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Romania's coal-fired power plants efficiency and pollution in the context of the European green deal

Vlad NERĂU
Bucharest University of Economic Studies, Romania
vlad.nerau@economie.ase.ro

Abstract. *This article analyses the efficiency of coal-fired power plants in Romania in the European Green Deal context. The focus is on the coal-fired power plants of the Oltenia and Hunedoara Energy Power Plants, as they generate over 97% of coal-fired electricity in Romania. Oltenia Energy Power Plant (CEO) is composed of eleven power plants with an average lifetime of 37 years while of Hunedoara Energy Power Plant (CEH) is composed of six power plants with an average lifetime of 42 years. At the same time, the article estimates the impact of the closure of these two energy groups on the main air pollutants and how close this would bring Romania to the targets set by the Green Deal for 2030. The article also estimates the losses from different energy sources incurred in the process of transforming raw electricity into electricity delivered to the consumers and finds that oil & gas and coal sectors have considerably higher losses than other electricity sources, with wind being the most efficient from this perspective.*

Keywords: Green Deal; coal; energy transition; pollution.

JEL Classification: O13; P18; P28; Q43.

1. Introduction

The European Green Deal is currently the most critical policy-framework for the long-term sustainability goals in European Union Member States. It was launched by the European Commission in December 2019 and through the 2030 climate & energy framework aimed to achieve: a cut in emissions by 2030 of at least 55% in comparison with 1990 levels (current policies will only reduce greenhouse gas emissions by 60% by 2050); the share of renewable energy in the electricity production mix should be of at least 32%; an improvement in energy efficiency of at least 32.5% and by 2050 EU should reach carbon neutrality.

Claeys et al. (2019), considers that "*European Green Deal might become a blueprint for other countries and a tangible example that pursuing climate neutrality is technically feasible and economically and politically viable*". Consequently, to deliver the European Green Deal, the EU Member States and the European Commission must rethink their energy and non-energy policies. There is a specific need for clean energy supply across the economy and industry, production and consumption, transport and infrastructure, digitalization, food and agriculture, construction, and other economic sectors with significant environmental impact. According to Senior Advisor to the President, World Economic Forum Geneva, Martina Larkin (2020), the European Commission estimates that reaching the net-zero 2050 target will require around 1,000 billion euro of public and private investment over the next decade. Given that the European governments and institutions are responding to the coronavirus crisis with the largest stimulus packages since the Great Depression, there is a real opportunity to deploy this stimulus strategically to fast-track a fossil-free and competitive economy for Europe. Germany has agreed a package worth up to 750 billion euro to mitigate the damage of the virus, and in Spain and Italy the size of the stimulus packages is estimated to be 7.3% and 5.7% of GDP respectively. The Commission has estimated that achieving the current 2030 climate and energy targets will require 260 billion euro of additional annual investment, about 1.5% of 2018 GDP 28.

However, there are several states that strongly rely on the coal sector. Consequently, as Claeys et al. (2019) affirms, these countries can use the employment potential issues as an argument to delay the necessary transformation, while EU should provide solutions (including financial and energy security) to implement coal phase-out measures. The authors emphasize that EU efforts within Green Deal targets should be exported, having in mind that EU generate less than 10 percent of global greenhouse-gas emissions and the impact on global temperature level will be insignificant without a proper global action together with other major countries.

Among the European countries, Poland has the largest hard coal reserves, but there are also important deposits in Czech Republic, Spain and Germany and Spain. Moreover, from the perspective of lignite, Germany has the largest deposits, followed by Poland, Greece, Czech Republic, Hungary, Bulgaria and Romania (Kavouridis and Koukouzas, 2008).

Historically, coal has been one of the European economy's primary fuels during the last century. Alves Dias et al. (2018) argues that in 1990, coal provided for almost 41% of the gross energy consumption in the EU28 Member States, and 39% of power generation. Despite the gradual decrease of its use since the 1990s, coal remains important. In particular for many of the Member States that joined the EU in 2004 and 2007, which rely on indigenous coal for power generation. In 2015, 16% of the gross EU energy consumption was supplied by coal as well as and 24% of electricity generation. Today, 6 Member States rely on coal for at least 20% of their total energy needs (Bulgaria, the Czech Republic, Germany, Greece, Poland and Slovakia), while the reliance of Poland exceeds 50%.

The article is structured in 5 sections: introduction, literature review, methodology, main results and discussion, and conclusions. It analyses the energy efficiency of coal-fired power plants, using the heat rate that represents the efficiency of conversion of fossil fuel energy input to electrical energy output. A lower heat rate represents a more efficient coal-fired power plant since it requires less heat input to generate a KWh of electricity. We built on the research done by the JRC (2018), that found that most of the Romanian coal-fired power plants have an efficiency between 30-34% and even lower, which is below the EU average, mainly because most of these coal-fired power plants were built during the communist epoch and they have exceeded their technical life span. Further the article analyses the share of electricity generated from coal energy sources in the national electricity mix using data provided by Transelectrica(1), and estimates the losses incurred in the process of delivering net electricity to consumers. The last part of this article estimates the impact on pollution generated by the Oltenia and Hunedoara Energy Power Plants which generate 97% of total electricity from coal sources. Using the data provided by Oltenia and Hunedoara Energy Power Plants through their annual reports we analyse what the impact of their full closure will be in terms of pollution reduction in order to find out if this will suffice in reaching the pollution targets set by the Directive (EU) 2016/2284 of the European Parliament and of the Council on the reduction of national emissions of certain atmospheric pollutants.

The results obtained from the current analysis show that a full closure of both energy Power Plants will only help Romania reach its SO_2 pollution target for 2030. As for NO_x and PM 2.5, other measures and public policies should be implemented, because other economic sectors (e.g. transport for NO_x, and residential, commercial and institutional for PM 2.5) are major pollution generators. Thus a full closure of the two energy Power Plants will only have a limited impact on bringing Romania closer to the 2030 targets.

