237	211	211	204	202
Total reported emissions for all sectors (kt)	5597	4257	3781	3344	3310	2940	2470	2245	2065	1716	1769
Refineries contribution to total SO_x emissions reported to E-PRTR	10%	12%	12%	12%	11%	11%	10%	9%	10%	12%	11%
Reported emissions per mass of crude oil transformed in refineries (ppm)	857	760	704	634	610	514	416	372	353	344	330
Number of refineries reporting	113	107	106	104	103	99	90	88	84	82	81

Figure 2 Trends of oxides of sulphur air emissions reported for European refineries, during 2007-2017

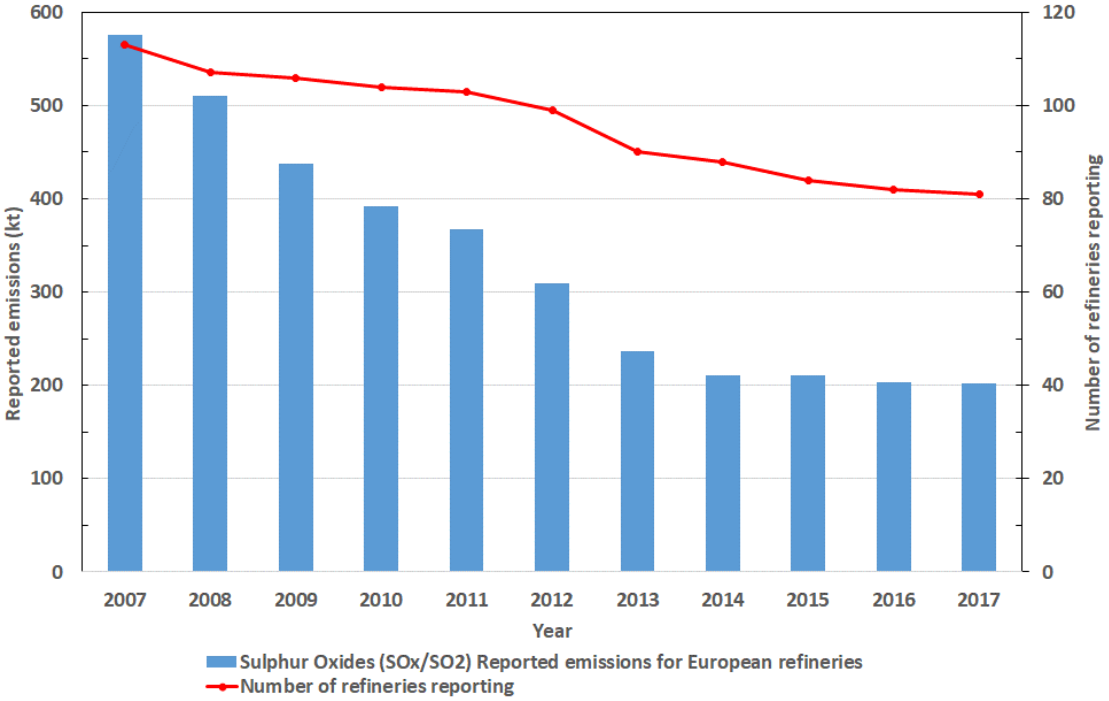
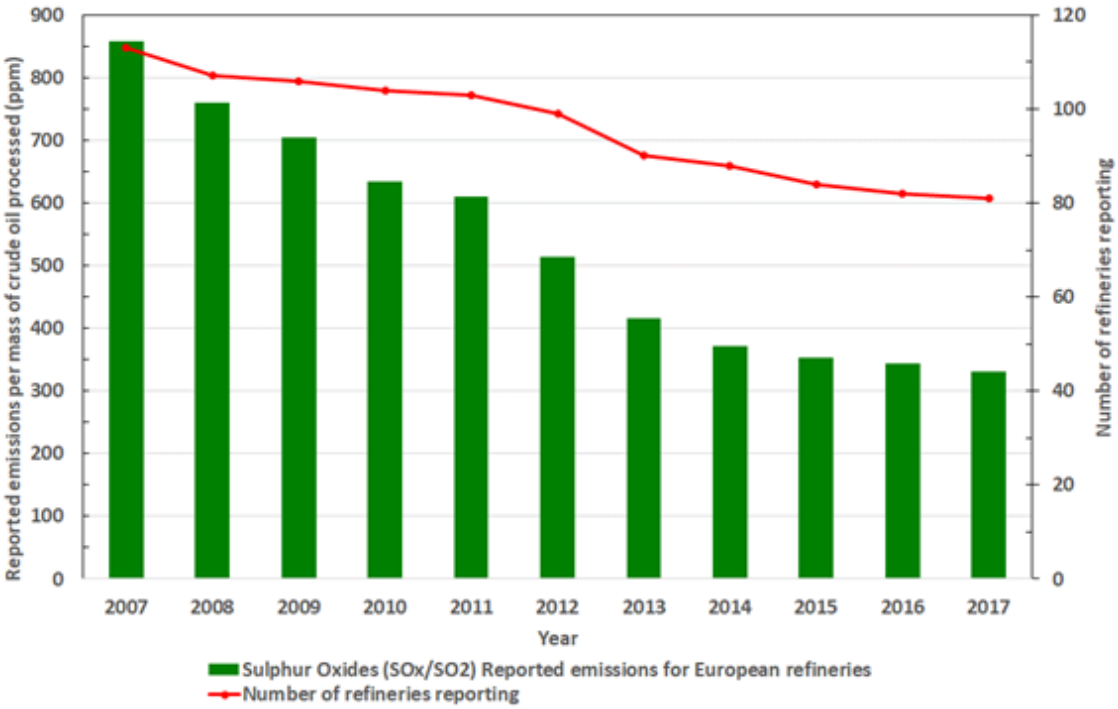


Figure 3 Trends of oxides of sulphur air emissions reported for European refineries during 2007-2017, expressed as per unit of crude processed



3.1.2. Statistical analysis

Table 6 provides the median, maximum and minimum values of the data submitted for refineries for each reporting year. It also gives the values of the 5th, 25th, 75th, and 95th percentiles, the upper outlier boundary (UOB) and the number of outliers above the UOB. The analyses are represented graphically in **Figure 4** and **Figure 5**. The results show a wide scatter of the reported emissions from 2007-2011, which narrows down from 2012 onwards. The number of outliers also reduces from 2012, while in 2017, 95% of the refineries report emissions below 6.7 kt/y, more than two times lower than the respective percentile in 2007.

Table 6 Statistical analysis of oxides of sulphur air emissions [kt/y] for European refineries

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Minimum	0.16	0.16	0.18	0.15	0.18	0.18	0.16	0.18	0.22	0.20	0.15
Median	3.53	3.59	3.22	2.67	2.57	2.20	1.95	1.73	2.14	2.06	2.12
Maximum	21.0	20.4	21.0	22.4	21.0	20.7	10.1	7.85	11.0	11.0	9.24
5th percentile	0.24	0.39	0.26	0.26	0.26	0.22	0.25	0.25	0.27	0.29	0.27
25th percentile	1.49	1.38	1.16	1.21	0.79	0.82	0.91	0.81	0.73	0.76	0.70
75th percentile	7.38	6.45	5.51	4.87	4.77	4.39	3.62	3.56	3.55	3.40	3.51
95th percentile	16.28	13.73	12.03	11.14	11.63	9.76	7.68	6.53	5.97	5.75	6.66
Upper outlier boundary	19.16	16.59	14.21	12.19	12.2	11.52	9.03	7.68	9.18	8.66	9.14
Number of outliers	4	2	3	4	4	1	1	1	1	1	1

Figure 4 Statistical analysis of oxides of sulphur air emissions for European refineries: 25th and 75th percentiles

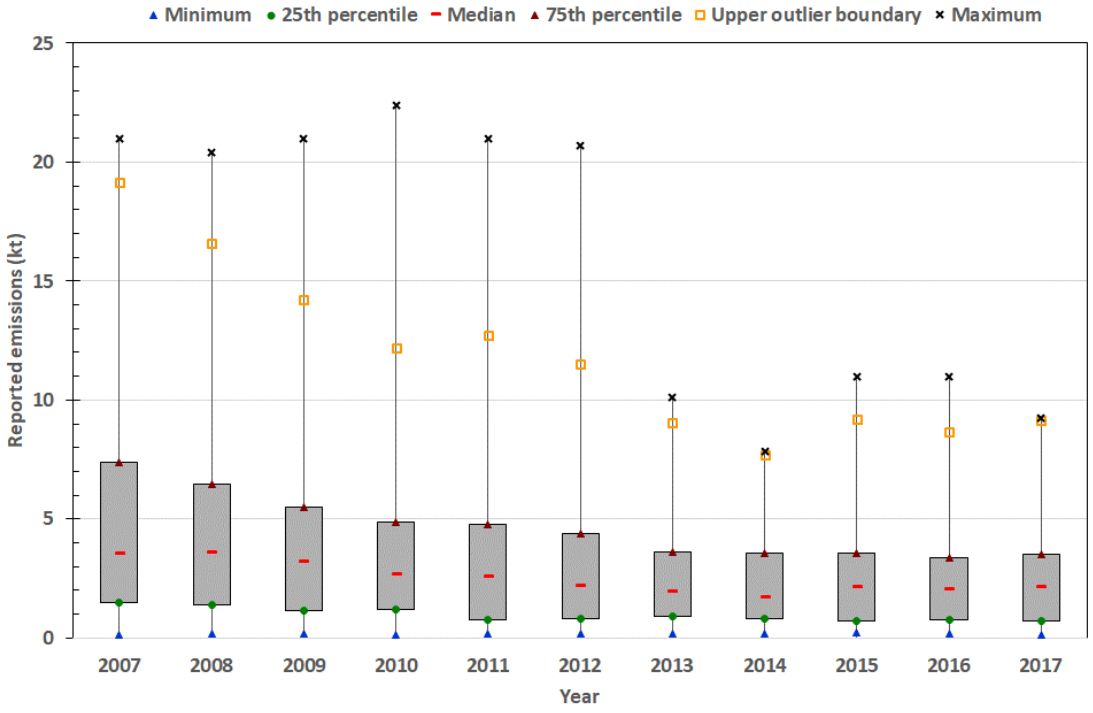
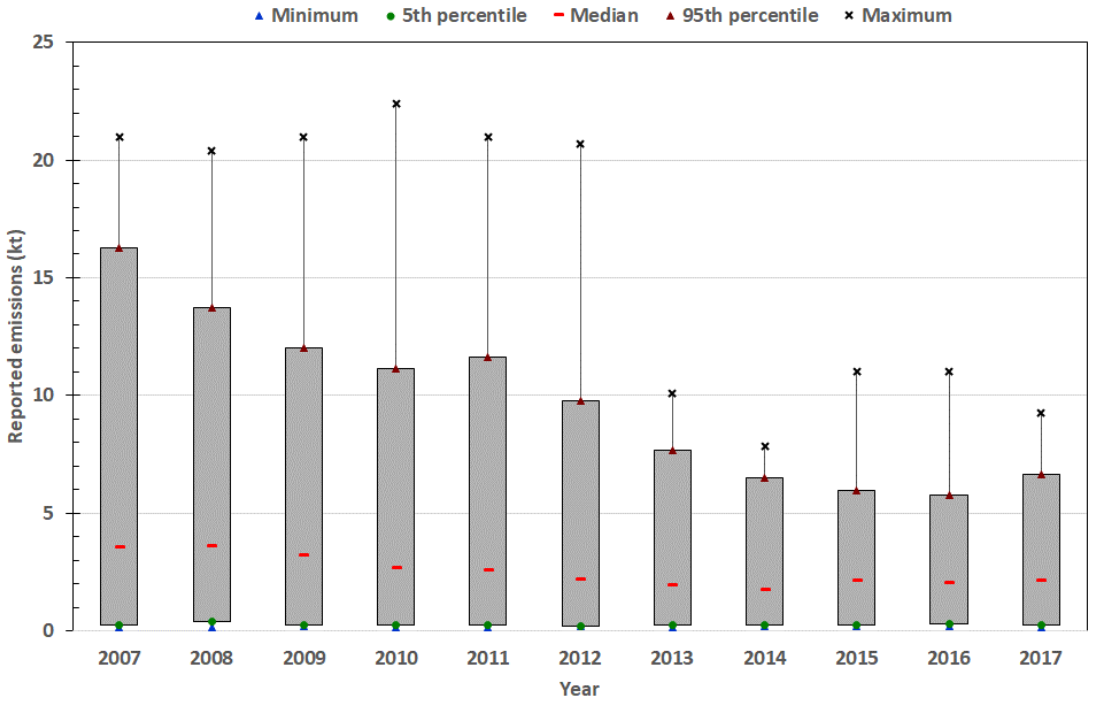


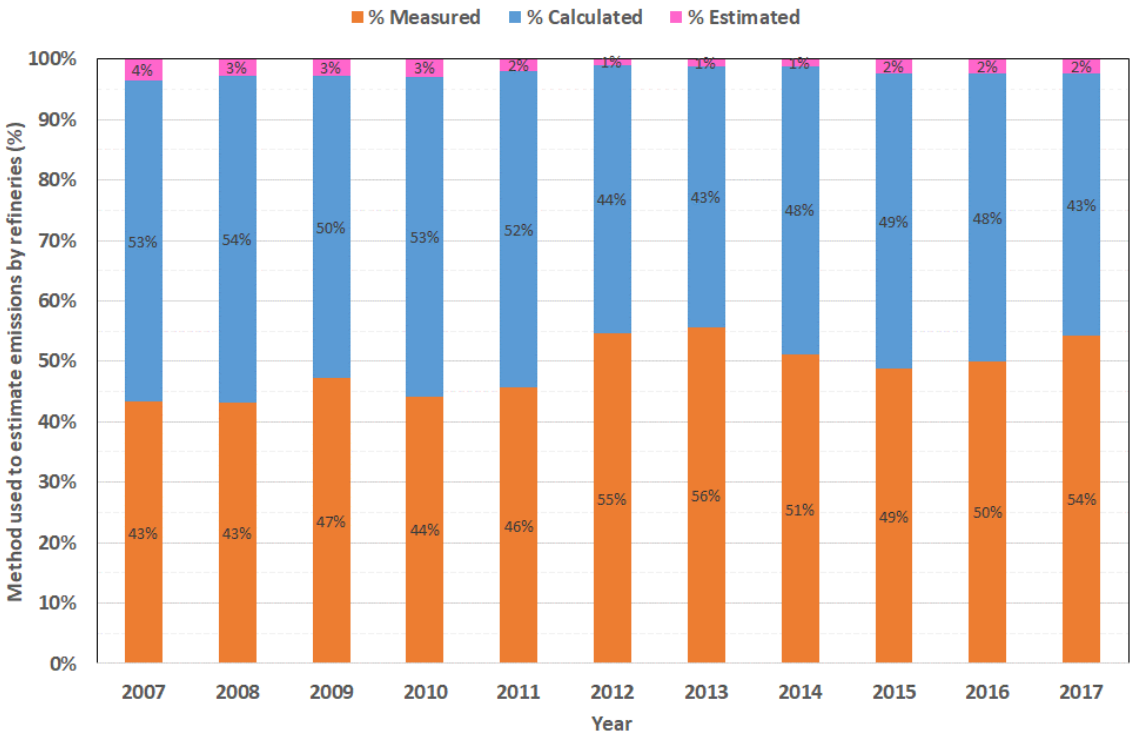
Figure 5 Statistical analysis of oxides of sulphur air emissions for European refineries: 5th and 95th percentiles



3.1.3. Methods used to determine the emissions

Figure 6 shows the degree to which the three different determination methods (as defined in reference [5] and summarised in Section 3) have been used to report SO_x emissions. The results show that approved estimation methodologies ("calculation") and measurement were used at virtually all installations.

Figure 6 Methods used to determine oxides of sulphur air emissions for European refineries



3.1.4. Emissions by sector

Figure 7 illustrates the contribution of those Annex I sectors of activity for which SO_x air emissions have been reported to E-PRTR in the period 2007 to 2017. The results show that sulphur oxides air emissions reported in the E-PRTR database originate mainly from the energy sector (80% – 90% contribution). In terms of absolute values, reported SO_x emissions from the energy sector have reduced by approximately 3,400 kt (71%) from 2007 to 2017 (**Figure 8**).

The energy sector is divided into six different economic activities. **Figure 9** shows the contribution of each of these to the total energy sector reported SO_x air emissions. The main contributor to the energy sector SO_x emissions are "thermal power stations and other combustion installations" (85-88%).

Figure 7 Percentage contribution of each Annex I sector of activity to total oxides of sulphur air emissions reported in the E-PRTR database during 2007-2017

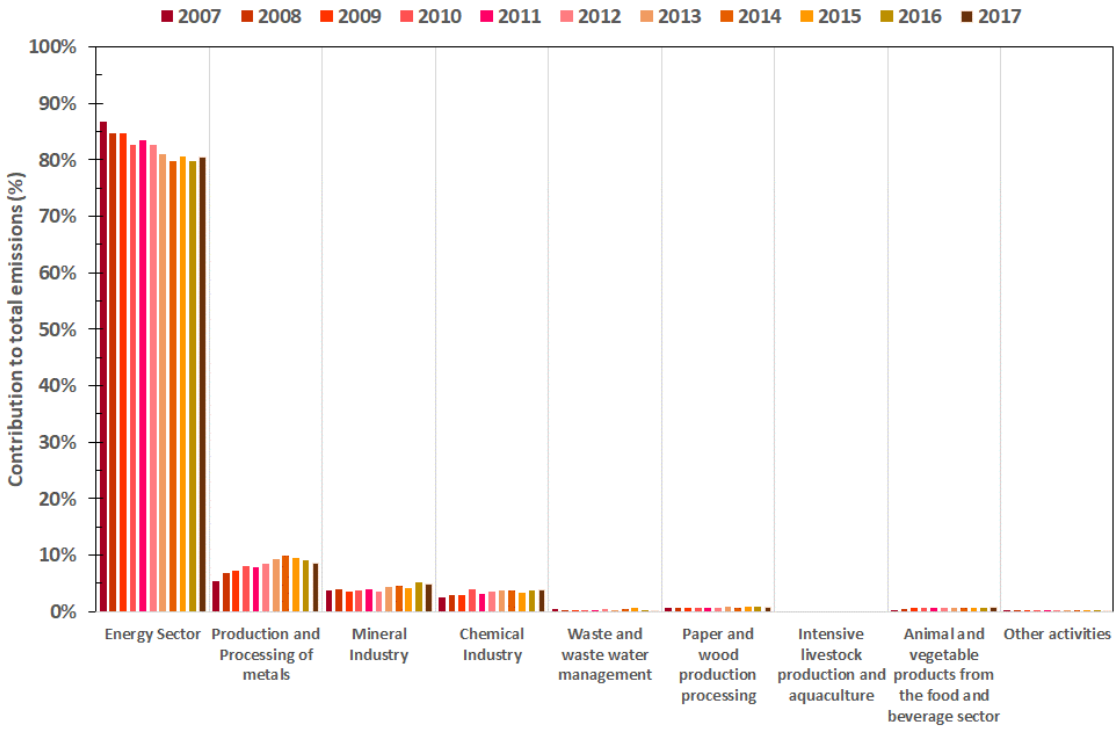


Figure 8 Oxides of sulphur air emissions reported in the E-PRTR database during 2007-2017 for each Annex I sector of activity

