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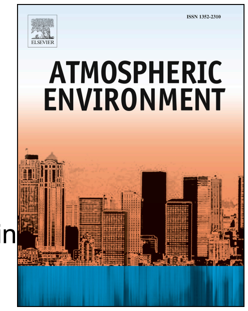

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Gabriel Năstase, Alexandru Șerban, Alina Florentina Năstase, George Dragomir, Alin Ionuț Brezeanu

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Air quality, primary air pollutants and ambient concentrations inventory for Romania

Gabriel NĂSTASE*, Alexandru ȘERBAN, Alina Florentina NĂSTASE, George DRAGOMIR, Alin Ionuț BREZEANU

Pre-publication corresponding author: Gabriel NĂSTASE (email: gabrielnastase@unitbv.com)

Post-publication corresponding author: Alexandru ȘERBAN (email: alexandru.serban@unitbv.ro)

Abstract

Air pollution is among the greatest risk factors for human health, but it also poses risks to the food security, the economy and the environment. The majority of the pollutants emitted by human activities derive from the production and use of fossil-fuel-based energy. Most energy-related emissions contain sulfur dioxide and nitrogen oxides. The principal source of sulfur dioxide originates from coal, and the main sources of nitrogen oxide emissions are power generation and use of vehicles. Other important pollutants are the inhalable coarse particles (PM_{10}) and the fine particulate matter ($PM_{2.5}$), which arises from the building sector.

Over the last decade, since Romania joined the European Union on the 1st of January 2007, the use of fossil fuels has decreased dramatically, as consumers switched to either natural gas or biomass. This was as a result of the European Commission encouraging the member countries to make use of renewable sources (including biomass). To reduce the PM emissions, in April 2015 EC has extended the EcoDesign Directive to solid-fuel boilers and solid-fuel space heaters. The boilers need to generally meet certain requirements that will be introduced by 1 January 2020. In this article, we are highlighting the fluctuations in air pollution in Romania from the European WebDAB – EMAP database and trends in ambient concentrations of air pollutants using Romania's national air pollution monitoring network.

Romania's Air Pollutants/ Air Quality Monitoring Network consists of 142 automatic air quality monitoring stations. The results indicate that Romania's annual average mass emissions of CO decreased from 3,186 Gg in 1990 to 774 in 2014 (decrease by <76%), SOx decreased from 1,311 Gg to 176 Gg (decrease by ~60%), NOx decreased from 546 Gg to 218 (decrease by ~87%), CO_2 decreased from 66.226 Gg/year in 2007 to 38.916 Gg/year in 2014 (decrease by <41%).

Key words: *air pollution, country profile, inventory, Romania's policies, sustainable energy*

Abbreviations

EU, European Union; RES, Renewable Energy Sources; GC, Green Certificates; ANRE, National Regulatory Authority for Energy; GHG, Greenhouse-gas emissions; HPP, Hydroelectric Power Plant.

Contents

1. Introductions

The continuously increasing demands for electricity, thermal energy and production in industries such as metallurgical, chemical, oil refinery and mineral processing for the construction sector, along with the terrestrial and air transportation have caused the escalation in concentration of some constituents of the atmosphere (NO_2, SO_2, O_3, particulate matter, CO, CO_2, etc.), with unpleasant consequences, often severe harm to humans and the environment. The quality of our life on Earth is strictly correlated and influenced by air quality. The consequences of a polluted air on the body are varied and complex. Awareness of those effects generated the necessity of taking environment protection measures, which are meant to cut back air pollutant concentration to meet up the national and regional target values.

Most of the last decade environmental problems in Europe originate in the dramatic growth of energy consumption, rapid development of economies and the explosive increase in road/non-road transportation.

Historical ambient air quality monitoring data permit a wide range of trend, apportionment, health risk and other analyses [1]. As examples, trend analyses can help evaluate the effectiveness of mitigation and control measures, e.g., low emission zones [2], and receptor models can identify and apportion contributions of pollutant sources. Both trend and apportionment studies can help to evaluate dispersion and exposure models [3]. Monitoring data also have been widely used to estimate exposures for epidemiology and risk studies investigating and predicting the health consequences of pollutant exposure [4]. Such applications are especially important in areas with susceptible populations and where concentrations exceed ambient standards, and for those emission sources that are difficult to characterize or that have changed rapidly, e.g., on-road emissions, due to recent shifts in fuels, emission controls, and fleet mix [1].

Air quality has been a major issue in Europe since the early 1970s. In 1996, the EU adopted a series of ambitious actions to further decrease pollutant emissions throughout the continent. The most important was the setting of air quality binding targets and the implementation of a harmonized structure for monitoring, reporting and managing air quality across the EU through the 1996 AQFD and its daughter directives. These daughter directives set limit values and alert thresholds for the most prevalent air pollutants in order to protect human health [5]. Ambient air pollution consists of a highly variable and complex mixture of different substances, which may occur in the gas, liquid or solid phase [6]. Air pollution is a problem particularly in urban areas, where there is a large concentration of pollutants [7]. In some Eastern European countries, solid fuels still account for a much more sizeable share of energy consumption in buildings than the European average (e.g. around 40% in Romania and Bulgaria) [8]. The complementary features of low-carbon power sources are a central issue in designing energy transition policies [9]. The problem today is that unprecedented rates of change are expected in the next century, not only of environmental conditions such as climate but also of socioeconomic conditions such as renewable resource consumption and populations (of both people and of automobiles). In rapidly changing situations, policies must be adopted that strengthen resilience and ecosystem integrity; that is, society must increase its ability to adapt [10]. Many states in Eastern and Central Europe (ECE) possess extensive district heating (DH) networks that were constructed during the days of communist rule in order to provide a universally accessible energy service that supported Soviet development policies. But the post-communist transition was marked by the exacerbation of the sector's numerous technical, economic, regulatory and environmental problems, accompanied by its abandonment in favor of alternative methods of domestic heating. Recent efforts to increase the use of DH in ECE as a result of environmental and energy security concerns have taken place in an absence of critical, context-sensitive research [11].

The rapid urbanization and growing number of megacities and urban complexes requires new types of research and services that make best use of science and available technology [12]. By 2030, the expected growth in many of the sectors (industries, residential, transportation, power generation, and construction) will result in an increase in pollution related health impacts for most cities. The available information on urban air pollution, their sources, and the potential of various interventions to control pollution, should help us propose a cleaner path to 2030 [13]. The interaction between climate change, pollutant emissions and atmospheric concentrations is still of great debate and much has still to be explored in order to understand and accurately predict the changes in pollutant levels under future climatic conditions and at different spatial scales [14]. In 2016, China, US, EU28, India, Russia and Japan, the world's largest emitters in decreasing order of CO_2 emissions, accounted for 51% of the population, 65% of global Gross Domestic Product, 67% of the total primary energy supply and emitted 68% of total global CO2 and circa 65% of total global GHGs. Emissions from international transport (aviation and shipping) contribute another 3% to the total global GHG emissions. These six countries show different trends: with 2% decreases for US and Russia, a 1% decrease for Japan, constant emissions for China and EU28 and a 5% increase for India. EU28 emissions have decreased over the past two decades, such that emissions in 2016 are 20.8% less than in 1990 and 17.9% less than in 2005 [15].

Romania is rich in biodiversity, with mountain peaks that are over 2,000 m high, the largest Delta in Europe – the Danube Delta (which is also a World Heritage Site since 1991), extended cultivation areas and large old-growth forests. These are the main reasons why the Romanian government need to develop and implement effective environmental policies and invest in renewable, recyclable and sustainable energy sources. Therefore, the reduction of air pollution must be a priority. In Romania the fossil CO_2 emissions decreased 42%, from 186.341 Mt CO_2/yr to 78.771 Mt CO_2/yr, while the greenhouse gas emissions (GHG) as CO_{2eq}/cap has decreased in the same time almost 46%.

2. Materials and methods

Our general approach was as follows: we started with a systematic overview of the EU and Romania's regional measurements, trends and databases and used the available information to generate an air pollution inventory. In this study, we processed and analyzed the measured atmospheric emissions of CO, O_3, NO_2, SO_2, $PM_{2.5}$ and PM_{10aut}. The data presented in this article is extracted from the European WebDab - EMEP emission database and from the Romanian National Network of Air Quality Monitoring database.

The WebDab is the emission database of EMEP (the co-operative program for monitoring and evaluation of long range transmission of air pollutants in Europe), open to public for interactive use via the Internet [16]. The Romanian database on air quality parameters is dedicated to public use in real time. The monitoring network consists of more than 100 stations all over Romania and is available online at www.calitateaer.ro[17].

For the main pollutants, CO, NO_2 and SO_2, the information covers the time scale from 1990 to today, as for the remaining pollutants, from 2005 to 2014.

We processed raw collected information and focused on translating these data into charts and maps for an improved understanding of atmospheric emissions over Romania.

The motivation and the clear arguments regarding unique contributions that is made through this work are as follows:

- the current study is the very first effort to assess and provide sufficient information to estimate the principal air pollutants and ambient concentrations in the atmosphere locally, over the entire territory of Romania and regionally in the European context;
- it is well known that air pollution exposure is associated with human health effects and longtime trends monitoring can serve as a basis for long-term human exposure analysis, which can offer more accurate results;
- our study highlights the spatial aggression of the primary air pollutants in Romania and contributes to the knowledge of the interactions between emissions, quality of air, regional and global climates;
- explores the local and regional policy on air quality implemented to effectively reduce environmental pollution and the human health impacts;
- lastly, this work identifies the main gaps in the regional familiarity of air pollution and highlights the significance and need of further research to be performed in the field.

3. Results

3.1. Romania's national air pollution monitoring network

Romania is a south-eastern European country, located north of the Balkan Peninsula, on the Lower Danube and on the northwestern coast of the Black Sea. The country has been a member of the European Union since January 1, 2007.

Romania's Air Pollutant Monitoring Network consists of 142 automatic air quality monitoring stations and 17 mobiles that cover all 41 counties. They are all represented in Figure 1. The network includes 24 traffic stations, 57 industrial stations, 37 urban stations, 15 suburban stations, 6 regional stations and 3 EMEP stations. All stations have a 24-h monitoring program that provides hourly average of the key air pollutants.

