SoER 2019

Air Quality

Update of State of the Environment Report 2018

NCESD

NATIONAL CENTRE for the ENVIRONMENT & Sustainable Development

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Foreword

The National Center of Environment and Sustainable Development (NCESD) was established in 2000 with the aim to contribute to the integration of the environmental dimension into broader development policy, in individual sectors and in strategic planning, providing an appropriate know-how and objective information.

According to the Presidential Decree 325/2000 (A '266)) concerning the establishment of NCESD, and in particular point (e) of paragraph 2 of Article 3, it is provided that the NCESD “shall draw up an annual report evaluating the environmental status of the country and undertaking assessments of the objectives, directions and measures of the actual environmental policy.”

In November 2018, NCSD presented the 2018 State of the Environment Report (SoER 2018, https://ekpaa.ypeka.gr/wp-content/uploads/2019/10/181019_Book-YPEKA_LOW.pdf) the first after 2013 (covering the period 2008-2011), being the fourth overall State of the Environment Report of Greece. The SoER 2018 is a comprehensive overview of the developments and challenges that face key areas of the environment and aims to provide to citizens and the State with detailed information as well as to show the connection with the corresponding European Environment Agency's report. For the elaboration of the Report, NCESD collaborated with academic institutions, research centers and technical companies. The SoER 2018 includes detailed information on the state of the environment in Greece in the areas of climate change, air quality, noise, nature, water, waste and horizontal environmental issues, thus providing to all interested stakeholders with an objective database and useful information.

The current update of the SoER 2018 in the field of Atmospheric Environment was based on the most recent data available and focuses only on issues of atmospheric environment for which there are more recent official data compared to SoER 2018. The aim of the update is to provide an objective basis for information as well as to contribute to the public dialogue on guidelines and policy measures in the field of atmospheric environment with a view to a sustainable future.

The Project Group for the update of the SoER 2018 in the field of Atmospheric Environment consisted of Al. Adamopoulos, P. Varelidis and K. Korizi.

We would like to thank the Directorate of Atmospheric Quality and Climate Change of the Ministry of Environment for providing the required data.

Petros Varelidis — Zoi Vrontisi

Executive Director of NCESD — President of NCESD

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Annual variation of gas emissions

The environmental indicators set by the European Environment Office to assess the variation of gas emissions in Greece are a useful tool to monitor the progress made towards achieving the goals set by the Directive (EU) 2016 / 2284 (National Emission Ceilings Directive - NEC) concerning the reduction of national emissions of certain air pollutants as this has been transferred to the national law by CMD 174111/525/2017.

The Directive (EU) 2016/2284 replaces 2001/81/EU in the context of revising the regime of maximum limits of national emissions, with a view to harmonize with the international commitments of the European Union and its Member States (in relation to the revised protocol of Gothenburg) and limiting the impact of air pollution on health. The Directive set out binding rates on the reduction of air emissions for the years between 2020-2029 and for the years from 2030 onwards, with reference to 2005. Air pollutants now include fine suspended $PM_{2.5}$ particles.

As part of monitoring and evaluating the gas emissions, the variation of the situation for the period 1990-2017 is recorded, as well as the trends based on the reference year 2005 as part of compliance with the objectives to reduce national gas emissions.

The data for national gas emissions come from the official national report under the new NEC Directive (funded by NCESD[1]) with the last reference year 2017, being available in the central online repository of the European Environment Information and Observation Network (EIONET, 2019). The data on methane (CH_4) emissions come from the country's official report to the United Nations Framework Convention on Climate Change (UNFCCC, 2019). The data on electricity and heat generation come from the European Statistical System database (category "Transformation output - Conventional Thermal Power Stations").

The emissions and the corresponding values of the indices are mentioned overall and separately for the following areas of activity (classification following NFR / CLRTAP):
- energy production and distribution
- energy use in industry
- industrial processes
- road transport
- non-road transport
- commercial-residential uses
- use of solvents
- agricultural uses
- waste management.

[1] https://ekpaa.ypeka.gr/atmosfairiko-perivallon/yposthriktikes-draseis-gia-apografes/

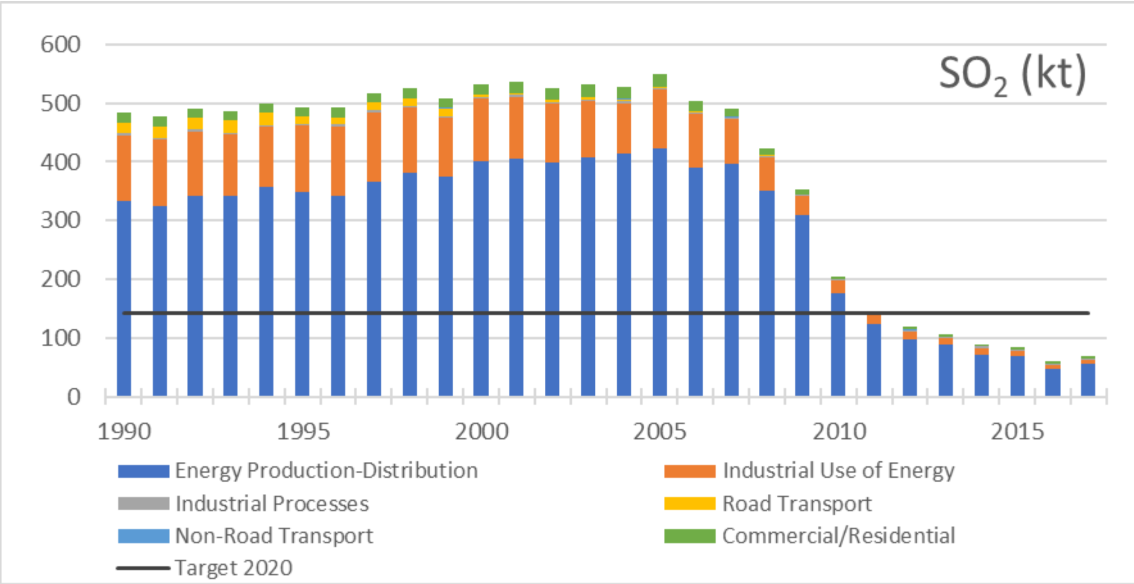
1. Emissions of primary air pollutants

1.1 Sulfur dioxide emissions

The EEA APE 001 index tracks the annual variation of anthropogenic sulfur oxide emissions from 1990 onwards (Graph 1), which illustrates the contribution of the activity sectors. 2017 emissions (69.2 kt) decrease of about 85.7% compared to 1990, mainly from 2007 onwards. Already since 2007, emissions are recorder to be lower than the national target of the Directive 2001/81/EU.

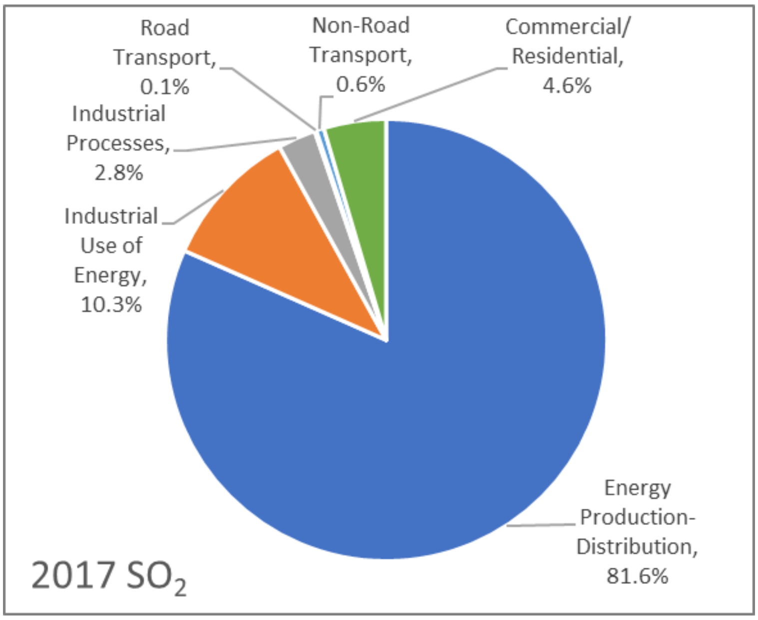
The decrease recorded for 2017 compared to the reference year 2005, which is the base year for the projected future reductions under Directive (EU) 2016/2284 (new NEC Direction) on national emission ceilings, is 87,4%. According to the new NEC Direction, the country should reduce its SO_2 emissions by 74% by 2005 until 2020 and by 88% for the years after 2030. As a result, the country has already achieved its 2020 target and is on track to reach the expected national target for 2030.

Graph 1: Annual evolution of sulfur dioxide (SO_2) emissions in Greece



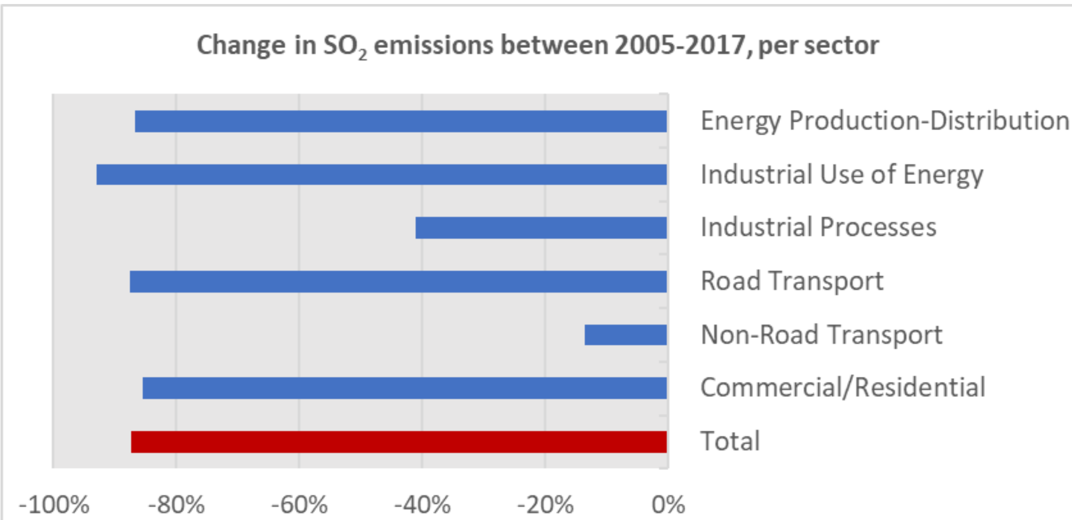
The contribution of the various activity sectors in the emissions during 2017 is presented in Graph 2. The sector of energy production and distribution (power generation) presents the largest contribution, generating the 4/5 of the emissions (81.6%), while the contribution of the industrial sector is also significant, with a combined contribution from energy use and industrial processes, corresponding to about 1/8 of the emissions. The minimum contribution of the transport sector's emissions is pointed out, estimated on the basis of the amount of fuel sold, with their contribution in the total emissions not exceeding 1%.

Graph 2: Participation of the different activity sectors in national sulfur dioxide (SO_2) emissions in 2017

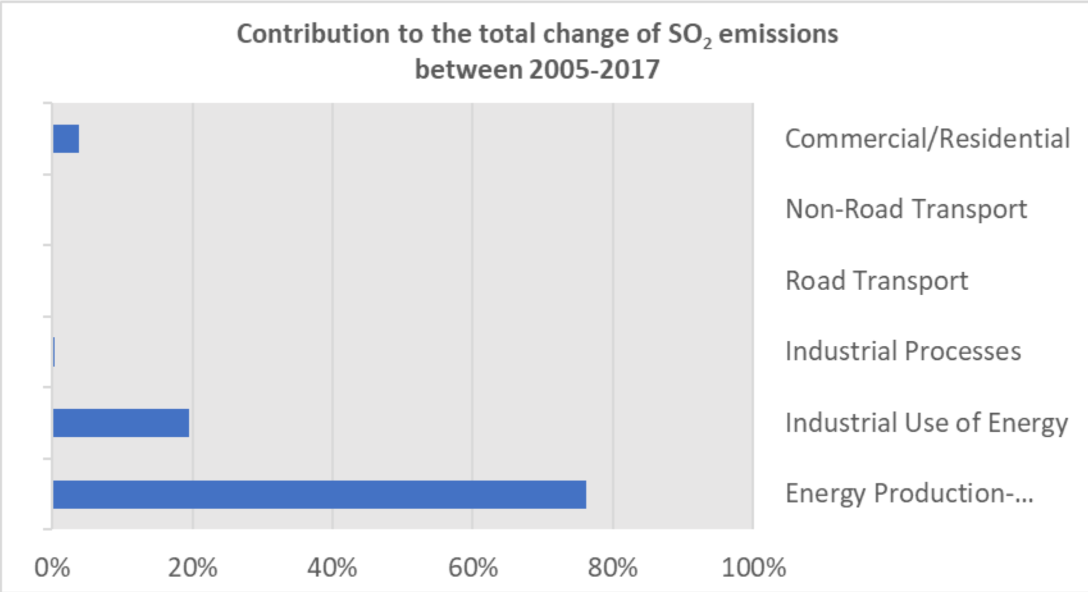


The relative emissions reductions for the period 2005-2017 by activity sector, as well as the contribution of each sector to the overall emissions reduction, are shown in Graph 3. The emissions from energy production and industrial use of energy, the road transport and commercial - residential activities have been reduced by more than 50%. The increase the share of natural gas units and RES in energy production and the modernization of older polluting plants, the measures to reduce sulfur content in liquid fuels and the increased use of natural gas as a fuel in the commercial and industrial sector as well as for domestic heating (with reduced consumption), are responsible for the observed decrease in emissions. 76% of the total decrease in emissions is attributed to the reduction of emissions from electricity generation, while the contribution of the reduction of emissions from industrial energy use is also significant (19%).

Graph 3: Change in national SO_2 emissions in 2017 compared to 2005



Graph 4: Contribution to the total change of national SO_2 emissions for the period 2005-2017



The expected further variation of SO_2 emissions by 2030, assuming that the policies and measures already adopted will not be modified, and the comparison with national maximum limits of Directive (EU) 2016/2284 (new NEC Directive) are shown in Table 1. A further decrease in sulfur dioxide emissions is expected during the period 2020-2030, which exceeds both the national commitment to reduce SO_2 emissions in the years 2020-2029 (74%) but also from 2030 onwards (88%).

Table 1: Expected variation of national SO_2 emissions by 2030
(without modifying the policies and measures already adopted)

	2020	2025	2030
Total SO_2 emissions (kt)	50,54	38,11	26,39
Expected % of reduction of SO_2 emissions compared to 2005	90,8%	93,1%	95,2%
National commitment of reducing SO_2 emissions (%)		74%	88%

1.2 Nitrogen oxide emissions

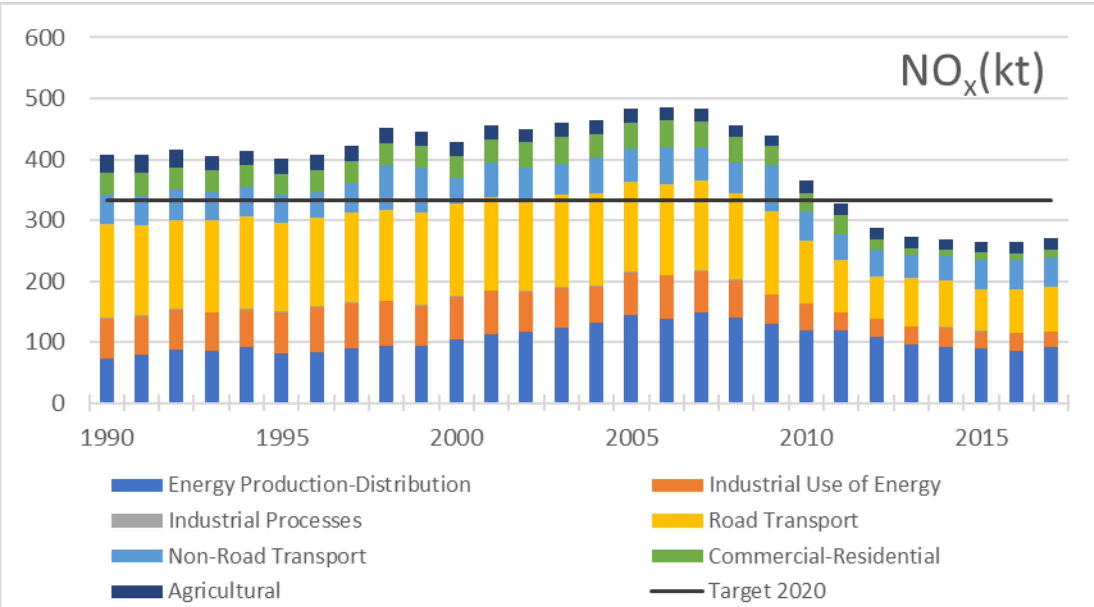
The emitted nitrogen oxides exert high environmental pressure in urban areas, as the levels of nitrogen dioxide concentrations have decreased compared to the previous decade, still exceeding the corresponding limits for air quality in Athens.

The EEA APE 002 indicator monitors the annual variation of anthropogenic nitrogen oxide (NOx) emissions since 1990 onwards, providing information on overall and by sector emissions. Since the emissions are reported in accordance with the requirements for the assessment of the compliance with national commitments under Directive (EU) 2016/2284 (new NEC Directive), some sub-categories of the agricultural sector are excluded from the total emissions.

The annual variation of NOx emissions is presented in Graph 5. It is observed that the decreasing trend with time since the middle of the previous decade has not the same magnitude as the one recorded for sulfur oxide emissions. The annual emissions are significantly reduced from 2009 to 2012, while stabilizing over the five-year period 2013-2017.

The emissions of 2017 (270 kt) are reduced by 33.8% compared to 1990. In 2010, the target value for the national upper limit of Directive 2001/81/EU is reached. Regarding the base year 2005 of the new NEC Directive on national emissions limits, 2017 emissions are reduced by 44%, already exceeding the national target of reduction for 2020, being 31% by 2020 (compared to 2005) and estimating that the target of 55% reduction by 2030 can be achieved.

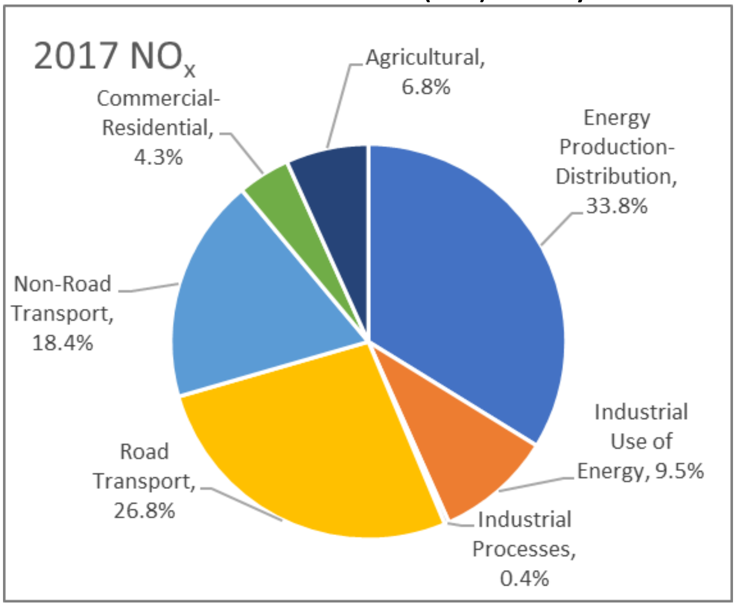
Graph 5: Annual variation of nitrogen oxide (NOx) emissions in Greece



The contribution of the different activity sectors in the NOx emissions in 2017 is shown in Graph 6, where a more isometric distribution of the sectors' contribution in total NOx emissions is observed, compared to sulfur oxides. Although energy production remains the category with the largest contribution (33.8%), the contribution of the road sector emissions (26,8%) is also significant.

