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# Fossil Fuels Subsidy Rationalization and Renewable Energy Initiatives in Malaysia: Results from a CGE Analysis

(Rasionalisasi Subsidi Bahan Api Fosil dan Inisiatif Tenaga Boleh di Perbaharui di Malaysia: Hasil daripada Analisis CGE)

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*ABSTRACT*

*The paper aims to analyse the economic and environmental impacts of Malaysia's fossil fuel subsidy on GDP, electricity prices and output, external trade, sectoral outputs, employment, welfare, demand and price effects, and $CO_2$ emissions. It further examines the Renewable Energy (RE) expansion policy. The study employs Computable General Equilibrium (CGE) model with a disaggregated electricity sector, tailored to Malaysia's subsidy schemes by considering different types of fossil fuels and consumer categories. The recently published GTAP database is utilized as the base data source, with 2017 as the reference year. The study updates and extends the database to model policy simulations for two periods: 2017-2022 and 2023-2025. To prevent overestimation of energy transition costs, through modelling and database improvements, this study incorporates real data for natural gas subsidies, disaggregates electricity generation, transmission and distribution for power generation sector, and differentiates between production and consumption subsidies. This paper adds to the current literature by addressing empirical and methodological gaps through detailed energy sector disaggregation modelling and counterfactual policy impact evaluations. There is a trade-off between subsidized natural gas for power generation and export opportunities. Efficiency improvements from subsidy rationalization generate positive effects, although energy-intensive sectors experience a slight decline in their competitiveness. Policy implications suggest reviewing the adverse impacts of subsidy rationalization in favour of targeted subsidies. The study incorporates updated energy trade data for Malaysia, substitution possibilities between fossil fuels and RE, real natural gas subsidy values, disaggregated electricity generation mix (including transmission and distribution), and differentiation between production and consumption subsidies. The fossil fuel subsidy rationalization together with RE expansion, foster greater decarbonization. To better achieve the 2050 zero-emissions target, the government should phase out natural gas and coal subsidies and reinvest in solar power and biofuel development.*

*Keywords: Energy subsidy; renewable energy; Malaysia; computable general equilibrium; electricity mix change*

*ABSTRAK*

Kertas ini bertujuan untuk menganalisis impak ekonomi dan alam sekitar subsidi bahan api fosil Malaysia terhadap KDNK, harga elektrik dan output, perdagangan luar, output sektor, pekerjaan, kesejahteraan, kesan permintaan dan harga, serta pelepasan CO2. Ia juga mengkaji dasar pengembangan Tenaga Boleh di Perbaharui (RE). Kajian ini menggunakan model Keseimbangan Umum Boleh Dikira (CGE) dengan sektor elektrik yang berasingan, disesuaikan dengan skim subsidi Malaysia dengan memgambil kira pelbagai jenis bahan api fosil dan kategori pengguna. Pangkalan data GTAP yang baru diterbitkan digunakan sebagai sumber data asas, dengan tahun rujukan 2017. Kajian ini mengemas kini dan memperluaskan pangkalan data untuk mensimulasikan dasar bagi dua tempoh: 2017-2022 dan 2023-2025. Bagi mengelakkan penganggaran yang berlebihan terhadap kos peralihan tenaga, melalui pemodelan dan penambahbaikan pangkalan data, kajian ini mengambil kira data benar untuk subsidi gas asli, memisahkan penjanaan elektrik, penghantaran dan pengagihan untuk sektor penjanaan kuasa, serta membezakan antara subsidi pengeluaran dan subsidi penggunaan. Kertas ini menyumbang kepada literatur semasa dengan menangani jurang empirik dan metodologi melalui pemodelan berasingan sektor tenaga dan penilaian impak dasar sebenar. Terdapat tukar ganti di antara gas asli yang disubsidi untuk penjanaan kuasa dan peluang eksport. Penambahbaikan kecekapan daripada rasionalisasi subsidi memberikan kesan positif, walaupun sektor yang berintensifkan tenaga mengalami sedikit penurunan dalam daya saing mereka. Implikasi dasar mencadangkan semakan terhadap kesan negatif rasionalisasi subsidi demi subsidi yang disasarkan. Kajian ini menggabungkan data perdagangan tenaga yang terkini untuk Malaysia, kemungkinan penggantian antara bahan api fosil dan RE, nilai subsidi gas asli benar, campuran penjanaan elektrik yang terperinci (termasuk penghantaran dan pengagihan), dan pembezaan antara subsidi pengeluaran dan subsidi penggunaan. Rasionalisasi subsidi bahan api fosil bersama dengan pengembangan RE, memacu dekarbonisasi yang lebih besar. Untuk mencapai sasaran sifar pelepasan menjelang 2050, kerajaan perlu menghapuskan subsidi gas asli dan arang batu serta melabur semula dalam pembangunan tenaga solar dan biofuel.

*Kata kunci: Subsidi tenaga; tenaga boleh diperbaharui; Malaysia; keseimbangan umum pengkomputeran; perubahan campuran elektrik.*

JEL: D580; H200; Q210; Q310; Q370; Q380
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## INTRODUCTION

Considering the endeavours initiated at COP26 and COP27 to limit the rise in global temperatures, current trends show no significant reductions in greenhouse gas (GHG) emissions (Pflieger 2023). With the summer of 2023 being the warmest on record, fuel switching and transition to low-carbon alternatives formed the main agenda in COP28 (2023) leading countries to contribute towards reducing emissions by transiting from fossil fuels to renewable and sustainable sources. Under the Paris Agreement (2015), and as signatories to the UNFCCC,[1] governments were committed to reducing emission intensity by up to 45% relative to GDP by 2030 through the adoption of renewable energy (RE).[2] Further, a target of net zero emissions as early as 2050 was established at COP26 and reaffirmed at COP27 (EPU 2022). To meet the COP28 objectives, and demonstrate its commitment to energy transition from fossil fuels to renewable and sustainable energy alternatives, Malaysia's National Energy Policy (2022-2040) aims to increase the share of RE to 31% of the generation mix by 2025.[3] Figure 1 illustrates that Malaysia ranks third in absolute emissions and first in per capita emissions, among ASEAN member countries. The relatively high emissions are mainly attributed to its energy mix.

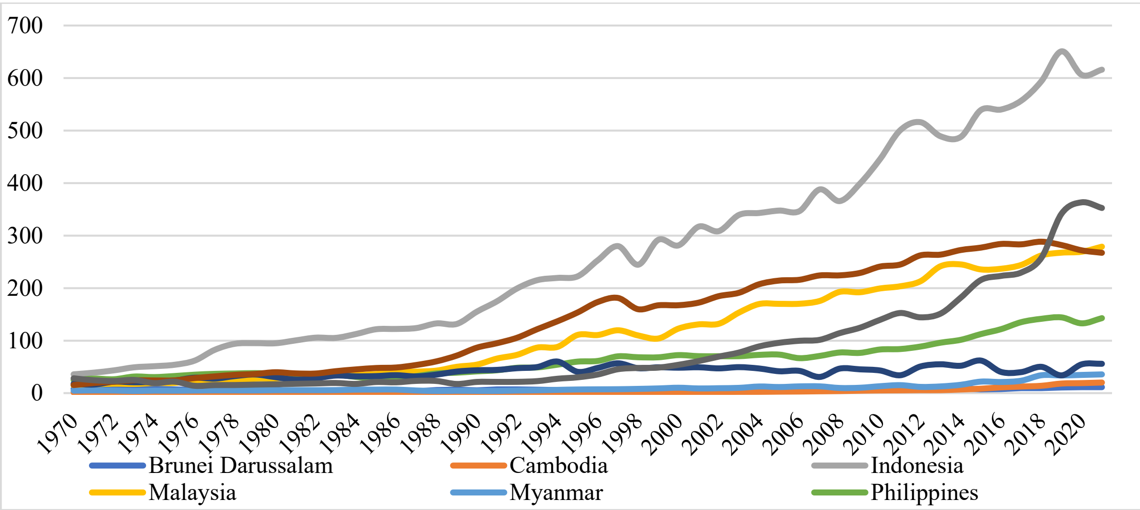


FIGURE 1. $CO_2$ emissions in selected ASEAN countries (Mt)
*Source:* Author's elaboration based on Friedlingstein et al. (2020)

Although Malaysia possesses both price and quantity instruments to achieve emission abatement targets, implementing a carbon tax policy would pose a significant challenge for this developing country. Further, a carbon pricing mechanism requires essential conditions to balance the different objectives of environmental protection, economic development and social equity. In response to COP26's call for a phased reduction in coal power reliance and the removal of inefficient fossil fuel subsidies (Mountford et al. 2021), re-evaluating these measures would be a viable option towards achieving renewable energy and sustainable targets while curbing $CO_2$ emissions. However, the costs and benefits of such approach need to be balanced when formulating any policy for addressing these challenges. Given the intricate interrelationships and policy responses, it is important to ensure that subsidy rationalization does not lead to a reduction in sectoral outputs or increased prices. Consequently, there is a pressing need for a quantitative model that accounts for all these factors and evaluate the potential economic impacts of any energy subsidy rationalization and the transition to renewable energy within Malaysia's economy.

The main issue of this paper is Malaysia's unique situation regarding energy subsidies (both production and consumption types), its reliance on importing coal for electricity generation, and $CO_2$ emission abatement goals. Specifically, it examines how transitioning fossil fuels to renewable energy might impact Malaysia's economy as a whole. In lieu of the debates on the impacts of subsidy rationalization on achieving targeted emissions abatement, it becomes apparent that current energy polices need to be expanded. Public leaders require enhanced knowledge to translate macroeconomic and environmental changes into actionable policy structures. Table 1 summarizes and reviews the main issues addressed in the paper.