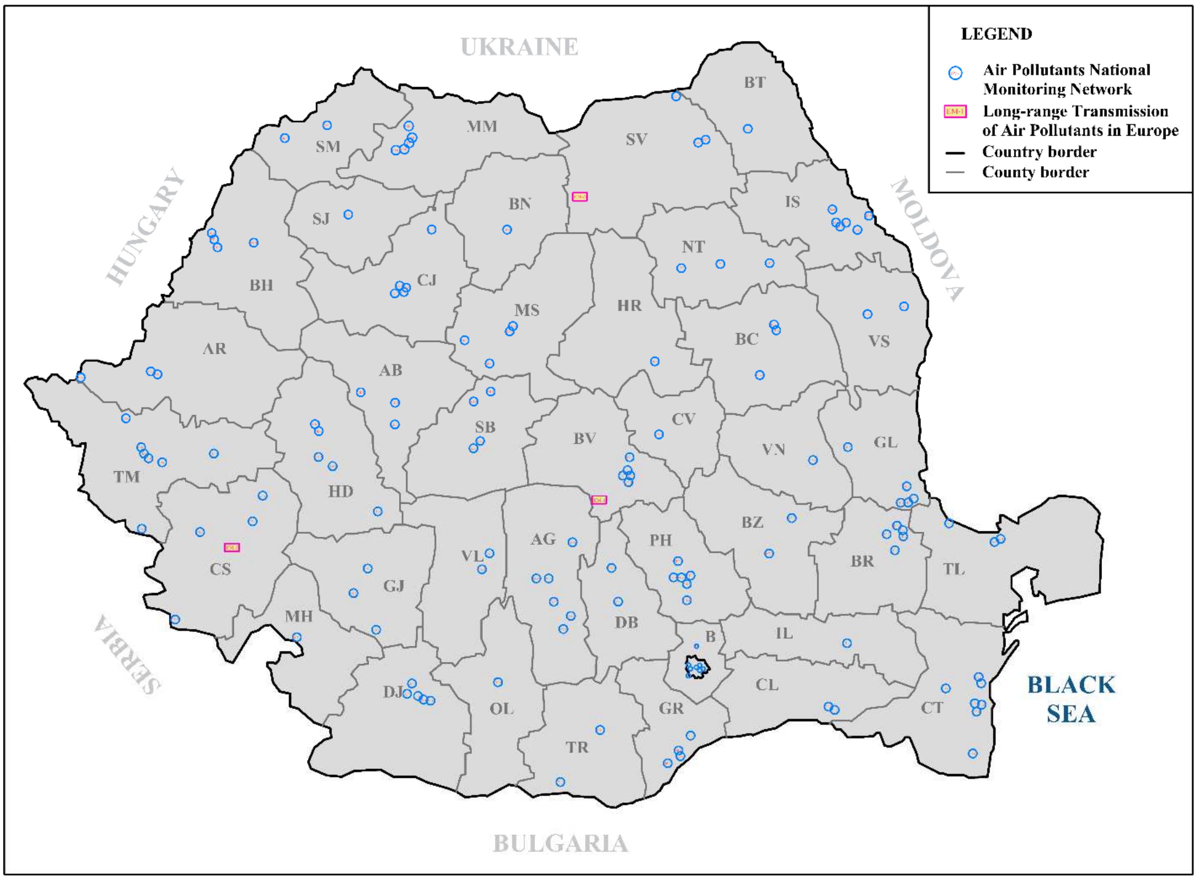


Figure 1. Romania's Air Pollutant Monitoring Network[17]

3.2. Pollutants, sources and emissions

In this article, we make an effort to link the most recent air pollutant trends in Romania, from 1990 onward. Decreasing trends have been observed for all important air pollutants: NO_2, SO_2, CO, CO_2, $PM_{2.5}$ and PM_{10}.

Romania's annual average mass emissions of CO decreased from 3,186 Gg in 1990 to 774 in 2014 (decrease by <76%). In the same interval, SOx decreased from 1,311 Gg to 176 Gg (decrease by ~60%) and NOx decreased from 546 Gg to 218 (decrease by ~87%). All these variations may be observed for the considered time frame in Figure 2. If we consider as a time reference Romania's EU accession, in 2007, the percentages of reduction are 10.3% for CO, 26.9% for NOx as NO_2 and 66.7% for SOx as SO_2.

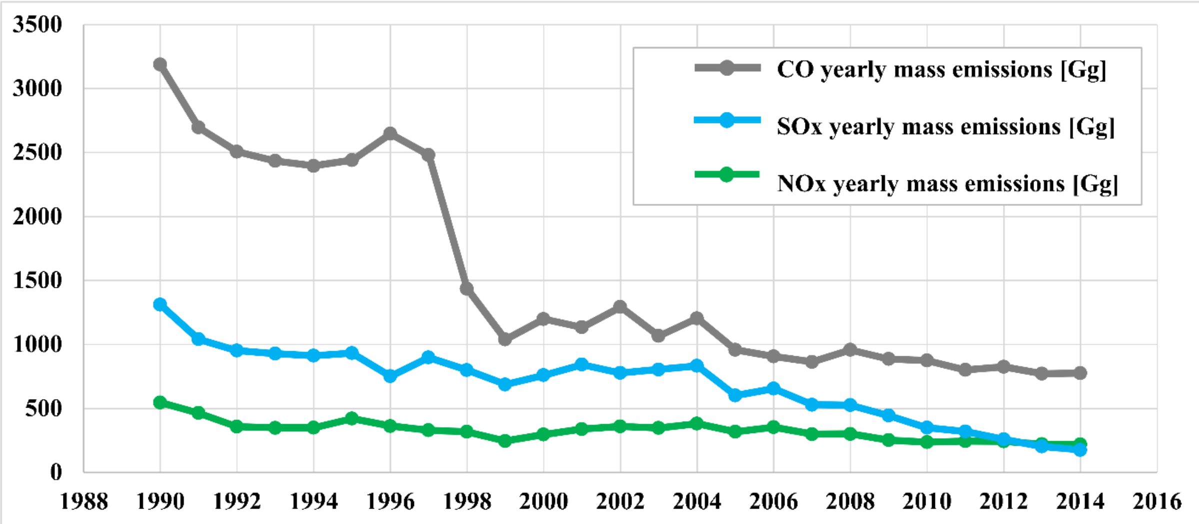


Figure 2. Romania's annual average mass emission variation of CO, NOx and Sox, between 1990 and 2014[18]

Carbon monoxide (CO)

CO is an odorless, colorless gas which can be lethal if inhaled in considerable amounts. Carbon monoxide is found in a very low concentration in our atmosphere. In Romania, the greatest carbon monoxide emitters are the power plants, the district heating stations and the motor vehicles, because of the incomplete combustion of fossil fuels. Obviously, the power plants and motor vehicles can be considered as a constant throw-out the year, with regards to CO emissions. The district heating is needed only in the cold period, so typically the highest concentration of CO is registered in the winter.

Carbon dioxide (CO_2)

As people exhale CO_2, there are many processes involving the release of CO_2 in the atmosphere. The year 2016 was the warmest year on record globally since recordkeeping began in 1880, and most probably this year (2017) will surpass the last year's record warmth. The gases that absorb heat in the atmosphere are called greenhouse gases (GHG) and include CO_2, methane, nitrous oxides, fluorinated gases etc. Most of the studies report atmospheric emissions in CO_2-equivalent, as CO_2 is the largest contributor to air pollution.

In 2015, the five largest emitting countries and the European Union, which together account for two thirds of total global emissions, were: China (with a 29% share in the global total), the United States (14%), the European Union (EU-28) (10%), India (7%), the Russian Federation (5%) and Japan (3.5%) [19].

The Greenhouse gas emissions given as single greenhouse gas CO_2 emissions are based on a life-cycle perspective (LCA) , thus including upstream and downstream impacts throughout the electricity generation value chain [20]. The weighted average environmental life-cycle based CO_2 emissions for renewables and fossil fuels are given in Table 1.

Table 1. The weighted average environmental life-cycle based CO_2 emissions for renewables and fossil fuels[20]

Energy source/technology		LCA CO_2 (kg/kWh)
Renewable	Solar	0.0624
	Wind	0.0182
	Hydro & Marine	0.0053
	Geothermal	0.0549
	Biomass & Biogas	0.1181
	Unspecified (renewable)	0.0299
Fossil	Hard Coal	1.0382
	Lignite (or brown coal)	1.1986
	Natural Gas	0.5258
	Oil	0.8869
	Unspecified (fossil)	0.806

Carbon dioxide is released into the atmosphere through burning fossil fuels, wood products and solid waste, and because of certain chemical reactions in some industrial processes. Carbon dioxide is absorbed from the atmosphere by everything that performs photosynthesis.

The CO_2 emission intensity (g CO_2/kWh) is calculated as the ratio of CO_2 emissions from public electricity production (as share of CO_2 emissions from public electricity and heat production related to electricity production) to the gross electricity production. The CO_2 emission intensity since Romania was admitted to the European Union (2007) until 2014, compared with EU-28 emissions for the same period, is presented in Figure 3.

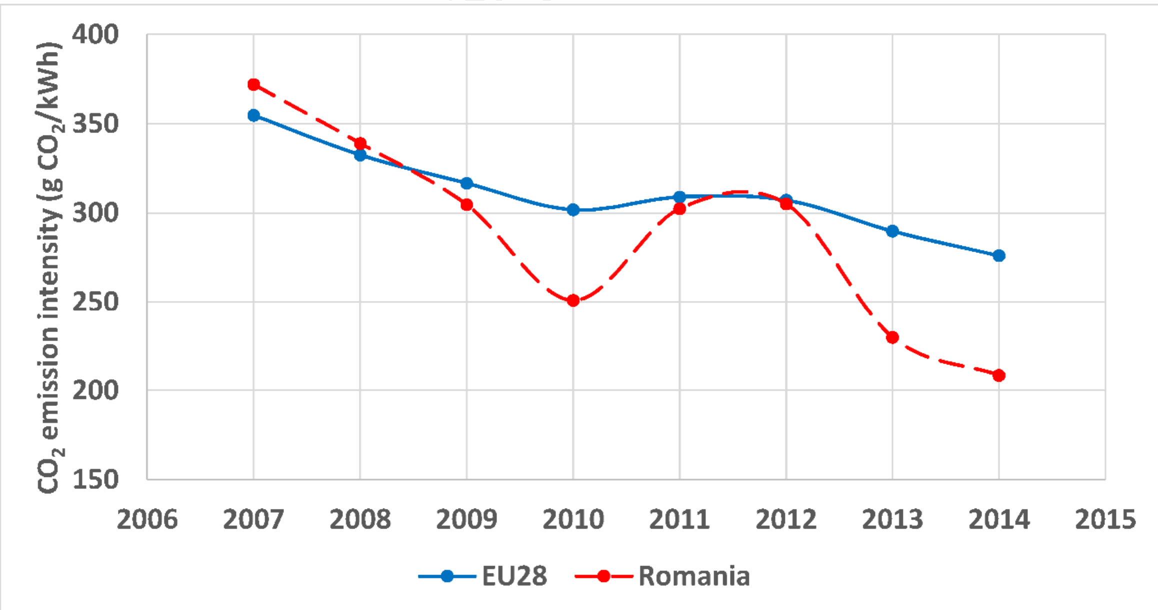


Figure 3. CO_2 emission intensity (g CO_2/kWh) in EU28 and Romania between 2007-2014[21]

In 2015 and 2016, in Romania, the CO_2 emissions from electricity generation had an average value of 299.02 g/kWh and 287.11 respectively, as can be observed in Table 2.

