ENERGY CONSUMPTION AND AIR POLLUTION IN THE JIU VALLEY: ANALYZING INDUSTRIAL IMPACT AND SUSTAINABLE SOLUTIONS

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ABSTRACT (TNR 10 pt Bold): This study examines the relationship between energy consumption and air quality in the Jiu Valley, a historically coal-dependent region. It analyzes how industrial processes and reliance on fossil fuels contribute to air pollution, adversely affecting public health and the environment. Using recent emissions data for key pollutants—such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), and particulate matter (PM10)—the study correlates pollution levels with energy consumption trends in the region. The paper also reviews pollution mitigation efforts and the shift towards renewable energy sources like solar and wind. Findings indicate a strong association between increased fossil fuel energy use and air quality degradation, emphasizing the need for strategic energy policies to protect the environment. This research advances our understanding of how energy usage affects public health and supports the development of sustainable strategies to improve living conditions and preserve the environment in the Jiu Valley.

KEY WORDS: Energy Consumption, Coal Mining, Renewable Energy, Energy Transition.

1. INTRODUCTION

The Jiu Valley, located in Romania, has long been a center for coal mining and energy production, establishing the region as heavily coal-dependent. This dependency has led to significant environmental and public health impacts. The recent shift from coal to more sustainable energy sources is critical for the area, as industrial emissions continue to degrade air quality. Pollutants such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), and particulate matter (PM10) are not only harmful to the environment but also pose serious risks to public health.[1]

The challenge faced by the Jiu Valley is a microcosm of a much broader global issue: how to transition from fossil fuel-dependent energy systems to cleaner, more sustainable alternatives while addressing the legacy of environmental degradation caused by industrialization. The intersection of energy consumption and air quality is central to this dilemma. In regions like the Jiu Valley, energy production and industrial processes are intricately linked to pollution levels, creating a cycle where increased energy consumption leads to deteriorating air quality, which in turn harms public health and the environment.

Understanding this connection is vital for policymakers, environmentalists, and local communities as they work to find effective solutions to both energy demand and environmental sustainability.[2,3]

The Jiu Valley's industrial legacy is rooted in its rich coal reserves, which have been mined since the 19th century. In the early 1900s, the development of coal extraction technologies and the establishment of the region's first large coal mines helped shape the economy of the area. Over the

decades, the valley became an industrial hub, with coal-fired power plants and metallurgical industries driving economic growth. By the mid-20th century, the region was one of the key energy-producing areas in Romania, contributing significantly to the national energy grid.

However, this growth came at a significant environmental cost. The extensive mining operations, along with coal-based power generation, released enormous amounts of pollutants into the air, water, and soil. The smoke from industrial processes, the particulate matter from coal combustion, and the emissions from transportation systems all contributed to poor air quality in the region.

For decades, the economic benefits of coal extraction were prioritized over environmental concerns, leading to a situation where the region's natural environment, as well as the health of its population, was severely compromised.

This study aims to explore the relationship between energy consumption, particularly fossil fuel use, and air quality degradation in the Jiu Valley. By analyzing current emissions data, the study correlates energy consumption patterns with air pollution levels and evaluates efforts to mitigate this pollution through renewable energy sources. The findings of this research are essential for understanding the broader implications of energy policies on both human health and the environment.

2. Methodology

In recent years, there has been increasing recognition of the need to transition away from fossil fuel-based energy systems in order to mitigate the environmental and health impacts of energy production. The European Union, of which Romania is a member, has made significant strides in promoting renewable energy sources such as wind, solar, and hydropower, and encouraging the reduction of greenhouse gas emissions. As part of its commitments under the Paris Agreement, Romania has set ambitious targets for reducing emissions and increasing the share of renewable energy in its energy mix.

For the Jiu Valley, this transition represents both a challenge and an opportunity. The region's reliance on coal-based power generation and heavy industry makes it difficult to rapidly reduce emissions without risking economic disruption.

However, the growing interest in renewable energy offers a potential solution to the dual problems of energy demand and air pollution. Wind and solar power, in particular, have the potential to significantly reduce the reliance on coal and other fossil fuels, thereby improving air quality and public health.[4]

Recent efforts to promote renewable energy in the Jiu Valley include the installation of solar panels in both urban and rural areas, as well as the development of wind farms in the broader region. These initiatives, though still in the early stages, hold promise for reducing air pollution levels and mitigating the health impacts associated with fossil fuel combustion. However, challenges remain in terms of scaling up renewable energy infrastructure, addressing economic concerns related to job displacement in the coal industry, and ensuring that the transition to a green economy is equitable and sustainable. [5,6]

To accurately correlate energy consumption with air quality, the following data was collected and analyzed: energy consumption data, air quality data and emission factors.

The primary method for evaluating the relationship between energy consumption and air quality was through statistical correlation analysis. Time series analysis was used to examine how changes in energy consumption correlate with changes in air pollution levels over time.