TABLE 1. Critical review of the literature and contributions of this paper

| | Previous Studies | Current Study |
|---|---|---|
| I | Lacked primary fossil fuel trade linkages. | Explicitly captures updated trade flows for natural gas, coal and petroleum between Malaysia and other country/regions. |
| II | Analysed the impacts of fossil fuel subsidy removal without capturing RE technologies as alternatives. | Captures substitution possibilities between fossil fuel and RE technologies to prevent overestimating policy costs through incorporating efficiency improvements. |
| III | Lacked real data for natural gas subsidies. | Uses real data for natural gas subsidies to capture foregone revenue accurately. |
| IV | Lacked comprehensive subsidy rates for domestic and imported refined oil products. | Allocates refined oil products for electricity generation, manufacturing and household sectors using differentiated subsidy rates. |
| V | Included actual power generation energy mix | Under the baseline simulation, Malaysia's power generation mix comprises 38% natural gas, 51% coal, 3% oil, and 9% renewables.[4] |
| VI | Included electricity generation, transmission and distribution. | Disaggregates electricity generation, transmission and distribution in the applied model. |
| VII | Lacked a comprehensive differentiation between production and consumption subsidies. | Differentiates production and consumption subsidies: coal, refined oil products and gas-fuelled generators receive production subsidies for corresponding fuel types, while households, manufacturers, and energy industries benefit from consumption subsidies for refined oil products. |

*Source:* Current study

The specific objectives of this research are as follows: i) to examine the economic impacts of revisiting Malaysia's fossil fuel subsidy and RE expansion policy on GDP, electricity prices and output, external trade, sectoral outputs, employment, welfare and demand and price dynamics; ii) to estimate the sectoral and total $CO_2$ emissions arising from differentiated baseline and policy scenarios; and iii) to analyse and compare the impacts of production and consumption subsidy reform policies. To achieve these objectives, a computable general equilibrium (CGE) model was employed, equipped with disaggregated electricity sector and updated trade and macro database.

The remainder of the paper is organized as follows: The next section outlines the stylized facts and summarizes the data on Malaysia's sectoral emission and energy mix. Section 3 systematically reviews the literature. Section 4 describes the methodology, data and simulation scenario design. Section 5 presents results and discussion, while Section 6 provides conclusion and policy recommendations. Finally, Section 7 discusses research limitations and proposals for future research topics.

## STYLIZED FACTS ON MALAYSIA'S SECTORAL EMISSIONS AND ENERGY MIX

Sectoral CO2 emission trends confirm the contributions of different fossil fuels in Malaysia's energy mix. As depicted in Figure 2, the electricity sector contributed the most to total CO2 emissions followed by the transportation sector.

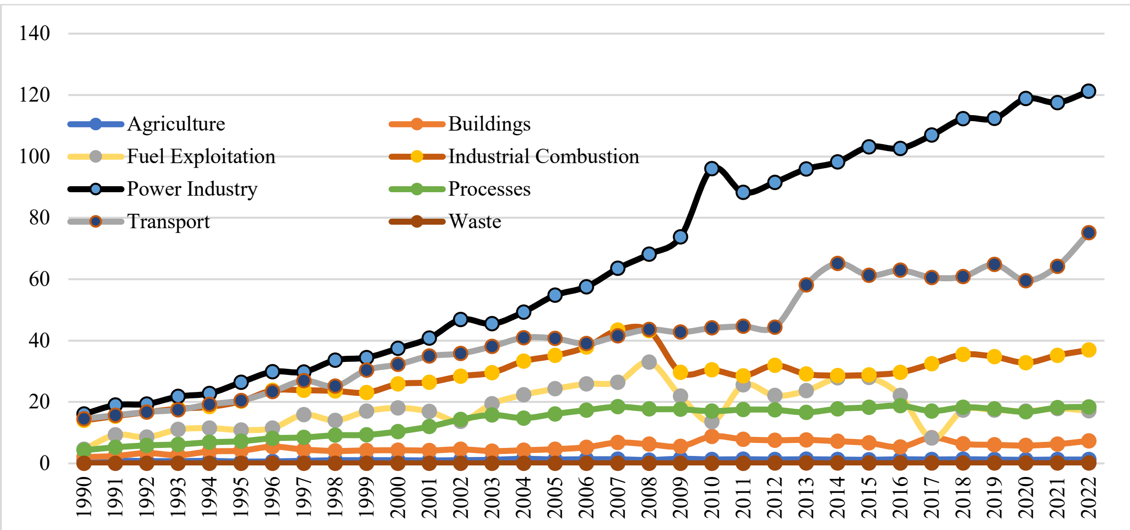


FIGURE 2. Malaysia's $CO_2$ emissions by sector (Mt)
*Source*: Author's elaboration based on EDGAR (2023); IEA (2022a); (IEA, 2022b)

Among the various fossil fuels, natural gas and coal have accounted for more than 95% of Malaysia's total primary energy mix over the past decade (Figure 3). Specifically, fossil fuels constitute approximately 80% of Malaysia's total electricity generation, a reduction from around 90% in 2010. Due to the low marginal cost, coal has become the country's largest source of electricity generation, followed by natural gas, due to its abundant reserves.

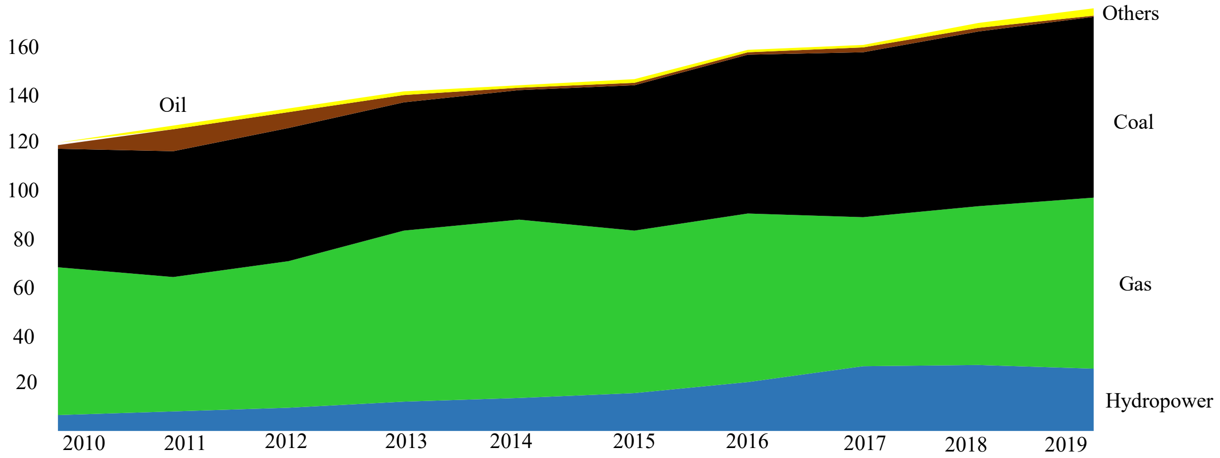


FIGURE 3. Energy sources in the electricity generation mix
*Source:* IRENA (2023); (ST 2021)

The supply of subsidized refined petroleum products, natural gas and coal to the electricity sector, as well as petroleum products for the manufacturing, transport and household sectors, largely explains the trends seen in Figure 3. This is further corroborated by Figure 4 which shows the estimated volume of energy subsidies provided in Malaysia. Petroleum products are directly subsidized, as indicated by the revenue foregone owing to the natural gas subsidy for power generation. Additionally, electricity generation-related subsidies are another energy subsidy paid to final consumers.

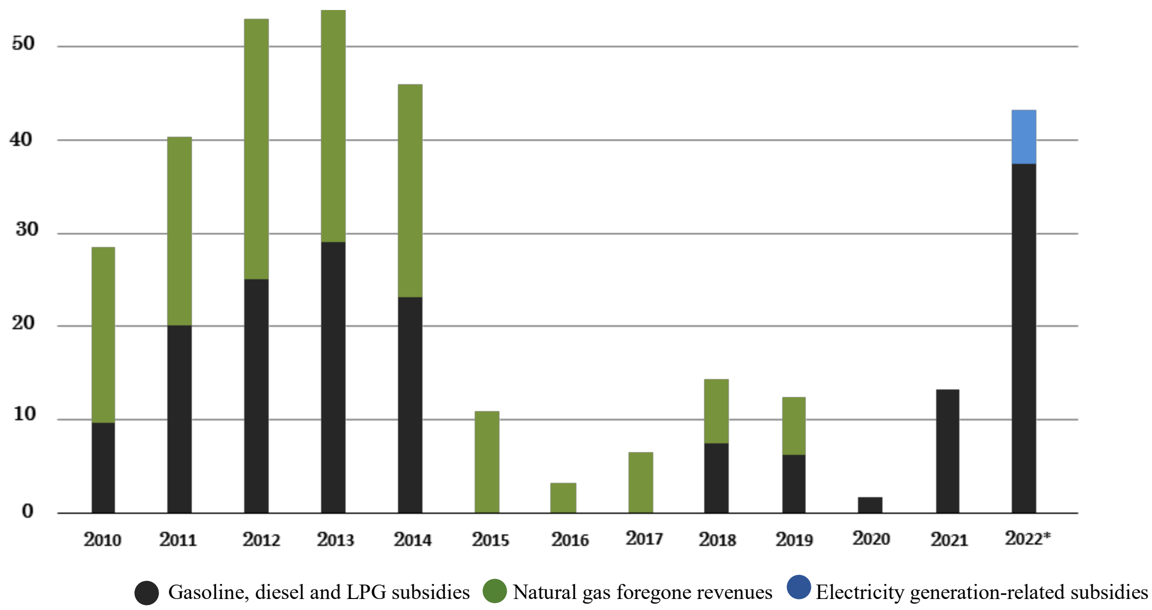


FIGURE 4. Estimated energy subsidies in Malaysia, 2010 to 2022 (billion MYR)

*Source:* IRENA (2023); (MOF, 2020, 2022; PETRONAS, 2020a)

## SYSTEMATIC LITERATURE REVIEW

A substantial body of literature exists on the rationalization of energy subsidies to address policy issues and RE expansion in the Malaysian context. Figure 5 highlights the number of publications within Scopus and Web of Science (WOS) datasets based on different time-series and policies. The data reveals an increasing trend in publications, corresponding to the growth in policies and targets.

