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## Chapter

# Assessing the Advancement of IEA Association Member Countries on SDG7

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## Abstract

This empirical study assesses the progress made by Association countries of the International Energy Agency (IEA) towards achieving Sustainable Development Goal Seven (SDG 7). The research employs dynamic panel data models, specifically the Difference GMM, System GMM, and Poisson Fixed-Effect models. These models provide estimates for indicators such as access to clean cooking solutions, energy intensity, and energy use. The estimates provided are robust and independent of the study unit, effectively mitigating endogeneity. The analysis covers the period from 2001 to 2021, unveiling notable advancements in energy accessibility, clean cooking alternatives, and private sector involvement in energy investment. Nonetheless, it also underscores the limited headway in energy efficiency and the adoption of renewable energy, underscoring the imperative for focused policies and investments to augment the deployment of renewable energy sources.

**Keywords:** dynamic panel models, Association Member countries, SDG 7,  
energy

**JEL Code:** Q4 Q01, Q43, Q56, C3

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## 1. Introduction

The primary objective of Sustainable Development Goal Seven (SDG 7) is to guarantee universal access to affordable, reliable, sustainable, and modern energy by the year 2030. Despite the collective global commitments, the advancement towards the attainment of SDG7 has been inconsistent, encountering substantial obstacles in the form of regulatory expenses and inadequate financial resources[1]. The objective of this study is to assess the advancements achieved by the Association Member countries of the International Energy Agency (IEA) between 2001 and 2021. Complex econometric models are utilized to examine various indicators related to energy access, clean cooking solutions, energy intensity, and renewable energy consumption. Consequently, numerous countries have made gradual advancements in enhancing sustainable, equitable, and cost-effective energy as well as ensuring access to clean energy sources, specifically in developing nations. Empirical research has conducted investigations on these narratives[2-6]. The literature suggests that several developing countries still fall behind in meeting some critical SDGs [3, 7].

The significance of energy consumption in economic growth cannot be disregarded, while simultaneously, environmental implications, such as climate change, should not be neglected in development initiatives. Following the introduction of the SDGs agenda, the IEA implemented the Association Member concept in 2015. As of June 2022, the IEA has granted association member country status to ten nations. This group consists of Argentina, Brazil, Egypt, India, Indonesia, Singapore, Thailand, China, Morocco, and South Africa. The members of the IEA Association play a crucial role in global energy consumption, operating both on a global scale and within their respective continents or regions. For example, China is the largest energy consumer worldwide and in Southeast Asia and the largest emitter of carbon dioxide (CO<sub>2</sub>) in terms of volume [8-10]. Also, according to [11] China is the leading destination for foreign direct investment (*FDI*) particularly for investments in energy power supply. Moreover, China's energy intensity (*EI*) has fallen consistently at 3.1% yearly between 2002-2021, owing to the structural change and technological shifts in the economy and industry[12]. Besides, China is committed to its NDCs to peak carbon emission by 2030 and achieve carbon neutrality by 2060 [13]. Also, Indonesia has improved the electricity access rate to near-universal in 2020, from a rate of 53% in the 2000s [14]. This was made possible through rural and nationwide

electrification programs, and through renewable energy projects, rooftop solar lamps. Presently, there is an escalation in energy investments by South Africa and Brazil, who are part of the IEA Association as member states[15] via private-sector programs such as the REIPPP and the IDB conditional line of credit to financed projects (CCLIP) to a tune of \$2.4B. Additionally, India's energy demand is currently forecasted to grow by 50% between 2019 and 2030; nonetheless, it is predicted to reach 35% under the Stated Policy scenario (SPS)[16]. In a similar vein, Morocco's energy mix, within the context of Association Members, predominantly consists of fossil fuels, with imports making up approximately 90% [17]. The Associate Member countries of the IEA currently play a significant role in the attainment of SDG 7. This can be attributed to their utilization of approximately 50% of the global energy supply and the consequent release of CO<sub>2</sub>, which has implications for various Sustainable Development Goals by 2030. Apart from Singapore, the remaining nine countries are classified as emerging economies, signifying the difficulty they face in managing energy demands.

