International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2023, 13(3), 469-477.

Gas Consumption as a Key for Low Carbon State and its Impact on Economic Growth in Malaysia: ARDL Approach

Temitayo B. Majekodunmi[1], Mohd Shahidan Shaari[1], Nor Fadzilah Zainal[2], Nor Hidayah Harun[2], Abdul Rahim Ridzuan[3,4,5,6,7]*, Noorazeela Zainol Abidin[1], Nur Hayati Abd Rahman[3]

[1]Faculty of Business and Communication, Universiti Malaysia Perlis, Malaysia, [2]Faculty of Business and Management, Universiti Teknologi MARA, Pulau Pinang Campus, Malaysia, [3]Faculty of Business and Management, Universiti Teknologi MARA, Melaka Campus, Malaysia, [4]Institute for Big Data Analytics and Artificial Intelligence, Universiti Teknologi MARA, Shah Alam Campus, Malaysia, [5]Centre for Economic Development and Policy, Universiti Malaysia Sabah, Malaysia, [6]Institute for Research on Socio Economic Policy, Universiti Teknologi MARA, Malaysia, [7]Accounting Research Institute, Universiti Teknologi MARA, Shah Alam Campus, Malaysia. *Email: Rahim670@uitm.edu.my

Received: 06 January 2023 **Accepted:** 15 April 2023 **DOI:** https://doi.org/10.32479/ijeep.14134

ABSTRACT

Natural gas consumption contributes the least to CO2 emissions than other non-renewable energy such as oil and coal. Thus, it is important to replace oil in generating economic activities and leading the country towards low carbon state. Despite the environmentally friendly energy, most previous studies did not study gas consumption. Therefore, this study investigates the effects of gas consumption and other selected macroeconomic determinants such as labour, capital, foreign direct investment, trade openness, and financial development on Malaysia's economic growth from 1980 to 2019. The Augmented Distributed Lag (ARDL) approach is employed, and the results show that gas consumption plays a vital role in boosting economic growth in the short and long run. Based on these findings, all economic sectors should consume more natural gas instead of oil, including industries and transportation. This move can conserve the environment and support clean energy for sustainable development. The remaining variables also increased economic growth except for financial development. Based on these outcomes, the country's policymakers can construct a suitable policy that can improve all the potential macroeconomic determinants besides the use of natural gas consumption in accelerating growth in Malaysia.

Keywords: Gas Consumption, Economic Growth, Sustainable Development, ARDL
JEL Classifications: O11, Q43, Q53, Q56

1. INTRODUCTION

Countries worldwide are committed to increasing their energy resources, including petroleum, electricity, natural gas, and coal, to sustain economic growth while also conserving the environment (Voumik et al., 2023a; Voumik et al., 2023b). Energy is a critical production factor in every country, and developing economies require it to grow (Pujiati et al., 2023; Shaari et al., 2022; Ridzuan et al., 2022a; Ridzuan et al., 2022b; Krkošková, 2021; Imran and Siddiqui, 2010; Shaari et al., 2013; Arto et al., 2016). The relationship between energy consumption and economic growth has therefore received much attention, particularly with the emergence of environmental problems like ozone depletion and global warming. The Kyoto Protocol was established to prioritize clean energy solutions to address these issues, leading many developed and developing countries to invest in energy sources, including natural gas, which could provide cleaner energy options in the future.

After the 1973 oil crisis, natural gas started to gain popularity as a non-renewable energy source and has been increasingly used worldwide (Economides and Wood, 2009). In 2018, global natural gas consumption reached 3.9 trillion cubic meters, which was a 4.6% increase from the previous year, driven by China's high demand and the United States' transition from coal to natural gas (International Energy Agency, 2022). Many countries have introduced policies to increase natural gas consumption as it emits the least amount of CO_2 compared to other non-renewable energy sources like oil and coal. Natural gas produces 20% less CO_2 than coal and 50% less than petroleum (Aydin, 2018), making it a cleaner energy source that can help preserve the environment. This aligns with Malaysia's commitment to green technology, as stated in the 11th Malaysia Plan, which aims to reduce carbon emission intensity by 45% by 2030 and increase industrial output through cleaner energy initiatives, supporting sustainable development goals of a low-carbon state.

Malaysia has abundant natural gas reserves, and due to challenges in generating renewable energy, it has been identified as a "bridge fuel" in the transition from coal to a near-zero emission energy system (Zhang et al., 2016). In the short-and medium-term transition phases, natural gas can complement renewable energy, as suggested by Safari et al. (2019) and Mohamed Yusoff et al. (2023). Shaari et al. (2020) found that natural gas consumption has a lesser impact on CO_2 emissions than oil consumption, making it an attractive option to achieve Sustainable Development Goals (SDGs) 8 and 13, which emphasize economic growth and climate change. Economic growth, society, and the environment are three critical elements highlighted in the SDGs, and most economic activities require energy consumption to produce goods and services for society while simultaneously promoting sustainable development through economic growth. Natural gas can become an attractive alternative to boost economic growth due to its efficiency in reducing CO_2 emissions and low costs (Shahbaz et al., 2013), thereby contributing to controlling global warming by reducing CO_2 emissions (Levi, 2013).

Theoretical models suggest that rich countries concerned about their environment may relocate polluting activities to developing countries through specialisation and exchanges, as indicated by Antweiller et al. (2001). Various studies from different countries and regions have explored the relationship between economic growth and environmental degradation, with results varying depending on sample size and study period (Koengkan et al., 2019a; Chishti et al., 2021; Qin et al., 2021). The Environmental Kuznets Curve (EKC) hypothesis, which investigates the relationship between economic growth and environmental quality, has been used extensively by researchers in numerous countries such as the United States, Pakistan, Malaysia, China, and the OECD (Yilanci and Pata, 2020; Atasoy, 2017; Rehman et al., 2021; Nurgazina et al., 2021; Pata and Caglar, 2021; Cao et al., 2022). However, some studies have failed to establish a link between economic growth and environmental degradation, such as Zambrano-Monserrate et al.'s (2018) investigation of the Peruvian nexus and Koc and Bulus's (2020) study on South Korea.

In terms of energy consumption and environmental degradation, particularly CO_2 emissions, several studies have been conducted. Wasti and Zaidi (2020) find a link between energy consumption and environmental degradation in Kuwait, while Adebayo and Akinsola (2021) reveal a bidirectional link between environmental degradation and energy consumption in Thailand. Using different approaches, Ahmed et al. (2017), Aye and Edoja (2017), and Musah et al. (2021) identify energy consumption as a major contributor to CO_2 emissions in five South Asian countries, 31 emerging economies, and North Africa, respectively.