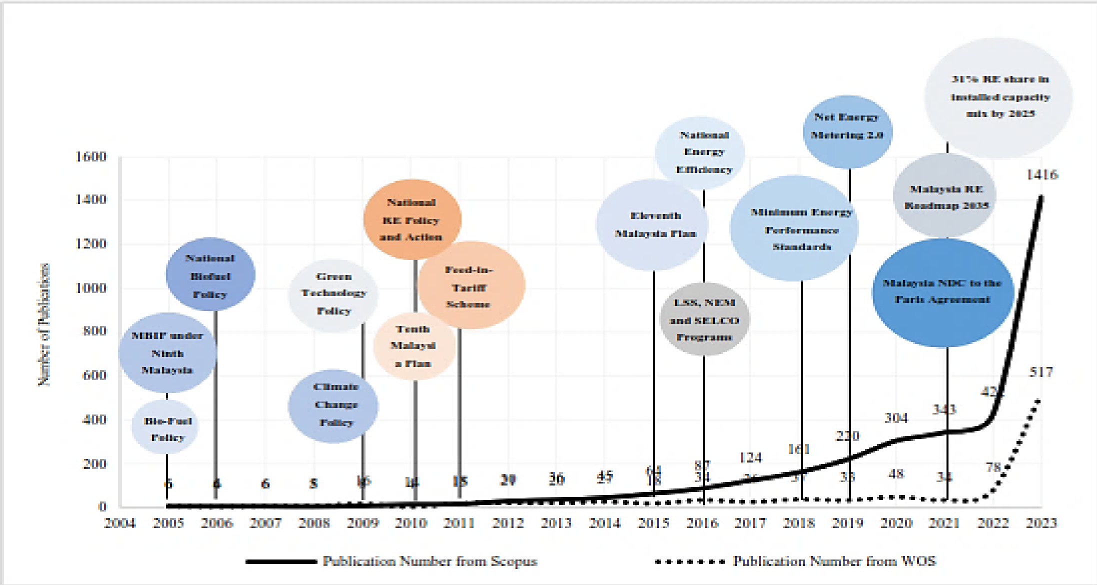


FIGURE 5. Time series of publication trends
*Source:* Author's elaboration based on WOS and Scopus

To retrieve and analyse the literature, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol (Page et al. 2021) was employed. The overarching question addressed in this review is: "What are the environmental and economic impacts of fossil fuel energy subsidy removal or reforms in Malaysia?" The analysis primarily focuses on three aspects; namely methodology, economic implications, and environmental impacts. Figure 6 provides a schematic representation of the review process.

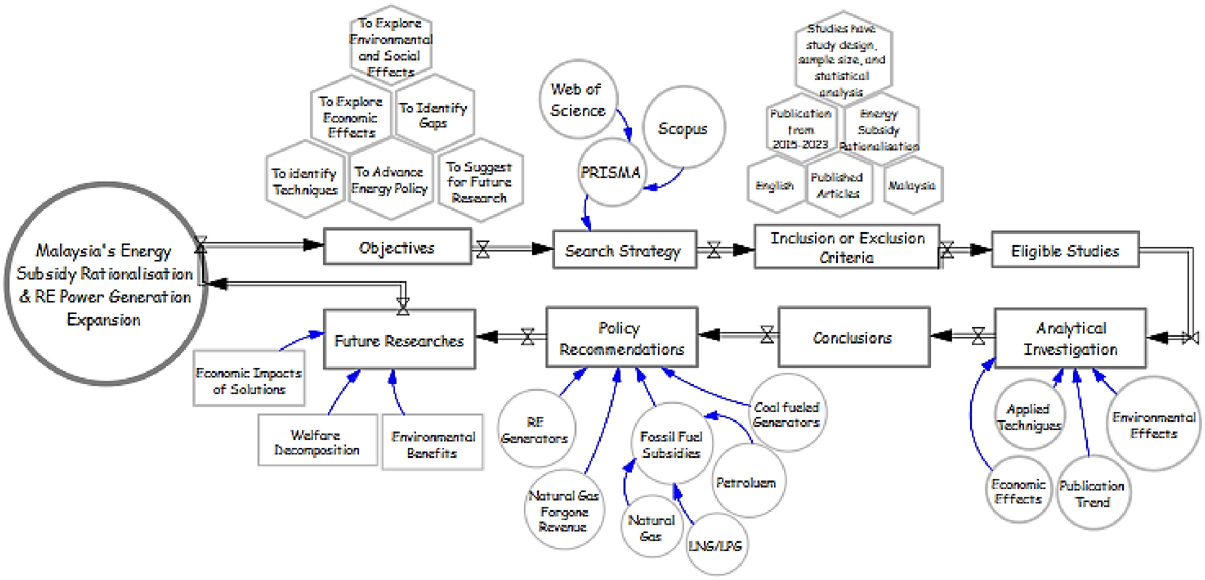


FIGURE 6. Literature review process
*Source:* Current research

## SEARCH STRATEGY BASED ON WEB OF SCIENCE AND SCOPUS

In the screening phase, PRISMA methodology principles were applied to select articles with titles and abstracts of thematic relevance. Multiple keywords related to this query were utilized to ensure a comprehensive and integrative literature review. Figure 7, representing the PRISMA flow diagram, outlines the different stages of the review. To maintain the timeliness of the results, the review covers the period from 2005 to 2023. Furthermore, since fossil fuel energy subsidies intersect with various disciplines, including engineering and chemistry, the extant literature spans diverse fields. Consequently, to narrow down the scope of research outcomes, this review focuses on areas related to economics, business, and management. Following the review process, 26 studies were selected for detailed analysis.

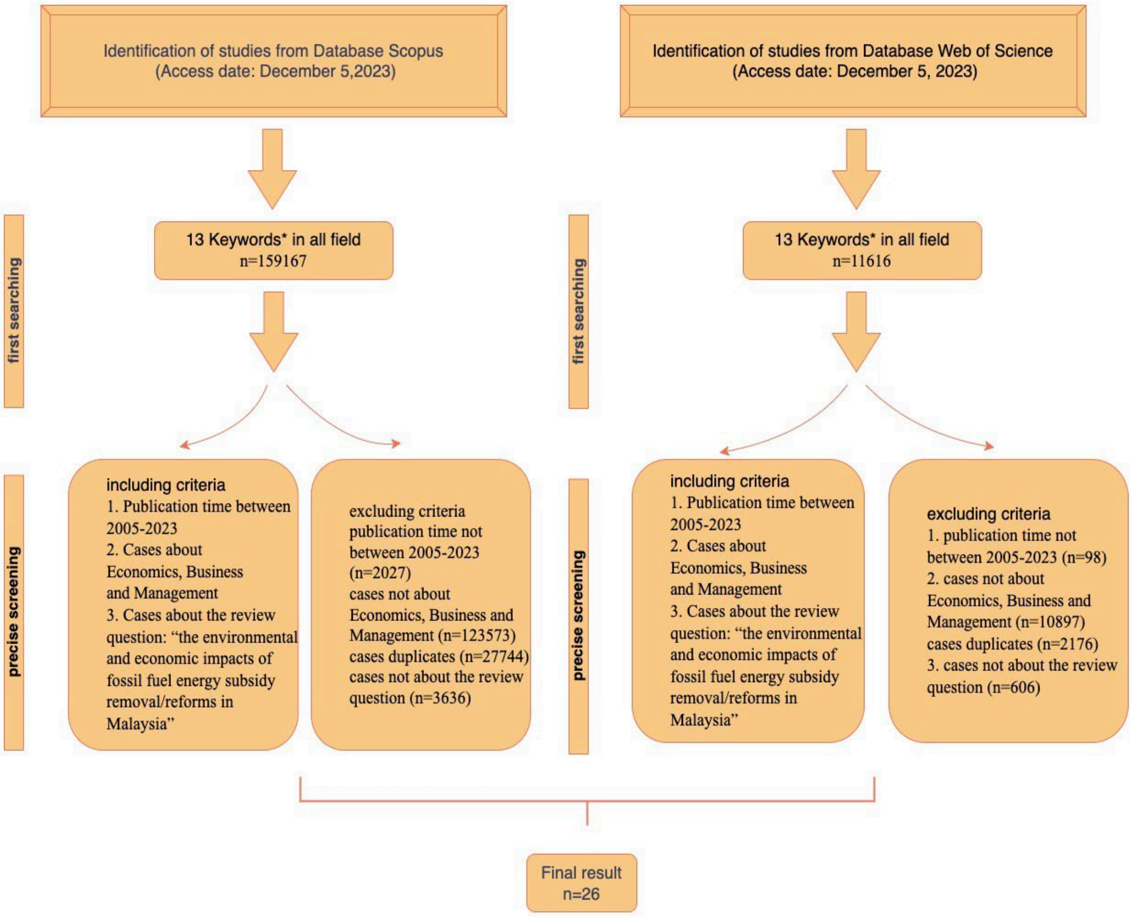


FIGURE 7. PRISMA flow diagram
*Source:* Author's elaboration

The bibliometric analysis presented in Figure 8 reveals that the core focus of previous research cantered around topics such as sustainable development, natural resources and carbon emissions.

