

report

report no. 4/18

Air emissions from the refining sector. Analysis of E-PRTR data 2007-2014



ISBN 978-2-87567-083-0



9 782875 670830 >

Air emissions from the refining sector. Analysis of E-PRTR data 2007-2014

Prepared by the Concaawe Air Quality Management Group's Special Task Force on
Emission Reporting Methodologies (STF-69):

Alvarez M.
Bakker A.
Benavente Q.
Duclaux O.
Durand M.
Kangas P.
Leventos D.
Ribeiro N.
Roberts P.
Sanchez A.
Smithers B.
Vaskinen K.

Hoven L. (Science Executive)
Megaritis A. (Research Associate)

Reproduction permitted with due acknowledgement

© Concaawe
Brussels
February 2018

ABSTRACT

This report is an updated version of the Concaawe Report No 2/15 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 2014. Detailed analyses are given for five pollutants of interest (SO_x, NO_x, NMVOCs, benzene, and CO₂).

Emissions of the five pollutants reviewed have decreased significantly between 2007 and 2014: SO_x by 63%, NO_x by 44%, NMVOCs by 40%, benzene by 51% and CO₂ by 21%. The mass of crude processed over the same eight-year period reduced by 15%. When emissions are expressed as t per Mt of crude processed the reduction between 2007 and 2014 is: 57% for SO_x, 34% for NO_x, 30% for NMVOCs, 42% for benzene and 6.5% for CO₂.

KEYWORDS

E-PRTR, Emissions, Refineries, Sulphur oxides (SO_x/SO₂), Nitrogen oxides (NO_x/NO₂), Benzene, Carbon dioxide (CO₂), Non-methane volatile organic compounds (NMVOCs)

INTERNET

This report is available as an Adobe pdf file on the Concaawe website (www.concaawe.org).

NOTE

Considerable efforts have been made to assure the accuracy and reliability of the information contained in this publication. However, neither Concaawe nor any company participating in Concaawe can accept liability for any loss, damage or injury whatsoever resulting from the use of this information.

This report does not necessarily represent the views of any company participating in Concaawe.

| CONTENTS | Page |
|---|-------------|
| SUMMARY | 5 |
| 1. INTRODUCTION | 7 |
| 2. OVERVIEW OF REPORTING | 9 |
| 2.1. NUMBER OF SITES | 9 |
| 2.2. POLLUTANTS | 11 |
| 3. REFINERIES EMISSIONS SUMMARY | 13 |
| 3.1. OXIDES OF SULPHUR (SO _x /SO ₂) | 14 |
| 3.1.1. <i>Emissions from European refineries</i> | 14 |
| 3.1.2. <i>Statistical analysis</i> | 15 |
| 3.1.3. <i>Methods used to determine the emissions</i> | 17 |
| 3.1.4. <i>Emissions by Sector</i> | 18 |
| 3.2. NITROGEN OXIDES (NO _x /NO ₂) | 21 |
| 3.2.1. <i>Emissions from European refineries</i> | 21 |
| 3.2.2. <i>Statistical analysis</i> | 22 |
| 3.2.3. <i>Methods used to determine the emissions</i> | 24 |
| 3.2.4. <i>Emissions by Sector</i> | 25 |
| 3.3. NON-METHANE VOLATILE ORGANIC COMPOUNDS (NMVOC) | 28 |
| 3.3.1. <i>Emissions from European refineries</i> | 28 |
| 3.3.2. <i>Statistical analysis</i> | 29 |
| 3.3.3. <i>Methods used to determine the emissions</i> | 31 |
| 3.3.4. <i>Emissions by Sector</i> | 32 |
| 3.4. BENZENE | 35 |
| 3.4.1. <i>Emissions from European refineries</i> | 35 |
| 3.4.2. <i>Statistical analysis</i> | 36 |
| 3.4.3. <i>Methods used to determine the emissions</i> | 38 |
| 3.4.4. <i>Emissions by Sector</i> | 39 |
| 3.5. CARBON DIOXIDE (CO ₂) | 42 |
| 3.5.1. <i>Emissions from European refineries</i> | 42 |
| 3.5.2. <i>Statistical analysis</i> | 43 |
| 3.5.3. <i>Methods used to determine the emissions</i> | 45 |
| 3.5.4. <i>Emissions by Sector</i> | 46 |
| 4. ANNEX I CODE 1.(A) AND NACE 19.20 NON-REFINING INSTALLATIONS | 49 |
| 4.1. GENERAL | 49 |
| 4.2. CONTRIBUTION OF NON-REFINING INSTALLATIONS TO EMISSION INVENTORIES | 49 |
| 5. DISCUSSION | 51 |
| 6. GLOSSARY | 53 |
| 7. REFERENCES | 54 |
| APPENDIX 1 CRUDE OIL TRANSFORMATION INPUT IN REFINERIES | 55 |

SUMMARY

This report updates the Concaawe Report No 2/15 [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 2014. Detailed analyses are provided for emissions of the five pollutants reported for the majority of refineries (SO_x, NO_x, NMVOCs, benzene, and CO₂). The changes in reported emissions for each pollutant over the eight-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 2014 data there were 105 oil refineries in 24 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 code¹. There are a number of facilities using the refinery codes that do not meet the definition of oil refinery used in this report. Care must therefore be taken when searching E-PRTR for refineries using one or both activity codes.

In the data corresponding to 2007 there are 22 facilities under Annex I code 1.(a) (16% of the total number of installations classified as 1.(a)), and 13 under NACE code 19.20 (10% of the total number of installations classified as 19.20) that reported air emissions to E-PRTR database, which do not meet the definition of refinery given in this report. In 2014 the number of facilities that do not meet the definition of oil refinery used in this report are 33 under IA 1.(a) and 15 under NACE 19.20. These facilities have a significant effect on the E-PRTR inventories for some pollutants (e.g. in 2014 they contribute more than 78% of the hydrochlorofluorocarbons (HCFCs) and more than 55% of the methane (CH₄) inventories). The analysis undertaken by Concaawe for this report does not include the data submitted for those installations as they are not deemed to be oil refineries.

The total number of air pollutants for which at least one submission has been made for a refinery between 2007 and 2014 is 33. 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. Concaawe cannot establish the accuracy of the

¹ 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.

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

Detailed analyses have been undertaken for emissions of five pollutants (SO_x, NO_x, NMVOCs, benzene, and CO₂) reported for the majority of oil refineries over the period 2007 to 2014. The analysis indicates that the reported air emissions from refineries, for each of the pollutants (SO_x, NO_x, NMVOCs, benzene, CO₂), show a clear downward trend. The percentage emissions reductions between 2007 and 2014 are: SO_x 63%, NO_x 44%, NMVOCs 40%, benzene 51%, and CO₂ 21%.

The mass of crude processed, which has a direct impact on the air emissions from refineries, has also declined by almost 15% over the same eight year period (2007-2014). 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 2014 for the five pollutants are: 57% for SO_x, 34% for NO_x, 30% for NMVOCs, 42% for benzene, and 6.5% for CO₂.

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 May 2017, there had been a further eight data sets added to the register, up to and including that for 2015, although with no data available for Italy during 2015 as they were not reported by the required deadline.

The objectives of this report are:

- to review the changes in the emissions of five air pollutants (SO_x, NO_x, NMVOCs, benzene, and CO₂) reported for the majority of refineries from 2007 to 2014;
- 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 2015 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 NACE² (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 Concaawe database of oil refineries was used to identify these facilities. Based on the 2014 E-PRTR inventory there were 105 refineries in 24 countries that reported air emissions.

In total there are 64 E-PRTR air pollutants. Concaawe report 4/17 [2] 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 exist at the majority of refineries, the pollutants emitted, the methodologies available in the public domain for estimating these and the likelihood that the emissions will exceed the E-PRTR reporting thresholds. It is the

² Nomenclature Générale des Activités Economiques dans l’Union Européen

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 2014 is 33. 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. Five pollutants are reported for the majority of oil refineries: SO_x, NO_x, NMVOCs, benzene and CO₂. The data available in 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 [4] (except for ammonia) 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 reported values for oil refineries 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 emissions that may have occurred in the initial main upload. It should be noted that for the analyses in this report the latest version of the E-PRTR database (E-PRTR v.11, published in July 2017) is used, which contains reported data from 2007 to 2015. However, E-PRTR data for 2015 are not included in the analyses due to the lack of available data from Italy as they were not reported by the required deadline.

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 used 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 Concaawe’s definition of refinery as well as refineries that are classified under another category, a cross-check of the E-PRTR database with the Concaawe refinery list was undertaken. **Table 1** summarises the total number of installations which meet Concaawe’s definition of refinery given in this report and for which air emissions have been reported to E-PRTR from 2007 to 2014.

Table 1 Total number of refineries³ for which air emissions have been reported to E-PRTR during 2007-2014.

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|--|------|------|------|------|------|------|------|------|
| Number of refineries reporting air emissions | 122 | 120 | 116 | 118 | 115 | 112 | 106 | 105 |

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.

³ In 2014, 84 refineries are operating in Europe (FuelsEurope (2015) Statistical Report 2015). The difference in the number of refineries that report air emissions is due to the fact that some large sites report air emissions as two E-PRTR installations.

Table 2 Classification of refineries, for which air emissions have been reported to E-PRTR database during 2007-2014, by Annex I Activity Name.

| Annex I Activity Name / Code | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|--|------------|------------|------------|------------|------------|------------|------------|------------|
| Mineral oil and gas refineries, 1.(a) | 118 | 115 | 113 | 115 | 112 | 109 | 103 | 103 |
| Chemical installations for the production on an industrial scale of basic organic chemicals, 4.(a) | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| Installations for the recovery or disposal of hazardous waste, 5.(a) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Installations for gasification and liquefaction, 1.(b) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| Thermal power stations and other combustion installations, 1.(c) | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 0 |
| Independently operated industrial waste-water treatment plants, 5.(g) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Total | 122 | 120 | 116 | 118 | 115 | 112 | 106 | 105 |

Table 3 Classification of refineries, for which air emissions have been reported to E-PRTR database during 2007-2014, by NACE coding.

| NACE Main Economic Activity Name/Code | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|--|------------|------------|------------|------------|------------|------------|------------|------------|
| Manufacture of refined petroleum products, 19.20 | 117 | 118 | 110 | 115 | 112 | 103 | 102 | 103 |
| Manufacture of oils and fats, 10.41 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| Manufacture of other organic basic chemicals, 20.14 | 2 | 2 | 0 | 0 | 0 | 1 | 0 | 0 |
| Manufacture of refractory products, 23.20 | 3 | 0 | 4 | 1 | 1 | 2 | 2 | 1 |
| Treatment and disposal of non-hazardous waste, 38.21 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| Wholesale of solid, liquid and gaseous fuels and related products, 46.71 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| Manufacture of other chemical products n.e.c., 20.59 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Raising of poultry, 1.47 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Warehousing and storage, 52.10 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Total | 122 | 120 | 116 | 118 | 115 | 112 | 106 | 105 |

Table 4 compares the number of refineries (according to Concaawe’s definition of refinery given in this report) 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 2014 the facilities that did not meet the definition of oil refinery were 33 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 |
|--|------|------|------|------|------|------|------|------|
| Annex I – 1.(a) Classification | | | | | | | | |
| Total number of installations | 140 | 141 | 142 | 140 | 136 | 136 | 138 | 136 |
| Number of installations as 1.(a) which meet Concaawe’s definition of refinery | 118 | 115 | 113 | 115 | 112 | 109 | 103 | 103 |
| NACE 19.20 Classification | | | | | | | | |
| Number of installations as NACE 19.20 | 130 | 130 | 123 | 129 | 124 | 117 | 116 | 118 |
| Number of installations as NACE 19.20 which meet Concaawe’s definition of refinery | 117 | 118 | 110 | 115 | 112 | 103 | 102 | 103 |

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

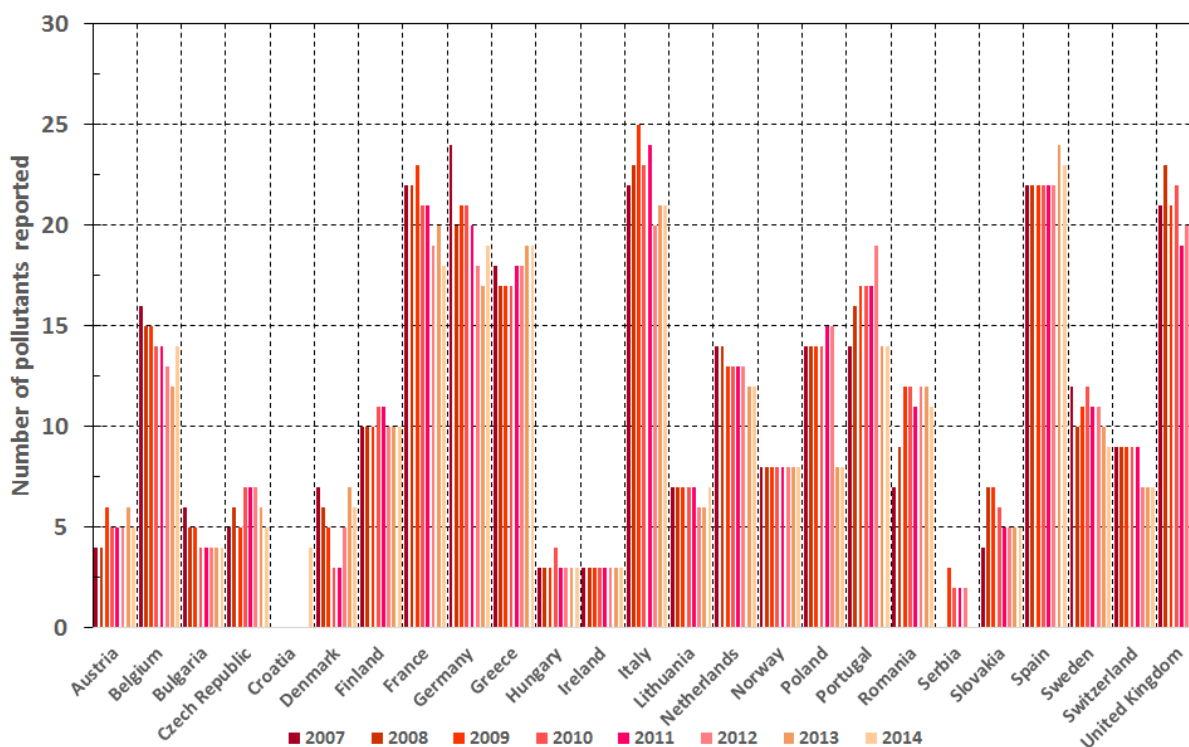
An analysis of the impact of all non-refining emissions is provided in chapter 4, where the contribution of the installations which do not meet the definition of refinery given in this report to the total reported air emissions of pollutants is discussed.

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 total number of air pollutants reported for oil refineries on a pan-European basis in the E-PRTR between 2007 and 2014 is 33.

3. REFINERIES EMISSIONS SUMMARY

This chapter presents detailed analyses of the emissions of five pollutants to air that are reported for European refineries over the period from 2007 to 2014. 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 eight year period. The emissions per unit of crude processed have therefore also been determined to take this into account.

Concaawe 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 (v11) database in the EEA website. E-PRTR data for 2015 are not included in the analyses due to the lack of available data from Italy as they were not reported by the required deadline.

2. Statistical analyses of submitted data

These include the median, maximum and minimum values as well as the 5th, 25th, 75th, and 95th 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 $75^{\text{th}} + 2 \times (75^{\text{th}} - 25^{\text{th}})$.

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 Concaawe report 4/17 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 2007-2014.