Nevertheless, there has been no empirical research conducted to assess the advancement of IEA Association Member countries in attaining SDG 7 since its establishment in 2015. Empirical studies including[3], have investigated the SDG 7 with comprehensive review of the global performance in achieving all the SDGs. Also,[18, 19] deployed a qualitative analysis and found that SDG 7 is the underpinning goal compared to the rest of the SDGs. Similarly, [20] discovered that sustainable economic development and energy efficiency (*EE*) go hand in hand, using the DEA approach analysis.

In addition to filling the literature gap, this study contributes new knowledge as the study makes use of dynamic panel data models, the Bond, (1991), Difference GMM, the (Arellano & Bover, 1995) system GMM alongside the Poisson fixed model (PFE) [21, 22] to evaluate the progress of the Association Member countries of the IEA on SDG 7. Prior, Experiential research concerning the SDG 7, such as [3], gave a comprehensive review of the world's performance in achieving the SDGs. Also, [18]deployed a qualitative analysis and found that SDG 7 is the underpinning goal compared to the rest of the SDGs. Similarly,[20] discovered that sustainable economic development and EE go hand in hand, using the DEA approach in their analysis. However, these models have not yet been utilized to assess SDG 7 in the Association Member countries of the IEA. According to [23], the following indicator variables are the pillars in measuring the achievement of the SDG 7; universal electrification, access to clean and modern cooking solutions, and the reduction of energy-intensive levels of the economies, that

is, the decoupling of the energy consumption for economic growth, while growing the consumption of RES in the final primary energy consumption of countries. Therefore, the study presents the following contributions. First, the author models the SDG 7 measurement pillars to examine the progress of the Association Member countries of the IEA using dynamic panel data models, which hitherto have not been applied to study these Association member countries. The advantages of using these models are that they can encapsulate heterogeneity among the study units and the dynamics. Secondly, the study finds that the study countries have made significant gains on the SDG 7 and need to solidify these gains by remaining committed to unabated strategies on competitive, reliable energy for their populace; this is based on the significance of access to clean cooking solutions, energy use, energy intensity on the Difference GMM model. Furthermore, the Poisson fixed effects model shows consistent results, underscoring the significance of both private sector participation in energy investment and the consumption of renewable energy. Fourthly, the study reveals that the study countries lag in energy intensity and renewable consumption. Since the passage of the SDG 7, an analysis of the data trends reveals that a significant number of the study countries have witnessed either stagnation or retrogression in the deployment of renewable energy in their total energy consumption.

The rest of the paper is structured as follows; section two deals with literature that explores the energy consumption patterns of these countries regarding the SDG 7, as well as their NDCs. Section three offers an in-depth examination of the methodologies and data utilized in the study. Section four presents the results and discussion, and section five wraps up with the conclusion.

## **2. Literature Review**

Sustainable development goal 7 serves as the central pillar for the attainment of the remaining SDGs. Access to ample, sustainable energy is imperative for the optimal development of any economy. The involvement of IEA Association members is crucial in the attainment of the overarching SDGs, with a specific focus on SDG 7. Singapore successfully achieved universal access to electricity in 2015, thanks to the government's unwavering commitment through various programs and schemes, as stated by [24, 25]. Certain countries have successfully achieved universal accessibility to clean cooking solutions and technologies. Consequently, Singapore has attained

commendable progress in these indicators. However, the crucial question remains: does Singapore derive its energy consumption from sustainable energy sources? The answer is obviously no because the country generates about 95% of its power from natural gas imported from Malaysia and Indonesia via pipelines[24, 26]. Singapore, a country constrained by the options to alternative energies, has targeted to achieve 350WM of solar capacity by 2020 and 2 GW by 2030 [27].