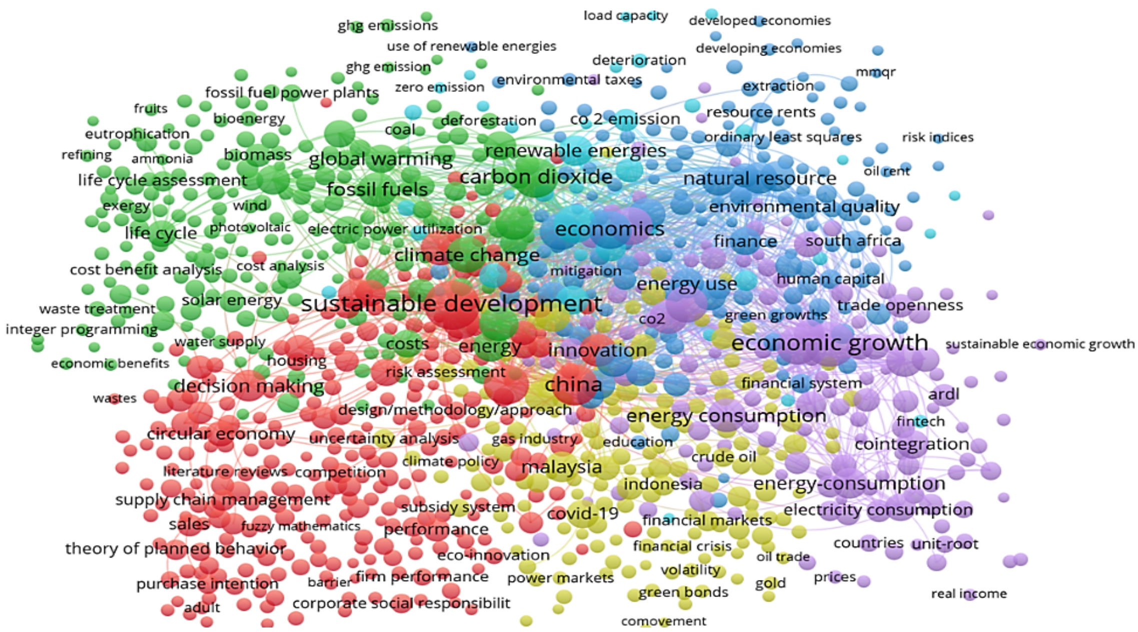


FIGURE 8. Bibliometric analysis
*Source:* Author's elaboration based on data from Scopus

From a methodological perspective, CGE and other econometric models are the primary tools for assessing the impacts of policy adjustments or reforms. Past researchers have focused on various subsectors of the Malaysian economy. For example, Solaymani (2021), Solaymani and Kari (2014), and Solaymani et al. (2014), examined the transportation sector, while Yusoff and Bekhet (2016) studied the manufacturing subsectors. Loo and Harun (2020) addressed economic transmission channels and fiscal integration, while Li et al. (2017) analysed the impacts of subsidy removal within a disaggregated household's framework. In the context of econometric models, Husaini et al. (2019) applied the Pooled Mean Group (PMG) model to evaluate the impacts of subsidy reforms and estimate long-term coefficients for industrial development. Similarly, Murjani (2022) adopted the Autoregressive Distributed Lag (ARDL) approach to examine the relationship between price dynamics and energy subsidies. The Granger causality relationship between energy subsidy reforms and sustainability was investigated by Husaini et al. (2023). However, key issues not addressed by the earlier studies include identifying the linkages between sources of energy subsidies and differentiating between production and consumption measures.

The detailed literature review provides insights from various perspectives, categorizing the effects of subsidy reform into positive and negative aspects. Positive economic impacts had three main facets on enhancing the economy: namely investments, exports, and consumption. Subsidy reforms were found to increase real GDP and investment, reduce overall energy demand, and initially decrease CO2 emissions, and the demand for electricity, natural gas, and oil products (Solaymani et al. 2014). Li et al. (2017) concluded that the removal of oil and gas subsidies could improve efficiency and potentially increase GDP by 0.65%, with emission reductions ranging from 1.84 - 6.63%. Husaini et al. (2019) found that an increase in subsidies is expected to augment export growth. Coady et al. (2017) observed that removing fossil fuel subsidies might yield both economic and environmental benefits. In terms of economic structural changes, Roos and Adams (2020) posited that removing subsidies eliminates significant economic distortions, facilitating adjustments in economic structures. Resosudarmo et al. (2021) suggested that Malaysia would greatly benefit from the removal of subsidies, potentially increasing GDP and reaping benefits from reduced CO2 emissions, thereby improving welfare distribution. Conversely, negative economic impacts have also been highlighted. Harun et al. (2018) and Ilias et al. (2012) found that removing fuel subsidies would produce a significant impact on inflation in Malaysia. Concerns have also been raised regarding the implications for manufacturing, production levels and exports, and transportation (Loo & Harun 2019; Sulaiman et al. 2022). Ubaidillah (2021) concluded that removing fuel subsidies could negatively impact demand for motorcycles, and by extension, the entire transportation sector. In terms of welfare changes, scholars have focused on the loss of welfare, particularly the issues of wealth gaps and income inequality. For instance, Solaymani (2016) noted increased inequality, while Abdul Hakim et al. (2014) discovered that fuel subsidies primarily benefited the affluent individuals, while the costs of their removal were mainly borne by the middle class. In a more recent study, Solarin (2022) suggested that higher fossil fuel subsidies contribute to greater income inequality.

The removal of fossil fuel energy subsidies has significant environmental implications, including reducing energy demand, improving energy conservation, and enhancing energy efficiency (Chepeliev & van der Mensbrugghe 2020; Danlami et al. 2018; Li et al. 2017; Solaymani 2021). Some researchers have concluded that eliminating energy subsidies, when complemented with environmental solutions and RE expansion, could strengthen efforts to achieve emission abatement targets (Chatri et al. 2018; Yahoo & Othman 2017a, 2017b). Ramachanderan et al. (2017) concluded that removing fossil fuel subsidies could contribute to mitigating climate change. Conversely, Jewell et al. (2018) argued that by 2030, the removal of fossil fuel subsidies would have only a minimal impact on global energy demand and CO2 emissions, and would not significantly increase the use of renewable energy.

The systematic literature review reveals the following key findings: (i) CGE models are the most widely used analytical method for assessing composite effects involving multiple mechanisms, followed by econometric approaches; (ii) the analysis of economic impacts varies significantly. Positive effects are predominantly observed at the national level where key economic indicators such as consumption, investment, exports, and economic structural adjustments, exhibit improvement. However, these positive effects appear limited at the individual level, with negative impacts largely observed at the microeconomic-scale. Apart from concerns on inflation in the macroeconomic context, residents and producers within the transportation and energy sectors have experienced noticeable adverse effects. Moreover, opinions differ on whether these impacts are positive or negative, but with no clear consensus; (iii) several studies indicate that subsidy rationalization predominantly favour the affluent groups, while the middle class and low-income groups, especially in rural areas, bear the greatest losses; and (iv) many scholars emphasize the significant positive environmental outcomes with the removal of fossil fuel subsidies.

In Malaysia, the rationalization or elimination of energy subsidies has significantly impacted economic, social, and environmental dimensions. Liu (2024) systematically reviewed the literature on how alternating price subsidies affects consumption and production patterns, emphasizing the role of revenue recycling schemes in mitigating the negative impacts of subsidy rationalization policies. Focusing on energy subsidies, from an economic and environmental perspective, Yahoo et al. (2024) identified a trade-off between subsidized natural gas for the electricity sector and export opportunities. Their findings also indicated welfare improvements associated with renewable energy expansion policies. They further suggested that when subsidy rationalization is complemented by renewable energy expansion, the positive economic impacts become more pronounced. Hasan et. Al (2024), employing the Willingness to Pay (WTP) method, emphasised the importance of subsidy reduction as payment mechanism. Similarly, Li et al. (2017) suggested that the removal of oil and natural gas subsidies could enhance economic efficiency, increase GDP by 0.65%, and reduce carbon emissions by 1.84% to 6.63%. Li and Solaymani (2021) also found that reducing Malaysia's energy subsidies can decrease energy consumption and emissions, improving long-term economic performance and short-term energy efficiency. Additionally, Yusoff and Bekhet (2016) demonstrated that eliminating fuel and tax subsidies significantly reduced fossil fuel consumption, improved actual GDP and alleviated fiscal deficit in the government budget. However, in terms of specific impact on industries, Sulaiman et al. (2022) utilized a CGE model to show that cancelling fuel subsidies increased input costs, negatively affected output and employment in manufacturing, particularly in oil-dependent industries. However, the policy boosted the demand for both high- and medium-skilled labour. Yusoff and Bekhet (2017) using a CGE model, showed that subsidy reforms significantly boosted real GDP and reduced fiscal deficits, although they also led to higher prices for energy-related commodities. Ying and Harun (2019) argued that while the removal of fuel subsidies generally reduced domestic output, this could be mitigated through increasing investment in the agricultural sector. Solaymani and Kari (2014) found that the removal of energy subsidies increased production costs and reduced use of household vehicles. Although the policy improved GDP and investment, and reduced carbon emissions, it also significantly lowered household consumption and welfare.