Different scenarios were modeled based on projected changes in energy consumption and the expected adoption of renewable energy technologies. These scenarios will predict how pollutant levels could change over the next 5, 10, and 20 years.

We analyzed three key scenarios:

- Business as Usual- Continuation of the current energy consumption patterns, without significant changes to the energy mix.

- Moderate Transition-A gradual shift towards renewable energy, with a focus on wind and solar power expansion.
- Aggressive Transition -Rapid adoption of renewable energy, including investments in solar, wind, and energy storage technologies, along with energy efficiency measures.

To visualize the expected reductions in air pollutants (SO_2, NO_x, and PM10) resulting from the transition to renewable energy and other mitigation efforts, we can make projections based on historical trends and assumed future actions.

Table 1. Table for Pollutant Reductions Over 10 Years

Year	SO_2 (BAU)	SO_2 (Mod.)	SO_2 (Aggr.)	NO_x (BAU)	NO_x (Mod.)	NO_x (Aggr.)	PM10 (BAU)	PM10 (Mod.)	PM10 (Aggr.)
0	100	100	100	100	100	100	100	100	100
1	98	97	96	99	98	97	99	98	98
2	96	94	92	98	95	94	98	96	96
3	94	91	89	97	92	91	97	94	93
4	92	88	85	96	89	88	96	92	90
5	90	85	80	95	86	85	95	90	87
6	88	82	76	94	83	82	94	88	84
7	86	79	72	93	80	79	93	85	81
8	84	76	68	92	77	76	92	82	78
9	82	73	64	91	74	73	91	79	75
10	80	70	60	90	71	70	90	76	72