2. Literature review

The green transition from coal to other energy resources generates an essential impact on both supply and consumption sides. As Melsted and Pallua (2018) showed, coal fuelled the late nineteenth and early twentieth centuries. It was "the backbone of industrial society" used for steam-powered transportation, residential heating, industrial production, and electricity generation.

Hafner and Raimondi (2020) analysed the current development of the energy transition in several European countries (i.e. Italy, UK, Germany, and Poland). They emphasized the different pace among European countries in order to implement EU energy and climate targets, based on the political commitment at national level. On one hand, Italy and the UK registered a positive trend towards renewable energy transition: Italy more state-driven through the feed-in schemes; UK – more market-driven. On the other hand, the authors considered that Germany and Poland have failed in the energy transition implementation. In Germany, despite ambitious commitment, CO_2 emissions increased due to "coal-fired power generation that closed the power generation gap caused by nuclear decommission" after Fukushima incident (Hafner and Raimondi, 2020). The reason why coal replaced nuclear is that the cost of generating power from coal has declined over the past decade. In Poland, the main problem was related to employment (i.e. significant number of mining employees) and energy security. The most recent governmental Energy Policy valid until 2040 mentioned that hard coal would remain the single most important source of electricity production by 2040, although its role would be decreasing.

However, earlier studies considered that coal could play a full part in the energy sector in EU and could be an important element for a sustainable future (Kavouridis and Koukouzas, 2008; Bugge et al., 2006) if there are efforts aiming at technology and efficiency improvement, and a new legal framework to reduce barriers to cleaner coal power.

Bugge et al. (2006) analysed the Denmark case of new coal-fired power plants with high efficiency constructed in different locations (e.g., Skaerbaek, Nordjylland). Later on, the Danish energy authorities demanded that one of them should be converted to gas. The unit from Skaerbaek was successfully converted to gas, while the Nordjylland unit benefited from new clean technology, was fitted with flue gas cleaning consisting of high dust selective catalytic reaction NOx removal, electrostatic precipitator and wet scrubbing SO_2 removal, thus making the plant a really clean coal plant.

Additionally, Melsted and Pallua (2018) affirmed that it is vital to eliminate fossil fuels in the long run, not only coal resources, and that the transition is more complex and requires the rearrangement of the primary energy mix. Moreover, the transition to renewable energy will not necessarily be made directly from one resource to another, but more likely will entail several phases of hybridization and multi-fuel use while the supply systems are modified. On the one hand, it must favour renewables resources. On the other hand, the fuel consumers from main sectors (like transportation, residential heating, industries, and electricity generation) must actively choose to substitute fossil fuels with renewable alternatives.

Oei et al. (2020) analysed Germany's situation from the perspective of hard coal mining phase-out in the last 60 years to identify the most important qualitative and quantitative characteristics of the largest German hard coal mining areas, Saarland and Ruhr. The analysis concludes that to achieve a fair and optimal transition, the challenges are complex, starting with the coal companies' formal and informal political influence, and reducing subsidies for the coal industry. It is also essential to diversify the economy and address unemployment with well-customized policies that attract new initiatives, including subsidies, premiums and tax concessions, depending on "the availability of labor force" and the existing local or regional endowments. Moreover, citing different other articles (Healy and Barry, 2017; Mayer, 2018; Newell and Mulvaney, 2013) on the labour market development, Oei et al. (2020) emphasize the role of the active and passive labour market and social policies for an in-time transition, mentioning measures as retraining of employees and early communication of phase-out plans. These early measures can ease the pressure of potential unemployment to face the upcoming changes, "helping coal miners to stay in the labour market and encourage new generations to choose education and employment tracks with better future perspectives". Frigeli (2009) showed that in Germany, early retirement steps were used to alleviate labour market pressures and support miners. According to the 2007 hard coal financing law, any worker over 42 was covered from unemployment. After the end of their employment in coal mines in 2018, workers would work three years in decommissioning and then receive payments for another five years to bridge the time until they entered the regular pension fund at age 62 in 2027.

Also, in the case of Germany, Brauers et al. (2018) considered that there could be fears for energy-intensive industries to lose their competitiveness because of a higher price. Analysing the same regions of Ruhr and Saarland as Oei et al. (2020), they concluded that the coal regions usually face the challenges many rural areas have in terms of a lack of infrastructure, emigration, aging population, low fertility rates, and dependency on coal production. Consequently, there is a need in these regions for different kind of support policies to keep the population size and to attract new people, such as:

- Modern infrastructures (transport, internet, railways, etc.), including the shift toward less carbon-intensive transport vehicles or bicycle paths.
- A network of education and research facilities, with an accent on the connection with other metropolitan areas.
- Attractive living conditions (more opportunities for cultural activities and leisure time, low level of air pollution, etc.).
- Stimulus to the local entrepreneurial ecosystem and corporations that provide jobs fit for the future.

In the case of Poland, Manowska et al. (2017) affirmed that coal remains essential for the Polish energy production mix and energy safety policy, and that the production mix was strongly correlated with the effectiveness of the mining industry's restructuring program. The article also draws attention "to the search for restructuring solutions for Polish hard coal mining companies in areas other than human capital".

Complementary, Sobczyk et al. (2020) analyzed the financial situation of Polish enterprises dealing with the extraction of solid fossil energy materials (hard coal and lignite) during the restructuration period between 2013-2017, concluding that, in order to maintain its ability to settle their liabilities towards employees and suppliers, the mining enterprises were selling their assets and products usually at a price lower than production costs.

