

Accelerating the Renewable Energy Transition: Short-Run and Long-Run Effects of Trade, Investment, and Industrial Development in Sweden, Denmark, and Austria

Maizatul Saadiah Mohamad¹, Halimahton Borhan^{2*}, Azhana Othman³, Rozita Naina Mohamed⁴

¹Universiti Teknologi MARA (UiTM) Cawangan Melaka Kampus Alor Gajah KM 26, Jalan Lendu 78000 Alor Gajah, Melaka, Malaysia

²Universiti Teknologi Mara Melaka Malaysia

³Universiti Teknologi Mara Melaka Malaysia

⁴Universiti Teknologi Mara Kampus Puncak Alam Selangor Malaysia

*Corresponding Author

DOI: <https://doi.org/10.47772/IJRISS.2026.100700526>

Received: 24 July 2026; Accepted: 30 July 2026; Published: 06 August 2026

ABSTRACT

Renewable energy consumption (REC) has become increasingly important in achieving sustainable economic growth and reducing environmental degradation. This study investigates the factors influencing renewable energy consumption in Sweden, Denmark, and Austria from 1985 to 2024. Using annual panel data obtained from the World Bank, the study examines the effects of imports of goods and services (IGS), exports of goods and services (EGS), industrial development (IDT), foreign direct investment (FDI), and gross capital formation (GCF) on renewable energy consumption. The analysis employs panel regression and the Autoregressive Distributed Lag (ARDL) approach to evaluate both short-run and long-run relationships among the variables. The panel regression results indicate that exports of goods and services and gross capital formation significantly influence renewable energy consumption, while foreign direct investment and industrial development are statistically insignificant. The ARDL long-run estimates reveal that gross capital formation has a significant positive effect on renewable energy consumption, whereas industrial development has a significant negative effect. In contrast, exports and foreign direct investment do not exhibit significant long-run impacts. The short-run analysis shows that most explanatory variables have insignificant effects on renewable energy consumption, suggesting that the benefits of investment, trade, and industrial transformation require time to materialize. Furthermore, the cointegration test indicates the absence of a stable long-run equilibrium relationship among the variables, and therefore no error correction mechanism is established. The findings highlight the importance of sustained capital investment in promoting renewable energy adoption and provide valuable policy implications for enhancing renewable energy development in European economies.

Keywords: Renewable Energy Consumption, Gross Capital Formation, ARDL Model, Short-Run and Long-Run Relationship, Sweden-Denmark-Austria.

INTRODUCTION

Renewable energy has emerged as a critical component of sustainable economic development due to growing concerns regarding climate change, environmental degradation, and energy security. The increasing dependence on fossil fuels has contributed significantly to greenhouse gas emissions, prompting governments worldwide to

accelerate the transition toward cleaner and more sustainable energy sources (Qamruzzaman, 2024). Renewable energy sources, including solar, wind, hydroelectric, geothermal, and biomass energy, offer long-term solutions for reducing carbon emissions while supporting economic growth and environmental sustainability (Ghafoor et al., 2024). European countries have been at the forefront of renewable energy adoption, particularly Sweden, Denmark, and Austria, which consistently record among the highest shares of renewable energy consumption in the region. These countries have implemented comprehensive energy policies, invested heavily in renewable energy infrastructure, and promoted technological innovation to support the transition towards low-carbon economies. As a result, they provide an ideal context for examining the economic factors that influence renewable energy consumption.

Previous studies suggest that renewable energy consumption is closely linked to several macroeconomic determinants. International trade, represented by imports and exports of goods and services, facilitates the transfer of advanced renewable energy technologies and promotes investment in sustainable energy infrastructure (Rahman et al., 2020; Chen, 2017). Imports can increase access to renewable energy equipment and technologies that may not be available domestically, while exports generate economic growth and financial resources that can be reinvested in renewable energy development (Khan et al., 2024; Güneş et al., 2022). Furthermore, industrial development plays a significant role in shaping energy demand and encouraging the adoption of cleaner energy sources as industries seek to improve energy efficiency and comply with environmental regulations (Paramati et al., 2017; Balogun, 2024).