The ARDL model has been widely applied in the field of environmental economics to investigate long-term and short-term relationships between related variables. For example, Bosah et al. (2021) used panel data from 15 countries to examine the impact of energy consumption, economic growth, urbanisation, and carbon emissions on environmental quality. Their findings indicated that energy consumption harms the environment in both the long and short term, while urbanisation has no significant impact on environmental quality. Ali et al. (2017) and Pata (2018) investigated the relationship between urbanisation and carbon emissions in Singapore and Turkey, respectively, but their findings differed. Urbanisation in Singapore inhibits carbon emissions, while urbanisation in Turkey promotes carbon emissions. In another study, Ahmed et al. (2021) examined the impact of globalisation, economic growth, and financial development on carbon footprint in Japan. Their findings showed that increased energy consumption and financial development substantially increase carbon footprint, while the relationship between economy and carbon footprint exhibits an inverted U shape, confirming the validity of EKC in Japan.

A growing body of literature has investigated the relationship between corruption and environmental sustainability (Usman, 2022; Wang et al., 2020). Corruption is believed to contribute to environmental degradation both directly and indirectly (Wang et al., 2020). For instance, Usman (2022) used a dynamic ARDL simulation technique to investigate the effects of social and economic factors on environmental quality in Nigeria. They found that while economic growth exacerbated environmental degradation, corruption and internal conflict mitigated environmental degradation by reducing investment and growth. Wang et al. (2020) used system GMM on provincial panel data in China's industry from 2005 to 2015 and found that corruption influences CO_2 emissions through environmental policy distortion and lower monitoring levels. Moreover, Habib et al. (2020) investigated how corruption affects CO_2 emissions and economic growth in Africa using a panel quantile regression method. Their findings showed that corruption has a positive effect on CO_2 emissions in higher emitting countries, while it has a negative effect on CO_2 emissions in lower emitting countries. Overall, the positive effect of corruption on CO_2 emissions outweighs the negative effect, making corruption a positive factor in increasing CO_2 emissions.

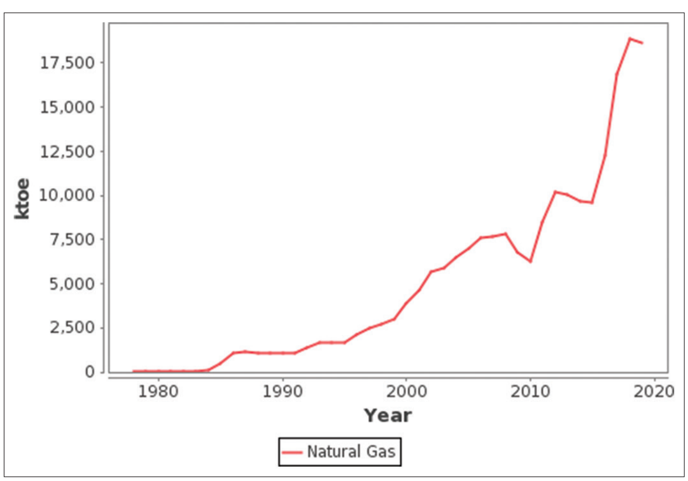
The impact of foreign direct investment (FDI) on CO_2 emissions has been a topic of interest in environmental economics research. Ahmed et al. (2021) found that developing countries, such as most African countries, tend to have lenient environmental regulations as economic growth is prioritized over environmental quality. Their study also revealed that FDI leads to an increase in CO_2 emissions and contributes to environmental degradation. This finding is consistent with the research of Abdouli and Hammami (2017) and Pata et al. (2022), which found that FDI has a positive impact on the environmental quality of developed countries but has a negative impact on the environmental quality of poor or developing countries.

In the study by Behera and Sethi (2022), green technology, FDI, and environmental regulation were analyzed to assess their impact on environmental innovation. The authors found that environmental regulation had a significant positive effect on green technology innovation, whereas FDI had a negative effect on green technology innovation.

Based on Diagram 1 above, the demand for natural gas consumption has experienced steady growth from earlier 1980 until 2008. The trend decreased in 2009 due to global economic recession that reduced the country's productivity on products and services due to slower demand. However, the trend improved after 2010 and again showed a decreasing trend at a slower rate between 2014 and 2015. Later after that period, the demand for natural gas has shown a drastic upward trend until 2019. Overall, the use of natural gas in Malaysia exhibits strong growth due to its relatively cleaner prices than coal.

Although all countries are heading towards consuming more renewable energy sources to conserve the environment, most developing countries find it hard to depend solely on renewable energy due to its low and intermittent supply. This is because using more renewable energy sources requires a high cost and more advanced technologies. In addition, the cost of generating renewable energy sources is much higher than the cost of generating fossil fuel. The problem intensifies when the need for energy storage is undeniably high. Natural gas is not only an abundant energy source but also a good alternative energy source to meet the growing global demand for energy. It is also the best alternative to solve the intermittency of renewable energy supply (Mohammad et al., 2021). A better quality of life is dependent on access to energy. Therefore, natural gas is more stable and reliable than renewable energy sources due to its ability to be a baseload supplier.

Diagram 1: The demand for natural gas consumption from 1978 until 2020



Despite the environmental advantage of gas consumption, studies on the effect of gas consumption on economic growth are still sparse. Most previous studies focused on total energy, such as Alshehry and Belloumi (2015), Yaşar (2017), and Wang et al. (2018), rather than gas. Hence, there is little literature using gas consumption as a proxy for energy consumption (Shahbaz et al., 2013; Destek, 2016). However, their findings are still mixed, and the issue remains perplexing whether gas consumption can be as important as coal and oil in generating eco-nomic activity. Therefore, the relationship between these two things (gas consumption and economic growth) must be explored, especially in Malaysia, as the country has increased gas consumption in the transportation and industrial sectors in the aftermath of the oil crisis. More interestingly, natural gas is a Malaysian natural resource that exists in large volume. Thus, it can supply for the long term.

