DECOMPOSITION OF CO_2 EMISSIONS FROM FUEL COMBUSTION IN LAO PDR

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Abstract*— This study analyzes the key drivers of carbon dioxide (CO_2) emissions in Lao PDR from 2000 to 2022, examining the interplay between economic growth, energy consumption, and environmental sustainability. Using the Kaya identity and a two-factor decomposition method, the research quantifies the contributions of carbon intensity, energy efficiency, economic activity, and population growth to CO_2 emissions. Findings indicate that increased reliance on fossil fuels, particularly due to the introduction of the Hongsa Lignite power plant, has significantly contributed to emissions growth. While hydropower dominates electricity generation, the country remains dependent on imported petroleum and coal for transportation and industry. Additionally, deforestation from agricultural expansion and infrastructure development has further exacerbated emissions by reducing carbon sinks. Despite a rise in per capita emissions, Lao PDR's levels remain below the global average. However, the rapid increase underscores the need for urgent policy measures, including enhancing energy efficiency, investing in renewable energy, and promoting reforestation. Balancing economic expansion with environmental stewardship is crucial for sustainable development. This study highlights the necessity of coordinated efforts among policymakers, industries, and communities to reduce emissions while ensuring continued economic progress.

Index Terms—*decomposition, efficiency, energy, sustainability*

I. INTRODUCTION

Carbon dioxide (CO_2) emissions have become a critical concern globally, with countries striving to balance economic development and environmental sustainability. In Lao PDR, the drivers of CO_2 emissions are multifaceted, influenced by rapid industrialization, energy consumption patterns, deforestation, and reliance on fossil fuels for transportation and electricity generation. Despite its commitment to renewable energy, the country faces challenges in mitigating emissions while maintaining economic growth. Understanding these drivers is essential for developing effective policies to reduce emissions and promote sustainable development.

Lao PDR's economic structure plays a significant role in shaping its CO_2 emissions. The country has experienced rapid economic growth in recent years, driven by sectors such as manufacturing, construction, and agriculture (Figure 1). While these sectors contribute to economic development, they also lead to increased energy consumption and CO_2 emissions. The industrial sector, in particular, has become a major source of emissions due to the reliance on fossil fuels for production processes and transportation.

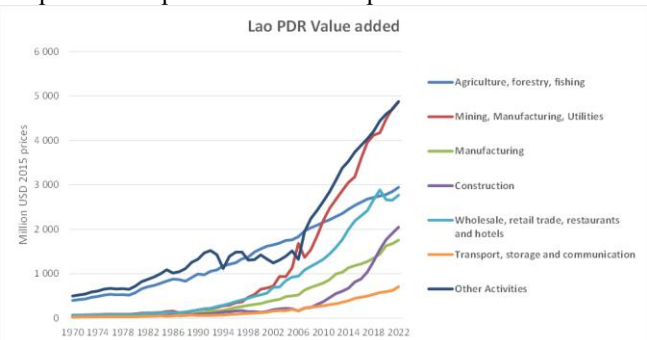

Figure 1. Value added in different economic sectors in Lao PDR, 1970–2022. Data source: [1].

The energy sector in Lao PDR is characterized by a mix of renewable and non-renewable sources (Figure 2). Hydropower has been the dominant energy source, making up a large portion of electricity generation (Figure 3). However, the country still depends on imported fossil fuels, such as coal and petroleum, to meet the energy demands of industries, transport, and households. The high dependency on fossil fuel imports not only raises energy security concerns but also contributes to rising CO_2 emissions.

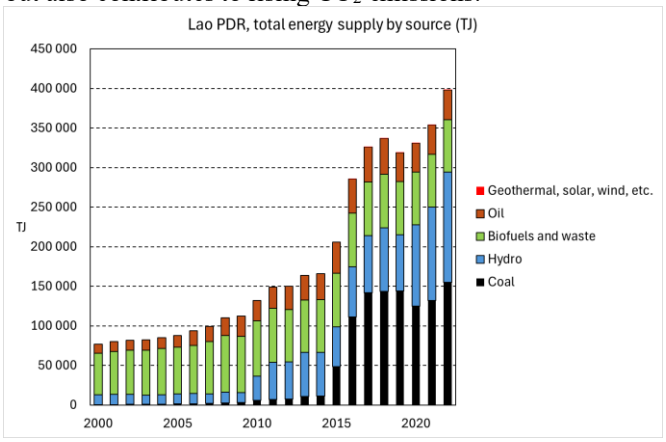

Figure 2. Energy supply by source in Lao PDR, 2000–2022. Data source: [2].