There is a lack of scientific literature regarding the energy transition from coal to other energy resources in Romania's case. Dudău and Catuti (2020) considered that, in the context of the new European Green Deal, "the protracted use of the existent energy production and infrastructure assets, many of them old, polluting and inefficient, oftentimes operating beyond their technical lifetimes, translates in flattening trajectories towards the 2030 targets for GHG emissions reduction, renewable energy sources, and energy efficiency". Also, in the same context of the European Green Deal Agreement, Ionescu (2020) considered the implementation of Green Deal will "encourage investment in renewable energy and the gradual reduction of the coal use", while the nuclear energy and natural gas levels would be maintained. However, the authors estimated that Romania will obtain up to 65% clean energy from renewable sources.

3. Methodology

In order to highlight the efficiency of coal-fired power plants in Romania compared to those in the European Union, we consolidate on the findings obtained by Alves Dias et al. (2018) which estimated the thermal efficiency of the individual power plants based on the available information on the installed capacity, the age and type of power plant. The CO_2 emissions of a power plant are proportionally related to the type of fuel used, the amount of fuel consumed during the year, and therefore the generated electricity and the efficiency. The following formula was used:

$$\text{Eff} = \frac{\text{generation} * 3.6}{\frac{\text{CO2 emissions excl. biomass}}{\text{Intensity fuel}} + \frac{\text{CO2 emissions} - \text{CO2 emissions excl. biomass}}{\text{Intensity biomass}}} \quad (1)$$

where:
$\text{Intensity}_{\text{fuel}}$: The CO_2 content per calorific energy in the fuel expressed in tonnes CO_2 per TJ.
Generation: annual net generation of the power plant in MWh.
CO_2 emissions: Annual emissions in kg.

The dataset used to calculate the thermal efficiency of coal-fired power plants is from JRC Open Power Plants Database (JRC-PPDB-OPEN) (EU JRC, 2020). To emphasize the contribution of each energy source in the electricity production mix we used the data provided by Transelectrica for 2019 (Transelectrica, 2020).

In order to calculate the energy losses from the process of transforming gross energy into energy available in the network for consumption, we used Transelectrica methodology (Transelectrica, 2020) which is based on the following formula:

$$NP = GAP - (PCOS + SCGS + PLTB) \quad (2)$$

where:
NP (net power) – The power that the generator can deliver to the network for marketing purposes.
GAP (gross available power) – total electricity produced by the generator.
PCOS – power consumed in own services.
SCGS – The share of consumption of general services.
PLTB – Power losses in the transformer block.

To calculate the pollution impact of the Oltenia Energy Power Plant and the Hunedoara Energy Power Plant, we used the companies 2018 environment reports and the data provided in them in relation to CO_2, SO_2, NOx, and PM 2.5 emissions. Next, starting with the amount of greenhouse gas emissions (SO_2, NOx, and PM 2.5) at national level, the data used being those from the European Environment Agency (EEA, 2020), we analyzed the impact that a total closure of these two Power Plants would have in terms of reducing greenhouse gas pollution and if such a scenario is relevant for reaching the 2030 air pollution targets imposed by the EU Green Deal. The impact was calculated at national level by subtracting from the current air pollution levels, the pollution generated by the two energy Power Plants.

4. Results and discussion

4.1. Electricity production mix in Romania and energy loss by a different type of sources

Under the new climate action objectives at EU level, Romania would have to change its energy mix, in favour of a bigger share for renewables, closing down many of its coal sites. However, in Romania's energy production mix, the coal sector has a major historical contribution to energy production at around 24% of the total production registered at the end of 2019. Furthermore, the share is increasing to 40% during winter period. Two sorts of coal are mined in the country's two main basins, respectively: hard coal in Jiului Valley, and lignite in South West Oltenia region.

Energy production facilities in the CEE countries in general, and in Romania in particular, have been mainly constructed before 1990, starting with 1970s. With the addition of thermal coal power plants in the 1970s and 1980s, the Jiului Valley turned into a hub of power generation, with more than 60,000 employees in 16 coal mines in 1989. However, in the 1980s, the coal-fired plants started to cogenerate heat, which fuelled the region's district heating systems.

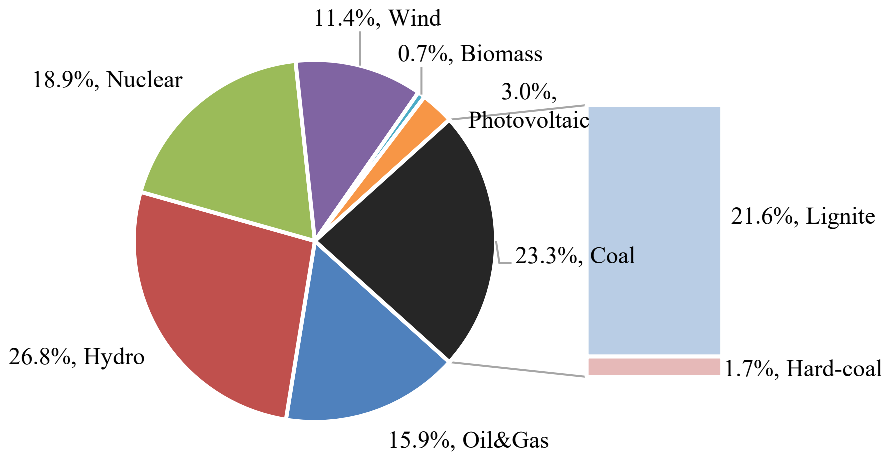
Starting with 1990s and until present, the mining activity has started to decline in Jiului Valley. The collapse of activity during 1997-2017, may be observed by the reduction of mining perimeters in operation from 16 mining perimeters of 163,35 km^2 to 4 mining perimeters of 22,3 km^2 (Barbu, 2020).