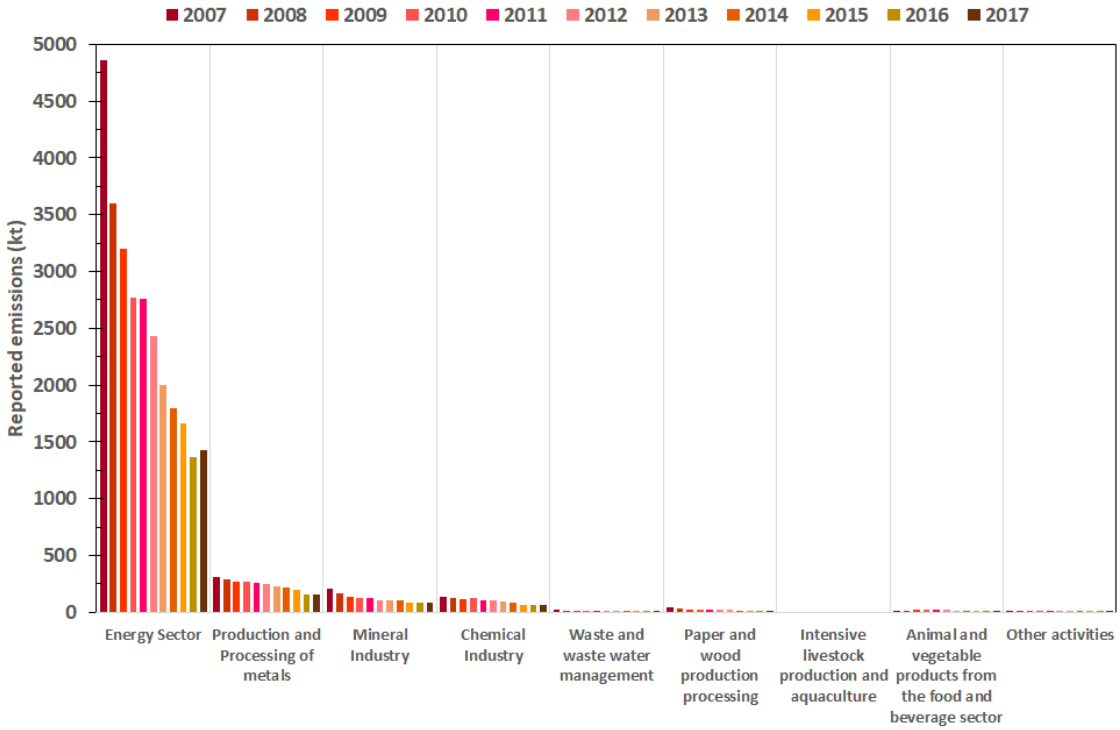
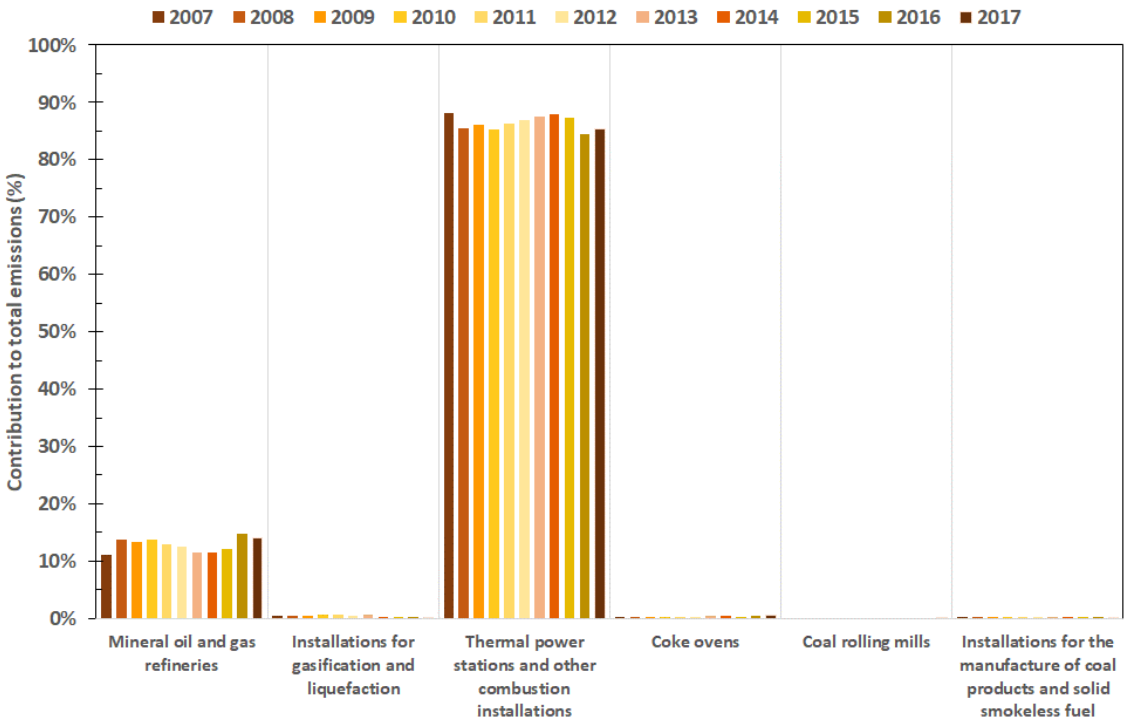


Figure 9 Oxides of sulphur air emissions reported in the E-PRTR database during 2007-2017 – contribution of different energy sector activities



3.2. NITROGEN OXIDES (NO_X/NO_2)

3.2.1. Emissions from European refineries

Table 7 summarises the reported emissions of nitrogen oxides to air from the European refineries. The reporting threshold for emissions of nitrogen oxides to air is 0.1 kt/a. Since 2007, there has been a decrease in their overall reported nitrogen oxides emissions, year on year, until 2014, a slight increase in 2015, and decrease from 2016 to 2017.

Figures 10 and 11 show the trend observed for the years 2007 to 2017. The reported emissions in 2017 are 45% lower than those in 2007 **(Figure 10)**. When emissions are expressed per unit of crude processed, the reduction is 40% **(Figure 11)**.

Table 7 Nitrogen oxides emissions to air reported for refineries in the E-PRTR database during 2007-2017

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Reported emissions for refineries (kt)	194	181	165	152	143	135	116	109	111	108	106
Total reported emissions for all sectors (kt)	3416	2992	2644	2560	2519	2466	2293	2110	2010	1821	1773
Refineries contribution to total NO_x emissions reported to E-PRTR	6%	6%	6%	6%	6%	5%	5%	5%	5%	6%	6%
Reported emissions per mass of crude oil transformed in refineries (ppm)	289	269	266	246	237	224	204	192	185	182	174
Number of refineries reporting	113	108	107	104	103	98	94	93	88	87	86

Figure 10 Trends of nitrogen oxides air emissions reported for European refineries, during 2007-2017

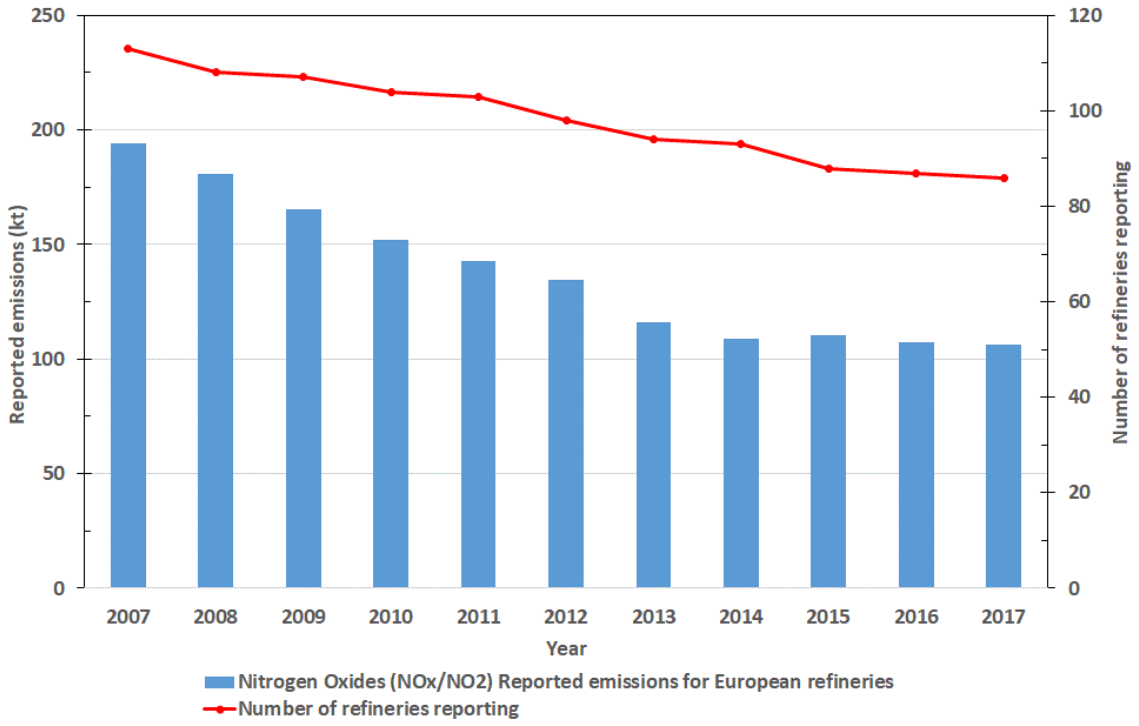
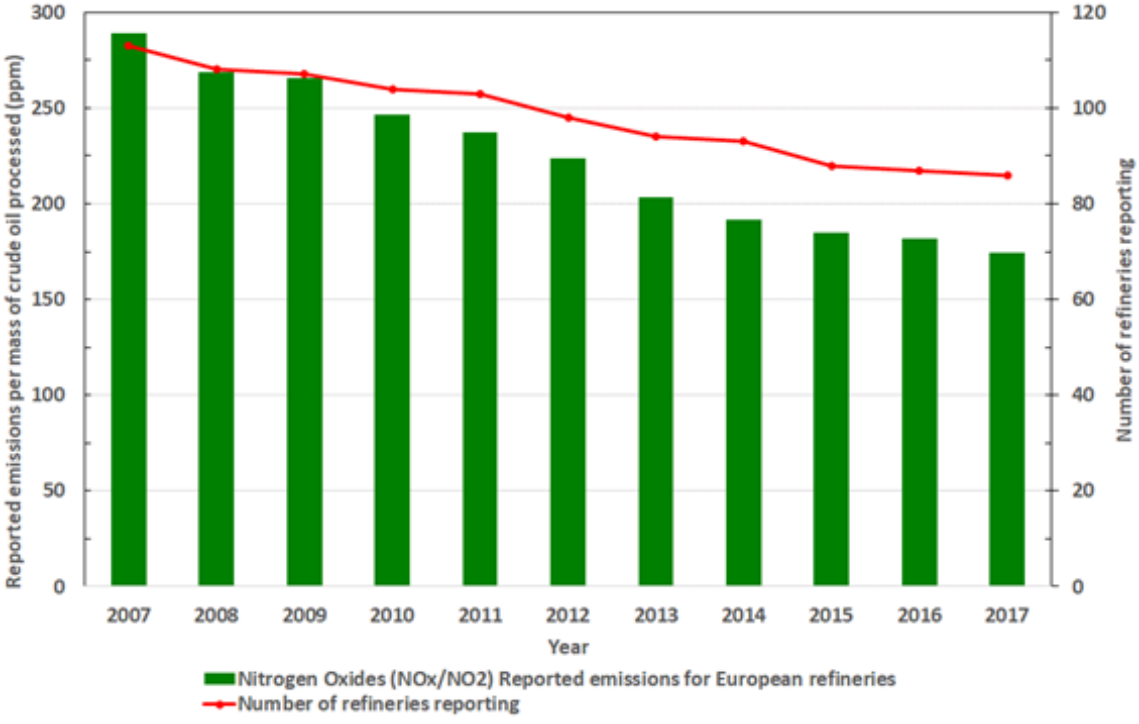


Figure 11 Trends of nitrogen oxides air emissions reported for European refineries during 2007-2017, expressed as per unit of crude processed



3.2.2. Statistical analysis

Table 8 provides the median, maximum and minimum values of the data submitted for refineries for each reporting year. It also gives the values of the 5th, 25th, 75th, and 95th percentiles, the upper outlier boundary (UOB) and the number of outliers above the UOB. The analyses are represented graphically in **Figure 12** and **Figure 13**. A wide spread of data can be seen from 2007 to 2012, which slightly narrows from 2013 to 2017. In 2016 and 2017, none of the reported emissions from the refineries is considered as an outlier.

Table 8 Statistical analysis of nitrogen oxides air emissions [kt/y] for European refineries

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Minimum	0.10	0.10	0.11	0.11	0.11	0.11	0.14	0.12	0.11	0.11	0.14
Median	1.26	1.30	1.13	1.07	0.94	0.94	0.89	0.86	1.01	0.98	0.98
Maximum	7.47	6.82	7.12	8.46	8.03	7.82	4.43	4.51	5.34	4.11	3.52
5th percentile	0.18	0.21	0.21	0.22	0.16	0.21	0.23	0.24	0.17	0.22	0.23
25th percentile	0.53	0.58	0.54	0.57	0.50	0.53	0.48	0.45	0.43	0.51	0.48
75th percentile	2.48	2.18	2.13	2.09	1.99	2.02	1.78	1.77	1.84	1.72	1.84
95th percentile	4.81	4.43	4.18	3.85	3.56	3.44	3.22	3.08	3.53	3.14	3.17
Upper outlier boundary	6.38	5.35	5.32	5.13	4.95	4.99	4.39	4.41	4.65	4.14	4.55
Number of outliers	2	4	3	1	3	2	1	1	1	0	0

Figure 12 Statistical analysis of nitrogen oxides air emissions for European refineries: 25th and 75th percentiles

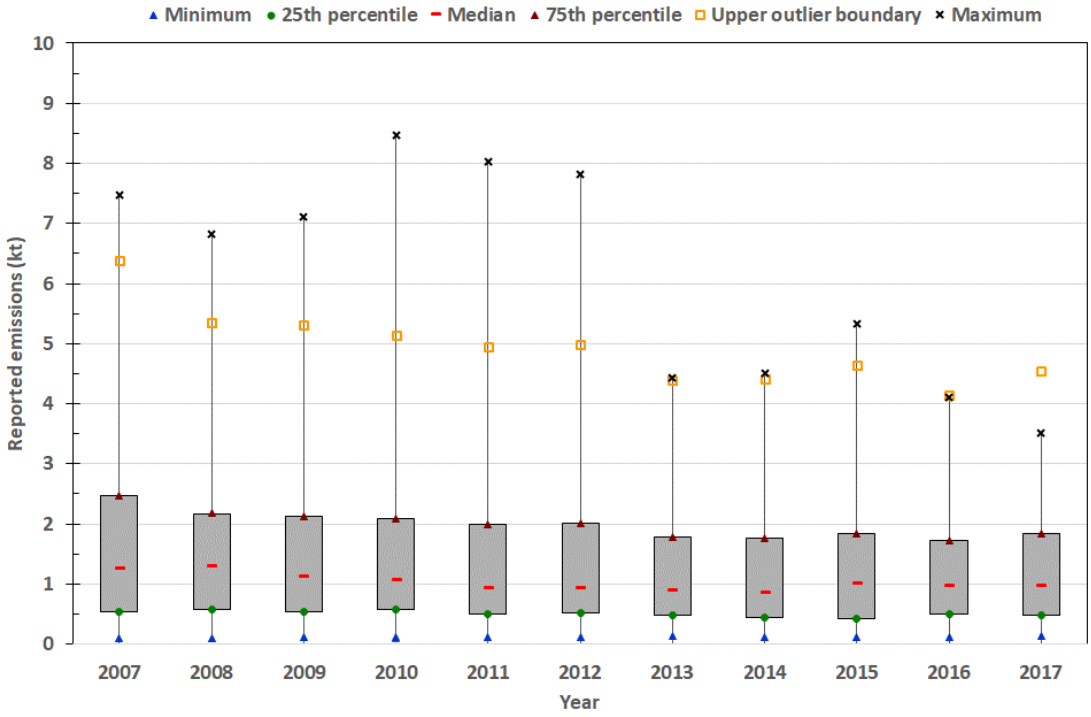
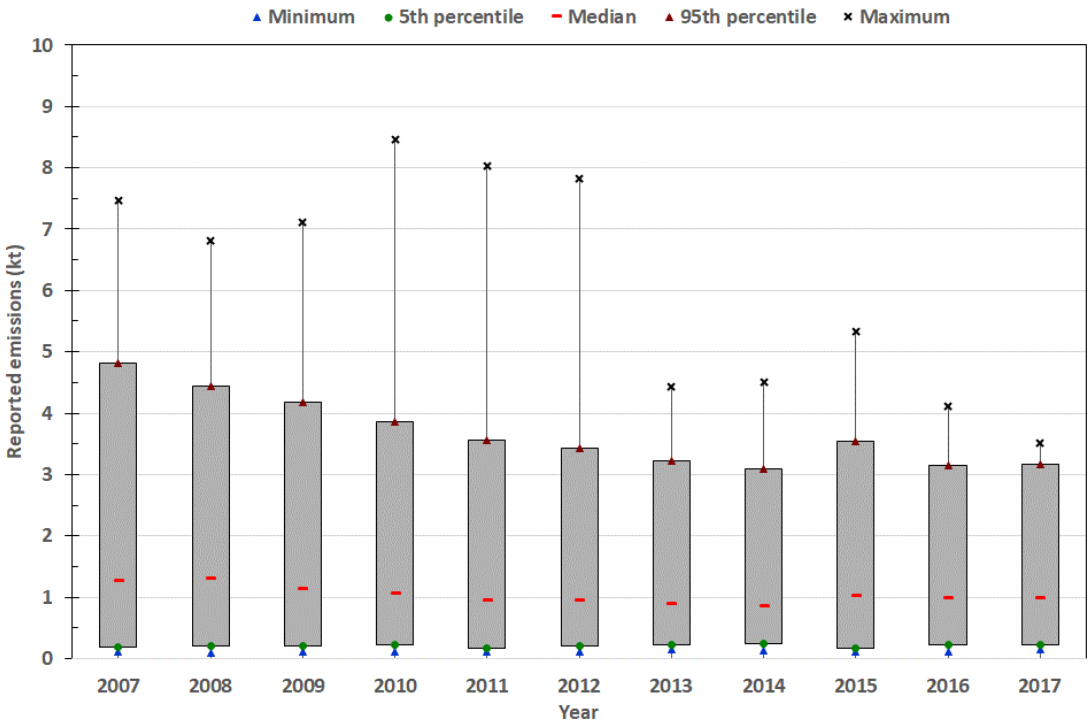


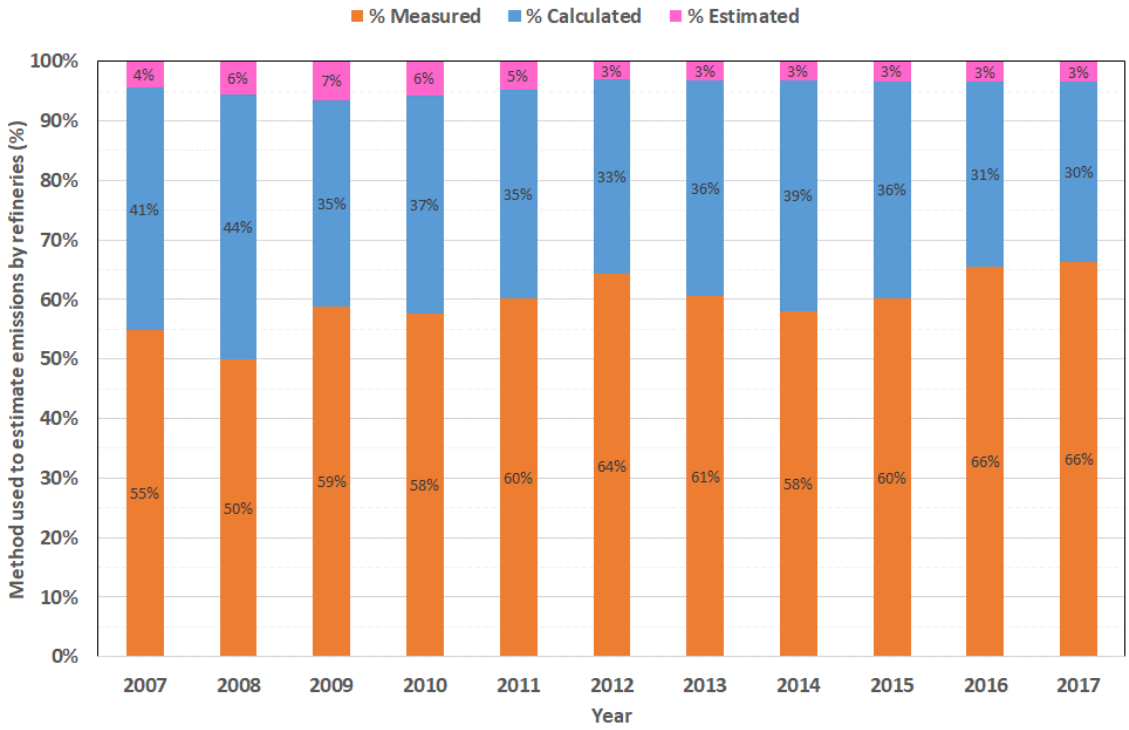
Figure 13 Statistical analysis of nitrogen oxides air emissions for European refineries: 5th and 95th percentiles



3.2.3. Methods used to determine the emissions

Figure 14 shows the degree to which the three different determination methods (as defined in reference [5]) have been used to estimate NO_x emissions. The results show that approved estimation methodologies ("calculation") and measurement were used at virtually all installations, with the majority of sites undertaking the latter.