Table 2. Specific average CO_2 emissions by primary sources[22], [23]

Primary source	Specific CO_2 emissions in 2015 [g/kWh]	Specific CO_2 emissions in 2016 [g/kWh]
Coal	898.76	910.73
Natural gas	411.07	395.90
Black oil	777.26	593.10
Other conventional sources	794.20	843.60
Renewable sources	0	0
Average	**299.02**	**287.11**

Ozone (O_3)

Ozone pollution measured at any location can be caused by precursor NO_x (= NO + NO_2) and organic emissions at various distances upwind of the measurement site [24]. Tropospheric ozone contributes to the removal of air pollutants from the atmosphere but is itself a pollutant that is harmful to human health and vegetation [25]. Changes in climate and air pollutant emissions will affect future air quality from global to urban scale [14]. The analysis of tropospheric ozone concentrations is highly important since, apart from being a greenhouse gas, its strong oxidant properties, at certain levels, can affect animals, vegetation, materials and have an effect on human health not only for pre-disposed patients, such as asthma sufferers and children, but also for previously healthy individuals [26], [27], [28].

Ozone pollution is influenced by many factors like season, air temperature and humidity, solar radiation, wind speed and direction, urban and industrial activity, traffic density etc. To reduce ozone ground-level pollution, we need to limit the use of gasoline-powered automobiles or replace them with electric or hydrogen-fueled ones, as well as conserve energy.

Nitrogen Dioxide (NO_2)

A limit value for the annual mean NO_2 concentration in the ambient air of 40 μg/m^3 came into force in the European Union (EU) at the beginning of 2010[29]. The use of NOx (NO + NO_2) emissions inventories is essential to our understanding of air quality. Their application ranges from local street scale to regional and global scales and includes compliance with European Union (EU) limit values, estimating ozone (O_3) health impacts and deposition, understanding particle matter (PM) concentration trends and the acidification and eutrophication of sensitive ecosystems [30]. Nitrogen oxides (NO_x), comprising nitric oxide (NO) and nitrogen dioxide (NO_2), are emitted during fossil fuel combustion processes [31].

While the stationary NOx emissions from the large combustion plants decreased, the moving emissions from the combustion engines in the automobiles have increased, because the number of vehicles is growing year by year, both in Romania and in the EU. This makes out of nitrogen oxides emissions mainly an urban air pollution problem, because in cities the density of power plants and vehicles is much higher than in rural areas.

The most frequent human health problems associated with the NO_2 exposure are related to acute or chronical changes in lung function, which makes the asthmatics patients more susceptible to aggravate their health problems.

NO_2 and NO can also affect vegetation, but it depends on the concentration and absorption rate. Nitrogen oxides are absorbed by vegetation through stomata, the same way as the CO_2 is. One can notice the same decreasing trend when correlating Romania's annual average concentrations and mass variation of NO_2 between 2007 and 2014, as presented in Figure 4.

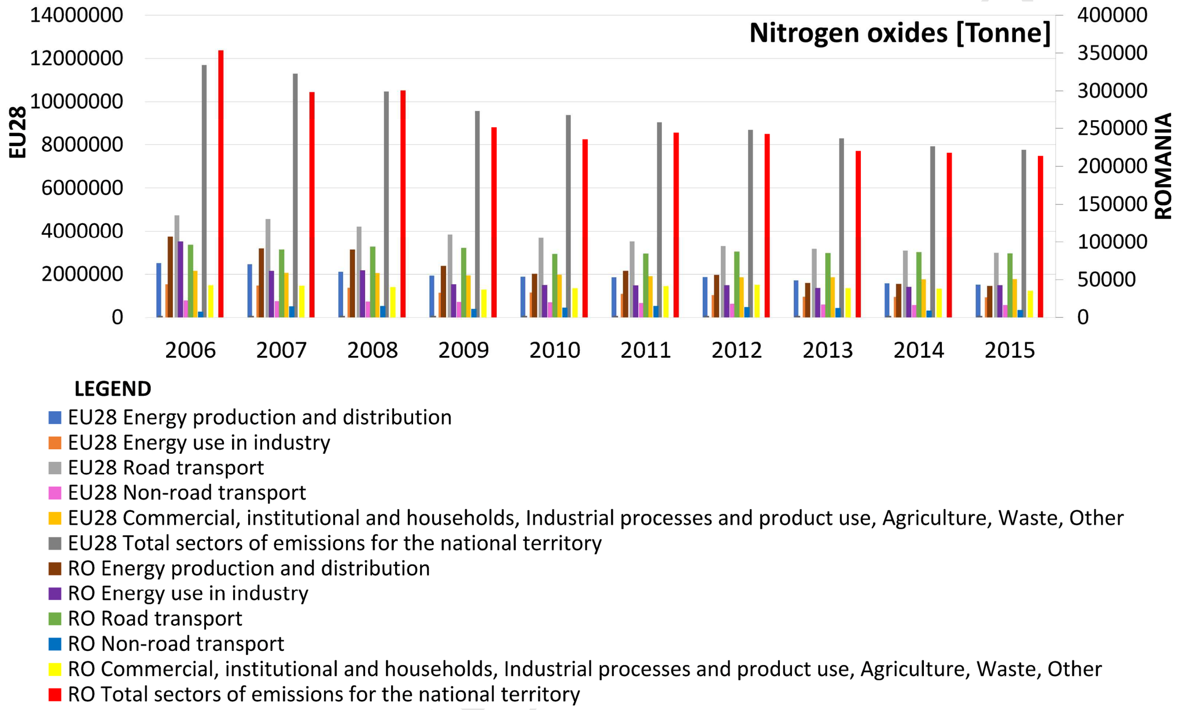


Figure 4. Mass variation of Nitrogen oxides (NOx) by source sector, in EU28 and Romania between 2006 and 2015 [33]

As can be observed in Figure 4 over the years the largest emissions in case of NOx, in both, EU28 and Romania are generated by road transport (mainly Diesel cars). This is also the reason in many European cities the annual NO_2 concentration exceeds the established air quality standards.

Sulfur Dioxide (SO_2)

Sulfur dioxide (SO_2) gas is emitted both naturally and anthropogenically through volcanic eruptions and fossil fuel combustion [34].An analysis of the hourly SO_2 pollution patterns with time can be a useful tool for policy makers and stakeholders in developing more effective local policies in relation to air quality as it facilitates a deeper understanding of concentrations and potential source apportionment [35].

Sulfur oxides are emitted from almost the same sources as the nitrogen oxides but can also include industrial plants that process sulfur. In the same manner, the human health problem associated with sulfur oxides are related to the respiratory system.

Sulfur oxides can combine in the atmosphere with other chemical compounds to form small particles that can cause particle matter pollution.

Figure 5 illustrates the mass variation of Sulphur oxides (SOx) by source sector, in EU28 and Romania between 2006 and 2015 and we can conclude that in the last 10 years the total sectors emissions have decreased in both cases at the same time.

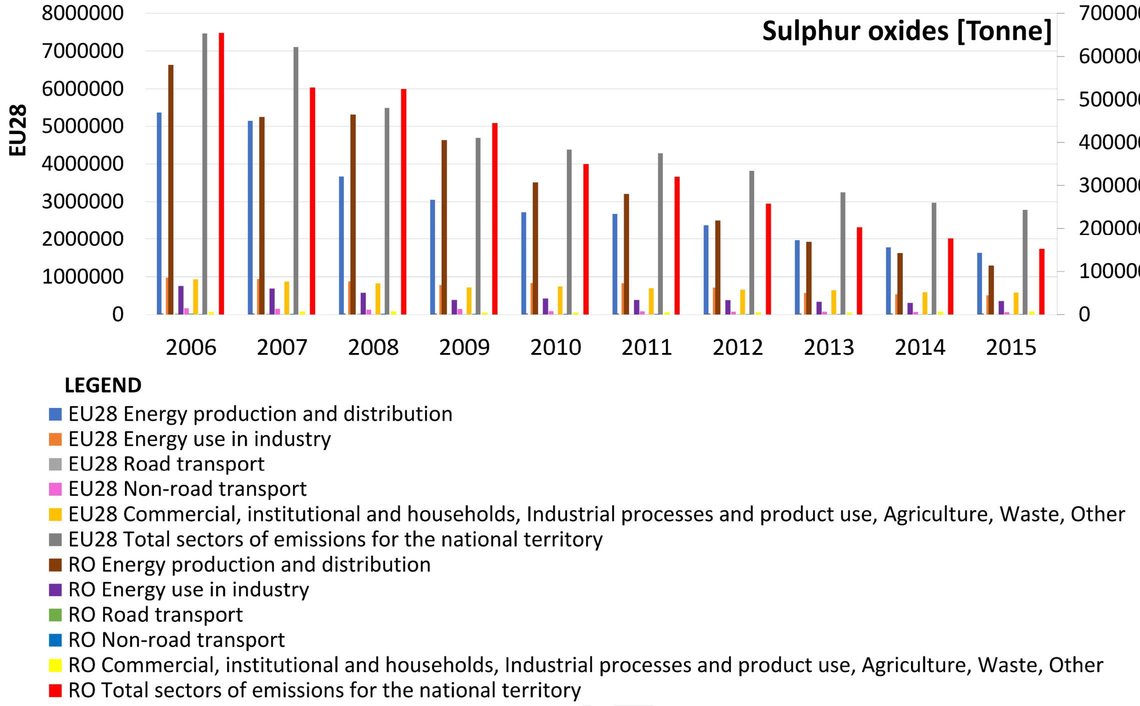


Figure 5. Mass variation of Sulphur oxides (SOx) by source sector, in EU28 and Romania between 2006 and 2015 [33]

In case of SO_x the largest annual emissions in EU28 are generated by the Energy production and distribution sector, followed by the Commercial, institutional and households, Industrial processes and product use, Agriculture, Waste, Others group. In Romania, the largest emissions of SO_x are also generated by the Energy production and distribution sector and are fallowed by the Energy use in industry sector (Figure 5). We can conclude this way that the largest sources of SO_2 emissions are from fossil fuel combustion at power plants and other industrial facilities.

Fine particulate matter ($PM_{2.5}$)

Atmospheric particulate matter (PM) is directly emitted into the air (primary PM) or generated in the atmosphere from precursor gases (secondary PM) [36]. Research has indicated high levels of particulate air pollution in Central and Eastern Europe with considerable variations between seasons, likely to be caused by local heating [37]. Knowledge of ground-wind circulation and potential long-range transports is fundamental to evaluating in what way and to what extent the local or external sources affect the air quality at a receptor site [38].

As shown in Figure 6, the largest PM2.5 emissions in EU28 and Romania, are generated by the Commercial, institutional and households, Industrial processes and product use, Agriculture, Waste, Others group.