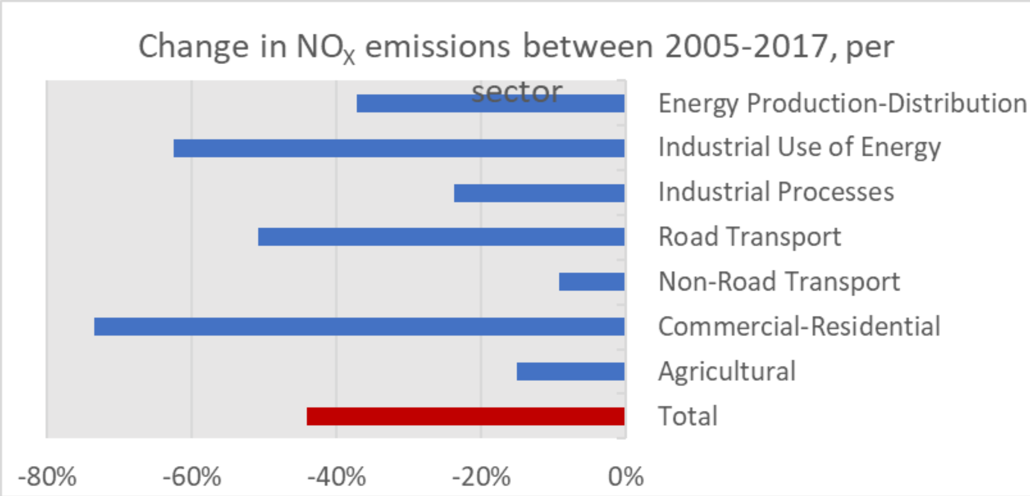
The contribution of road sector emissions has been significantly reduced compared to the two previous decades as a result of the gradual renewal of the fleet, with the full prevalence of catalytic vehicles and the increased participation of new technology vehicles for which lower NOx emissions are anticipated from the European legislation. Despite the increased use of natural gas and RES for energy production, as well as the use of advanced technologies in combustion processes and pollution control facilities, the reduction in emissions from the energy sector has been lower over the last decade than in the sector of road transport.

Graph 6: Participation of the various sectors of activity to national emissions of nitric oxide (NOx) for the year 2017

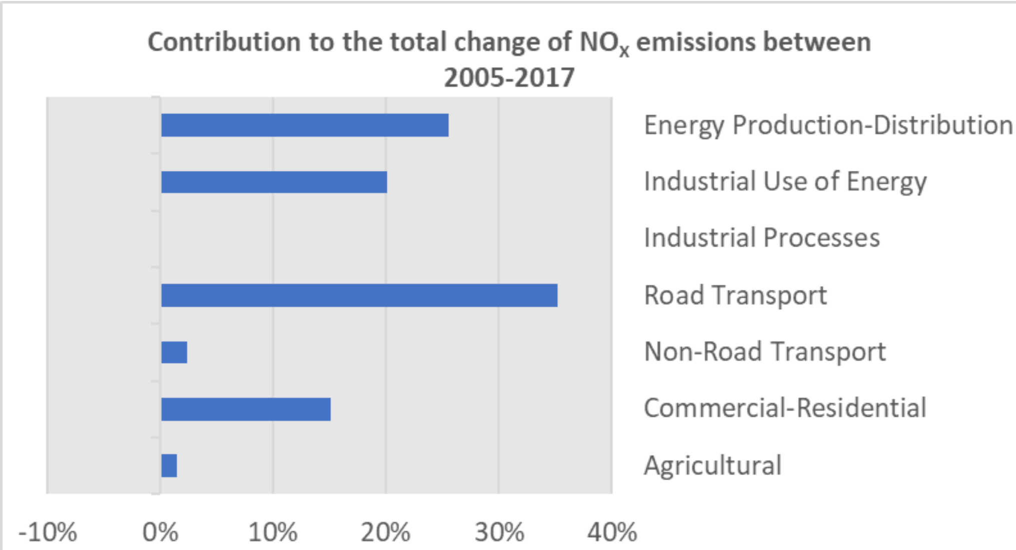


The relative decrease in emissions for the period 2005-2017 by activity sector, as well as the contribution of each sector to the overall emissions reduction are shown in Graphs 7 and 8. The largest decrease is observed for domestic and commercial NOx emissions, which approaches 73%. More than 50% is the reduction of emissions for the road transport sector, which accounts for the largest percentage (35%) of total emissions reduction. Emissions reductions from production and industrial use of energy are the highest and in addition they account for approximately 1/2 of total emissions reductions. The observed reduction of emissions from the agricultural sector does not have a significant effect, given this sector's minimal contribution (2%) in total emissions, as accounted in the national total.

Graph 7: Change in national NOx emissions for 2017, compared to 2005



Graph 8: Contribution to the total change of national NOx emissions for the period 2005-2017



The projected further change of NOx emissions by 2030, assuming that the policies and measures already approved will not be modified, and the comparison with national upper limits of Directive (EU) 2016/2284 (new NEC Directive) are shown in Table 2. In the period 2020-2030, further reduction of nitrogen oxide emissions is expected, exceeding both the national commitment to reduce NOx emissions in the years 2020-2029 (31%) and from 2030 onwards (55%).

Table 2: Expected national variation of NOx emissions by 2030
(without modifying the policies and measures already adopted)

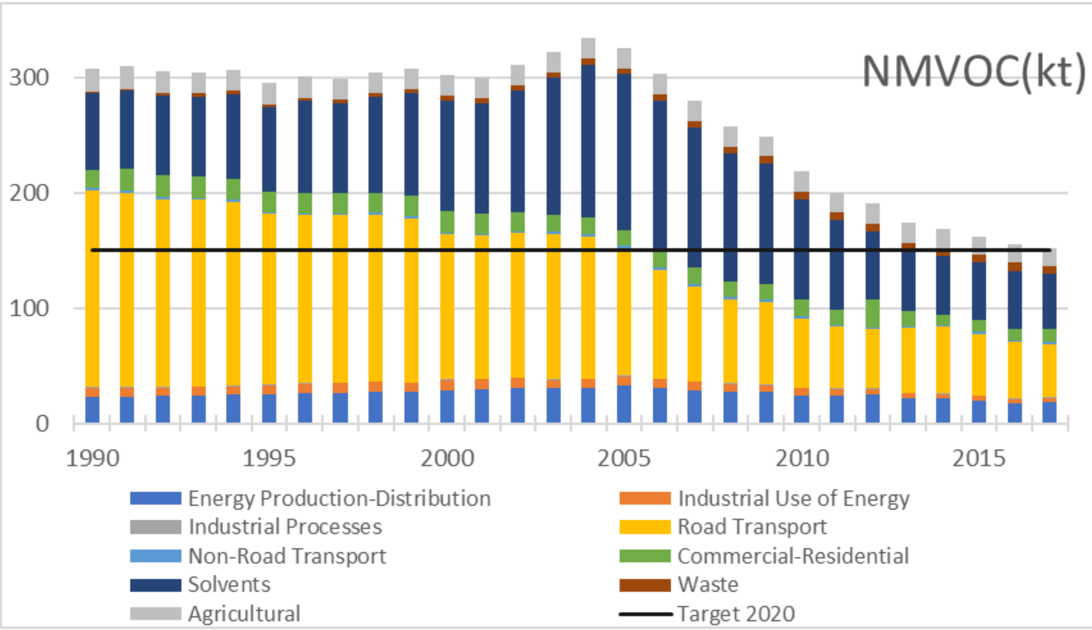
	2020	2025	2030
Total NOx emissions (kt)	203,52	182,74	155,58
Expected % of reduction of NOx emissions compared to 2005	56,0%	60,4%	66,3%
National commitment of reducing NOx emissions (%)	31%		55%

1.3 Emissions of non-methane volatile organic compounds

The EEA APE 004 index describes the change in anthropogenic emissions of non-methane volatile organic compounds (NMVOCs) during the period 1990-2017. In correspondence with NOx and in accordance with the provisions for the assessment of compliance with national commitments under the new NEC guideline for the NMVOCs emissions, certain subcategories of the agricultural sector are excluded from total emissions.

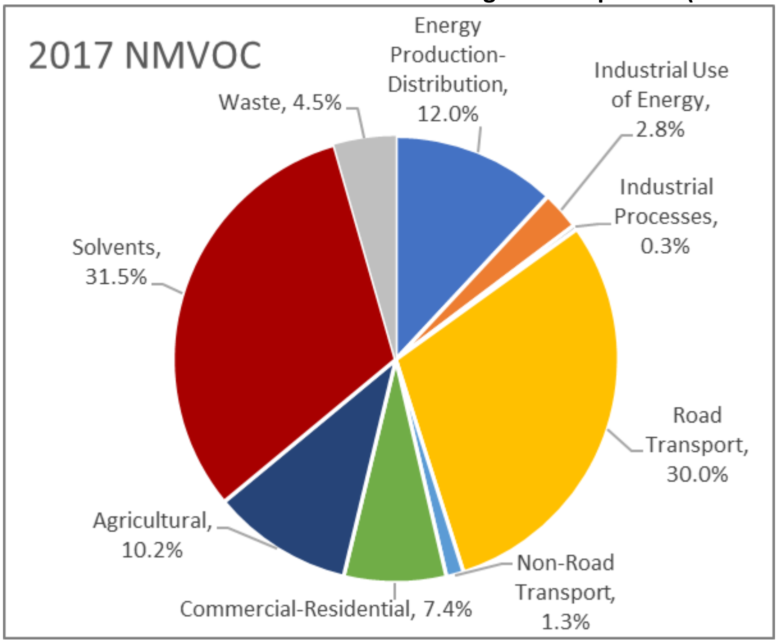
The results of the emissions' annual variation (Graph 10) show a steady decline in NMVOCs after 2004, recording decrease by 50.4% in 2017 compared to 1990. The envisaged objective of Directive 2001/81/EU appears to have been achieved since 2009. The new NEC Directive predicts the reduction of NMVOCs emissions by 54% till 2020 and 62% till 2030 compared to the reference year 2005. The data for 2017 indicate a 53.3% decrease compared to 2005, so it seems that achieving the national goal for 2020 will be marginal, while achieving the 2030 reduction goal will require additional measures.

Graph 9: Annual variation of non-methane volatile organic compounds (NMVOC) emissions in Greece



The various volatile organic compounds are emitted from a large number of different sources (Graph 11) but exhibit similar behavior in the atmosphere. The use of products containing or using organic solvents and vehicle traffic are the categories with the major contribution (31.5% and 30% respectively in 2017).

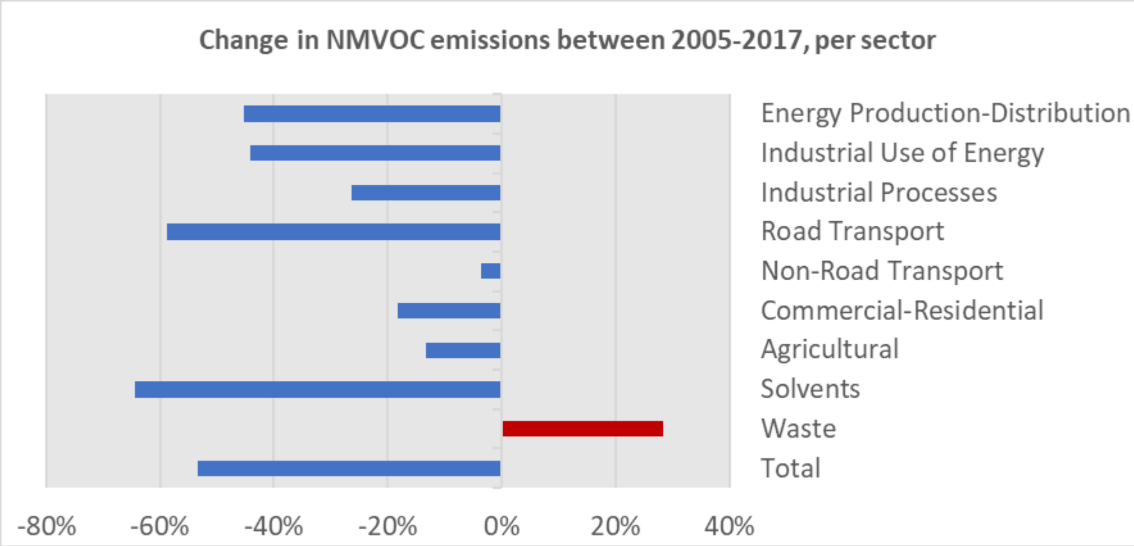
Graph 10: Contribution of the various activity sectors to the national emissions of Non-Methane Volatile Organic Compounds (NMVOC) for 2017



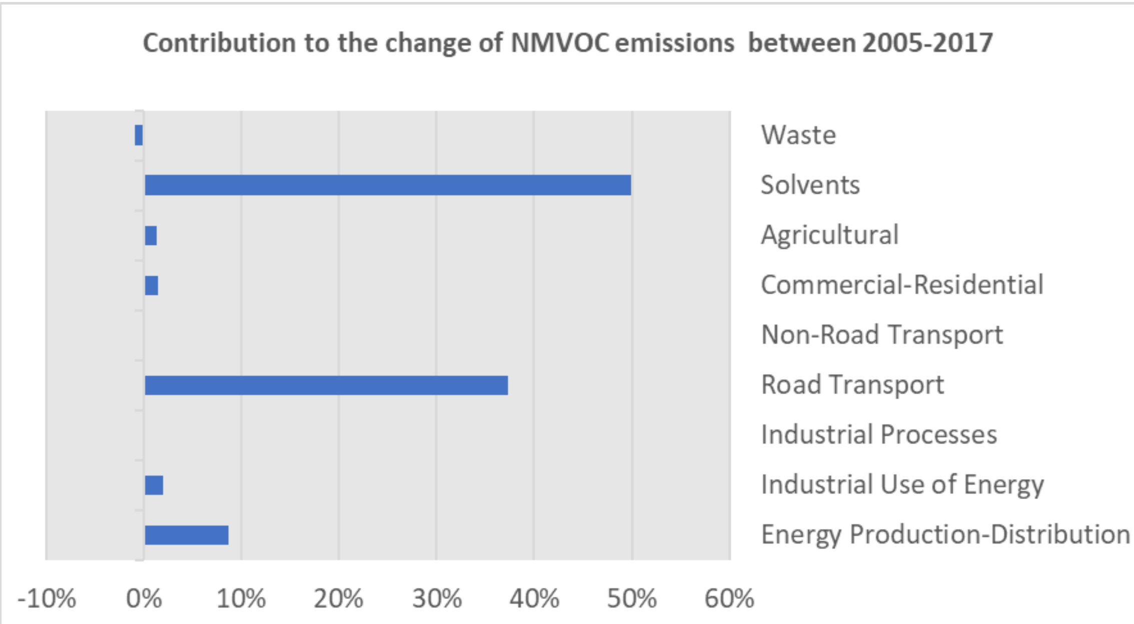
The decline recorded in emissions from vehicles as a result of the European legislation on emissions from new vehicles and the gradual renewal of the passenger and professional fleet, largely explains the observed reduction in total emissions. The NMVOCs emissions from solvents, although not far from 1990 levels, have fallen significantly compared to the much higher values recorded in the middle of the last decade as a result of targeted legislative interventions (Solvents Directive - 1999/13/EU, Paints Directive - 2004/32/EU). Emissions in the sector of energy production and distribution are mainly associated with evasive emissions from oil refining and oil storage and less with direct emissions from production processes.

Graph 12 and 13 show the change in NMVOC emissions per sector between 2005-2017, as well as the contribution of each sector to the overall change. It appears that the largest contribution comes from the sector of solvents. Almost for all sectors reductions have been recorder, that exceed 40% for the products containing or using organic solvents, the road transport as well as the production and the industrial use of energy. The waste sector is the only one presenting a decreasing trend but has a negligible contribution in total emissions.

Graph 11: Change in national NMVOC emissions for 2017 compared to 2005



Graph 12: Contribution to the change of national NMVOC emissions for the period 2005-2017



The expected further development of NMVOC emissions by 2030 and the comparison with the national upper limits of Directive (EU) 2016/2284 (new NEC Directive) are presented in Table 3. Assuming that the policies and measures already approved for the period 2020-2030 will not be modified, it is expected that the reduction in emissions of non-methane volatile organic compounds covers both the national commitment to reduce NMVOC emissions for the years 2020-2029 (54%) and from 2030 onwards (62%) as well.

Table 3: Expected national variation of NMVOC emissions by 2030
(without modifying the policies and measures already adopted)

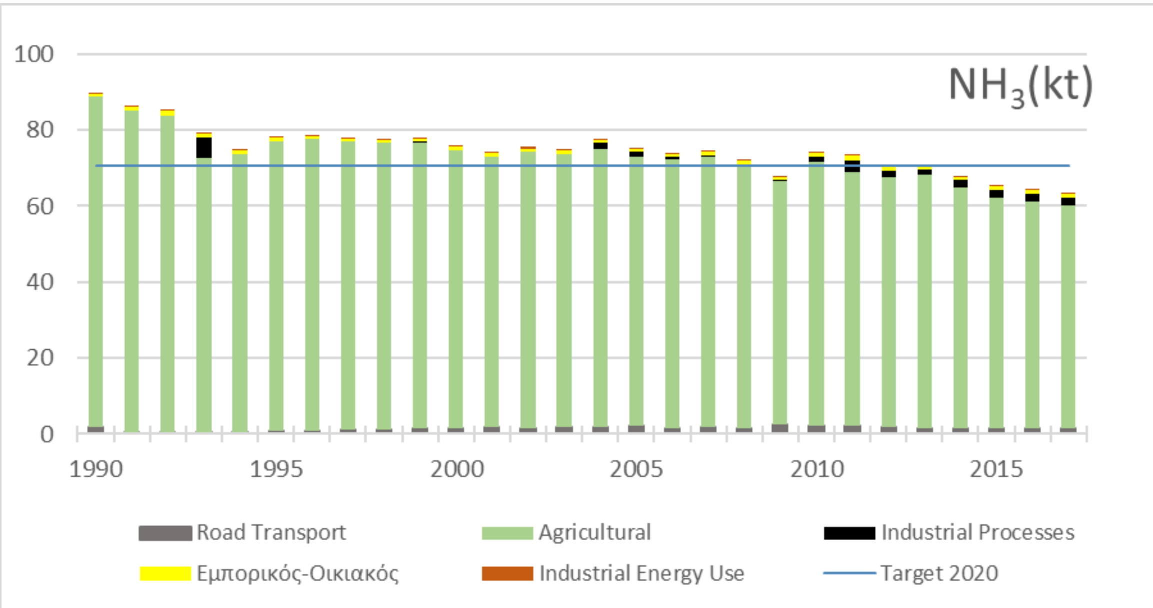
	2020	2025	2030
Total NMVOC emissions (kt)	125,76	115,82	106,06
Expected % reduction of NMVOC emissions compared to 2005	59,2%	62,4%	65,6%
National commitment of reducing NMVOC emissions (%)		54%	62%

1.4 Ammonia emissions

The EEA APE 003 indicator monitors the annual evolution of anthropogenic emissions of ammonia (NH_3) over the atmosphere, from 1990 onwards, overall and per sector (Graph 9). The activities reported for NH_3 emissions fall into the five sectors: agriculture, road transport, industrial processes, industrial energy use and the commercial-residential sector. As most of the emissions (> 90%) come from one key sector, agriculture, it is possible to immediately observe the effectiveness of specific policies to limit total emissions.

The emissions levels of ammonia have been relatively stable during the last decade, with a steady decrease of 1-4% per year over the last five years. In 2017, ammonia emissions decreased by 29.5% compared to the base year 1990. The national target of reducing ammonia emissions, compared to 2005, as described in the new NEC Directive, is 7% by 2020 and 10% by 2030 and onwards. For 2017, the rate of reduction of NH_3 emissions compared to 2005 is 16%. Consequently, the country has already achieved not only the 2020 target but also the 2030 target.

Graph 13: Annual variation of ammonia (NH_3) emissions in Greece



The main part of ammonia emissions comes from the agricultural sector, whose contribution for the year 2017 amounts to 92.4%. The emissions reduction from the sector for 2017 compared to the base year 2005 is reduced by 17.1%, although emissions have only decreased by 8.4% since 2009. In Greece, this reduction over time is associated with the reduction of nitrogen fertilizers use and the parallel development of organic farming, as well as the implementation of good agricultural practices, while the impact of changes in the livestock sector is less significant.

Regarding ammonia emissions from the road sector, these come from passenger cars exhaust gases, as ammonia is produced by a series of reactions in the three-way catalysts. Compared to 2005, there is a 25% decrease, while between 2013-2017 the emissions are stabilized at 1.5%. In 2009, the highest emissions from the road sector (2.3kt) are recorded, which by 2017 record an overall decrease by 34.8%. A small proportion of NH_3 emissions (3.1%) are attributed to chemical industrial processes, and in particular to the production of ammonium nitrate for use in fertilizers. Finally, a small but appreciable proportion is occupied by ammonia emissions from the commercial-residential sector and the industrial energy use.

The expected further change of NH_3 emissions by 2030 and comparison with the national upper limits of Directive (EU) 2016/2284 (new NEC Directive) is presented in Table 4. Assuming that the policies and measures already approved for the period 2020-2030 will not be modified, the reduction in ammonia emissions is expected to cover both the national commitment to reduce NH_3 emissions during the years 2020-2029 (7%) and from 2030 onwards (10%) as well.