Similarly, Thailand aims to achieve a 30% share of renewable energy in total final energy consumption by 2036, accounting for 15 to 20% of total renewable electricity supply[27]. The specific vulnerability of the ASEAN region to climate change is greater compared to other regions globally. Yet, it is one of the world's fastest-growing economic regions [27]. To back this assertion, [28] said Thailand was one of the most affected countries in the world due to extreme weather conditions between 2000-2019. About three of these countries are found in the ASEAN region. Also, [29] discovered that developing economies in Asia need to expend \$200B in capital expenditure yearly on low carbon electricity supply as well as in EE to achieve their nationally determined contributions (NDCs). On the other hand, Indonesia was the fifth biggest subsidizer of its fossil fuels in 2018[27]. In this vein, [30] highlighted that 759M people still lack access to electricity, and three out of four reside in Sub-Saharan Africa. Additionally, one of the indicators measuring the SDG 7, EE, needs to be advanced from 2% between 2010-2018 to 3% in 2030, according to[30].The Sustainability report [30] further reiterated the minimal deployment of RES, particularly within the transport and heat sectors; for instance, clean energy sources proportion of total final energy consumption for the power sector is 24.5%, heat sector 9.2%, and the transport sector is 3.4%. Likewise, according to [31], since wind and solar are believed to be utility-focused investments that continuously have financing within power purchase agreement, more private firms are investing in renewables in the United States; the same can be said of the developing world too [32]. Thus, capital expenditure is yet on the increase as renewables and grid modernization continues to increase [31]. In measuring the progress of the world in achieving SDG 7, [33]unraveled that about 733M people are without access to electricity, 2.4B cooking with polluting sources, 17.7% of RES consumption in total final consumption. So, [34] study found that e-cooking could be affordable in many locations and is projected to become cheaper in the coming years. Plus, energy intensity estimated as the rate of primary energy intensity dropped to 4.7MJ/USD, and \$10.2B of financial flow to emerging countries in assistance of clean energy[35]. Globally, access to

electricity increased significantly between 2010-2020, around 83% to 91%, [35]. According to [36], the achievement of SDG 7 relies on the availability of finance. The authors suggest that Public Development Banks (PDBs) can accelerate the institutionalization of the SDGs by integrating their leverage position into systemic and cross-cutting strategic practices, leading to transformative changes in their operations and investment choices. Moreover, India is home to approximately 80% of the South Asian population and ranks as the sixth largest contributor to global pollution, responsible for 75% of greenhouse gas emissions in the South Asian region [37]. The country's building sector will continue to grow in the cause of the two decades, with 70% of new building taking place in the urban centers [16]. This implies energy consumption will continue to grow unabated.

In a similar vein, Argentina accounts for 0.81% of global emissions. The country has achieved notable successes and has officially submitted its revised NDCs, which reflect lower pollution levels. The reason behind this achievement is the government's recognition of a climate and ecological emergency in July 2019 [38]. Argentina also committed to an unconditional economy-wide cap on net pollution of 349 MtCoe in 2030 [38, 39]. Brazil, a member country of the Association from Latin America, has made the decision to decrease its greenhouse emissions by 37% in 2025, in comparison to the levels of 2005. Additionally, Brazil aims to reduce its overall emissions by 50% by 2030 [40]. Indeed, Brazil's energy mix is one of the most pollution-free generation sources in the world; in 2020, RES made up 48.4% of its total energy demand [41]. Moreover, the proportion of RES in the power mix makes up about 84.8% of the energy mix [41]. South Africa, as the leading driver of renewable energy deployment in the Sub-Saharan African region, stands as the first country within the Association member countries. Its renewable energy independent power project procurement program (REIPPP) has successfully attracted substantial private sector investment, particularly in wind and solar energy [42, 43]. Also, Morocco aims as a business as usual (BAU) to reduce its greenhouse gases emissions levels to 17% by 2030 and increase its overall emissions level by 25% by 2030 relative to the BAU approach, assuming a total of 42% [44]. It is an indisputable fact that the achievement of the SDG 7 will be hinged on the availability of storage in all forms since the variable nature of solar and wind required for this task are intermittent. This narrative is corroborated by a study by [45], where they stressed the vital functions of storage in the modernized grid system crucial to abating climate change.

In general, the existing literature emphasizes the urgency for the countries under study to expedite their efforts in achieving SDG 7. This is due to the fact that certain countries are falling behind in certain indicators, thereby jeopardizing the realization of the Paris Accord.