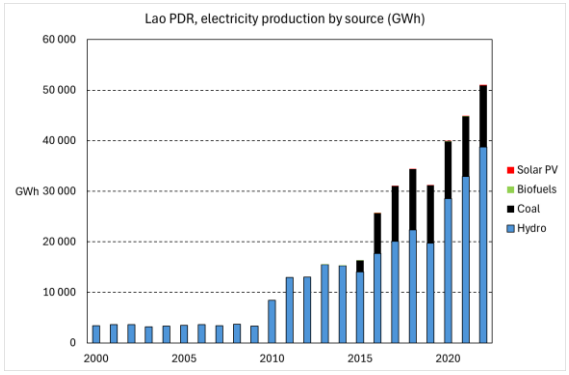

Figure 3. Electricity production by source in Lao PDR, 2000–2022.

Data source: [2].

Deforestation is another key factor affecting CO_2 emissions in Lao PDR. The expansion of agricultural land, logging activities, and infrastructure development have resulted in significant forest loss, reducing the country's capacity to absorb carbon dioxide. As forests act as natural carbon sinks, deforestation exacerbates the effects of greenhouse gas emissions.

To address these challenges, Lao PDR has implemented policies to enhance energy efficiency, promote the use of clean energy, and reduce CO_2 emissions from key sectors. Strategies such as investment in renewable energy projects, the adoption of energy conservation measures, and reforestation programs are crucial in mitigating not only CO_2 emissions, but also other environmental impacts of economic activities.

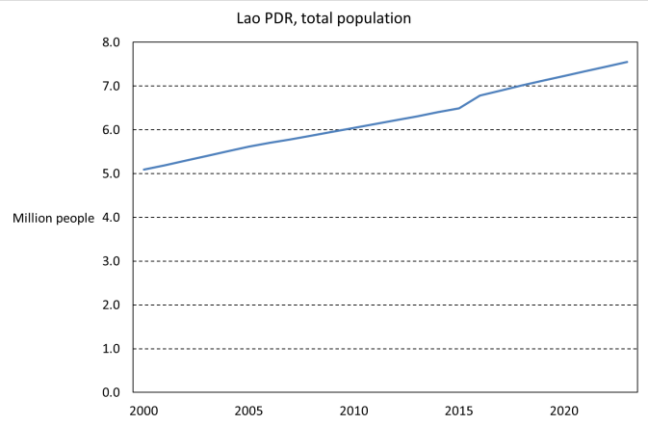

Figure 4. Number of population in Lao PDR 2000–2022. Data source: [3].

II. METHODOLOGY

The objective of this paper is to decompose the observed change of carbon dioxide (CO_2) emissions in Lao PDR into contributions of factors identified in equation (1) which is known as the Kaya identity [4]:

$$CO2 \equiv CO2/TPES \times TPES/FEC \times FEC/GDP \times GDP/POP \times POP \quad (1)$$

where CO2 is carbon dioxide emissions, TPES is total primary energy supply, FEC is total final energy consumption, GDP is total gross domestic production, and POP is the amount of population.

The factor CO2/TPES refers to carbon (dioxide) intensity of the entire energy system. CO_2 intensity can change due to several things such as fuel switch or change from one energy form to another.

TPES/FEC describes the efficiency of the studied energy transformation system, i.e. efficiency of transforming primary energy sources to final energy via different energy carriers such as electricity, heat, and combustible fuels. A switch from fuel use to electricity use is an example of changes that affect the contribution of this factor to CO_2 emissions.

FEC/GDP is an energy intensity of the whole economy. For instance, shift between industrial branches and business sectors, and technological development inside industries and businesses affect the contribution of this factor to CO_2 emissions.

The factor GDP/POP refers to the amount of economic activity per capita which changes by economic growth or degrowth. The amount of population (POP) has an effect to CO_2 emissions via change in birth/death rates and emigration/immigration.