According to Transelectrica 2019 annual report the installed power decreased from 24714 MW at the beginning of 2017 to 20696 MW at the end of 2019, Romania losing more than 4,000 MW in this period mostly due to reduction of coal (-1453 MW) and oil and gas (-2553 MW) during three years, while biomass and photovoltaic slightly increased. Complementary, hydropower, and wind power decreased.

In terms of production, in 2019 compared to 2018, the variation of production by types of resources decreased in the most primary sources of power, with values between 0.94% for nuclear production, respectively 13.56% for oil and gas production. At the same time, there were significant increases in output from renewable sources, respectively wind (+7.14%), biomass (+27.56%), and photovoltaic (+0.34%). Hydropower production decreased by 10.28% compared to the previous year. This was caused by the decrease of hydraulicity on inland rivers, from 97% in 2018 – typical year, to 85% in the year 2019 – subnormal year. However, given that renewable sources' production is very volatile (variations in output over 1,000 MW between concomitant intervals), the integration in the National Electrical System of wind power plants was facilitated, to no small extent, due to variation of the production in the hydropower plants.

Figure 1 shows that even if the mix of electricity production mix of Romania is a balanced one, fossil fuels still play an important role. Any decrease in the share of electricity generated from coal or oil & gas must be covert by an increase from renewable sources because the balance was deficient, on average, throughout 2019. We must also take into account the fact that energy production from current hydro sources is declining due to the desertification process as argued by Owen, W. Phil et.al 2018 in the report Combating desertification in the EU: a growing threat in need of more action.

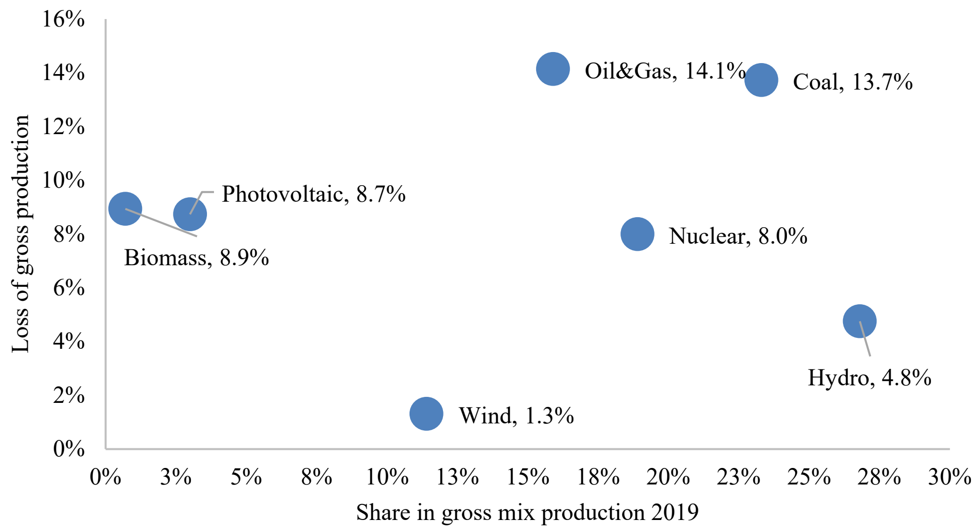
Figure 1. *Electricity production mix by primary resources in Romania (2019)*



Source: Transelectrica – SEN

There is a difference between gross production and net power delivered in the network in the energy production process. Using the formula (2) from methodology section.

Figure 2. *Loss in energy production by source type*



Source: Own calculation based on Transelectrica data.

Figure 2 shows that larger losses in energy production process are incurred for coal, oil and gas (approximatively 14% of the gross energy production for both categories), having an essential share in the energy production mix (16% for oil and gas, and 24% for coal). The problem caused by these losses is all the thornier for coal-fired power plants, as they are financially inefficient anyway due to the high costs of CO_2 allowances. A loss of 14% of the gross energy produced by these plants does nothing but put additional pressure on the budgets of the two energy Power Plants.

4.2. The potential impact of full closure of CEO and CEH on Greenhouse Gas Emissions

The five primary air pollutants according to the "Directive (EU) 2016/2284 of the European Parliament and of the Council on the reduction of national emissions of certain atmospheric pollutants" are nitrogen oxides (NOx), non-methane volatile organic compounds (NMVOCs), sulphur dioxide (SO_2), ammonia (NH3), and fine particulate matter (PM2.5). In coal burning, besides CO_2, the other pollutants emitted are NOx, SO_2, and P.M 2.5. The unit of measure (for the above-mentioned air pollutants) used by the European Environment Agency is Gigagrams (1 Gigagram = 1,000 tons).

Table 1 shows the level of pollution produced by the two energy Power Plants responsible for 97% of the electricity generated from coal sources. In the case of CEH, we used extrapolation based on electricity produced and similar level of pollution with CEO. Given the similar efficiency and lifespan of the coal-fired power plants of the CEO and CEH, it was considered that the level of pollution per MWh generated, is similar.