Table 1 shows the final energy consumption by fuel type. Table 1 shows that in 2016 petroleum products maintained their status as the dominant fuel consumed in the country, accounting for 53.7% of the total fuel. Then, it was followed by electricity at 21.7%, natural gas at 21.5%, and coal and coke at 3.1%. From 1996 to 2016, the consumption of all types of fuel exhibited upward trends. The significant increase was led by natural gas, which grew by 12.8%, amounting to 12,304 ktoe in 2016, mark-edly different from 2,079 ktoe in 1996. The total electricity consumption in 2016 posted an increase of 5.8% and thus amounted to 12,392 ktoe, compared to 1996 the final consumption of total petroleum products decreased by 19.3% to hit 30,737 ktoe than in 1996 at 17,203 ktoe.

This research paper investigates further the impact of natural gas consumption by treating it as one of the potential determinants for the economic growth model for Malaysia. The outcome was assessed based on short-and long-run estimations. Both outcomes will provide more comprehensive views on this topic, especially to policymakers.

The structure of the paper is as follows; the next section will focus on the literature review. Section 3 highlights the methodology used in these studies. Chapter 4 discusses in detail all the analyses involved, while the last chapter focuses on the conclusion and policy recommendations.

2. LITERATURE REVIEW

Concerning the importance of energy in generating economic activities, most previous empirical studies focused on the effects

Table 1: Final energy consumption by fuel types

Fuel type	1996 (%)	2016 (%)
Petroleum	17,203 (72.3)	30,737 (53.7)
Natural Gas	2,079 (8.7)	12,304 (21.5)
Electricity	3,777 (15.9)	12,392 (21.7)
Coal and Coke	727 (3.1)	1,785 (3.1)
Biodiesel	-	389 (0.7)
Total	23,786	57,218

Source: The energy commission of malaysia of energy consumption on economic growth without specifying gas consumption, such as Belke et al. (2011), Chaudhry et al. (2012), and Sama and Tah (2016). However, several studies divided energy into some types, such as coal, oil and gas, as seen in Ighodaro (2010) and Shaari et al. (2013). Therefore, studies on gas consumption and economic growth are still sparse. Moreover, little literature only focused on this issue, such as Shahbaz et al. (2011 and 2013), Aydin (2018), and Li et al. (2019).

Shahbaz et al. (2011) examined the relationship between the two variables (gas and economic growth) and other control variables, particularly capital and labour, in Pakistan from 1972 to 2009. The ARDL bound test was performed, and the results showed a positive effect of gas consumption on economic growth. Shahbaz et al. (2012) extended the study by including real export with the premise that they played an essential role in determining production. The data from 1972 to 2010 were analysed using the ARDL bound test. The results showed that natural gas consumption related to economic growth.

Shahbaz et al. (2013) used the Cobb-Douglas production function to underline their study in France. Their study included export, capital and labour in the factor of production. It examined the connection be-tween economic growth and gas consumption from 1970 to 2010. The ARDL bounds test was employed. The results showed a relationship between economic growth and gas consumption in the long run. In addition, the VECM-based causality test was performed to see directional relationships. The findings showed that gas consumption did affect economic growth without feedback. Therefore, Li et al. (2019) supported the results of Shahbaz et al. (2013) that gas consumption could influence economic growth. However, Li et al. (2019) investigated thirty provinces in China using a different method, a panel quantile regression analysis. The analysis was divided into three groups but still produced consistent findings.

Balitskiy et al. (2015) found a bidirectional relationship between gas consumption and economic growth in the short run. This study treated fixed capital formation and labour force as control variables. GMM was employed to analyse the data from 1997 to 2008 in 26 EU Member States. In the top 10 natural gas-consuming countries, gas consumption was also found by Aydin (2018) to have a positive effect on economic growth. The analysis was done by using panel Granger causality. The findings were divided into three categories. Firstly, the relationship running from gas consumption to eco-nomic growth. Secondly, the relationship runs from economic growth to gas consumption. Thirdly, the bidirectional relationship between gas consumption and economic growth. Nevertheless, the main finding was that gas consumption could undeniably boost economic growth.

Differently, Fadiran et al. (2019) found the effects of gas consumption on economic growth only in the long run, not in the short run, using a panel data analysis from 1991 to 2016. The study was conducted using data from 12 European countries. Fixed capital formation, labour force and trade were treated as control variables. Kum et al. (2012) argued that gas consumption did not affect economic growth. Boot-strap-corrected Granger causality was employed, and data on real GDP, natural gas consumption and per capita were ana-lysed from 1970 to 2008. The results showed no co-integration.

3. METHODOLOGY

This study adopts the Cobb-Douglas production function that shows the relationship between inputs, such as capital and labour, and output. The Cobb-Douglas pro-duction function is as follows.

$$Q = K^{\alpha} L^{\beta} \quad (1)$$

Due to its simplicity, the above production function omits gas consumption as an important input. Gas is also used to generate economic activity. Therefore, it is as important as capital and labour. Adding this variable to equation (1) yields the following:

$$Q = K^{\alpha} L^{\beta} GAC^{\gamma} \quad (2)$$

Where G is gas consumption while γ is the gas elasticity of output. Like other parameters, is assumed to be a positive fraction, $0 < \gamma < 1$. To have linear regression, all the variables are transformed into logarithms. Doing so and adding the error term u as well as the time subscript t, the model becomes as follows:

$$LnQ_t = \alpha LnK_t + \beta LnL_t + \gamma LnGAC_t + \mu_t \quad (3)$$

The analysis for this study is based on time series data for 40 years from 1980 to 2019. Previous studies such as Shahbaz et al. (2011) and Balitskiy et al. (2016) usually adopted only four variables. Those four variables named real GDP (GDP) are represented by output (Q), fixed capital formation (K), labour force (L) and gas consumption (GAC). In this study, we have modified our proposed model by including other potential macroeconomic variables such as foreign direct investment inflows (FDI), trade openness (TO) and financial development (FD). The new equation is stated as below:

$$\begin{aligned} LnQ_t &= \alpha LnK_t + \beta LnL_t + \nu LnFDI_t + \varsigma LnTO_t \\ &+ \theta LnFD_t + \gamma LnGAC_t + \mu_t \end{aligned} \quad (4)$$

The data of all these variables, as displayed in Equation 4, were collected from Malaysia Energy Information Hub and the World Development Indicator, produced by World Bank. This study employed the ARDL approach introduced by Pesaran et al. (2001) to examine the short-run and long-run effects of gas consumption on economic growth in Malaysia. The dynamic integrations among the variables can also be ana-lysed. To conduct this analysis, we must comply with several rules. First, the procedure to use this method is easier than the Johansen co-integration method, as the Johansen co-integration method uses the least square root (OLS). The ARDL method is more robust and can produce better results with a small sample size of data. It can also estimate a long-run linear regression model in the presence of co-integration among the variables. Several co-integration techniques, such as Engle and Granger (1987) and Johansen and Juselius (1990), can be employed. However, these techniques require all the variables to be integrated in the same order. The order of integration for the ARDL approach can be purely I(0) and I(I) or mixed but not I(2).