Socially, Solaymani (2016) pointed out that urban households suffer the most from subsidy reforms due to increased expenditures, thereby exacerbating overall economic inequality. However, the adverse effects of these reforms can be mitigated through appropriate government policy measures, such as support for infrastructure and other public services. Significant attention has been directed towards the expansion of renewable energy in Malaysia. Basri et al. (2015) proposed that Malaysia's energy policy has shifted from a singular reliance on fossil fuels to a more diversified energy structure incorporating renewable and other low-carbon sources. The transition has positively influenced domestic electricity production and contributed to reducing carbon emissions. Similarly, Chatri et al. (2018) through using a CGE model analysis, found that reallocating funds saved from reduced natural gas subsidies towards renewable energy projects could significantly increase the share of renewable energy in electricity production. This shift was shown to have minimal impact on the macroeconomy while effectively reducing carbon emissions. Additionally, Solaymani and Sharafi (2021) found that policies promoting fuel efficiency were more effective in driving economic growth and reducing energy consumption and carbon emissions than increasing subsidies. These findings emphasized the critical role of renewable energy policies in advancing sustainable economic development in Malaysia's energy transition strategy.

Internationally, Hasudungan and Sabaruddin (2018), examining the Indonesian context, found that the Feed-in Tariff (FiT) policy had a minimal short-term macroeconomic effect but long-term potential for promoting renewable energy development. Similarly, research by Dai et al. (2016) in China showed that large-scale renewable energy development not only positively impacts the economy but also delivers substantial environmental co-benefits, offering valuable insights for Malaysia's renewable energy expansion.

In summary, while the rationalization or elimination of energy subsidies may have adverse effects on Malaysia's economy and social welfare in the short term, these policies enhanced economic efficiency, reduced carbon emissions, and support the promotion of long-term sustainable development goals. Policymakers should incorporate these research findings to formulate and implement appropriate compensatory strategic measures to mitigate short-term impacts. Malaysia's renewable energy policies and initiatives in expanding renewable energy have begun to show results. Despite some challenges, effective policy combinations can facilitate large-scale renewable energy development, promoting sustainable economic growth and reducing dependence on fossil fuels.

The literature review identifies significant gaps in current research on Malaysia's fossil fuel subsidy rationalization. These include issues such as fossil fuel-RE substitution in power generation, differentiated production and consumption subsidies, electricity sector disaggregation, varied subsidy rates for different fuels and users and energy-trade linkages. This study thus addresses these knowledge gaps, to evaluate the trade-off between natural gas subsidies for the domestic power sector and external trade. Through updating the database to 2022, the study could identify improved efficiency patterns. The policy scenarios employed address actual challenges facing the existing fuel mix in Malaysia's power sector, thus enhancing the relevance of this research. Additionally, the findings underline the importance of adapting global models to the unique requirements of developing countries, contributing to a broader understanding of their applicability. Finally, these results have practical implications for decision-making and policy implementation, for more effective energy strategies in Malaysia.

## METHODOLOGY, DATA AND SIMULATION SCENARIO DESIGN

Analysing the impacts of fossil fuel subsidy rationalization and RE expansion requires a comprehensive framework that incorporates detailed disaggregation of electricity generation technologies, distribution mechanisms, and the associated transition and external linkages. For this purpose, the core model proposed by Peters (2016) is utilized. In line with this model, Figure 9 illustrates Malaysia's electricity generation and transmission systems with Independent Power Producers (IPPs) and Tenaga Nasional Berhad (TNB) dominating the nation's electricity capacity.

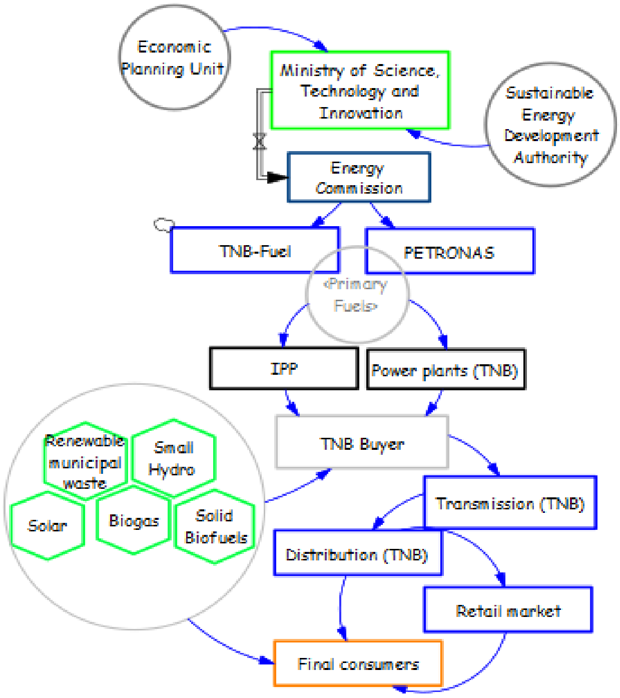


FIGURE 9. Malaysia's electricity generation and transmission process
*Source:* Author's elaboration

In evaluating the magnitude and direction of the impacts of transitioning from fossil fuels to renewable energy and subsidy rationalization on firms, households, and other economic variables, different modelling aspects need to be considered. First, the model framework should encompass the global economy with detailed regional disaggregation including Malaysia's main trade partners, and the sources and destinations of energy resources. Second, economic equations should integrate energy and environmental extensions including $CO_2$ emissions. Third, to quantify household's utility and welfare changes, the model needs to capture consumption linkages. Fourth, it should account for the interactions between electricity generation, distribution linkages, output, intermediate and primary input markets and inter-market relationships. To realize these objectives, the study will employ a CGE model that links global data to the corresponding structural changes at national and regional levels, incorporating economic, energy and environmental dimensions. CGE modelling numerically simulates key macroeconomic and microeconomic interactions, capturing the dynamics among firms (sectors), households, government, and companies. It is a common tool widely used by international organisations such as the International Monetary Fund (Hunt et al. 2020; Schwerhoff et al. 2022) and the World Bank to empirically evaluate scenario outcomes. The CGE model employed in the study calibrates equations, with country-specific, regional and global economic data, creating a baseline representation of the global economy and enabling quantification of theoretical impacts (Itakura 2020).

Figure 10 shows the nested production design employed in the current study. Electricity generation in Malaysia is divided into transition and distribution phases, with generation further disaggregated into peak and base load technologies using the Constant Elasticity of Substitution (CES) functional form. Since Malaysia's power generation sector is heavily reliant on coal and natural gas, this functional form helps to prevent overestimation of the costs associated with various subsidy removal policy scenarios.

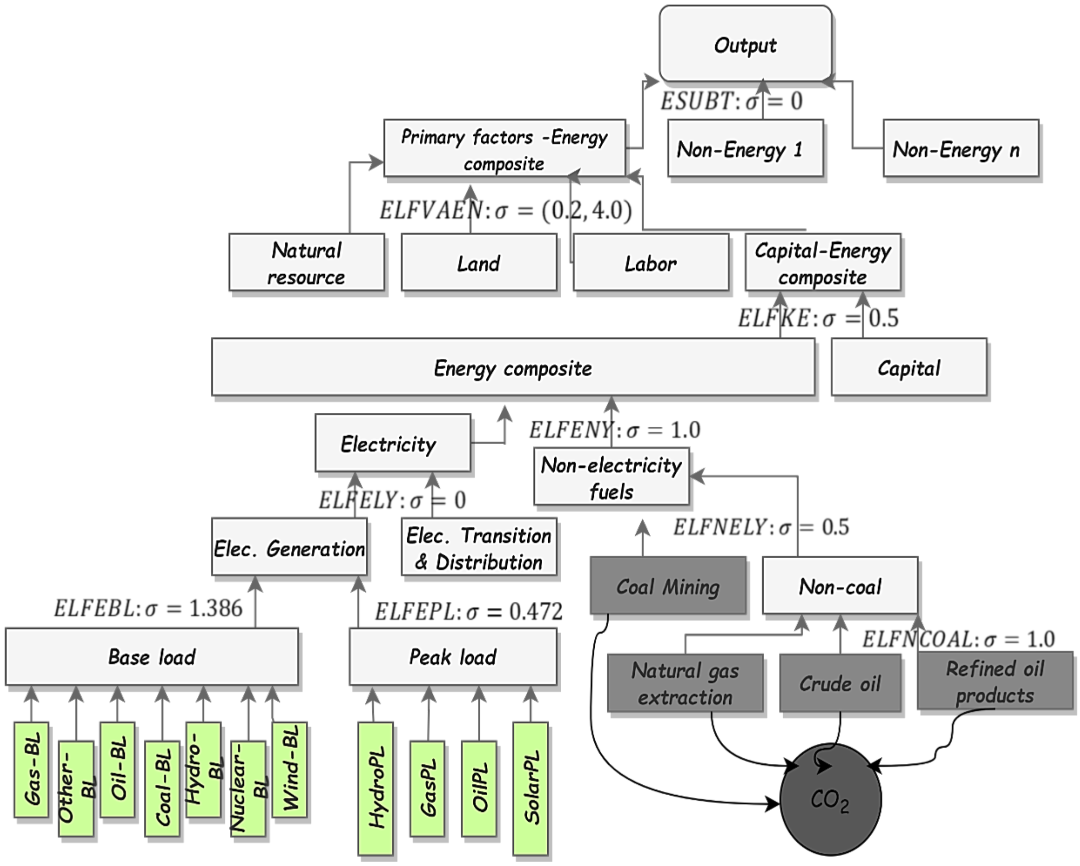


FIGURE 10. The nested production design
*Source:* Author's elaboration based on (Burniaux & Truong 2002; Corong et al. 2017; Peters 2016)

Given that Malaysia's energy sector is reliant on imported fuels and has export potentials for natural gas, it is necessary to analyse its energy trade flows within regional and global linkages. This study utilises the recently published GTAP database (Aguiar et al. 2022) as the source for base data. Since the GTAP reference year is 2017, the modelling contribution in this study includes updating and extending its analysis to cover two distinct periods: 2017-2022 and 2023-2025. GDP growth rates up to 2022 are sourced from the World Bank (2023), with forecasts to 2025 derived from the IMF (2023). Population growth rates data and projections to 2025 are sourced from UN data (2022), while labour growth patterns are updated using data from ILOSTAT (2023) and Higashi et al. (2022). Regional and sectoral disaggregation schemes are detailed in Supplementary Tables A1 and A2 (Appendix A).

