Analysis Report: Impact of Sector-Specific CO_2 Emissions on Urban Air Quality in Luxembourg

Introduction

The single biggest environmental health concern in Europe is air pollution, which has a substantial negative influence on people's health, especially in urban areas, and the climate change in general. Even though major air pollutants' emissions and ambient air concentrations have decreased dramatically in Europe over the previous 20 years, many regions still have poor air quality. (European Environment Agency, 2024)

In Luxembourg, as in many other urban centres, air pollution primarily stems from various sectors, with energy combustion being a significant contributor. The City of Luxembourg has developed an air quality strategy with the Ministry of the Environment, Climate and Sustainable Development. (Ville de Luxembourg, 2023) This report is based on data from 2018 to 2022 from the Luxembourg Statistical Office (LUSTAT) and aims to analyse the impact of sector-specific CO_2 emissions on urban air quality indicators in Luxembourg in order to be able to advise policy makers. Therefore, the following research question was introduced: How do sector-specific CO_2 emissions from energy combustion influence urban air quality indicators in Luxembourg?

Used Data

The analysis relies on the two main datasets - annual air quality data and quarterly CO_2 emissions per sector. The period period from 2018 to 2022 was chosen to be analysed, since the more recent data was not yet available or was still under the quality check. The data was fetched from the LUSTAT, processed, cleaned and organised, and presented through graphs afterwards. The data is compliant with the respective licenses of the sources from which they were obtained.

The first dataset covered levels of various air pollutants such as sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), particulate matter ($PM_{2.5}$ and PM_{10}), carbon monoxide (CO), benzene (C_6H_6), lead (Pb), arsenic (As), cadmium (Cd), nickel (Ni), and benzo[a]pyrene (BaP) measured annually in micrograms per cubic meter (µg/m³) or nanograms per cubic meter (ng/m³). The dataset also provided information on the European Union norm regarding those pollutants.

The second dataset showed CO_2 emissions from various sectors such as road transport, air transport, and other sectors.

From both of these datasets, it was possible to see potential increases or decreases over the specified period. The data was presented in graphs in order to be able to visually compare and see the changes.

Analysis

As mentioned in the introduction, Luxembourg government recognises that sector-specific CO_2 emissions from energy combustion significantly influence urban air quality indicators, with the transport and energy sectors being the primary contributors. However, in order to suggest new environmental policies for the city or adjust the current ones, it is essential to know the trends. Therefore, to be able to answer the research question, a two-step analysis needed to be performed. Firstly, it was important to identify trends and answer the following two sub-questions:

1) What were the trends in CO_2 emissions across different sectors from 2018 to 2022?
2) How did pollutant levels change over the same period?

Afterwards, a correlation analysis needed to be performed. It was essential to determine the strength and direction of the relationship between sector-specific CO_2 emissions and various pollutants.

There was a declining trend in total CO_2 emissions from 2018 to 2022. Specifically, road transport had major improvements, exhibiting a gradual decline, and, therefore, shift towards cleaner technologies and better compliance with sustainability norms. Slight downward trend was noticed for air transport, as well as others remained relatively stable.

Concerning pollutant level, there wasn't a common trend for all of the pollutants. For example, there was a slight decrease over time for NO_2 and SO_2, which signifies a potential improvement in combustion processes and emission controls. On the other side, $PM_{2.5}$ and PM_{10} levels stayed relatively stable, which most likely signifies that there are some challenges in controlling those matters. However, if we look at O_3 emissions, we can see it peaking in certain years and going down in other. This suggests variability influenced by weather conditions and precursor emissions.

Answering the main research question and the sub-questions, it is important to highlight that there wasn't a general deterioration, which means that the current measures are working, although there is always a possibility for improvement. For example, there is a

minor decline in NO_2 levels in correlation with the lowering trend in CO_2 emissions from road transport, indicating that emission reduction measures in the transport sector are working. The steady but somewhat declining trend in PM levels, nonetheless, suggests ongoing or renewed efforts are required to manage particle pollution from various sources. Since Luxembourg state recognises those two pollutants as the most common, it is fair to say that both measures for NO_2 and PM need continuous control and improvement. Concerning ozone levels, which had an unpredictable behaviour, it is important to highlight that the variability in ozone levels results from a intricate interplay of meteorological conditions, photochemical processes, and emissions of such pollutants as NO_x and VOCs. Understanding these interactions is crucial for effective air quality management and for predicting future trends in ozone pollution under changing climate and emission scenarios.

In conclusion, the analysis provided in this chapter provides valuable insights into the complex relationship that exists between CO2 emissions and pollution levels in Luxembourg between 2018 and 2022. The findings imply that whereas total CO2 emissions have clearly decreased as a result of cleaner technology improvements and adherence to sustainability standards, the changes in air pollution levels are more complex. These results highlight the significance of maintaining and improving the environmental policies that are currently in place.

Conclusions

This report thoroughly explores how CO_2 emissions from different sectors impact the air quality in areas of Luxembourg between 2018 and 2022. By analysing data and correlations valuable insights have been uncovered regarding the connection between emissions from sectors and the levels of various air pollutants. The results show a decrease in CO_2 emissions from road transport indicating progress towards cleaner technology and improved regulatory compliance. Despite these changes in emission reduction the varying levels of air pollutants like NO_2, SO_2, $PM_{2.5}$ PM_{10} and O_3 underscore the complexities involved in managing air quality and the influence of factors such as weather conditions and technological advancements.

It is noticeable that ozone levels fluctuate and particulate matter levels remain stubbornly high. This highlights the fact that while some of our current approaches are working, it is important to keep refining them. Moreover, the persistent presence of pollutants highlights the need for a sharper focus in the environmental policies, taking into account the different sources and interactions that affect urban air quality.

One bright spot is the clear drop in NO_2 levels, which goes hand in hand with the reduced CO_2 emissions from vehicles. This shows that the changes in the transport sector are making a difference and need to be pushed further. On the other hand, the consistent presence of PM and the changing levels of ozone require solutions and ongoing monitoring to develop effective strategies that can address these issues comprehensively.

While the question was largely answered, some uncertainties remain due to the complex interplay of factors affecting ozone levels and the contributions of various sectors to particulate matter pollution. For instances, the following limitations were imposed:

- Data range: The data is limited to the period from 2018 to 2022. This timeframe includes the COVID-19 pandemic, during which there was a significant reduction in transportation activities, potentially skewing the trends in CO_2 emissions and pollutant levels.
- Current relevance: The data is not current, and there may have been significant changes in emissions and air quality indicators since 2022. The findings may not fully reflect the current situation, as there are a lot of environment and climate initiatives being taken by governments on a monthly basis.

Therefor, further research and more granular data are needed to fully understand these dynamics and develop targeted strategies for improving current urban air quality in Luxembourg. Collaboration among government entities, research organisations and industry players will be crucial in crafting and implementing environmental policies. These policies should aim to maintain progress, as well as to address new challenges in order to safeguard the health and well being of urban residents contributing to global initiatives against climate change and environmental harm. By continually updating the policies and striving for better, Luxembourg City can reinforce its leadership in environmental sustainability and air quality management, setting an example for others to follow.