The new model specification with minor arrangement for this study is as follows:

$$LnGDP_t = \alpha_1 + \alpha_2 LnL_t + \alpha_3 LnK_t + \alpha_4 LnFDI_t + \alpha_5 LnTO_t + \alpha_6 LnFD_t + \alpha_7 LnGAC_t + \varepsilon_t \quad (5)$$

Where,
lnGDP = log of real gross domestic product
lnL = log of labour force
lnK = log of fixed capital formation
lnFDI = log of foreign direct investment inflows
lnTO= log of trade openness
lnFD = log of financial development proxied by broad money, M2
lnGAC = log of natural gas consumption

Most time series data analyses require unit root tests to check whether data are stationary. There are numerous methods for unit root tests that can be used to examine the stationarity of data. This study conducts a unit root test based on Augmented Dickey-Fuller (ADF). Previous studies widely use ADF. The hypothesis is as follows:
H0 = α = 0 (not stationary)
H1 = α ≠ 0, (stationary)

The equation for ADF is as follows:

$$\Delta y_t = \alpha y_{t-1} + \sum_{i=1}^{n} \Psi_i \Delta y_{t-i} + \varepsilon_t \quad (6)$$

Where Δ is the first differentiation operator is the error term and is the variables.

The first step in the ARDL method is to conduct a bound test to examine the co-integrated relationship between the variables (GDP, L, K, FDI, TO, FD, GAC). The test can calculate the value of the F-statistic. Therefore, the hypothesis is as follows:
H0: δ1 = δ2 = δ3 = δ4 = δ5 = δ6 = δ7 = 0 (no co-integration)
H0: δ1 ≠ δ2 ≠ δ3 ≠ δ4 ≠ δ5 ≠ δ6 ≠ δ7 ≠ 0 (no co-integration)

$$\begin{aligned}\Delta LNGDP_t &= \alpha_1 + \delta_1 LNGDP_{t-1} + \delta_2 LNK_{t-1} + \delta_3 LNL_{t-1} \\ &+ \delta_4 LNFDI_{t-1} + \delta_5 LNTO_{t-1} + \delta_6 LNFD_{t-1} + \delta_7 LNGAC_{t-1} + \\ &+ \sum_{i=1}^{a} \beta_i \Delta GDP_{t-i} + \sum_{i=0}^{b} \gamma_i \Delta LNK_{t-i} + \sum_{i=0}^{c} Z_i \Delta LNL_{t-i} \\ &+ \sum_{i=0}^{d} \lambda_i \Delta LNFDI_{t-i} + \sum_{i=0}^{e} \vartheta_i \Delta LNTO_{t-i} + \sum_{i=0}^{f} \psi_i \Delta LNFD_{t-i} \\ &+ \sum_{i=0}^{g} \varpi_i \Delta LGAC_{t-i} + \mu_t ...(7.0) + \sum_{i=0}^{i} \rho_i \Delta LNURB_{t-i} + \upsilon_t\end{aligned} \quad (7)$$

The estimation of the ARDL bound testing is as follows:

According to Pesaran (2001), if the value of the F-statistic is higher than the value of the upper bound, this suggests that the null hypothesis is rejected. Thus, there is a long-run relationship between the variables. On the other hand, the value of the F-statistic lower than the value of the lower bound suggests that the null hypothesis cannot be rejected. Thus, there is no long-run relationship. Suppose the value of F-statistic is between the lower and upper bounds. In that case, this implies that the result is inconclusive whether there is a long-run relationship. Suppose our bound test result shows a long-run relationship between the variables. Then, we estimate long-run coefficients. Akaike Infomation Criterion (AIC) is used to determine the lag for this model. The model for the long-run estimations is as follows:

$$\begin{aligned}\Delta LNGDP_t &= \alpha_1 + \delta_1 LNGDP_{t-1} + \delta_2 LNK_{t-1} \\ &+ \delta_3 LNL_{t-1} + \delta_4 LNFDI_{t-1} + \delta_5 LNTO_{t-1} \\ &+ \delta_6 LNFD_{t-1} + \delta_7 LNGAC_{t-1} + \upsilon_t\end{aligned} \quad (8)$$

$$\begin{aligned}\Delta LNGDP_t &= \alpha_1 + \sum_{i=1}^{a} \beta_i \Delta LNGDP_{t-i} + \sum_{i=0}^{b} \gamma_i \Delta LNK_{t-i} \\ &+ \sum_{i=0}^{c} Z_i \Delta LNL_{t-i} + \sum_{i=0}^{d} \lambda_i \Delta LNFDI_{t-i} + \sum_{i=0}^{e} \vartheta_i \Delta LNTO_{t-i} \\ &+ \sum_{i=0}^{f} \psi_i \Delta LNFD_{t-i} + \sum_{i=0}^{g} \varpi_i \Delta LGAC_{t-i} + \mu_t ...(7.0) \\ &+ \sum_{i=0}^{i} \rho_i \Delta LNURB_{t-i} + ECT_t\end{aligned} \quad (9)$$

The next step is to estimate a short-run relationship by including the error correction term, and the equation is as follows:

Where are the short-run coefficients and is the coefficient of speed adjustment (ECT) to correct the disequilibrium. The value must be significantly negative, and then the results of the long-run relationship can be conclusive.

4. RESULTS AND DISCUSSION

Table 2 shows the results of the ADF test to check whether the variables are stationary. Based on the table, the results show that lnGDP, lnK, lnL, LnFDI, and LNTO are not stationary at intercept and intercept with trend except for LnFDI, found to be significant at 1% at the level for intercept and trend. Meanwhile, LnTO and LnGAC are found to be stationary at a 5% significant level at the level for both intercepts and intercept with the trend. After testing the variables at the level, we proceed with the unit root test based on the first difference. As a result, all the variables are confirmed to be stationary at a 1% significant level. Based on these findings, it can be concluded that the ARDL method can be employed due to the mixed stationarities of the variables used in this study.