Table 2 outlines the simulations and scenarios, to address the gaps in CGE models in the existing literature to enhance the reliability and validity of the findings. Simulation I swap the technical change variable with GDP to endogenously achieve the targeted GDP growth rate. Simulation II updates the database to 2023. Following preparation of the database for the baseline, policy simulations are subsequently introduced, with target variables shocked across Scenarios I to V.

TABLE 2. Contents of simulations and scenarios

| Simulations/scenarios | | Contents |
|---|---|---|
| Simulation I (2017-2022) | | The GTAP basic closure is modified by setting the technical change variable as endogenous and the variable GDP as exogenous for all regions. "Expand" variable is treated as exogenous. Labour force and population variables have been shocked accordingly. |
| Simulation II (2023) | | Uses the basic closure by setting the growth rate for productivity, capital stock obtained from the former simulation, and the growth rate of labour force and population. The data is then updated from 2017 to 2022. |
| Simulation III (2025) | Scenario I | Removal of subsidies on extracted natural gas supplied to the gas and gas-fired power generation sectors. |
| | Scenario II | Removal of subsidies on domestic and imported refined oil products for the manufacturing, energy, and household sectors. |
| | Scenario III | Removal of subsidies on extracted natural gas, coal, and oil products paid to corresponding electricity generation power plants. |

| | |
|---|---|
| Scenario IV | Removal of subsidies on extracted natural gas, coal, and oil products to the electricity generation sector coupled with a 20% production subsidy for RE-based power generators. |
| Scenario V | Removal of subsidies on domestic and imported refined oil products for the manufacturing, energy, and household sectors. Removal of subsidies on extracted natural gas, coal, and oil products for electricity generation. Additionally, a 20% production subsidy is introduced for RE-based power generators. |

*Source:* Current research

The five scenarios, included in Simulation III, capture the varying energy subsidy types and rates for different fuel consumers. Figure 11 schematically illustrates the database updating and policy simulation process. Results were obtained using the GEMPACK economic modelling software (Horridge et al. 2018).

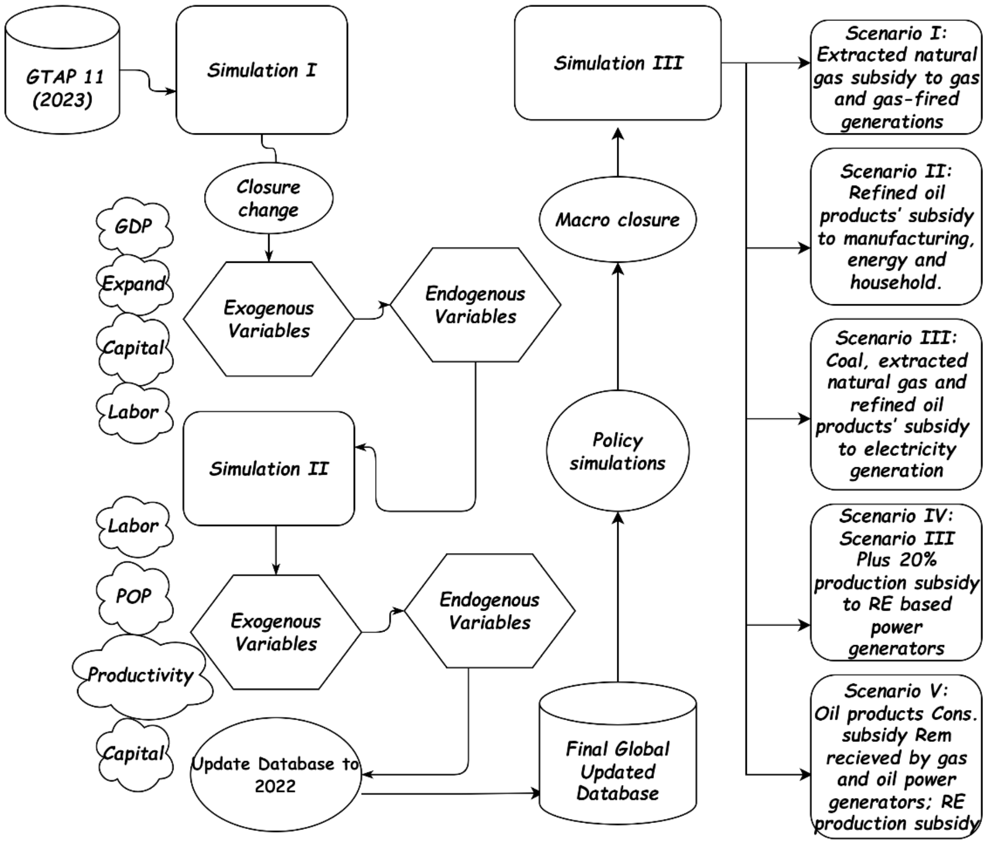


FIGURE 11. Database updating and policy simulation process
*Source:* Author's elaboration

RESULTS AND DISCUSSION

Table 3 highlights the impacts of different scenarios on macroeconomic variables. Interestingly, subsidy rationalization complemented with a RE subsidy generates significantly more positive results, in line with findings of Li et al. (2017). This may be due to several factors. First, RE generators increase their production to meet rising demand. Second, due to the substitution effect, energy intensive industries transition towards RE, as prevailing prices adjust after subsidy rationalization, and finally, the factor of enhanced energy efficiency impact. The resultant energy price increases, apparent in the combined scenario, drive the highest inflationary impact, as consistent with Harun et al. (2018). Scenario 5 produces the largest $CO_2$ reduction, confirming the results of Chatri et al. (2018). The availability of cost-effective RE technologies encourages their adoption by the manufacturing and household sectors. Welfare gains, measured by the Equivalent Variation (EV), are most pronounced under Scenario 5. The reduction in electricity prices raise household incomes, enhancing utility equivalent to an actual price decline (as shown in Table 9). This is further confirmed by the highest recorded positive percentage increases in household utility, demonstrating that RE expansion and energy efficiency improvements effectively mitigate the negative effects of any pure subsidy rationalization (Li & Solaymani 2021). Additionally, a notable percentage change in savings demand corresponds with higher investment levels, as confirmed by Husaini et al. (2019). Private consumption expenditure also increases as substitution and income effects move in the same direction, following subsidy rationalization.

TABLE 3. Simulated changes macroeconomic indices (percentage)

| Variable/ Scenario | I | II | III | IV | V |
|---|---|---|---|---|---|
| GDP | -0.0001 | 0.0347 | -0.00002 | -0.0065 | 0.0268 |
| GDP price index | 0.0003 | 0.091 | 0.0001 | 0.0199 | 0.11 |
| $CO_2$ Emission | -0.02 | -0.83 | -0.005 | -0.99 | -1.83 |
| EV ($ US Million) | -0.16 | 167 | -0.05 | 16 | 179 |
| Terms of trade[5] | -0.00003 | 0.01 | 0.000 | 0.017 | 0.028 |
| Export quantity index | 0.002 | 0.005 | 0.0002 | -0.113 | -0.11 |
| Import quantity index | 0.0004 | -0.23 | -0.0004 | -0.007 | -0.236 |
| Household Utility | -0.0001 | 0.06 | -0.00002 | 0.005 | 0.064 |
| Demand for NET saving | 0.0005 | 0.207 | 0.0001 | -0.0027 | 0.202 |
| Private consumption expenditure | 0.0004 | 0.157 | 0.0001 | 0.012 | 0.168 |

[*] Numbers are in percentage change (%), unless otherwise stated. For small percentage changes we used 5 decimal points and for larger effects showed 3 decimal points.

The positive percentage change in terms of trade is due to Malaysia's reliance on imported coal and refined oil products. With subsidy rationalization, the demand for imported energy decreases while exports of natural gas and refined oil products increase. This change in the trade patterns has a positive effect on the country's terms of trade and contributes to GDP growth (Yahoo & Othman 2017b). However, changes in the export and import quantity indices indicate that energy- intensive industries may experience reduced export competitiveness following subsidy rationalization. Nevertheless, the reduced imports of coal, oil and refined oil products, together with increased RE exports, enhance the overall aggregate export index.

$CO_2$ emissions by fuel types under different scenarios are shown in Figure 12. Scenarios 2 and 5 record the largest decline in $CO_2$ emissions from crude oil and refined oil products, attributed to the substitution effect. In the two scenarios, emissions from coal and natural gas increase marginally when only the subsidies on refined oil products in the manufacturing, energy and household sectors are removed. The percentage increase from coal emissions is highest due to its higher release patterns compared to natural gas following subsidy rationalisation. The slight increase in coal emissions under Scenario 1 was expected, as coal fuelled generators need time to adjust to demand fluctuations. On the other hand, gas and oil power generators are able to adjust more quickly and competitively to meet peak demand.