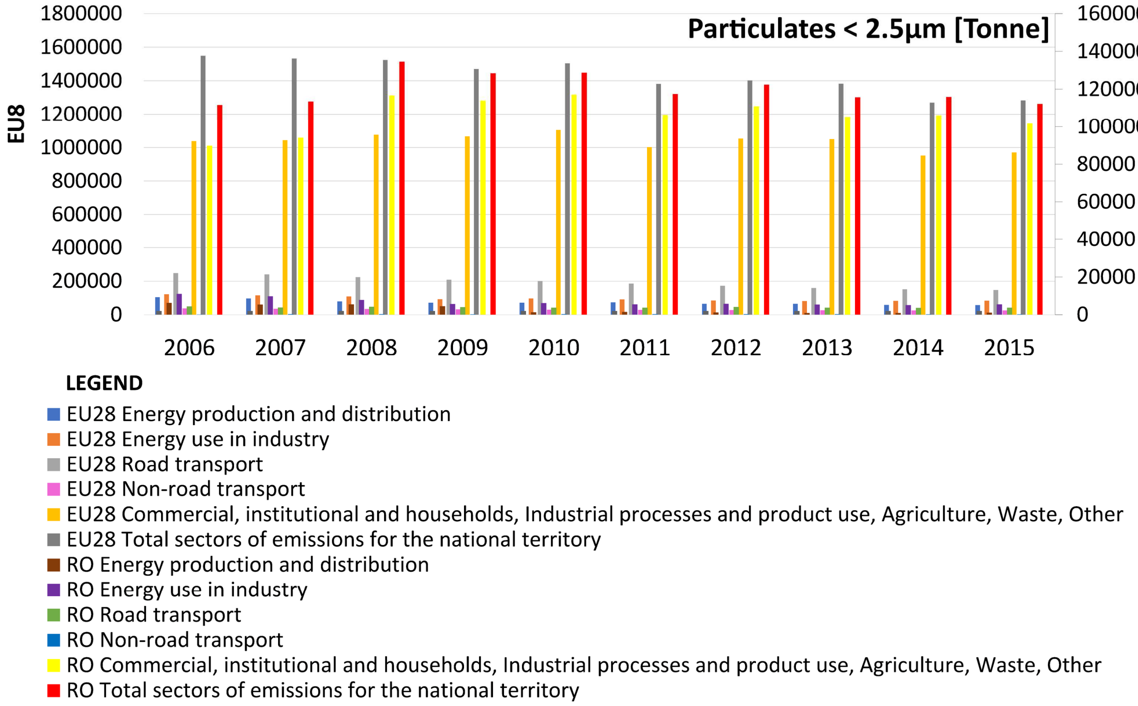


Figure 6. Mass variation of Particulates<2.5µm (PM2.5) by source sector, in EU28 and Romania between 2006 and 2015 [33]

Inhalable coarse particles from vehicles (PM_{10aut})

One of the major pollutants that are of great concern with respect to human health is the particulate matter (PM_{10}). The rate and variability of PM_{10} concentrations are influenced by natural and anthropogenic emissions, as well by meteorological conditions [39].

The impact of vehicular emissions on air depends, among other factors, on the composition of fuel and the technology used to build the engines [40].

As can be observed in Figure 7, the largest PM10 emissions, in both cases EU28 and Romania are just like in case of PM2.5, from the Commercial, institutional and households, Industrial processes and product use, Agriculture, Waste, Others group.

Comparing all charts, we observe a declined trend for all analyzed pollutants, over the years, both locally and regionally, in the last decade.

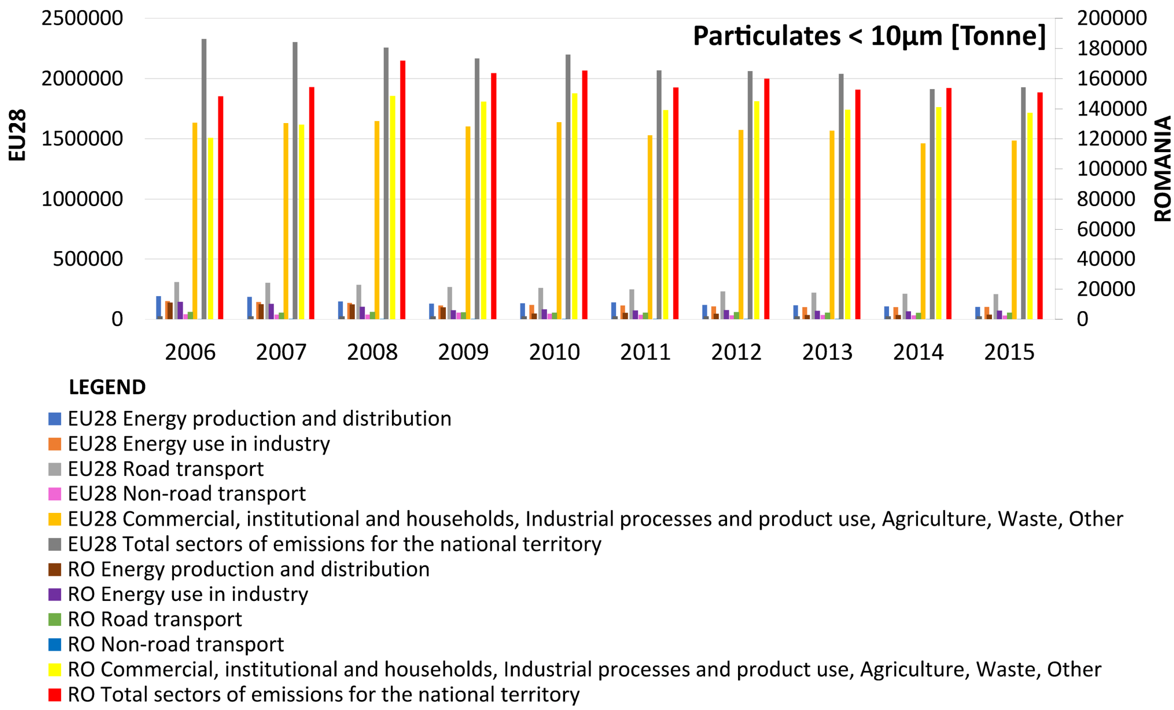


Figure 7. Mass variation of Particulates<10µm (PM10) by source sector, in EU28 and Romania between 2006 and 2015 [33]

These results suggest that the new legislative measures implemented in accordance with EU regulations have had a noticeable effect on Romania's air quality over the years. They also emphasize that effective air-quality measures and policies require cooperation and action at local, regional and global level.

3.3. Air quality index

Romania's Air Pollutant Monitoring Network is continuously measuring the main pollutants: SO_2 (sulfur dioxide), NO_x (nitrogen oxides), CO (carbon monoxide), O_3 (ozone), PM_{10} (coarse particles) and $PM_{2.5}$ (fine particles), C_6H_6 (benzene), and Pb (lead). However, in some counties even though the stations operate continuously, they monitor less pollutants and access to the monitoring data is limited. The air quality in each station of the national network is represented by the suggestive quality indices, derived from the five of the main air pollutants' measured concentration values. In Romania, the air quality index is a number between 1 and 6, indicating the level of air quality, from excellent (1) to very bad (6). The levels of air quality can be associated with the levels of health concern, which vary from good (1) to hazardous (6). The range of concentration for all five pollutants related to the levels of air quality is detailed in Table 3.

Table 3. Air quality specific indexes in Romania [41]

Specific index	1	2	3	4	5	6
Level of air quality	Excellent	Very good	Good	Medium	Bad	Very bad
Level of health concern	Good	Moderate	Unhealthy for Sensitive Groups	Unhealthy	Very Unhealthy	Hazardous
Sulfur Dioxide (SO_2) [$\mu g/m^3$]	0-49.(9)	50-74.(9)	75-124.(9)	125-349.(9)	350-499.(9)	>500
Nitrogen Dioxide (NO2) [$\mu g/m^3$]	0-49.(9)	50-99.(9)	100-139.(9)	140-199.(9)	200-399.(9)	>400
Ozone (O_3) [$\mu g/m^3$]	0-39.(9)	40-79.(9)	80-119.(9)	120-179.(9)	180-239.(9)	>240
Carbon Monoxide (CO) [mg/m^3]	0-2.(9)	3-4.(9)	5-6.(9)	7-9.(9)	10-14.(9)	>15
Particulate Matter (PM_{10}) [$\mu g/m^3$]	0-9.(9)	10-19.(9)	20-29.(9)	30-49.(9)	50-99.(9)	>100

To calculate the overall index in a station, at least 3 specific indexes corresponding to the monitored pollutants must be measured over a certain period. The air quality specific index is used to inform the population of Romania about how polluted the air is at a specified time.

3.4. Energy production and air pollution in Romania

The energy consumption is an indicator for a country's level of development. All types of energy sources have a unique benefit, cost and impact on the environment. The current global energetic system is dominated by traditional energy sources but renewable energy sources have rapidly increased in recent years.

The gross energy consumption declined significantly after 1990, reaching 377 TWh in 2015 and the final energy consumption was 254 TWh. The main energy consumer is the population with a consumption of 87 TWh, followed by the industrial sector with an usage of 74 TWh, transports with 65 TWh and the agriculture and services with 28 TWh [42]. Romania's energy mix in 2015 is shown in Figure 8, where, the main source of energy being fossil fuels with 277 TWh, but significant amounts are also represented by biomass with 46 TWh, nuclear power with 35 TWh and renewable energy sources with 24 TWh. The significant share of biomass is due in particular to the fact that 90% of the dwellings in the countryside and 15% of the urban ones are heated by burning wood in the stoves. The usage of biomass combustion heaters results into incomplete combustion of fuel but also leads to emission of PM2.5 and PM10 particles into the atmosphere because they are not provided with particle filters.

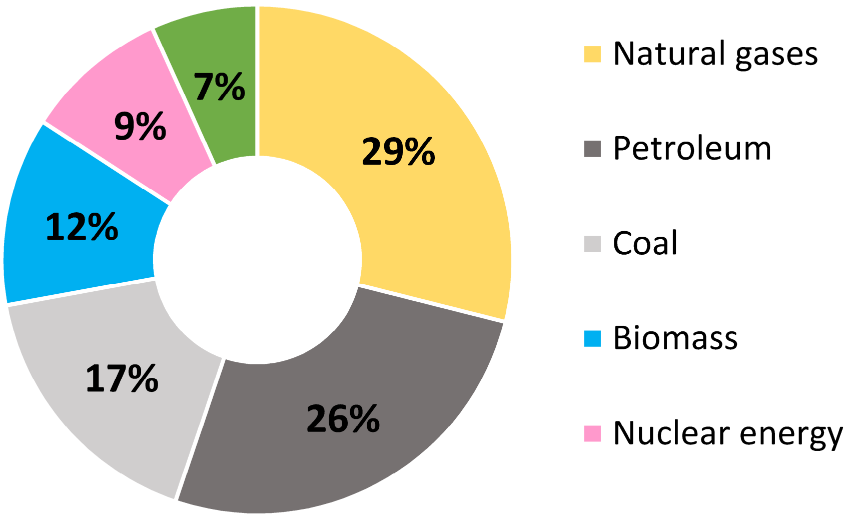


Figure 8. The mix of primary energy consumed in Romania in 2015

Fossil fuels account for about 72% of the total primary energy consumption used in Romania. The most used fossil fuel in Romania is the natural gas with 29% of the total primary energy, its widespread distribution being mainly due to the significant domestic resources, the existence of an extensive national infrastructure and the capacity of the gas generators natural balance of RES. After a continuous drop in natural gas consumption, in the last years it's stabilized to 73.6 TWh (in relation to the low calorific value) in 2015, its consumption distribution being shown in Figure 9.