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/SO₂)

3.1.1. Emissions from European refineries

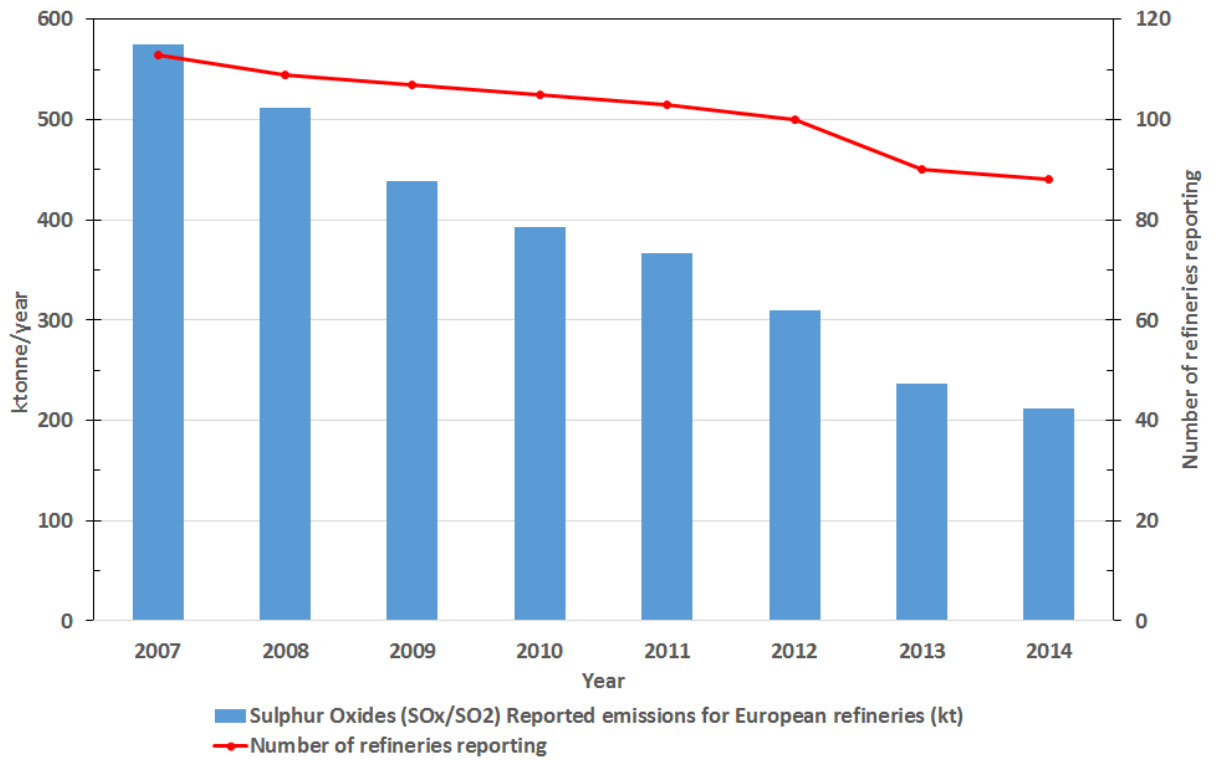
Table 5 summarises the reported emissions of oxides of sulphur to air from the European refineries. Since 2007, there has been a decrease in their overall reported emissions, year on year.

Figure 2 shows the trend observed for the years 2007 to 2014. The reported emissions in 2014 are 63% lower than those in 2007.

Table 5 Oxides of sulphur emissions to air reported for refineries in the E-PRTR database during 2007-2014.

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|------|------|------|------|------|------|------|------|
| Reported emissions for refineries (kt) | 576 | 512 | 439 | 393 | 367 | 310 | 237 | 211 |
| Total reported emissions for all sectors (kt) | 5655 | 4261 | 3780 | 3350 | 3338 | 2957 | 2464 | 2243 |
| Refineries contribution to total SO _x emissions reported to E-PRTR | 10% | 12% | 12% | 12% | 11% | 10% | 10% | 9% |
| Reported emissions per mass of crude oil transformed in refineries (t/Mt) | 859 | 762 | 708 | 636 | 608 | 513 | 415 | 371 |
| Number of refineries reporting | 113 | 109 | 107 | 105 | 103 | 100 | 90 | 88 |
| Reporting threshold (kt) | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 |

Figure 2 Trends of oxides of sulphur air emissions reported for European refineries, during 2007-2014.



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 3** and **Figure 4**.

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

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|-----------------------------|------|------|------|------|------|------|------|------|
| Minimum | 0.16 | 0.16 | 0.18 | 0.15 | 0.18 | 0.18 | 0.16 | 0.18 |
| Median | 3.5 | 3.3 | 3.1 | 2.6 | 2.6 | 2.2 | 1.9 | 1.7 |
| Maximum | 21.0 | 20.4 | 21.0 | 22.4 | 21.0 | 20.7 | 10.1 | 7.9 |
| 5 th percentile | 0.2 | 0.4 | 0.3 | 0.3 | 0.3 | 0.2 | 0.3 | 0.2 |
| 25 th percentile | 1.5 | 1.4 | 1.1 | 1.2 | 0.8 | 0.8 | 0.9 | 0.8 |
| 75 th percentile | 7.4 | 6.4 | 5.5 | 4.9 | 4.8 | 4.4 | 3.6 | 3.6 |
| 95 th percentile | 16.3 | 13.6 | 12.0 | 11.1 | 11.6 | 9.7 | 7.7 | 6.5 |
| Upper outlier boundary | 19.2 | 16.5 | 14.2 | 12.2 | 12.7 | 11.5 | 9.0 | 7.7 |
| Number of outliers | 4 | 2 | 3 | 4 | 4 | 1 | 1 | 1 |

Figure 3 Statistical analysis of oxides of sulphur air emissions for European refineries: 25th and 75th percentiles.

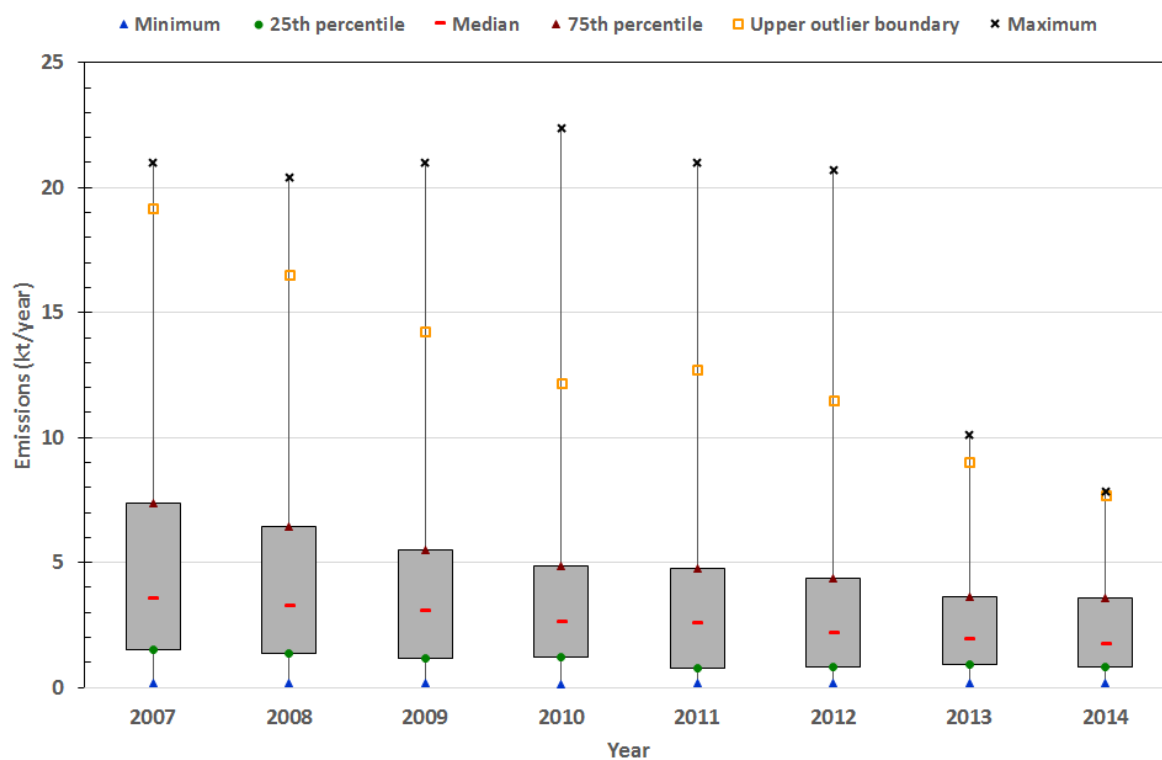


Figure 4 Statistical analysis of oxides of sulphur air emissions for European refineries: 5th and 95th percentiles.



3.1.3. Methods used to determine the emissions

Figure 5 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 5 Methods used to determine oxides of sulphur air emissions for European refineries.



3.1.4. Emissions by Sector

Figure 6 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 2014. The results show that sulphur oxides air emissions reported in the E-PRTR database originate mainly from the energy sector (80% – 90% contribution). Although, in terms of absolute values, reported SO_x emissions from the energy sector have reduced by 3.300 kt (64%) from 2007 to 2014 (**Figure 7**).

The energy sector is divided into six different economic activities. **Figure 8** 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 (85-89%).

Figure 6 Percentage contribution of each Annex I sector of activity to total oxides of sulphur air emissions reported in the E-PRTR database during 2007-2014.

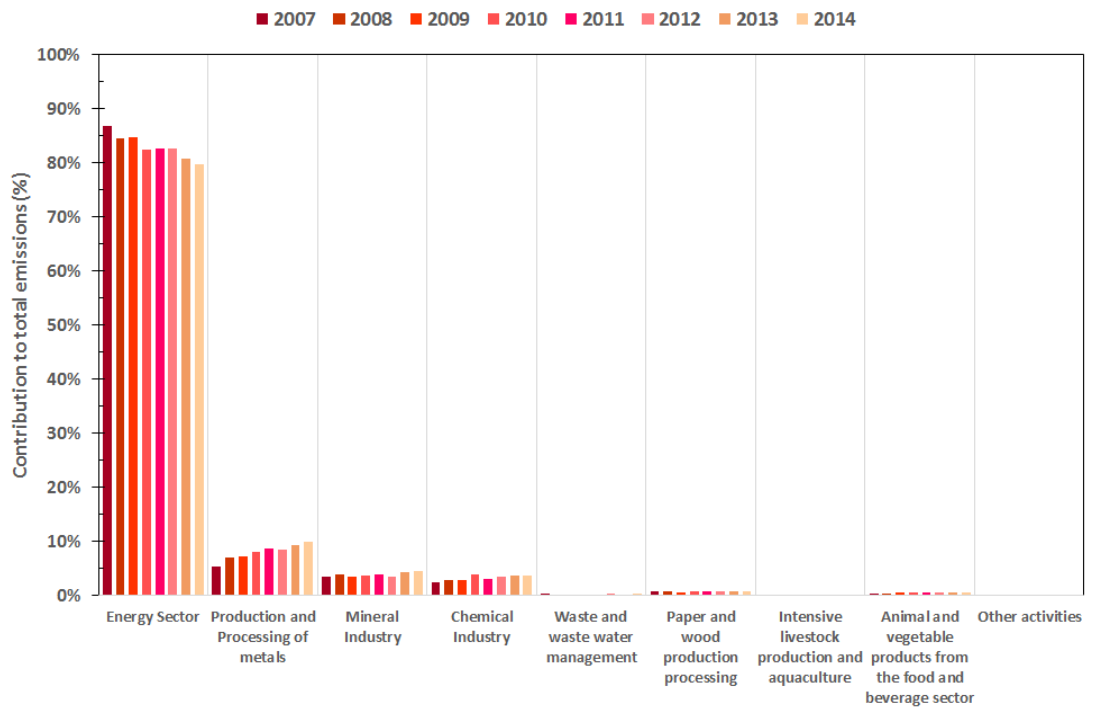


Figure 7 Oxides of sulphur air emissions reported in the E-PRTR database during 2007-2014 for each Annex I sector of activity.

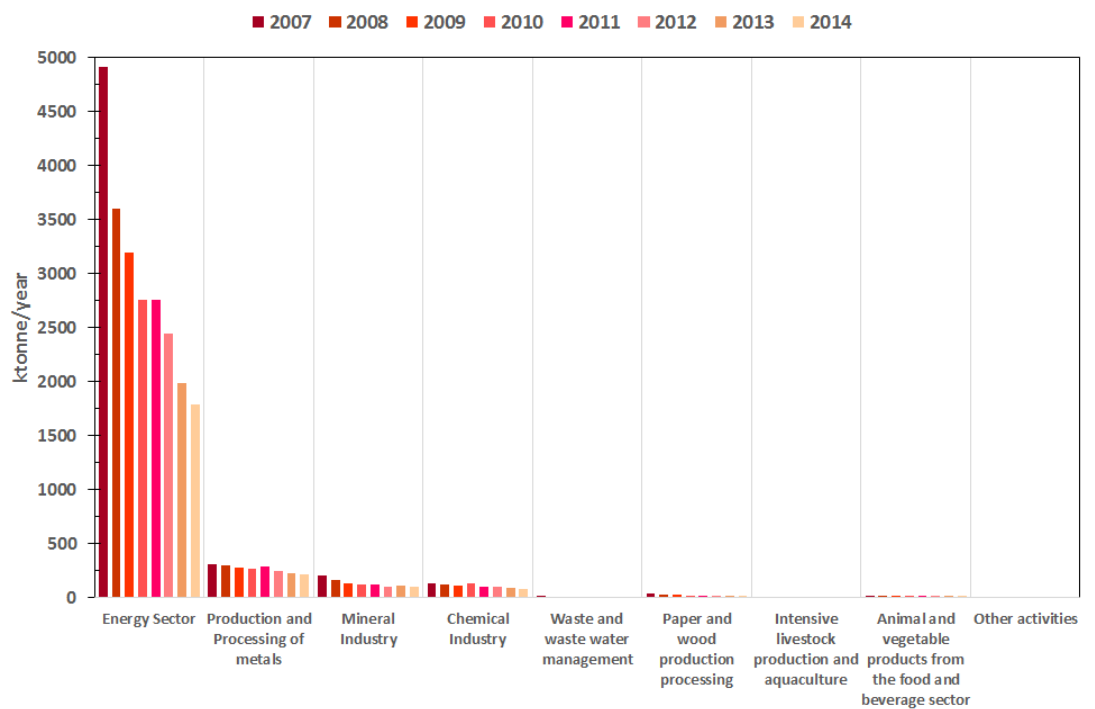
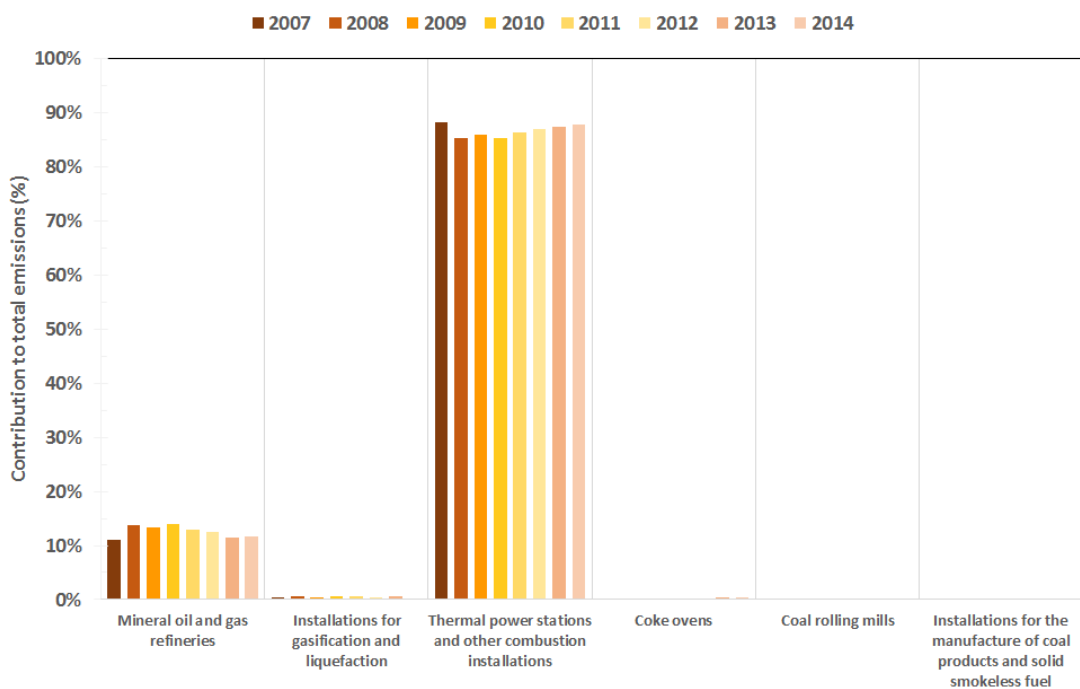


Figure 8 Oxides of sulphur air emissions reported in the E-PRTR database during 2007-2014 – contribution of different energy sector activities.