Table 3 shows the results for the bound test with lnGDP as an independent varia-ble and lnL, lnK, LnFDI, LnTO, LnFD and lnGAC as independent variables. Based on the results, it can be learnt that there is a co-integrating relationship between the variables at a 10% significant level. Moreover, the value of the F-statistic, 3.354, is higher than the critical value of the upper bound, 3.23. Thus, this model's long-run relationships can be estimated using ARDL.

Table 2: ADF unit root test

Variables	Intercept		Intercept and trend	
	Level	First difference	Level	First difference
lnGDP	−0.485 (0)	−5.216 (0)***	−1.841 (0)	−5.145 (0)***
lnL	−0.552 (0)	−5.801 (0)***	−1.966 (0)	−5.744 (0)***
lnK	−1.495 (0)	−4.662 (0)***	−2.644 (1)	−4.597 (0)***
lnFDI	−5.283 (0)	−7.015 (1)***	−5.336 (0)***	−6.912 (1)***
lnTO	−1.393 (1)	−3.645 (0)***	−0.043 (0)	−4.296 (0)***
lnFD	−3.191 (0)**	−5.905 (1)***	−3.755 (1)**	−5.885 (1)***
lnGAC	−3.452 (2)**	−4.338 (1)***	−3.661 (2)**	−4.971 (1)***

***and ** are significant at 1% and 5%, respectively. ADF: Augmented dickey-fuller

Table 4 shows the results for long-run estimations using the ARDL approach. Based on the results, it can be seen that lnK is significant at 1%, and the coefficient is 0.261. This result suggests that a 1% in-crease in the capital can boost the country's GDP by 0.26% in the long run.

Besides, lnL is also significant at 1%, and the coefficient value is 1.401. Statistically, 1% in labour in-creases the country's GDP by 1.4%, representing the largest magnitude based on this analysis. Between LnK and LnL, the country relies more on labour to facilitate economic activity. This is quite common for developing countries like Malaysia, which is an abundant country focusing on labour-intensive production.

Moreover, both LnFDI and LnTO were significant at 1% and had a positive relationship with LnGDP. Based on the figures, 1% increases in LNFDI and LNTO will elevate economic growth by 0.03% and 0.17%, respectively. Through foreign investment, the country received benefits such as the transfer of technology, increased job creation and many more, which escalated higher economic productivity, as addressed by Ridzuan et al. (2017 and 2018). The foreign sector also plays a crucial role in facilitating international trading that helps local producers gain more business transition through export activities. LnFD, on the other hand, fails to influence the country's economic growth level.

Lastly, there is a positive and significant relationship between LnGAC and LnGDP. This implies that gas consumption can affect economic development. For example, a 1% increase in gas consumption can increase GDP by 0.05% in the long run. Higher consumption of natural gas especially in the manufacturing sector does not help the country to experiences higher economic growth but also directing the country towards low carbon state.

Table 5 shows the results for short-run estimations using the ARDL approach. The results show that lnK is significant at 1%, and the coefficient value is 0.222, meaning that capital can affect GDP. A 1% in-crease in the capital can enhance GDP by 0.22% in the short run. LnL and LnTO are found to have a negative and significant relationship with LnGDP based on the past 3 years' outcome. However, this effect changed into a positive relationship in the long run. Next, LnFDI is confirmed to impact economic growth at a 1% significant level positively. A 1% increase in LnFDI boosts the economy by 0.013% in the short run. Lastly, lnGAC is also significant at 1%, based on the previous 3 years' lag. The coefficient value is 0.052, implying that a 1% rise in gas consumption can cause GDP to escalate by 0.052% in the short run. Finally, the coefficient value for ECT is 0.849 and is negatively significant. This means that all variables will converge in the long run, thus providing useful insight for policymakers to formulate a suitable policy based on the short and long-run analysis.

Table 3: Bound test

F-statistic		
3.354*		
Critical value		
Significance level	Lower bound	Upper bound
10%	2.12	3.23
5%	2.45	3.61
1%	3.15	4.43

*is significant at 10%

Table 4: ARDL long-run estimations (2, 4, 4, 0, 4, 0, 2)

Variable	Coefficient	T-statistic	Prob.
LnK	0.261***	9.616	0.000
lnL	1.401***	19.434	0.000
lnFDI	0.028***	4.729	0.000
lnTO	0.175***	7.880	0.000
lnFD	−0.008	−0.339	0.739
lnGAC	0.054**	−2.193	0.045
C	−15.018***	−14.372	0.000

***, **denotes significance at 1 and 5%. ARDL: Augmented distributed lag

Table 5: ARDL Short-run estimation (2, 1, 0, 2)

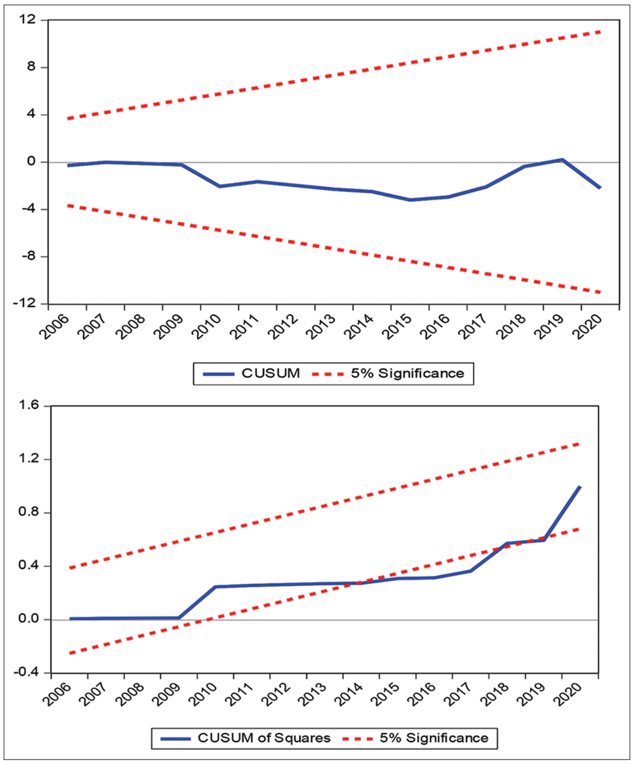
Variable	Coefficient	T-statistic	Prob.
$DLnGDP_{(-1)}$	−0.199*	−1.992	0.066
DLnK	0.222***	9.202	0.000
DLnL	0.034	0.155	0.878
$DLnL_{(-1)}$	0.241	0.720	0.483
$DLnL_{(-2)}$	−0.154	−0.474	0.642
$DLnL_{(-3)}$	−1.295***	−4.942	0.000
DLnFDI	0.013***	4.294	0.000
DLnTO	−0.0003	−0.005	0.995
$DLnTO_{(-1)}$	−0.121	−1.469	0.163
$DLnTO_{(-2)}$	0.128	1.705	0.110
$DLnTO_{(-3)}$	−0.156***	−3.044	0.008
DLnFD)	−0.007	−0.341	0.737
DLnGAC	−0.055	−1.494	0.157
$DLnGAC_{(-1)}$	0.002	0.065	0.949
$DLnGAC_{(-2)}$	−0.051	−1.719	0.107
$DLnGAC_{(-3)}$	0.052***	3.182	0.006
ECT	−0.849***	−10.059	0.000