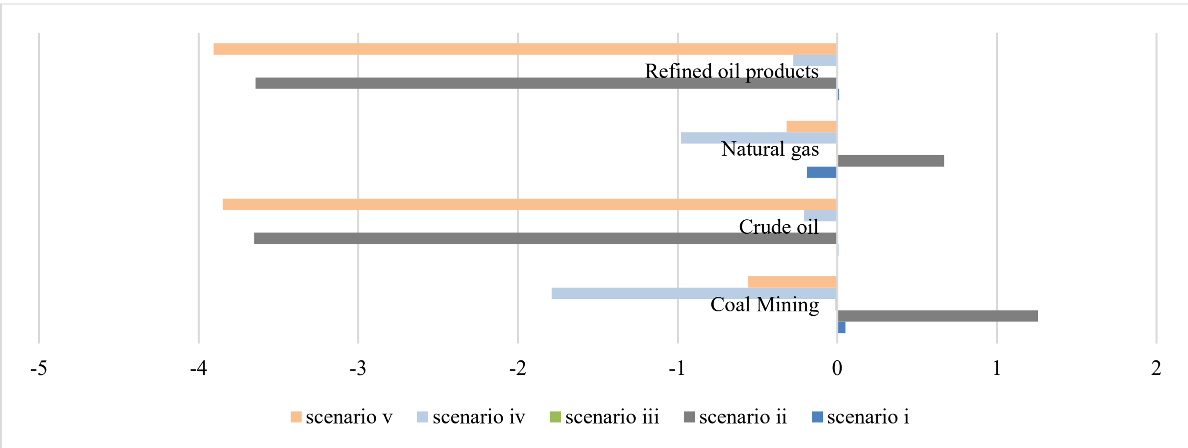


FIGURE 12. Simulated changes in Malaysia's carbon dioxide emissions by fuel (%) ~~(percentage)~~
*Source*: Simulation results

In all scenarios, the policy shocks are exclusively applied to Malaysia, with minimal effects on other regions. Approximately 94% of coal consumed by coal-fuelled generators is mainly imported from Indonesia while a further 90% of domestically produced coal is similarly utilised. Due to their comparative advantage, energy intensive products and other manufactured goods are the main exportable commodities of Malaysia. Table 4 shows the percentage change in export patterns.

TABLE 4. Simulated changes in Malaysia's exports by destination country ~~(percentage)~~

| Region/Scenario | I | II | III | IV | V |
|---|---|---|---|---|---|
| China | -0.0001 | -0.0118 | 0 | 0.0014 | -0.0103 |
| Malaysia | 0.0025 | 0.0053 | 0.0002 | -0.1131 | -0.1099 |
| Indonesia | -0.0003 | -0.0101 | 0 | 0.0106 | 0.0006 |
| East Asia | 0 | -0.0032 | 0 | 0.0004 | -0.0028 |
| SEAsia | 0 | -0.0085 | 0 | -0.0001 | -0.0086 |
| Rest of World | 0 | 0.0009 | 0 | 0.0008 | 0.0017 |

*Source:* Simulation results

Table 5 illustrates changes in Malaysia's export patterns, in line with aggregate export index. As the subsidy for natural gas is rationalized, the exports of gas-based plants significantly declined. Interestingly, removing the subsidy would increase the amount of natural gas exports, confirming that without the subsidy, the reserves can be more efficiently allocated for exports. Under Scenario 2, rationalizing subsidies for refined oil products leads to increase crude oil exports, while that of energy intensive sectors decline. Results from Scenarios 4 and 5 show the export opportunities arising from RE power generators.

TABLE 5. Changes in Malaysia's exports by commodity

| Commodity/ Scenario | I | II | III | IV | V |
|---|---|---|---|---|---|
| Agriculture, Forestry & Fishing | 0.003 | -0.111 | 0.001 | 0.136 | 0.03 |
| Coal Mining | -0.009 | 0.571 | 0.007 | 0.186 | 0.738 |
| Crude oil | -0.005 | 4.51 | -0.001 | 0.035 | 4.53 |
| Natural gas extraction | 0.103 | 0.705 | 0.006 | -0.02 | 0.677 |
| Refined oil products | 0.001 | 1.091 | 0 | -0.064 | 1.022 |
| Electricity transmission and distribution | -0.013 | 0.328 | -0.072 | 0.009 | 0.334 |
| Coal base load | -0.002 | 0.21 | -0.057 | -0.11 | 0.098 |
| Gas base load | -0.979 | -3.99 | -0.107 | -0.075 | -4.064 |
| Hydro base load | 0.007 | 1.098 | 0.002 | 163.957 | 166.666 |
| Other base load | 0.004 | 1.162 | 0.001 | 207.45 | 210.753 |
| Gas peak load | -1.016 | -4.206 | -0.041 | -0.048 | -4.254 |
| Oil peak load | -0.002 | -69.732 | -0.025 | -0.098 | -69.769 |
| Solar peak load | 0.006 | 1.236 | 0.002 | 200.126 | 203.487 |
| Energy intensive industries | -0.008 | -2.71 | -0.002 | 0.042 | -2.663 |
| Other Industries | 0.002 | 0.452 | 0 | -0.167 | 0.282 |
| Other services | 0.001 | 0.415 | 0 | -0.124 | 0.288 |

*Source:* Simulation results

Almost all imported crude oil for local refineries (25% of the total, compared to 75% from domestic oil reserves) and about 80% of refined oil inputs for oil-based generators are sourced from domestic reserves. Table 6 shows that the impact on the import index is more pronounced under Scenarios 4 and 5. Under Scenario 3, Malaysia's imports from Indonesia declines as subsidies for imported coal are rationalized.

TABLE 6. Simulated changes in Malaysia's import from different source country

| Region/Scenario | I | II | III | IV | V |
|---|---|---|---|---|---|
| China | 0 | 0.0028 | 0 | -0.0015 | 0.0012 |
| Malaysia | 0.0004 | -0.2286 | -0.0004 | -0.007 | -0.2354 |
| Indonesia | 0.0001 | -0.0006 | -0.0001 | -0.006 | -0.0067 |
| East Asia | 0 | 0.0009 | 0 | 0.0001 | 0.001 |
| SEAsia | 0 | -0.0077 | 0 | -0.001 | -0.0087 |
| Rest of World | 0 | 0.0012 | 0 | -0.0003 | 0.0009 |

*Source:* Simulation results

Results for the aggregate import, match commodity import patterns as shown in Table 7. Following the removal of natural gas subsidies, imports of gas and gas-based electricity subsequently increase. The most significant changes in import patterns occur under Scenario 5, where imports of crude oil, refined oil products and RE-based power plants decline the most. Due to price increases in domestically produced commodities, imports of energy-intensive commodities increase. In consequence, commodities with a larger initial share in Malaysia's import basket, will experience greater impacts.

TABLE 7. Simulated changes in Malaysia's aggregate imports by commodity

| Commodity/ Scenario | I | II | III | IV | V |
|---|---|---|---|---|---|
| Agriculture, Forestry & Fishing | -0.002 | -0.002 | 0 | -0.105 | -0.111 |
| Coal Mining | 0.051 | 1.224 | -0.012 | -1.798 | -0.599 |
| Crude oil | 0.01 | -5.482 | 0.002 | -0.219 | -5.677 |
| Natural gas extraction | 0.082 | 0.024 | 0 | -0.288 | -0.261 |
| Refined oil products | 0.01 | -5.088 | 0.002 | -0.252 | -5.324 |
| Electricity transmission and distribution | -0.054 | -0.328 | 0.034 | 1.469 | 1.147 |
| Coal base load | 0.052 | 0.948 | 0.026 | -1.653 | -0.715 |
| Gas base load | 0.38 | 2.402 | 0.042 | -1.664 | 0.704 |
| Hydro base load | 0.05 | 0.679 | 0.006 | -28.164 | -27.671 |
| Other base load | 0.05 | 0.714 | 0.006 | -28.168 | -27.651 |
| Gas peak load | 0.523 | 1.448 | 0.02 | -0.567 | 0.878 |
| Oil peak load | -0.091 | 81.584 | 0.009 | -0.54 | 80.622 |
| Solar peak load | -0.094 | -1.682 | -0.006 | -40.609 | -41.603 |
| Energy intensive industries | 0 | 0.188 | 0 | -0.054 | 0.132 |
| Other Industries | -0.002 | -0.134 | 0 | 0.066 | -0.068 |
| Other services | -0.002 | -0.193 | 0 | 0.072 | -0.121 |

*Source:* Simulation results

The simulation results for sectoral outputs, shown in Table 8, highlights the most significant differences mainly attributed to the energy sectors. With the removal of natural gas subsidies, coal power plants would step up output to meet demand. The largest increase in industrial output is captured by RE generators under Scenarios 4 and 5, as expected.

Interestingly, output from electricity transmission and distribution sector also increases. However, subsidy rationalization negatively affects output in energy-intensive sectors.