Table 4: Expected national variation of NH_3 emissions by 2030
(without modifying the policies and measures already adopted)

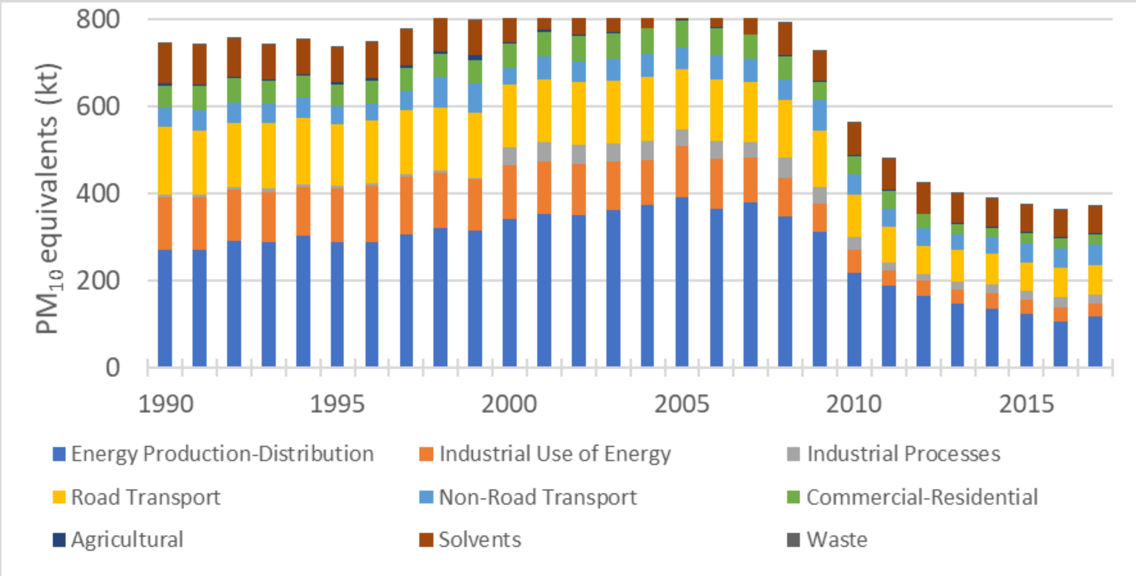
	2020	2025	2030
Total NH_3 emissions (kt)	65,13	63,4	67,02
Expected % reduction of NH_3 emissions compared to 2005	14,0%	16,3%	11,5%
National commitment of reducing NH_3 emissions (%)	7%		10%

1.5 Particulate matter emissions

The CSI 003 and ENER 007 indicators detect changes in the anthropogenic emissions of the primary particles (PM_{10} and $PM_{2.5}$) and of the main atmospheric pollutants (NOx, SO_2 and NH_3) involved in secondary particle formation processes.

According to the results of the change of particulate matter PM_{10} emissions evolution, there is a gradual reduction in the production of particulate matters from 2007 onwards (Graph 14). In 2017 the decrease is 50.3% compared to 1990, and 57.6% compared to 2005. There is also a smoothing during the period 2012-2017.

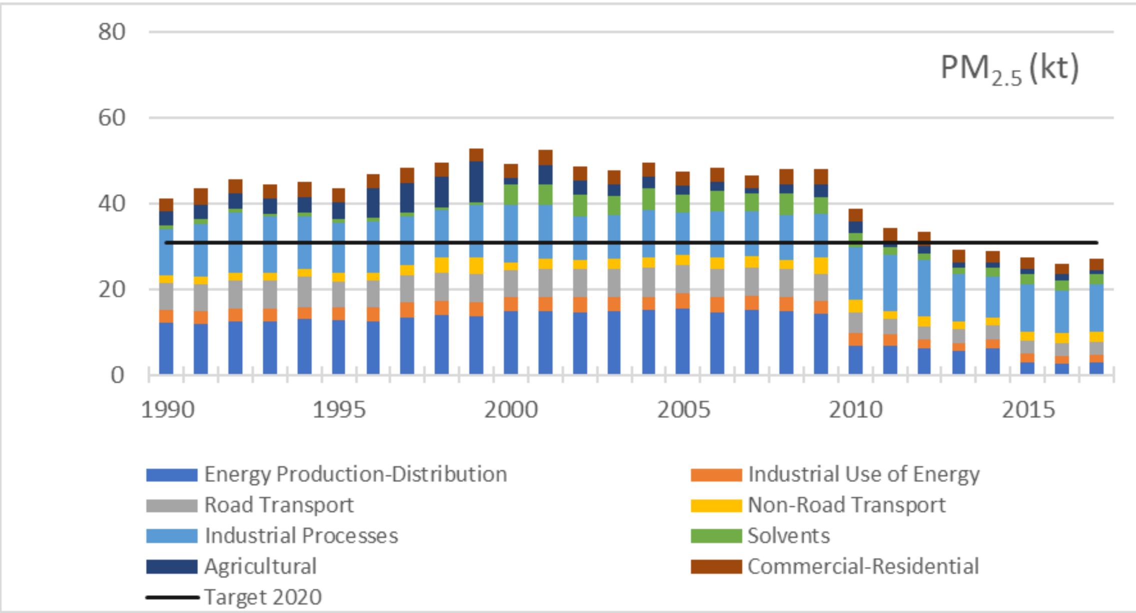
Graph 14: Annual variation of primary particles PM_{10} emissions in Greece



Graph 15 shows the overall and per sector variation of $PM_{2.5}$ emissions, which are now incorporated, under the new NEC Directive, into pollutants for which national emission limits are set.

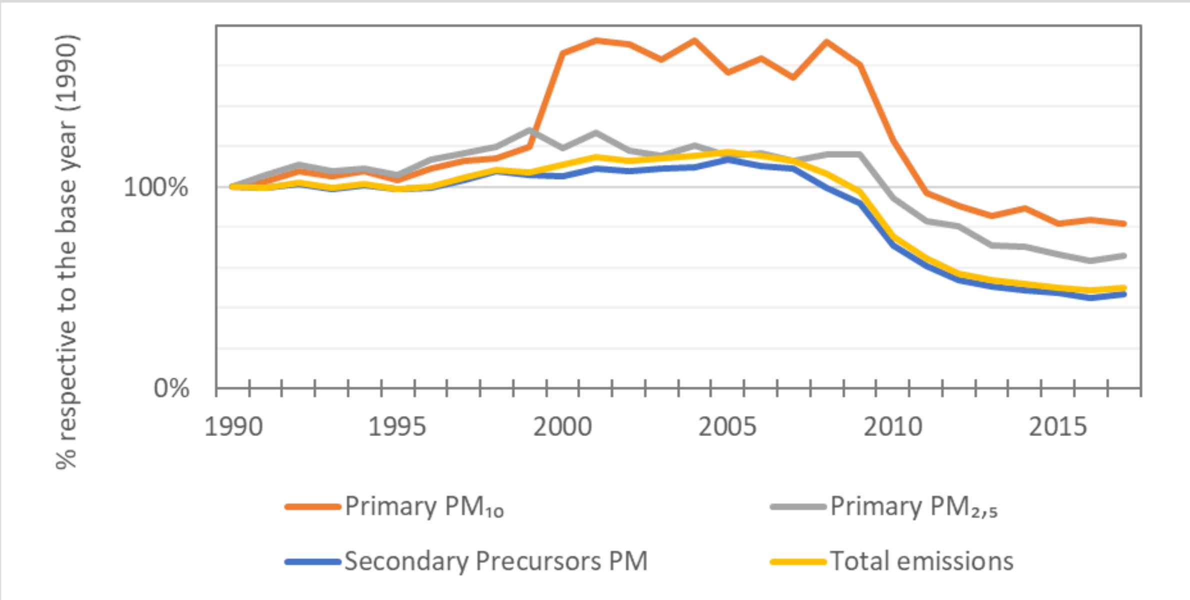
It is observed that after a significant decrease over the period 2009-2013, $PM_{2.5}$ emissions are stabilized and even record a decrease (7.6%) over the period 2013-2017. The national target of reducing $PM_{2.5}$ emissions compared to 2005, according to the new NEEC Directive, is 35% by 2020 and 50% by 2030. The year 2017 has recorded a decrease of 42.9% compared to 2005, meaning that the target of 2020 has already been exceeded, while the achievement of the national target for 2030 is expected to require additional measures.

Graph 15: Annual variation of emissions of primary particles $PM_{2.5}$ in Greece



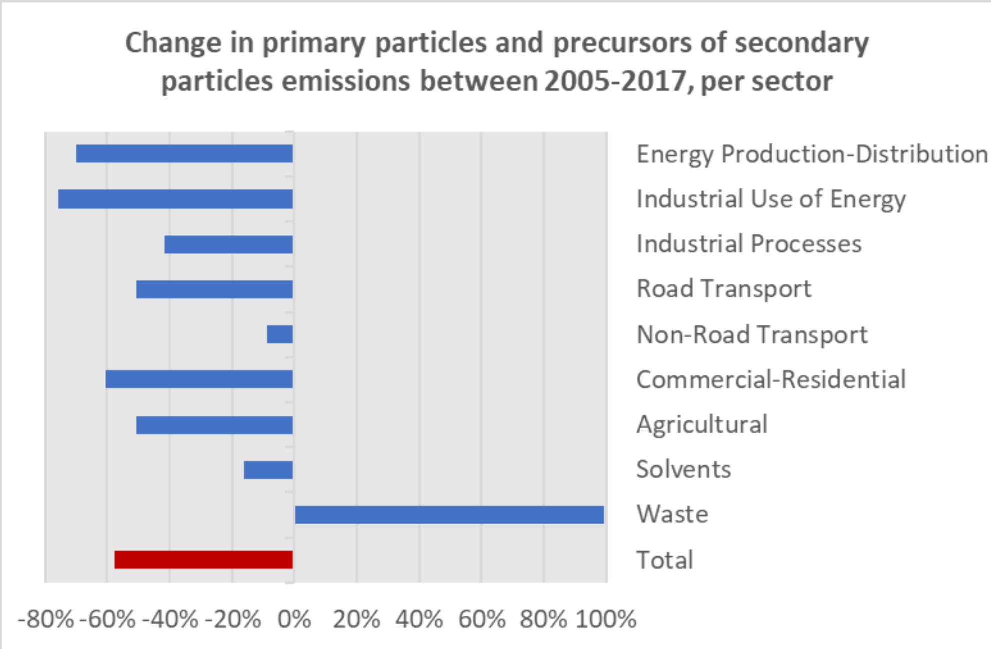
During the period 1990-2017, the observed reductions of primary particles emissions, 18% for PM_{10} and 34.2% for $PM_{2.5}$, remain below the reduction of equivalent emissions of secondary particle precursors amounting to 53.4% (Graph 16). All three parameters have similar annual variation, with the reduction observed in the last decade to be attributed to the gradual change of the energy mixture and the implementation of clean technologies in production plants, to the reduced emissions from private and professional vehicles in accordance with the provisions of European legislation, but also to the overall reduction of energy consumption in the context of the economic recession.

Graph 16: Annual variation in particulate and their precursors emissions



As can be seen from Graph 14, the decrease recorded by the EEA CSI 003 index over the period 2005-2017 is largely related to the reductions in the emissions from the energy-related sectors. Except for the waste emissions, the rest of the sectors report reduction in emissions, with the most significant reductions in the sectors of production and industrial uses of energy, in industrial processes, in road transport, in the commercial-residential sector, in rates ranging between 42-76% (Graph 14).

Graph 17: Change in national emissions of primary particles and precursors of secondary particles between 2005-2017 per sector



The expected further variation of $PM_{2.5}$ emissions till 2030 and the comparison with the national upper limits of Directive (EU) 2016/2284 (new NEC Directive) are presented in Table 5. Assuming that the policies and measures already approved for the period 2020-2030 will not be modified, the reduction in $PM_{2.5}$ emissions is expected to be in line with the national commitment to reduce $PM_{2.5}$ emissions during the years 2020 -2029 (35%) and from 2030 onwards (50%).

Table 5: Expected national variation of $PM_{2.5}$ emissions by 2030
(without modifying the policies and measures already adopted)

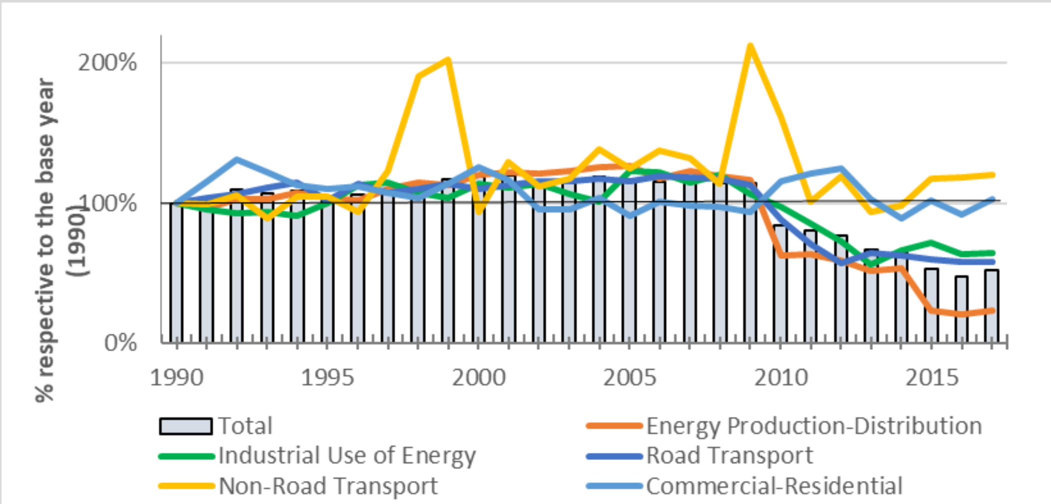
	2020	2025	2030
Total $PM_{2.5}$ emissions (kt)	24,44	22,7	21,73
Expected % reduction of $PM_{2.5}$ emissions compared to 2005	48,7%	52,4%	54,4%
National commitment of reducing $PM_{2.5}$ emissions (%)		35%	50%

Energy-related particles emissions

Given the large contribution of emissions from the specific sectors to the total emissions of equivalent particulate matter, it is important to consider the energy-related anthropogenic particles emissions. The EEA ENER 007 indicator tracks the total anthropogenic emissions of the primary particles PM_{10} and $PM_{2.5}$, from the sectors of energy production-distribution, industrial energy use, road and non-road transport and commercial/residential energy use.

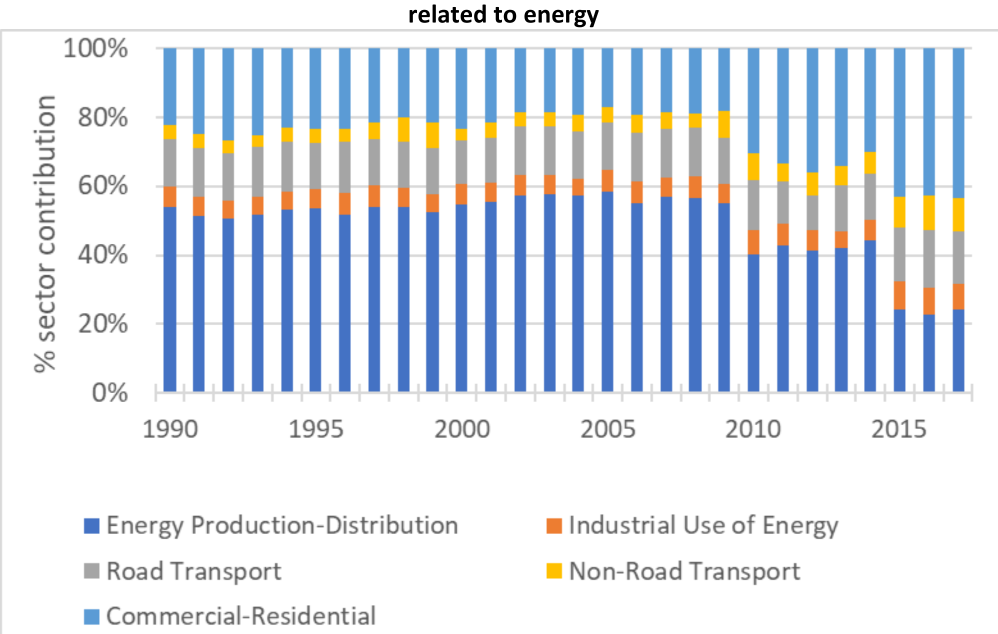
Graph 18 shows the annual variation of primary PM_{10} emissions, totally and per sector. A decrease of 47.7% compared to 1990 and 55.3% compared to 2005 is recorded. The greatest reductions since 1990 are observed for the sectors of energy production (76.5%) and industrial energy use (35.4%), as well as for the road transport sector (42.1%). Emissions from the non-road transport sector are characterized by highly variability and in 2017 still exceed the emissions of the base year 1990.

Graph 18: Annual variation of PM_{10} primary emissions related to energy, per sector



As can be seen from Graph 19, the contribution of primary emissions of particulate matter from energy production has been reduced to 1/2 compared to 1990, accounting for 24.2% of total emissions. The largest contribution is now made by residential and commercial energy use, pointing to the relative stability of primary emissions, whose rate of reduction, especially in the period 2005-2017, seems to be much lower than for other pollutants.

Graph 19: Contribution of sectors to the total emissions of primary particles PM_{10} related to energy



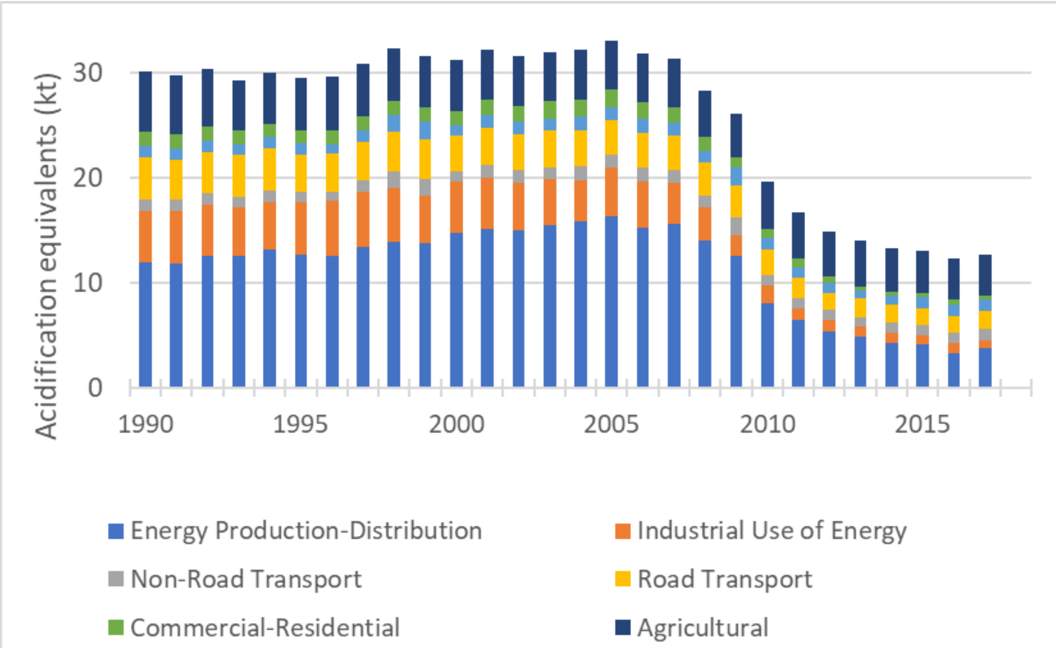
2. Emissions of acidifying substances

The EEA CSI 001 and EEA ENER 006 indicators record the total and per sector emissions of atmospheric pollutants (SO_2, NO_x and NH_3), which cause acidification upon deposition and are associated with a number of adverse effects on ecosystems and damages to buildings and materials.