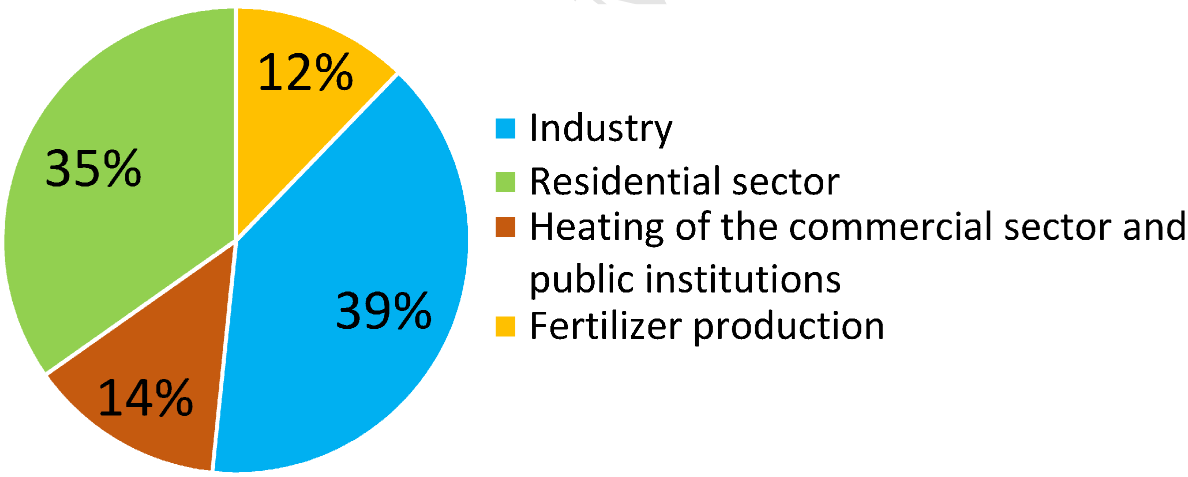
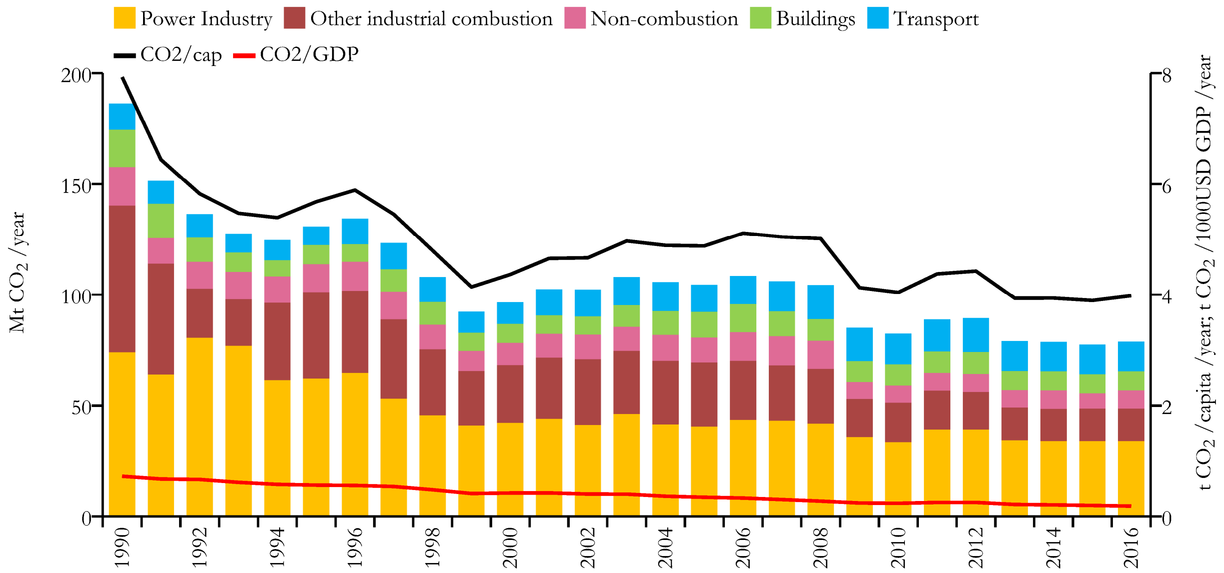


Figure 9. Share of natural gas consumption by sectors [42]

The petroleum has an important share in Romania's energy mix around 26%, domestic consumption is mainly based on imports, and the one exploited in Romania covers about 40% of consumption. The CO_2 and GHG emissions from fossil fuels have fallen sharply since the early 1990s as a result of major changes in the economy (Figure 10 and Figure 11).

Another significant drop in these emissions occurred in 2009 due particularly to the global economic crisis that has also affected the Romanian economy. The CO_2 emissions from the burning of fossil fuels in Romania fell by 57.7% in 2016 compared to Romania's 1990 emissions.



Year	Mt CO_2/yr	t CO_2/cap/yr	t CO_2/kUSD/yr	population
2016	78.771	3.978	0.184	19778083
1990	186.341	7.929	0.719	23489373

Figure 10. Fossil CO2 emissions by sector [15]

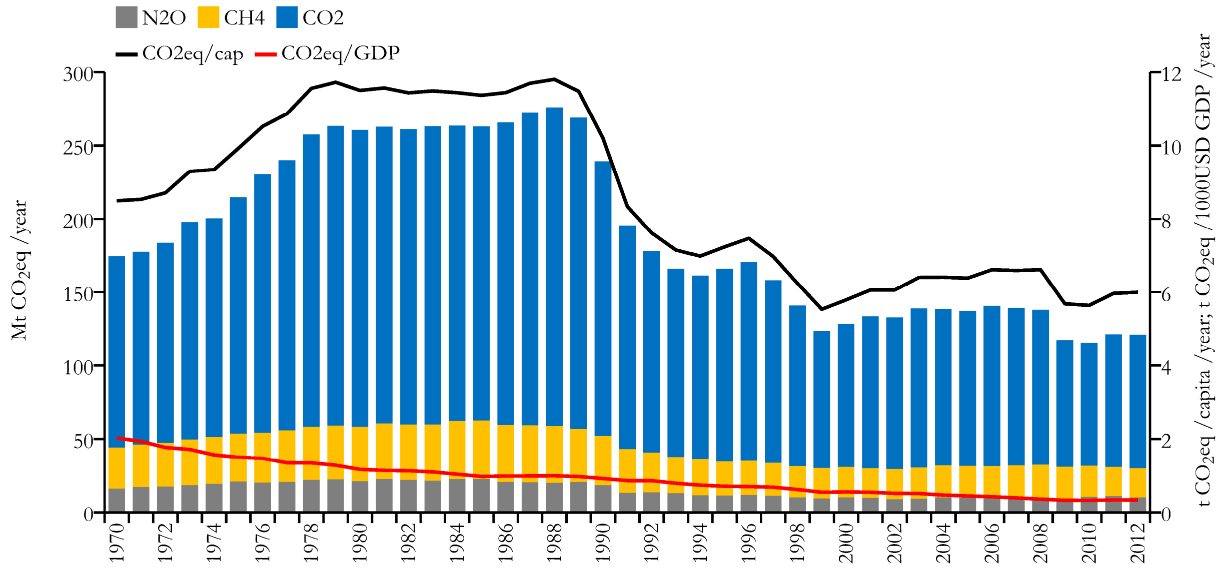


Figure 11. Greenhouse gas emissions [15]

The energy industry is one of the main factors that harm the environment by various phenomena, including global warming emissions, environmental pollution by oil, long-term storage of nuclear waste and mining, deforestation brisk, damage to public health, wildlife and habitat loss, land use, water use etc. To reduce the environmental impact of the Romanian energy sector, the country transposed and implemented in 2003 the Directive 2001/80/EC[43] on the limitation of emissions of certain pollutants into the air from large combustion plants. This regulation is aimed to limit the emissions of sulfur dioxide, nitrogen oxides and particles from large combustion plants (i.e. plants which have a thermal power of 50

MW or higher). To reduce the impact of energetic sector on the environment Romania has three options: change the fuel used, upgrade and/or rehabilitate the existing large combustion plants, or switch to renewables.

The electricity produced from renewable sources increased between 1990 and 2014 by 184 %, at an average annual rate of 4.5 %. After 2005, the rate increased to 7.3 % per year. The acceleration observed since 2005 occurred in the context of national and EU renewable energy support policies and significant cost reductions achieved by certain renewable energy technologies, such as the solar photovoltaics, in recent years. In 2014, 44 % of the renewable electricity was generated from hydro (94 % in 1990), 27 % from wind (0 % in 1990), 18 % from biomass (4 % in 1990), 11 % from solar (0 % in 1990) and 1 % from geothermal power (1 % in 1990) [21].

Romania has an immense potential for using renewable energy: hydroelectric, wind, solar, biomass and geothermal. In February 2016, the share of electricity from renewable sources in Romania was of 46% of the total electric power produced[44].

An overview of the types of renewable energy sources and their potential in Romania can be found in the National Renewable Energy Action Plan (NREAP) (Table 4) [45], [46].

In 2015 in Romania, the average electricity production was of 7,343 MWh and the average consumption was of 6,590 MWh. The average hydropower generated was of 1,894 MWh, which is equal to 26% of the total production[47].

Owing to the 2010 legislative measures, the installed capacity of wind power increased from 7 MW in 2009 to 976 MW peak in 2012, by 2015 reaching a total installed power of 2,990 MW. Promotion of electricity from renewable sources from 2010 to2013 through the national subsidy policy has led to a significant drop in greenhouse-gas emissions linked to electricity production from 438 g/ kWh in 2011 to 326 g/kWh in 2015 [44].

Biomass energy is generated using a variety of sources: forest wastes, energy crops, agricultural waste and household waste, being the most easily accessed and affordable of all renewable energies. Romania has forests that cover more than a quarter of the country and large agricultural lands (43.4% of the country's surface) [48].

Table 4. Potential of renewable energy sources in Romania. Source: NREAP [46], [45]

Renewable energy source	Annual energy potential [GWh]	Economic energy equivalent (ktoe)	Application
Solar thermal	16,667	1,433	Thermal energy
Photovoltaic	1,200	103.2	Electrical energy
Wind	23,000	1,978	Electrical energy
Hydro, out of which	40,000	3,440	Electrical energy
Under/< 10 MW	6,000	516	Electrical energy
Biomass	88,333	7,597	Thermal energy
Geothermal	1,944	167	Thermal energy

The evolution of traditional energy sources in contrast with the renewable energy sources from 2008 to 2016 can be observed in Figure 12.