3.2. NITROGEN OXIDES (NO_x/NO₂)

3.2.1. Emissions from European refineries

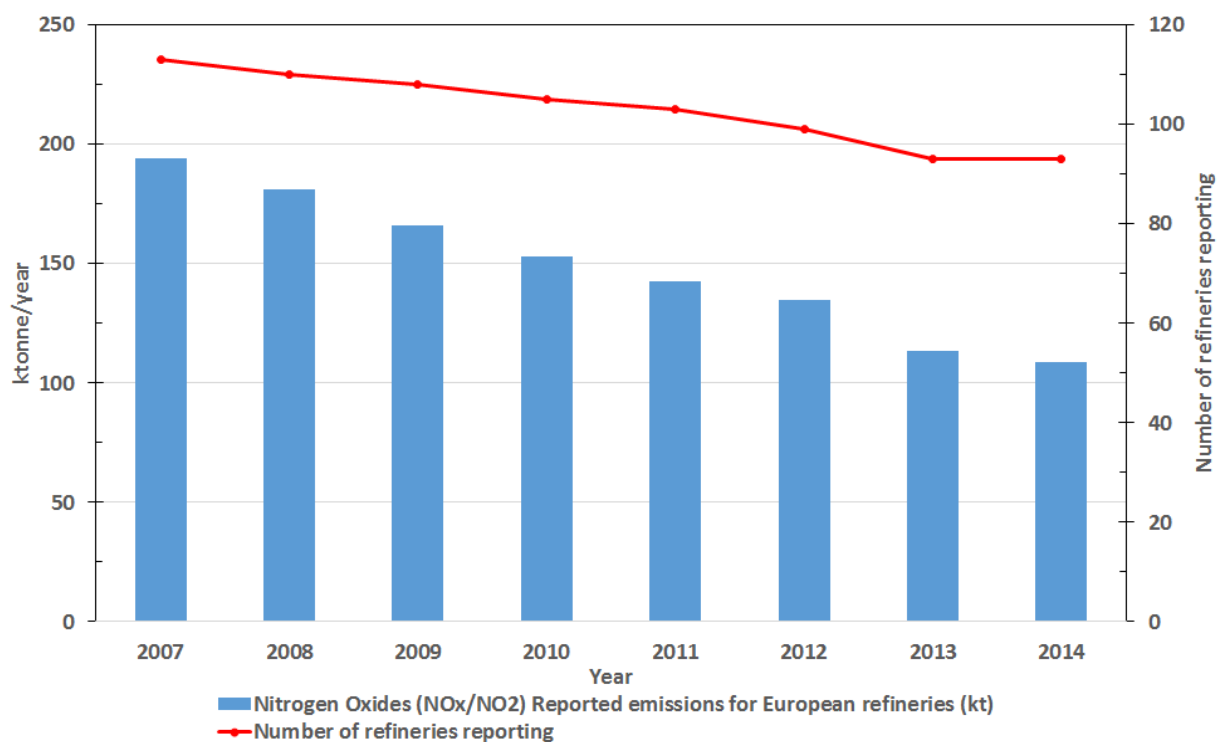
Table 7 summarises the reported emissions of nitrogen oxides to air from the European refineries. Since 2007, there has been a decrease in their overall reported nitrogen oxides emissions, year on year.

Figure 9 shows the trend observed for the years 2007 to 2014. The reported emissions in 2014 are 44% lower than those in 2007.

Table 7 Nitrogen oxides emissions to air reported for refineries in the E-PRTR database during 2007-2014.

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|------|------|------|------|------|------|------|------|
| Reported emissions for refineries (kt) | 194 | 181 | 166 | 153 | 143 | 135 | 114 | 109 |
| Total reported emissions for all sectors (kt) | 3471 | 2999 | 2645 | 2562 | 2520 | 2481 | 2306 | 2114 |
| Refineries contribution to total NO _x emissions reported to E-PRTR | 6% | 6% | 6% | 6% | 6% | 5% | 5% | 5% |
| Reported emissions per mass of crude oil transformed in refineries (t/Mt) | 290 | 270 | 268 | 248 | 236 | 223 | 199 | 191 |
| Number of refineries reporting | 113 | 110 | 108 | 105 | 103 | 99 | 93 | 93 |
| Reporting threshold (kt) | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |

Figure 9 Trends of nitrogen oxides air emissions reported for European refineries, during 2007-2014.



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 10** and **Figure 11**.

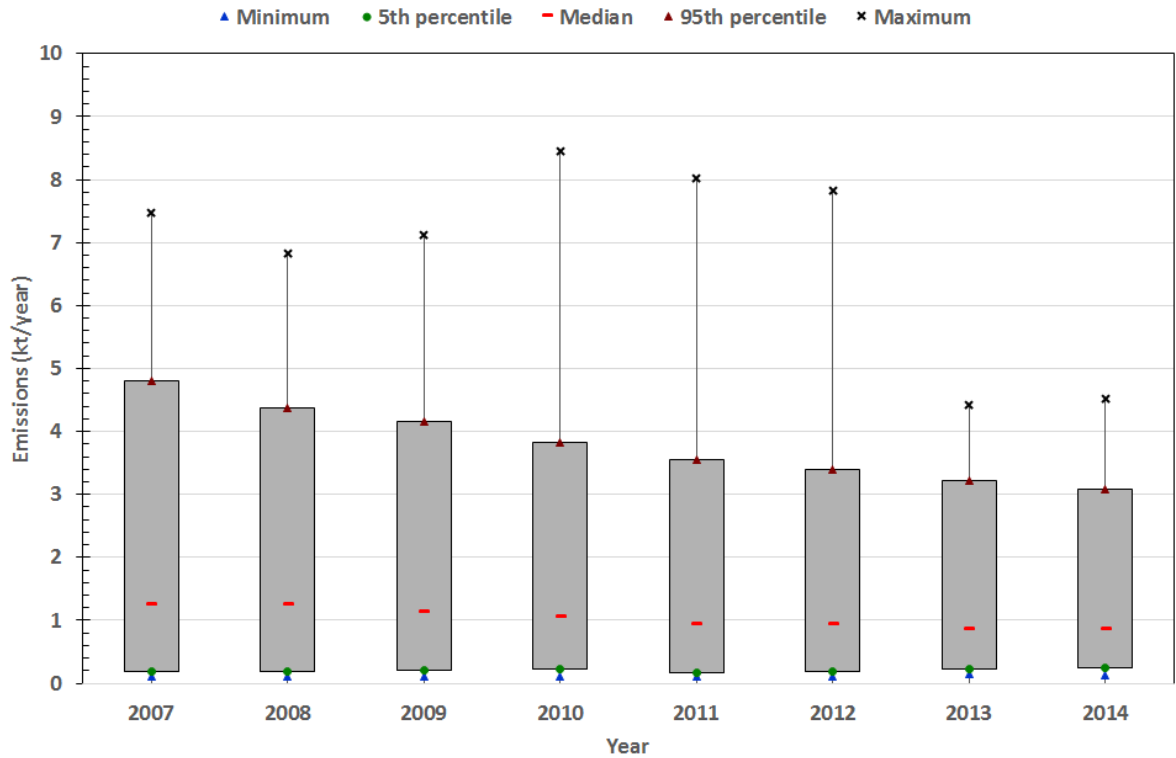
Table 8 Statistical analysis of nitrogen oxides air emissions [kt/y] for European refineries.

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|-----------------------------|------|------|------|------|------|------|------|------|
| Minimum | 0.10 | 0.10 | 0.11 | 0.11 | 0.11 | 0.11 | 0.14 | 0.12 |
| Median | 1.26 | 1.25 | 1.13 | 1.05 | 0.94 | 0.94 | 0.87 | 0.86 |
| Maximum | 7.47 | 6.82 | 7.12 | 8.46 | 8.03 | 7.82 | 4.43 | 4.51 |
| 5 th percentile | 0.18 | 0.20 | 0.21 | 0.22 | 0.16 | 0.19 | 0.23 | 0.24 |
| 25 th percentile | 0.53 | 0.55 | 0.54 | 0.58 | 0.50 | 0.50 | 0.47 | 0.45 |
| 75 th percentile | 2.48 | 2.17 | 2.11 | 2.07 | 1.99 | 2.01 | 1.76 | 1.77 |
| 95 th percentile | 4.81 | 4.38 | 4.16 | 3.83 | 3.56 | 3.40 | 3.22 | 3.08 |
| Upper outlier boundary | 6.38 | 5.39 | 5.25 | 5.06 | 4.95 | 5.03 | 4.34 | 4.41 |
| Number of outliers | 2 | 4 | 3 | 1 | 3 | 2 | 1 | 1 |

Figure 10 Statistical analysis of nitrogen oxides air emissions for European refineries: 25th and 75th percentiles.



Figure 11 Statistical analysis of nitrogen oxides air emissions for European refineries: 5th and 95th percentiles.



3.2.3. Methods used to determine the emissions

Figure 12 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 12 Methods used to determine nitrogen oxides air emissions for European refineries.



3.2.4. Emissions by Sector

Figure 13 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 2014. The data show that nitrogen oxides air emissions reported in the E-PRTR database are coming mainly from the energy sector (60% - 70% contribution). From 2007 to 2014 the reported NO_x emissions from the energy sector have shown a reduction of 1.600 kt (68%) (**Figure 14**).

The energy sector is divided into six different economic activities. **Figure 15** 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%).

Figure 13 Percentage contribution of each Annex I sector of activity to total nitrogen oxides air emissions reported in the E-PRTR database during 2007-2014.

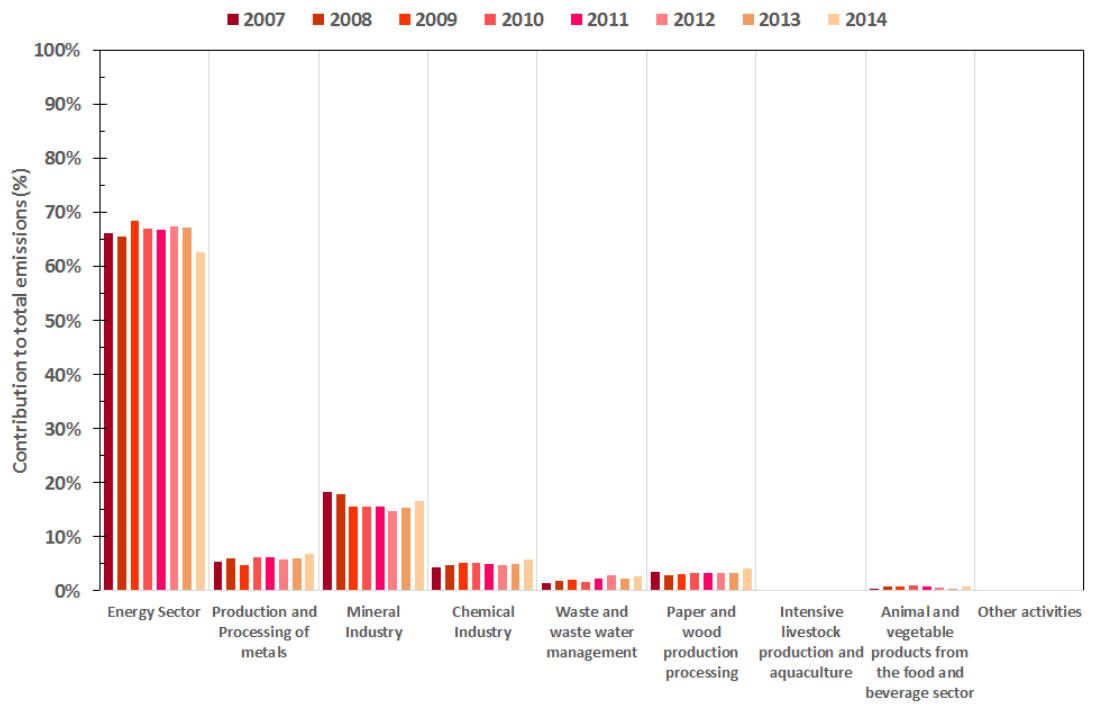


Figure 14 Nitrogen oxides air emissions reported in the E-PRTR database during 2007-2014 for each Annex I sector of activity.

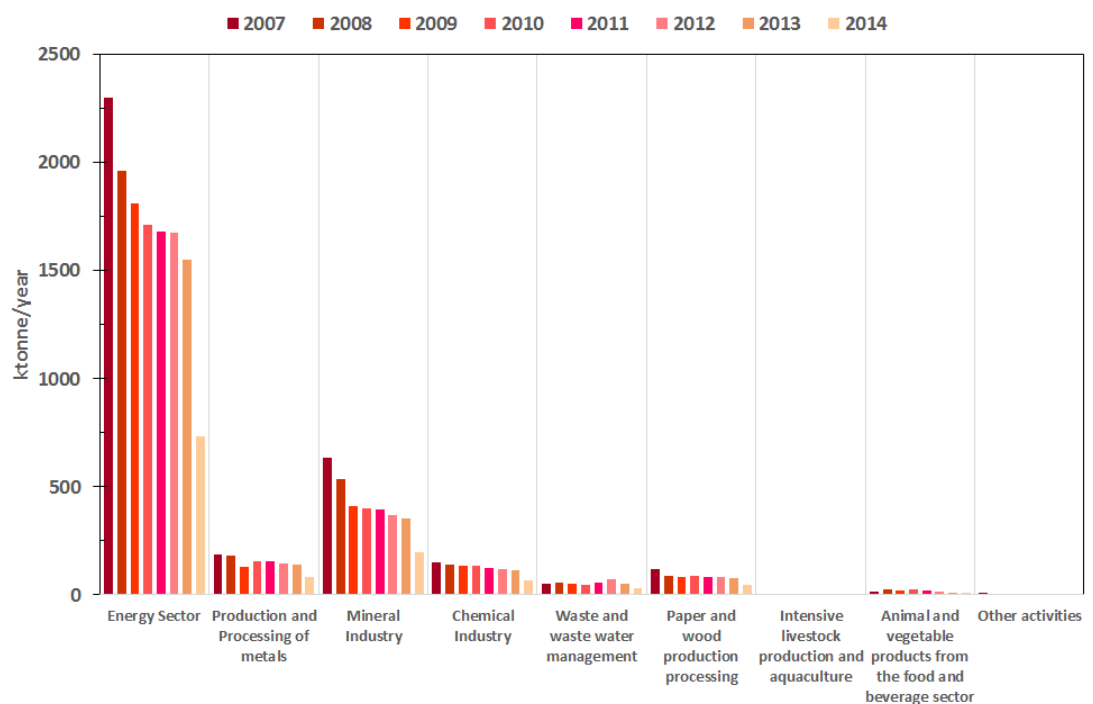
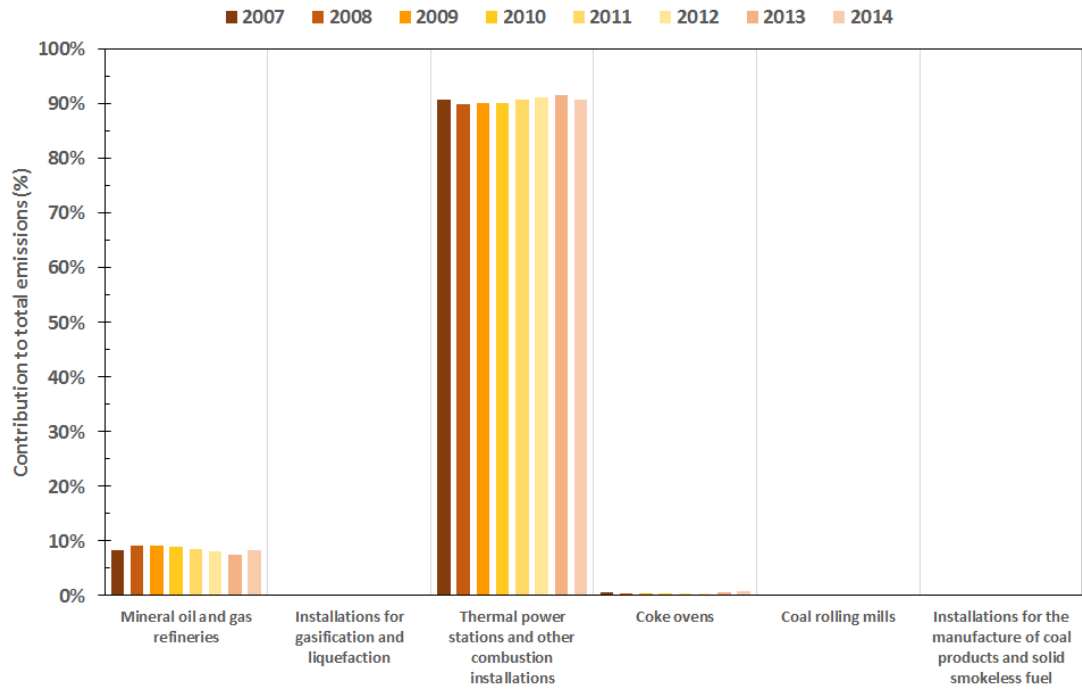


Figure 15 Nitrogen oxides air emissions reported in the E-PRTR database during 2007-2014 - contribution of different energy sector activities.