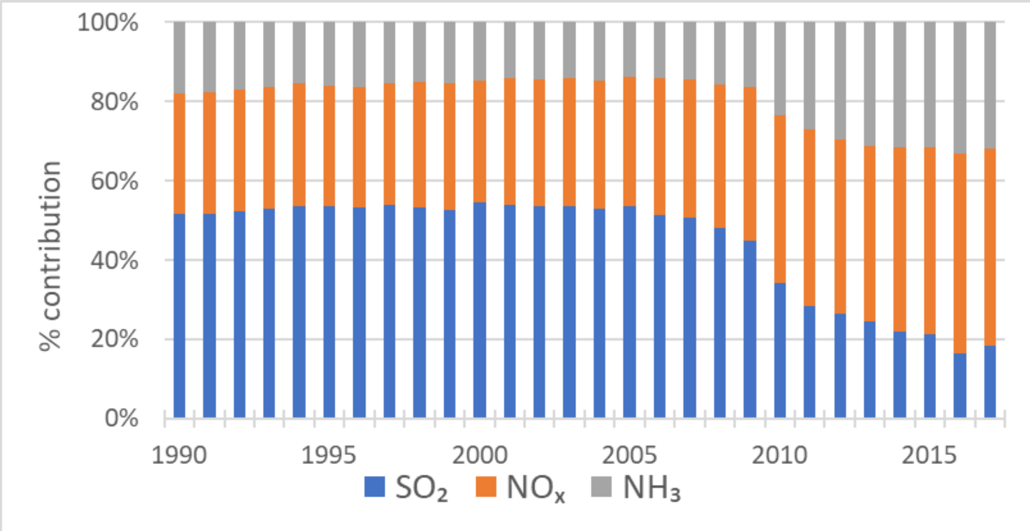
The change in total acidifying substances emissions (EEA CSI 001 index), distributed in the activity sectors is illustrated in Graph 20 for the period 1990-2017. Over half (59.8%) of the total emissions have been reduced compared to 1990, mainly from 2008 onwards, while the decreasing trend has been normalized in 2012-2017.

The relative contribution of the three atmospheric pollutants to the estimated acidification potential is shown in Graph 21. Until 2010, sulfur oxide emissions were the main acidifying factor, being replaced from 2011 and onwards from nitrogen oxide emissions, which decreased in a relatively slower rate. The contribution of ammonia emissions, which show greater stability over time, have gradually exceeded the 1/4 of the total.

Graph 20: Annual variation of the emissions of acidifying substances in Greece

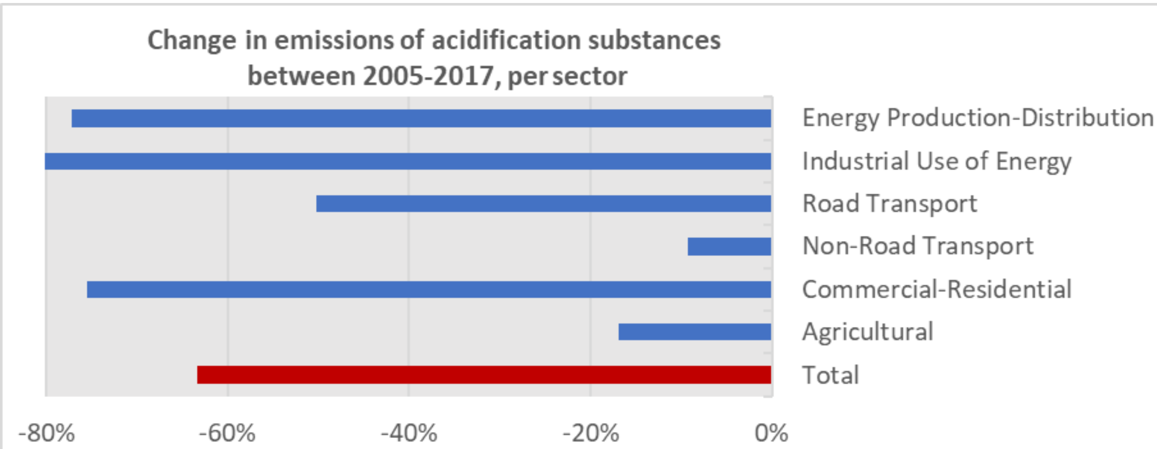


Graph 21: Relative contribution of air pollutants in total acidification potential



Compared to 2005, the total emissions of acidifying substances have decreased by 63.3%. The change by activity sector is shown in Graph 22, where there is a significant reduction in emissions from sectors involving the use of fuels (for energy production, road transport and industrial / commercial / residential uses), the reduction of which exceeding 50%. The relative stability over time of emissions from the agricultural sector is highlighted, with a total change of 32.9% compared to 1990 and 16.9% compared to 2005.

Graph 22: Variation of acidification emissions between 2005-2017, per sector

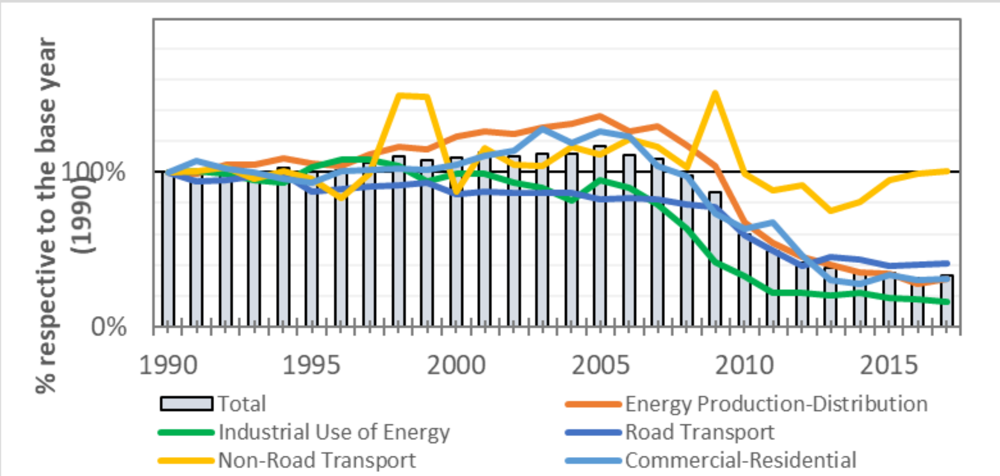


Changes in energy-related emissions of acidification substances are described by the EEA ENER 006 indicator. The areas of activity included in the indicator's estimation are energy production-distribution, energy use in industry, road transport and commercial-residential energy use. Graph 23 shows the time-varying of total and per sector energy-related emissions of acidification substances as a percentage over the base year 1990. The reduction in total emissions from the energy sectors is significant, with emissions for 2017 appearing half compared to 1990, recording a decrease of 67% registered after 2009.

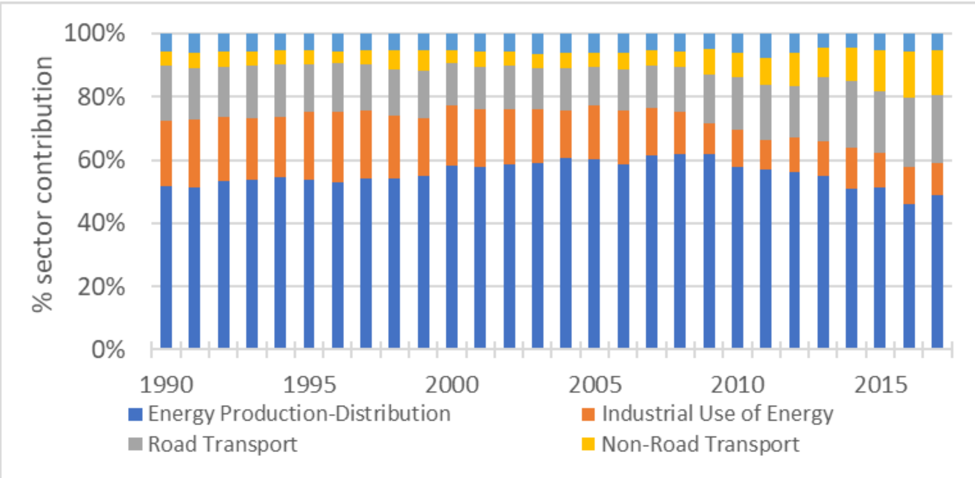
Emissions from energy production and distribution, which is the factor with the largest contribution to the indicator (Graph 24), until 2009 exceeded those of the base year. To their rapid decline, during the following period, the reduction in overall emissions is largely attributed.

Emissions from industrial and commercial/residential energy use have been greatly reduced to account for 19.8% and 6.5%, respectively, of the reduction in total emissions between 2005-2017. Also, the reduction of road transport emissions between 2005-2017 (50.2%) corresponds to 8.6% of the reduction in total emissions. Emissions from the non-road transport sector show a wide range of variation and a relatively smaller decrease, while during 2017 there is a decrease of 9.3%.

Graph 23: Annual variation of energy-related emissions of acidification substances



Graph 24: Sectors contribution to the total energy-related emissions of acidification substances



3. Emissions of ozone precursors

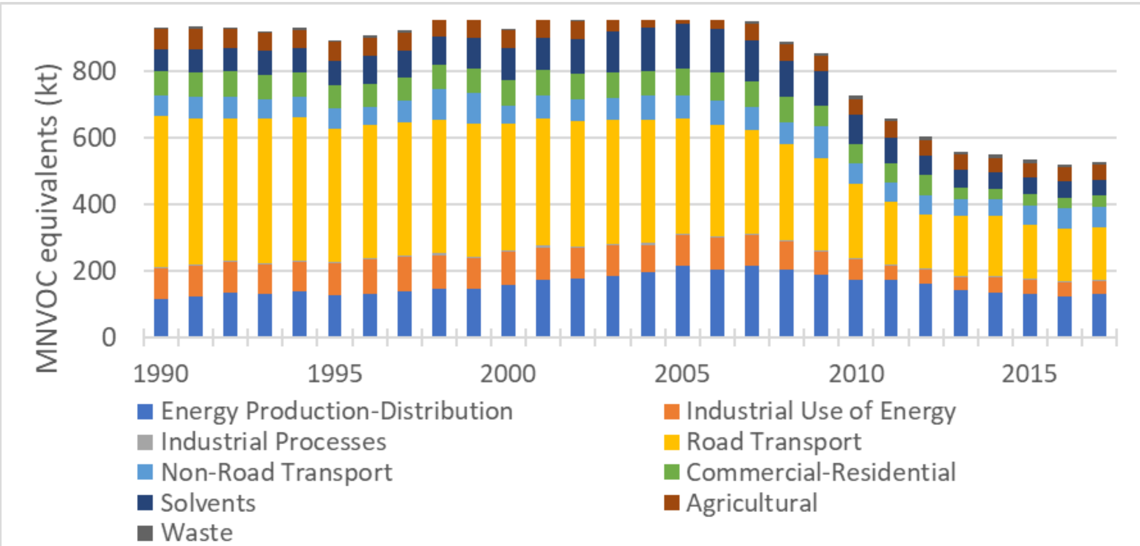
The EEA CSI 002 and EEA ENER 005 indicators record the total and per sector emissions of air pollutants (NO_x, NMVOC, CO and CH_4) that contribute to the formation of tropospheric ozone.

The EEA CSI 002 indicator tracks the change of the total emissions of ozone precursors, which is shown, during the years 1990-2017, by activity sector (Graph 25). Compared to 1990, the total potential of ozone formation from precursor compounds, for 2017, appears reduced by 43.4%, a decrease that occurs mainly between 2009-2013.

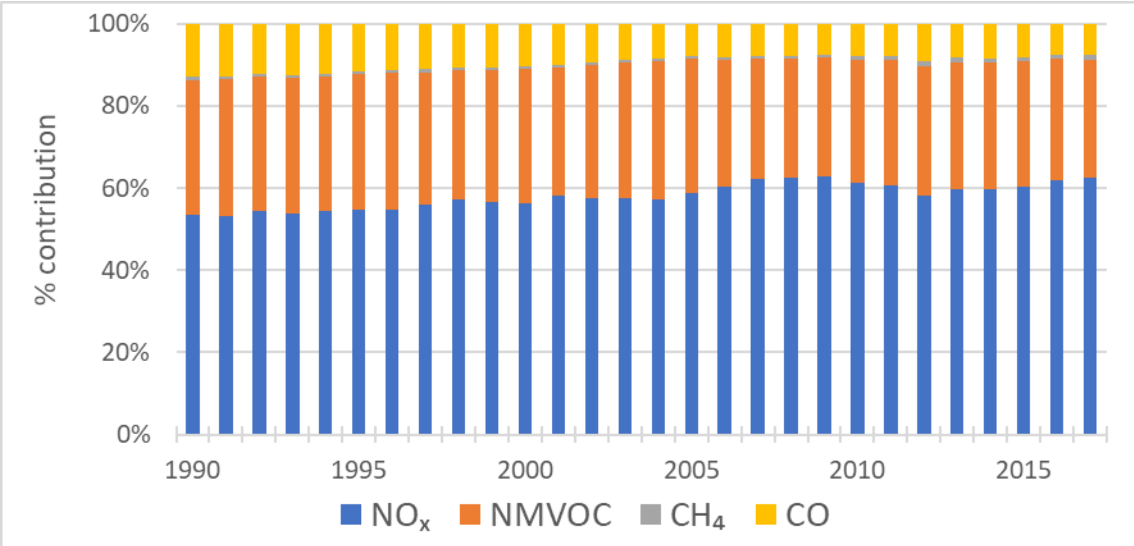
Nitrogen oxides are the precursor compound of tropospheric ozone with the highest relative contribution (Graph 26), which in 2017 is decreased by 33.8% compared to 1990. In addition, the relative contribution of organic compounds emissions is decreased by 50.4% compared to 1990 after 2005. Despite their significant annual reduction, carbon monoxide emissions still account for about 7.7% to the total potential for tropospheric ozone formation. The contribution of methane emissions is around 1.1% due to its limited contribution to secondary reactions of O_3 production.

During the period 2005-2017, significant reductions in emissions of ozone precursors are recorded for the sectors of production and industrial use of energy, industrial processes, road transport, commercial and residential energy use and solvent use, varying between 41.8 - 76.0% (Graph 27). On the other hand, in the agricultural sector and in the non-road transport there is a significantly lower decrease of 16.3% and 8.9% respectively, with the exception of the waste sector which records an increase of 99.4%.

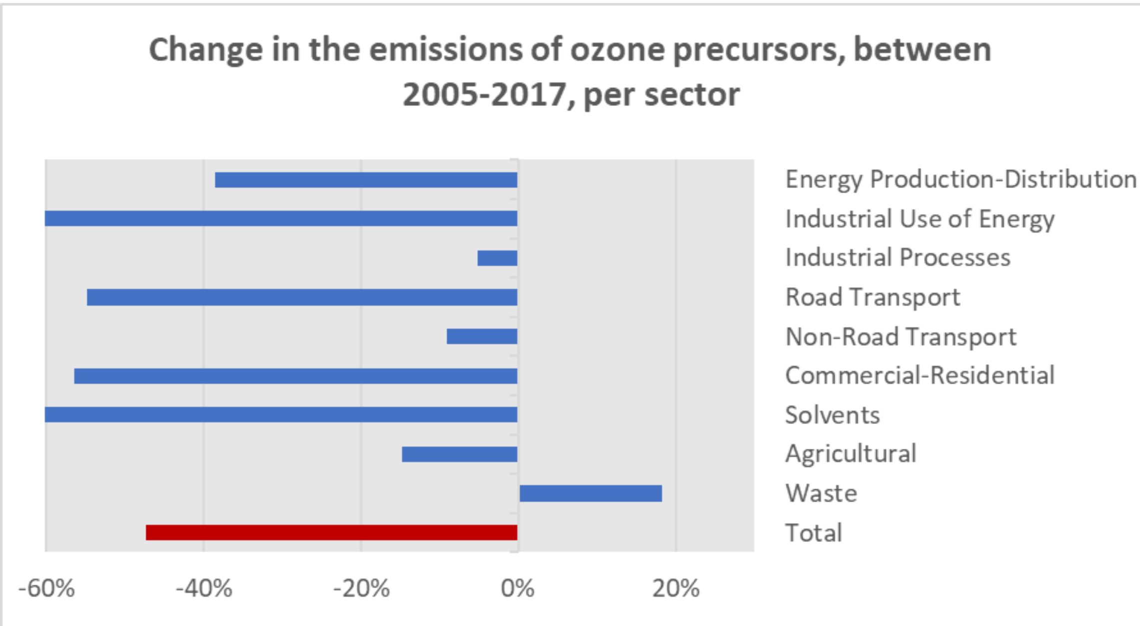
Graph 25: Annual variation of emissions of ozone precursors in Greece



Graph 26: Relative contribution of air pollutants to the total potential of tropospheric ozone formation

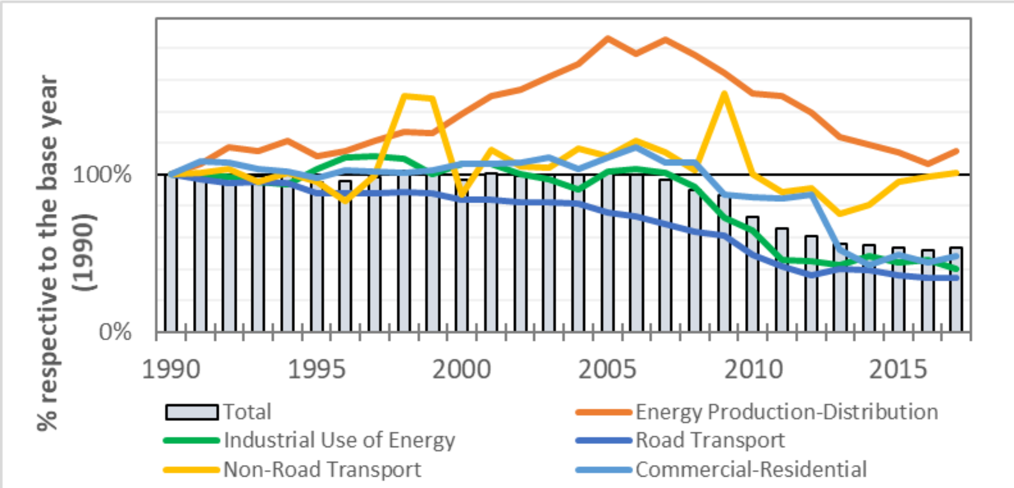


Graph 27: Change in the emissions of ozone precursors between 2005-2015, per sector



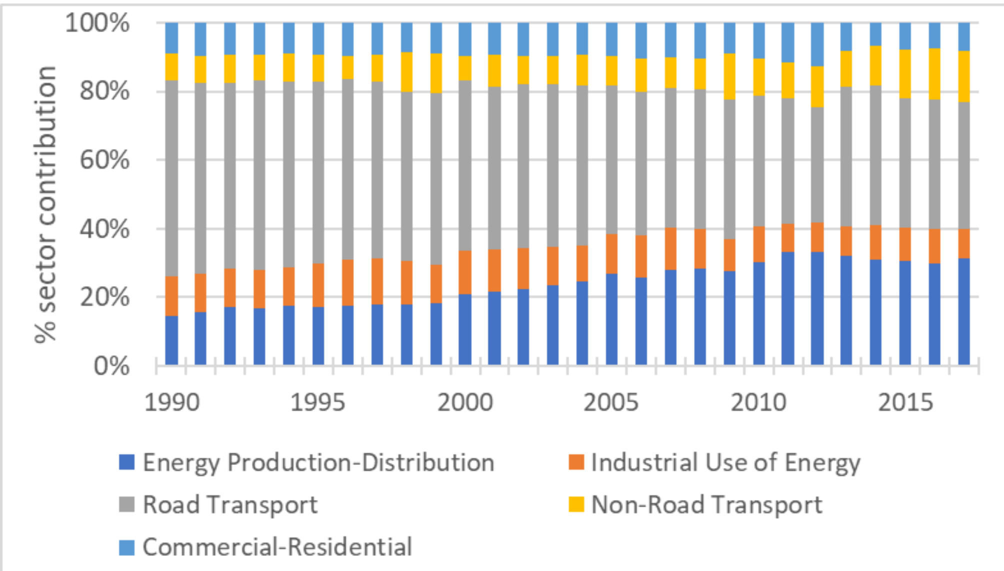
As it turns out, the emissions of precursor compounds related to energy production have a decisive contribution to the change of the total potential of O_3 formation, which, for the observed decrease over the period 2005-2017, amounts to 80.2%. Therefore, it is of particular interest to examine separately their changes (Graph 28), as provided by the EEA ENER 005 indicator. The index description considers the same activities as in the EEA ENER 006 indicator (energy production-distribution, industrial use of energy, road and non-road transport and commercial-residential energy use). Despite the relative increase (14.6%), compared to the baseline year, of the emissions coming from the sector of energy production, the total potential of tropospheric ozone formation, for 2017, decreased by 43.4% compared to 1990, and 47.2% compared to 2005. The decrease is mainly due to very low emissions from the sector of road transport (by 65.6% compared to 1990).