The methodology applied to CO_2 emissions from fuel combustion in Lao PDR is chained two-factor decomposition method [5],[6]. The methodology is based on the Sun/Shapley decomposition. It has a significant advantage of data robustness, i.e. it handles all data similarly, also data with zero values and negative values – unfortunately this is not the case with the recommended and widely used methods based on the logarithmic function such as LMDI (cf. [7], [8]). This makes the methods applicable to datasets with expected negative values such as CO_2 emissions in the future.

III. RESULTS

Figure 5 shows the total change in the CO_2 emissions in Lao PDR in the time period 2000–2022.

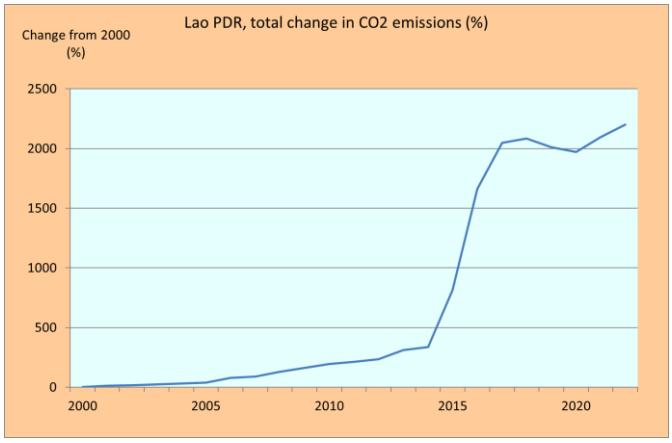

Figure 5. Total change in carbon dioxide emissions (CO_2) in Lao PRD, 2000–2022.

Figures 6–10 illustrate total changes in the drivers identified in equation (1): carbon intensity of the total energy supply in Lao PDR (CO2/TPES; Figure 6), efficiency of the Laotian energy transformation system (TPES/FEC; Figure 7), energy intensity of the Laotian economy (FEC/GDP; Figure 8), gross domestic product per capita in Lao PDR (GDP/POP; Figure 9), and the amount of population in Lao PDR (POP; Figure 10). The changes illustrated in Figures 2–6 are presented in 2000–2022, the same time periods as the total change in CO_2 emissions (Figure 5).

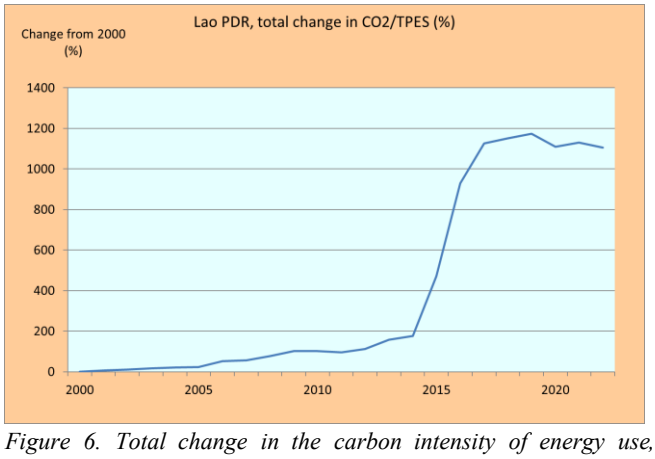

Figure 6. Total change in the carbon intensity of energy use,

measured by the ratio between CO_2 emissions from fuel combustion and total primary energy supply (CO2/TPES) in Lao PDR, 2000–2022.

The huge increase in the factor CO2/TPES is the result of the introduction of the Hongsa Lignite power plant which is the only fossil fuel based power plant in Laos. The increase of petroleum products as the primary energy, especially in the transport sector, has an impact on the slow increase of the CO2/TPES factor before the introduction of the Hongsa Power plant. The increase in CO2/TPES means that more fossil fuels, with CO2 emissions, have been used as the primary energy sources.

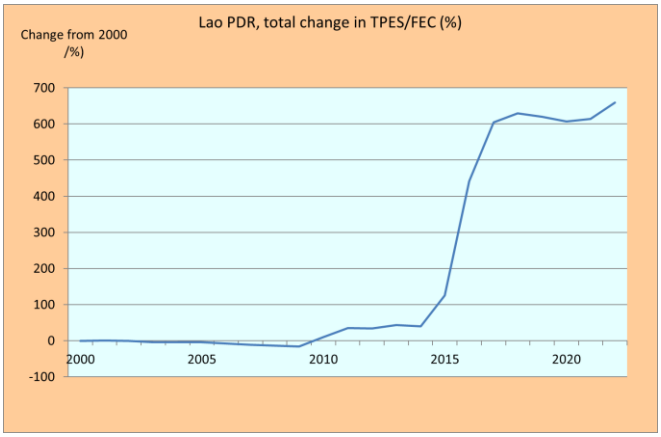

Figure 7. Total change in the efficiency of the energy transformation system measured by the ratio between total primary energy supply and final energy consumption (TPES/FEC) in Lao PDR, 2000–2022.