Figure 14 Methods used to determine nitrogen oxides air emissions for European refineries



3.2.4. Emissions by sector

Figure 15 illustrates the contribution of those Annex I sectors of activity for which NO_x air emissions have been reported to E-PRTR in the period 2007 to 2017. The data show that nitrogen oxides air emissions reported in the E-PRTR database are coming mainly from the energy sector (62% - 69% contribution). From 2007 to 2017, the reported NO_x emissions from the energy sector have shown a reduction of 1,190 kt (52%) (**Figure 16**).

The energy sector is divided into six different economic activities. **Figure 17** shows the contribution of each of these to the total energy sector reported NO_x air emissions. It can be seen that the "thermal power stations and other combustion installations" are the major NO_x contributors to the energy sector (~90% in all years).

Figure 15 Percentage contribution of each Annex I sector of activity to total nitrogen oxides air emissions reported in the E-PRTR database during 2007-2017

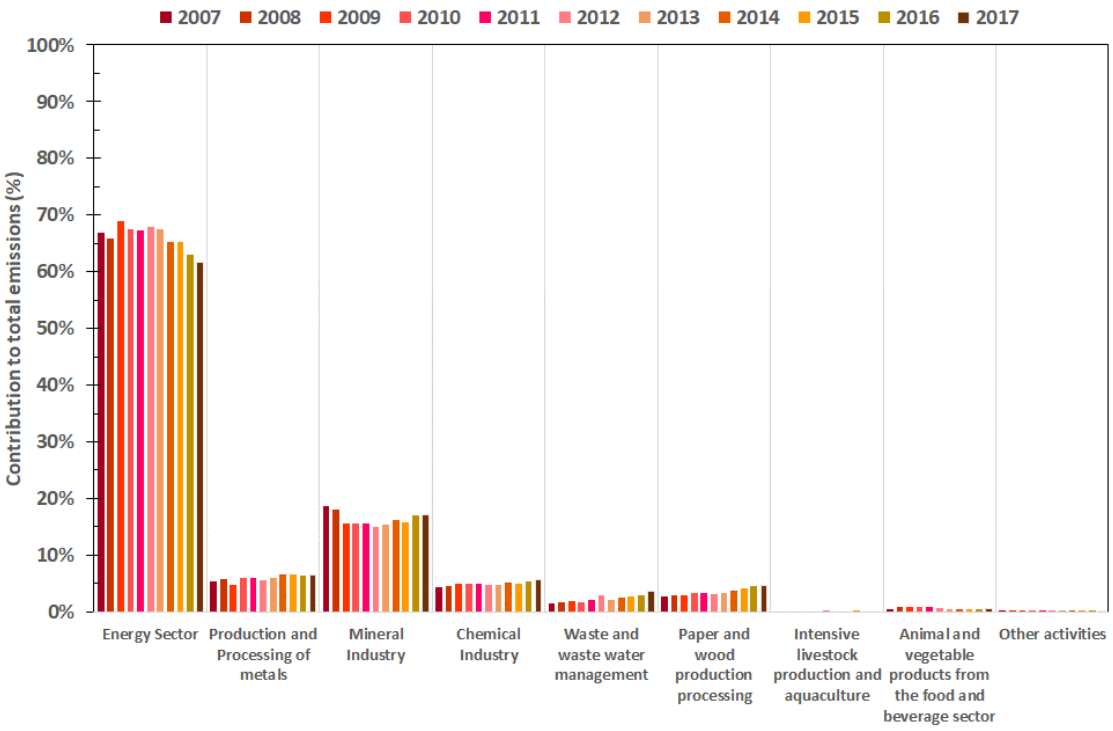


Figure 16 Nitrogen oxides air emissions reported in the E-PRTR database during 2007-2017 for each Annex I sector of activity

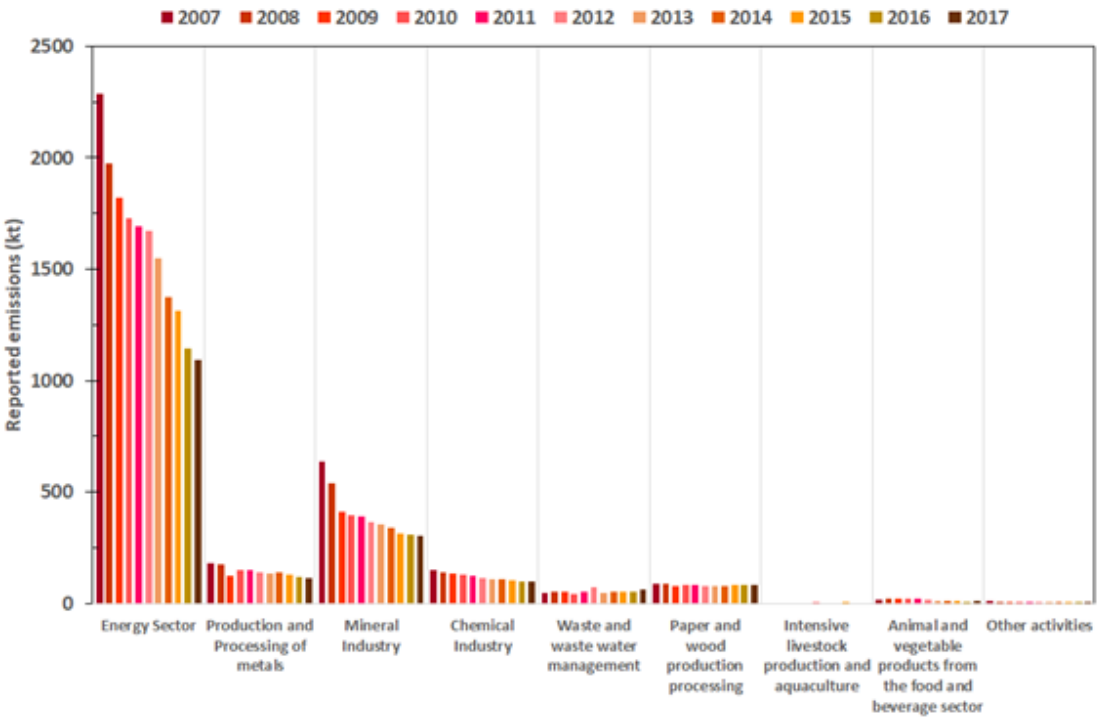
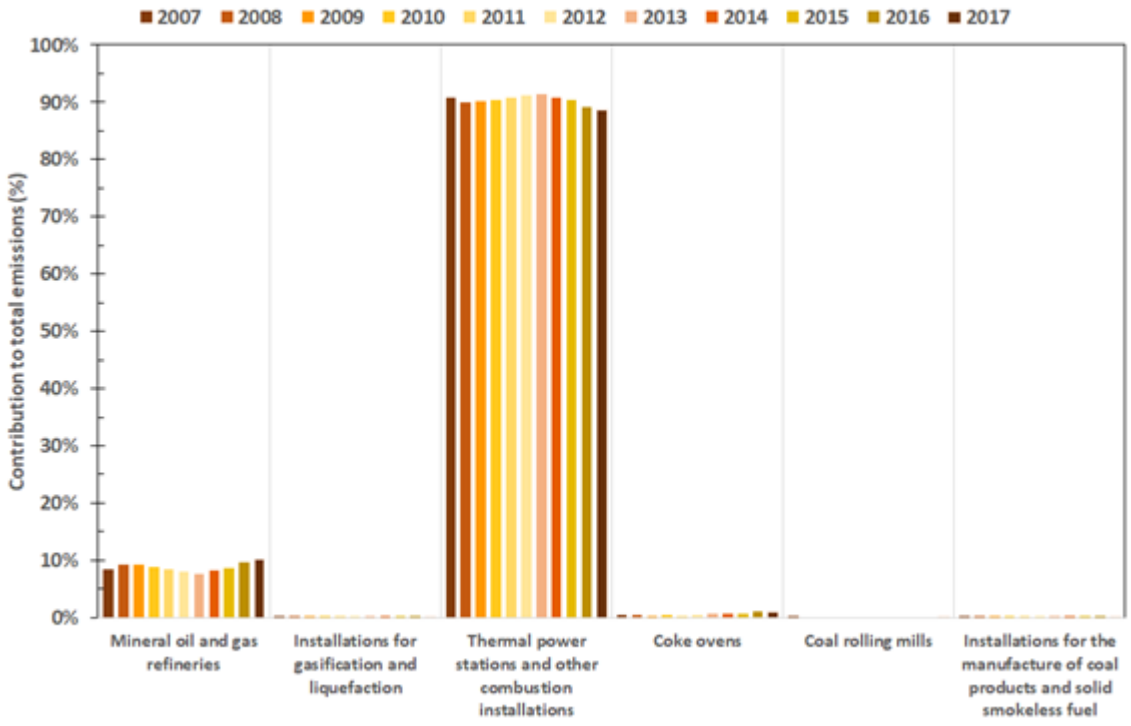


Figure 17 Nitrogen oxides air emissions reported in the E-PRTR database during 2007-2017 - contribution of different energy sector activities



3.3. NON-METHANE VOLATILE ORGANIC COMPOUNDS (NMVOC)

3.3.1. Emissions from European refineries

Table 9 summarises the reported emissions of NMVOCs to air from the European refineries. The reporting threshold for emissions of NMVOCs to air is 0.1 kt/a. NMVOCs emissions show a year on year reduction from 2007 to 2014, a slight increase in 2015, and decrease in 2016. NMOVCs emissions in 2017 were slightly higher compared to the reported 2016 data.

Figures 18 and 19 show the trend observed for the years 2007 to 2017. The reported emissions in 2017 are 38% lower than those of 2007 **(Figure 18)**. When NMVOCs emissions are expressed per unit of crude processed, the reduction is 32% **(Figure 19)**.

Table 9 NMVOCs emissions to air reported for refineries in the E-PRTR database during 2007-2017

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Reported emissions for refineries (kt)	183	164	145	133	124	126	124	110	114	110	113
Total reported emissions for all sectors (kt)	715	599	512	491	467	458	446	454	449	428	429
Refineries contribution to total NMVOCs emissions reported to E-PRTR	26%	27%	28%	27%	27%	27%	28%	24%	25%	26%	26%
Reported emissions per mass of crude oil transformed in refineries (ppm)	272	245	232	215	205	209	217	194	191	187	184
Number of refineries reporting	99	100	96	97	93	94	90	88	81	81	81

Figure 18 Trends of NMVOCs air emissions reported for European refineries, during 2007-2017

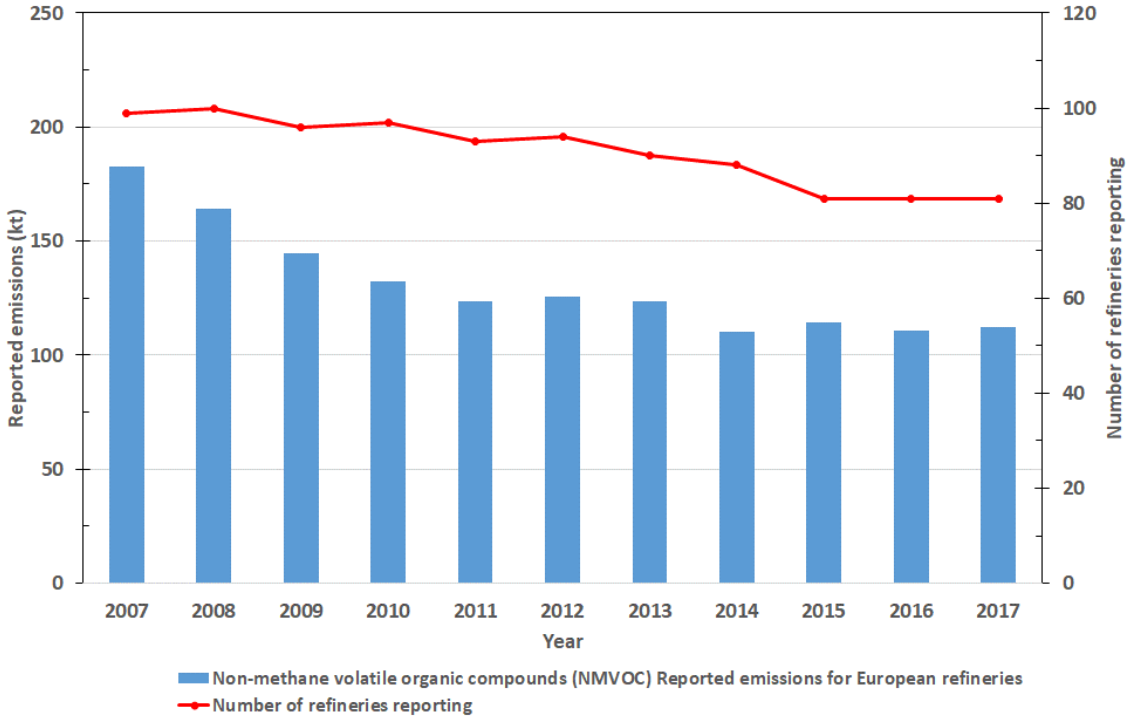
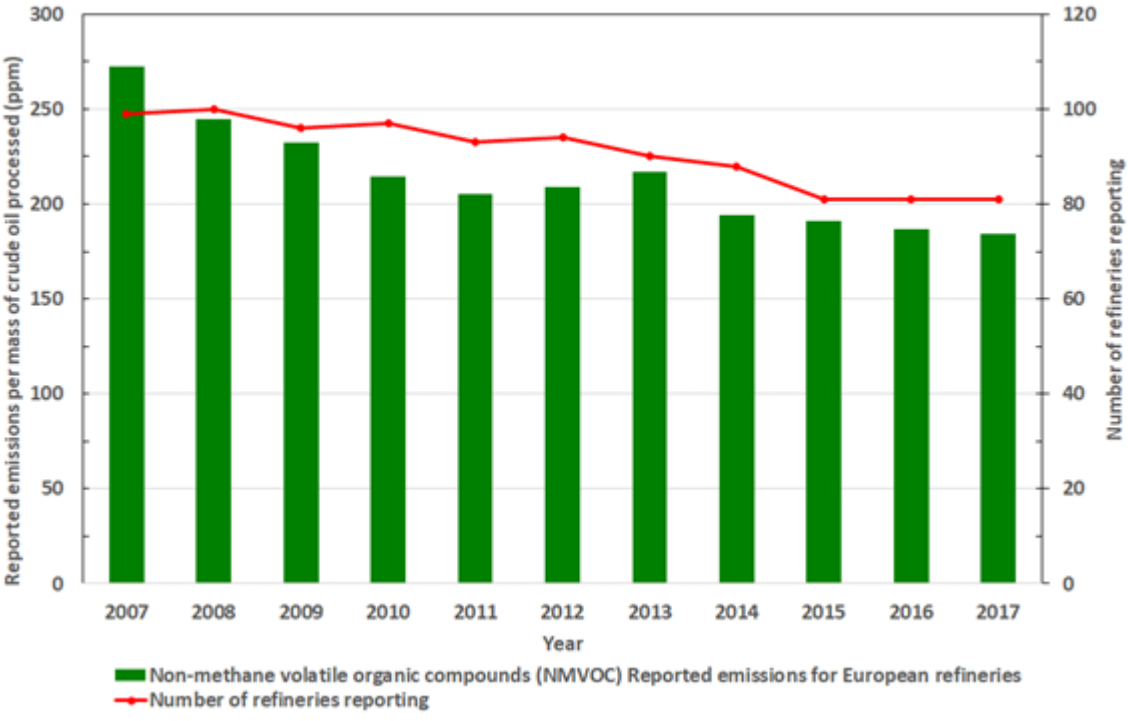


Figure 19 Trends of NMVOCs air emissions reported for European refineries during 2007-2017, expressed as per unit of crude processed



3.3.2. Statistical analysis

Table 10 provides the median, maximum and minimum values of the data submitted for refineries for each reporting year. It also gives the values of the 5th, 25th, 75th, and 95th percentiles, the upper outlier boundary (UOB) and the number of outliers above the UOB. The analyses are represented graphically in **Figure 20** and **Figure 21**. In all years, the analysis show a wide scatter of the reported emissions, while the number of outliers increases year on year (10% of the refineries in 2017).

Table 10 Statistical analysis of NMVOCs air emissions [kt/y] for European refineries

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Minimum	0.11	0.10	0.10	0.10	0.12	0.10	0.11	0.10	0.11	0.11	0.10
Median	1.10	0.99	0.94	0.83	0.73	0.75	0.71	0.58	0.57	0.55	0.55
Maximum	11.40	11.10	9.71	9.44	9.59	9.48	9.86	8.80	9.29	9.81	10.40
5th percentile	0.16	0.16	0.15	0.15	0.16	0.13	0.15	0.13	0.13	0.13	0.16
25th percentile	0.51	0.43	0.44	0.35	0.33	0.29	0.27	0.26	0.35	0.30	0.27
75th percentile	2.69	2.22	2.11	2.00	1.83	1.68	1.79	1.47	1.65	1.50	1.59
95th percentile	5.22	5.00	4.46	4.23	3.87	4.33	4.66	4.37	4.87	4.88	5.64
Upper outlier boundary	7.02	5.82	5.50	5.31	4.83	4.46	4.86	3.89	4.24	3.90	4.23
Number of outliers	3	4	3	3	3	5	4	6	7	7	8

Figure 20 Statistical analysis of NMVOCs air emissions for European refineries: 25th and 75th percentiles.