Table 1. *Greenhouse gas emissions generated by the Oltenia Energy Power Plant (CEO) and the Hunedoara Energy Power Plant (CEH) (2017-2018)*

Emissions/Source	CEO	CEH	Total
CO_2	5,141.304	349.063	5,490.37
SO_2	11.83	0.867*	12.63
NO_x	14.286	0.970*	15.26
Particulate matter (P.M 2.5)	0.76	0.052*	0.82

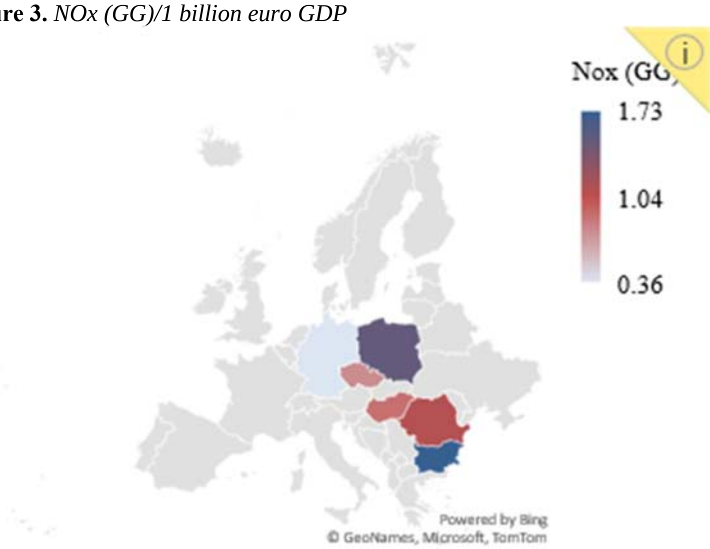
Note: All values are in gigagrams. *Extrapolation based on electricity produced and similar levels of pollution with CEO.
Source: CEO 2018 Environment report. CEH 2017 annual administrators report.

The analysis of greenhouse gas emissions must consider the economy's structural legacy; countries of Central and Eastern Europe, compared to Western Europe, have a higher share of industry in GDP. Consequently, a higher percentage of industry in GDP, especially if the extractive industry and the manufacture of low and medium gross value-added goods are the ones that make up the bulk of the industrial sector which consume more energy, will generate higher levels of greenhouse gas emissions per 1 billion euro GDP.

Compared to the other Central and Eastern European member states that have economies with a structure similar to that of Romania, our country ranks better than Bulgaria and Poland in terms of pollution with NOx/1 billion euro GDP, being structurally closer to Hungary and the Czech Republic, although all Central and Eastern European countries have higher NOx pollution than the EU average (see Figure 4).

The leading cause of reducing NOx emissions from energy production came on the back of a declining share of electricity produced by coal-fired power plants (from 45% in 2007 to 25% in 2018). Moreover, higher efficiency filters have been introduced in coal-fired power plants that have continued to operate to this day, diminishing even further the NOx emissions that eventually reach the air.

Figure 3. *NOx (GG)/1 billion euro GDP*



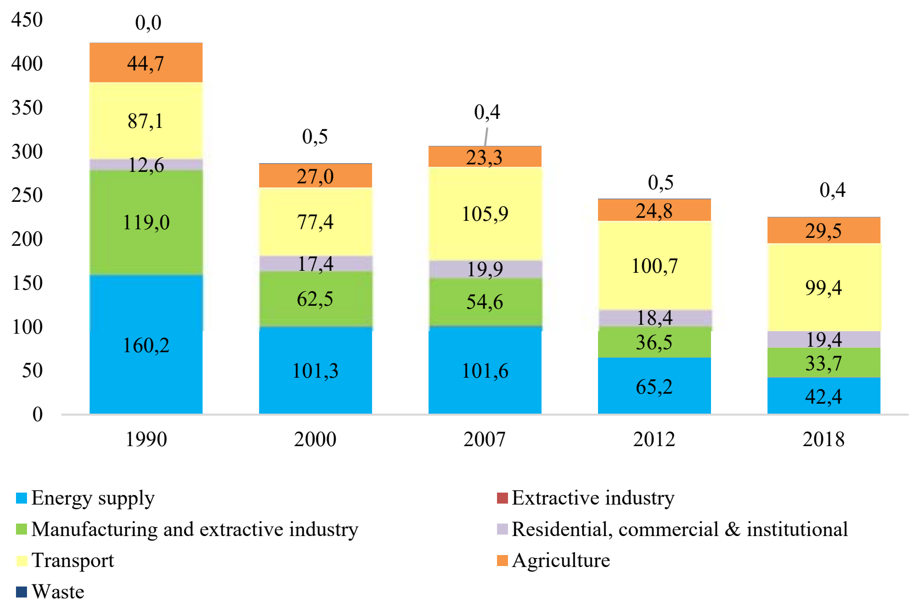
*EU28 average is 0.46 GG/1 billion euro GDP.
Source: Own calculation based on Eurostat GDP data & European Environment Agency National Emission Ceilings Directive emissions data.

Compared to the period of admission to the European Union (2007), Romania managed to reduce NOx emissions from 306.3 GG to 225.4 GG in 2018 (See Figures 5 and 6). The substantial reduction of these emissions comes from the energy production sector, whose contribution decreased from 101.6 GG to 42.GG. In other words, the energy production sector reduced its contribution from a share of 33.17% in total NOx emissions in 2007 to a share of only 18.8% in 2018.

Figure 4 shows the contribution of each sector to NOx emissions form 1990-2018. 1990 was chosen because is the first year after the fall of the communist regime and of central planned economy, also 1990 is the reference year for one of the targets proposed through the European Green Deal, namely the reduction of emissions by 2030 by at least 55%. From 2000 to 2007, Romania enjoyed a strong economic growth, although above the potential GDP, combined with an intensification of economic activity, which also led to an increase in NOx emissions. 2007 was the year when Romania was admitted to the European Union and started enforcing more rigorous pollution norms. Between 2007 and 2012, Romania went through the Great Depression with considerable fiscal effort, a substantial part of the decrease in the level of NOx emissions is also due to the slowdown in economic activity. The latest available data are for 2018.

Even with a complete closure of the Oltenia and Hunedoara Energy Power Plants would reduce NOx emissions by another 15.26 GG, as can be seen in Table 1, but even so, there would still be a substantial difference between the actual (2018) level of 225.4 GG and the 2030 target (122.28 GG).

Figure 4. *NOx Emissions evolution by sector (GG)*



Source: European Environment Agency (EEA).