3.3. NON-METHANE VOLATILE ORGANIC COMPOUNDS (NMVOC)

3.3.1. Emissions from European refineries

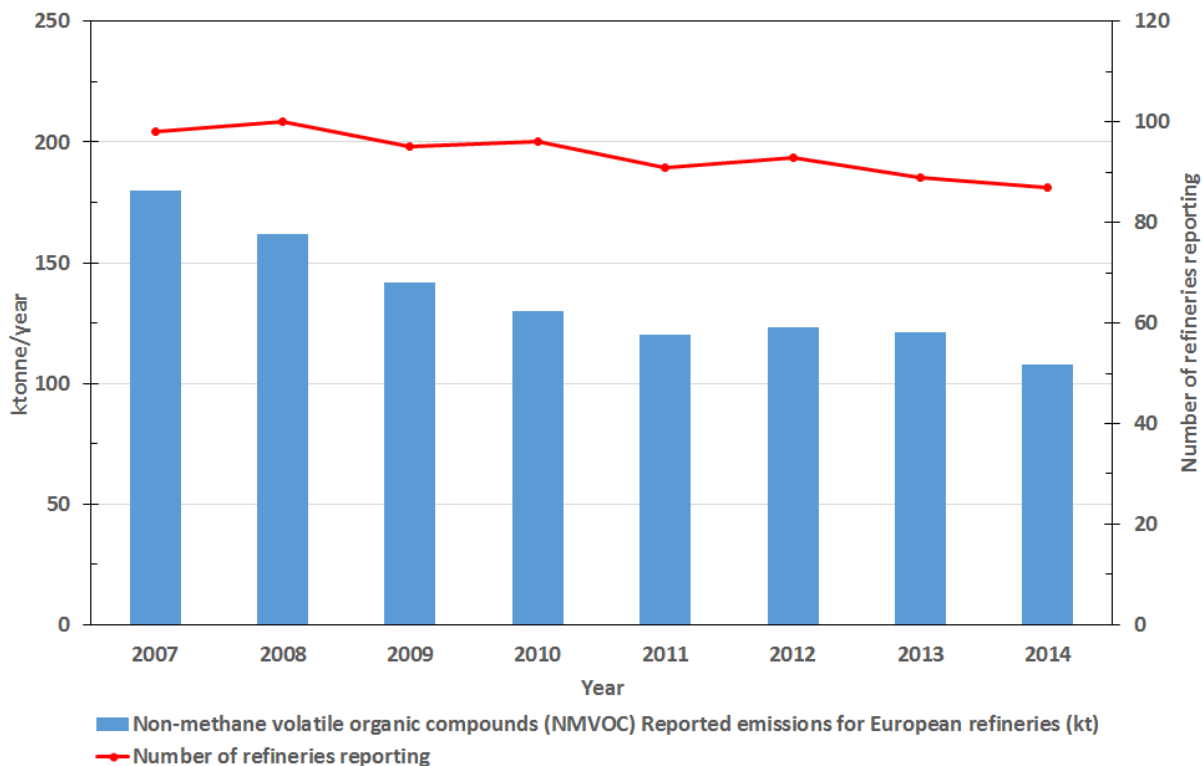
Table 9 summarises the reported emissions of NMVOCs to air from the European refineries. NMVOCs emissions show a year on year reduction from 2007 to 2011, a slight increase in 2012, and decrease from 2013 to 2014.

Figure 16 shows the trend observed for the years 2007 to 2014. The reported emissions in 2014 are 40% lower than those of 2007.

Table 9 NMVOCs emissions to air reported for refineries in the E-PRTR database during 2007-2014.

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|------|------|------|------|------|------|------|------|
| Reported emissions for refineries (kt) | 180 | 162 | 142 | 130 | 120 | 123 | 121 | 108 |
| Total reported emissions for all sectors (kt) | 712 | 599 | 511 | 488 | 462 | 455 | 443 | 451 |
| Refineries contribution to total NMVOCs emissions reported to E-PRTR | 25% | 27% | 28% | 27% | 26% | 27% | 27% | 24% |
| Reported emissions per mass of crude oil transformed in refineries (t/Mt) | 269 | 241 | 229 | 210 | 199 | 204 | 213 | 189 |
| Number of refineries reporting | 98 | 100 | 95 | 96 | 91 | 93 | 89 | 87 |
| Reporting threshold (kt) | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |

Figure 16 Trends of NMVOCs air emissions reported for European refineries, during 2007-2014.



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 17** and **Figure 18**.

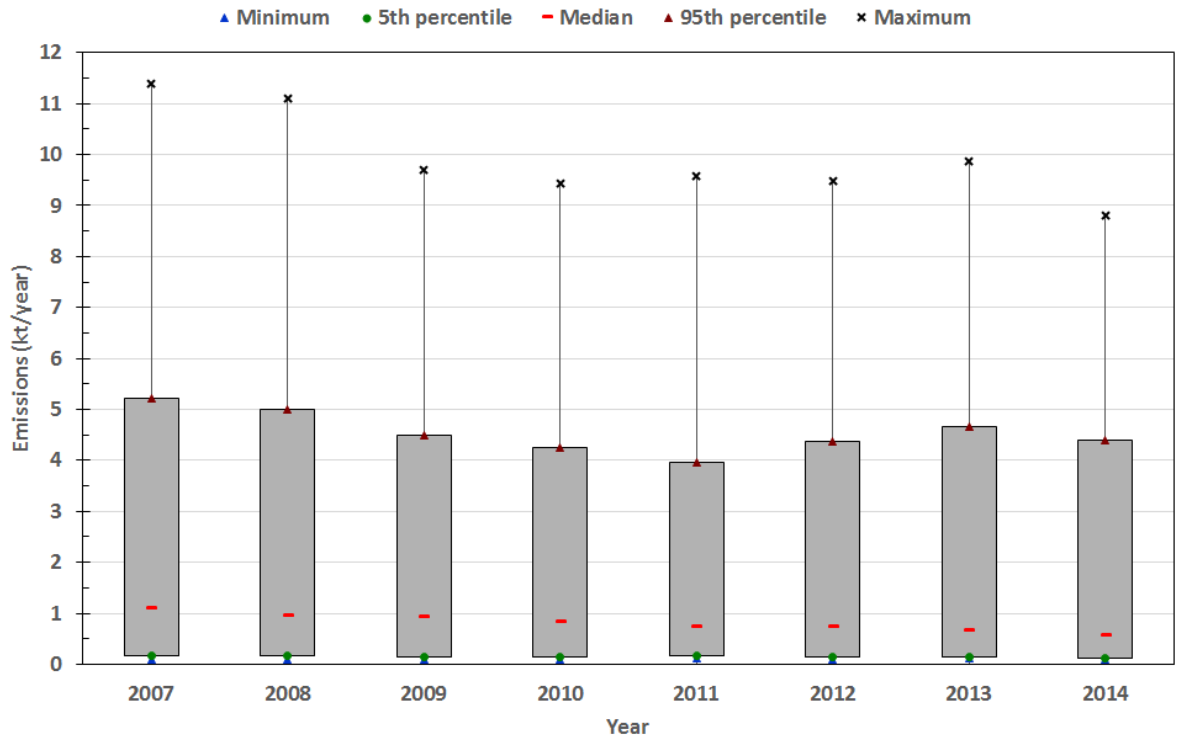
Table 10 Statistical analysis of NMVOCs air emissions [kt/y] for European refineries.

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|-----------------------------|-------|-------|------|------|------|------|------|------|
| Minimum | 0.11 | 0.10 | 0.10 | 0.10 | 0.12 | 0.10 | 0.11 | 0.10 |
| Median | 1.09 | 0.96 | 0.93 | 0.83 | 0.72 | 0.74 | 0.66 | 0.58 |
| Maximum | 11.40 | 11.10 | 9.71 | 9.44 | 9.59 | 9.48 | 9.86 | 8.80 |
| 5 th percentile | 0.16 | 0.16 | 0.15 | 0.15 | 0.16 | 0.13 | 0.15 | 0.13 |
| 25 th percentile | 0.51 | 0.42 | 0.43 | 0.35 | 0.33 | 0.29 | 0.26 | 0.26 |
| 75 th percentile | 2.57 | 2.21 | 2.07 | 1.78 | 1.77 | 1.67 | 1.51 | 1.43 |
| 95 th percentile | 5.22 | 5.00 | 4.49 | 4.26 | 3.97 | 4.36 | 4.67 | 4.39 |
| Upper outlier boundary | 6.69 | 5.81 | 5.35 | 4.65 | 4.64 | 4.43 | 4.00 | 3.77 |
| Number of outliers | 3 | 4 | 3 | 5 | 4 | 5 | 7 | 6 |

Figure 17 Statistical analysis of NMVOCs air emissions for European refineries: 25th and 75th percentiles.



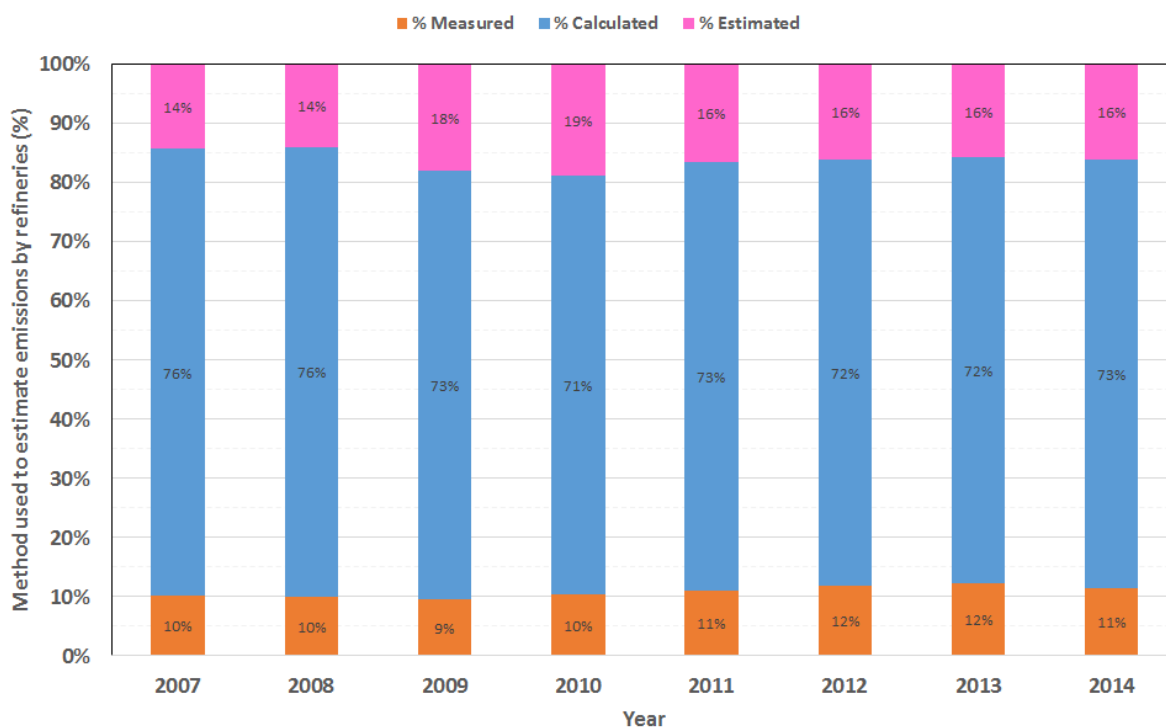
Figure 18 Statistical analysis of NMVOCs air emissions for European refineries: 5th and 95th percentiles.



3.3.3. Methods used to determine the emissions

Figure 19 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 19 Methods used to determine NMVOCs air emissions for European refineries.



3.3.4. Emissions by Sector

Figure 20 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 2014. The NMVOCs emissions reported in the E-PRTR database are coming mainly from the energy sector (around 35-40% of the total reported NMVOCs air emissions to E-PRTR). From 2007 to 2014 the reported NMVOCs emissions from the energy sector have reduced by 133 kt (46%) (**Figure 21**).

The energy sector is divided into six different economic activities. **Figure 22** 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 (68-75%).

Figure 20 Percentage contribution of each Annex I sector of activity to total NMVOC air emissions reported in the E-PRTR database during 2007-2014.

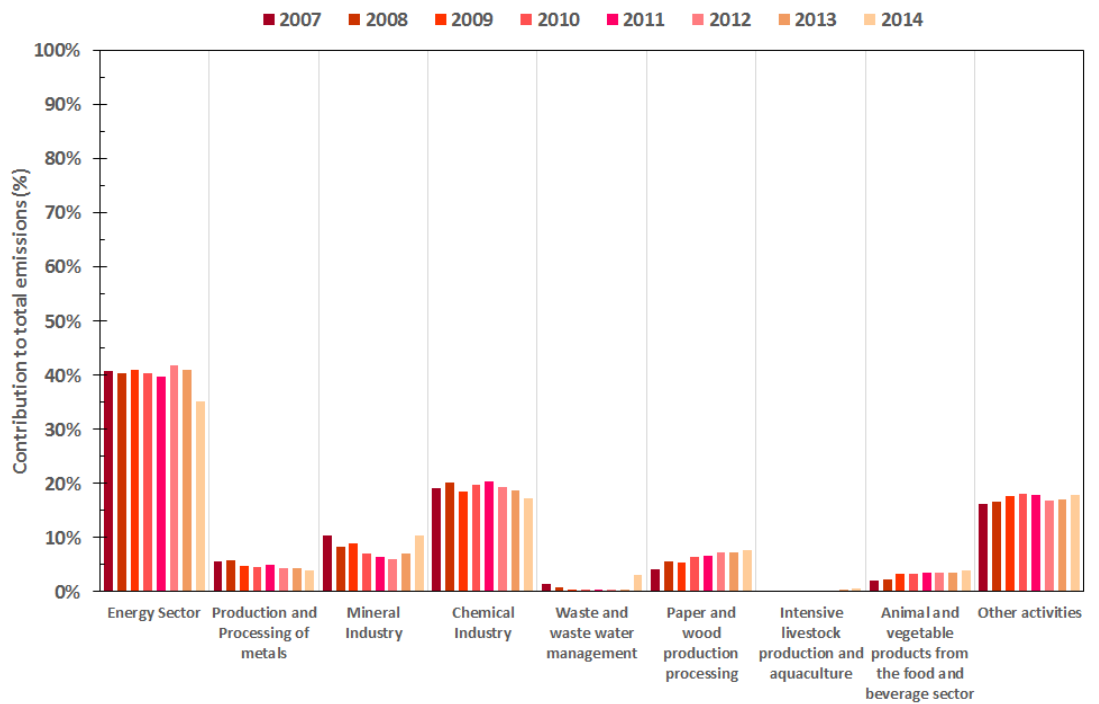


Figure 21 NMVOCs air emissions reported in the E-PRTR database during 2007-2014 for each Annex I sector of activity.