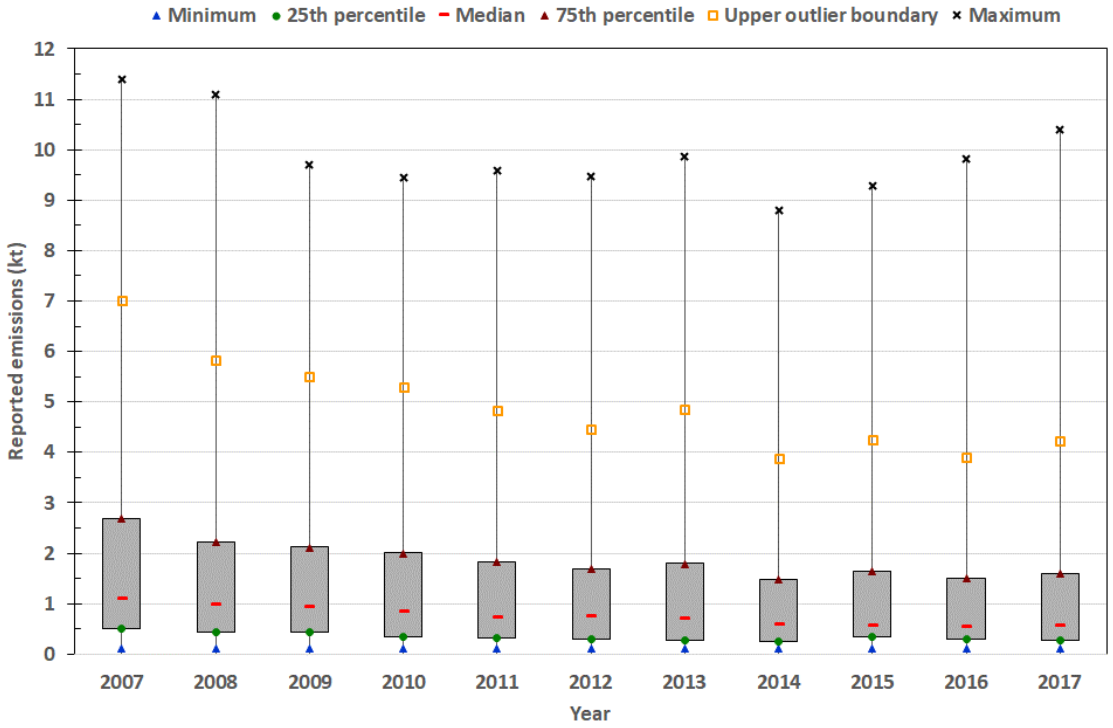
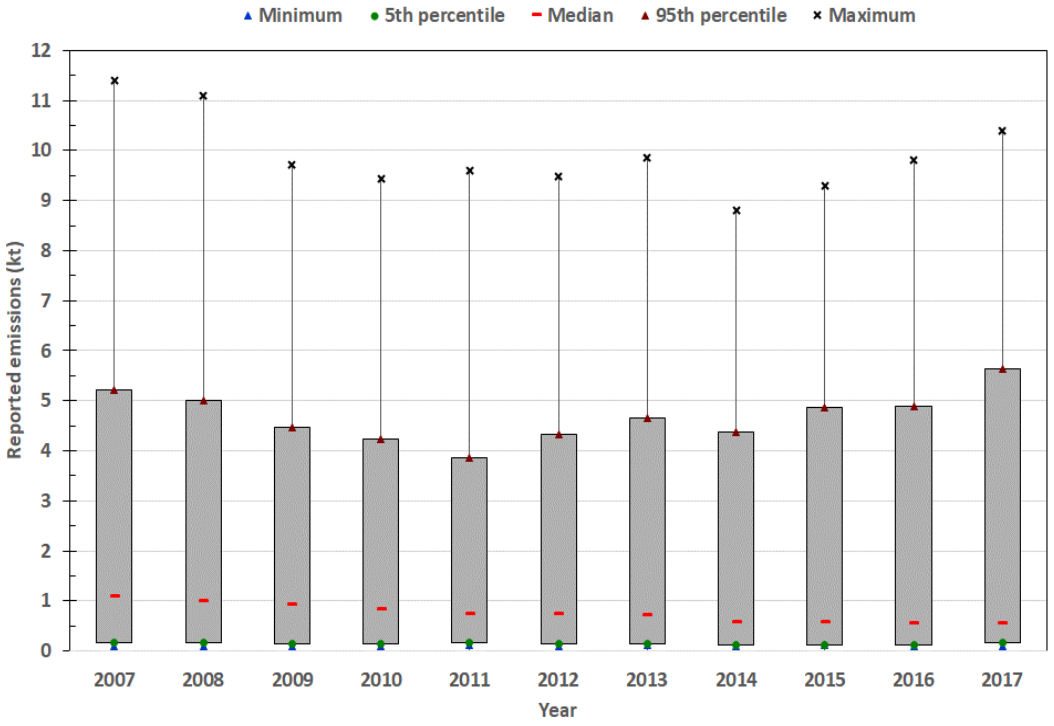


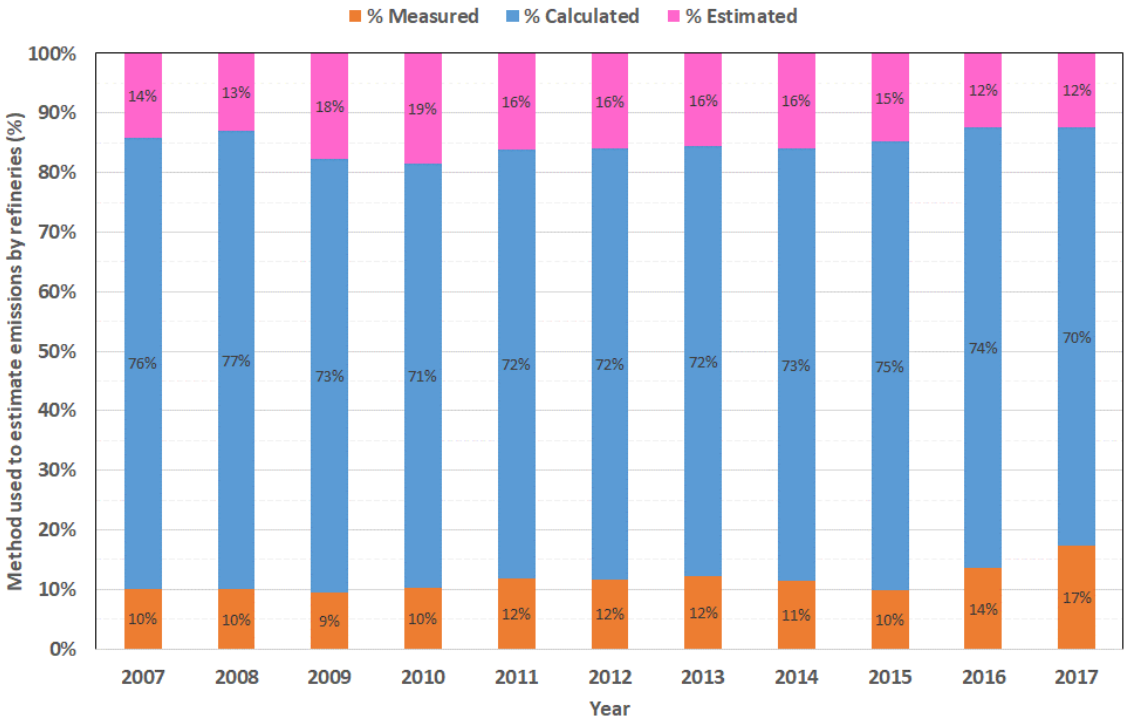
Figure 21 Statistical analysis of NMVOCs air emissions for European refineries: 5th and 95th percentiles



3.3.3. Methods used to determine the emissions

Figure 22 shows the degree to which the three different determination methods (as defined in reference [5]) have been used to estimate NMVOCs 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 22 Methods used to determine NMVOCs air emissions for European refineries



3.3.4. Emissions by sector

Figure 23 illustrates the contribution of those Annex I sectors of activity for which NMVOCs air emissions have been reported to E-PRTR in the period 2007 to 2017. The NMVOCs emissions reported in the E-PRTR database are coming mainly from the energy sector (around 35-43% of the total reported NMVOCs air emissions to E-PRTR, depending the year). From 2007 to 2017 the reported NMVOCs emissions from the energy sector have reduced by 136 kt (46%) (**Figure 24**).

The energy sector is divided into six different economic activities. **Figure 25** shows the contribution of each of these to the total energy sector reported NMVOCs air emissions. It can be seen that mineral oil and gas refineries are the major NMVOCs contributors to the energy sector (68-76%).

Figure 23 Percentage contribution of each Annex I sector of activity to total NMVOC air emissions reported in the E-PRTR database during 2007-2017

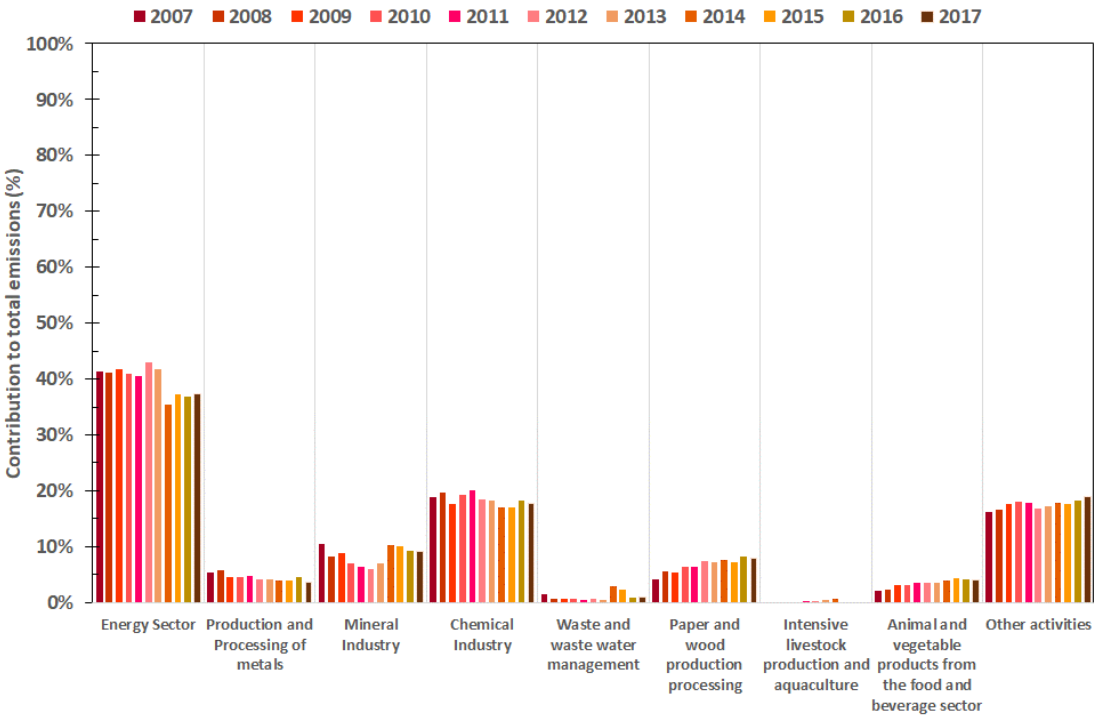


Figure 24 NMVOCs air emissions reported in the E-PTRT database during 2007-2017 for each Annex I sector of activity

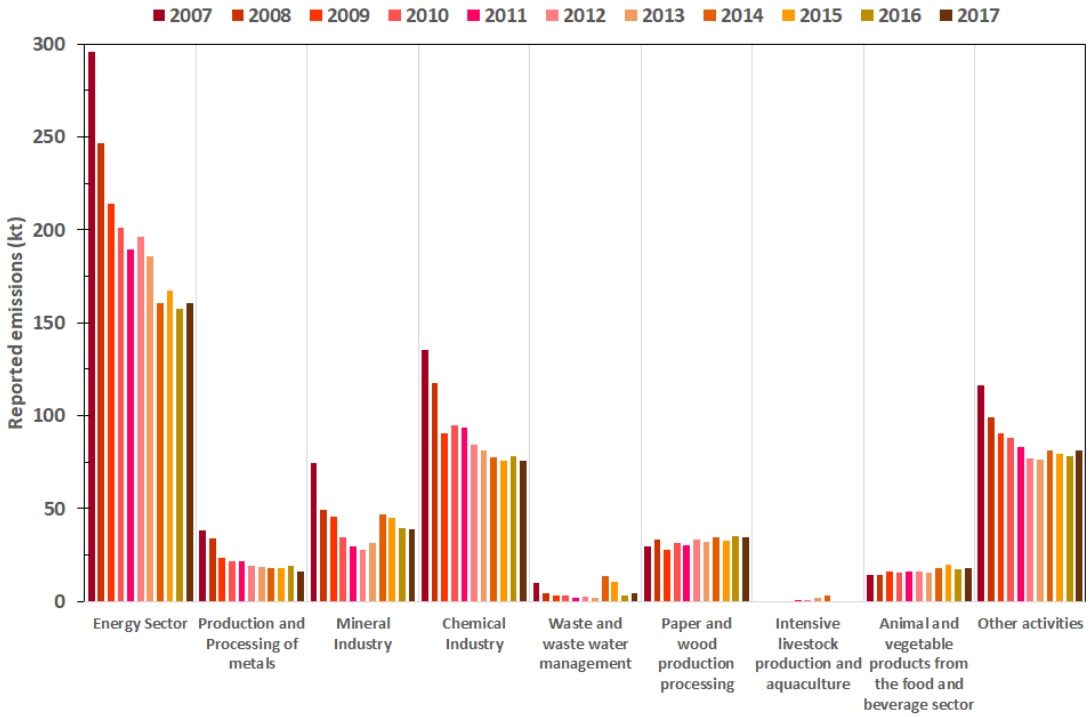
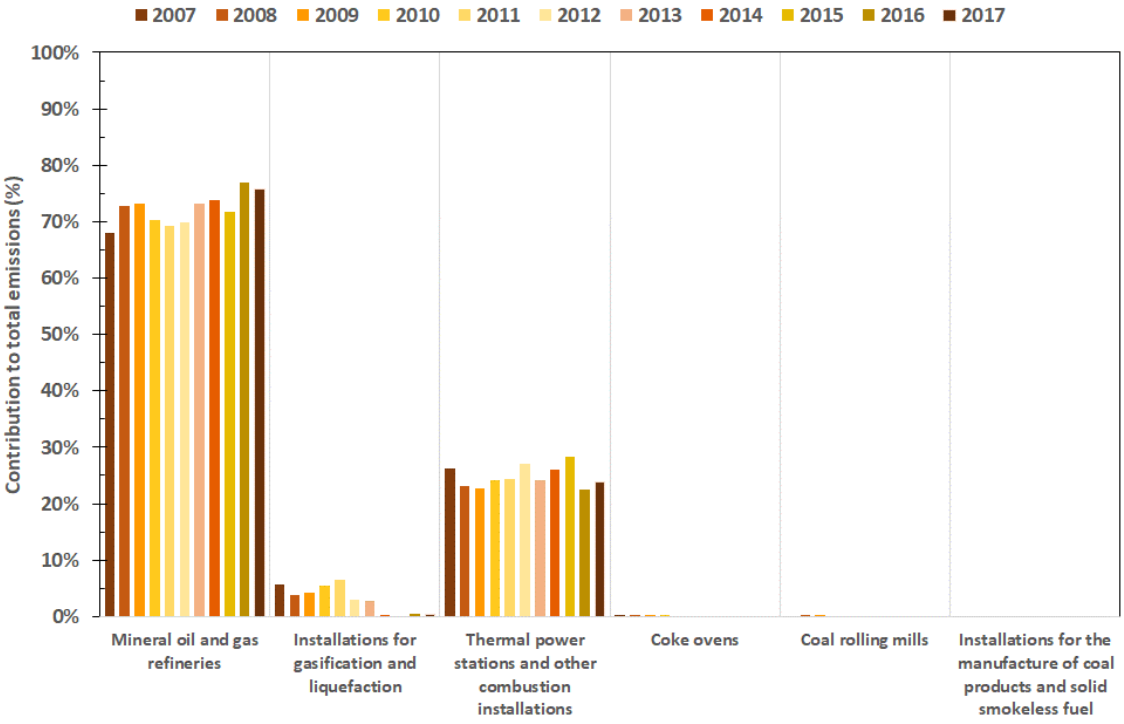


Figure 25 NMVOCs air emissions reported in the E-PRTR database during 2007-2017 - contribution of different energy sector activities



3.4. BENZENE

3.4.1. Emissions from European refineries

Table 11 summarises the reported emissions of benzene to air from the European refineries. The reporting threshold for emissions of benzene to air is 0.001 kt/a. The data show a variable change of the reported benzene air emissions during the period examined. From 2007 to 2011, there has been a decrease in the overall reported benzene emissions from refineries, while benzene emissions in 2012 were slightly higher compared to 2011 (5%). Lower emissions have been reported for 2013, and 2014, while in 2015 benzene emissions were 10% higher compared to 2014 data. In 2016 and 2017, benzene emissions were lower compared to 2015 data.

Figures 26 and 27 show the trend observed for the years 2007 to 2017. The reported emissions in 2017 are 50% lower than those of 2007 **(Figure 26)**. When benzene emissions are expressed per unit of crude processed, the reduction is 45% **(Figure 27)**.

Table 11 Benzene emissions to air reported for refineries in the E-PRTR database during 2007-2017

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Reported emissions for refineries (kt)	2.15	2.01	1.94	1.65	1.30	1.36	1.17	1.06	1.16	1.10	1.08
Total reported emissions for all sectors (kt)	4.67	4.13	3.53	3.42	3.06	3.01	2.69	2.91	2.98	2.79	2.69
Refineries contribution to total benzene emissions reported to E-PRTR	46%	49%	55%	48%	42%	45%	43%	36%	39%	40%	40%
Reported emissions per mass of crude oil transformed in refineries (ppm)	3.20	2.98	3.11	2.66	2.15	2.26	2.05	1.87	1.94	1.86	1.77
Number of refineries reporting	66	67	65	64	61	58	53	51	48	48	47

Figure 26 Trends of benzene air emissions reported for European refineries, during 2007-2017

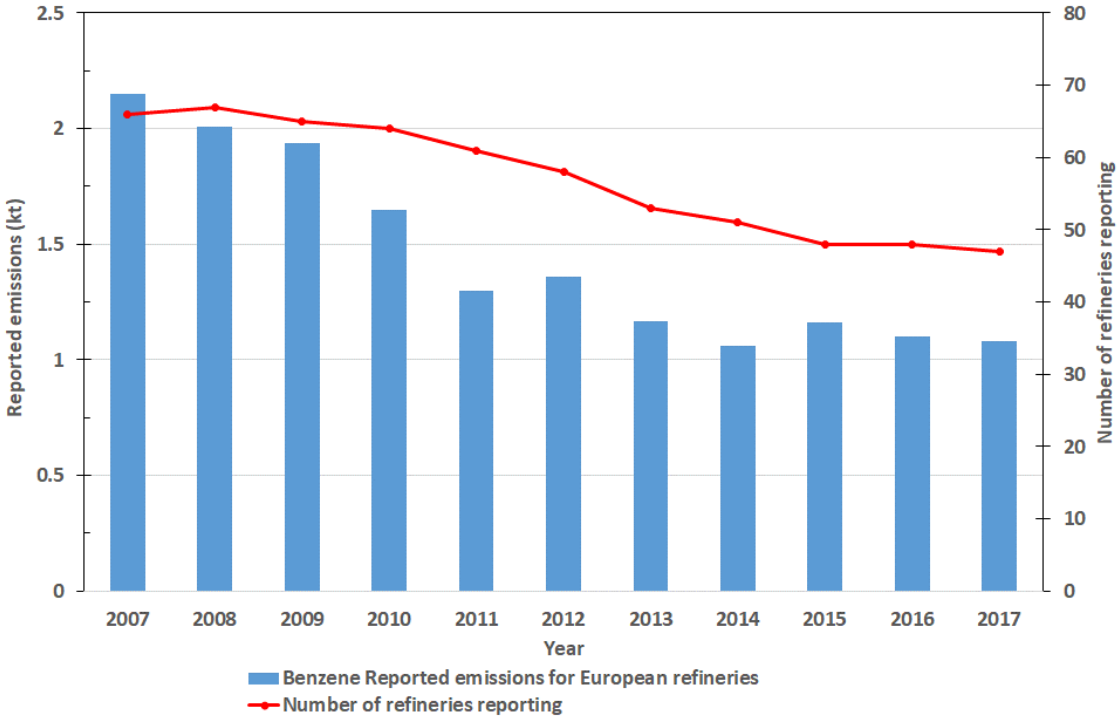
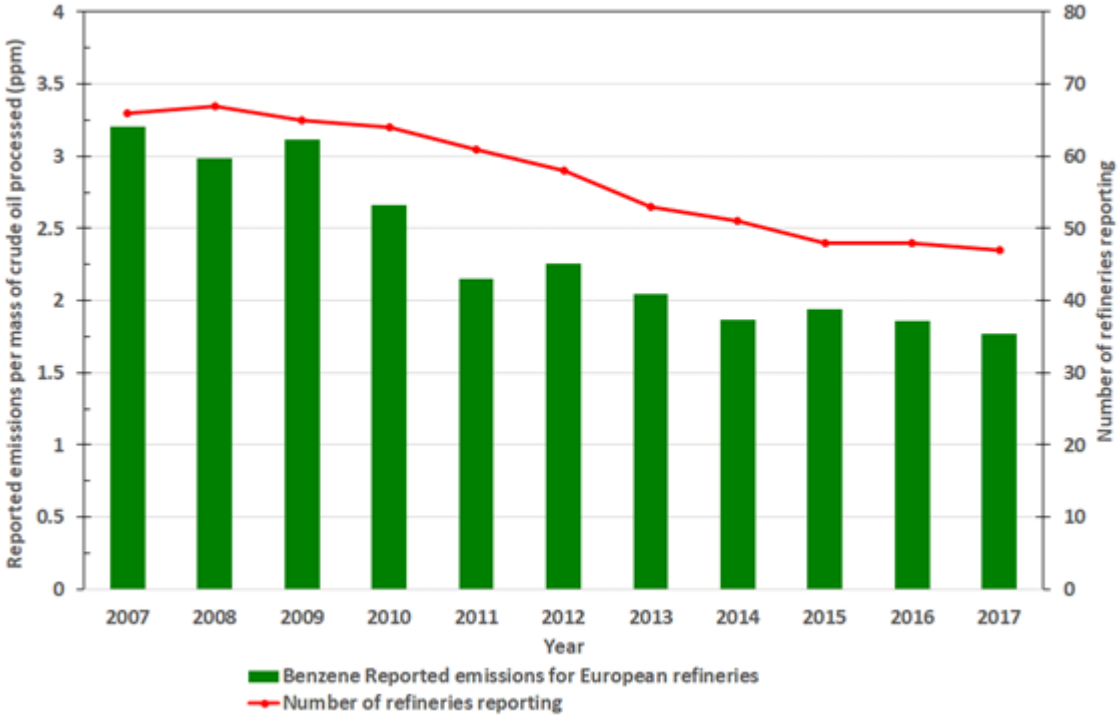