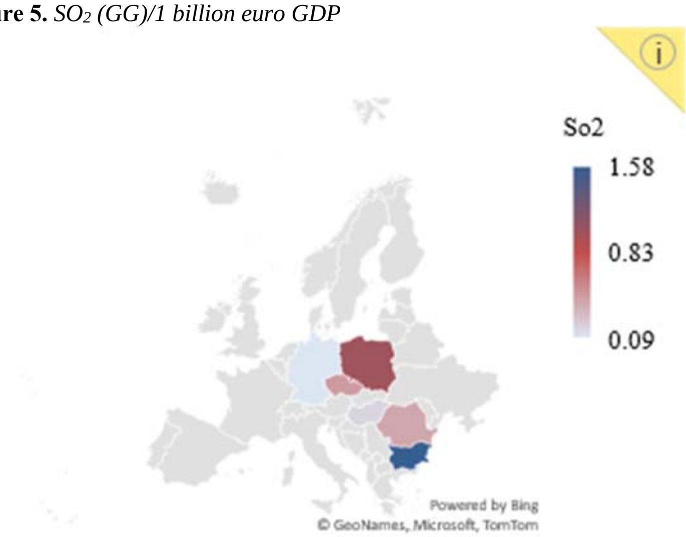
As can be seen, the primary source of NOx emissions is the transport sector. NOx emissions generated in 2007 was of 105.9, of which 89.1 GG was generated by road transport. In 2018 NOx emissions from the transport sector was of 99.4 GG, of which 89.9 was generated by road transport (see Figures 8 and 9).

We should consider that even if engine emissions regulation has become tighter, the number of passengers' cars in Romania has increased significantly in this period (approx. 3.54 million in 2007 to approx. 6.45 million in 2018), which means that better road infrastructure (including a higher number of electric charging stations) and a shift towards more efficient engines and a higher share of electric cars will have a more consistent impact on NOx emission reduction, than the closure of CEO and CEH.

Further on, we discuss SO_2 emissions which lead to acid deposition, which, in turn, can lead to changes in soil and water quality. The subsequent impacts of acid deposition can be significant, including adverse effects on aquatic ecosystems in rivers and lakes and damage to forests, crops and other vegetation. SO_2 emissions also aggravate asthma conditions and can reduce lung function and inflame the respiratory tract.

The largest source of SO_2 emissions in the atmosphere is the burning of fossil fuels by power plants and other industrial facilities. Other sources with lower SO_2 emissions are industrial processes such as extracting metal from ore. Romania's heavy industry and the heating system based on a large proportion of thermal energy resulting from coal-burning were a significant source of SO_2 pollution in the post-communist and pre-admission to European Union era.

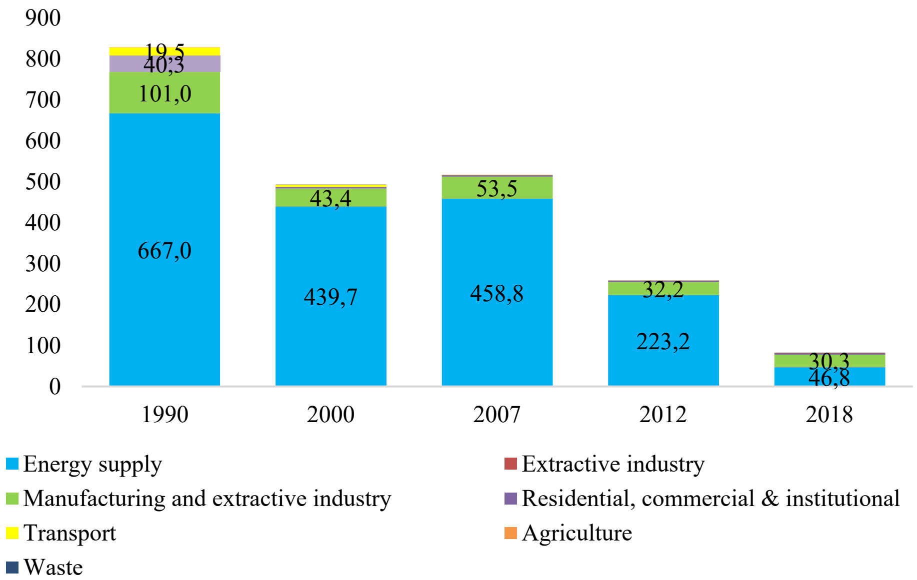
Figure 5. *SO_2 (GG)/1 billion euro GDP*



*EU28 average is 0.13.
Source: Own Calculation based on Eurostat GDP data & European Environment Agency National Emission Ceilings Directive emissions data.

Following Romania's admission to the European Union and the implementation of pollution regulations, SO_2 emissions have been significantly reduced (see Figure 8), mainly by refurbishing the coal-fired power plants' filtering processes and closure of the most inefficient facilities. In 2007, SO_2 emissions had a value of 516.6 GG, of which 458.8 represented energy supply, meaning a share of 88.8% of total SO_2 emissions.

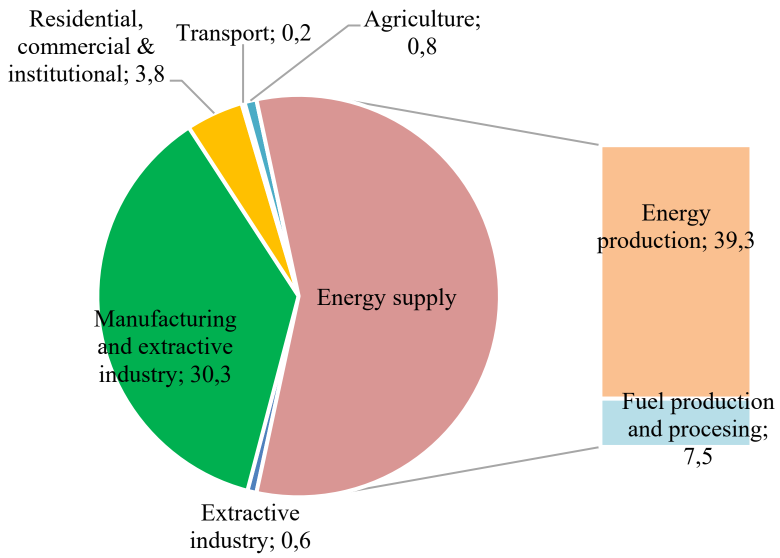
Figure 6. *SO_2 Emissions evolution by sector (GG)*



Source: European Environment Agency (EEA).