Graph 28: EEA ENER 005: Annual variation of emissions from ozone precursors, related to energy



The observed decrease compared to 2005, is attributed by 54.7%, to the reduction in the emissions of road transport sector and by 61.0% to the reduction in emissions of the industrial energy use sector. The contribution of the emissions (Graph 29) from energy production processes has gradually reached less than 1/3 of the total (31% for 2017) and is almost comparable to the contribution of the road transport sector (37% for 2015). The participation of the other three sectors is limited to 9-15%.

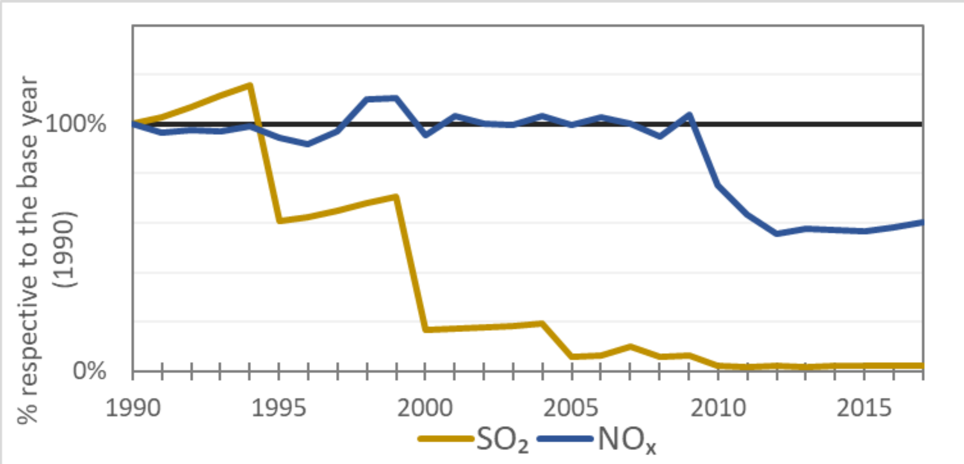
Graph 29: Sectors contribution to the total emissions of ozone precursors related to energy



4. Intensity of emissions of the transport sector

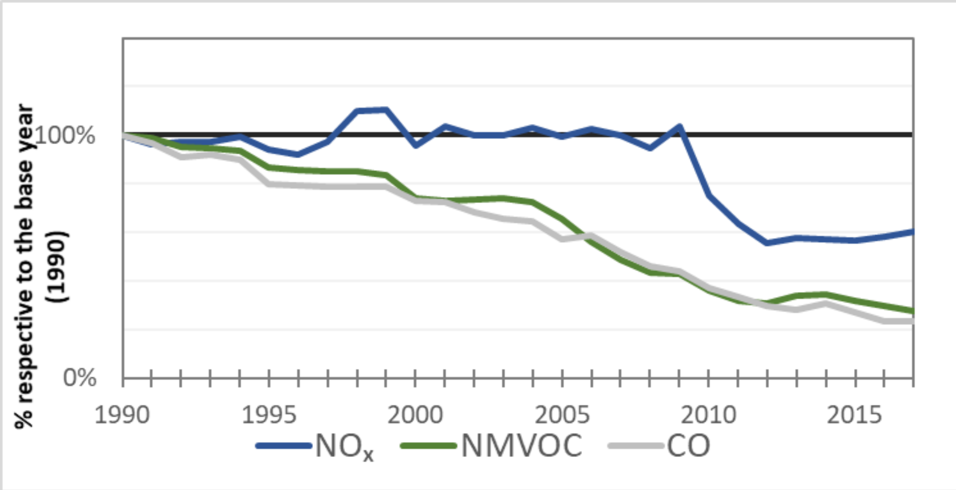
Graph 30 shows the annual emissions of transport acidification substances (excluding seagoing shipping), as percentage over the year 1990. The reduction in sulfur dioxide levels is rapid, as 2017 emissions account for only 2% of the 1990s and 41% of those in 2005, reflecting the long-term success of their reduction strategies by reducing sulfur content in fuel. In contrast, nitrogen oxide emissions from transport show a smoother annual variation, with 2017 recording 60% of those in 1990, with the decline occurring from 2005 onwards. It is noted, however, that in recent years NO_x emissions have stagnated due to increased traffic coupled with the poor control of diesel technology circulating in Athens (only EURO 5 or later are allowed).

Graph 30: Annual variability of emissions of acidification substances from the transport sector



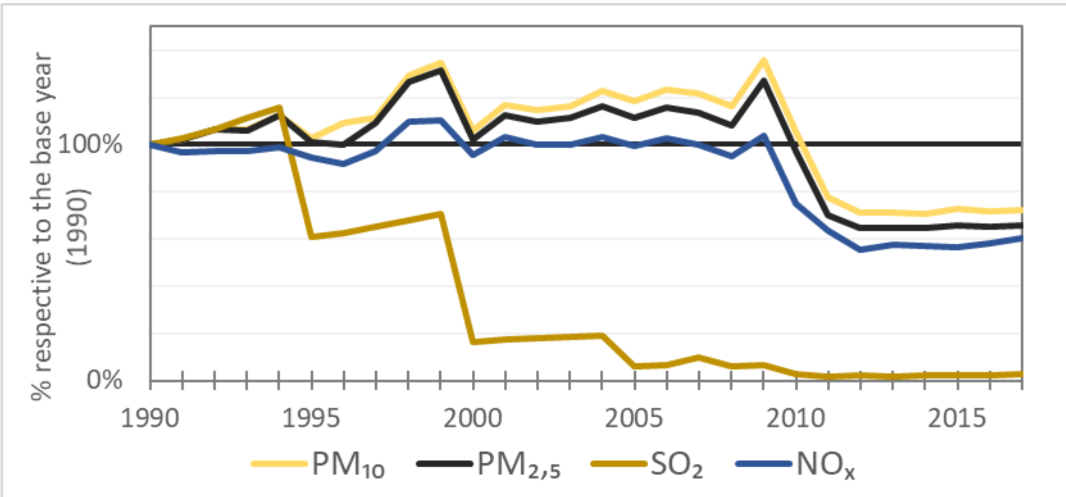
In contrast to nitrogen oxides, the other ozone precursor compounds examined by the indicator are characterized by a steady annual decrease in their emissions (Graph 31). NMVOCs and CO emissions for 2017 are reduced by 72.3% and 76.6%, respectively, compared to 1990, indicating the effectiveness of the application of vehicle emission limits regulations, at least for specific pollutants. It is noted that the emissions of NMVOCs from the road sector, in addition to direct exhaust emissions, also come from fuel evaporation, especially during the prevalence of warm weather conditions.

Graph 31: Annual variation of emissions of ozone precursors from the transport sector



Emissions of primary suspended particles from the road transport sector are not only limited to exhaust gases released directly into the atmosphere, but to a significant extent can also include particles coming from the wear of braking materials, tires and mechanical parts of vehicles, but also from the wear of the road surface due to traffic. These non-combustion emissions are mainly related to PM_{10} particles, but to a lesser extent they also contain $PM_{2.5}$. The emissions of primary suspended particles from the transport sector, after a period of limited fluctuation (1990-2009), have been gradually reduced from 2010 onwards, so that in 2017 they are reduced by 28.1% and 34% compared to 1990, for PM_{10} and $PM_{2.5}$ respectively (Graph 32).

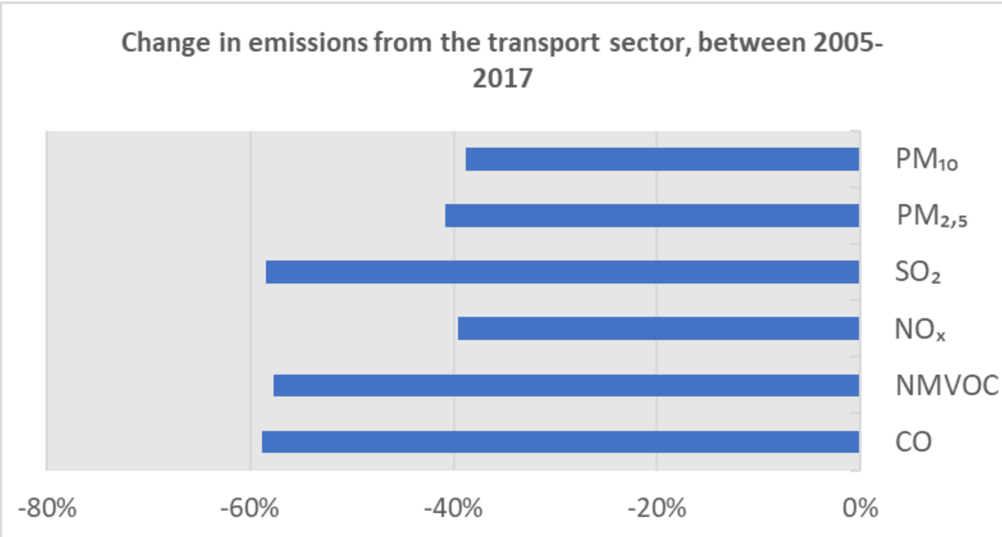
Graph 32: Annual variation of emissions of primary particles and precursors of secondary particles from the transport sector



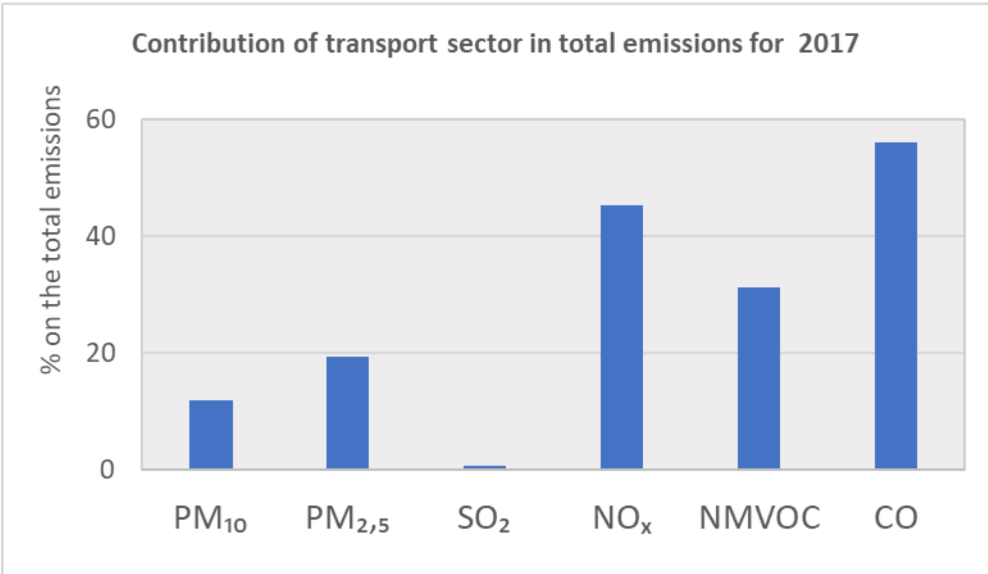
In 2017, all air pollutants under study from the transport sector show a significant decrease compared to 2005 (Graph 33), exceeding 38% separately for each pollutant. The reduction in SO_2 emissions, recorder at 58.4%, is mainly attributed to the reduction in road transport emissions.

The relative contribution of the transport sector in the total emissions of the various pollutants for 2017 is shown in Graph 34. While for SO_2 the contribution is limited to 0.7%, for NO_x, NMVOCs and CO, the transport sector has the largest contribution to the total emissions (45.2%, 31.3% and 56% respectively).

Graph 33: Change in pollutants emissions from the transport sector, between 2005-2015



Graph 34: Contribution of transport sector in national pollutants emissions for 2017



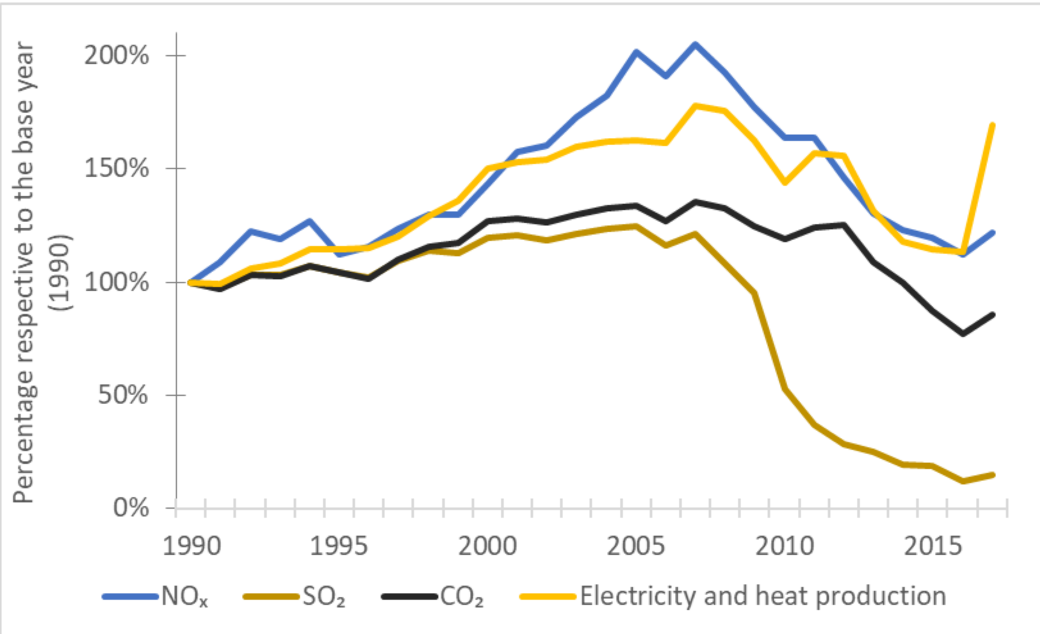
5. Intensity of emissions of electricity and heat generation sector

Monitoring and controlling the quantities released according to the energy produced (emission intensity) by the power plants is central in the effort to limit their environmental impacts. The EEA ENER 008 indicator offers a measure to track the relative changes in gas emissions in relation to the amount of energy (electrical and / or thermal) produced by the same processes leading to their emission.

Graph 35 shows the annual change of gas emissions from the use of fossil fuels to produce electricity and heat for public use, as well as the corresponding change in energy production. It is observed that after the phase of steady growth of both production and emissions for the period 1990-2007, from 2008 onwards there is a gradual decrease for all emissions.

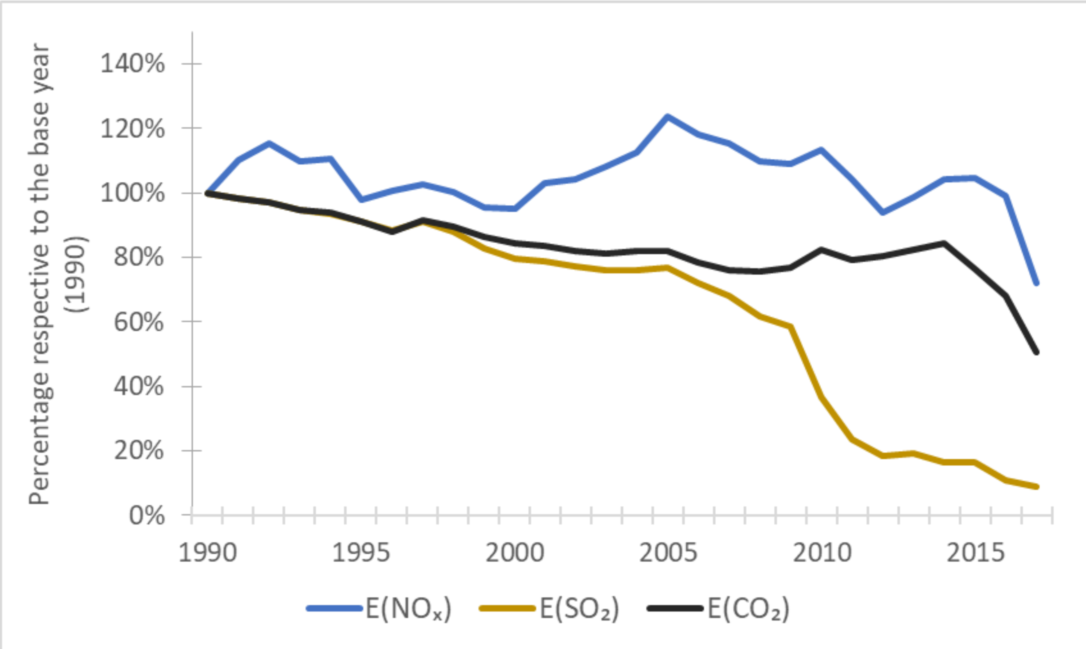
Emissions reductions have been significant over the last decade, recording a decrease of 86.1% for SO_2, 36.7% for NO_x and 35.3% for CO_2 during the period 2008-2017. Overall, fluctuations in emissions appear to track the variability in electricity production, mainly in terms of annual fluctuations and less in terns of absolute rate of change. Compared to the base year 1990, in 2017 SO_2 emissions now account for only 15% of the corresponding 1990 emissions, CO_2 emissions are reduced by 14%, and NO_2 emissions are increased by 22%.

Graph 35: Annual variation in production of public electricity and heat from fossil fuels and corresponding emissions



The intensity of emissions per unit of produced energy is shown in Graph 36, which shows a sharp decrease in the intensity of SO_2 emissions, which is particularly pronounced during the period 2009-2012, while at 2017 it is at 9% compared to the base year 1990. The intensity of NO_x emissions shows greater variability and after a period of strengthening in 2001-2008, in 2012 it was for the first time since 2000 below the levels of the base year, while at 2017 it accounts for the 72% of the emissions of the base year. The intensity of CO_2 emissions is more stable with a steady downward trend, recording a decrease of 49% in 2017 compared to the base year 1990.

Graph 36: Annual variation of the intensity of emissions per unit of produced electricity and heat from fossil fuels



Air quality status

Monitoring the evolution of air quality is based on the available measurement data from the stations of the National Air Pollution Monitoring Network, which covers most of the country's major urban centers.

Table 6. Measurement Stations of the National Air Pollution Monitoring Network - 2018

Station	Characterization	Measured Pollutants						
		SO_2	NO_x	CO	O_3	PM_{10}	$PM_{2.5}$	C_6H_6
ATHENS [a]								
Ag. Paraskevi – Ag. PAR.	Suburban-Background		x		x	x	x	
Thrakomakedones – THR.	Suburban-Background		x		x	x	x	
Koropi - KOR	Suburban-Background	x	x		x	x		
Liosia - LIO	Suburban-Background		x		x	x		
Lykovrysi - LYK	Suburban-Background		x		x	x	x	
Nea Smyrni - SMY	Urban - Background		x	x	x	x		x
Peristeri - PEP	Urban - Background		x		x	x		
Athens - ATH	Urban - Traffic	x	x	x	x			
Aristotelous - ARI	Urban - Traffic	x	x			x	x	
Marousi - MAR	Urban - Traffic		x	x	x	x		
Patision – PAT	Urban - Traffic	x	x	x	x			x
Piraeus – PIR	Urban - Traffic	x	x	x	x	x	x	x
Agricultural - GEO	Suburban -Industrial		x	x	x			
Eleusina - ELE	Suburban -Industrial	x	x		x	x	x	x
THESSALONIKI [b]								
University - AUTH	Urban - Background	x	x		x			
Kalamaria -KAL	Suburban-Background	x	x	x	x	x		
Neochorouda - NEOC	Suburban-Background		x		x	x		
Panorama - PAN	Suburban-Background		x		x	x	x	
Ag. Sofia - AG.SOF.	Urban - Traffic	x	x	x	x	x	x	x
Kordelio - KOR	Suburban -Industrial	x	x	x	x	x		
Sindos - SIN	Suburban -Industrial	x	x	x	x	x		
OTHER URBAN AREAS [b]								
Aliartos - ALI [a]		x	x		x	x	x	
Amfissa - AMP	Urban - Background					x		
Volos - VOL	Urban - Background	x	x	x	x	x	x	
Ioannina - IOA	Urban - Background		x		x	x	x	x
Kavala - KAV	Urban - Background							x
Karpenissi - KAR	Urban - Background					x		
Lamia - LAM	Urban - Background					x		
Livadia - LIV	Urban - Background					x		
Chalkida - CHA	Urban - Background					x		
Larissa - LAR	Urban - Traffic	x	x	x	x	x		
Patras 1 - PAT-1	Urban - Traffic	x	x	x	x	x	x	x
Patras 2 - PAT-2	Urban - Traffic	x	x	x		x		

[a] They operate under the responsibility of the Ministry of Environment and Energy, [b] They operate under the responsibility of the Regions

There are 14 measuring stations in the wider area of Athens: 7 urban and suburban background stations, 5 traffic stations and 2 suburban-industrial stations. Due to the gradual decentralization of industrial activities from the center of the Basin, the Agricultural Station can now be considered to gather the characteristics of a suburban background station.