Figure 27 Trends of benzene air emissions reported for European refineries during 2007-2017, expressed as per unit of crude processed



3.4.2. Statistical analysis

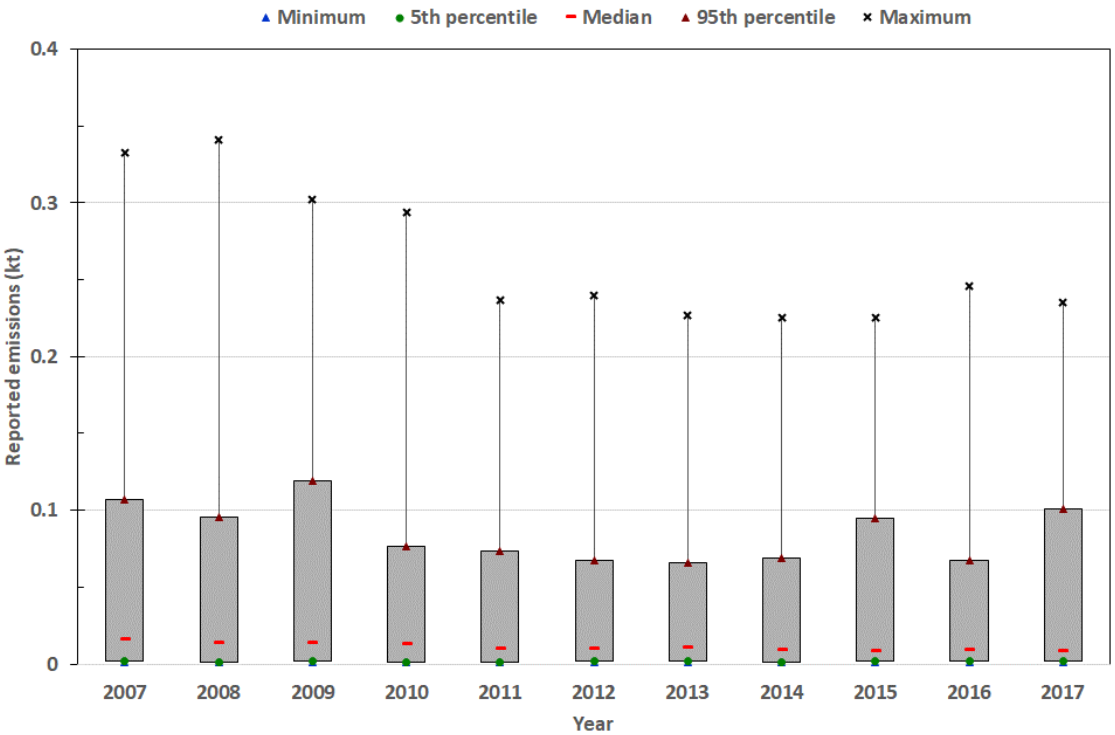
Table 12 provides the median, maximum and minimum values of the data submitted for refineries for each reporting year. It also gives the values of the 5th, 25th, 75th, and 95th percentiles, the upper outlier boundary (UOB) and the number of outliers above the UOB. The analyses are represented graphically in **Figure 28** and **Figure 29**. In all years, a variable scatter of the data is seen, while around 6-13% of the data are considered as outliers, depending on the year.

Table 12 Statistical analysis of benzene air emissions [kt/y] for European refineries

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Minimum	1.0E-03	1.1E-03	1.0E-03	1.0E-03	1.0E-03	1.0E-03	1.1E-03	1.2E-03	1.0E-03	1.2E-03	1.2E-03
Median	1.6E-02	1.4E-02	1.3E-02	1.3E-02	9.6E-03	9.6E-03	1.1E-02	9.4E-03	8.5E-03	8.9E-03	8.7E-03
Maximum	3.3E-01	3.4E-01	3.0E-01	2.9E-01	2.4E-01	2.4E-01	2.3E-01	2.3E-01	2.3E-01	2.5E-01	2.4E-01
5th percentile	2.1E-03	1.4E-03	2.2E-03	1.4E-03	1.2E-03	1.6E-03	1.6E-03	1.5E-03	1.8E-03	2.0E-03	1.8E-03
25th percentile	5.7E-03	5.1E-03	4.6E-03	4.6E-03	4.1E-03	4.0E-03	3.7E-03	3.4E-03	3.5E-03	4.1E-03	4.0E-03
75th percentile	3.4E-02	2.9E-02	2.5E-02	2.6E-02	2.6E-02	2.2E-02	2.7E-02	2.5E-02	2.1E-02	2.3E-02	2.6E-02
95th percentile	1.1E-01	9.5E-02	1.2E-01	7.7E-02	7.3E-02	6.7E-02	6.6E-02	6.9E-02	9.5E-02	6.8E-02	1.0E-01
Upper outlier boundary	9.0E-02	7.6E-02	6.6E-02	6.7E-02	7.1E-02	5.9E-02	7.2E-02	6.9E-02	5.5E-02	6.1E-02	7.0E-02
Number of outliers	4	5	7	5	4	5	3	3	6	3	4

Figure 28 Statistical analysis of benzene air emissions for European refineries: 25th and 75th percentiles

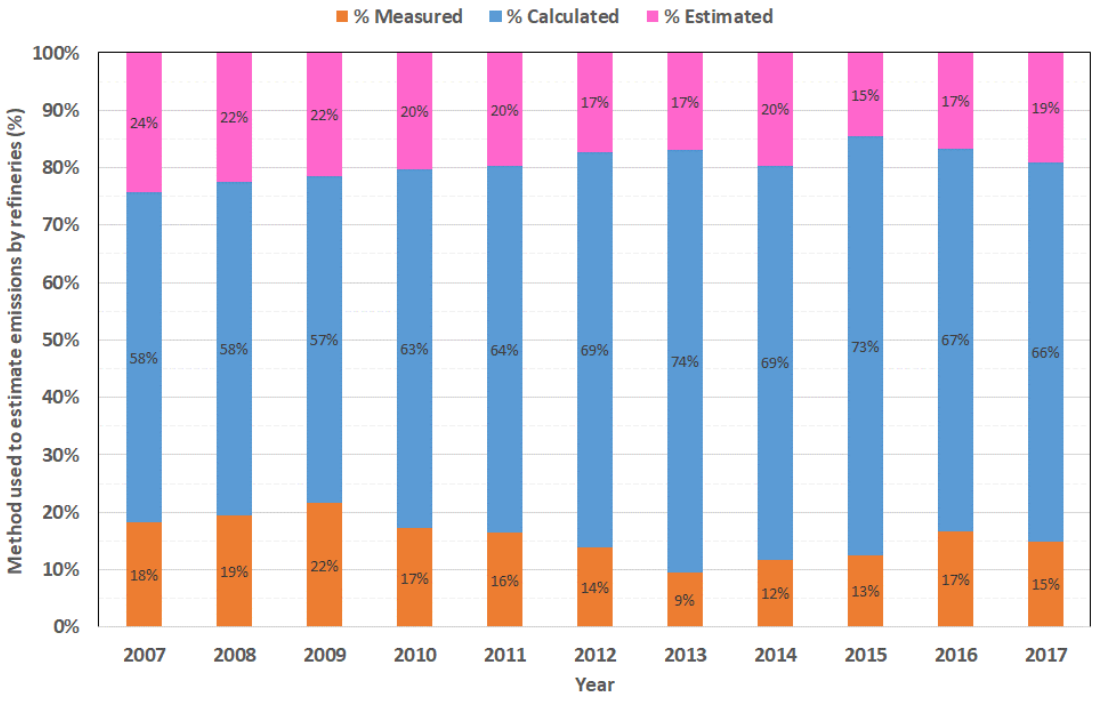
Figure 29 Statistical analysis of benzene air emissions for European refineries: 5th and 95th percentiles



3.4.3. Methods used to determine the emissions

Figure 30 shows the degree to which the three different determination methods (as defined in reference [5]) have been used to estimate benzene emissions. This shows that the use of approved estimation methodologies ("calculation") and measurement were used at more than 75% of sites (more than 80% since 2011), with other "non-standardised" estimation methods (as defined in [5]) used elsewhere.

Figure 30 Methods used to determine benzene air emissions for European refineries



3.4.4. Emissions by sector

Figure 31 illustrates the contribution of those Annex I sectors of activity for which benzene air emissions have been reported to E-PRTR in the period 2007 to 2017. The benzene emissions reported in the E-PRTR database are coming mainly from the energy sector (50-68% of the total reported benzene air emissions to E-PRTR). In terms of absolute values, benzene air emissions from the energy sector have shown a reduction of 32% from 2007 to 2011 (0.75 kt) (**Figure 32**). From 2012 to 2017 the reported benzene air emissions from the energy sector show a variable trend. In 2012, benzene air emissions are 7% higher compared to 2011 (0.17 kt), while in 2013 they decrease by 13% (0.23 kt) compared to 2012. Higher benzene air emissions are reported from the energy sector during 2014, and 2015. In 2016, 21% lower emissions are reported compared to 2015, while in 2017, benzene emissions increase again, by 11% compared to 2016. Overall, from 2007 to 2017 the reported benzene air emissions from the energy sector have reduced by 24% (0.55 kt).

The energy sector is divided into six different economic activities. **Figure 33** shows the contribution of each of these to the total energy sector reported benzene air emissions. Mineral oil and gas refineries are the major benzene contributors to the energy sector (50-85%).

Figure 31 Percentage contribution of each Annex I sector of activity to total benzene air emissions reported in the E-PRTR database during 2007-2017

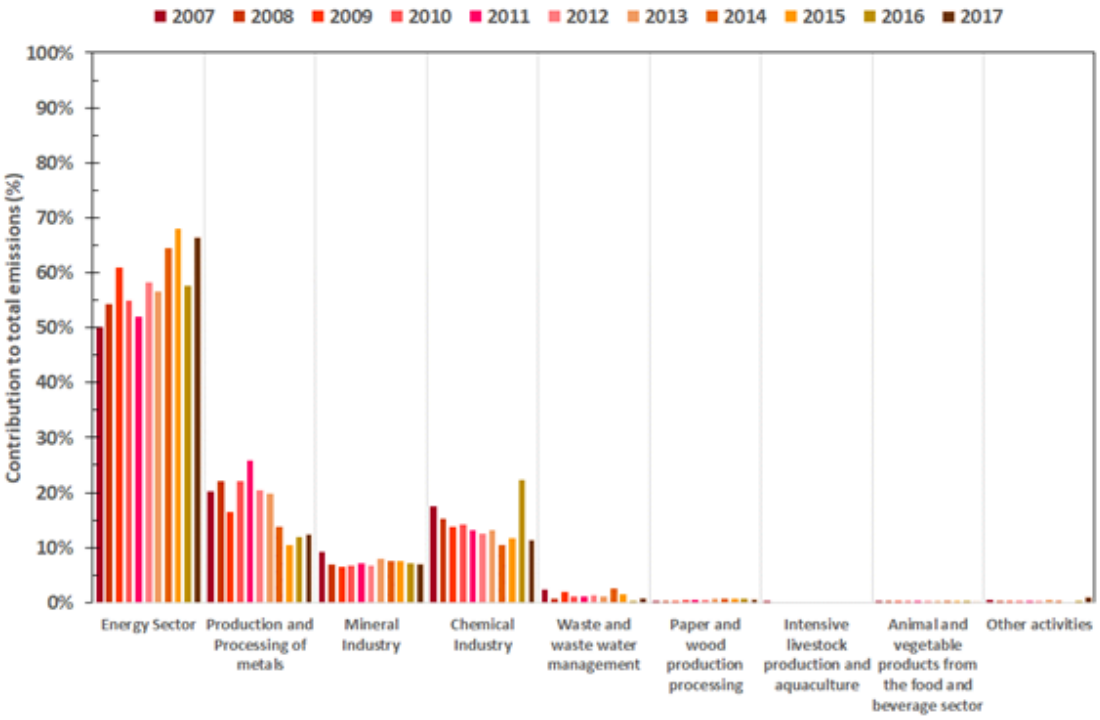


Figure 32 Benzene air emissions reported in the E-PRTR database during 2007-2017 for each Annex I sector of activity

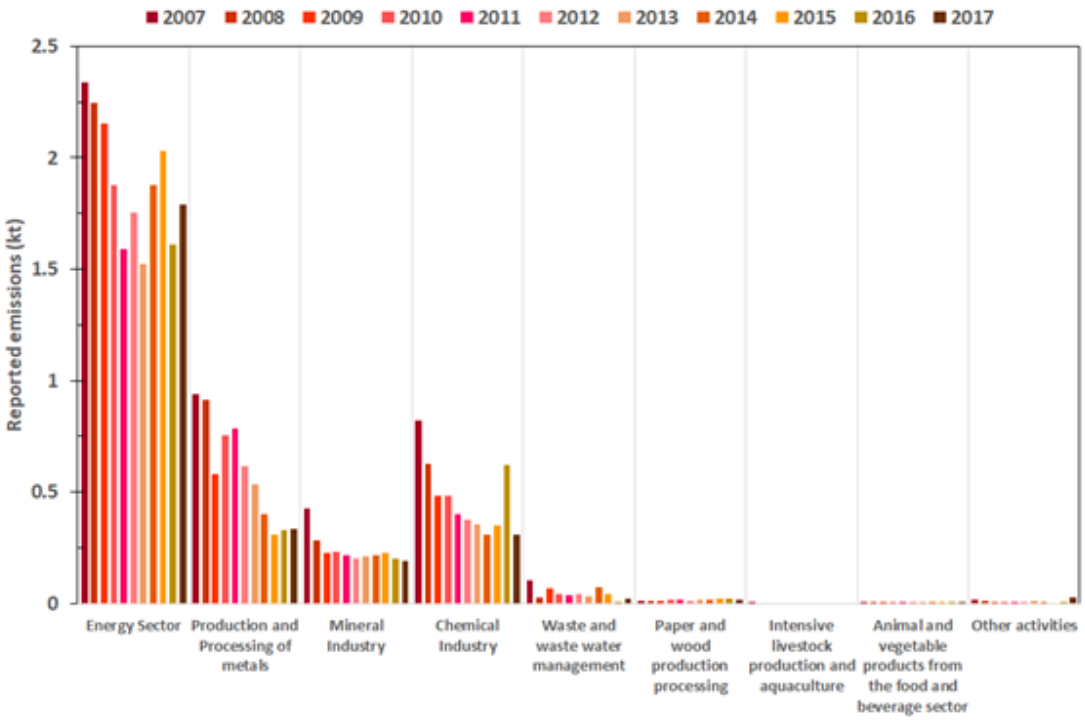
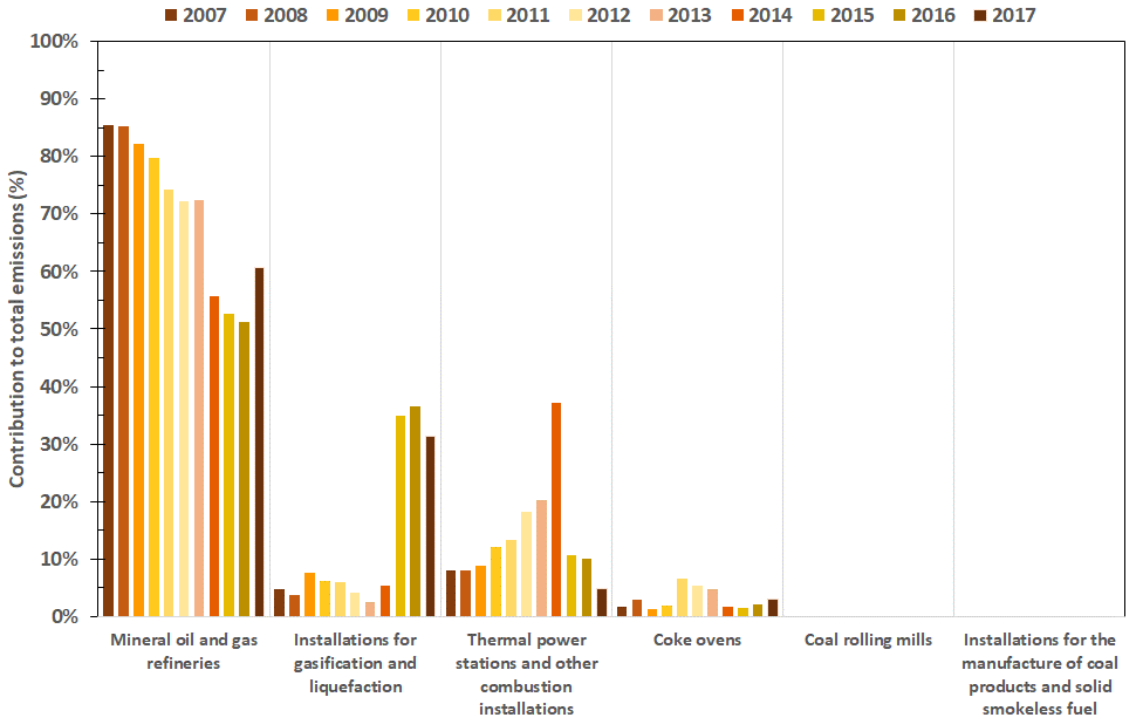


Figure 33 Benzene air emissions reported in the E-PRTR database during 2007-2017 - contribution of different energy sector activities



3.5. CARBON DIOXIDE (CO_2)

3.5.1. Emissions from European refineries

Table 13 summarises the reported emissions of "total" carbon dioxide (carbon dioxide including releases from biomass) to air from the European refineries. The reporting threshold for emissions of CO_2 to air is 100 kt/a. E-PRTR also provides reported data on CO_2 emissions due to biomass combustion.

Figure 34 and 35 show the trend observed for the years 2007 to 2017. The reported emissions in 2017 are 20% lower than those in 2007 **(Figure 34)**. When CO_2 emissions are expressed per unit of crude processed, the reduction is 12% **(Figure 35)**.