### **3. Methodology**

#### **3.1. Data and Variables**

The objective of this study is to assess the progress of IEA Association Members in achieving Sustainable Development Goals 7. The achievement of SDG 7 will be assessed empirically using dynamic panel data models to identify contributing factors. The member countries of this Association represent some of the largest economies within their respective subregions or continents. The objective of Sustainable Development Goal 7 is to achieve a sustainable, affordable, and equitable energy system for all by 2030. Thus, the ability of these countries to achieve this noble goal will, in totality, ensure the world reaches the SDGs. The data was derived from the World Bank development indicators (WDI) from 2001 to 2021. The dependent variable is the energy use applied in the studies of [46, 47]. Understandably, energy access (eneacc) denotes the number of people with access to electricity in the total population. It is one of the key determinants to attaining SDG 7; without it, the other indicators can't be measured.

Additionally, access to clean cooking solutions is important since these economies are yet developing; this dimension of the SDG7 explains the percentage of people mainly cooking with clean technologies and fuels. Besides, investment in energy with private sector participation illustrates the commitment to energy infrastructure that has attained financial closure and explicitly serves the public's interest. Also, energy intensity explains the quantum of energy used to produce a unit of the GDP. Minimal values mean that a small amount of energy is used to create a unit of the GDP, which is the ideal situation. Renewable energy consumption (REC) is the total energy consumed in the final aggregate energy consumption.

#### **3.2. Model Specification**



The study uses dynamic panel models that are appropriate for approximating macroeconomic parameters. These methods are primarily utilized in the context of economic growth, where the parameters are often not exogenous but instead estimated concurrently with the explained parameter. Also, for certain variables, the dependent parameter is impacted by their lagged values figure, hence making them dynamic and the need to ensure the lag value is estimated as [48-50]. The dataset makes room for cross-country dimensions but equally to discover time-invariant characteristics. Thus the study deploys dynamic data panel models such as the Difference GMM dynamic models [51, 52], Arellano-Bover/Blundell-Bond estimation [53], the Panel fixed-effect models (PFE)[21, 22] that remove restrictions on the exogeneity of the models. From the model,  $y$  depicts the explained variable energy use.

Below is the specification of the xtabond model:

$$y_{it} = \sum_{j=1}^p a_j y_{it-j} + X_{it} + \beta_1 + \omega_{it} + \beta_2 + v_i + e_i \quad i = 1, \dots, N, t = 1, \dots, T \quad (1)$$

Here,  $\beta_1$   $\beta_2$  depict parameter vectors to estimate  
 $X$  =represents the exogenous covariates vector  
 $w$  =represents the covariate vector  
 $i$  =represents the  $i$ th country, 10 countries and  
 $t$  =represents the period.

Further [53], Arellano and Bond contend that further instruments can be derived from evolving longitudinal data equations, if one applies the orthogonality circumstance that exist along lagged values of  $y_{it}$  and the stochastic term  $e_i$ .

According to [54], the elongated system generalized methods of moment approximates goes beyond the autoregressive -distributed lag models, like in equation (1). In these circumstances, [55, 56] depict that a necessary condition for the validity of the extra moment circumstances, such as equation (1) ( $y_{it}$ ,  $X_{it}$ ) series with every one of them meeting the mean stationarity presumption. Thus, within the sample, the first differences of  $\Delta y_{it}$ , is expressed as below:

$$\Delta y_{it} = a^{t-2} \Delta y_{i2} + \sum_{s=0}^{t-3} a^3 \beta \Delta x_{i,t-s} + \sum_{s=0}^{t-3} a^3 \Delta v_{i,t-s} \quad (2)$$

For  $i = 1, 2, \dots, N$  and  $t = 3, 4, \dots, T$ .

So, the validity of these extra moment circumstances regarding the levels models is tested. Furthermore, [54, 57] present a test that examines the hypothesis of the absence of serial order correlation in the noise term of the differenced model. This test is vital owing to the fact the consistency of the GMM approximators depends heavily on the reason that  $E[\Delta v_{i,t-2}] = 0$ . The equation below specifies the [58] test for the first-order and second-order serial correlation is derived.

$$M_2 \frac{\widehat{v}'_{-2} \widehat{v}^*}{\widehat{v}^{1/2}} \bar{a} N(0,1) \quad (3)$$

Within ( $E[\Delta v_{i,t-2}] = 0$ , where  $\widehat{v}$  is presented by

$$\begin{aligned} \widehat{v} = & \sum_{i=1}^N v' i(-2) \widehat{v} i * \widehat{v}_{i(-2)} \\ & - 2 \widehat{v}'_{-2} X_* (X' Z N_N)^{-1} X' Z A_N \left( \sum_{i=1}^N Z' i \widehat{v} i \widehat{v}' i * \widehat{v}_{i(-2)} \right) \\ & + \widehat{v}'_{-2} X_* a v \widehat{a} \widehat{r} (\widehat{\delta}) X' * \widehat{v}_{-2} \end{aligned}$$

The  $M_2$  statistic tests for the absence of second-order serial correlation within the first difference residuals.