In addition, foreign direct investment (FDI) has been recognized as a key driver of renewable energy development because it provides capital inflows, technological expertise, and managerial knowledge that facilitate the expansion of renewable energy projects (Fan & Hao, 2020; Azam & Haseeb, 2021). Similarly, gross capital formation (GCF) reflects investments in physical infrastructure and productive assets that support the deployment and expansion of renewable energy systems (Rahman et al., 2024; Bank-Ola et al., 2024). Empirical evidence generally indicates that these economic factors contribute positively to renewable energy consumption, although the magnitude and significance of their effects vary across countries and regions.

Despite the growing body of literature on renewable energy consumption, limited studies have simultaneously examined the combined effects of imports of goods and services, exports of goods and services, industry, foreign direct investment, and gross capital formation on renewable energy consumption in advanced renewable energy economies such as Sweden, Denmark, and Austria. Moreover, existing studies often focus on developing economies or broader regional panels, leaving a gap in understanding the specific determinants of renewable energy consumption in leading European renewable energy countries.

Therefore, this study aims to investigate the factors influencing renewable energy consumption in Sweden, Denmark, and Austria using panel data from 1985 to 2024. Specifically, the study examines the effects of imports of goods and services, exports of goods and services, industry, foreign direct investment, and gross capital formation on renewable energy consumption. The findings are expected to contribute to the renewable energy literature and provide valuable insights for policymakers in designing strategies that enhance renewable energy adoption and support sustainable economic development.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

This study reviews the theoretical and empirical literature on the determinants of Renewable Energy Consumption (REC) in Sweden, Denmark, and Austria. The chapter is grounded in Endogenous Growth Theory (Romer, 1986), Keynesian Economics (Keynes, 1936), and Sustainability Transition Theory (Geels, 2002), which collectively suggest that investment, technological progress, government intervention, and industrial transformation play important roles in promoting renewable energy adoption.

The literature review focuses on four key determinants of REC: Exports of Goods and Services (EGS), Industry (IDT), Foreign Direct Investment (FDI), and Gross Capital Formation (GCF). Previous studies examined both short-run and long-run relationships between these variables and renewable energy consumption.

The relationship between imports of goods and services and renewable energy consumption has been widely examined in both developed and developing economies. Existing studies consistently suggest that imports facilitate the transfer of renewable energy technologies, equipment, and technical knowledge, thereby promoting the adoption and utilization of renewable energy sources. In the long run, imports have been found to exert a positive and significant influence on renewable energy consumption. Studies conducted in Nordic countries, Turkey, European Union countries, selected Asian countries, and African countries demonstrate that greater import activity enhances access to clean energy technologies, supports renewable energy infrastructure development, and contributes to energy diversification and sustainability (Rahman et al., 2020; Katircioğlu, S., & Altinay, M., 2017; Pié, L., Fabregat-Aibar, L., & Saez, M., 2018; Khan et al., 2024).

In contrast, the short-run relationship between imports and renewable energy consumption appears to be weaker and less significant. Rahman et al. (2020) and Katircioğlu, S., & Altinay, M. (2017) found that the benefits of imported renewable energy technologies require time to be fully integrated into domestic energy systems. Similarly, Pié, L., Fabregat-Aibar, L., & Saez, M., (2018) reported that institutional barriers, regulatory constraints, and implementation delays may limit the immediate impact of imports on renewable energy consumption. Therefore, while imports contribute substantially to renewable energy development over time, their short-run effects are often constrained by adjustment costs and the gradual nature of technology adoption.

Overall, the empirical literature suggests that imports of goods and services serve as an important channel for promoting renewable energy consumption, with stronger effects observed in the long run than in the short run (Rahman et al., 2020; Katircioğlu, S., & Altinay, M., 2017; Pié, L., Fabregat-Aibar, L., & Saez, M., 2018; Khan et al., 2024).

The literature generally supports a positive long-run relationship between exports and renewable energy consumption. Export expansion encourages economic growth, technological advancement, and investments in cleaner production methods, which increase renewable energy use. Chen (2017) found that exports positively influenced renewable energy consumption in China, while Shahzad et al. (2020), Fareed et al. (2021), and Güneş et al. (2022) reported significant positive long-run effects across G7, BRICS, OECD, and emerging economies. However, short-run effects were mixed and often insignificant due to infrastructure limitations and adjustment costs associated with renewable energy investments.