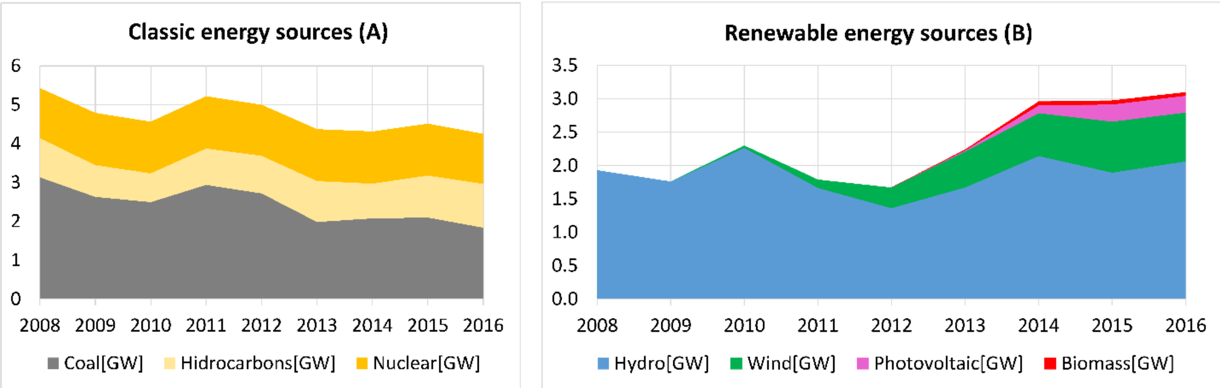


Figure 12. Primary production of energy in Romania by types of sources. Panel A: The decrease of traditional energy sources, 2008-2016. Panel B: The increase of renewable energy sources, 2008-2016 [55]

In order to ensure Romania's energy security in the next decades, it will be necessary to consider a fresh approach incorporating a global long-term perspective based on the latest trends in energy systems [49].

3.5. Romania and the EU legislation on air quality

Global climate warming and pollution-related effects on human health have placed air pollution at the heart of policy decision-making. Developed countries, particularly the European Union (EU) and the United States, have implemented strict regulations to improve air quality, while developing countries are generally characterized by weaker environmental regulations [5]. To protect human health and the environment, it is particularly important to mitigate emissions of pollutants at source and to identify and implement the most effective emission reduction measures at local, national and EU level. Therefore, emissions of harmful air pollutants should be avoided, prevented or reduced, and appropriate objectives set for ambient air quality considering relevant World Health Organization standards, guidelines and programs[50].

One way by which the EU has succeeded improving air quality was to set binding and non-binding EU-wide limits for certain airborne pollutants. In addition to establishing air quality standards, the European legislation was also designed to directly target certain sectors that act as sources of air pollution. Because the emissions of air pollutants in the energy sector had a high environmental impact due to the high share of energy used for household activities, the legislation regarding energy consumption had to be improved.

Next administrative approach of the EU to enhance air quality levels was to set up yearly outflow constrains for specific pollutants, member states being directly in charge and responsible for the implementation of the mandatory measures to ensure that their pollution levels are below the limits. Because EU identified the pollution sources, specific legislation, designed to target directly, certain sectors that act as sources of air pollution was adopted, which resulted into real measures for the pollution reduction and improving air quality. This is primarily targeted at reviewing European legislation on ambient air quality for pollution purposes at levels that minimize harmful effects on human health and the environment.

According to the Directive 2001/80/EC, member states should reduce exposure to fine particles called PM 2.5 in urban environments by 20% on average by 2020 compared to 2010 levels. States are required to bring the exposure levels below 20 μg / m^3 by 2015 in urban area. In the rest of the territory, member States will have to respect the PM 2.5 limit of 25 μg / m^3, which should be reached by 2015 and where it can be up to 2010 [51]. This directive introduced new targets for PM 2.5 fine particles but did not change existing air quality standards. It offers, however, to member sates the opportunity to enjoy greater flexibility in meeting these regulations in areas where implementation was very difficult.

In 2013, another important step into rising air quality, was made, when the EU adopted Clean Air Policy Package, which include Clean Air Program for Europe and sets objectives for 2020 and 2030, and also a new set of legislative measures.

In Romania, Law No.104/2011[52] on air quality aims to protect the environment as a whole as well as human health by regulatory measures meant to maintain air quality whenever the regulations established by this law are met, and also to improve the air quality in all other cases.

In accordance with the regulations of this Law on ambient air quality, the responsibility for monitoring the ambient air quality in Romania lies with the Environmental Protection Agency. The monitoring of the pollutants, the measurement methods, the limit values, the alert and information thresholds, together with the criteria for the monitoring location of points are also established by the same Law on atmospheric protection, which complies with the requirements of European regulations.

The above mentioned Law has created the legal framework for the regulation of measures, which aim to maintain and to improve air quality following the established and clear standards in the domain, ensuring the alignment of the national legislation with the European regulations in this field and the fulfillment of Romania's obligations as a European Union state member [17]. At the same time, it creates the organizational, institutional and legal framework for co-operation between the public authorities and institutions with expertise in the field in order to evaluate and manage air quality in a unitary manner/ consistently throughout Romania's territory, as well as to inform the EU and international agencies about air quality.

This law ensures the transposition into the national legal framework of the Directive 2008/50/CE on ambient air quality and cleaner air for Europe, and the Directive 2004/107/CE on arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air.

Romania is also part of and has ratified various bilateral, regional and international conventions and treaties on environmental matters, including the 1992 UN Framework Convention on Climate Change (UNFCCC) – ratified by Law 24/1994, and its 1997 Kyoto Protocol – ratified by Law 3/2001. On December 12, 2015, in the twenty-first session of the Conference of the Parties (COP 21) to the UNFCCC, 195 countries adopted the Paris Agreement. The contribution of our country to this agreement is part of the EU contribution, which was submitted to the UNFCCC Secretariat for publication on March 6, 2015.

While the Romanian legislation for air quality reflects the global and EU requirements, the application of law remains a challenge because of the poor coordination and planning of the administrative mechanisms and because of low accession of EU funds. As a result of this lack of effective policies many companies are allowed to break the law, which resulted in mass scale pollution affecting the lives of many people.

3.6. Current maps of air pollutants

Daily average levels of O_3, NO_2 and SO_2 over Romania display a homogeneous variation, most of the values ranging from excellent to good levels (Fig. 13A, Fig. 13B and Fig. 13C).

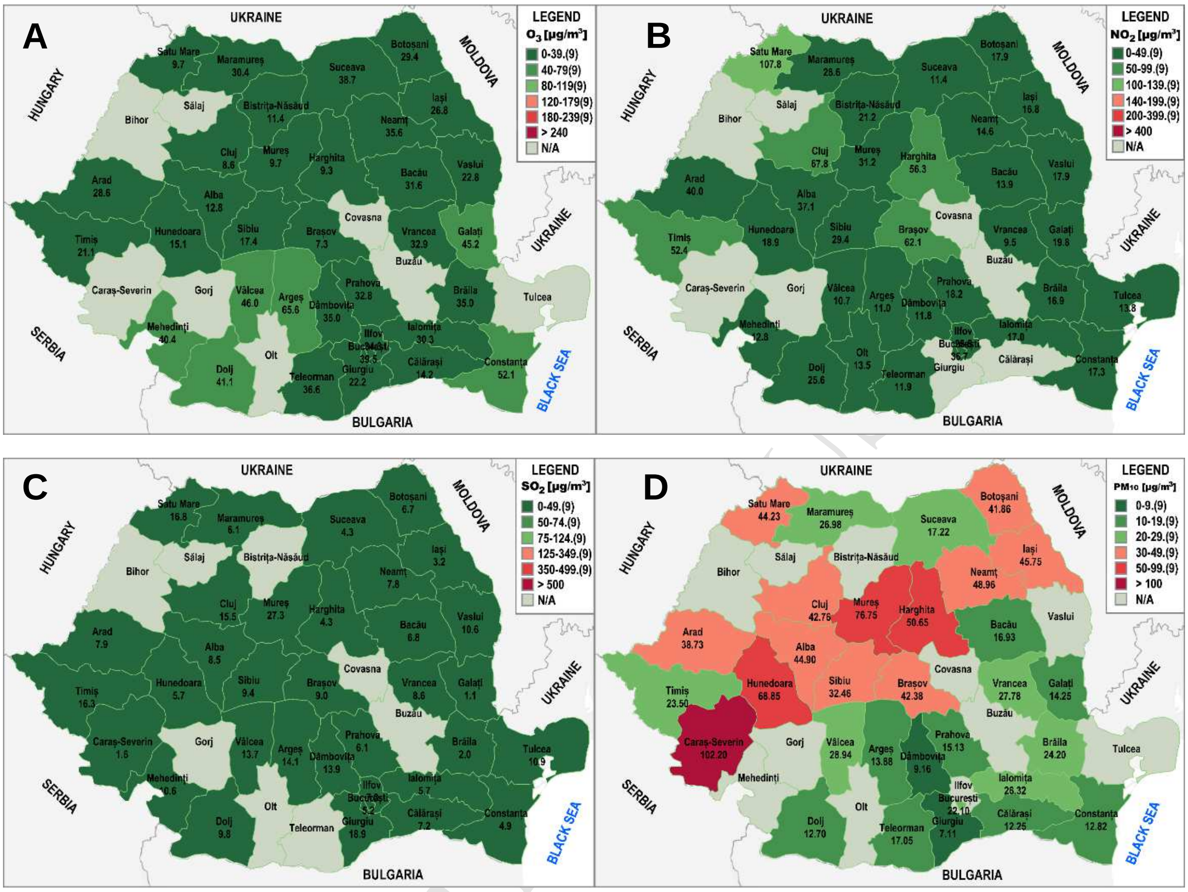


Figure 13. Specific index map of ozone (A), Nitrogen Dioxide (B), Sulfur Dioxide (C) and PM_{10aut} (D), in Romania, for November 23, 2016 [17]

The minimum, maximum, average and limit concertation values for the main air pollutants are presented in Table 5. According to both National Air Quality Law [53] and Directive 2000/69/EC of The European Parliament and of The Council [50], the limit concentration values in the ambient air must not exceed the values indicated in Table 5. The daily mean concentration for Ozone, Nitrogen Dioxide, Sulfur Dioxide observed in this study did not exceed the limit values as it did in the case of PM_{10aut}.