There are 7 measuring stations in the wider area of Thessaloniki: 4 urban and suburban background stations, 1 traffic station in the city center (Agia Sofia), and 2 industrial stations in the Eleftheriou-Kordeliou and Sindou areas. It is noted that the Kalamaria background station does not provide with measurement data after 2015.

The National Air Pollution Monitoring Network has stations installed in 10 other major cities in the country, as well as a station (Aliartos) operating under the European Monitoring and Evaluation Program (EMEP) for the transport of transboundary pollution over long distances. It is noted that in Volos, only suspended particles have been monitored during the last decade.

Background stations, which represent the largest part of the population, are used to examine the evolution of air quality in urban areas. It is noted that in cities with no background stations (Patra and Larissa) traffic stations measurements are used. In the cases of Athens and Thessaloniki where data from multiple sites of background or traffic conditions are available, the levels of concentration of air pollutants are reflected in a range of values.

The assessment of atmospheric air quality in an urban area is carried out by examining compliance with the limit values provided by the Directives 2008/50/EU and 2004/107/EU on the protection of human health. In particular, the air pollutants and the limit values taken into account for the evaluation are the following:

- O_3: daily maximum 8hrly mean value (93.15° annual percentile)- 120 μg/m^3
- NO_2: mean annual value - 40 μg/m^3
- PM_{10}: mean daily value (90,4° annual percentile) - 50 μg/m^3
- $PM_{2.5}$: mean annual value - 25 μg/m^3
- SO_2: mean daily value (99,2° annual percentile) - 125 μg/m^3
- Benzene (C_6H_6): mean annual value - 5 μg/m^3
- Benzo (a) pyrene: mean annual value - 1 ng/m^3

To assess the impact of traffic on air pollution levels, a comparison is made between the measurements from the background stations and the traffic stations, usually located in central points of urban areas. This study is performed for nitrogen dioxide (NO_2) pollutants and suspended particles (PM_{10} and $PM_{2.5}$) in the greater area of Athens and Thessaloniki, as traffic and background stations do not operate simultaneously in other cities of the country.

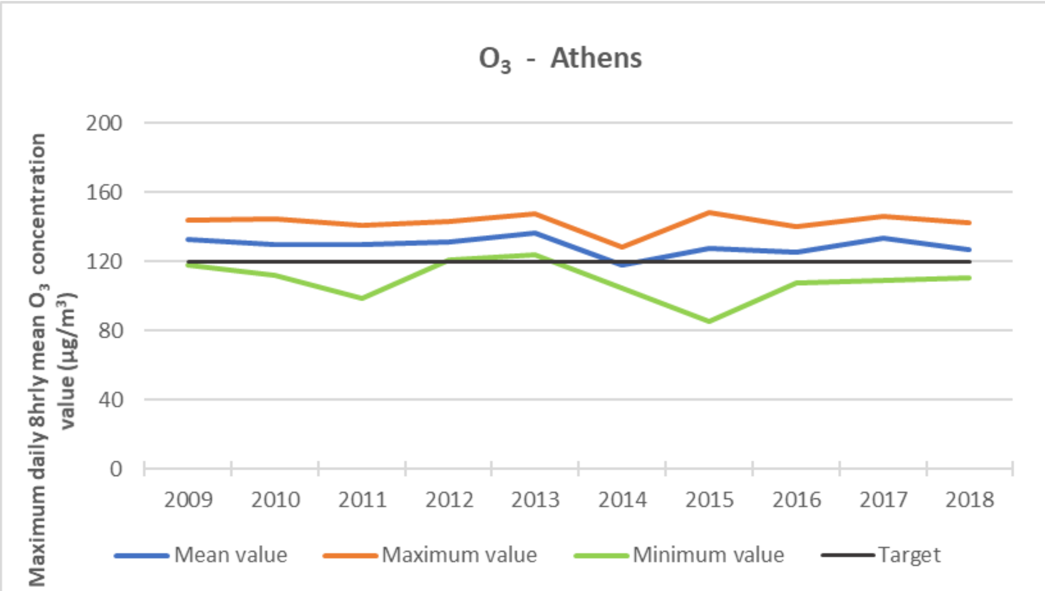
Data on annual time series statistics for each station were obtained from the Air Quality Database maintained by European Environmental Agency (AirBase up to 2011 and AIDE F for 2012-2018), taking into account station measurements with at least 75% collection of valid data per calendar year. It is noted that this percentage is less stringent than the 90% provided in the Directive 2008/50/EU on the examination of compliance with limit values in order to enhance the assessment capability, without significantly increasing the uncertainty. For years when the minimum of 75% completeness is not met, the data are marked with a distinct label as indicative.

1. Ozone

To monitor the temporal variation in the levels of ozone concentration, data from the maximum daily 8hrly mean concentration value (expressed as the 93.15° percentile of the maximum daily 8hrly values of the year corresponding to the 26th maximum value within the year) are used as an indicator which examines whether or not the target for human health protection set by the legislation is exceeded (120 μg/m³)[2].

In the wider area of Athens, the levels of the indicator are on average consistently higher than the target (Graph 37). It is characteristic that the target is exceeded in 5 out of 8 background stations almost during the entire decade. Regarding the comparison with the limit value (3 years average) *, exceedances were recorded in 6 out of 8 background stations for the period 2016-2018. Due to the secondary nature of the pollutant, the occurrence of elevated levels depends on both the intensity of the primary emissions and the climatic conditions of the Basin that promote tropospheric ozone formation. The intense sunshine, the higher temperatures, and the basin's topographic features increase the frequency of high O_3 levels, especially during the summer period, but also during the other months of the year.

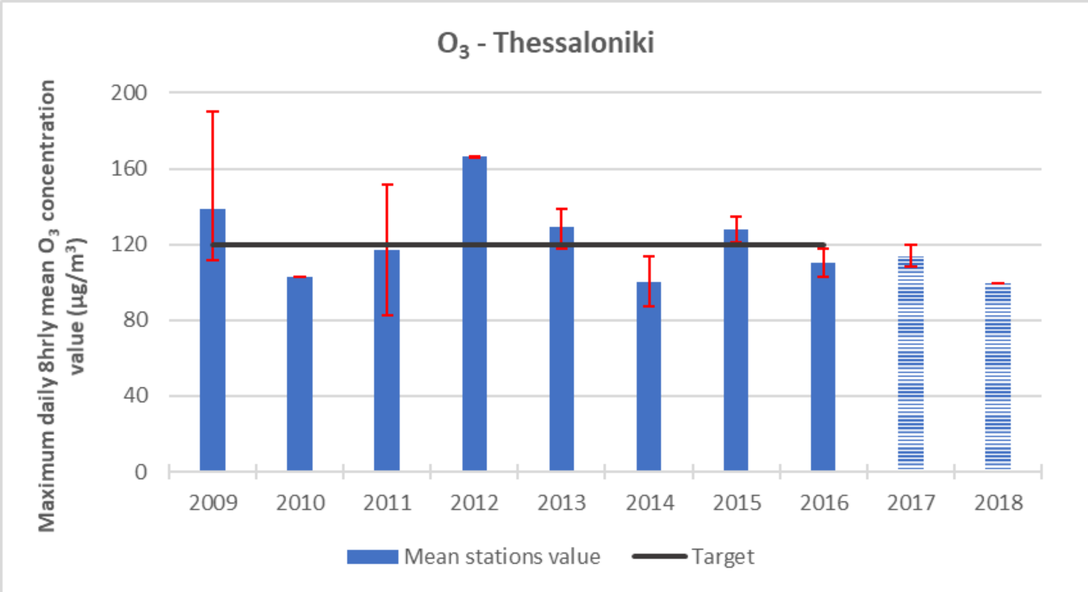
Graph 37: Maximum daily 8hrly mean O_3 concentration of background stations in the wider area of Athens (2009-2018)



In the case of Thessaloniki background stations (Graph 38), target exceedances are also recorded, though with greater variability and less intensity compared to Athens. Regarding the comparison with the limit value (3 years average), there were no exceedances for the three-year period 2016-2018. It is worth noting that the meteorological conditions of northern Greece are less favorable for the processes of photochemical ozone formation compared to Athens.

[2] According to the law, the limit value of 120 mg/m³ (should not exceed more than 25 days per calendar year on average in 3 years) is the maximum daily 8hrly mean in 3 years and the long-term target 120 mg/m³ is the maximum daily 8hrly mean in a year.

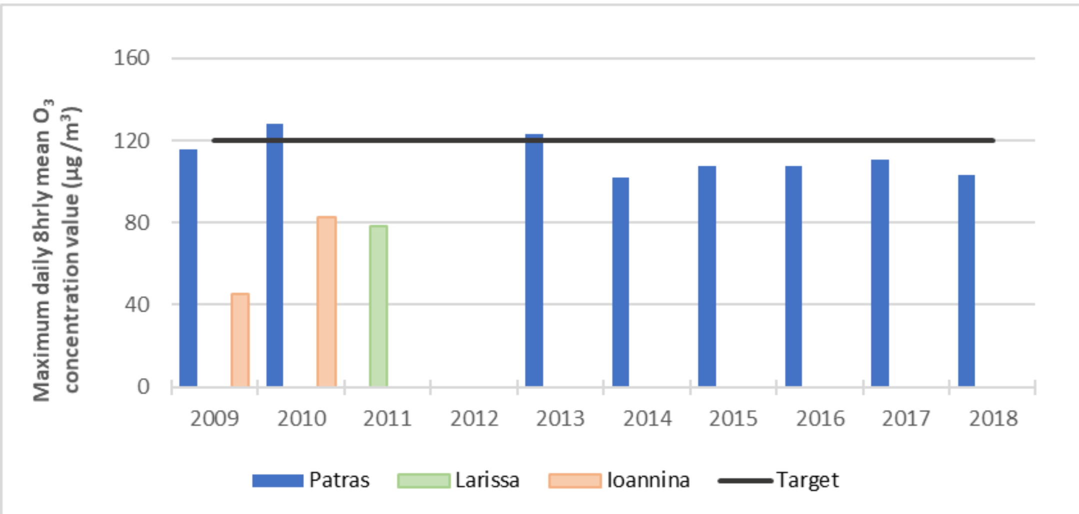
Graph 38: Maximum daily 8hrly mean O_3 concentration value of background stations in the wider area of Thessaloniki (2009-2018)



** Unsatisfactory completeness of dotted line measurements (2017-2018)*

There is no spatial and temporal representativeness of the monitoring of ozone levels for the rest of the country. Ozone concentration levels are systematically monitored only for Patras, where compliance with the target has been observed for the last five years. For the years that there is available data for the cities of Ioannina and Larissa, the target is not exceeded (Graph 39). Regarding the comparison with the limit value (3 years average), there were no exceedances for the three-year period 2016-2018.

Graph 39: Maximum daily 8hrly mean O_3 concentration value of other urban areas (2009-2018)

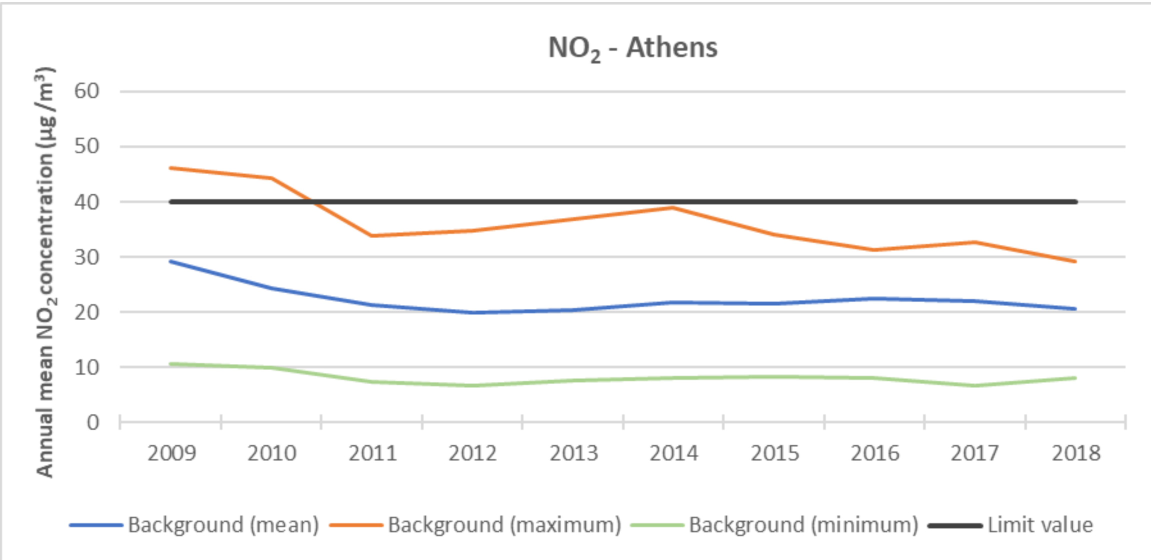


2. Nitrogen dioxide

To monitor the annual variation in nitrogen dioxide NO_2 concentration levels, the mean annual value index is used, which is compared with the annual limit value for the protection of human health (40 μg/m^3).

It is characteristic that in the wider aera of Athens (Graph 40) after 2010 there are no longer any exceedances of the limit value in the background positions, while there is trend to stabilize on average and at the same time a reduction of the maximum value of the index which is reduced by 34% in 2018 compared to 2010.

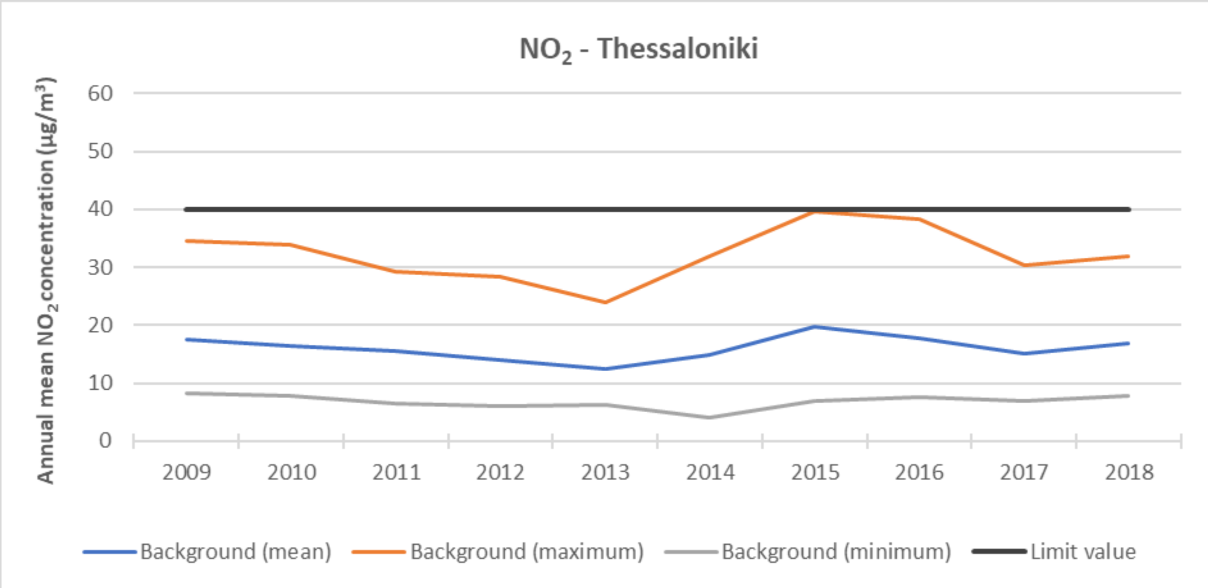
Graph 40: Mean annual NO_2 concentration of background stations in the wider area of Athens (2009-2018)



** Insufficient measurements completeness for the year 2018 (3 stations)*

In Thessaloniki it is observed that NO_2 levels in the background stations are lower than the levels in the Athens background stations, with no exceedances recorded during the last decade (Graph 41). It is worth noting that the time evolution of the index is not in line with the levels of Athens, noting an increase in the period 2013-2015, with the maximum value of the index reaching the limit value.

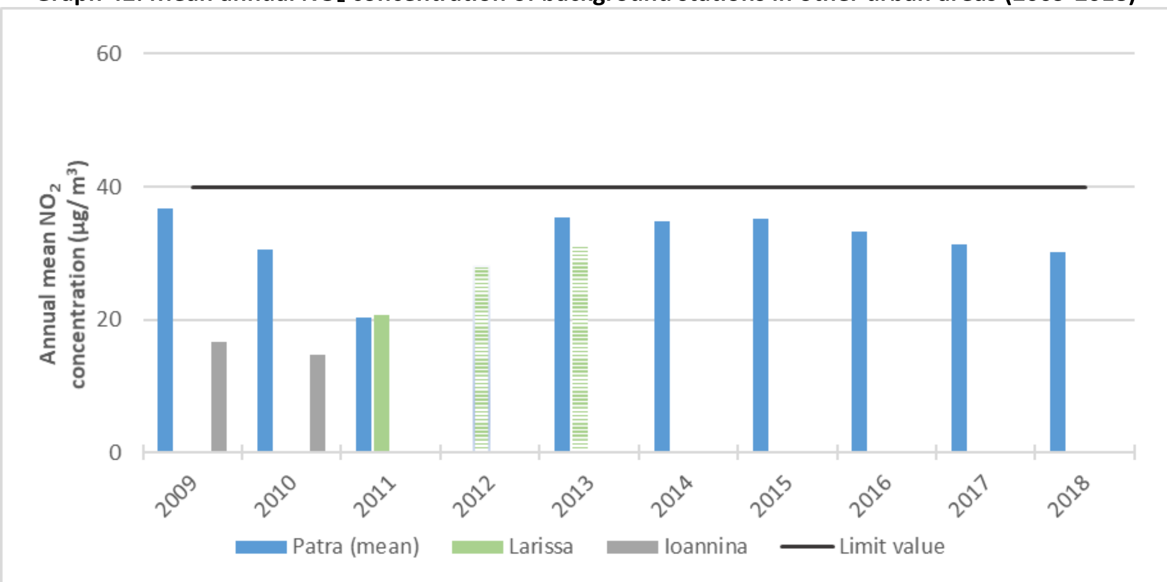
Graph 41: Mean annual NO_2 concentration of background stations in the wider area of Thessaloniki (2009-2018)



** Insufficient measurements completeness for the years 2009, 2010, 2014, 2017 & 2018.*

There is no spatial and temporal representativeness of monitoring NO_2 levels for the rest of the country. Systematic monitoring of NO_2 concentration levels is performed only for Patras, where compliance with the limit value has been recorded throughout the last decade. For the years with available data for the cities of Ioannina and Larissa the limit value is not been exceeded (Graph 42).

Graph 42: Mean annual NO_2 concentration of background stations in other urban areas (2009-2018)



** Insufficient measurements completeness with dotted line (Larisa, 2012-2013)*

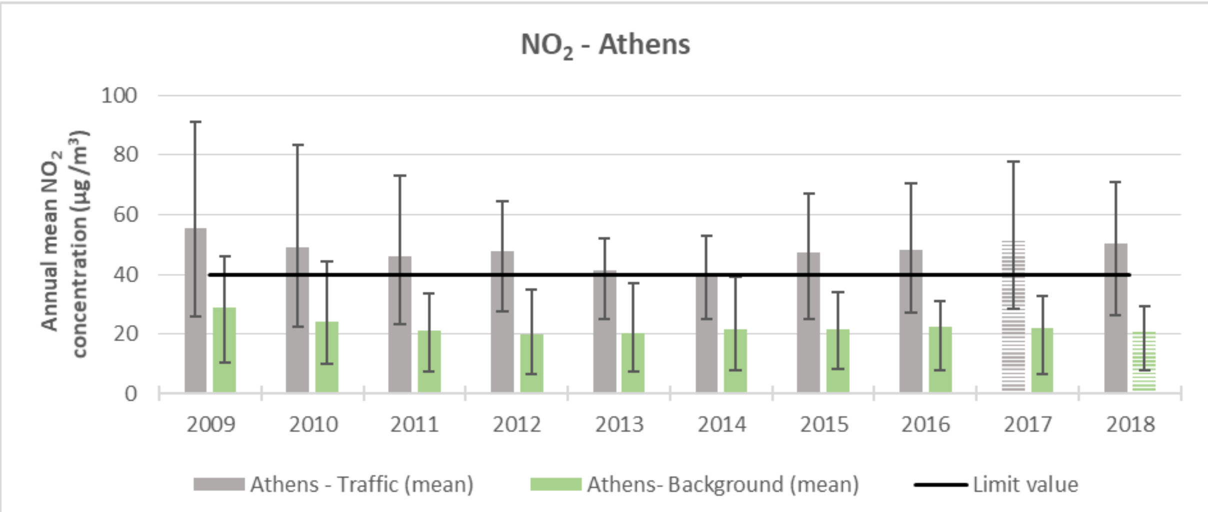
Examination of NO_2 levels due to traffic

Throughout the period 2009-2018, the annual limit value is exceeded at Athens traffic stations. The station with the highest prices is Patision, which determines the maximum value of the index in traffic locations. At Maroussi station, which is relatively further from the nearest high-traffic road, the lower concentrations are recorded, which do not exceed the limit value. For 2016 and 2017, 3 out of 5 traffic stations record concentrations above the threshold value, while in 2018 there are exceedances in 4 traffic positions.