Previous studies suggest that industrial development (IDT) can influence renewable energy consumption differently in the short and long run. Alsayegh et al. (2023) found significant positive short-run and long-run relationships between industry and renewable energy consumption in Bahrain. Similarly, Paramati (2017) reported a positive long-run equilibrium relationship in G20 countries, while Sartbayeva (2023) found that industrial modernization promotes renewable energy adoption in Kazakhstan. However, Kurniawan (2023) reported weak short-run effects, indicating that industries may require time before transitioning toward cleaner energy sources.

The literature indicates that Foreign Direct Investment (FDI) is generally associated with a positive long-run impact on renewable energy consumption because foreign investment facilitates technology transfer, infrastructure development, and financial support for renewable energy projects. Fan and Hao (2020) found long-run causality between FDI and renewable energy consumption in China. Likewise, Azam and Haseeb (2021), Kang et al. (2021), and Mert et al. (2019) reported significant long-run positive effects of FDI on renewable energy adoption. Nevertheless, short-run effects were often insignificant because renewable energy projects require substantial investment and time before generating measurable outcomes.

Among the reviewed variables, Gross Capital Formation (GCF) showed the strongest and most consistent relationship with renewable energy consumption. Bank-Ola, T., Adeyemi, O., & Yusuf, M. (2024) found that GCF significantly promotes renewable energy investment in both the short run and long run. Similarly, reported that GCF supports renewable energy infrastructure development across ASEAN-5 countries, while Qamruzzaman (2024) highlighted the importance of capital investment in expanding renewable energy systems in developing economies. These studies suggest that capital accumulation directly contributes to renewable energy adoption by financing infrastructure and technological improvements.

Variable	Short-Run Findings	Long-Run Findings	Key References
Imports of Goods and Services (IGS)	Positive but generally weak and less significant effects on renewable energy consumption due to implementation delays, adjustment costs, and regulatory constraints.	Positive and significant relationship with renewable energy consumption through technology transfer, access to renewable energy equipment, infrastructure development, and energy diversification.	Rahman et al. (2020); Katircioğlu, S., & Altinay, M.. (2017); Pié, L. (2018); Khan et al. (2024);
Exports (EGS)	Mixed or insignificant effects	Positive and significant relationship with REC	Chen (2017); Shahzad et al. (2020); Fareed et al. (2021); ; Güneş et al. (2022)
Industry (IDT)	Weak or mixed effects	Positive relationship with REC	Alsayegh et al.(2023); Paramati (2017); Sartbayeva (2023)
FDI	Mostly insignificant	Positive relationship through technology transfer and investment	Fan & Hao (2020); ; Kang et al. (2021); Mert et al. (2019)
GCF	Positive effect on renewable infrastructure development	Strong positive relationship with REC	Bank-Ola, T., Adeyemi, O., & Yusuf, M. (2024); ; Qamruzzaman (2024)

Hypotheses Development

Based on the theoretical foundations and empirical findings, the study proposed hypotheses to examine both direct relationships and equilibrium relationships between the explanatory variables and renewable energy consumption.

Specific Hypothesis

Hypothesis	Expected Outcome
H1	There is a short-run and long-run equilibrium relationship between all independent variables and REC.
H1a	There is a short-run and long-run equilibrium relationship between IGS and REC.
H1b	There is a short-run and long-run equilibrium relationship between EGS and REC.
H1c	There is a short-run and long-run equilibrium relationship between IDT and REC.
H1d	There is a short-run and long-run equilibrium relationship between FDI and REC.
H1e	There is a short-run and long-run equilibrium relationship between GCF and REC.

In conclusion, this study reviewed the theoretical and empirical literature on the determinants of renewable energy consumption. The literature suggests that exports, foreign direct investment, gross capital formation, and industrial development may affect renewable energy consumption differently in the short run and long run. Most studies reported insignificant or weak short-run effects due to adjustment costs and implementation delays, whereas stronger long-run relationships were observed as economies adapted to renewable energy investments. Gross capital formation and foreign direct investment were consistently identified as important drivers of renewable energy adoption, while exports and industrial development demonstrated mixed but generally positive

long-run effects. Based on these findings, the study developed hypotheses to test both the direct effects and the short-run and long-run equilibrium relationships between the selected variables and renewable energy consumption in Sweden, Denmark, and Austria.