### 3.2.1. Panel Poisson Fixed Model (PFE)

Here, the analysis fits the Poisson model to the Panel fixed-effect model. As depicted in [21, 22]. The PFE estimator  $\beta_{PFE}$  specified below:

$$\begin{aligned} Pr = (Y_{it} = y_{it} | x_{it}) &= \exp\{(a_i + x_{it}\beta)\} \exp(a_i + x_{it}\beta)^{y_{it}} / y_{it}! \quad (4) \\ &= \frac{1}{y_{it}!} \exp\{-\exp(a_i) \exp(x_{it}\beta) + a_i y_{it}\} \exp(x_{it}\beta)^{y_{it}} \\ &= F_{it} \end{aligned}$$

$x$  = is the vector of the exploratory variables

$Y$  = is the Explained parameter

As stated in [22]

$$\sum_{i=1}^n \left( \frac{\partial \rho_i(\beta_o)}{\partial} \right)' W_i(\beta_o)^{-1} \rho_i(\tilde{\beta}_{PFE}) = 0 \quad (5)$$

Inferring from equation (1), similar condition as in [22].  $\tilde{\beta}_{PFE}$  is consistent for  $\beta_o$  asymptotically equal to  $\tilde{\beta}_{PFE}$  so explained by the above equation (5).

### 3.2.2. Cross Section Dependence Test

The empirical assessments employ the application of CD to ascertain the causal factors' magnitude in attaining SDG 7 among the IEA's Association member countries. The purpose of this analysis is to assess the interdependence among the economies of the Association in their efforts to achieve SDG 7 by 2030, as well as to examine the potential dependency of these macroeconomic variables across different countries.

$$CD = \sqrt{\frac{2T}{N(N-1)} \sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{ji}}$$

It is seen from the table that under  $H_0 =$  with  $T \rightarrow \infty$

Different from the  $LM$  test statistic, the  $CD_{lm}$  is the test mentioned above derives precisely zero mean, about fixed effects values of  $T$  and  $N$  within a comprehensive longitudinal dataset, comprising heterogenous evolving models based on multiple breaks in their slope coefficient and stochastic variance, given the fact that the unconditional means of  $y_{it}$  and  $x_{it}$  are time-invariant, and their energy use is symmetrically distributed [59].

## 4. Results and Discussions

The descriptive statistics of the model variables are presented in Table 1. Investment in the energy sector by the private sector participation derives the highest mean value. The attainment of Sustainable Development Goal 7 hinges on the accessibility of financial resources. Several countries under study have implemented regulatory measures to encourage private involvement in the industry, such as China's offshore wind energy tariff policy and the South African renewable energy independent power project procurement program (REIPPP). The variable with the highest mean value that follows is energy use (Eneu). It is comprehensible that around 90% of these nations fall under the category of emerging countries, thus displaying a substantial need for energy in diverse forms to support their industrial and

economic endeavors. Hence the high mean value of energy use. It aligns with conventional economic thinking that adequate energy underpins economic development and growth. Nevertheless, the least mean overall value is obtained by energy intensity (EI). On the other hand, countries such as China and South Africa have EI rates between 10 and 9. Indeed, South Africa and China have the highest EI values. Surprisingly, Singapore is a developed economy among the study countries; its EI is lower than some developing countries like Thailand, India, and South Africa. The economic reason for this might be due to the decoupling of Singapore's GDP or its Demand Side Management (DSM) practices and energy efficiency.