Over time, a relatively similar evolution of NO_2 levels has emerged between background and traffic stations. After 2014, there is an increase in the mean levels of the indicator, especially in traffic stations.

The mean value of the indicator of the mean annual nitrogen dioxide value of traffic stations over the period 2009-2018 is on average 25 μg/m^3 (2.1 times) higher than that of background stations.

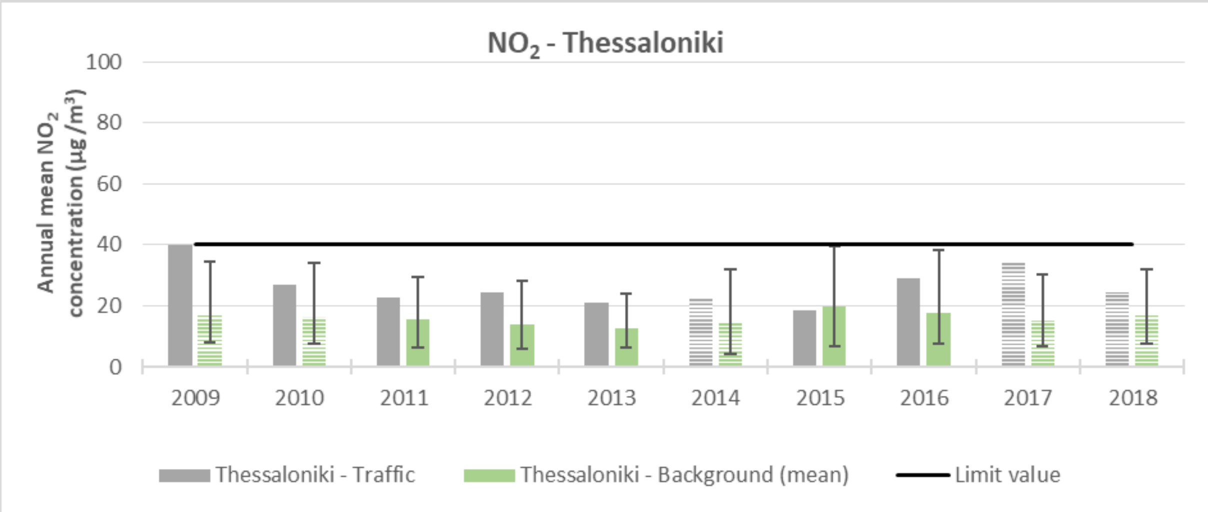
Graph 43: Comparison of mean annual NO_2 concentration of background and traffic stations in the wider area of Athens (2009-2018)



** Insufficient measurements completeness with dotted line (2 stations in 2017 and 3 stations in 2018)*

There is a traffic station in Thessaloniki (Agia Sophia Square), which has not exceeded the annual limit value since 2009. Over time, a relatively similar evolution of NO_2 levels has been recorded among the underlying traffic stations until 2013, which is not maintained thereafter. The concentration levels of Ag. Sofia traffic station, during 2009-2018, are on average 10 μg/m^3 (1.7 times) higher than the background station levels.

Graph 44: Comparison of the mean annual NO_2 concentration of background and traffic stations in the wider area of Thessaloniki (2009-2018)



** Insufficient measurements completeness with dotted line*

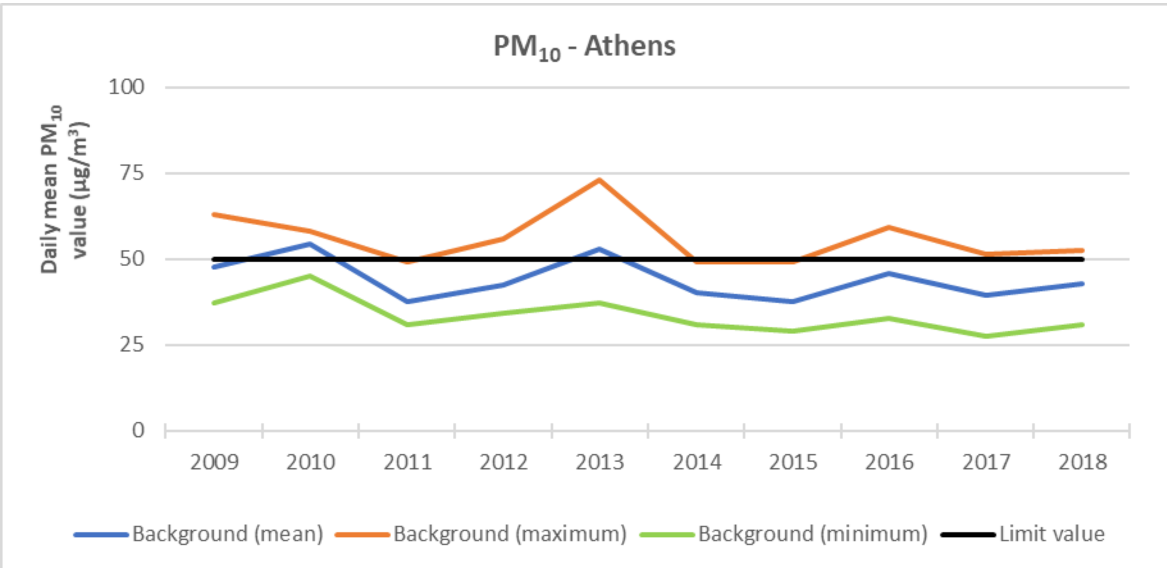
3. Suspended particles

(a) PM_{10}

To monitor the annual evolution of the concentration levels of suspended particles PM_{10}, the index of the mean daily value is used (expressed as the 90.4° percentile corresponding to the number of 35 exceedances in a full annual time series), which examines the compliance with the daily limit value for the protection of human health (50 μg/m^3).

Graph 45 shows a slight decrease in the index at the background stations of the wider area of Athens of 8% over the past decade, and in particular as regards the maximum values of the index by 18%. Despite the decrease in PM_{10} concentration levels, exceedances are recorded in 1 main station in the period 2009-2013 and in 2 stations in 2016-2018. For interpreting the results, it is necessary to take into account that the effect of phenomena of cross-border transport of suspended particles of natural origin (e.g. African dust) are changing over the years. According to the statistics of the Ministry of Environment Annual Reports, when removing the natural contribution, exceedances of the daily limit value due to anthropogenic activity are recorder only in the years 2009 and 2013 in 1 background station (Lykovrisi). Increased PM_{10} concentration levels after 2011 are also due to the increased contribution from biomass combustion for domestic heating during the winter months.

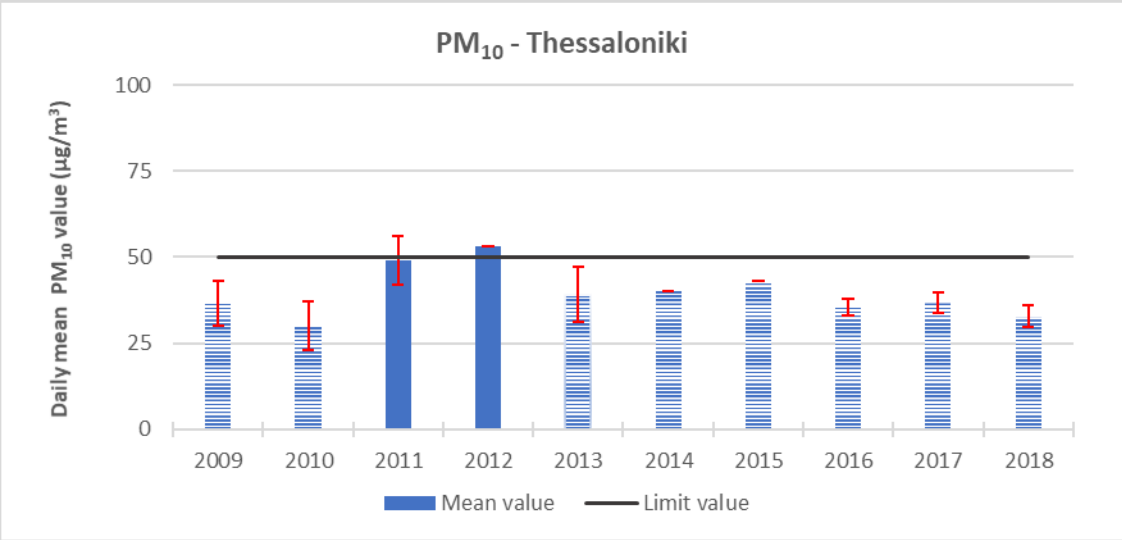
Graph 45: Mean daily PM_{10} concentration of background stations in the wider area of Athens (2009-2018)



** PM_{10} measurement data is available at 4 stations in 2009-2015 and at 7 stations in 2016-2018*

In Thessaloniki, although PM_{10} levels are monitored at background locations, with systematic monitoring in at least one station (Panorama), the data do not have the required completeness of measurements (> 75%), except for 2011 and 2012. Graph 46 illustrates indicatively the statistics of the last decade, showing a decreasing trend of index of mean daily PM_{10} concentration after 2012.

Graph 46: Mean daily PM_{10} concentration of background stations in the wider area of Thessaloniki (2009-2018)

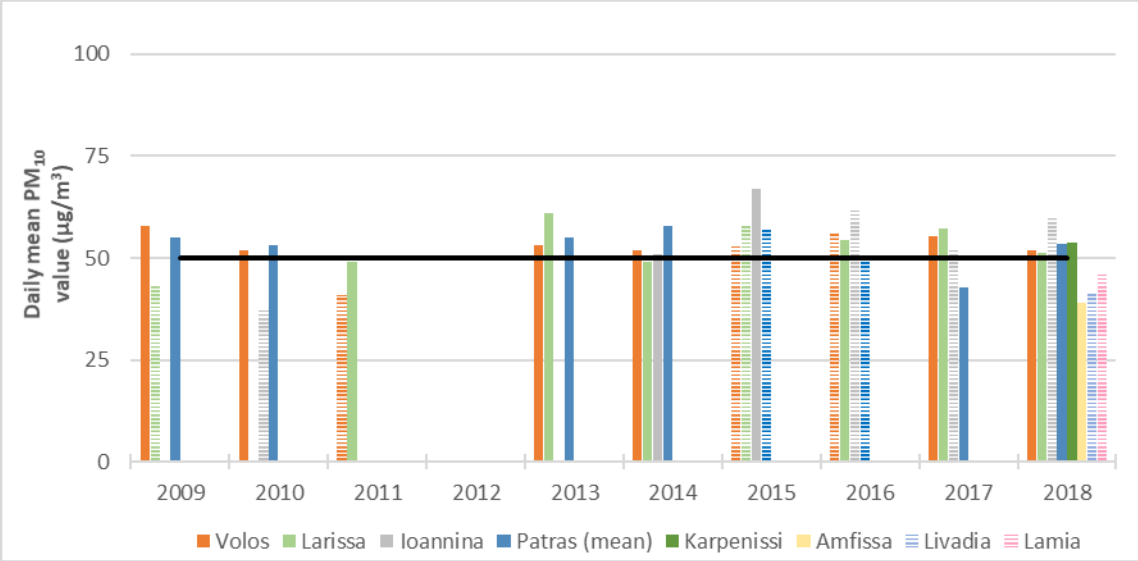


** Insufficient completeness of measurements with dotted line*

According to the Ministry of the Environmnet Annual Reports, after removal of the natural contribution of dust transfer, exceedances of the daily limit value remain for the years 2011 and 2012 at the Panorama station. It should be noted that the increased use of biomass in domestic heating during the winter months during the economic recession is believed to contribute in the observed increase of the PM_{10} levels also in Thessaloniki in the aforementioned years.

Graph 47 shows the available time series of the index of the mean daily PM_{10} concentration of other urban areas of the country. For the filling of the time series and the presentation of the more cities possible, measurements that do not have the required completeness (at least 75%) and which are taken as indicative, are also included.

Graph 47: Mean daily PM_{10} concentration of other urban areas (2009-2018)



** Insufficient measurements completeness with dotted line*

The data show that in 5 out of the 8 cities where PM_{10} measurements are carried out, exceedances were recorded in the period of 2009-2018. Patras and Larissa are expected to have relatively increased PM_{10} levels given that the measurements come from traffic stations.

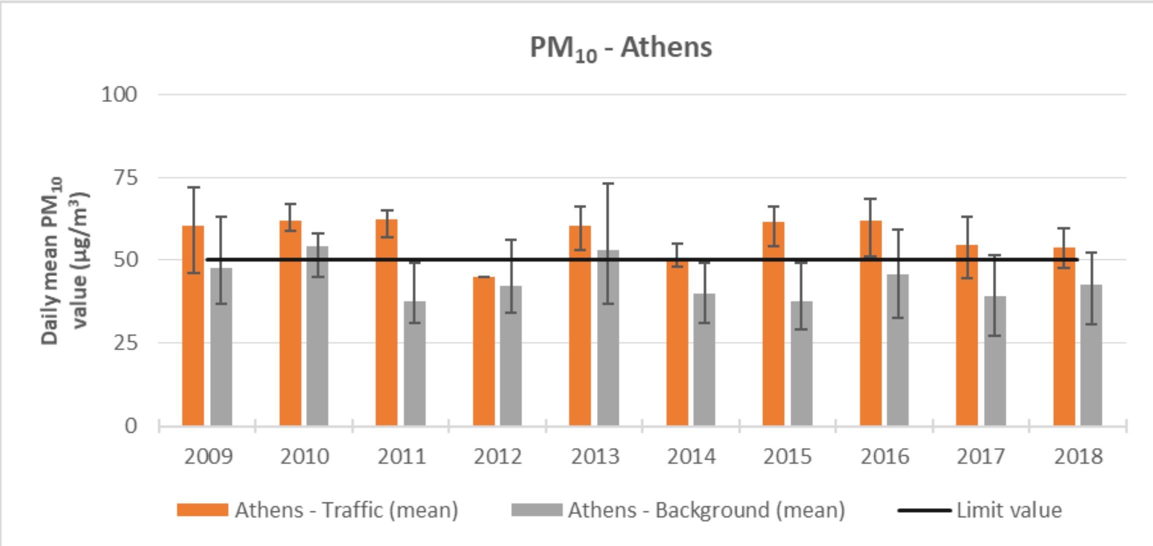
The above results should take into account the natural contribution that inevitably affects the interpretation of the excesses. In 2018, while excesses are recorded in 5 cities, when removing the physical contribution, there is no exceedance in any city due to anthropogenic activity. According to the statistics of the Ministry of Environment Annual Reports, exceedances due to anthropogenic activity in the period 2009-2018 are recorded in Patras in 2009 and 2016, in Larissa in 2013, 2015 and 2017, in Volos in 2017 and in Ioannina in 2015.

Examination of PM_{10} levels due to traffic

The index levels of the mean daily value in the Athens traffic stations are constantly higher than the daily limit value in 2009-2018, with exceedances being recorded mainly at Aristotelous and Piraeus stations, and less at Maroussi station. The mean index value of the mean annual PM_{10} value for traffic stations during 2009-2018 is on average 15 μg/m^3 (1.4 times) higher than that of background stations.

According to statistics of the Annual Reports of the Ministry of Environment, when subtracting the natural contribution, the intensity of exceedances is lower by 30% on average (range 7-63%), while no exceedances from anthropogenic activity are recorded at Marousi Station after 2011. In the period 2013-2014 there are no exceedances of anthropogenic origin, similarly and in the year 2018.

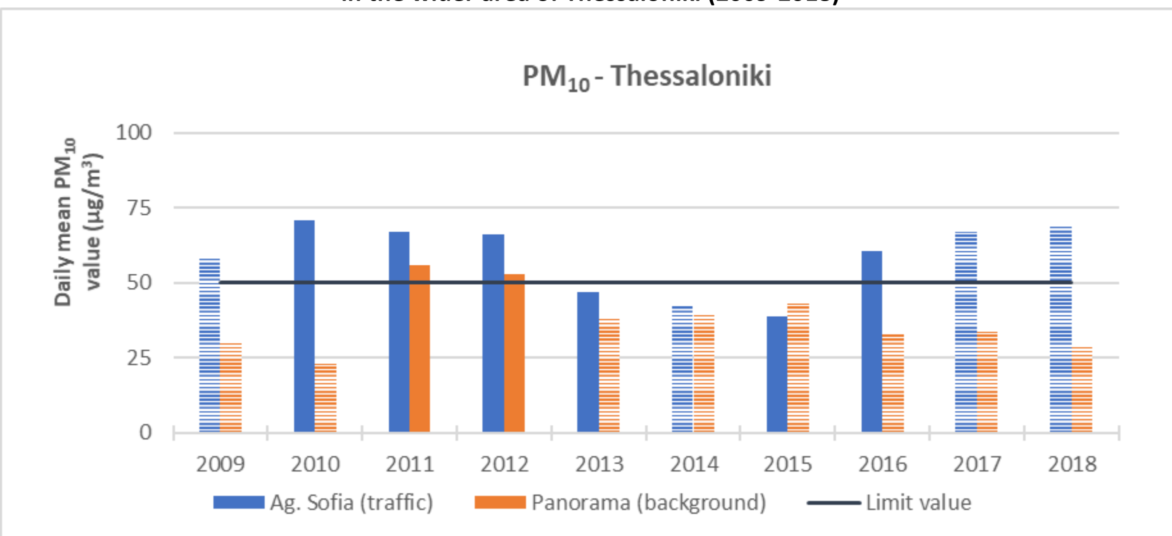
Graph 48: Comparison of mean daily PM_{10} concentration of background and traffic stations in the wider area of Athens (2009-2018)



In Thessaloniki there is a traffic station (Agia Sophia Square), where, in addition to the period 2013-2015, continuous exceedances of the annual limit value are recorded. For the background levels, the Panorama station is indicated, which, although available in time series, does not have the required completeness (> 75%) in data to make it possible to compare the levels of the index of the mean annual PM_{10} value among traffic - background stations in the long run.

According to the statistics of the Ministry of Environment Annual Reports, the intensity of observed exceedances at the Ag. Sofia traffic station is much lower due to the natural contribution of 20% on average (3-34% range).

Graph 49: Comparison of mean daily PM_{10} concentration of background and traffic stations in the wider area of Thessaloniki (2009-2018)



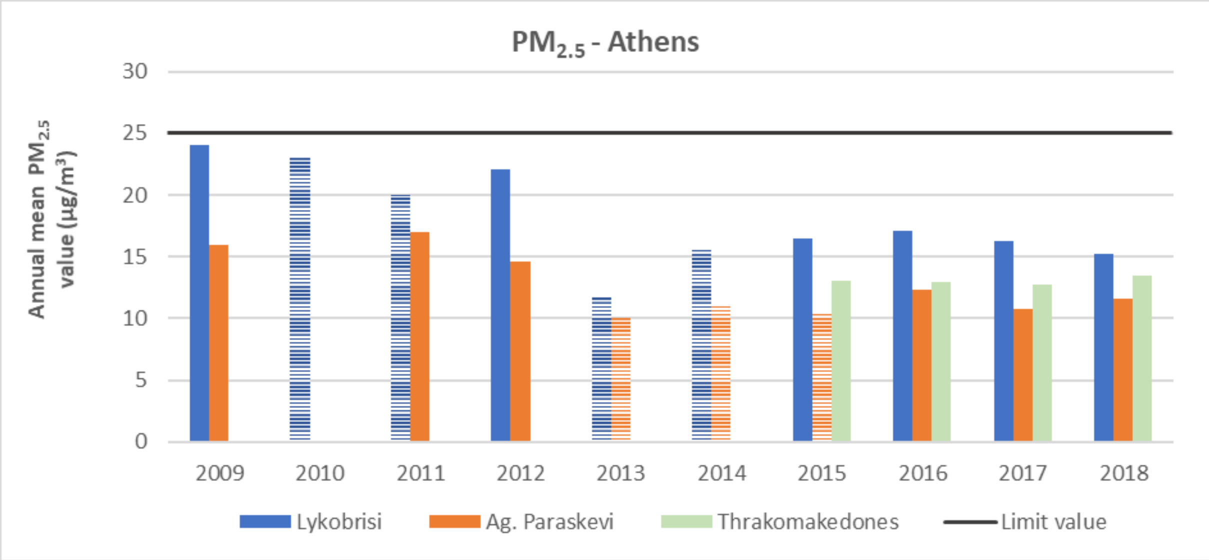
** Insufficient measurements completeness with dotted line*

(b) $PM_{2.5}$

The monitoring of the annual variation of the concentration levels of $PM_{2.5}$ suspended particles is carried out with the index of mean annual value, which examines the compliance with the annual limit value for the protection of human health (25 μg/m^3).