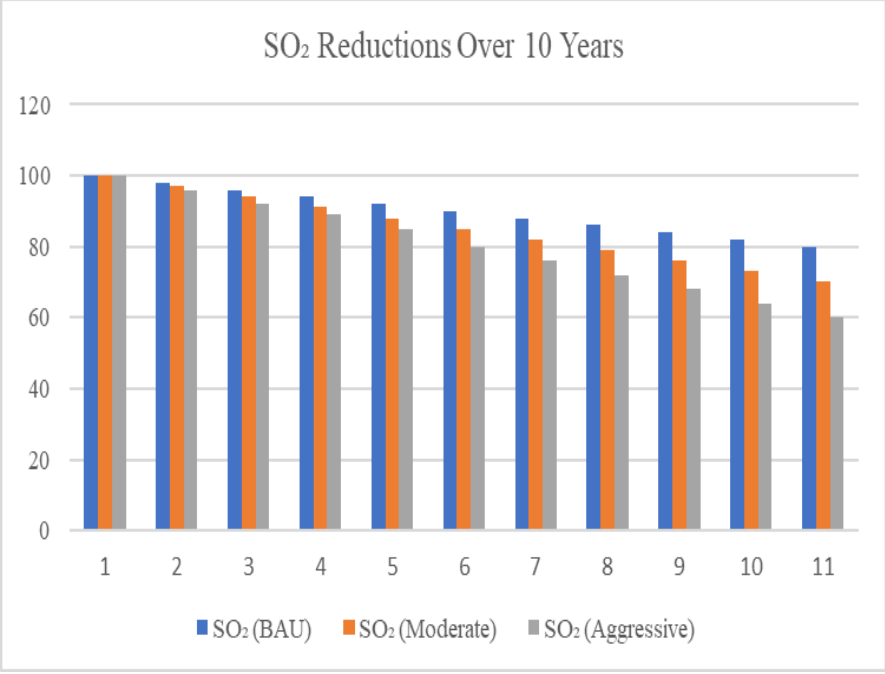

Figure 1. SO_2 Reductions Over 10 Years

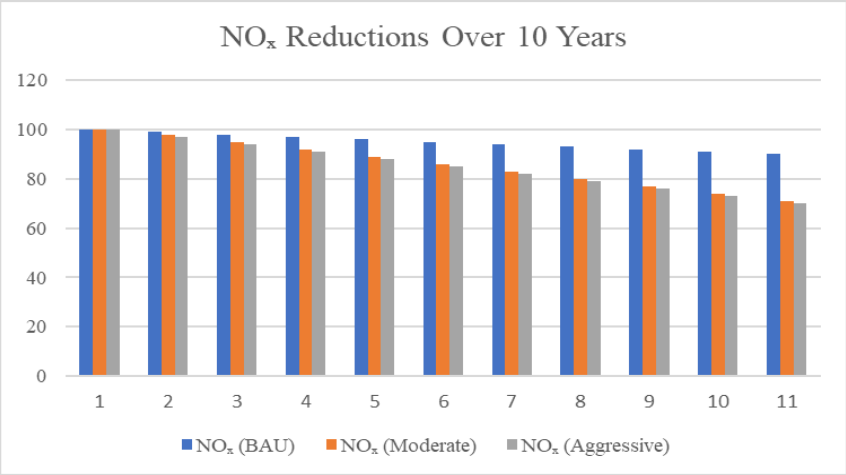

Figure 2. NO_x Reductions Over 10 Years

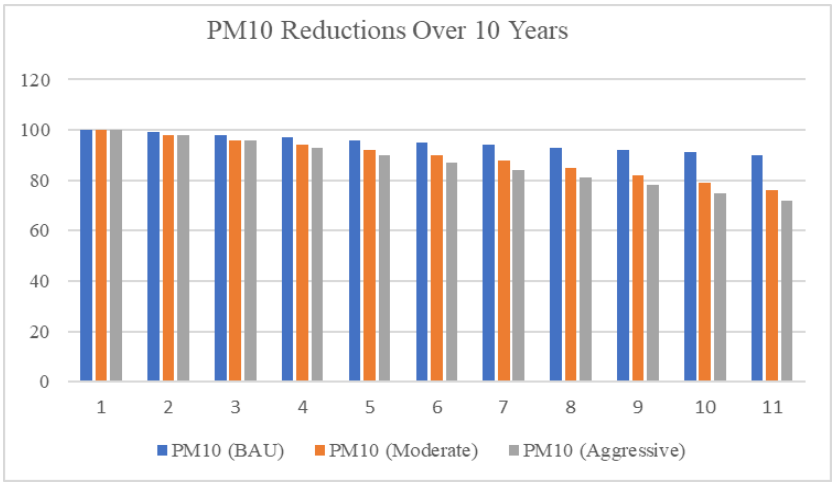

Figure 3. PM10 Reductions Over 10 Years

Table 2. 5- and 10-year reductions for each pollutant and scenario

Pollutant	BAU Reduction (5 years)	BAU Reduction (10 years)	Moderate Reduction (5 years)	Moderate Reduction (10 years)	Aggressive Reduction (5 years)	Aggressive Reduction (10 years)
SO_2	10%	20%	15%	30%	20%	40%
NO_x	5%	10%	8%	15%	15%	30%
PM10	5%	10%	7%	12%	12%	25%

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As is shown in the graphs and table above the first scenario - Business as Usual (BAU)- present the current energy consumption trends (heavy reliance on coal). If this continue, pollutants like SO_2, NO_x, and PM10 will remain largely stable or decrease only slightly due to improvements in technology, but the overall trend would be one of stagnation. SO_2 will have a slight reduction of ~2% per year, NO_x: will have a minimal reduction, around 1% annually and PM10 will have no significant change due to continuous coal dependence.

For the second scenario- Moderate Transition- A moderate increase in renewable energy sources (5% annually) and gradual energy efficiency measures will lead to some reductions in emissions. SO_2 will present a

reduction of 10% in 5 years and 20% in 10 years, NO_x will have a reduction of 8% in 5 years and 15% in 10 years. PM10 reduction will be of 5% in 5 years, 12% in 10 years.

The last scenario - Aggressive Transition – represent the best choice for our area because it is a rapid adoption of renewables (10-15% annual growth) and significant energy efficiency measures, including widespread adoption of electric vehicles and industrial decarbonization, will result in the most significant reductions. SO_2 will have a reduction of 20% in 5 years and 40% in 10 years, NO_x will have a reduction of 15% in 5 years and 30% in 10 years. PM10 will be reduced with 12% in 5 years and 25% in 10 years.

3. CONCLUSION

The study on energy consumption and air pollution in the Jiu Valley clearly demonstrates the strong connection between the region's reliance on coal and the degradation of air quality.

Coal has been a major source of energy in the valley for over a century, and this dependency has contributed to high levels of pollutants such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), and particulate matter (PM10), which pose significant risks to public health and the environment.

The research reveals that without a shift in energy sources, pollution levels will likely stagnate or decrease only slightly, even with technological improvements in existing systems. However, the transition to renewable energy sources such as wind and solar offers a promising solution.

The analysis of different scenarios—Business as Usual, Moderate Transition, and Aggressive Transition—demonstrates that a gradual move toward renewable energy can result in noticeable reductions in emissions.

An aggressive transition, in particular, could lead to the most significant improvements, with SO_2, NO_x, and PM10 levels potentially decreasing by up to 40%, 30%, and 25% over a ten-year period, respectively. While the environmental benefits are clear, the transition also presents economic challenges, particularly with regard to job displacement in the coal industry.

Addressing these challenges through targeted policies, such as the creation of green jobs and workforce retraining, will be essential for a just transition. Ultimately, the study emphasizes the importance of strategic policy interventions that balance the region's energy needs, economic stability, and environmental protection.

A shift from fossil fuels to renewable energy is crucial not only for improving air quality but also for preserving public health and ensuring long-term sustainability in the Jiu Valley.

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