A lower EI value is preferable for countries, as it serves as a significant metric for evaluating the advancements of SDG 7 in terms of energy efficiency. The mean value of the EI rate implies that these Association countries have not progressed well in achieving their SDG 7. In general, they have made greater progress in other indicators, including energy use, energy access, access to clean cooking, and investment in the energy sector with the involvement of the private sector. The highest mean value is derived from energy investment with private sector participation, indicating a significant level of funding from the private sector. The world requires about \$5.7T yearly to 2030 to attain a just energy transition and to avoid stranded asset investments of \$1.07T from conventional energy sources [3, 60, 61]. In accordance with the findings of [3], low-income countries necessitate increased fiscal expenditure to achieve the SDGs.

**Table 1.** Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Eneu	210	1053.741	1363.291	0	7370.653
Eneacc	210	93.47794	12.53456	0	100
Accclkg	210	73.07214	30.77835	0	100
Invene	210	2.26E+09	4.91E+09	-1.74e	3.45E+10
EI	210	4.201857	2.582781	0	10.83
Rec	210	16.12501	15.7077	0	50.8298

Source. Author's estimations.

Furthermore, table 2 is the correlation matrix of the variables. There exists a notable positive correlation between the accessibility of clean cooking solutions and investments in energy (investEne). This implies that heightened investments in the energy sector are expected to enhance the availability of clean cooking technologies. This can be attributed to strategic investments

focused on improving energy infrastructure and accessibility. The most robust correlation observed in the matrix is between the consumption of renewable energy and investEne. With the rise in renewable energy consumption, investEne also experiences growth. This correlation suggests that the expansion of renewable energy sources necessitates significant financial investments, underscoring the pivotal role of financial contributions in fostering renewable energy technologies. The Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) in South Africa has greatly increased private sector involvement in the renewable energy industry. This program has effectively encouraged greater private sector investments, promoting the growth of renewable energy projects. The achievement of this endeavor highlights the significance of meticulously organized procurement programs in attracting investments. The adjustments made on-grid feed-in tariffs for onshore and offshore wind energy in China have resulted in a surge of wind energy installations. The implementation of these policy changes, which were designed to encourage renewable energy projects, has resulted in significant growth in wind energy capacities. The expected conclusion of these projects by 2022 demonstrates the swift expansion propelled by advantageous policies and investment environments.

There exists a negative correlation between renewable energy consumption and other variables, such as energy access and access to clean cooking technologies. The presence of this negative correlation suggests that there is no significant direct association between REC and these variables. This implies that enhancements in renewable energy consumption do not inherently lead to improved energy accessibility or access to clean cooking solutions. To tackle these aspects, it is imperative to implement comprehensive strategies that encompass targeted investments and policy interventions.

**Table 2.** Correlation Matrix

Eneu	Eneacc	Accclkg	investEne	Ei	Rec
eneu 1.0000					
eneacc 0.0823	1				
accclkg 0.2285	0.3796	1			
investEne -0.0798	-0.0795	-0.0342	1		
ei 0.2645	-0.1311	-0.008	0.1022	1	
rec -0.1189	-0.2145	-0.2348	0.5191	0.286	1

Source. Author's Estimations.

Table 3 presents the analysis of the dynamic panel analysis making use of [57] approaches. The first model utilizing the `xtabond` command demonstrates the significance of energy use to its lagged dependent variable. This outcome is consistent with the findings of [62]. Furthermore, the Arellano Bond GMM estimator reveals a significant coefficient of -1.751 for the regressor of access to clean cooking solutions. The sign of the coefficient shows a decreasing trend between access to cooking sources and energy use. This result is backed by [63], where other social factors inhibit clean cooking adoption in SSA.

Nevertheless, the significance of this variable indicates substantial progress made by these Association countries in attaining the sustainable development goals (SDG 7) pertaining to the access of clean cooking solutions. Apart from Singapore, the remaining economies have varying levels of access to clean cooking solutions, ranging from a minimum of 67.9% in India to a maximum of 99.9% in other economies. In summary, the countries affiliated with the International Energy Agency (IEA) have made significant progress on this Sustainable Development Goal 7 indicator.

Similarly, EI is significant and attains a direct coefficient (65.36). The magnitude of the meaningfulness depicts an immediate growth in EI and energy use [64]. The significance of this variable highlights its importance in achieving the SDG7. Indeed, it is one of the indicators for measuring the progress of economies in attaining SDG 7. A lower value denotes a country is efficient in energy consumption.