TABLE 8. Simulated changes in industrial output

| Sector/ Scenario | I | II | III | IV | V |
|---|---|---|---|---|---|
| Agriculture, Forestry & Fishing | 0.0002 | 0.099 | 0.0001 | -0.047 | 0.051 |
| Coal Mining | 0.046 | 1.602 | -0.007 | -1.656 | -0.093 |
| Crude oil | 0.003 | -0.234 | 0.001 | -0.108 | -0.342 |
| Natural gas extraction | -0.007 | 0.681 | 0.001 | -0.361 | 0.313 |
| Refined oil products | 0.008 | -3.835 | 0.002 | -0.206 | -4.027 |
| Electricity transmission and distribution | -0.056 | 0.43 | -0.012 | 1.181 | 1.622 |
| Coal base load | 0.056 | 1.628 | -0.013 | -1.954 | -0.356 |
| Gas base load | -0.269 | 0.198 | -0.028 | -1.943 | -1.748 |
| Hydro base load | 0.059 | 1.901 | 0.008 | 34.32 | 36.863 |
| Other base load | 0.058 | 1.879 | 0.008 | 34.774 | 37.295 |
| Gas peak load | -0.215 | -1.13 | -0.009 | -0.853 | -1.973 |
| Oil peak load | -0.084 | -12.538 | -0.006 | -0.859 | -13.292 |
| Solar peak load | -0.084 | -0.467 | -0.003 | 11.491 | 10.992 |
| Energy intensive industries | -0.006 | -1.957 | -0.001 | 0.008 | -1.945 |
| Other Industries | 0.001 | 0.346 | 0.0003 | -0.134 | 0.209 |
| Other services | -0.001 | -0.007 | -0.0002 | -0.003 | -0.011 |

*Source:* Simulation results

Table 9 presents the simulation results of changes in commodity prices. The subsidy rationalization increases the production costs of energy and energy intensive sectors and these increase output prices. Under Scenario 1, gas-fuelled generators experience the most significant price increases. As a result of increasing output prices and a reduction in demand, both the demand for and price of natural gas also decline. Under Scenario 2, the largest price rise is observed in the case of oil-based peak load generators. Conversely, the negative price change can be seen in RE-based generators, as output subsidies reduce their cost of production.

TABLE 9. Simulated changes in prices

| Commodity/ Scenario | I | II | III | IV | V |
|---|---|---|---|---|---|
| Agriculture, Forestry & Fishing | -0.0007 | 0.0264 | -0.0001 | -0.0331 | -0.0079 |
| Coal Mining | 0.0017 | -0.0991 | -0.0013 | -0.0378 | -0.1332 |
| Crude oil | 0.0005 | -0.4633 | 0.0001 | -0.0049 | -0.4664 |
| Natural gas extraction | -0.0039 | -0.0257 | -0.0002 | 0.00035 | -0.0254 |
| Refined oil products | -0.0001 | -0.2911 | -0.00003 | 0.0147 | -0.2752 |
| Electricity transmission and distribution | 0.0031 | -0.0763 | 0.0171 | -0.0044 | -0.08 |
| Coal base load | 0.0009 | -0.048 | 0.0143 | 0.0107 | -0.0371 |
| Gas base load | 0.2322 | 0.9646 | 0.0253 | 0.0029 | 0.9679 |
| Hydro base load | -0.0011 | -0.2378 | -0.0003 | -19.9186 | -20.1074 |
| Other base load | -0.0004 | -0.2216 | -0.0001 | -19.9602 | -20.1366 |
| Gas peak load | 0.2634 | 1.1094 | 0.0106 | 0.0017 | 1.1115 |
| Oil peak load | 0.0002 | 29.8383 | 0.0059 | 0.013 | 29.8587 |
| Solar peak load | -0.0013 | -0.2396 | -0.0003 | -19.9146 | -20.1049 |
| Energy intensive industries | 0.0014 | 0.4648 | 0.0003 | -0.0074 | 0.4563 |
| Other Industries | -0.0002 | -0.0625 | -0.0001 | 0.0235 | -0.0386 |
| Other services | -0.0004 | -0.1135 | -0.0001 | 0.0339 | -0.079 |

*Source:* Simulation results

## CONCLUSION AND POLICY IMPLICATIONS

Malaysia faces an energy "trilemma" of energy security, social protection, and environmental sustainability, particularly so when shielding consumers from rising energy prices through subsidies, notably for natural gas and oil products. However, these three elements need to be balanced as the nation strives to meet its $CO_2$ emission reduction targets. The main objective of this study is to evaluate the impacts of a comprehensive energy subsidy rationalization package. Using a CGE model with a disaggregated electricity sector - including base and peak loads, fossil-fuel power, and RE - various policy scenarios were analysed and compared. Prior to the policy analysis, a baseline simulation was conducted to update the database.

The simulation results indicate that increasing coal's share in Malaysia's electricity sector has challenged emission abatement targets. Further, replacing natural gas with RE, raises concerns over the cost of electricity production and welfare implications. While production subsidies for coal and gas power plants boost RE growth, its output however still remain insufficient to meet demand. The results confirm that natural gas will remain the dominant fuel. Removing production subsidies for fossil fuel-based generators, together with oil product consumption subsidies for oil and gas generators, and RE electricity subsidies, results in the greatest welfare increases due to efficient resource allocations. Hydro-based generators are more affected than other RE types. The results show that supplying low-cost natural gas for electricity generation, in the effort to reduce emissions, must account for subsidy rationalization and RE expansion. Failure to address coal's growing share in the power generation mix alongside these efforts could compromise the goals for emission reduction.

To address these challenges, the following policy recommendations are proposed for Malaysia: i) policymakers need to prioritize targets, since relying strictly on market mechanisms will not help attain a zero-carbon economy; ii) government should remove the subsidies for natural gas and reinvest the forgone revenue in expanding solar power and biofuel; iii) production subsidies allocated for coal and natural gas power plants should be eliminated in striving for 2050 zero-emissions target. This move is essential given the dominance of subsidized fossil fuels in the energy sector; iv) rationalization strategies should be introduced gradually, to ensure efficiency improvements that may generate positive effects for Malaysia's economy over time; v) developments in technology or complementary mechanisms, such as carbon permits or green certificate trading, should be explored to create specialized markets that support emission reduction.

## LIMITATIONS AND FUTURE RESEARCH OPPORTUITIS

The main limitation of this study lies in the static nature of the model. Analysing the economic and environmental impacts of achieving 2050 zero-emissions target by using a recursive dynamic or fully dynamic model, presents a potential avenue for future research. Additionally, comparing the effects of different types of emission abatement policies, such as market-based mechanisms and command-and-control approaches, could be another topic for future research.

## NOTES

1. United Nations Framework Convention on Climate Change.
2. Tonnes of CO2 emissions per unit of GDP.
3. RE including solar, hydropower, solid biofuels, renewable municipal waste, and biogas sources.
4. Including solar PV, hydro and other renewables such as biofuels, waste, geothermal, and tidal technologies.
5. tot= index of prices received for tradeables produced in Malaysia/ index of prices paid for tradeables imported by Malaysia.


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## APPENDIX A

TABLE A1. Country/region aggregation

| Country number | Countries/regions | Comprising countries in GTAP 11 |
|---|---|---|
| 1 | China | China |
| 2 | Malaysia | Malaysia |
| 3 | Indonesia | Indonesia |
| 4 | EastAsia | China, Hong Kong SAR; Japan; Republic of Korea; Mongolia; Taiwan Province of China; Rest of East Asia; Brunei Darussalam. |
| 5 | SEAsia | Cambodia; Lao People's Democratic Republic; Philippines; Singapore; Thailand; Viet Nam; Rest of Southeast Asia. |
| 6 | Rest of World | Rest of the world countries |

Source: Author's elaboration based on GTAP. 11b.

TABLE A2. Sectoral aggregation

| No. | sector | Comprising |
|---|---|---|
| 1 | Primary Agric., Forestry and Fishing | Paddy rice; Wheat; Cereal grains nec; Vegetables, fruit, nuts; Oil seeds; Sugar cane, sugar beet; Plant-based fibers; Crops nec; Bovine cattle, sheep and goats; Animal products nec; Raw milk; Wool, silk-worm cocoons; Forestry; Fishing. |
| 2 | Coal Mining | Coal. |
| 3 | Crude oil | Oil. |
| 4 | Natural gas extraction | Gas; Gas manufacture, distribution. |
| 5 | Refined oil products | Petroleum, coal products. |
| 6 | Electricity: Transmission and | Electricity transmission and d. |
| 7 | Nuclear base load | Nuclear power. |
| 8 | Coal base load | Coal power baseload. |
| 9 | Gas base load | Gas power baseload. |
| 10 | Wind base load | Wind power. |
| 11 | Hydro base load | Hydro power base load. |
| 12 | Oil base load | Oil power baseload. |
| 13 | Other base load | Other baseload. |
| 14 | Gas peak load | Gas power peak load. |
| 15 | Hydro peak load | Hydro power peak load. |
| 16 | Oil peak load | Oil power peak load. |
| 17 | Solar peak load | Solar power. |
| 18 | Energy intensive industries | Minerals nec; Chemical products; Basic pharmaceutical products; Rubber and plastic products; Mineral products nec; Ferrous metals; Metals nec. |
| 19 | Other industries | Bovine meat products; Meat products nec; Vegetable oils and fats; Dairy products; Processed rice; Sugar; Food products nec; Beverages and tobacco products; Textiles; Wearing apparel; Leather products; Wood products; Paper products, publishing; Metal products; Computer, electronic and optic; Electrical equipment; Machinery and equipment nec; Motor vehicles and parts; Transport equipment nec; Manufactures nec. |
| 20 | Other services | Water; Construction; Trade; Accommodation, Food and service; Transport nec; Water transport; Air transport; Warehousing and support activities; Communication; Financial services nec; Insurance; Real estate activities; Business services nec; Recreational and other service; Public Administration and defense; Education; Human health and social work a; Dwellings. |

Source: Author's elaboration based on GTAP. 11b.