*, **and *** denote significance at 10%, 5% and 1%, respectively. ARDL: Augmented distributed lag

Table 6: Diagnostic test

Test statistic	F-statistic (Prob.)
Jarque-bera	0.677 (0.712)
Breusch-godfrey serial correlation	1.349 (0.296)
Heteroskedasticity test	0.606 (0.854)
Ramsey RESET stability	1.034 (0.319)

Diagram 2: CUSUM and CUSUM of squares



Several diagnostic tests were conducted, such as Jarque-Bera, Breusch-Godfrey Serial Correlation, Heteroskedasticity Test, and Ramsey RESET stability. The results are reported in Table 6. Based on the table, all the diagnostic tests are insignificant, given that the probability value is larger than 10%. This suggests that the model is good as it does not suffer any diagnostic problems.

Diagram 2 shows the results of stability tests for CUSUM and CUSUM of Square. Based on the two graphs, it can conclude that the model used is stable at 5%. This is because the graphs plotted, represented by the blue dotted lines, move within the boundaries.

5. CONCLUSION AND POLICY RECOMMENDATIONS

Due to a limited number of studies investigating the effects of energy consumption, particularly gas, on economic growth, this study investigates the effects of this type of energy on economic growth in Malaysia. Data, ranging from 1980 to 2019, on gas consumption, real GDP, fixed capital formation, labour, foreign direct investment, trade openness and financial development were collected and analysed using the ARDL approach. The results show that gas consumption can boost economic growth not only in the short run but also in the long run. These findings supported the results of Destek (2016), Aydin (2018), and Fadiran et al. (2019). Therefore, it is crucial to increase gas consumption as it can boost economic growth. According to the US Energy Information Administration (2020), gas combustion contributes the least to CO_2 emissions than oil and coal. Therefore, this type of energy can be an alternative to oil, as oil can be more detrimental to the environment. This is in line with the National Depletion Policy, which aims to reduce oil consumption and the Fuel Diversification Policy, which aims to diversify energy sources. Due to the importance of gas in economic growth, using more of this energy type can help realise the low carbon objectives set under these policies. The other variables, such as capital, labour, foreign direct investment, and trade openness, positively impact the country's economic growth.

These findings lead to various policy recommendations. Firstly, the government can promote the use of gas in the manufacturing sector by offering incentives for manufacturers who switch from other forms of energy to gas. Besides, it is crucial to invest in developing more gas infrastructure, such as pipelines and storage facilities. With those infrastructures, the government can ensure that gas is readily available to businesses and consumers, which will encourage greater use of gas and enhance economic growth. For this reason, it is possible to have partnership between government and private institutions to develop the infrastructure and provide more incentives to encourage investments. Apart from that, the government should also promote research and development in the gas industry, which would then lead to the invention and innovation of new products and technologies. Greater fundings shall be injected for R&D projects to enhance collaboration between industry and academia, with the aims to enhance Malaysia's competitiveness level and promote higher economic growth. Furthermore, the government must ensure that the country's labour supply is sufficient to support economic development. Special attention must be given to manufacturing and construction sections with a lower labour supply than the other sectors. Besides, an investment in the capital by the government helps to improve the infrastructure or facilities needed to generate economic activities. Policy revision on tax, especially for foreign investors, must be done more frequently to meet the needs and expectations of potential investors. Finally, reducing the tax on trading activities also helps improve the country's export activities, thus facilitating international trade activities.

6. ACKNOWLEDGMENT

This research project is a collaboration between Universiti Malaysia Perlis, and Universiti Teknologi MARA, Malaysia.

7. FUNDING

This research paper is funded by Young Talent Researcher Grant -600-RMC/YTR/5/3 (003/2022), provided by Universiti Teknologi MARA, Malaysia.

REFERENCES

Abdouli, M., Hammami, S. (2017), Investigating the causality links between environmental quality, foreign direct investment and economic growth in MENA countries. International Business Review, 26, 264-278.

Adebayo, T.S., Akinsola, G.D. (2021), Investigating the causal linkage among economic growth, energy consumption and CO2 emissions in Thailand: An application of the wavelet coherence approach. International Journal of Renewable Energy Development, 10.

Ahmed, Z., Zhang, B., Cary, M. (2021), Linking economic globalization, economic growth, financial development, and ecological footprint: Evidence from symmetric and asymmetric ARDL. Ecological indicators, 121, 107060.

Ali, H.S., Abdul-Rahim, A.S., Ribadu, M.B. (2017), Urbanization and carbon dioxide emissions in Singapore: Evidence from the ARDL approach. Environmental Science and Pollution Research, 24, 1967-1974.

Alshehry, A.S., Belloumi, M. (2015), Energy consumption, carbon dioxide emissions and economic growth: The case of Saudi Arabia. Renewable and Sustainable Energy Reviews, 41, 237-247.

Antweiler, W., Copeland B.R. Taylor M.S. (2001), Is free trade good for the environment? American Economic Review, 91, 877-908.

Arto, I., Pérez, C.I., Lago, R., Bueno, G., Roberto, B. (2016), The energy requirements of a developed world. Energy for Sustainable Development, 33, 1-13.

Atasoy, B.S. (2017), Testing the environmental Kuznets curve hypothesis across the US: Evidence from panel mean group estimators. Renewable and Sustainable Energy Reviews, 77, 731-747.

Aydin, M. (2018), Natural gas consumption and economic growth nexus for Top 10 natural gas consuming countries: A granger causality analysis in the frequency domain. Energy, 165, 179-186.

Aye, G.C., Edoja, P.E. (2017), Effect of economic growth on CO2 emission in developing countries: Evidence from a dynamic panel threshold model. Cogent Economics & Finance, 5, 1379239.