METHODOLOGY

This study employed a quantitative research approach to examine the factors influencing renewable energy consumption in Sweden, Denmark, and Austria. The analysis utilized panel data obtained from the World Bank database covering the period from 1985 to 2023. Renewable energy consumption (REC) was used as the dependent variable, while imports of goods and services (MGS), exports of goods and services (EGS), industry (IDT), foreign direct investment (FDI), and gross capital formation (GCF) served as the independent variables.

Secondary data were selected due to their accessibility, reliability, and suitability for longitudinal economic analysis. The collected data underwent a rigorous verification and cleaning process to ensure consistency, completeness, and accuracy before analysis. Any discrepancies arising from missing observations or differences in reporting periods were addressed to improve data quality and reliability.

The study employed EViews software as the primary analytical tool due to its capability to handle panel data and perform advanced econometric analyses. To analyse both short-run and long-run relationships, the study adopted the Autoregressive Distributed Lag (ARDL) model. The ARDL approach was selected because it can estimate dynamic relationships among variables and distinguish between short-run effects and long-run effects. Prior to estimation, several diagnostic tests were conducted, including descriptive statistics, correlation analysis, multicollinearity testing, and panel unit root tests to determine the stationarity properties of the variables.

The short-run analysis was designed to examine the immediate effects of changes in MGS, EGS, FDI, GCF, and IDT on renewable energy consumption. Within the ARDL framework, differenced variables and lagged terms were used to capture temporary fluctuations and adjustment processes occurring within a short period. This analysis helps determine whether changes in economic activities have an instant impact on renewable energy consumption before the economy reaches its equilibrium level.

The long-run analysis aimed to determine whether MSG, EGS, FDI, GCF, and IDT have persistent effects on renewable energy consumption over time. The long-run coefficients generated by the ARDL model measure the equilibrium relationship between the variables after short-term adjustments have been completed. A cointegration test was also conducted to determine whether a stable long-run relationship exists among the variables. If cointegration were present, an Error Correction Model (ECM) would be estimated to measure the speed at which short-run deviations return to long-run equilibrium. Overall, the methodology adopted in this study provides a comprehensive framework for investigating the economic determinants of renewable energy consumption and generating robust empirical evidence regarding the influence of trade activities, industrial development, foreign investment, and capital formation on renewable energy adoption in Sweden, Denmark, and Austria.

In conclusion, this study used the methodology to investigate the determinants of renewable energy consumption in Sweden, Denmark, and Austria over the period 1985–2024. Using panel data obtained from the World Development Indicators database, the study employed the ARDL approach to estimate both short-run and long-run relationships between renewable energy consumption and selected economic variables. The short-run analysis examined the immediate effects of changes in exports, foreign direct investment, gross capital formation, and industrial activity, while the long-run analysis assessed their equilibrium effects over time. Unit root, multicollinearity, and cointegration tests were conducted to ensure the validity of the model before estimating the ARDL results.

RESULTS AND DISCUSSION

This study examined the factors influencing Renewable Energy Consumption (REC) in Sweden, Denmark, and Austria using panel data from 1985–2024. Before estimating the relationships, diagnostic tests confirmed that the data met the necessary assumptions. Due to severe multicollinearity between imports and exports of goods and

services, the import variable was removed from the final model. The Random Effects Model was selected as the most appropriate panel estimation model after the Likelihood Ratio and Hausman tests.

Table 4.1: Summary of Short-Run and Long-Run ARDL Results

Variable	Short-Run Effect	Significance	Long-Run Coefficient	Significance	Interpretation
Exports of Goods and Services (EGS)	Insignificant	Not Significant (p > 0.05)	0.1777	Not Significant (p = 0.5675)	Exports do not significantly influence renewable energy consumption in either the short run or long run.
Foreign Direct Investment (FDI)	Insignificant	Not Significant (p > 0.05)	0.0244	Not Significant (p = 0.4607)	FDI has no meaningful impact on renewable energy consumption over time.
Gross Capital Formation (GCF)	Mostly insignificant; one lagged effect negative and marginally significant	Weak Significance	2.0870	Significant (p = 0.0006)	Higher capital investment promotes renewable energy consumption in the long run.
Industry (IDT)	Negative but insignificant	Not Significant (p > 0.05)	-2.4825	Significant (p = 0.0014)	Industrial expansion reduces renewable energy consumption in the long run.