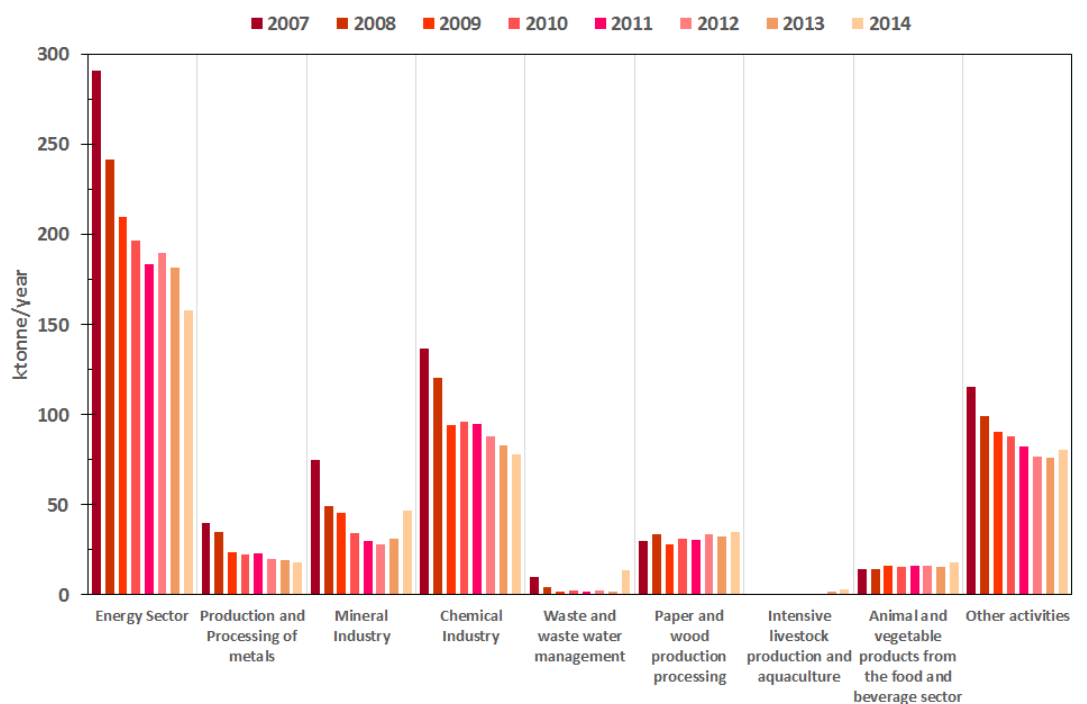
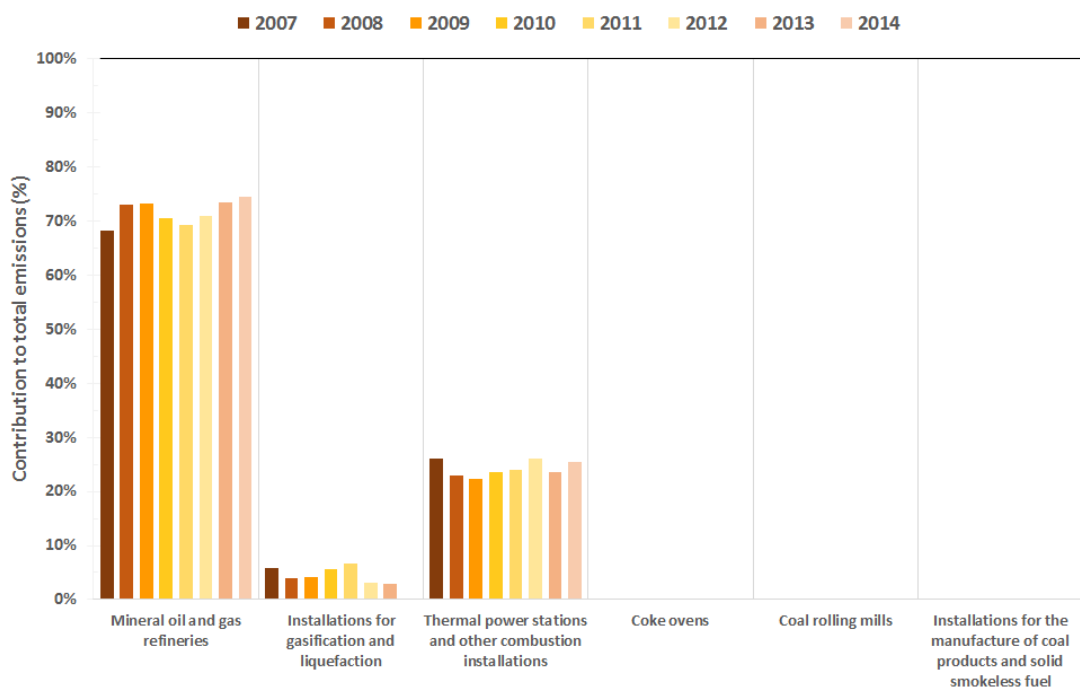


Figure 22 NMVOCs air emissions reported in the E-PRTR database during 2007-2014 - contribution of different energy sector activities.



3.4. BENZENE

3.4.1. Emissions from European refineries

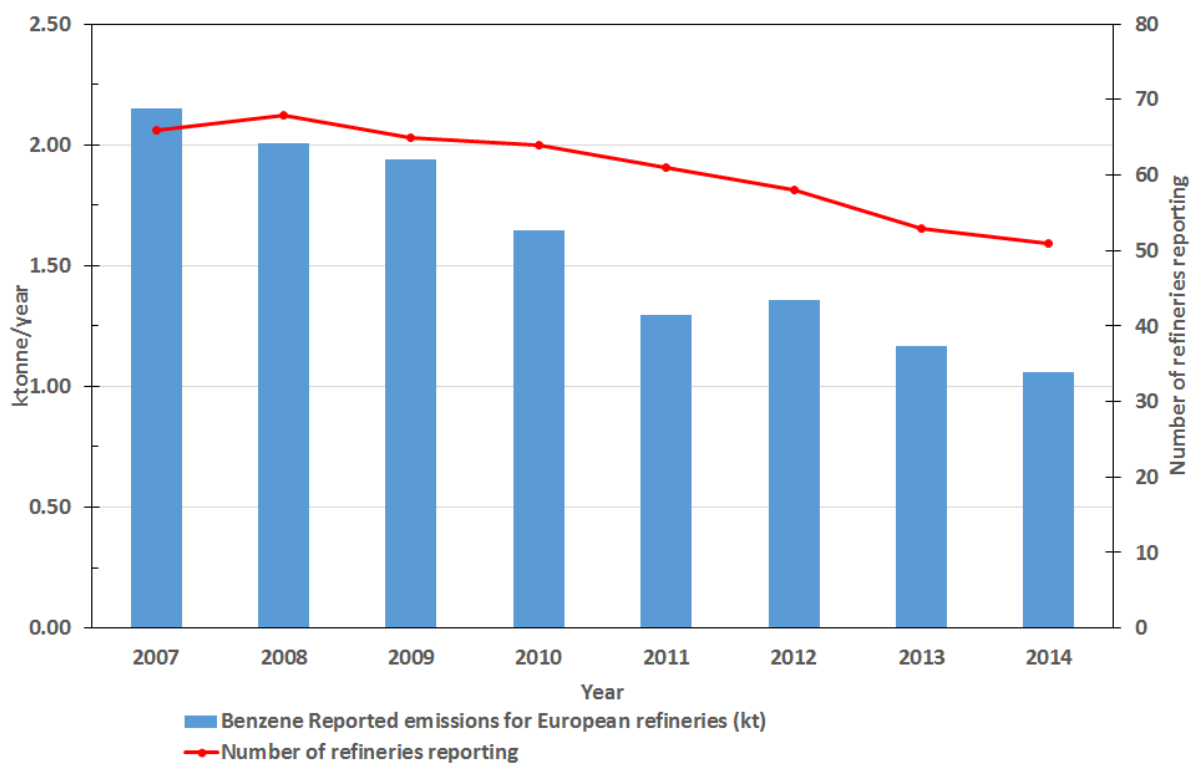
Table 11 summarises the reported emissions of benzene to air from the European refineries. The data show a variable trend to reported benzene air emissions during the period examined. From 2007 to 2011, there has been a decrease in the overall reported benzene emissions from refineries, while benzene emissions in 2012 were slightly higher compared to 2011 (5%). A reduction of benzene air emissions has been observed during 2013 and 2014, compared to the reported 2012 data.

Figure 23 shows the trend observed for the years 2007 to 2014. The reported emissions in 2014 are 51% lower than those of 2007.

Table 11 Benzene emissions to air reported for refineries in the E-PRTR database during 2007-2014.

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|-------|-------|-------|-------|-------|-------|-------|-------|
| Reported emissions for refineries (kt) | 2.15 | 2.01 | 1.94 | 1.65 | 1.30 | 1.36 | 1.17 | 1.06 |
| Total reported emissions for all sectors (kt) | 4.67 | 4.13 | 3.54 | 3.42 | 3.06 | 3.01 | 2.69 | 2.91 |
| Refineries contribution to total benzene emissions reported to E-PRTR | 46% | 49% | 55% | 48% | 42% | 45% | 43% | 36% |
| Reported emissions per mass of crude oil transformed in refineries (t/Mt) | 3.21 | 3.00 | 3.12 | 2.67 | 2.15 | 2.25 | 2.04 | 1.86 |
| Number of refineries reporting | 66 | 68 | 65 | 64 | 61 | 58 | 53 | 51 |
| Reporting threshold (kt) | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |

Figure 23 Trends of benzene air emissions reported for European refineries, during 2007-2014.



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 24** and **Figure 25**.

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

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|-----------------------------|----------|----------|----------|----------|----------|----------|----------|----------|
| Minimum | 1.01E-03 | 1.06E-03 | 1.04E-03 | 1.02E-03 | 1.03E-03 | 1.02E-03 | 1.12E-03 | 1.16E-03 |
| Median | 1.58E-02 | 1.36E-02 | 1.34E-02 | 1.28E-02 | 9.62E-03 | 9.64E-03 | 1.05E-02 | 9.41E-03 |
| Maximum | 3.33E-01 | 3.41E-01 | 3.02E-01 | 2.94E-01 | 2.37E-01 | 2.40E-01 | 2.27E-01 | 2.25E-01 |
| 5 th percentile | 2.14E-03 | 1.35E-03 | 2.20E-03 | 1.44E-03 | 1.19E-03 | 1.55E-03 | 1.56E-03 | 1.50E-03 |
| 25 th percentile | 5.71E-03 | 4.95E-03 | 4.62E-03 | 4.60E-03 | 4.08E-03 | 4.04E-03 | 3.66E-03 | 3.39E-03 |
| 75 th percentile | 3.39E-02 | 2.81E-02 | 2.50E-02 | 2.55E-02 | 2.63E-02 | 2.22E-02 | 2.65E-02 | 2.53E-02 |
| 95 th percentile | 1.07E-01 | 9.40E-02 | 1.19E-01 | 7.69E-02 | 7.33E-02 | 6.73E-02 | 6.56E-02 | 6.89E-02 |
| Upper outlier boundary | 9.01E-02 | 7.43E-02 | 6.58E-02 | 6.74E-02 | 7.07E-02 | 5.86E-02 | 7.22E-02 | 6.90E-02 |
| Number of outliers | 4 | 5 | 7 | 5 | 4 | 5 | 3 | 3 |

Figure 24 Statistical analysis of benzene air emissions for European refineries: 25th and 75th percentiles.

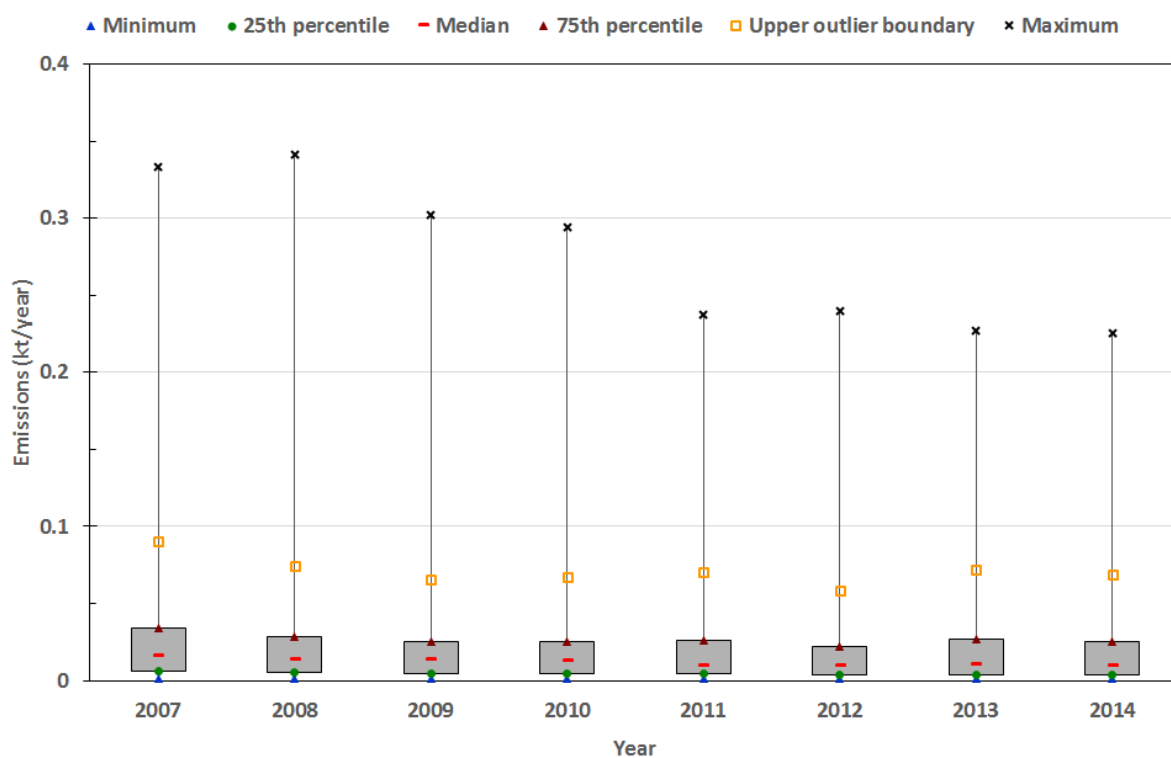
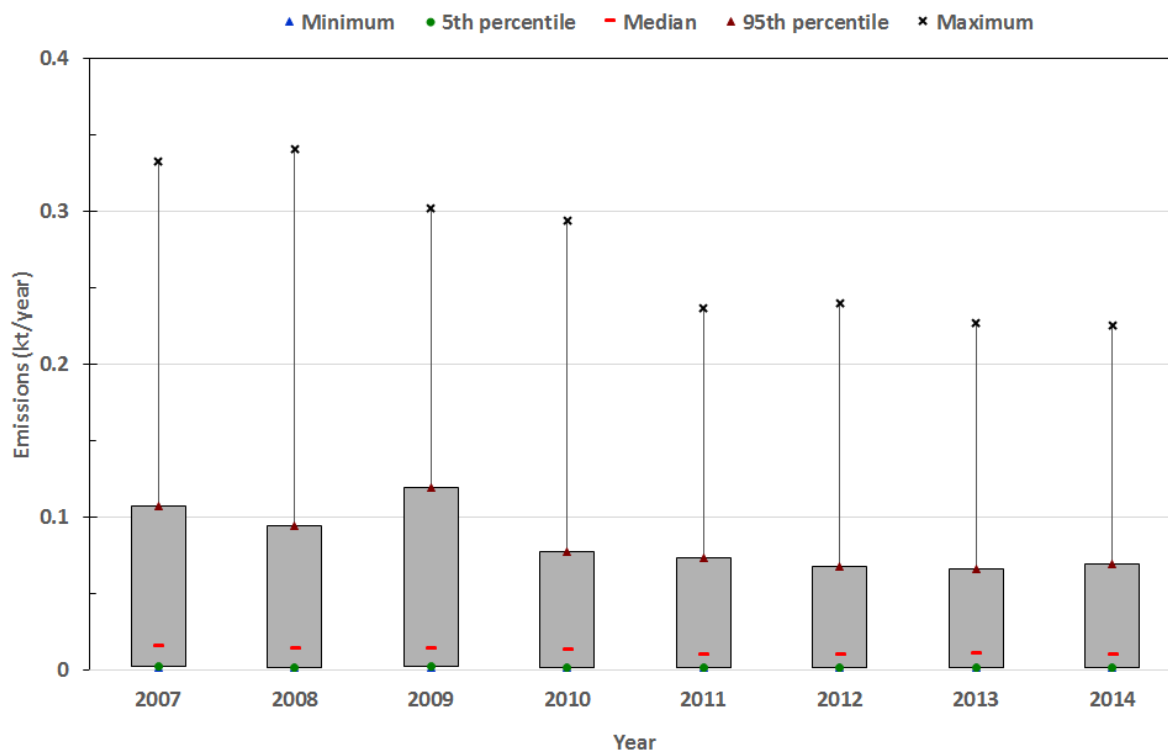