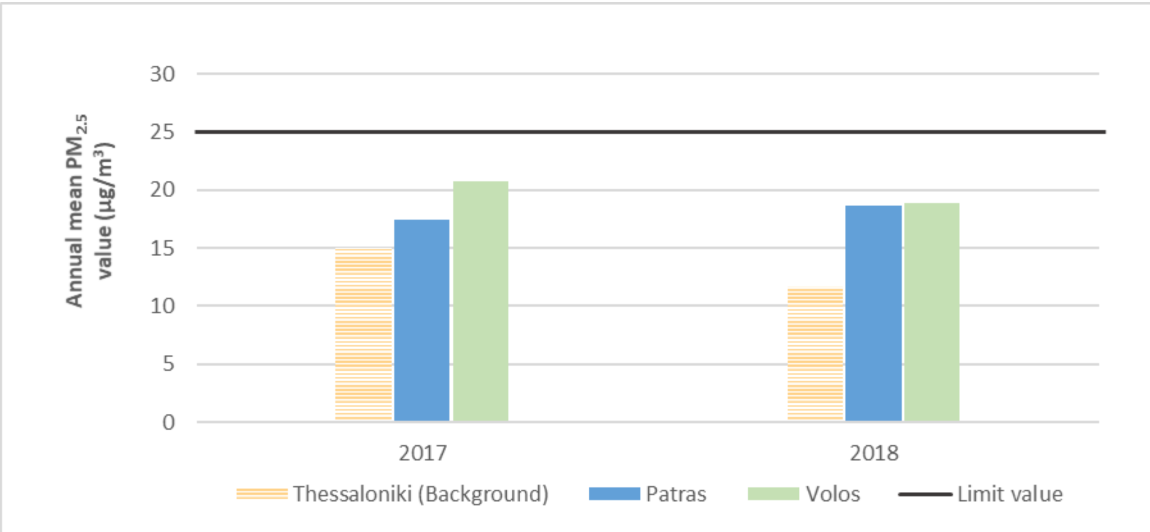
There are 2 background stations in the wider area of Athens to monitor the concentration levels of $PM_{2.5}$ suspended particles (Lykovrisi, Agia Paraskevi), and an additional one (Thrakomakedones) was added following the upgrade of the National Air Pollution Monitoring Network in 2015. In accordance with the PM_{10} concentration levels, $PM_{2.5}$ concentration levels are gradually decreasing, which do not exceed the annual limit value in all background stations during the period 2009-2018. After 2017, data on the index levels of the mean annual $PM_{2.5}$ value are now available and in the other 3 cities of the country (Thessaloniki, Patras and Volos) are now available, which show compliance with the annual limit value.

Graph 50: Mean annual $PM_{2.5}$ concentration of background stations in the wider area of Athens (2009-2018)



** Insufficient measurements completeness with dotted line*

Graph 51: Mean annual $PM_{2.5}$ concentration of other urban areas (2017-2018)



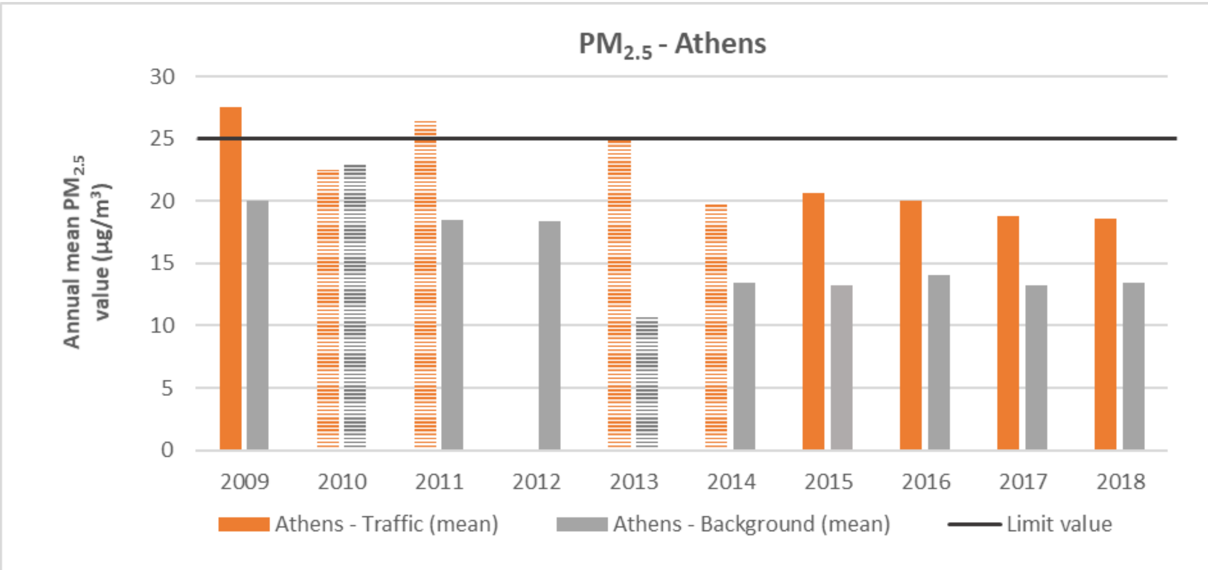
** Insufficient measurements completeness with dotted line*

Examination of $PM_{2.5}$ levels due to traffic

Up to 2015 there was a traffic station to monitor the index levels of the mean annual $PM_{2.5}$ value (Piraeus), which ceased to record exceedances after 2011. The additional traffic station (Aristotelous) records similar levels of $PM_{2.5}$. After 2016 the indicator in both stations records values below 20 μg/m³.

Given the few stations and the lack of time series with sufficient completeness (at least 75%) throughout 2009-2018, it is not possible to compare $PM_{2.5}$ concentration levels over time between background-traffic levels. The data for the period 2015-2018 show a similar decreasing trend. The mean index value at the stations during the same period is 5.9 μg/m³ (1.4 times) higher than the value of background stations.

Graph 52: Comparison of mean annual $PM_{2.5}$ concentration of background and traffic stations in the wider area of Athens (2009-2018)



** Insufficient measurements completeness with dotted line*

In Thessaloniki, although a traffic station is operating to monitor $PM_{2.5}$ concentration levels since 2017, the measurements are of insufficient completeness to draw safe conclusions.

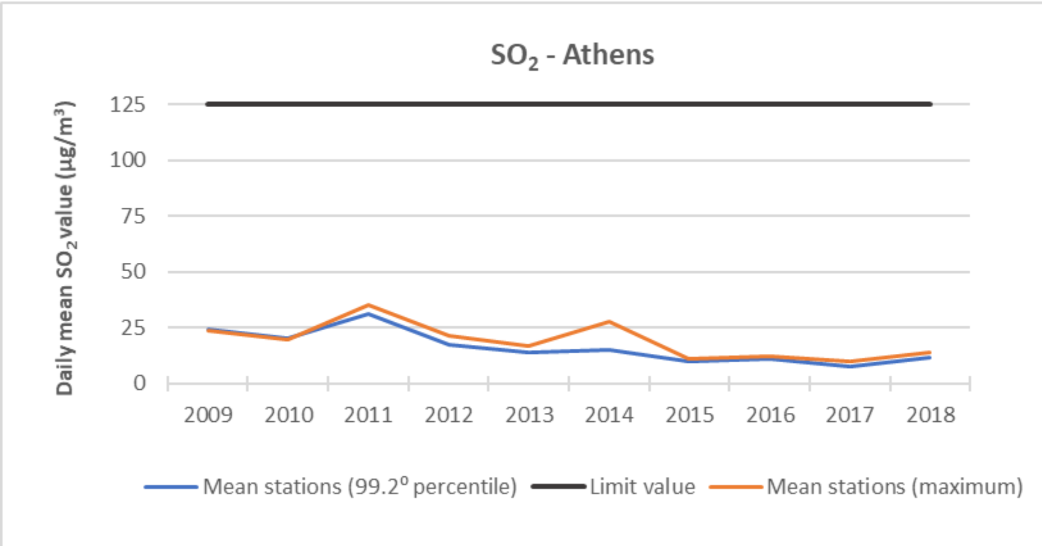
4. Sulfur dioxide

To monitor the annual evolution of the concentration levels of sulfur dioxide SO_2, the index of the mean daily value (expressed as 99.2° percentile corresponding to the number of exceedances 3 in a complete annual time series), is used, which is compared with the daily limit value for the protection of human health (125 μg/m³).

As shown in graph 53 for the background stations in the wider area of Athens, no more than the 3 permitted exceedances of the limit value per year have been observed. This applies not only to the Athens background stations but also to all background and traffic stations in the country (also for industrial stations).

The low levels of SO_2 concentrations for more than a decade are the result of legislative action to limit sulfur in fuels used in transportation, domestic heating and industry.

Graph 53: Average daily SO_2 concentration of background stations in the wider area of Athens (2009-2018)



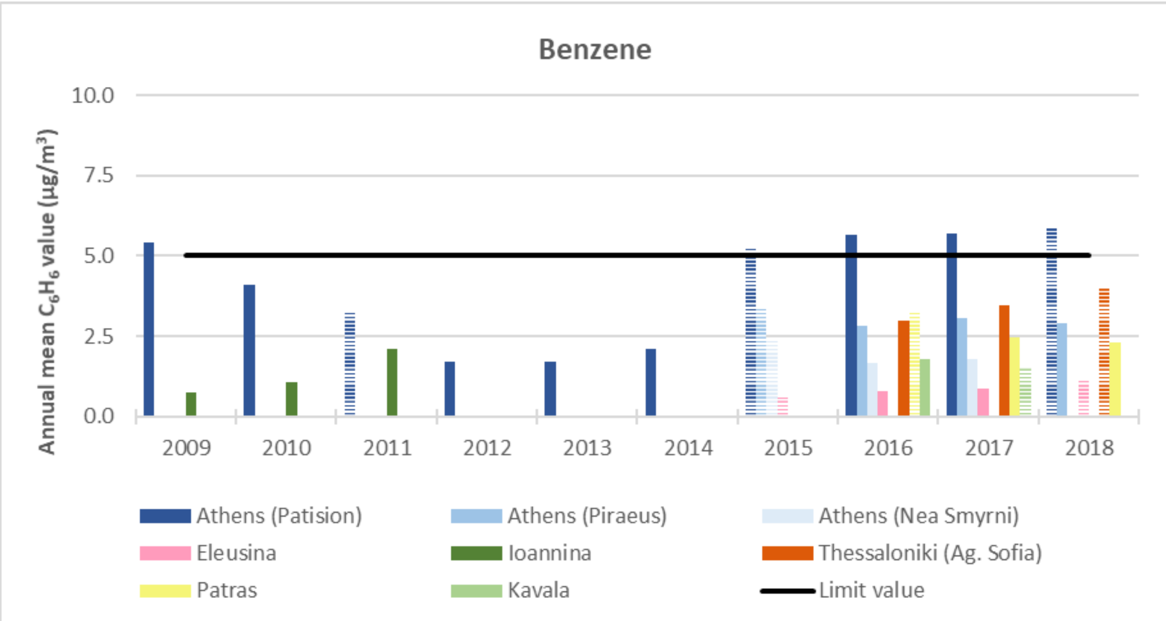
5. Benzene

The monitoring of the time variation of the concentration levels of benzene is performed with the indicator of the mean annual value, which is compared with the annual limit value for the protection of human health (5 μg/m^3).

Until 2014, data on the recording of benzene levels in Athens exist only for the central traffic station on Patision Street. In the period of 2010-2014, the levels of the index were lower than the annual limit value. In the years 2008-2011, benzene concentrations data for the Ioannina background station are also reported with sufficient completeness, indicating that the index levels of the mean annual value remained below the limit value for the whole period.

After the upgrade of the National Air Pollution Monitoring Network, the benzene monitoring is carried out in 3 additional sites in the wider area of Athens, while measuring instruments have been installed and in 3 other cities (Thessaloniki, Patras, Kavala). In the wider area of Athens, in 2016-2018, mean annual levels of benzene below the limit value are observed at all stations except the Patissia traffic station. At the same time, the index levels of the mean annual value of benzene in Thessaloniki and Kavala are lower than the limit value.

Graph 54: Mean annual benzene concentration in urban areas (2009-2018)



** Insufficient measurements completeness with dotted line*

6. Benzo (a) pyrene

The monitoring of the concentration levels of benzo(a)pyrene is carried out with the indicator of the mean annual value, which is compared with the annual limit value for the protection of human health (1 ng/m^3).

Although the required minimum percentage of valid data is 14% for indicative measurements according to Directive 2004/107/EU, from the available benzo(a)pyrene measurements it appears that the above minimum percentage is only covered at Aristotelous traffic station in Athens for the year 2017, recording a value of 0.34 ng/m^3, well below the limit value.

Conclusions and assessments of environmental policy objectives, guidelines and measures

Air quality in Greece has generally improved in recent decades. The reduction in the total national emissions of the main pollutants (NO_x, SO_2, $PM_{2.5}$, NH_3) is significant mainly due to cleaner electricity production (reduction of lignite plants in the total energy mixture, reduction of their atmospheric emissions by secondary measures, energy savings, RES), vehicles with newer technology cleaner engines etc.. According to the data for 2017 it is expected that the objectives of reducing national gas emissions set by the NEC Directive for 2020 will be achieved[3].

Regarding the urban air pollution, the evolution of measured concentrations of air pollutants over time shows that there is a downward trend or stabilization tendency, depending on the pollutant. This progress can be attributed to the reduction of pollutant emissions due to measures adopted in the previous decades which mainly concerned the technological upgrading of the passenger car fleet, the mandatory introduction of exhaust emission inspection and certification, the emission control measures from various sources, the use of fuels with higher quality standards/specifications, the expansion of metro lines and the introduction of tram in the public transport, the facilitation of circulation of public transports, the penetration of the natural gas in the domestic, industrial and tertiary sector and the completion of large road traffic projects. However, despite the improvement of the air quality, there are some exceedances of the air quality limit values of certain pollutants, mainly in Athens, as can be seen from the comparison of concentrations of measured pollutants with the applicable air quality limits.

The main characteristics of air pollution in urban areas of the country are summarized as follows:

- ozone remains almost stable whereas exceedances of limit values are frequent mainly in Athens, largely due to the country's climatic conditions
- PM_{10} suspended particulates exceeded daily limit values (steady trend over time) in Athens and Thessaloniki, mainly at traffic monitoring stations, which are largely due to natural contribution (e.g. African dust)
- $PM_{2.5}$ and SO_2 suspended particles do not exceed the limit value set by the EU in any monitoring station
- NO_2 exceedances of the limit values are monitored only in Athens and in road traffic monitoring stations
- benzene exceeds the limit value in a single traffic monitoring station in Athens
- no exceedances of benzo(a)pyrene are recorded in Athens

The EU'a clean air policy requires significant further improvement of air quality in order to reduce the effects on biodiversity and ecosystem services and, on the other hand, to approach the quality of the atmosphere gradually at the recommended quality levels of the World Health Organization (WHO) to address the long-term and short-term effects on public health.

[3]https://ekpaa.ypeka.gr/wp-content/uploads/2020/02/2018_1109_09-07-2018_NEC-2_ΕΛΚΕ-ΕΜΠ_ΤΕΛΙΚΟ-ΠΑΡΑΔΟΤΕΟ_Π2.pdf

Despite the undoubted improvement in air quality in Greece, air pollution is still a cause for concern. According to a study[4] of the Medical School of Athens University regarding the pollutants that exceed the recommended levels in the WHO guidelines, based on the most recently available data:

- approximately 6,500 premature deaths per year in urban areas of Greece (58% is related to premature deaths in Athens and 13% in Thessaloniki) are attributed to the long-term effects of $PM_{2.5}$,
- a little less than 5,000 premature deaths per year in the urban areas of Greece (69% is related to premature deaths in Athens and 12% in Thessaloniki) are attributed to the long-term effects of PM_{10} and
- around 160 premature deaths in Athens are attributed to the long-term effects of NO_2,

in relation to how many deaths or morbidity cases would be prevented if the concentrations of pollutants did not exceed the WHO recommended levels. Of these, more than 8,600 premature deaths are attributed to $PM_{2.5}$ exceedances, more than 5,700 to PM_{10} exceedances and approximately 160 to NO_2 exceedances.

The systematic renewal of the vehicle fleet, the energy shielding measures of the buildings, the further penetration of natural gas into central heating, the new metro lines and the reinforcement of public transport are measures expected to lead to further improvements. The preparation and implementation of the National Air Pollution Control Program[5] (under Directive 2016/2284) in conjunction with the implementation of the National Plan for Energy and Climate (Decision of the Government Economic Policy Council No. 4/2019 “Ratification of the National Plan for Energy and Climate”, B' 4893) in the coming decade are expected to effectively mitigate air pollutants emissions levels and contribute significantly to the achievement of air quality targets in country’s urban centers. Measures such as the gradual shutdown of lignite plants by 2028, the electrical interconnection of islands, the increase in the share of RES in electricity generation[6], the promotion of electric drive[7], the promotion of RES systems in buildings and scattered production systems through self-production and energy offset schemes[8], the improvement of the buildings energy efficiency through their renovation with the aid of programs such as "Saving at Home", the expansion of the natural gas distribution network, etc.

Furthermore, it could be studied the feasibility of measures aiming at:

- the acceleration the elaboration of the Operational Plan for the Fight against Air Pollution in Athens according to article 23 of Directive 2008/50,
- the improvement of railway infrastructure and accelerating the trains electrification.

[4] https://ekpaa.ypeka.gr/atmosfairiko-perivallon/syntaksh-ekthesis-epidraseis-sthn-yge/

[5] A relevant project has been assigned from NCESD to an external contractor – the phase of the public consultation is expected to begin.

[6] According to the National Plan for Energy and Climate, the national target for the share of RES in gross final electricity consumption in 2030 is to rise to at least 60%.

[7] According to the National Plan for Energy and Climate, the national target is in 2030 the 1/3 of new cars sales to be electric.

[8] According to the National Plan for Energy and Climate, it is planned that by 2030 the total operation of such power generation systems from RES of 1 GW will be able to cover the mean electricity consumption of at least 330,000 households.

- the increase in the participation of fixed track means of transport in the transport project (already launched projects for the expansion of the Athens metro and the operation of the Thessaloniki Metro, the expansion of the Suburban Railway, etc.),
- the renewal of the bus fleet with low-emission vehicles and / or alternative fuels
- the use of natural gas either in the form of compressed gas (CNG) for the road traffic of passenger and light vehicles (especially within the urban fabric) or in the form of liquefied natural gas for the traffic of heavy vehicles (especially on national roads), including biomethane use (in a mixture with natural gas)
- the improvement of vehicles emissions control procedures (e.g. exhaust gas control card, Vehicle Technical Control Center),
- the reduction of nitrogen oxide (NO_x) emissions in Athens (e.g. by restricting traffic for older vehicles as in other major European cities or imposing a fee for the circulation of older vehicles in the ring area financing, thus, tax reductions for the purchase of new ones, as an intermediate measure in the incentives for the pure electric (BEV) and plug-in hybrid (PHEV) vehicles to add incentives for the hybrids and possibly for the Euro 6 petrol engines with CO_2 emissions of up to 90 g / km to accelerate the fleet renewal),
- the implementation (policing) of the green ring using a cameras control system at key points and specialized software,
- elaboration of the Business Plan for the Fight against Air Pollution in Athens,
- the linking of traffic and classification fees with exhaust emissions - favorable treatment of gasoline-powered versus diesel-powered engines such as e.g. in Holland.
- further boost with financial incentives to replace diesel burners with natural gas and autonomous heating systems.
- the utilization of the air pollution monitoring stations installed in the framework of Decisions Approving Environmental Terms conditions, ensuring their proper positioning and calibration so as to meet the specifications required by the EU legislation are met,
- after the pilot application of cold ironing of passenger (and / or commercial) ships with electricity in the port of Kyllini, its expansion to other ports.