Balitskiy, S., Bilan, Y., Strielkowski, W., Štreimikienė, D. (2016), Energy efficiency and natural gas consumption in the context of economic development in the European Union. Renewable and Sustainable Energy Reviews, 55, 156-168.

Behera, P., Sethi, N. (2022), Nexus between environment regulation, FDI, and green technology innovation in OECD countries. Environmental Science and Pollution Research, 29, 52940-52953.

Belke, A., Dobnik, F., Dreger, C. (2011), Energy consumption and economic growth: New insights into the cointegration relationship. Energy Economics, 33(5), 782-789.

Bosah, C.P., Li, S., Ampofo, G.K.M., Liu, K. (2021), Dynamic nexus between energy consumption, economic growth, and urbanization with carbon emission: Evidence from panel PMG-ARDL estimation. Environmental Science and Pollution Research, 28, 61201-61212.

Cao, X., Kannaiah, D., Ye, L., Khan, J., Shabbir, M.S., Bilal, K., Tabash, M.I. (2022), Does sustainable environmental agenda matter in the era of globalization? The relationship among financial development, energy consumption, and sustainable environmental-economic growth. Environmental Science and Pollution Research, 29, 30808-30818.

Chaudhry, I.S., Safdar, N., Farooq, F. (2012), Energy consumption and economic growth: Empirical evidence from Pakistan. Pakistan Journal of Social Sciences (PJSS), 32(2), 371-382.

Chishti, M.Z., Ahmad, M., Rehman, A., Khan, M.K. (2021), Mitigations pathways towards sustainable development: Assessing the influence of fiscal and monetary policies on carbon emissions in BRICS economies. Journal of Cleaner Production, 292, 126.

Destek, M.A. (2016), Natural gas consumption and economic growth: Panel evidence from OECD countries. Energy, 114, 1007-1015.

Economides, M.J., Wood, D.A. (2009), The state of natural gas. Journal of Natural Gas Science and Engineering, 1(1-2), 1-13.

Engle, R.F., Granger, C.W. (1987), Co-integration and error correction: representation, estimation, and testing. Econometrica: Journal of the Econometric Society, 55, 251-276.

Fadiran, G., Adebusuyi, A.T., Fadiran, D. (2019), Natural gas consumption and economic growth: Evidence from selected natural gas vehicle markets in Europe. Energy, 169, 467-477.

Habib, S., Abdelmonen, S., Khaled, M. (2020), The effect of corruption on the environmental quality in African countries: A panel quantile regression analysis. Journal of the Knowledge Economy, 11, 788-804.

Ighodaro, C.A. (2010), Co-integration and causality relationship between energy consumption and economic growth: Further empirical evidence for Nigeria. Journal of Business Economics and Management, 11(1), 97-111.

Imran, K., Siddiqui, M.M. (2010), Energy consumption and economic growth: A case study of three SAARC Countries. European Journal of Social Sciences, 16(2), 206-213.

International Energy Agency. (2022), Gas Market Report. France: International Energy Agency. Available from: https://www.iea.org/reports/gas-market-report-q1-2022

Johansen, S., Juselius, K. (1990), Maximum likelihood estimation and inference on cointegration-with appucations to the demand for money. Oxford Bulletin of Economics and Statistics, 52(2), 169-210.

Koc, S., Bulus, G.C. (2020), Testing validity of the EKC hypothesis in South Korea: Role of renewable energy and trade openness. Environmental Science and Pollution Research, 27, 29043-29054.

Koengkan, M., Losekann, L.D., Fuinhas, J.A. (2019), The relationship between economic growth, consumption of energy, and environmental degradation: Renewed evidence from Andean community nations. Environment Systems and Decisions, 39, 95-107.

Krkošková, R. (2021), Causality between energy consumption and economic growth in the V4 countries. Technological and Economic Development of Economy, 27(4), 900-920.

Kum, H., Ocal, O., Aslan, A. (2012), The relationship among natural gas energy consumption, capital, and economic growth: Bootstrap-corrected causality tests from G-7 countries. Renewable and Sustainable Energy Reviews, 16(5), 2361-2365.

Levi, M. (2013), Climate consequences of natural gas as a bridge fuel. Climatic Change, 118(3), 609-623.

Li, Z.G., Cheng, H., Gu, T.Y. (2019), Research on dynamic relationship between natural gas consumption and economic growth in China. Structural Change and Economic Dynamics, 49, 334-339.

Mohamed Yusoff, N.Y., Ridzuan, A.R., Soseco, T., Whajoedi, W., Narmaditya, B.S., Ann, L.C. (2023), Comprehensive outlook on macroeconomic determinants for renewable energy in Malaysia. Sustainability, 15, 3891.

Mohammad, N., Ishak, W.W.M., Mustapa, S.I., Ayodele, B.V. (2021), Natural gas as a key alternative energy source in sustainable renewable energy transition: A mini review. Frontiers in Energy Research, 237, 625023.

Musah, M., Kong, Y., Mensah, I.A., Antwi, S.K., Osei, A.A., Donkor, M. (2021), Modelling the connection between energy consumption and carbon emissions in North Africa: Evidence from panel models robust to cross-sectional dependence and slope heterogeneity. Environment, Development and Sustainability, 1-15.

Nurgazina, Z., Ullah, A., Ali, U., Koondhar, M.A., Lu, Q. (2021), The impact of economic growth, energy consumption, trade openness, and financial development on carbon emissions: Empirical evidence from Malaysia. Environmental Science and Pollution Research, 28, 60195-60208.

Pata, U. K. (2018). Renewable energy consumption, urbanization, financial development, income and CO2 emissions in Turkey: Testing EKC hypothesis with structural breaks. Journal of cleaner production, 187, 770-779.

Pata, U.K., Caglar, A.E. (2021), Investigating the EKC hypothesis with renewable energy consumption, human capital, globalization and trade openness for China: Evidence from augmented ARDL approach with a structural break. Energy, 216, 119220.

Pata, U.K., Dam, M.M., Kaya, F. (2023), How effective are renewable energy, tourism, trade openness, and foreign direct investment on CO2 emissions? An EKC analysis for ASEAN countries. Environmental Science and Pollution Research, 30, 14821-14837.

Pesaran, M.H., Shin, Y., Smith, R.J. (2001), Bounds testing approaches to the analysis of level relationships. Journal of Applied Econometrics, 16(3), 289-326.