The PM_{10} level of the suspension was still elevated in the urban agglomerations where exceedances of the limit values were daily registered over the number allowed at one station or two stations respectively. Due to urban industrial activity, population heating system, thermoelectric power plants, road traffic contribution to dust pollution caused by machine tires, the PM10 levels are higer.in these areas. Usually, most of the exceedances of the particle tracer in PM_{10} are recorded during the cold season, with main sources of pollution being residential heating system, heavy traffic through the city, anti-skid material, lack of vegetation, all correlated with bad weather conditions like inversion thermal or atmospheric calm

For these agglomerations have been developed air quality management programs and are in course to develop air quality plans with reduction measures particulate concentrations in suspension, but in the current situation, the more and more frequent periods of high concentrations of PM_{10} in the air as well as long exposure will aggravate the cases of respiratory infections, especially in children.

As indicated in Figure 13, in 2016 there were no exceedances of the annual health limit in any station considered, the hourly limit value for the protection of human health was not exceeded at any station considered and there have been no exceedances of the alert threshold for nitrogen dioxide, sulfur dioxide and ozone.

Table 5. Minimum, maximum, average and limit concentration values for Ozone, Nitrogen Dioxide, Sulfur Dioxide and PM_{10aut}

Pollutant	Daily minimum values [μg/m^3]	Daily maximum values [μg/m^3]	Daily country mean values [μg/m^3]	Limit values [μg/m^3]
Ozone	7.3	65.6	28.5	120 μg/m^3 in 8 hours
Nitrogen Dioxide	9.5	107.8	27	200 μg/m^3 in one hour
Sulfur Dioxide	1.1	27.3	9.1	125 μg/m^3 in one day
PM_{10aut}	7.1	102.2	32.5	50 μg/m^3 in one day

3.7. GHG emission reduction in Romania

It is well known that most of the GHG emissions come mainly from the energy production. 68.17 Mt of CO_2 were emitted in Romania in 2014, out of which 27.3 Mt were emitted by the energy sector, the other sectors contributing with much lower quantities, as shown in Figure 14.

Since joining the EU in 2007, Romania has been forced to implement its policies to reduce GHG emissions and to use renewable energy sources. The results of these measures were significant, especially in the electricity sector due to the government schemes to help wind and photovoltaic electricity producers. An immediate effect of the development of these energy sectors was the significant increase in the total amount of electricity produced from renewable sources, especially wind power. This fact led to a significant decrease in CO_2 emissions produced by electricity generation. Although the amount of electricity produced in Romania has recently increased from 56.69 TWh in 2009 to 61.8 TWh in 2016, CO_2 emissions from its production have decreased from 25.36 million tCO_2 in 2009 to 17.74 million tCO_2.

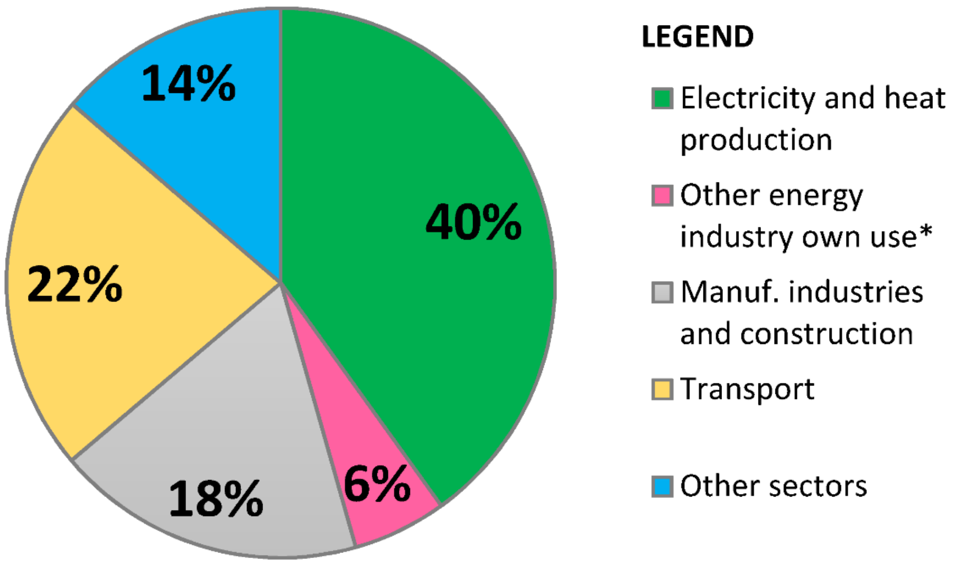


Figure 14. CO_2 emissions from fuel combustion by sector, in 2014, in Romania[54]

CO_2 emissions from electricity generation are characterized by high values in winter months, due to the increase in electricity consumption but also to the increase in the amount of electricity produced by the combustion of fossil fuels, especially coal. For the time mentioned, the trend regarding the high polluting electricity that is produced by burning coal is decreasing from around 40% in 2011 to 24% in 2016. The variation of CO_2 emissions from the electricity generation sector over the last 6 years is presented in Figure 15.

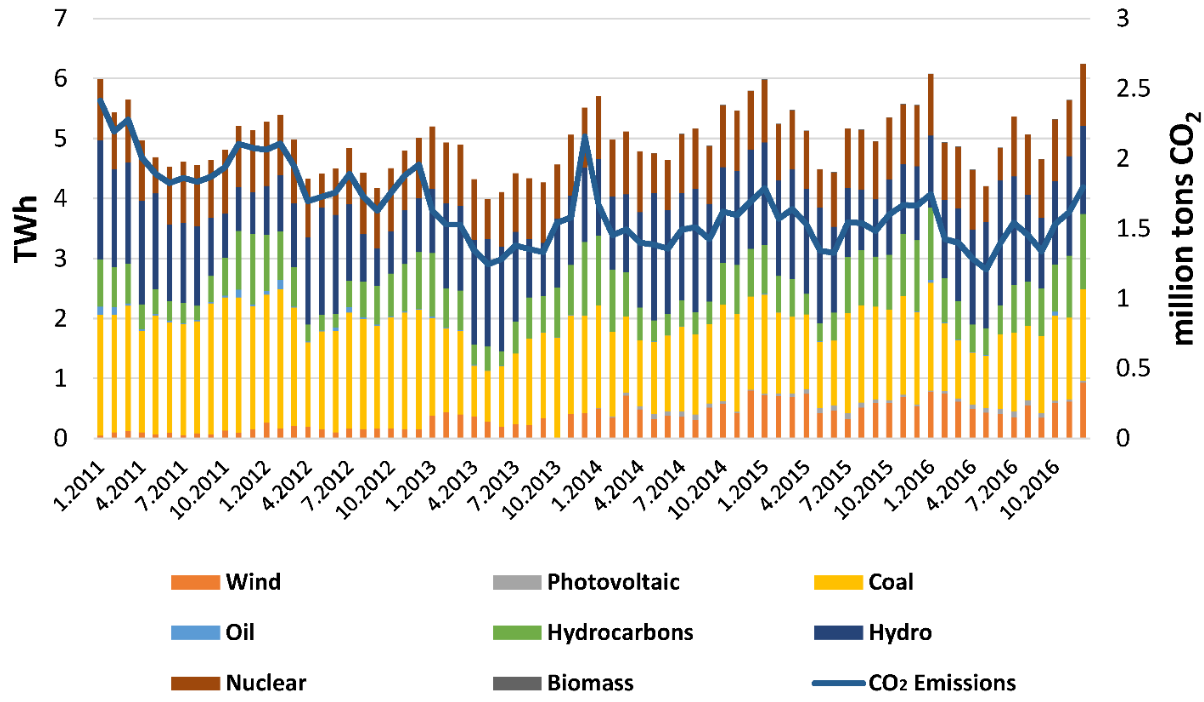


Figure 15. CO_2 emissions from the energetic sector over the last 6 years, in Romania[55]

Moreover, if we correlate the total emissions with the values from energy production and distribution, as in Figure 16, we observe the same decreasing trends over the last years.

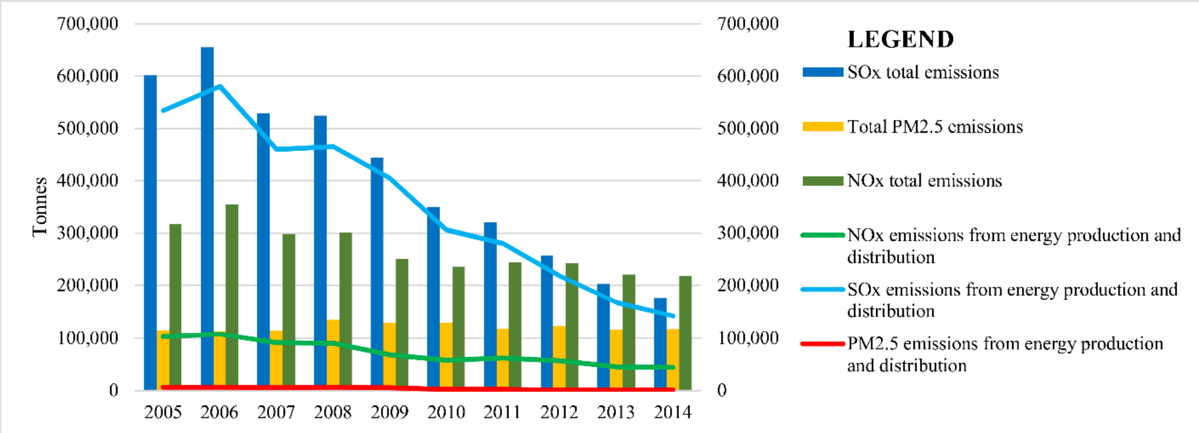


Figure 16. Total emissions as well as energy production and distribution emission correlation, for NOx, SOx and $PM_{2.5,}$ in Romania, from 2005 to 2014 [18]

4. Conclusions

This article aims to contribute to the knowledge of air pollution in Romania, presenting a recent assessment of the ground-level concentrations of major air pollutants using regional measurements, trends and databases, covering a period of almost 30 years. The ambient air pollution levels, their variability and trends are discussed in the context of air quality status and trends in Europe and worldwide, only to perform a more descriptive analysis of Romania. Specific air pollutant trends are analyzed in contrast with the latest variations of renewable energy sources installed all over the country.

The objective of this study was to analyze the air pollution over Romania and to evaluate the hypothesis of their decrement as a result of different changes such as: the increasing use of renewable energies, changes in legislation and because of a better awareness of climate change. We believe the scope has been reached and that the results support the above statement.

The results presented in this study are meant to contribute to implementing environmental effective policies, to encourage the development of renewable, recyclable and sustainable energy sources, together with arousing the interest of all the parts involved, from common people to decision makers, to preserve the biodiversity and make the breathable air a clean and healthy environment for everyone.

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6. References

[1] C. Milando, L. Huang, and S. Batterman, “Trends in PM2.5emissions, concentrations and apportionments in Detroit and Chicago,” *Atmos. Environ.*, vol. 129, pp. 197–209, 2016.

[2] A. M. Jones, R. M. Harrison, B. Barratt, and G. Fuller, “A large reduction in airborne particle number concentrations at the time of the introduction of ‘ sulphur free’ diesel and the London Low Emission Zone,” *Atmos. Environ.*, vol. 50, pp. 129–138, 2012.