As can be seen, energy production is the main sector that generates SO_2 emissions followed by the manufacturing and extractive industry. Together these two sectors generate over 90% of SO_2 emissions. The main sources of SO_2 pollution in Romania besides energy production are the production of petrochemical products, the production of cement and non-ferrous metals.

Figure 7. *SO_2 Emissions by sector (82.5 GG; 2018)*



Source: European Environment Agency (EEA).

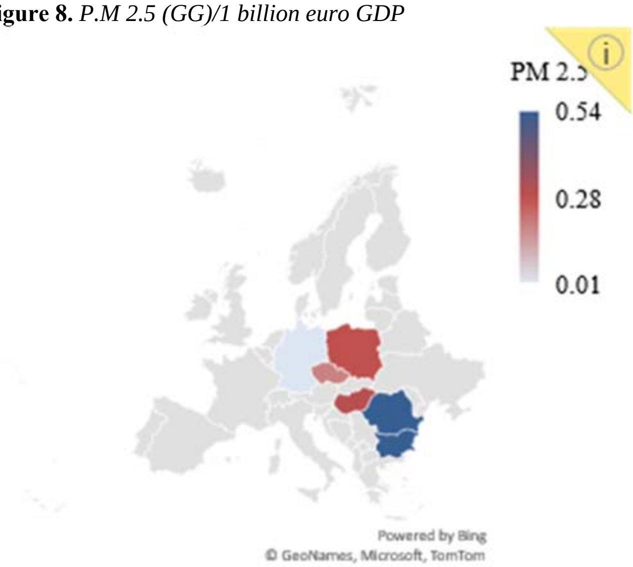
SO_2 emissions levels in 2018 were 82.5 GG, of which energy supply represented 56.72%. It is worth noting that the current level of SO_2 emissions is considerably lower than the 2020 target of 138.83 GG and slightly above the target assumed for 2030 of 72.43 GG. A full closure of the CEO and CEH would mean, *caeteris paribus,* reducing the current levels by 12.63 GG and thus reaching the 2030 target.

Finally, we will discuss particulate matter emissions. Particulate matter 2.5 are even more dangerous than Particulate matter 10, because they can get deep into the lungs, and some may even get into the bloodstream. Diseases that can occur due to exposure to P.M 2.5 are: irregular heartbeat, aggravated asthma, decreased lung function and increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing.

Also, P.M 2.5 is the main cause of reduced visibility (haze), phenomenon more frequently observed in large industrial cities. Particles can be carried over long distances by wind and then settle on ground or water. Depending on their chemical composition, the effects of this settling may include: making lakes and rivers acidic, changing the nutrient balance in coastal waters and large river basins, depleting the nutrients in soil, damaging sensitive forests and farm crops and affecting the diversity of ecosystems.

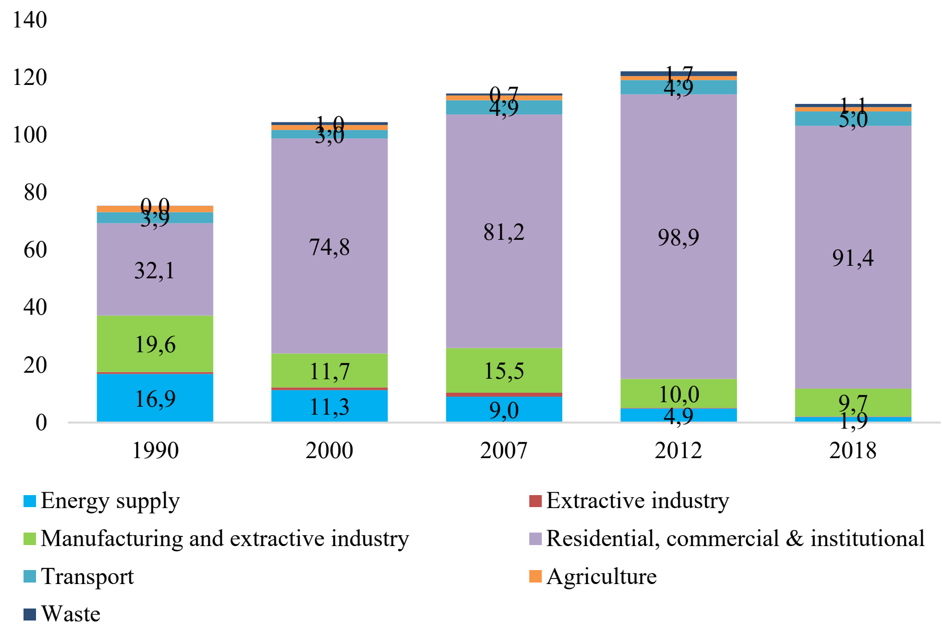
Figure 8 shows that Romania and Bulgaria register levels considerably higher than the EU average, and some of the main causes for particulate matter pollution are the poor quality of infrastructure, mainly road infrastructure, and low capacity of enforcing pollution norms on construction sites.