The increase of the component TPES/FEC is due to the use lignite fuel (part of TPES) in the Hongsa Lignite power plant and the export of electricity (FEC), which is not consumed in Laos. This means that the primary energy component has increased due to the introduction of the power plant, but the final energy component of the power plant has not increased because the electricity is not consumed in Laos.

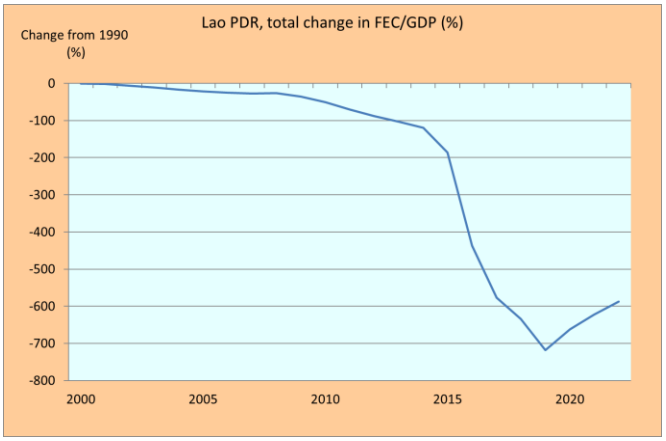

Figure 8. Total change in energy intensity of the economy, measure by final energy consumption (FEC/GDP), in Lao PDR, 2000–2022.

The considerable drop in the FEC/GDP curve with the introduction of Hongsa Lignite power plant is due to the fact that the final energy of the power plant, electricity, is not consumed in Laos, but it has an impact on GDP due to the income of the electricity export to Thailand. The slow decrease of the component before the Hongsa Power plant is due to the improvement of the production efficiency in the country – more GDP output is produced with less final energy input.

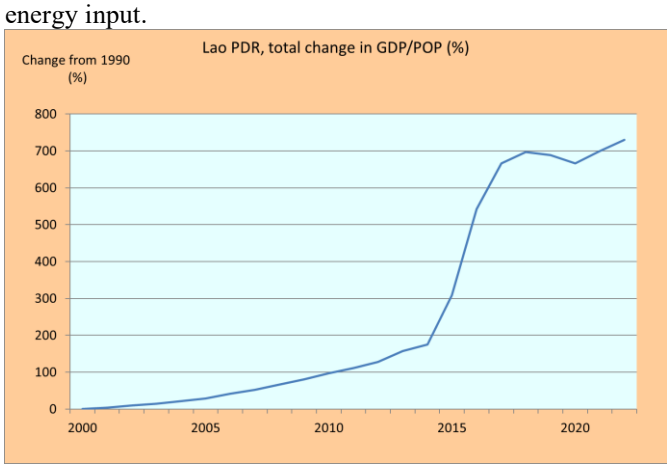

Figure 9. Total change in the gross domestic product per capita (GDP/POP) in Lao PDR, 2000–2022.

The increase of the component GDP/POP illustrates fast growth of GDP per capita in the country. The fast growth of income takes place at the same time as the introduction of the Hongsa Power plant, but it is not the only, or even the main factor, contributing to the increase in the average income.

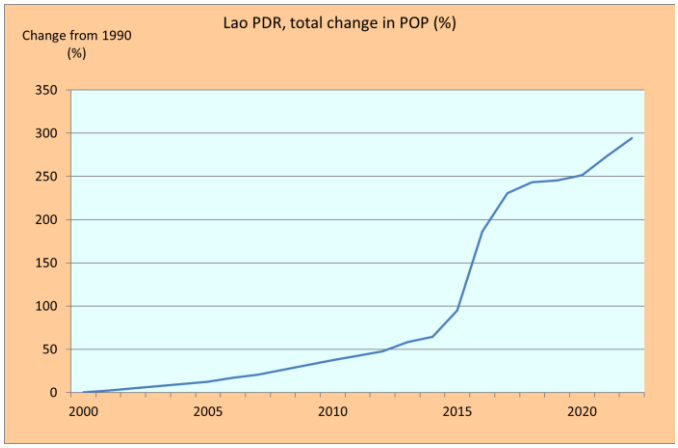

Figure 10. Total change in the amount of population (POP) in Lao PDR, 2000–2022)

The factor POP illustrates the increase of population in Laos. More population usually means more consumption of energy and hence increase in emissions.