Table 13 CO_2 emissions to air reported for refineries in the E-PRTR database during 2007-2017

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Reported emissions for refineries (kt)	1.6E+05	1.6E+05	1.5E+05	1.5E+05	1.5E+05	1.4E+05	1.3E+05	1.3E+05	1.2E+05	1.3E+05	1.3E+05
Total reported emissions for all sectors (kt)	2.2E+06	2.1E+06	2.0E+06	2.1E+06	2.0E+06	2.0E+06	1.9E+06	1.8E+06	1.8E+06	1.7E+06	1.8E+06
Refineries contribution to total CO_2 emissions reported to E-PRTR	7%	7%	8%	7%	7%	7%	7%	7%	7%	7%	7%
Reported emissions per mass of crude oil transformed in refineries (ppm)	2.4E+05	2.4E+05	2.4E+05	2.4E+05	2.4E+05	2.3E+05	2.3E+05	2.2E+05	2.1E+05	2.2E+05	2.1E+05
Number of refineries reporting	105	105	102	105	102	98	93	94	89	88	88

Figure 34 Trends of CO_2 air emissions reported for European refineries, during 2007-2017

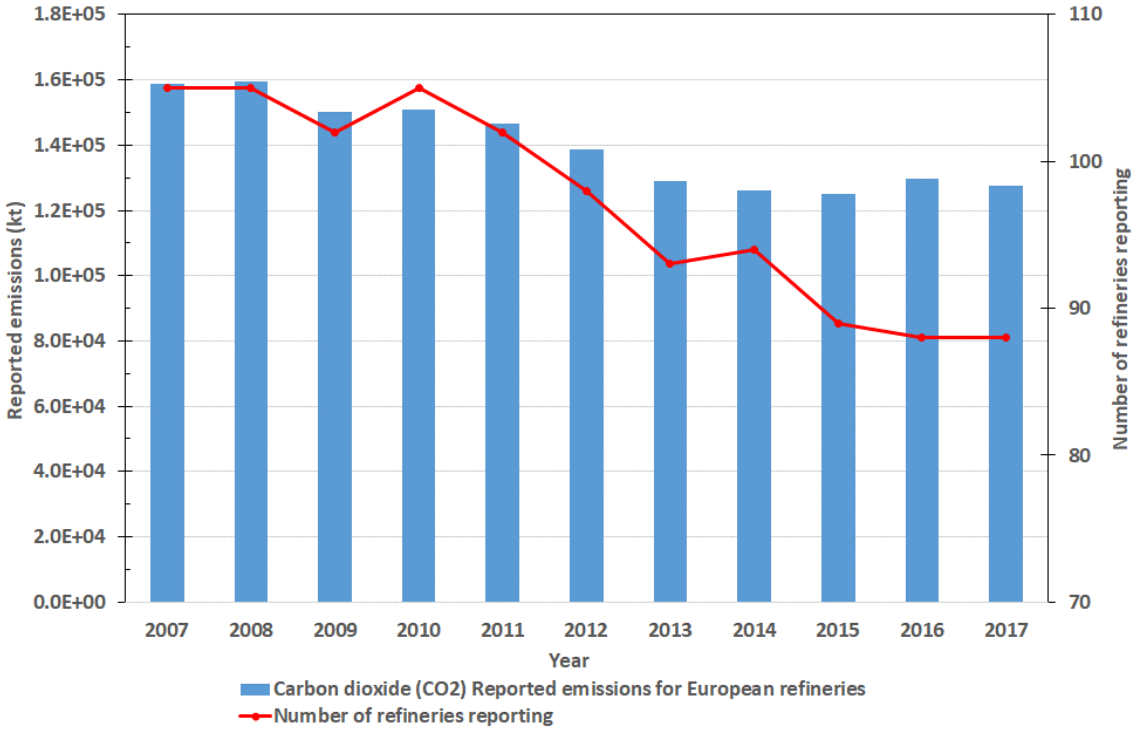
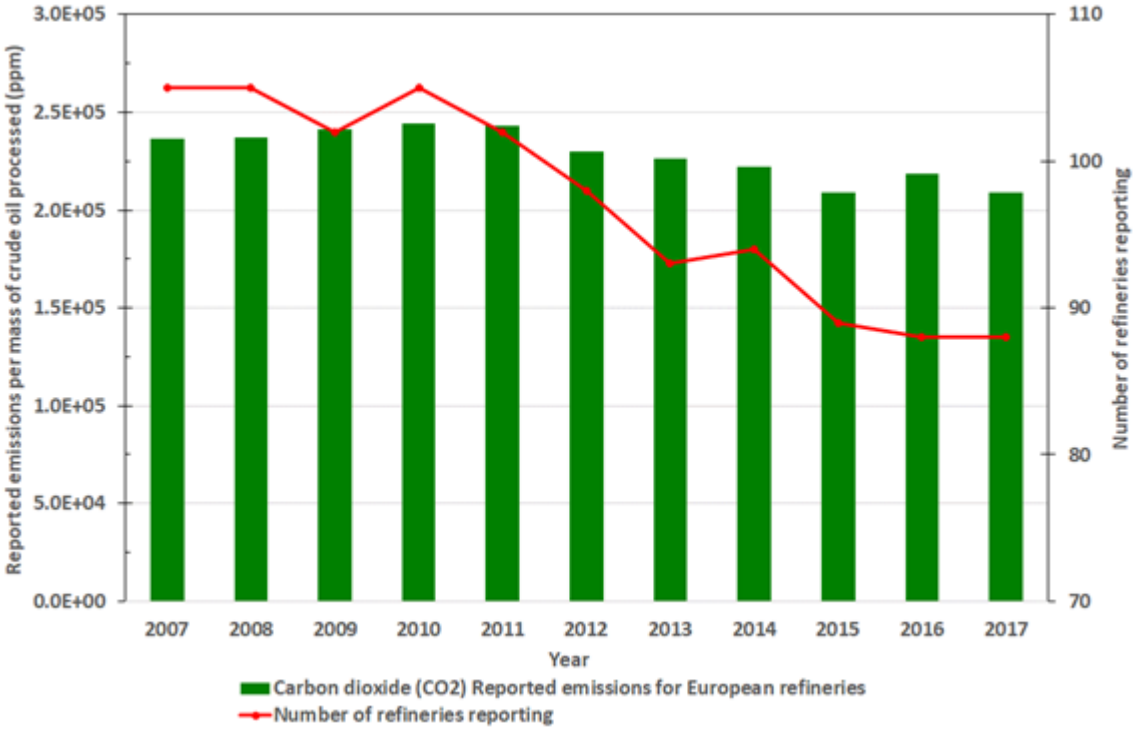


Figure 35 Trends of CO_2 air emissions reported for European refineries during 2007-2017, expressed as per unit of crude processed



3.5.2. Statistical analysis

Table 14 provides the median, maximum and minimum values of the data submitted for refineries for each reporting year. It also gives the values of the 5th, 25th, 75th, and 95th percentiles, the upper outlier boundary (UOB) and the number of outliers above the UOB. The analyses are represented graphically in **Figure 36** and **Figure 37**. A wide scatter of the reported CO_2 air emissions is shown in all years, while the number of outliers is relatively small (i.e., less than 3% in all years, and 1% from 2013 onwards).

Table 14 Statistical analysis of CO_2 air emissions [kt/y] for European refineries

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Minimum	151	151	146	106	109	112	126	137	116	118	117
Median	1,180	1,150	1,170	1,120	1,155	1,125	1,190	1,095	1,180	1,325	1,300
Maximum	6,240	6,160	6,130	6,350	6,230	6,110	5,890	5,760	6,590	6,510	6,370
5th percentile	272	265	307	187	173	238	287	257	296	273	286
25th percentile	592	645	632	557	538	534	574	513	554	709	610
75th percentile	2,040	2,050	1,968	1,930	1,968	1,970	1,940	1,903	1,870	2,010	2,055
95th percentile	3,862	3,870	3,778	3,660	3,681	3,430	3,156	2,997	3,064	3,123	3,247
Upper outlier boundary	4,936	4,874	4,640	4,676	4,828	4,842	4,672	4,682	4,502	4,612	4,945
Number of outliers	3	3	2	2	2	2	1	1	1	1	1

Figure 36 Statistical analysis of CO_2 air emissions for European refineries: 25th and 75th percentiles

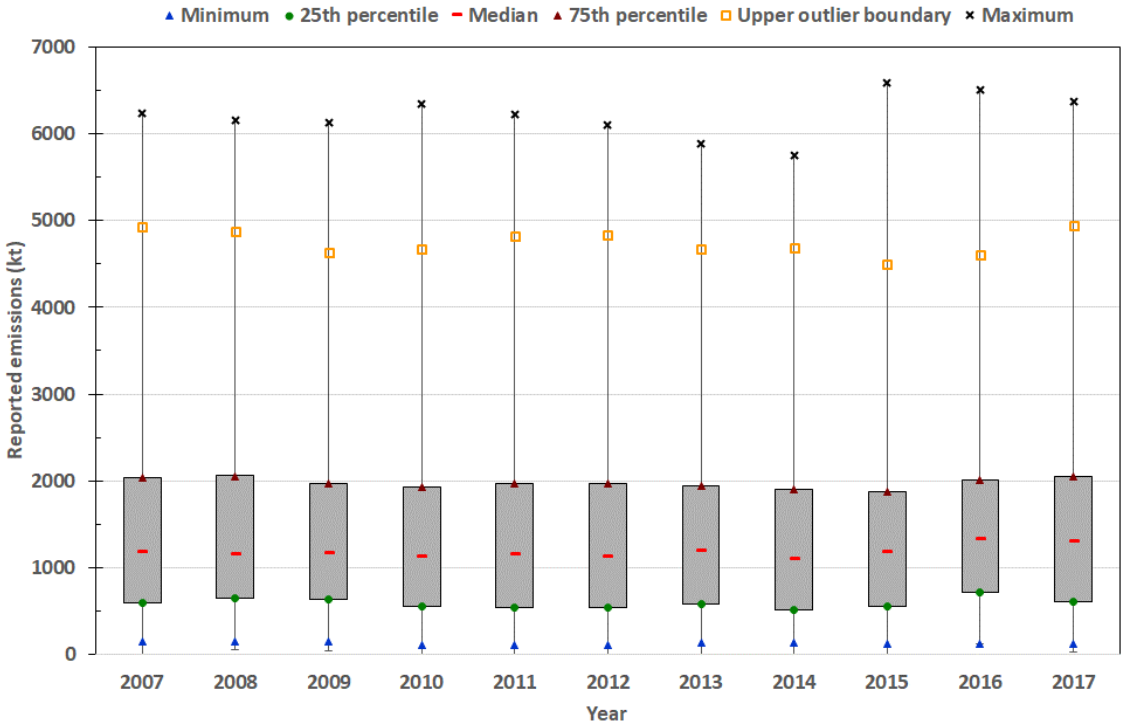
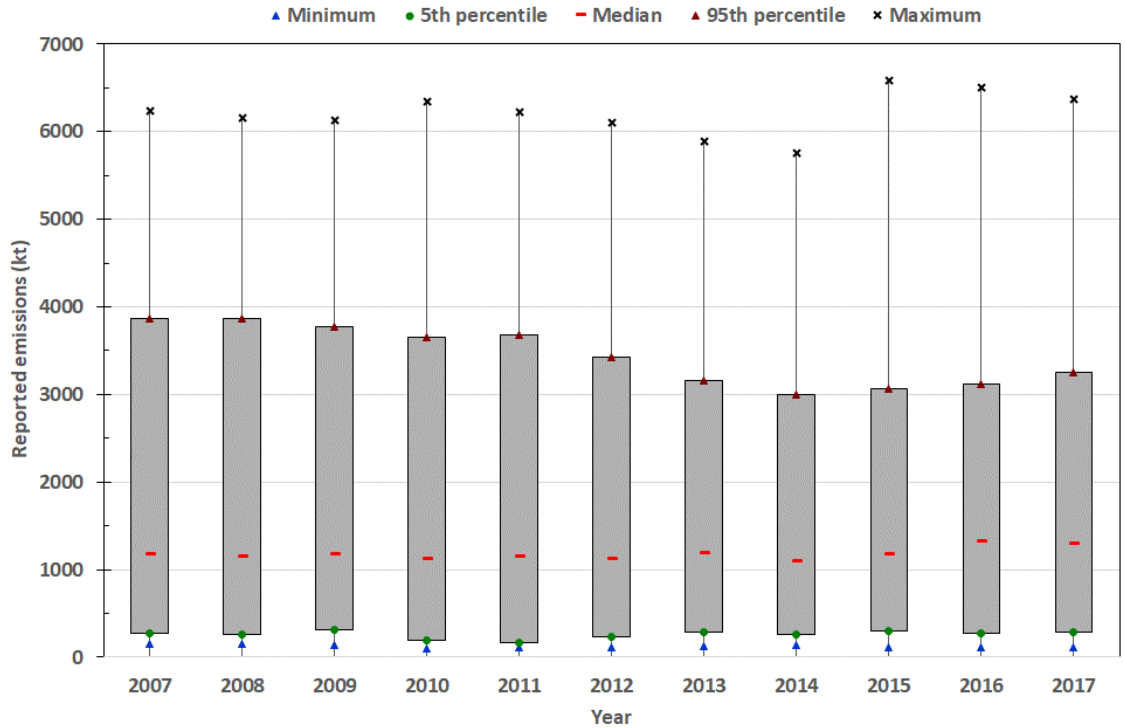


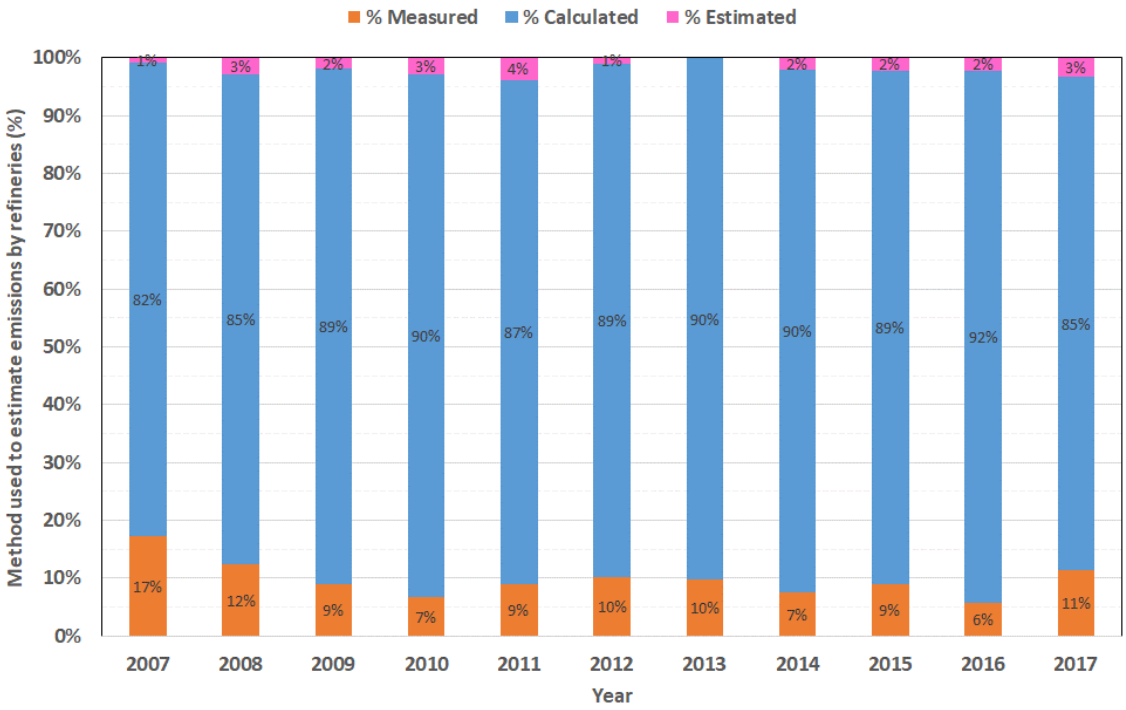
Figure 37 Statistical analysis of CO_2 air emissions for European refineries: 5th and 95th percentiles



3.5.3. Methods used to determine the emissions

Figure 38 shows the degree to which the three different determination methods (as defined in reference [5]) have been used to estimate CO_2 emissions. This shows that approved estimation methodologies ("calculation") and measurement were used at virtually all refineries.

Figure 38 Methods used to determine CO_2 air emissions for European refineries



3.5.4. Emissions by sector

Figure 39 illustrates the contribution of those Annex I sectors of activity for which CO_2 air emissions have been reported to E-PRTR in the period 2007 to 2017. The CO_2 emissions reported in the E-PRTR database are coming mainly from the energy sector (approximately 65%-73% of the total reported CO_2 air emissions to E-PRTR). From 2007 to 2017 the reported CO_2 air emissions from the energy sector have decreased by approximately 390.000 kt (25%) (**Figure 40**).

The energy sector is divided into six different economic activities. **Figure 41** shows the contribution of these to the total energy sector reported CO_2 air emissions. It can be seen that "thermal power stations and other combustion installations" are the major CO_2 contributors to the energy sector (approximately 90% in all years).

Figure 39 Percentage contribution of each Annex I sector of activity to total CO_2 air emissions reported in the E-PRTR database during 2007-2017

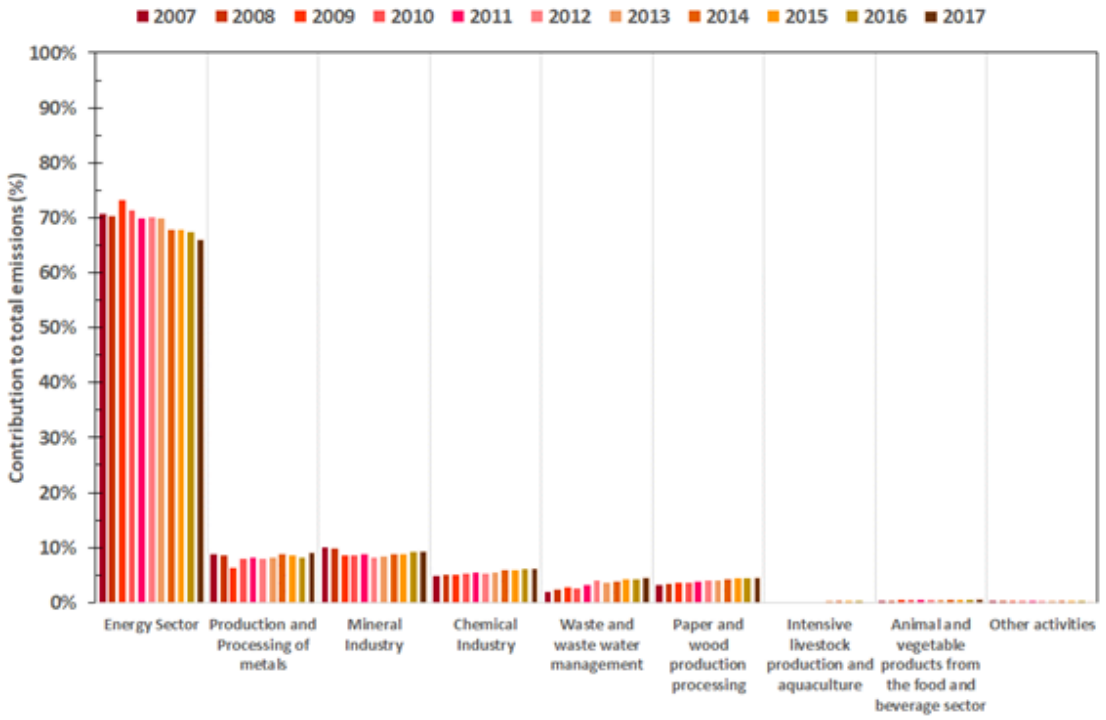


Figure 40 CO_2 air emissions reported in the E-PRTR database during 2007-2017 for each Annex I sector of activity

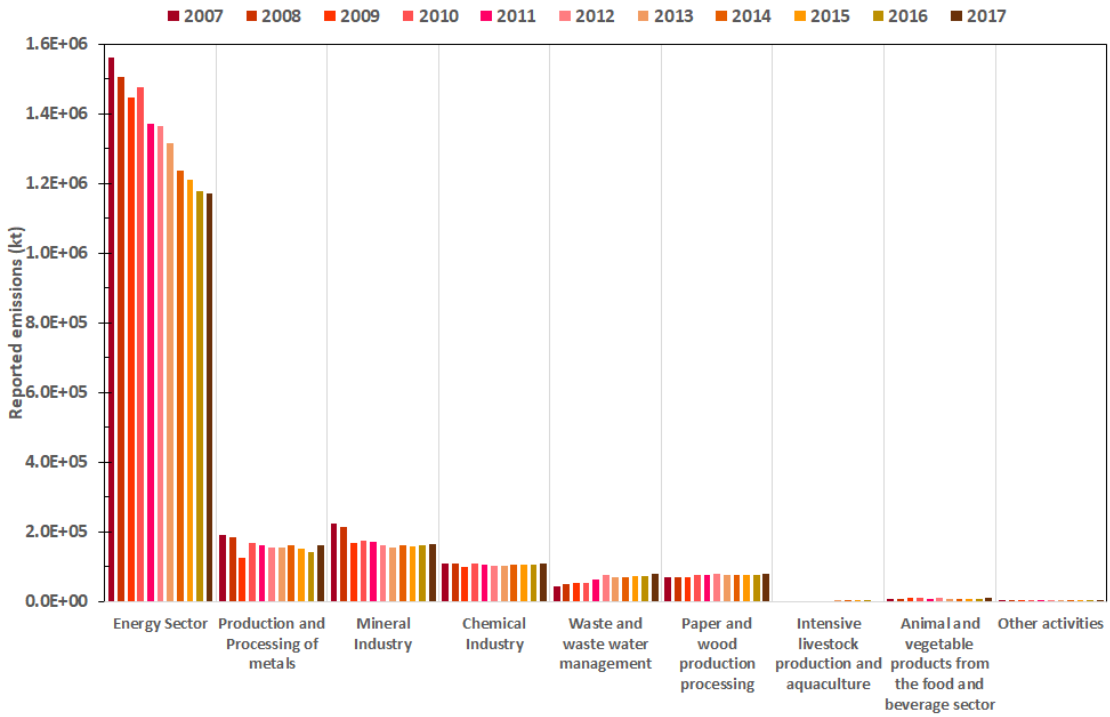
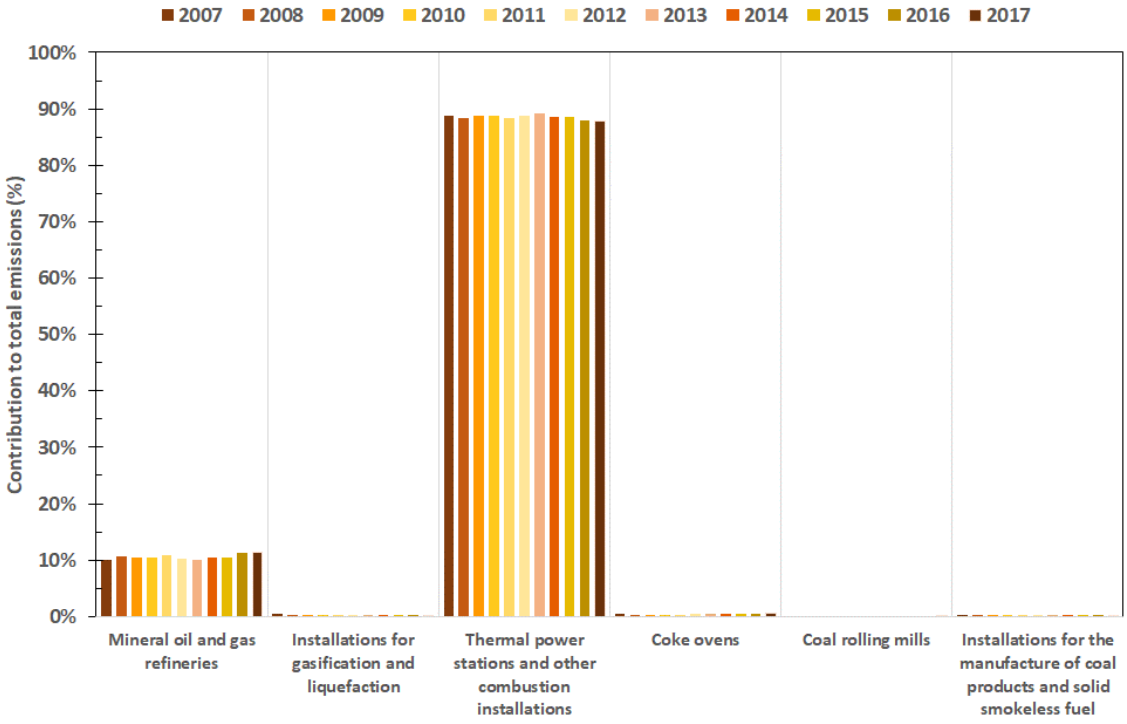


Figure 41 CO_2 air emissions reported in the E-PRTR database during 2007-2017 - contribution of different energy sector activities



3.6. PARTICULATE MATTER (PM_{10})

3.6.1. Emissions from European refineries

Table 15 summarises the reported emissions of PM_{10} to air from the European refineries. The reporting threshold for emissions of PM_{10} to air is 0.05 kt/a. Since 2007, there has been a decrease in their overall reported emissions, year on year, until 2011. PM_{10} emissions in 2012 were slightly higher compared to 2011 (3%). Lower emissions have been reported in 2013 onwards, until 2016, while in 2017, PM_{10} emissions were slightly higher compared to 2016 (8%).