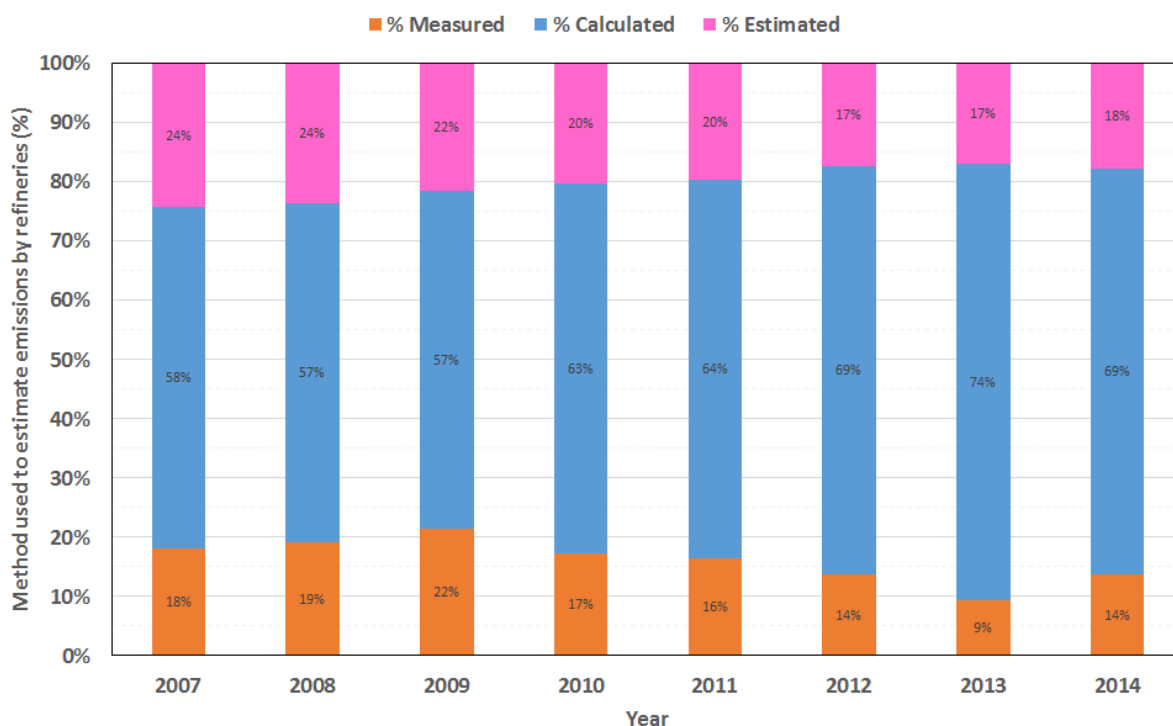
Figure 25 Statistical analysis of benzene air emissions for European refineries: 5th and 95th percentiles.



3.4.3. Methods used to determine the emissions

Figure 26 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% in 2014), with other “non-standardised” estimation methods (as defined in [5]) used elsewhere.

Figure 26 Methods used to determine benzene air emissions for European refineries.



3.4.4. Emissions by Sector

Figure 27 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 2014. The benzene emissions reported in the E-PRTR database are coming mainly from the energy sector (50-65% 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 33% from 2007 to 2011 (0.75 kt) (**Figure 28**). From 2012 to 2014 the reported benzene air emissions from the energy sector show a variable trend. In 2012 benzene air emissions are 10% higher compared to 2011 (0.16 kt), while in 2013 they decrease by 13% (0.22 kt) compared to 2012. Higher benzene air emissions are reported from the energy sector during 2014. Overall, from 2007 to 2014 the reported benzene air emissions from the energy sector have reduced by 19% (0.44 kt).

The energy sector is divided into six different economic activities. **Figure 29** 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 27 Percentage contribution of each Annex I sector of activity to total benzene air emissions reported in the E-PRTR database during 2007-2014.

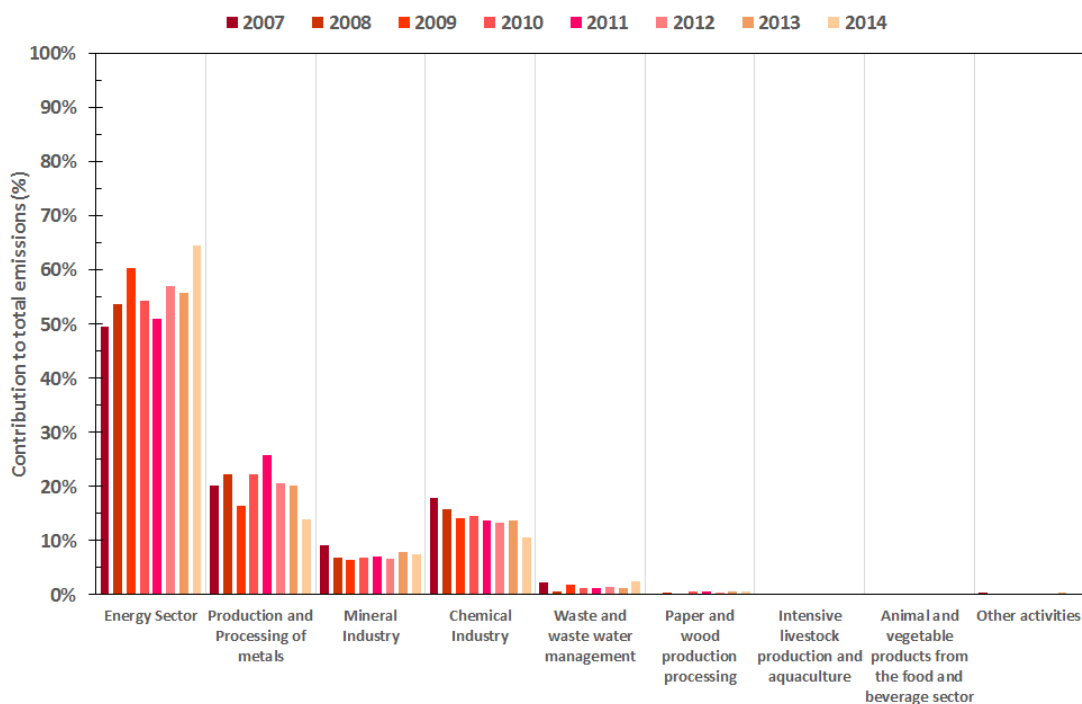


Figure 28 Benzene air emissions reported in the E-PRTR database during 2007-2014 for each Annex I sector of activity.

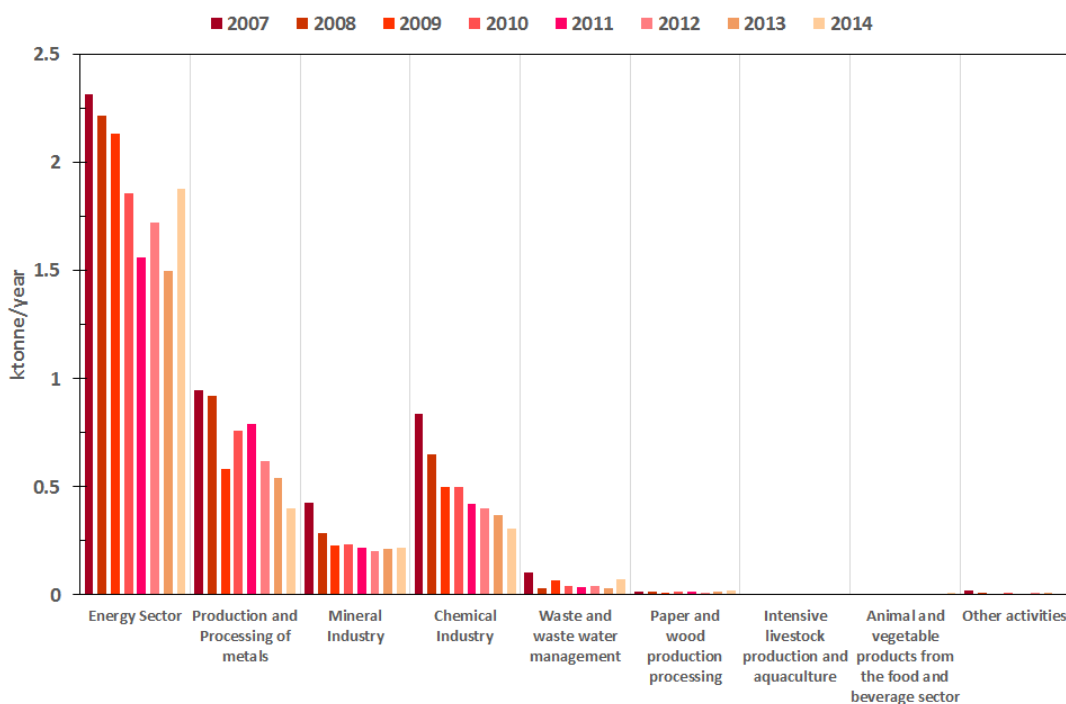
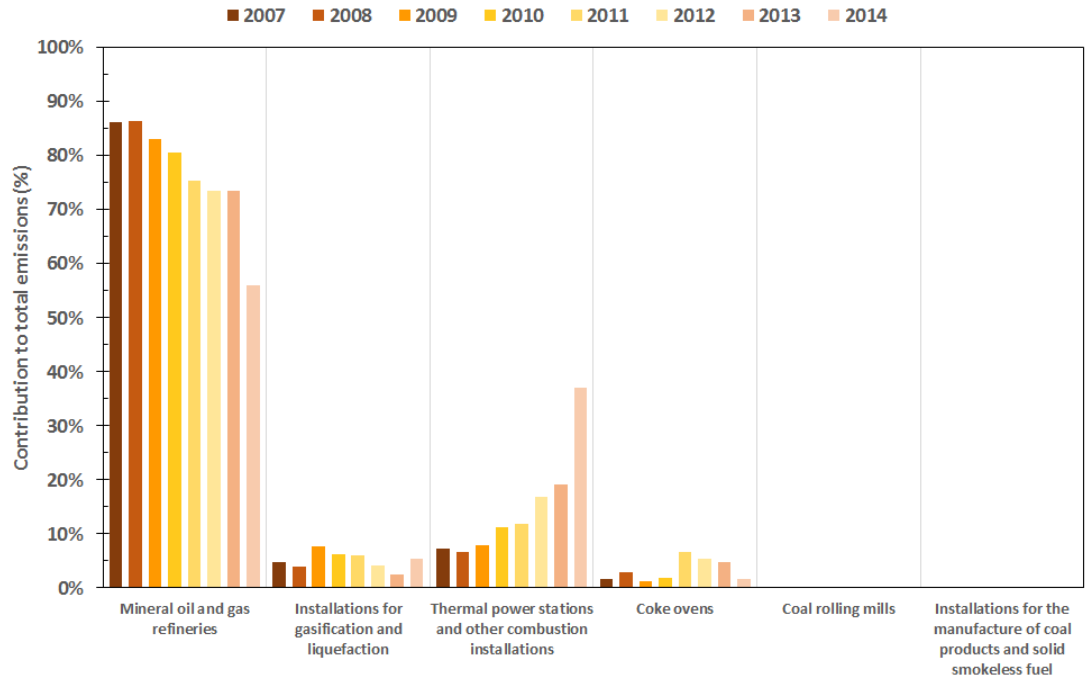


Figure 29 Benzene air emissions reported in the E-PRTR database during 2007-2014 - contribution of different energy sector activities.



3.5. CARBON DIOXIDE (CO₂)

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. E-PRTR also provides reported data on CO₂ emissions due to biomass combustion.

Figure 30 shows the trend observed for the years 2007 to 2014. The reported emissions in 2014 are 21% lower than those in 2007.

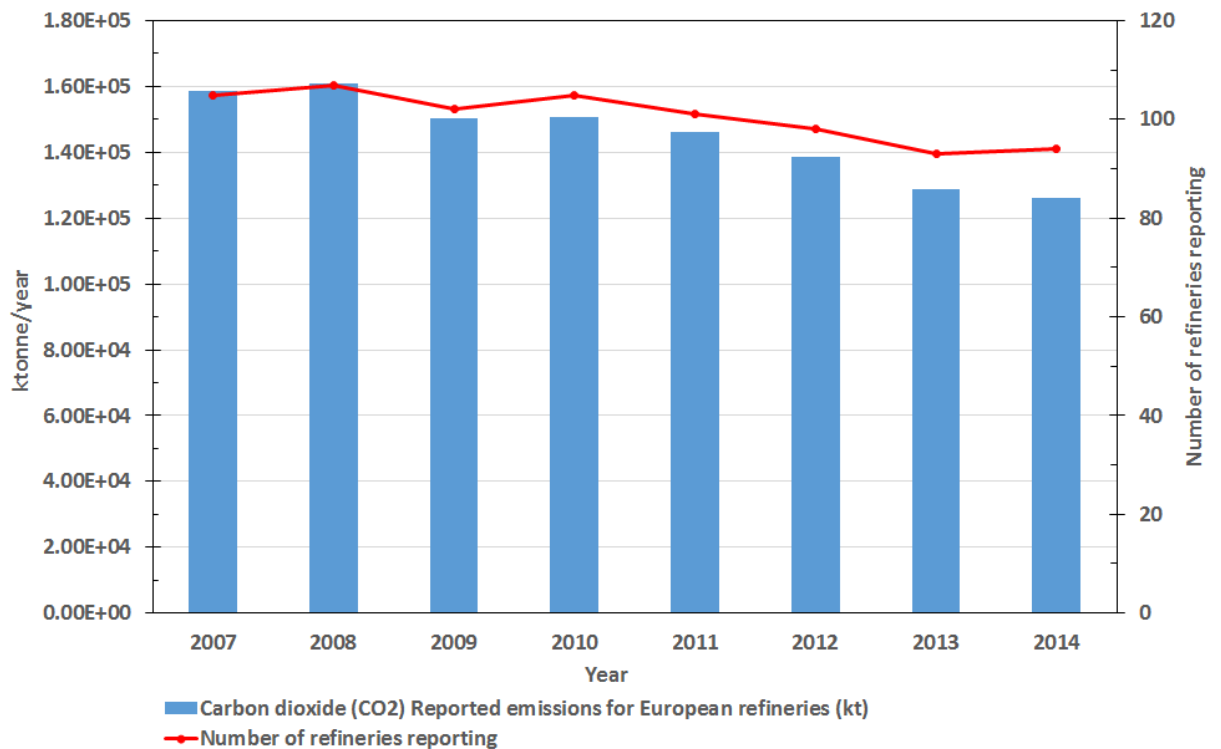
Table 13 Carbon dioxide emissions to air reported for refineries in the E-PRTR database during 2007-2014.