Pujiati, A., Handayani, B.D., Yanto, H., Ridzuan, A.R., Borhan, H., Shaari, M.S. (2023), The detrimental effects of dirty energy, foreign investment and corruption, on environmental quality: New evidence from Indonesia. Frontier in Environmental Science, 10, 1074172.

Qin, Z., Ozturk, I. (2021), Renewable and non-renewable energy consumption in BRICS: Assessing the dynamic linkage between foreign capital inflows and energy consumption. Energies, 14, 2974.

Rahman, M.M., Nepal, R., Alam, K. (2021), Impacts of human capital, exports, economic growth and energy consumption on CO2 emissions of a cross-sectionally dependent panel: Evidence from the newly industrialized countries (NICs). Environmental Science & Policy, 121, 24-36.

Ridzuan, A.R., Fianto, B.A., Esquivias, M.A., Kumaran, V.V., Shaari, M.S., Albani, A. (2022b), Do financial development and trade liberalization influence environmental quality in Indonesia? Evidence-based on ARDL model. International Journal of Energy Economics and Policy, 12(5), 342-351.

Ridzuan, A.R., Ismail, N.A., Che Hamat, A.F. (2017), Does foreign direct investment successfully lead to sustainable development in Singapore? Economies, 5(3), 29.

Ridzuan, A.R., Ismail, N.A., Che Hamat, AF. (2018), Foreign direct investment and trade openness: Do they lead to sustainable development in Malaysia? Journal of Sustainability Science and Management, 4, 79-97.

Ridzuan, A.R., Kumaran, V.V., Fianto, B.A., Shaari, M.S., Esquivias, M.A., Albani, A. (2022a), Reinvestigating the presence of environmental Kuznets curve in Malaysia: The role of foreign direct investment. International Journal of Energy Economics and Policy, 12(5), 217-225.

Safari, A., Das, N., Langhelle, O., Roy, J., Assadi, M. (2019), Natural gas: A transition fuel for sustainable energy system transformation? Energy Science and Engineering, 7(4), 1075-1094.

Sama, M.C., Tah, N.R. (2016), The effect of energy consumption on economic growth in Cameroon. Asian Economic and Financial Review, 6(9), 510-521.

Shaari, M., Hussain, N., Ismail, M. (2013), Relationship between energy consumption and economic growth: Empirical evidence for Malaysia. Business Systems Review, 2(1), 17-28.

Shaari, M.S., Karim, Z.A., Abidin, N.Z. (2020), The effects of energy consumption and national output on CO2 emissions: New evidence from OIC countries using a panel ARDL analysis. Sustainability, 12(8), 3312.

Shaari, M.S., Lee, W.C., Ridzuan, A.R., Lau, E., Masnan, F. (2022), The impacts of energy consumption by sector and foreign direct investment on CO2 emissions in Malaysia. Sustainability, 14, 16028.

Shahbaz, M., Chandran, V.G.R., Pervaiz, A. (2011), Natural Gas Consumption and Economic Growth: Co-integration Causality and Forecast Error Variance Decomposition Test for Pakistan. Available from: https://mpra.ub.uni-muenchen.de/35103/1/MPRA_paper_35103.pdf

Shahbaz, M., Farhani, S., Rahman, M.M. (2013), Natural Gas Consumption and Economic Growth Nexus: The Role of Exports, Capital and Labor in France. Available from: https://mpra.ub.uni-muenchen.de/50619/1/mpra_paper_50619.pdf

Shahbaz, M., Lean, H.H., Farooq, A. (2013), Natural gas consumption and economic growth in Pakistan. Renewable and Sustainable Energy Reviews, 18, 87-94.

Shahbaz. M., Lean, H.H., Shahbaz, M. (2012), Environmental Kuznets curve hypothesis in Pakistan: Cointegration and granger causality. Renewable and Sustainable Energy Reviews, 16(5), 2947-2953.

US Energy Information Administration Energy and the Environment Explained where Greenhouse Gases Come from. (2020), Available from: https://www.eia.gov/energyexplained/energy-and-the-environment/where-greenhouse-gases-come-from.php

Usman, O. (2022), Modelling the economic and social issues related to environmental quality in Nigeria: The role of economic growth and internal conflict. Environmental Science and Pollution Research, 29, 39209-39227.

Voumik, L.C., Islam, M.A., Ray, S., Mohamed Yusoff, N.Y., Ridzuan, A.R. (2023a), CO2 emissions from renewable and non-renewable electricity generation sources in the G7 countries: Static and dynamic panel assessment, Energies, 16, 1044.

Voumik, L.C., Rahman, M.H., Nafi, S.M., Hossain, M.A., Ridzuan, A.R., Mohamed Yusoff, N.Y. (2023b), Modelling a sustainable, non-renewable, and renewable energy based on the EKC hypothesis for Africa's most popular tourist destination, Sustainability, 15, 4029.

Wang, S., Li, G., Fang, C. (2018), Urbanization, economic growth, energy consumption, and CO2 emissions: Empirical evidence from countries with different income levels. Renewable and Sustainable Energy Reviews, 81, 2144-2159.

Wasti, S.K.A., Zaidi, S.W. (2020), An empirical investigation between CO2 emission, energy consumption, trade liberalization and economic growth: A case of Kuwait. Journal of Building Engineering, 28, 101104.

Yasar, N. (2017), The relationship between energy consumption and economic growth: Evidence from different income country groups. International Journal of Energy Economics and Policy, 7(2), 86-97.

Yilanci, V., Pata, U.K. (2020), Investigating the EKC hypothesis for China: The role of economic complexity on ecological footprint. Environmental Science and Pollution Research, 27, 32683-32694.

Yusoff, M.N.Y., Ridzuan, A.R., Soseco, T., Whajoedi, Narmaditya, B.S., Ann, L.C. (2023), Comprehensive outlook on macroeconomic determinants for renewable energy in Malaysia. Sustainability, 15, 3891.

Zambrano-Monserrate, M.A., Silva-Zambrano, C.A., Davalos-Penafiel, J.L., Zambrano-Monserrate, A., Ruano, M.A. (2018), Testing environmental Kuznets curve hypothesis in Peru: The role of renewable electricity, petroleum and dry natural gas. Renewable and Sustainable Energy Reviews, 82, 4170-4178.

Zhang, X., Myhrvold, N.P., Hausfather, Z., Caldeira, K. (2016), Climate benefits of natural gas as a bridge fuel and potential delay of near-zero energy systems. Applied Energy, 167, 317-322.