Figures 42 and 43 show the trend observed for the years 2007 to 2017. The reported emissions in 2017 are 65% lower than those in 2007 **(Figure 42)**. When PM_{10} emissions are expressed per unit of crude processed, the reduction is 61% **(Figure 43)**.

Table 15 PM_{10} emissions to air reported for refineries in the E-PRTR database during 2007-2017

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Reported emissions for refineries (kt)	7.96	7.09	6.72	6.33	5.51	5.69	4.08	3.67	3.21	2.59	2.81
Total reported emissions for all sectors (kt)	260	203	165	166	179	149	139	120	223	88	104
Refineries contribution to total PM_{10} emissions reported to E-PRTR	3%	3%	4%	4%	3%	4%	3%	3%	1%	3%	3%
Reported emissions per mass of crude oil transformed in refineries (ppm)	11.9	10.5	10.8	10.2	9.1	9.4	7.2	6.5	5.4	4.4	4.6
Number of refineries reporting	44	42	40	40	37	35	30	30	26	22	25

Figure 42 Trends of PM_{10} air emissions reported for European refineries, during 2007-2017

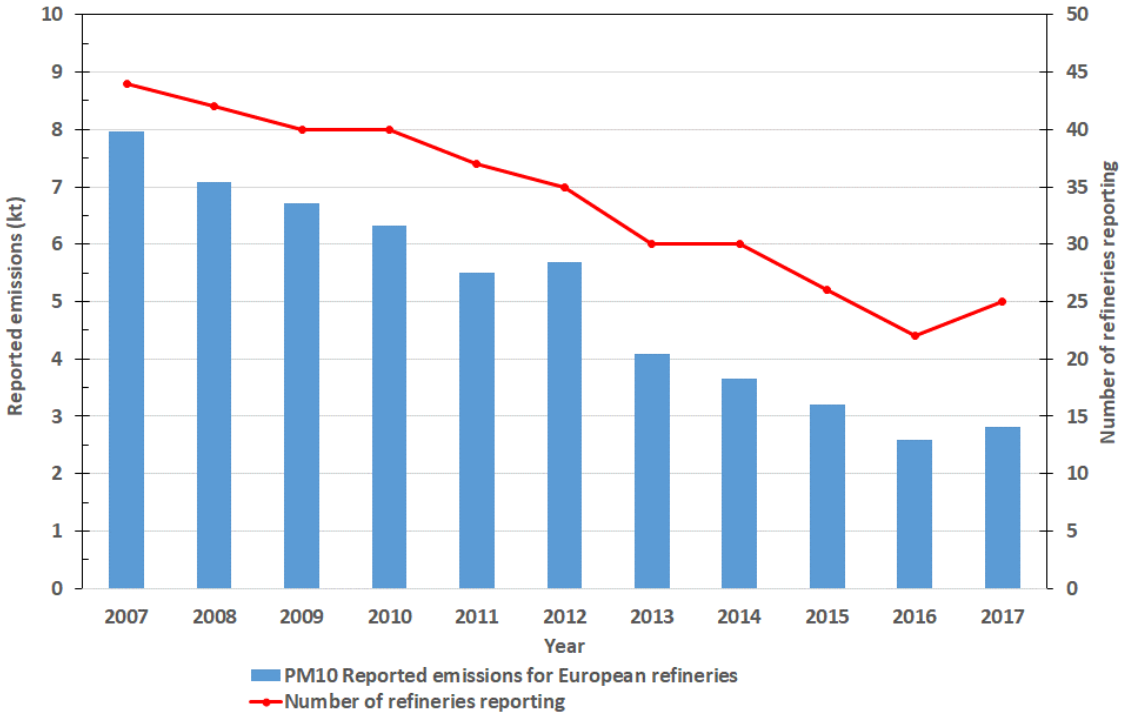
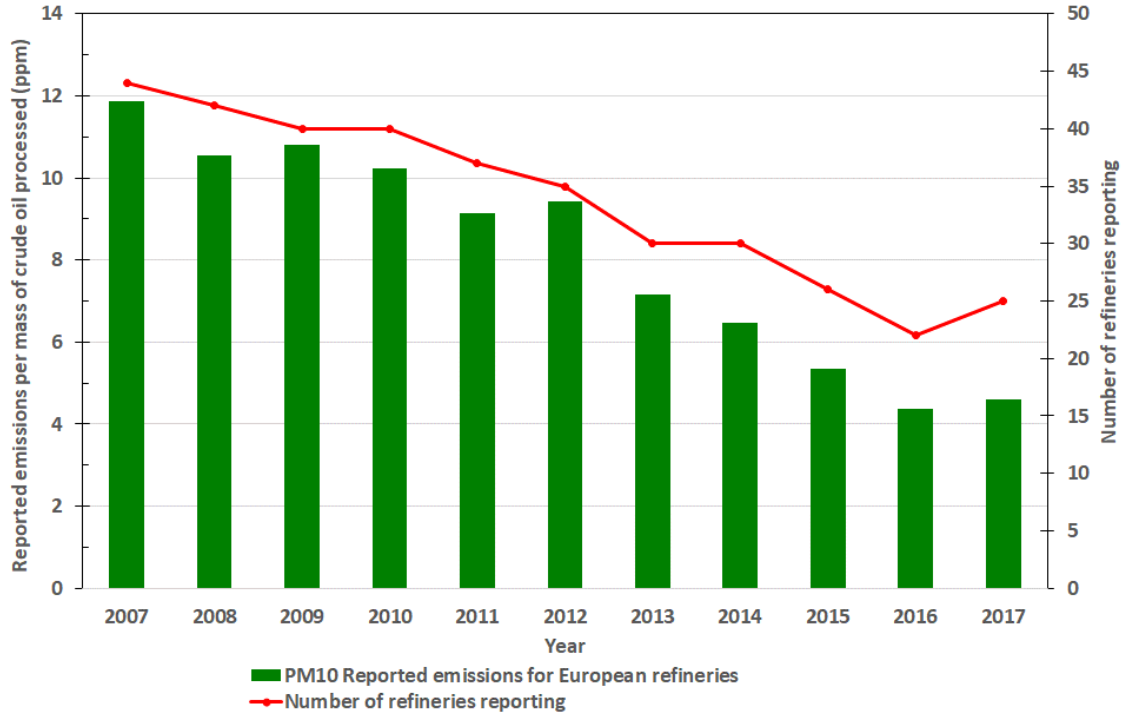


Figure 43 Trends of PM_{10} air emissions reported for European refineries during 2007-2017, expressed as per unit of crude processed



3.6.2. Statistical analysis

Table 16 provides the median, maximum and minimum values of the data submitted for refineries for each reporting year. It also gives the values of the 5th, 25th, 75th, and 95th percentiles, the upper outlier boundary (UOB) and the number of outliers above the UOB. The analyses are represented graphically in **Figure 44** and **Figure 45**. The analysis show a wide scatter of the reported emissions from 2007-2012, which narrows down from 2013 onwards. The number of outliers is relatively small in most of the years (i.e., with 2008 being the only exception), while in 2017 none of the reported emissions from the refineries is considered as an outlier.

Table 16 Statistical analysis of PM_{10} air emissions [kt/y] for European refineries

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Minimum	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.05
Median	0.15	0.13	0.14	0.11	0.11	0.12	0.10	0.11	0.11	0.10	0.11
Maximum	0.74	0.61	0.63	0.72	0.59	0.68	0.30	0.26	0.32	0.27	0.26
5th percentile	0.06	0.06	0.06	0.06	0.05	0.06	0.06	0.06	0.06	0.06	0.05
25th percentile	0.07	0.09	0.08	0.07	0.08	0.08	0.07	0.07	0.06	0.06	0.06
75th percentile	0.22	0.19	0.21	0.20	0.19	0.20	0.18	0.17	0.14	0.13	0.13
95th percentile	0.41	0.43	0.40	0.36	0.30	0.39	0.28	0.21	0.26	0.25	0.22
Upper outlier boundary	0.52	0.39	0.47	0.46	0.42	0.45	0.39	0.36	0.29	0.26	0.28
Number of outliers	1	4	1	1	1	1	0	0	1	1	0

Figure 44 Statistical analysis of PM_{10} air emissions for European refineries: 25th and 75th percentiles

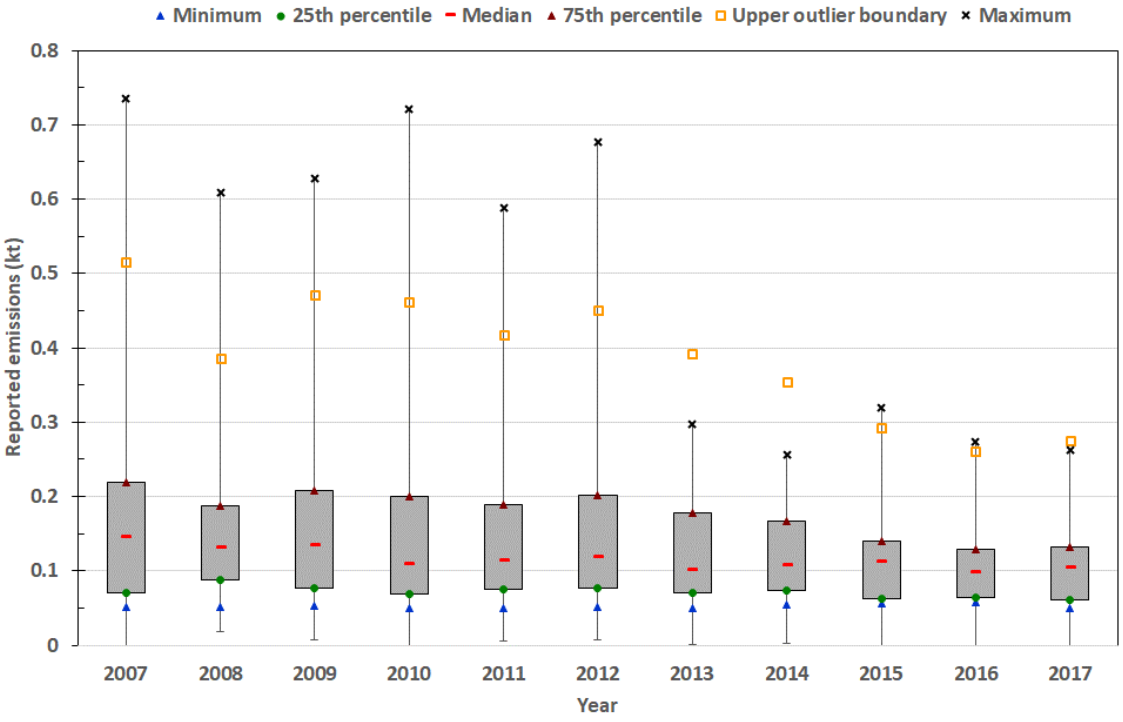
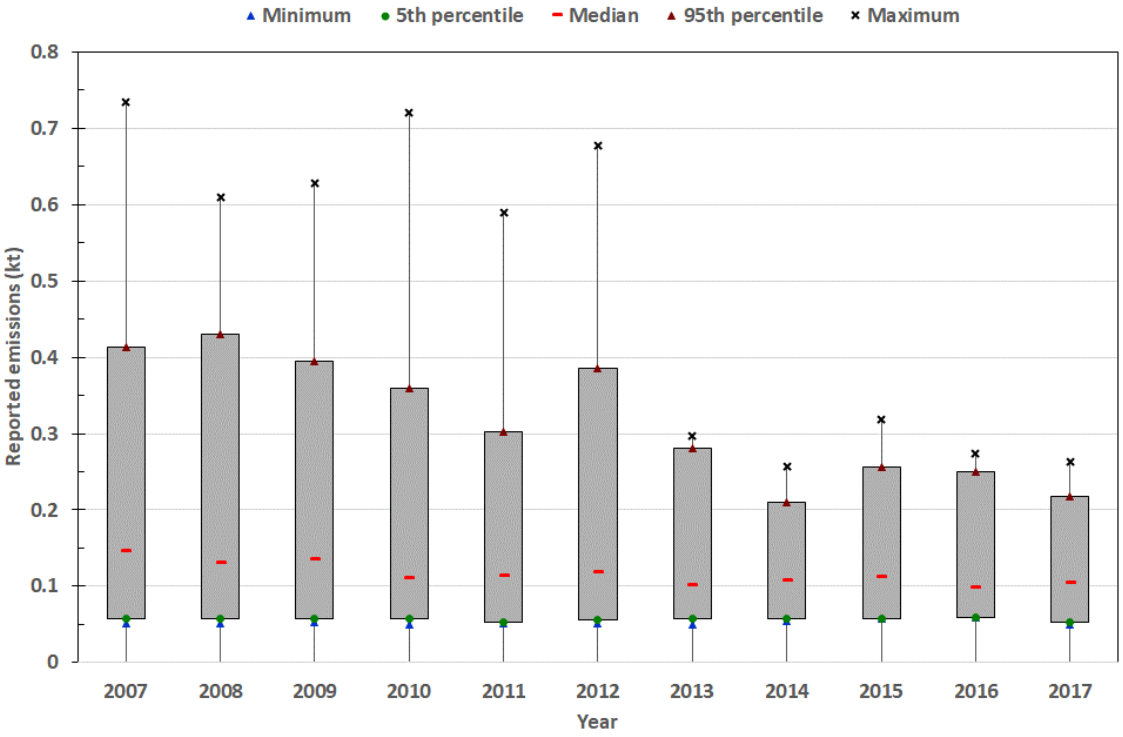


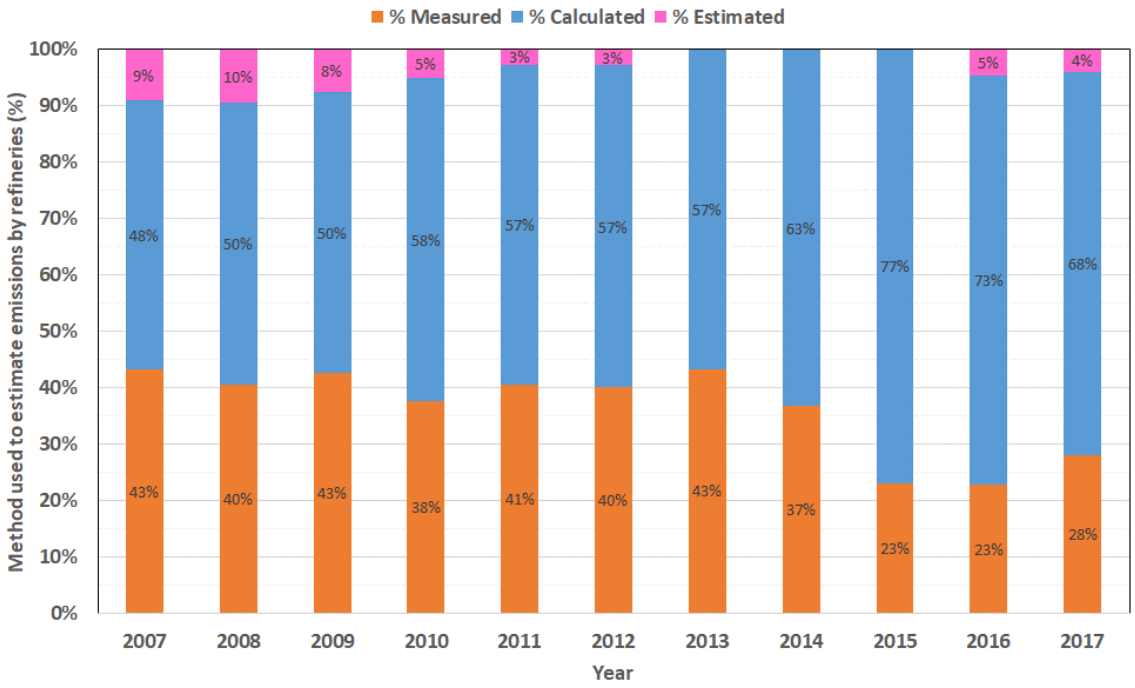
Figure 45 Statistical analysis of PM_{10} air emissions for European refineries: 5th and 95th percentiles



3.6.3. Methods used to determine the emissions

Figure 46 shows the degree to which the three different determination methods (as defined in reference [5] and summarised in Section 3) have been used to report PM_{10} emissions. The results show that approved estimation methodologies ("calculation") and measurement were used at virtually all installations (more than 90% in all years).

Figure 46 Methods used to determine PM_{10} air emissions for European refineries



3.6.4. Emissions by sector

Figure 47 illustrates the contribution of those Annex I sectors of activity for which PM_{10} air emissions have been reported to E-PRTR in the period 2007 to 2017. The results show that PM_{10} air emissions reported in the E-PRTR database originate mainly from the energy sector (50% – 70% contribution, depending the year) in almost all years. The only exception was in 2015, when the reported emissions from the mineral industry dominated the total PM_{10} emissions (58% of the total PM_{10} emissions), mainly due to extremely high emissions reported from a coal mine in UK. In terms of absolute values, reported PM_{10} emissions from the energy sector have reduced by 96 kt (60%) from 2007 to 2017 (**Figure 48**).

The energy sector is divided into six different economic activities. **Figure 49** shows the contribution of each of these to the total energy sector reported PM_{10} air emissions. The main contributor to the energy sector PM_{10} emissions are "thermal power stations and other combustion installations" (more than 90% in all years).