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|----------|-----------|----------|----------|----------|----------|----------|----------|
| Reported emissions for refineries (kt) | 1.59E+05 | 1.61E+05* | 1.50E+05 | 1.51E+05 | 1.46E+05 | 1.39E+05 | 1.29E+05 | 1.26E+05 |
| Total reported emissions for all sectors (kt) | 2.21E+06 | 2.15E+06 | 1.99E+06 | 2.09E+06 | 1.96E+06 | 1.97E+06 | 1.90E+06 | 1.82E+06 |
| Refineries contribution to total CO ₂ emissions reported to E-PRTR | 7% | 7% | 8% | 7% | 7% | 7% | 7% | 7% |
| Reported emissions per mass of crude oil transformed in refineries (t/Mt) | 2.37E+05 | 2.40E+05 | 2.42E+05 | 2.44E+05 | 2.42E+05 | 2.29E+05 | 2.26E+05 | 2.22E+05 |
| Number of refineries reporting | 105 | 107 | 102 | 105 | 101 | 98 | 93 | 94 |
| Reporting threshold (kt) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

* In ConcaWe report 1/13R⁴ the CO₂ emissions for the sector are considered to be 151 Mt, which indicates a difference of 10 Mt with the CO₂ appearing in E-PRTR database after correction for mis-classification. It should be considered that the figure reported in 1/13R excludes CO₂ emissions from integrated petrochemical plants.

⁴ ConcaWe (2013) Oil refining in the EU in 2020, with perspectives to 2030. Report No. 1/13R. Brussels: ConcaWe

Figure 30 Trends of carbon dioxide air emissions reported for European refineries, during 2007-2014.



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 31** and **Figure 32**.

Table 14 Statistical analysis of carbon dioxide air emissions [kt/y] for European refineries.

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|-----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Minimum | 151 | 151 | 146 | 106 | 109 | 112 | 126 | 137 |
| Median | 1.180 | 1.140 | 1.170 | 1.120 | 1.170 | 1.125 | 1.190 | 1.095 |
| Maximum | 6.240 | 6.160 | 6.130 | 6.350 | 6.230 | 6.110 | 5.890 | 5.760 |
| 5 th percentile | 272 | 269 | 307 | 187 | 172 | 238 | 287 | 257 |
| 25 th percentile | 592 | 647 | 632 | 557 | 539 | 534 | 574 | 513 |
| 75 th percentile | 2.040 | 2.035 | 1.968 | 1.930 | 1.970 | 1.970 | 1.940 | 1.903 |
| 95 th percentile | 3862 | 3835 | 3778 | 3660 | 3690 | 3430 | 3156 | 2997 |
| Upper outlier boundary | 4936 | 4811 | 4640 | 4676 | 4832 | 4842 | 4672 | 4682 |
| Number of outliers | 3 | 3 | 2 | 2 | 2 | 2 | 1 | 1 |

Figure 31 Statistical analysis of CO₂ air emissions for European refineries: 25th and 75th percentiles.

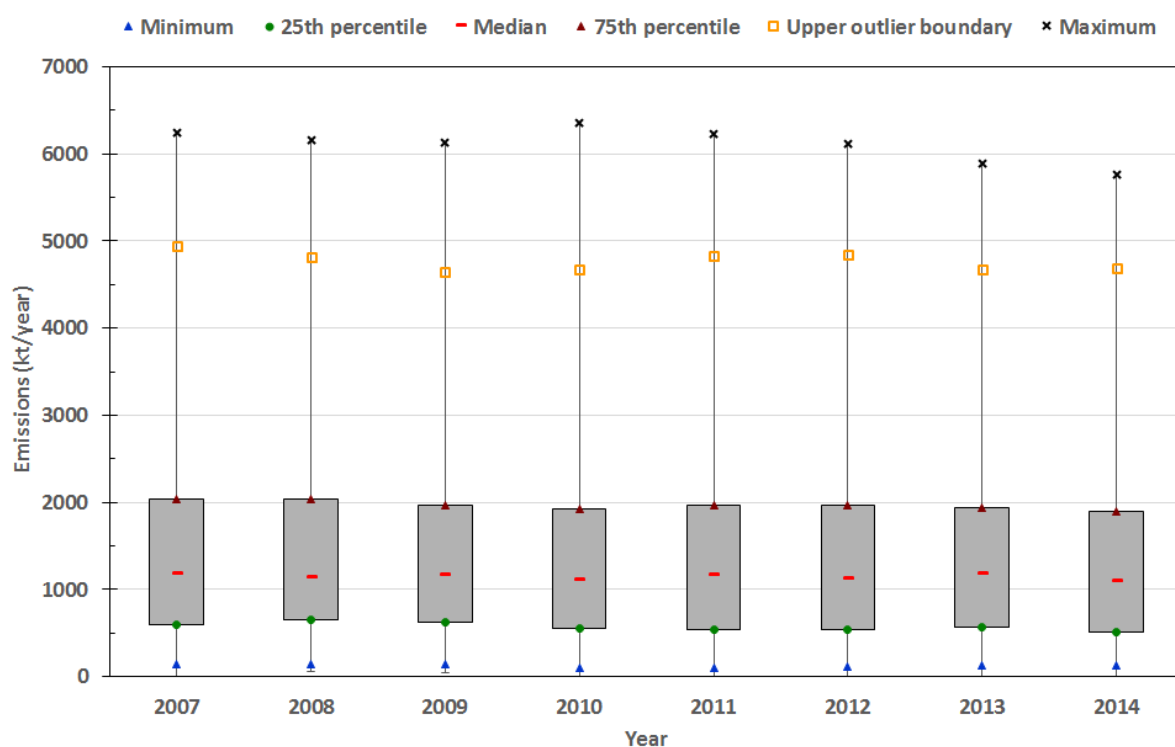
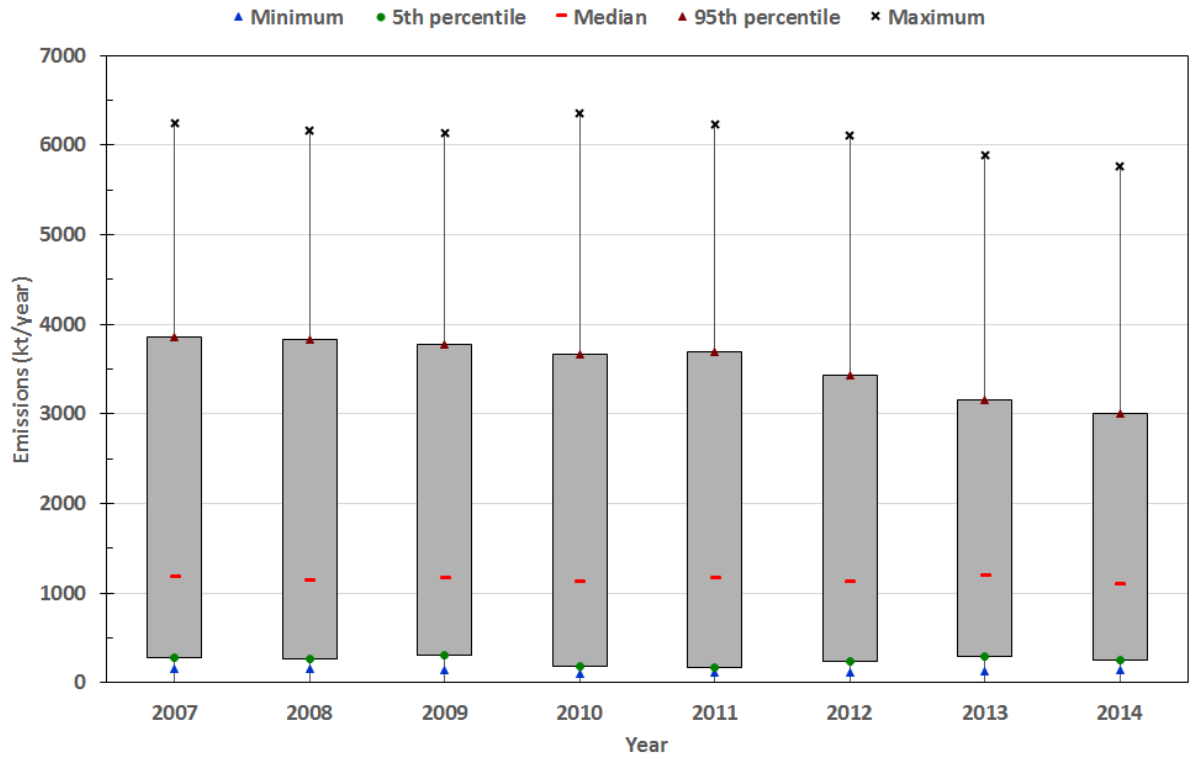


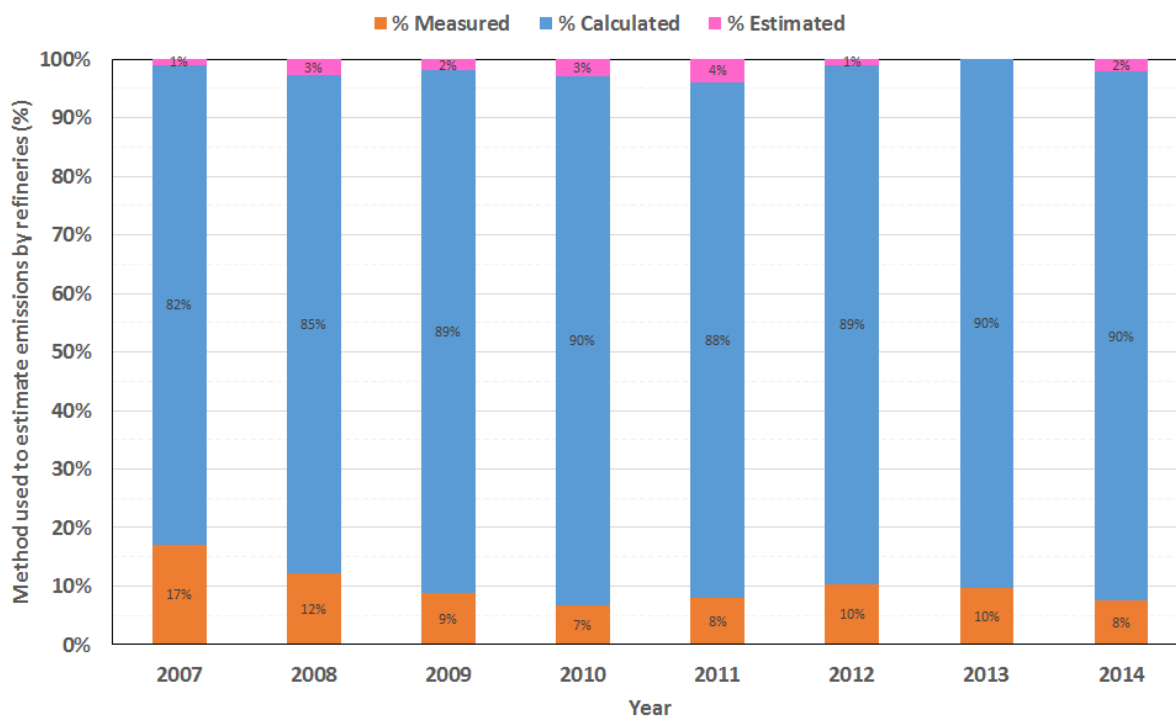
Figure 32 Statistical analysis of CO₂ air emissions for European refineries: 5th and 95th percentiles.



3.5.3. Methods used to determine the emissions

Figure 33 shows the degree to which the three different determination methods (as defined in reference [5]) have been used to estimate carbon dioxide emissions. This shows that approved estimation methodologies (“calculation”) and measurement were used at virtually all refineries.

Figure 33 Methods used to determine carbon dioxide air emissions for European refineries.



3.5.4. Emissions by Sector

Figure 34 illustrates the contribution of those Annex I sectors of activity for which CO₂ air emissions have been reported to E-PRTR in the period 2007 to 2014. The CO₂ emissions reported in the E-PRTR database are coming mainly from the energy sector (approximately 70% of the total reported CO₂ air emissions to E-PRTR). From 2007 to 2014 the reported CO₂ air emissions from the energy sector have decreased by 310.000 kt (20%) (**Figure 35**).

The energy sector is divided into six different economic activities. **Figure 36** shows the contribution of these to the total energy sector reported CO₂ air emissions. It can be seen that thermal power stations and other combustion installations are the major CO₂ contributors to the energy sector (around 90%).

Figure 34 Percentage contribution of each Annex I sector of activity to total carbon dioxide air emissions reported in the E-PRTR database during 2007-2014.

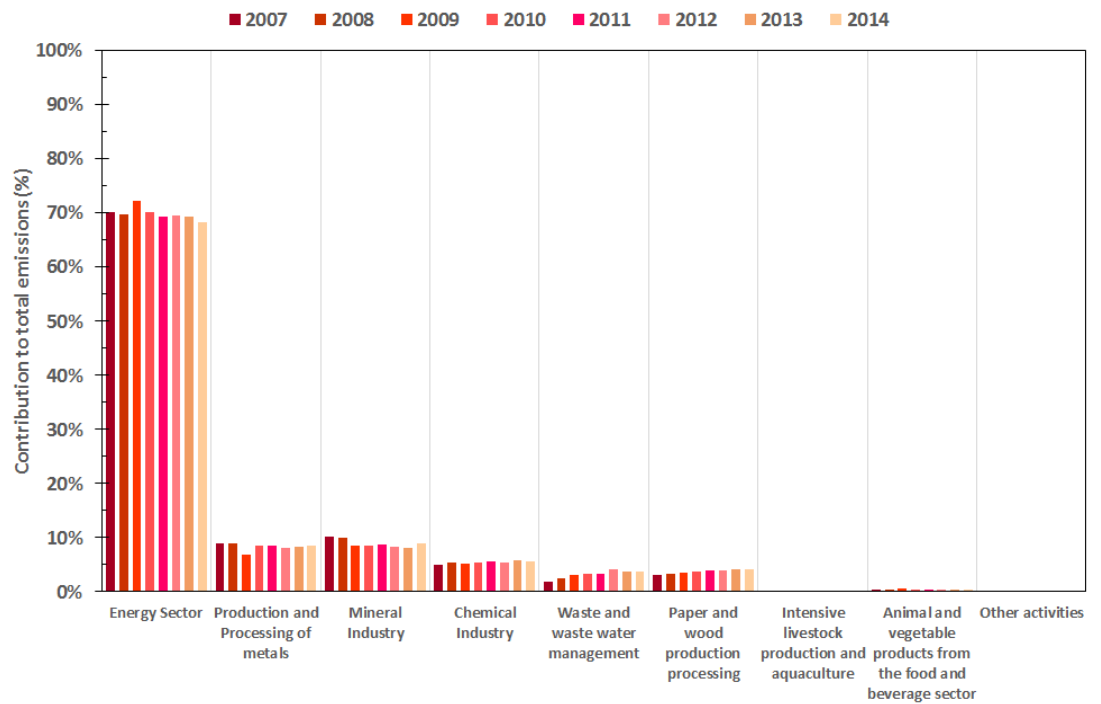


Figure 35 Carbon dioxide air emissions reported in the E-PRTR database during 2007-2014 for each Annex I sector of activity.