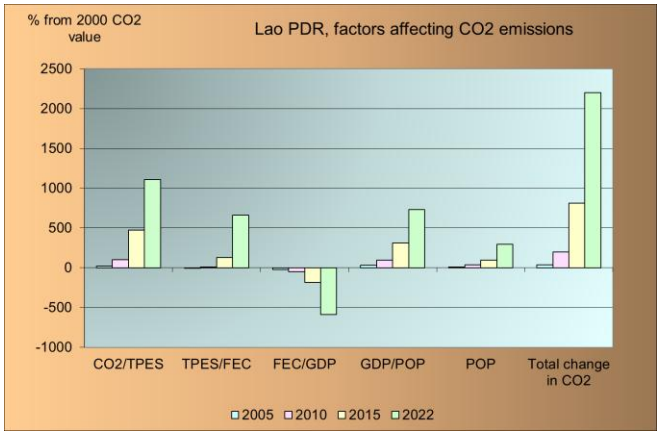

Figure 11. Factors affecting CO2 emissions from fuel combustion in Lao PDR during the time periods 2000–2005, 2000–2020, 2000–2015 and 2000–2022.

Figure 11 illustrates the impact of different driving factors (components of equation 1) on the CO_2 emissions in Laos during the different time periods compared to the base year 2000 emissions. The shift to increased use of fossil energy sources, lignite and petroleum products, is the most important driver of the increasing CO_2 emissions as can be seen from the factor CO2/TPES. The second component TPES/FEC has also contributed to the increase of CO_2 emissions in Laos. As mentioned earlier, the use of lignite as the primary energy input in the Hongsa power plant has increased the primary energy supply (TPES) but the export of the electricity has not increased the final energy consumption (FEC) in the country. The considerable improvement in the efficiency of the final energy utilisation for GDP production has contributed to the decrease in CO_2 emissions. The increased wealth of the population (GDP/POP) is the second largest contributor to the increase in CO_2 emissions. Increased wealth means increased resource use, which has led to increased emissions. Population growth (POP) is also an important contributor to the increase in CO_2 emissions.

The total change in CO_2 emissions from 2000 to 2022 is very large but here we have to keep in mind that the level of emissions in 2000 was very low, about 0.16 tons per capita. The level of emissions in 2022, 2.49 tons per capita, is still comparably low in international comparison, with the world average being about 4.7 tons per capita,

IV. DISCUSSION AND CONCLUSIONS

In conclusion, the analysis of CO_2 emissions in Lao PDR from 2000 to 2022 highlights the complex interplay of economic growth and environmental sustainability. While the country has made strides in renewable energy development, the heavy reliance on fossil fuels, particularly through the introduction of the Hongsa Lignite power plant, has significantly contributed to rising emissions. Deforestation, fueled by agricultural expansion and infrastructure projects, further compounds this issue by diminishing the natural carbon sinks that could help mitigate emissions.

The decomposition analysis reveals that the transition to fossil fuels and increased energy demands have played pivotal roles in escalating CO_2 emissions. Key factors such as energy intensity, economic growth, and population increase illustrate the dual challenge of fostering economic prosperity while keeping environmental impacts in check. Although the emissions per capita remain below the global average, the rapid increase signals the urgent need for effective policies aimed at enhancing energy efficiency, promoting sustainable practices, and embracing clean energy technologies.

As Lao PDR navigates its development trajectory, it is crucial to balance economic ambitions with environmental stewardship. Implementing strategic measures, such as investment in renewable energy and forest conservation, is essential to ensure a sustainable future for the nation, preserving both its natural resources and its commitment to reducing carbon footprints. Moving forward, collaborative efforts involving government, industry, and communities will be vital in creating a resilient and sustainable energy landscape that supports both economic growth and environmental integrity.

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