Figure 47 Percentage contribution of each Annex I sector of activity to total PM_{10} air emissions reported in the E-PRTR database during 2007-2017

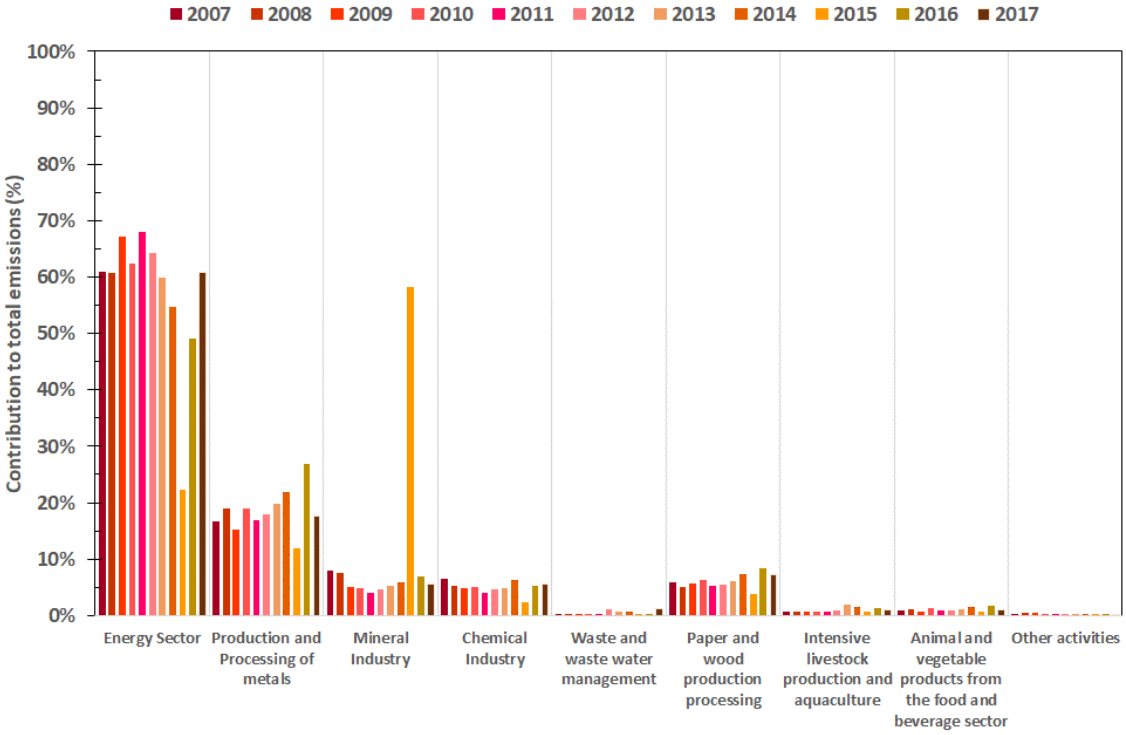


Figure 48 PM_{10} air emissions reported in the E-PRTR database during 2007-2017 for each Annex I sector of activity

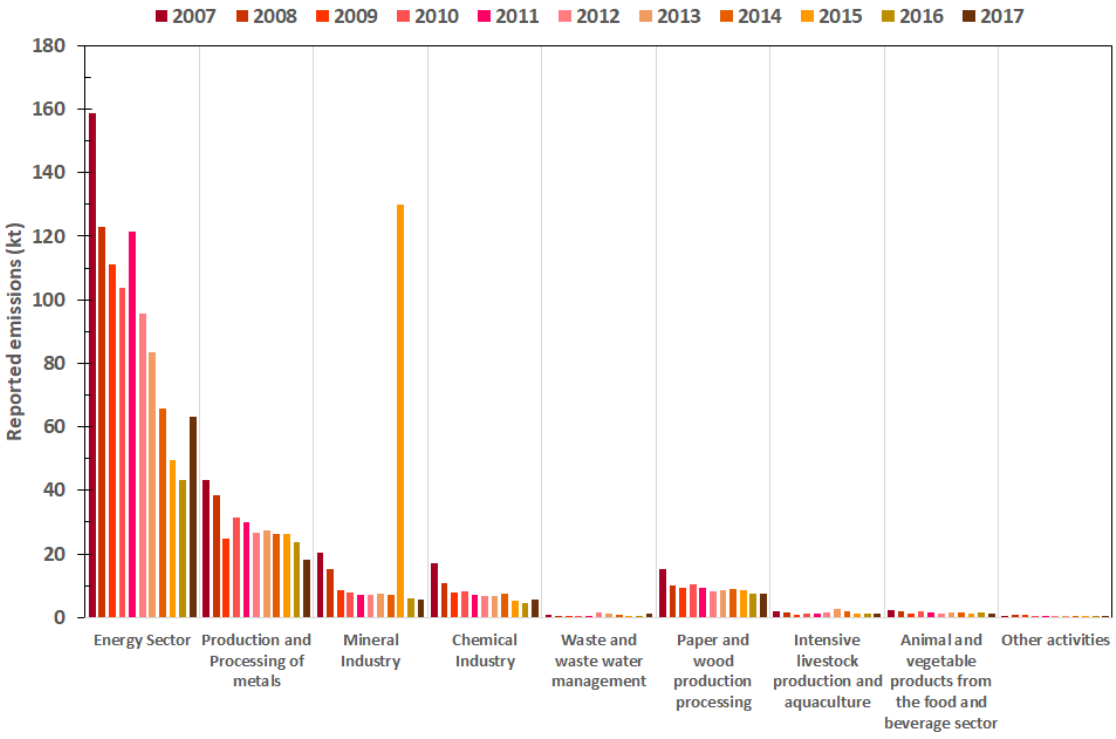
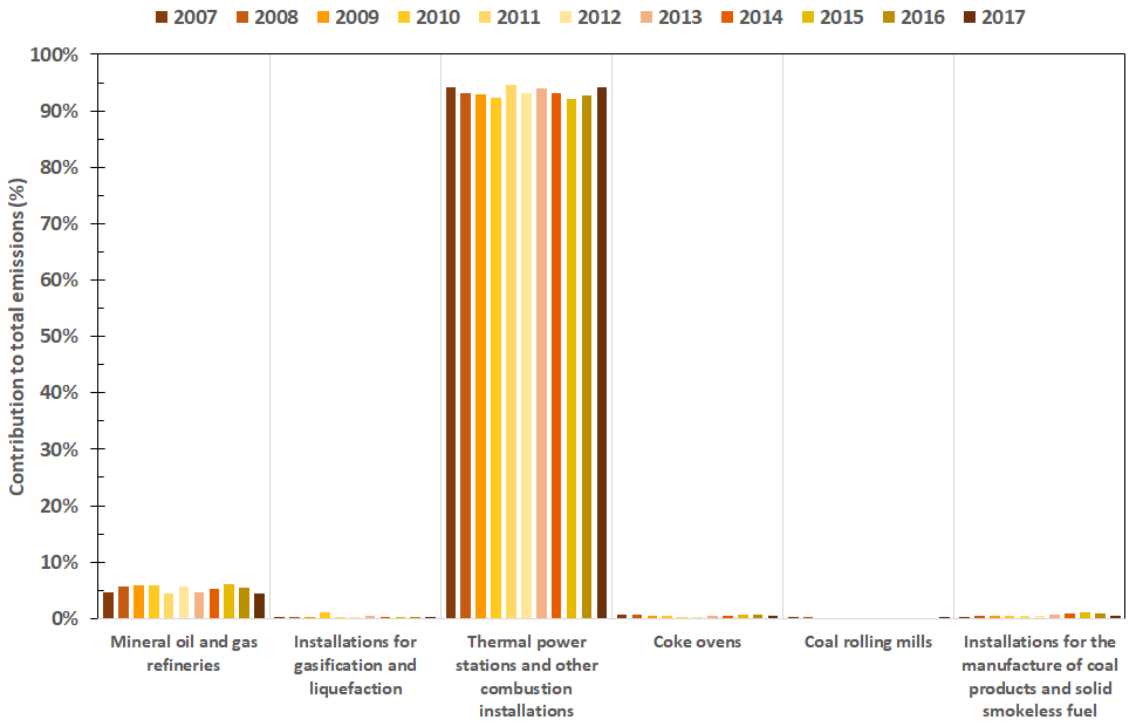


Figure 49 PM_{10} air emissions reported in the E-PRTR database during 2007-2017 – contribution of different energy sector activities



4. ANNEX I CODE 1.(A) AND NACE CODE 19.20 NON-REFINING INSTALLATIONS

4.1. GENERAL

Table 17 gives the total number of installations which do not meet the definition of refinery given in this report, although they are classified as Annex I, code 1.(a) and/or NACE code 19.20, and they have reported air emissions to the E-PRTR database.

Table 17 Number of installations submitting air emissions data classified as Annex I Code 1.(a) or NACE Code 19.20 facilities, which are not refineries as defined in this report

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Number of installations reported as Annex I code 1.(a): "Mineral oil and gas refineries", but they are not refineries.	22	26	30	26	25	28	35	31	30	42	31
Number of installations reported as NACE 19.20: "Manufacture of refined petroleum products", but they are not refineries.	13	12	13	14	12	14	14	14	13	15	15

4.2. CONTRIBUTION OF NON-REFINING INSTALLATIONS TO EMISSION INVENTORIES

Table 18 shows the contribution of the installations which do not meet the definition of refinery given in this report but are classified as Annex I, code 1.(a), to the total reported air emissions of the industrial activity 1.(a) ("Mineral oil and gas refineries"). The table presents only the pollutants for which the contribution of the non-refineries to the total reported air emissions of the industrial activity 1.(a) exceeded 5% during at least one of the years examined in this report (2007 – 2017).

Table 18 Percentage contribution of non-refineries air emissions to total reported air emissions of the industrial activity 1.(a). Results are shown for the pollutants of which the contribution of the non-refineries exceeded 5% during at least one of the examined years (2007-2017)

Pollutant	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Ammonia (NH_3)	0%	0%	0%	0%	0%	0%	0%	0%	0%	24%	0%
Benzene	2%	2%	2%	2%	3%	3%	3%	2%	3%	6%	4%
Carbon monoxide (CO)	18%	21%	26%	1%	1%	0%	0%	0%	5%	22%	27%
Hydro-chlorofluorocarbons (HCFCs)	57%	33%	65%	89%	93%	67%	92%	78%	90%	97%	89%
Hydro-fluorocarbons (HFCs)	95%	58%	30%	0%	0%	0%	0%	0%	0%	28%	55%
Mercury and compounds (as Hg)	0%	0%	0%	0%	0%	0%	0%	0%	10%	10%	5%
Methane (CH_4)	54%	60%	49%	54%	52%	56%	58%	58%	55%	49%	51%
Nitrogen oxides (NOx/NO_2)	4%	3%	3%	4%	4%	4%	5%	5%	5%	6%	6%
NMVOCs	15%	13%	13%	12%	12%	13%	15%	14%	14%	15%	16%
Particulate Matter (PM_{10})	0%	0%	4%	0%	0%	0%	2%	0%	2%	4%	8%

In addition, **Table 19** shows the contribution of the non-refining installations, which are classified as Annex I, NACE code 19.20 facilities, to the total reported air emissions for the economic sector 19.20 (“Manufacture of refined petroleum products”). The table presents only the pollutants for which the contribution of the non-refineries to the total reported air emissions of NACE 19.20 exceeded 5% during at least one of the years examined in this report (2007 – 2017).

Table 19 Percentage contribution of non-refineries air emissions to total reported air emissions of the economic sector (NACE) 19.20. Results are shown for the pollutants of which the contribution of the non-refineries exceeded 5% during at least one of the examined years (2007-2017)

Pollutant	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Ammonia (NH_3)	0%	0%	0%	0%	0%	3%	0%	4%	25%	25%	29%
Benzene	1%	0%	0%	0%	1%	14%	9%	11%	39%	36%	35%
Carbon monoxide (CO)	18%	19%	27%	28%	23%	34%	46%	51%	45%	53%	59%
Hydro-chlorofluorocarbons (HCFCs)	31%	8%	15%	40%	85%	2%	0%	0%	1%	0%	0%
Hydro-fluorocarbons (HFCs)	0%	0%	0%	0%	0%	0%	5%	4%	5%	3%	0%
Mercury and compounds (as Hg)	0%	0%	0%	0%	0%	0%	0%	0%	10%	10%	5%
Methane (CH_4)	8%	10%	9%	10%	15%	20%	20%	20%	13%	18%	18%
Naphthalene	24%	43%	100%	14%	33%	100%	30%	37%	45%	20%	1%
NMVOCs	6%	4%	5%	5%	5%	6%	5%	6%	5%	6%	5%
Particulate Matter (PM_{10})	0%	0%	0%	10%	0%	2%	2%	2%	3%	3%	3%

5. DISCUSSION

This report provides a review of the emissions of air pollutants for oil refineries located in 24 European countries submitted to the European Pollutant Release and Transfer Register (E-PRTR) database for the years 2007 – 2017. Based on the E-PRTR inventory there were 122 refineries that reported air emissions in 2007. In the 2017 E-PRTR inventory, air emissions data for 96 refineries are available. The reduction in refineries reporting reflects that several refineries ceased operations and closed during this time period.

Detailed analyses have been undertaken on the emissions of six pollutants reported for oil refineries over the period 2007 to 2017. These pollutants are SO_x, NO_x, NMVOCs, benzene, CO_2, and PM_{10}. The analysis indicates that the reported air emissions from refineries, for each of the pollutants, show a clear downward trend. The percentage emissions reductions between 2007 and 2017 are: SO_x 65%, NO_x 45%, NMVOCs 38%, benzene 50%, CO_2 20%, and PM_{10} by 65%.

It is reported that the emissions data for SO_x, NO_x, CO_2, and PM_{10} have been determined using approved estimation methodologies ("calculation") or measurement methods (as defined in reference [5]) at virtually all refineries. On the contrary, "non-standardised" estimation methods (as defined in [5]) have been used for NMVOCs and benzene in a significant number of refineries. Approximately 12%-19% of the refineries use "non-standardised" estimation methods to determine NMVOCs air emissions, while for benzene emissions "non-standardised" methods are used by approximately 15%-24% of the refineries.

The mass of crude processed, which has a direct impact on the air emissions from refineries, has also declined by almost 9% over the same period. The emissions per unit of crude processed have therefore been determined to take this into account. The percentage reductions in tonnes of reported emissions per Mt of crude processed between 2007 and 2017 for the six pollutants are shown in **Table 20**.

Table 20 Variations in reported air emissions per mass of crude processed between 2007 and 2017

Pollutant	Reported emissions per mass of crude processed in refineries (ppm)		Reduction %
	2007	2017	
SO_x	857	330	61
NO_x	289	174	40
NMVOCs	272	184	32
Benzene	3.20	1.77	45
CO_2	2.4E+05	2.1E+05	12
PM_{10}	11.9	4.6	61

Similar to the refining sector, where significant reductions have been reported since 2007 for all the pollutants examined in the report, the other sectors contributing to the overall E-PRTR inventories have also reported reduced emissions. The result has been that for most of the pollutants (SO_x, NO_x, CO_2, NMVOCs, and PM_{10}) the refining

contributions to these inventories has been relatively stable. On the contrary, for benzene inventory, the contribution of the refining sector varies over the years (36%-55%), being approximately 40% in 2017. **Table 21** provides an indication of the oil refining percentage contribution to the E-PRTR inventories of the five pollutants in both 2007 and 2017.

Table 21 Refining contribution to E-PRTR inventories: 2007 and 2017

Pollutant	Refining contribution to E-PRTR inventory %	
	2007	2017
SO_x	10	11
NO_x	6	6
NMVOCs	26	26
Benzene	46	40
CO_2	7	7
PM_{10}	3	3

For all the pollutants examined in the report, the data show that the majority of the total air emissions reported in the E-PRTR database are coming from the energy sector. Among the energy sector's different economic activities, the refining sector is the major contributor to the NMVOCs and benzene E-PRTR inventories. It must be recognised that these inventories are for those industries submitting data under the E-PRTR Regulation, and they do not include other potentially major sources such as transport and domestic heating.

6. GLOSSARY

CO	Carbon monoxide
CO_2	Carbon dioxide
CH_4	Methane
EC	European Commission
EEA	European Environment Agency
E-PRTR	European Pollutant Release and Transfer Register
FCCU	Fluidised Catalytic Cracking Unit
HCFCs	Hydro-chlorofluorocarbons
HFCs	Hydro-fluorocarbons
IA	Industrial Activity
NACE	Nomenclature Générale des Activités Economiques dans l'Union Européen
NECD	National Emission Ceiling Directive
NMVOC	Non-methane Volatile Organic Compound
NO_x	Oxides of nitrogen
NO_2	Nitrogen dioxide
PM_{10}	Particulate Matter
SO_x	Oxides of Sulphur
SO_2	Sulphur dioxide
UOB	Upper Outliers Boundary

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APPENDIX 1 CRUDE OIL TRANSFORMATION INPUT IN REFINERIES

Table 22 Annual data of crude oil transformation input in refineries [thousands of tonnes] [3]

COUNTRY	kT/YEAR										
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017[1]
Austria	8,548	8,666	8,306	7,749	8,298	8,349	8,566	8,435	8,881	8,185	8,398
Belgium	32,963	33,725	31,324	33,283	29,777	31,652	27,634	32,123	32,051	31,978	31,651
Bulgaria	7,096	7,146	6,247	5,475	5,083	5,894	5,622	5,154	6,037	6,258	6,001
Croatia	4,955	4,305	4,695	4,163	3,273	3,058	2,968	2,389	2,863	3,224	3,589
Czech Republic	7,394	8,249	7,376	7,901	7,098	7,247	6,664	7,496	7,223	5,422	7,207
Denmark	7,798	7,782	7,805	7,246	6,811	7,628	7,173	6,910	7,336	6,994	7,348
Finland	10,844	11,097	10,940	10,511	11,212	10,759	11,296	11,220	9,809	11,276	10,896
France	82,350	83,667	72,131	65,424	65,401	56,803	55,644	54,566	57,342	56,005	64,933
Germany	109,395	107,427	100,903	95,388	93,439	94,937	92,467	91,272	93,585	94,272	97,309
Greece	19,169	17,957	17,210	19,575	16,490	20,477	19,891	20,695	21,695	23,186	19,635
Hungary	7,087	6,967	6,324	6,389	6,596	6,097	5,969	6,507	6,477	6,637	6,505
Ireland	3,389	3,272	2,812	2,905	2,949	3,068	2,838	2,752	3,366	3,201	3,055
Italy	92,770	86,944	80,348	83,284	78,158	73,639	62,685	59,645	67,092	64,586	74,915
Lithuania	4,742	9,241	8,407	8,985	9,007	8,533	9,010	7,497	8,486	9,324	8,323
Netherlands	49,875	50,296	48,122	51,842	50,263	50,347	47,707	49,779	52,787	53,812	50,483
Norway	15,207	13,915	13,907	12,051	13,316	13,041	13,379	12,656	13,633	10,394	13,150
Poland	20,113	20,804	20,304	22,843	24,001	25,153	24,302	24,196	26,140	25,790	23,365

COUNTRY	kT/YEAR										
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017[1]
Portugal	12,314	12,046	10,406	11,297	10,275	11,054	11,912	10,792	13,847	13,908	11,785
Romania	13,006	12,981	11,210	10,050	9,675	9,101	9,410	10,455	10,352	11,409	10,765
Slovakia	5,955	5,847	5,700	5,453	5,991	5,399	5,791	5,220	5,930	5,738	5,702
Spain	57,704	58,610	52,651	52,794	52,316	59,233	58,142	59,022	65,031	64,988	58,049
Sweden	18,363	20,663	19,638	20,226	18,645	20,816	16,530	18,878	19,981	19,721	19,346
Switzerland[2]	4,674	5,021	4,748	4,488	4,354	3,394	4,759	4,864	2,776	3,007	2,895
United Kingdom	75,707	75,844	70,716	68,711	70,691	66,811	59,026	55,342	55,376	53,061	65,129
TOTALS	671,418	672,472	622,230	618,033	603,119	602,490	569,385	567,865	598,096	592,376	610,435

[1] No data for 2017 provided in [3]. Transformation input for that year determined from the average of the previous years.

[2] Data for Switzerland for 2011-2015 were taken from the yearly reports of the Swiss Petroleum Association (Erdöl-Vereinigung – EV7). Data for 2016-2017 were taken from the global energy statistics of the Swiss Federal Office of Energy.

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