Figure 8. *P.M 2.5 (GG)/1 billion euro GDP*



*EU28 average is 0.08.
Source: Own calculation based on Eurostat GDP data & European Environment Agency National Emission Ceilings Directive emissions data.

Figure 9. *P.M 2.5 Emissions evolution by sector (GG)*

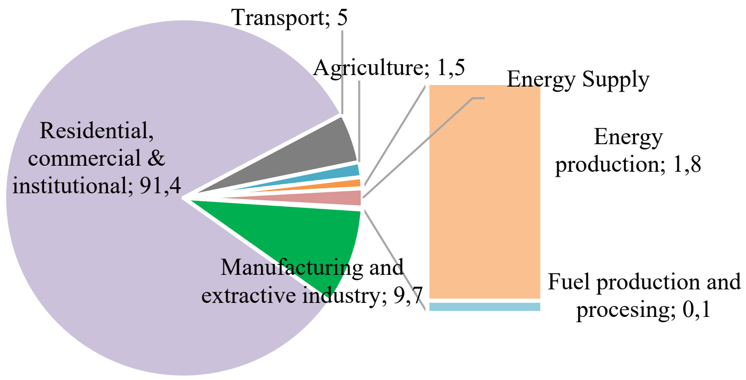


Source: European Environment Agency (EEA).

Anthropic sources of P.M 2.5 emissions are: industrial activity, population heating system, thermoelectric power plants. Road traffic contributes to the pollution with dust produced/raised in the air by the tires of moving cars, as well as by incomplete combustion of fuels (especially diesel engines) as it is show by the National Network of Air Quality Monitoring.

The Energy Supply sector does not have a significant impact on the P.M 2.5 emissions, and a full closure of the two energetic Power Plants will only reduce the P.M 2.5 emissions by 0.82 GG with no real impact on reaching the 2030 target of 50.51 GG, which represents approximatively half of the current level of P.M 2.5 emissions.

Figure 10. *P.M 2.5 Emissions by sector (110.7 GG; 2018)*



Source: European Environment Agency (EEA).

As it can be observed from Figure 10, the energy supply sector has a negligible contribution on P.M 2.5 pollution, the main cause for P.M 2.5 emissions being the residential, commercial, and institutional sector, which account for more than 82.5% of the total P.M 2.5. Romania currently has a total of approx. 8.5 million homes, of which about 7.5 million are inhabited. Of these, approx. 4.2 million are individual homes, and approx. 2.7 million households are apartments located in blocks of flats (condominium). Only 5% of the flats are energetically modernized by thermal insulation.

One-third of Romania's homes (almost 2.5 million) are heated directly with natural gas, using apartment plants and stoves with very modest thermic yields (at least 250,000 households). About 3.5 million homes (the vast majority in rural areas) use solid fuel – mostly wood and coal – burned in stoves with extremely low efficiency. The rest of the houses are heated with liquid fuels (heating oil, diesel, or LPG) or electricity. Unfortunately, and this is the case, especially in a rural area, more than half of the homes are only partially heated during the winter.

As timber trade is facing stiffer regulation and heat and fuel prices are liberalized, heating costs will increase, encouraging on one hand investment in thermal rehabilitation of homes, but on the other hand, puts more pressure on the short-term expenses a household has to bear with heating.

5. Conclusions

The first conclusion that can be deduced from this analysis is that the average efficiency of coal-fired power plants in Romania is below the European average. In the case of most of the still operational coal-fired power plants in Romania, they have exceeded their technical life span.

Both Energy Power Plants coal-fired power plants are financially inefficient, especially those operated by the Hunedoara Energy Power Plant, which is also in insolvency proceedings. Moreover, it is expected that the price of CO_2 European Emission Allowances will increase in the future, putting more pressure on the financial situation of both energy Power Plants.

Regarding the achievement of targets for air pollutants emissions, we can see that the closure of the two Power Plants will only help meet the target for SO_2 emissions because, in the case of NOx emissions, the transport sector is responsible for 44.13% of the total NOx emissions. At the same time, energy production has a share of only 15.8%, and fuel production has a share of 3%, which means that to achieve pollution targets, public policies must first address pollution from the transport sector.

Also, regarding the reduction of P.M 2.5 emissions, the impact of the two Power Plants' closure will be negligible because the main sector responsible for more than 82% of total P.M 2.5 emissions is the residential, commercial, and institutional sector. To achieve P.M 2.5 emissions, public policies must focus primarily on increasing residential, commercial, and institutional buildings' energy efficiency and thermal insulation.

It should also be noted that in the case of both coal and oil & gas electricity, there is a loss of about 14% of gross electricity in the process of transferring it to the final consumer, while in the case of nuclear energy, loses amount to 8%, 5% in the case of the Hydroelectricity and only 1% is lost in this process for wind energy, which leads to a further decrease in the financial efficiency of energy produced from fossil sources.

However, we should bear in mind, that a significant part of electricity is still generated from coal (24% of the energy production mix), which means that before we can shut down these two Power Plants, alternative sources of energy should be provided.

Without the prior provision of alternative energy sources, the closure of the two Power Plants will increase Romania's dependency on energy imports, which will result in a higher cost for consumers and a significant source of uncertainty for national energy security.

This paper accounts only for the impact of a full closure on air pollution and the gap that would remain in reaching the 2030 targets. Further research should focus on accounting the impact a full closure will have on regional employment and welfare, bearing in mind that the regions are highly dependent on coal sector activities. Also, further research should be focused on the role of coal fired power plants have in balancing the national electricity grid and on electricity supplied in heavy winter months, there were short periods of time (days) when coal fired power plants provided almost 40% of total electricity used at national level.

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Note

(1) Transelectrica is the Romanian Transmission and System Operator (TSO). It is responsible for electricity transmission, system and market operations, grid and market infrastructure development ensuring the security of the Romanian power system.

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