[3] S. E. Haupt, “A demonstration of coupled receptor/dispersion modeling with a genetic algorithm,” *Atmos. Environ.*, vol. 39, no. 37, pp. 7181–7189, 2005.

[4] P. SK, A. AH, O. MS, R. Prineas, C. JC, and J. Keeler, “Particulate Air Pollution, Metabolic Syndrome and Heart Rate Variability: the Multi-Ethnic Study of Atherosclerosis (MESA).,” *Env. Heal. Perspect*, 2010.

[5] I. Bagayev and J. Lochard, “EU air pollution regulation: A breath of fresh air for Eastern European polluting industries?,” *J. Environ. Econ. Manage.*, vol. 83, pp. 145–163, 2017.

[6] P. Fauser *et al.*, “Human exposure to carcinogens in ambient air in Denmark, Finland and Sweden,” *Atmos. Environ.*, vol. 167, pp. 283–297, 2017.

[7] I. Mavroidis and M. Ilia, “Trends of NO x, NO 2 and O 3 concentrations at three different types of air quality monitoring stations in Athens, Greece,” *Atmos. Environ.*, vol. 63, no. 2, pp. 135–147, 2012.

[8] International Energy Agency, “Energy and Air Pollution,” 2016.

[9] C. Cany, C. Mansilla, P. da Costa, G. Mathonnière, T. Duquesnoy, and A. Baschwitz, “Nuclear and intermittent renewables: Two compatible supply options? The case of the French power mix,” *Energy Policy*, vol. 95, pp. 135–146, 2016.

[10] R. E. Munn, “Towards sustainable development,” *Atmos. Environ.*, vol. 26A, no. 15, pp. 2725–2731, 1992.

[11] D. Poputoaia and S. Bouzarovski, “Regulating district heating in Romania: Legislative challenges and energy efficiency barriers,” *Energy Policy*, vol. 38, no. 7, pp. 3820–3829, 2010.

[12] A. Baklanov, L. T. Molina, and M. Gauss, “Megacities, air quality and climate,” *Atmos. Environ.*, vol. 126, pp. 235–249, 2016.

[13] S. K. Guttikunda, R. Goel, and P. Pant, “Nature of air pollution, emission sources, and management in the Indian cities,” *Atmos. Environ.*, vol. 95, pp. 501–510, 2014.

[14] E. S?? *et al.*, “Climate change and pollutant emissions impacts on air quality in 2050 over Portugal,” *Atmos. Environ.*, vol. 131, pp. 209–224, 2016.

[15] K. M. Janssens-Maenhout, G., Crippa, M., Guizzardi, D., Muntean, M., Schaaf, E., Olivier, J.G.J., Peters, J.A.H.W., Schure, “Fossil CO2 and GHG emissions of all world countries, EUR 28766 EN,” Luxembourg, 2017.

[16] Centre on Emission Inventories and Projections, “WebDab - EMEP database,” 2012. [Online]. Available: http://www.ceip.at/webdab-emission-database/. [Accessed: 05-Dec-2016].

[17] M. M. şi P. România, “Calitate aer. Retea nationala de monitorizare,” *1*, 2016. [Online]. Available: http://www.calitateaer.ro/. [Accessed: 01-Nov-2016].

[18] The European Monitoring and Evaluation Programme (EMEP), “WebDab search - Officially reported emission trends,” 2017. [Online]. Available:

http://webdab1.umweltbundesamt.at/official_country_trend.html?cgiproxy_skip=1. [Accessed: 10-Apr-2017].

[19] PBL Netherlands Environmental Assessment Agency, "Trends in global CO2 emissions. 2016 Report," The Hague, 2016.

[20] H. L. Raadal and C. Timpe, "Best practice of collection and provision of environmental data for electricity disclosure - Deliverable 5.2 of the RE-DISS II Project," 2015.

[21] European Environment Agency, "Overview of electricity production and use in Europe," Copenhagen, 2016.

[22] ANRE, "Raport privind rezultatele monitorizarii pietei de energie electrica in luna decembrie 2015," Bucharest, 2015.

[23] ANRE, "Raport privind rezultatele monitorizarii pietei de energie electrica in luna decembrie 2016," Bucharest, 2016.

[24] N. Aleksic, J. Kent, and C. Walcek, "Ozone concentrations in air flowing into New York State," *Atmos. Environ.*, vol. 141, no. April 2003, pp. 454–461, 2016.

[25] J. B. Beltman, C. Hendriks, M. Tum, and M. Schaap, "The impact of large scale biomass production on ozone air pollution in Europe," *Atmos. Environ.*, vol. 71, pp. 352–363, 2013.

[26] A. Santurt??n, J. C. Gonz??lez-Hidalgo, A. Sanchez-Lorenzo, and M. T. Zarrabeitia, "Surface ozone concentration trends and its relationship with weather types in Spain (2001-2010)," *Atmos. Environ.*, vol. 101, pp. 10–22, 2015.

[27] C. Yang *et al.*, "Alternative ozone metrics and daily mortality in Suzhou: The China Air Pollution and Health Effects Study (CAPES)," *Sci. Total Environ.*, vol. 426, pp. 83–89, 2012.

[28] J. I. Halonen *et al.*, "Ozone and cause-specific cardiorespiratory morbidity and mortality," *Source J. Epidemiol. Community Heal. J. Epidemiol. Community Heal.*, vol. 64, no. 9, pp. 814–820, 1979.

[29] EU, "Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe," *Off. J. Eur. Communities*, vol. 152, pp. 1–43, 2008.

[30] S. D. Beevers, E. Westmoreland, M. C. de Jong, M. L. Williams, and D. C. Carslaw, "Trends in NOx and NO2 emissions from road traffic in Great Britain," *Atmos. Environ.*, vol. 54, no. 2, pp. 107–116, 2012.

[31] S. Henschel *et al.*, "Trends of nitrogen oxides in ambient air in nine European cities between 1999 and 2010," *Atmos. Environ.*, vol. 117, pp. 234–241, 2016.

[32] J. R. C. Science and F. O. R. Policy, *JRC SCIENCE FOR POLICY REPORT Fossil CO 2 & GHG emissions of all world countries*. 2017.

[33] Eurostat, "Air pollutants by source sector," 2017. [Online]. Available: http://ec.europa.eu/eurostat/data/database. [Accessed: 23-Feb-2018].

[34] C. Calkins, C. Ge, J. Wang, M. Anderson, and K. Yang, "Effects of meteorological conditions on sulfur dioxide air pollution in the North China plain during winters of 2006–2015," *Atmos. Environ.*, vol. 147, pp. 296–309, 2016.

[35] S. Henschel *et al.*, "Ambient air SO2 patterns in 6 European cities," *Atmos. Environ.*, vol. 79, pp. 236–247, 2013.

[36] C. Arsene, R. I. Olariu, P. Zarmpas, M. Kanakidou, and N. Mihalopoulos, “Ion composition of coarse and fine particles in Iasi, north-eastern Romania: Implications for aerosols chemistry in the area,” *Atmos. Environ.*, vol. 45, no. 4, pp. 906–916, 2011.

[37] D. Houthuijs *et al.*, “PM10 and PM2.5 concentrations in Central and Eastern Europe:,” *Atmos. Environ.*, vol. 35, no. 15, pp. 2757–2771, 2001.

[38] S. Squizzato and M. Masiol, “Application of meteorology-based methods to determine local and external contributions to particulate matter pollution: A case study in Venice (Italy),” *Atmos. Environ.*, vol. 119, pp. 69–81, 2015.

[39] J. ??ibert, J. Cedilnik, and J. Pra??nikar, “Particulate matter (PM10) patterns in Europe: An exploratory data analysis using non-negative matrix factorization,” *Atmos. Environ.*, vol. 132, pp. 217–228, 2016.

[40] L. L. N. Guarieiro, A. F. de Souza, E. A. Torres, and J. B. de Andrade, “Emission profile of 18 carbonyl compounds, CO, CO2, and NOx emitted by a diesel engine fuelled with diesel and ternary blends containing diesel, ethanol and biodiesel or vegetable oils,” *Atmos. Environ.*, vol. 43, no. 17, pp. 2754–2761, 2009.

[41] M. Mediului si Padurilor, “Indici de calitate,” 2016. [Online]. Available: http://www.calitateaer.ro/indici.php. [Accessed: 11-Oct-2016].

[42] Ministerul Energiei, “Strategia Energetica a Romaniei 2016-2030, cu perspectiva anului 2050,” Bucharest, 2016.

[43] European Commission, “Directive 2001/80/EC of the European Parliament and of the Council of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants,” *Off. J. Eur. Union*, no. 309, pp. 1–21, 2001.

[44] G. Dragomir, A. Șerban, G. Năstase, and A. I. Brezeanu, “Wind energy in Romania: A review from 2009 to 2016,” *Renew. Sustain. Energy Rev.*, vol. 64, pp. 129–143, 2016.

[45] A. Zamfir, S. E. Colesca, and R. A. Corbos, “Public policies to support the development of renewable energy in Romania: A review,” *Renew. Sustain. Energy Rev.*, vol. 58, pp. 87–106, 2016.

[46] European Biodiesel Board, “National Renewable Energy Action Plan (NREAP),” Bucharest, 2010.

[47] G. Năstase, A. Șerban, A. Florentina Năstase, G. Dragomir, A. Ionuţ Brezeanu, and N. Fani Iordan, “Hydropower development in Romania. A review from its beginnings to the present,” 2017.

[48] S. E. Colesca and C. N. Ciocoiu, “An overview of the Romanian renewable energy sector,” *Renew. Sustain. Energy Rev.*, vol. 24, pp. 149–158, 2013.

[49] I. Iordache, D. Schitea, A. V. Gheorghe, and M. Iordache, “Hydrogen underground storage in Romania, potential directions of development, stakeholders and general aspects,” *Int. J. Hydrogen Energy*, vol. 39, no. 21, pp. 11071–11081, 2014.

[50] E. Parliament, “Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe,” 2008.

[51] EC, “Directive 2001/80/EC,” *Off. J. Eur. Union*, pp. 1–21, 2001.

[52] Romanian Parliament, *Law no. 104 from June 15, 2011*. Romania, 2011, p. 59.

[53] P. Romanian, “Law no. 104 from 15 of June 2011 on ambient air quality,” no. 104, 2011.

[54] International Energy Agency (IEA), “CO2 emissions from fuel combustion,” *OECD/IEA*, pp. 1–155, 2016.

[55] “Transelectrica SA,” *National Power Grid Company Transelectrica SA*, 2017. [Online]. Available: http://www.transelectrica.ro/web/tel/home. [Accessed: 13-Nov-2017].

Highlights

- Trends in ambient emissions and concentrations of air pollutants in Romania, from 1990 onward;
- Local and regional policy on air quality implemented;
- Energy production and air pollution in Romania;
- Decrease in CO, SOX, NOX, and CO2 emissions ranging from 41-87%.