Table 4.2: Long-Run ARDL Estimation Results

Variable	Coefficient	Standard Error	t-Statistic	Probability (p-value)	Decision
EGS	0.1777	0.3072	0.5785	0.5675	Not Significant
FDI	0.0244	0.0327	0.7442	0.4607	Not Significant
GCF	2.0870	0.5600	3.7270	0.0006***	Significant
IDT	-2.4825	0.7060	-3.5160	0.0014***	Significant

*Significant at 1% level (p < 0.01).

Table 4.3: Overall Findings of Short-Run and Long-Run Effects

Variable	Short-Run Finding	Long-Run Finding
EGS	No immediate impact on REC	No significant long-term impact on REC
FDI	No immediate impact on REC	No significant long-term impact on REC
GCF	Limited short-term effect	Significant positive effect on REC
IDT	Insignificant short-term effect	Significant negative effect on REC

Long-Run Results

The ARDL long-run estimation revealed that:

Gross Capital Formation (GCF) has a positive and significant effect on renewable energy consumption. Coefficient = 2.0870 and p-value = 0.0006. This indicates that increased investment in infrastructure and capital development promotes renewable energy adoption over time.

Industry (IDT) has a negative and significant effect on renewable energy consumption.

Coefficient = -2.4825 and $p\text{-value} = 0.0014$. This suggests that increased industrial activity tends to reduce renewable energy consumption in the long run, possibly because industries continue to rely heavily on conventional energy sources.

Exports of Goods and Services (EGS) and Foreign Direct Investment (FDI) were found to be statistically insignificant in the long run, meaning they do not have a meaningful long-term influence on renewable energy consumption in the selected countries.

Short-Run Results

The short-run ARDL results indicate that:

Exports (EGS), Foreign Direct Investment (FDI), Gross Capital Formation (GCF), and Industry (IDT) are generally statistically insignificant in the short run. Their effects are weak and do not immediately influence renewable energy consumption.

For GCF, one lagged coefficient [$D(GCF(-2))$] showed a negative effect (-0.5100) but was only marginally significant, suggesting that capital investments require time before producing noticeable impacts on renewable energy adoption.

For Industry, the short-run effects were mixed. Some lagged values were negative but statistically insignificant, indicating that industrial expansion may temporarily increase reliance on traditional energy sources before any transition to renewable energy occurs.

The findings suggest that Gross Capital Formation (GCF) is the strongest positive driver of renewable energy consumption in the long run, while Industry (IDT) negatively affects renewable energy consumption over time. In contrast, Exports (EGS) and Foreign Direct Investment (FDI) do not significantly influence renewable energy consumption in either the short run or long run. Furthermore, the absence of cointegration implies that the variables do not move together toward a stable long-term equilibrium. Overall, investment in capital formation is the key factor promoting renewable energy consumption in Sweden, Denmark, and Austria, whereas increased industrial activity tends to hinder renewable energy adoption in the long term.

CONCLUSION AND FUTURE RESEARCH

This study investigates the economic determinants of renewable energy consumption in Sweden, Denmark, and Austria. The findings are expected to provide evidence on how international trade, industrial activity, foreign investment, and capital formation contribute to renewable energy development. The study offers practical implications for policymakers aiming to strengthen renewable energy policies and achieve sustainable economic growth. Future studies may expand the sample to include additional European countries and incorporate environmental variables such as carbon emissions and energy efficiency indicators.

Funding Statement

No funding was received to assist with the preparation of this manuscript.

Informed Consent Statement:

Informed consent was obtained from all individual participants included in this study.

Data Availability Statement

Data are available from the World Bank database and from the corresponding author upon request.

Conflict of Interest Statement

The authors declare no conflict of interest.

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