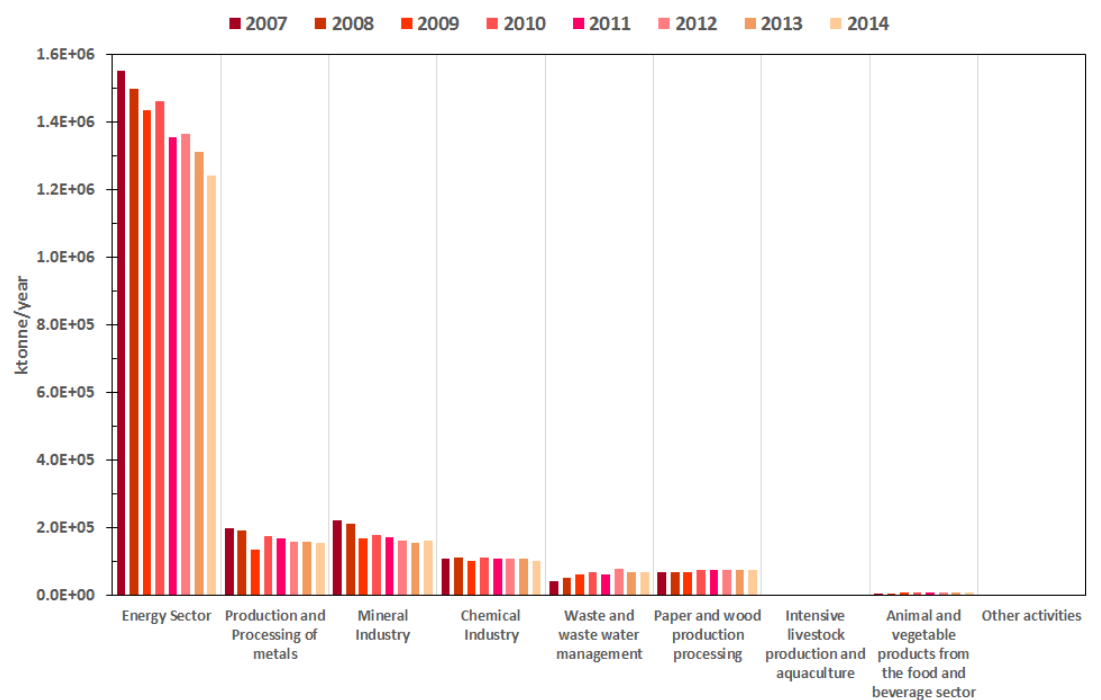
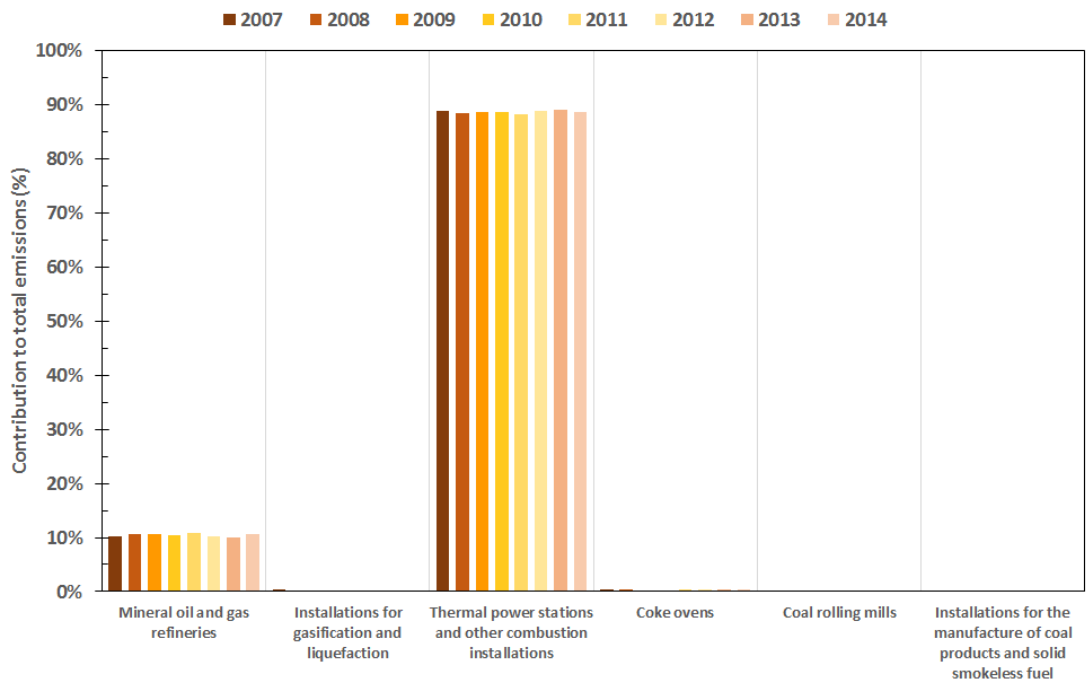


Figure 36 Carbon dioxide air emissions reported in the E-PRTR database during 2007-2014 - contribution of different energy sector activities.



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

4.1. GENERAL

Table 15 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 15 Number of installations submitting air emissions data classified as Annex I Code 1.(a) or NACE Code 19.20 facilities, being although non-refineries.

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|------|------|------|------|------|------|------|------|
| Number of installations reported as Annex I code 1.(a): "Mineral oil and gas refineries", but they are not refineries. | 22 | 26 | 29 | 25 | 24 | 27 | 35 | 33 |
| 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 | 15 |

4.2. CONTRIBUTION OF NON-REFINING INSTALLATIONS TO EMISSION INVENTORIES

Table 16 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 – 2014).

Table 16 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 (2007-2014).

| Pollutant | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|-----------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Carbon monoxide (CO) | 16.2% | 16.7% | 25.5% | 0% | 0% | 0% | 0% | 0% |
| Hydro-chlorofluorocarbons (HCFCs) | 0% | 0% | 41.6% | 60.1% | 91.2% | 67.3% | 91.9% | 78.2% |
| Hydro-fluorocarbons (HFCs) | 94.6% | 57.7% | 29.5% | 0% | 0% | 0% | 0% | 0% |
| Methane (CH ₄) | 54.4% | 60.3% | 48.8% | 54% | 56.2% | 60.4% | 58.3% | 57.5% |
| NMVOCs | 9.4% | 8.3% | 7.8% | 6.4% | 5.8% | 8.7% | 9.2% | 8.6% |

In addition, **Table 17** 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 – 2014).

Table 17 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 (2007-2014).

| Pollutant | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|--|-------|-------|--------|-------|-------|--------|-------|-------|
| Benzene | 0% | 0% | 0% | 0% | 0% | 0% | 5.4% | 11.2% |
| Carbon monoxide (CO) | 13.4% | 18.5% | 21.0% | 26.8% | 21.9% | 29.5% | 44.2% | 50.5% |
| Hydro-chlorofluorocarbons (HCFCs) | 22.2% | 8.1% | 0% | 40.3% | 85.5% | 0% | 0% | 0.15% |
| Methane (CH ₄) | 5.7% | 10.0% | 8.2% | 9.9% | 17.1% | 22.9% | 19.2% | 19.4% |
| Naphthalene | 24.3% | 43.3% | 100.0% | 13.7% | 33.2% | 100.0% | 29.8% | 37.3% |
| Particulate matter (PM ₁₀) | 0% | 0% | 0% | 6.7% | 0% | 0% | 0% | 0% |

5. DISCUSSION

This report provides a review of the emissions of air pollutants for oil refineries located in 25 European countries submitted to the European Pollutant Release and Transfer Register (E-PRTR) database for the years 2007 – 2014. Based on the E-PRTR inventory there were 122 refineries that reported air emissions in 2007. In the 2014 E-PRTR inventory, air emissions data for 105 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 of the emissions of the five pollutants reported for the majority of oil refineries over the period 2007 to 2014. These pollutants are SO_x, NO_x, NMVOCs, CO₂ and benzene.

The analysis indicates that the reported air emissions from refineries, for each of the pollutants (SO_x, NO_x, NMVOCs, benzene, CO₂), show a clear downward trend. The percentage emissions reductions between 2007 and 2014 are: SO_x 63%, NO_x 44%, NMVOCs 40%, benzene 51%, and CO₂ 21%.

It is reported that the emissions data for SO_x, NO_x and CO₂ 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 13%-20% of the refineries use “non-standardised” estimation methods to determine NMVOCs air emissions, while for benzene emissions “non-standardised” methods are used by approximately 17%-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 15% over the same eight year period (2007-2014). 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 2014 for the five pollutants are shown in **Table 18**.

Table 18 Variations in reported air emissions in t/Mt crude processed between 2007 and 2014.

| Pollutant | Reported air emissions for oil refineries t/Mt of crude processed | | Reduction % |
|-----------------|--|---------|----------------|
| | 2007 | 2014 | |
| SO _x | 859 | 371 | 57 |
| NO _x | 290 | 191 | 34 |
| NMVOCs | 269 | 189 | 30 |
| Benzene | 3.21 | 1.86 | 42 |
| CO ₂ | 237,000 | 222,000 | 6.5 |

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 in most of the pollutants (SO_x, NO_x, NMVOCs, and CO₂) the refining contributions to these inventories has been relatively stable. For benzene inventory, a significant reduction in the contribution by the refining sector has been reported since 2007. **Table 19** provides an indication of the oil refining percentage contribution to the E-PRTR inventories of the five pollutants in both 2007 and 2014.

Table 19 Refining contribution to E-PRTR inventories: 2007 and 2014.

| Pollutant | Refining contribution to E-PRTR inventory % | |
|-----------------|---|------|
| | 2007 | 2014 |
| SO _x | 10 | 9 |
| NO _x | 6 | 5 |
| NMVOCs | 25 | 24 |
| Benzene | 46 | 36 |
| CO ₂ | 7 | 7 |

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 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 |
| NMVO | Non-methane Volatile Organic Compound |
| NO _x | Oxides of nitrogen |
| NO ₂ | Nitrogen dioxide |
| SO _x | Oxides of Sulphur |
| SO ₂ | Sulphur dioxide |
| UOB | Upper Outliers Boundary |

7. REFERENCES

1. ConcaWe (2015) Air emissions from the refining sector. Analysis of E-PRTR data 2007-2011. Report No 2/15. Brussels: ConcaWe
2. ConcaWe (2017) Air pollutant emission estimation methods for E-PRTR reporting by refineries. Report No. 4/17. Brussels: ConcaWe
3. EEA (2015) Eurostat: Supply, transformation, consumption - oil - annual data. Copenhagen: European Environment Agency <http://www.eea.europa.eu/data-and-maps/data/external/supply-transformation-consumption-oil-annual-data>
4. EU (2001) Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants. Official Journal of the European Communities No. L309, 27.11.2001
5. EU (2006) Guidance document for the implementation of the European PRTR. Brussels: European Commission
6. EU (2006) Regulation (EC) No. 166/2006 of the European Parliament and of the Council of 18 January 2006 concerning the establishment of a European Pollutant Release and Transfer Register and amending Council Directives 91/689/EEC and 96/61/EC. Official Journal of the European Union No. L33, 04.02.2006
7. EU (2006) Regulation (EC) No. 1893/2006 of the European Parliament and of the Council of 20 December 2006 establishing the statistical classification of economic activities NACE Revision 2 and amending Council Regulation (EEC) No. 3037/90 as well as certain EC Regulations on specific statistical domains. Official Journal of the European Union No. L393, 30.12.2006

APPENDIX 1 CRUDE OIL TRANSFORMATION INPUT IN REFINERIES

Table 20 Annual data of crude oil transformation input in refineries [thousands of tonnes] [3].

| COUNTRY | YEAR | | | | | | | |
|----------------|----------------|----------------|----------------|----------------|--------------------|----------------|----------------|----------------|
| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
| Austria | 8,548 | 8,666 | 8,306 | 7,749 | 8,298 | 8,349 | 8,566 | 8,435 |
| Belgium | 32,963 | 33,725 | 31,324 | 33,283 | 29,777 | 31,652 | 27,634 | 32,123 |
| Bulgaria | 7,096 | 7,146 | 6,247 | 5,475 | 5,083 | 5,894 | 5,622 | 5,154 |
| Czech Republic | 7,394 | 8,249 | 7,376 | 7,901 | 7,098 | 7,247 | 6,664 | 7,496 |
| Denmark | 7,798 | 7,782 | 7,805 | 7,246 | 6,811 | 7,628 | 7,173 | 6,910 |
| Finland | 10,844 | 11,097 | 10,940 | 10,511 | 11,212 | 10,759 | 11,296 | 11,220 |
| France | 82,350 | 83,667 | 72,131 | 65,424 | 65,401 | 56,803 | 55,644 | 54,566 |
| Germany | 109,395 | 107,427 | 100,903 | 95,388 | 93,439 | 94,937 | 92,467 | 91,272 |
| Greece | 19,169 | 17,957 | 17,210 | 19,575 | 16,490 | 20,477 | 19,891 | 20,695 |
| Hungary | 7,087 | 6,967 | 6,324 | 6,389 | 6,596 | 6,097 | 5,969 | 6,507 |
| Ireland | 3,389 | 3,272 | 2,812 | 2,905 | 2,949 | 3,068 | 2,838 | 2,752 |
| Italy | 92,770 | 86,944 | 80,348 | 83,284 | 78,158 | 73,639 | 62,685 | 59,645 |
| Lithuania | 4,742 | 9,241 | 8,407 | 8,985 | 9,007 | 8,533 | 9,010 | 7,497 |
| Netherlands | 49,875 | 50,296 | 48,122 | 51,842 | 50,263 | 50,347 | 47,707 | 49,779 |
| Norway | 15,207 | 13,915 | 13,907 | 12,895 | 14,374 | 14,338 | 14,518 | 13,662 |
| Poland | 20,113 | 20,804 | 20,304 | 22,843 | 24,001 | 25,153 | 24,302 | 24,196 |
| Portugal | 12,314 | 12,046 | 10,406 | 11,297 | 10,275 | 11,054 | 11,912 | 10,792 |
| Romania | 13,006 | 12,981 | 11,210 | 10,050 | 9,675 | 9,101 | 9,410 | 10,455 |
| Serbia | 3,249 | 3,164 | 2,880 | 2,857 | 2,359 | 2,143 | 2,748 | 2,614 |
| Slovakia | 5,955 | 5,847 | 5,700 | 5,453 | 5,991 | 5,399 | 5,791 | 5,220 |
| Spain | 57,704 | 58,610 | 52,651 | 52,794 | 52,316 | 59,233 | 58,142 | 59,022 |
| Sweden | 18,363 | 20,663 | 19,638 | 20,226 | 18,645 | 20,816 | 16,530 | 18,878 |
| Switzerland | 4,674 | 5,021 | 4,748 | 4,488 | 4,733 ² | 4,733 | 4,733 | 4,733 |
| United Kingdom | 75,707 | 75,844 | 70,716 | 68,711 | 70,691 | 66,811 | 59,026 | 55,342 |
| TOTALS | 669,712 | 671,331 | 620,415 | 617,571 | 603,642 | 604,211 | 570,278 | 568,965 |

¹ No data for Switzerland for 2011-2014. Transformation input for this period determined from the average of the previous four years.

Concawe
Boulevard du Souverain 165
B-1160 Brussels
Belgium

Tel: +32-2-566 91 60
Fax: +32-2-566 91 81
e-mail: info@concaWe.org
website: <http://www.concaWe.org>