Moreover, it is worth noting that several of the countries analyzed in the study demonstrate EI rates reaching as high as 10.9. Despite its status as a developing nation, South Africa exhibits the second-highest rate of EI among the countries analyzed in the study. Conversely, Singapore, which is considered a developed country among the studied nations, exhibits the lowest EI based on WDI data. This illustrates the excessive dependence of South Africa on coal, which accounts for more than 80% of its energy consumption [65].

Likewise, the results of the System GMM analysis exhibit similarity to the analysis conducted using the Arellano and Bond Difference GMM. The GMM estimator for the system models the relationship between latent cross-section effects in linear longitudinal models and the lagged explained parameters, specifically energy use (ENeuse) as documented in (Blundell & Bond, 1998). The sole variable that exhibited significance in this model is energy access. The majority of these countries under study are approaching the point of achieving universal electricity access. Overall, the economies

under study have made significant progress in achieving near-universal access to electricity. With the exception of Singapore, which successfully achieved universal access in the early 2000s. It is possible that they will achieve this objective by 2030 for those who have not yet achieved universal access. Model 3 illustrates a two-stage least squares approach using instrumental variables to instrument investment in energy sector with private sector participation. This method is implemented to eliminate unobserved heterogeneity among the variables. In accordance with this model, the variables lack statistical significance, yet they yield resilient coefficients. To assess the strict conditional exogeneity, the PFE model utilizes a Poisson model that is adjusted to a panel fixed-effect model. Energy consumption demonstrates a significant relationship with the dependent variable, as indicated by the adjusted panel PFE method, aligning with the findings of [53]. Furthermore, it offers estimators that are both consistent and robust. The majority of the exploratory variables demonstrate significant impact on the dependent variable. Apart from the provision of clean cooking solutions, there is a substantial significance in investing in energy with the participation of the private sector. Within the PFE model, Energy Intensity (EI) and the incorporation of renewable energy consumption hold equal significance. The PFE model yields superior outcomes, as it elucidates that Association countries of the IEA have made significant advancements in achieving SDGs 7. Taking into account the significance of these indicators. However, it is imperative to increase investments in energy, as recent research [66] indicates that the global expenditure on the power sector alone amounts to approximately \$900B annually. To accomplish the Sustainable Development Goals 7 by 2030, global investment in clean energy must be increased annually to reach \$4.5 trillion by 2030. This is crucial to ensure universal access to clean energy (SDG 7.1) and decarbonize the global energy sector (SDG 7.2), in alignment with efforts to limit the global temperature rise to 1.5 degrees Celsius [67].

To test for serial correlation in the first order [68], models three and four estimates the first and second-order autocorrelation within the initial differenced errors, as done in [69]. The null hypothesis illustrates robust evidence of no significant serial autocorrelation in the first differenced errors at order two, both in the Difference GMM model and the System GMM models.

The study countries' energy use undergoes a cross-section dependence test, aiming to assess the progress of IEA Association member countries in

achieving SDG 7. The results demonstrate cross-section dependence among study countries since the null hypothesis is rejected. Because these are macroeconomic variables and are susceptible to geopolitical risks emanating from different countries. Energy use has the highest cross-section dependence value because some countries depend on the global oil markets for their domestic consumption. The current energy crisis occasioned by Ukraine - Russia conflict impacts the entire global economy and reduces the energy use of various economies. For instance, [70], the conflict caused crude prices to rise to never before multiyear levels necessitating the release of strategic petroleum reserves (SPRs), buffer stocks, and decreased energy demand globally.

**Table 3.** Dynamic Panel Analysis

Variable	Diff GMM1	Sys GMM2	IVE 3	PFE 4	estatabo- ndtest5	estat abondtest6
Main						
L.eneu	0.859***	0.848***			0.859***	0.848***
	-86.99	-137.49			-86.99	-137.49
Eneacc	2.544	3.221*		-0.00320***	2.544	3.221*
	-1.66	-2.15		(-5.21)	-1.66	-2.15
L.eneacc	-2.39	-1.726			-2.39	-1.726
	(-1.17)	(-1.05)			(-1.17)	(-1.05)
D.eneacc			0.0522			
			-0.01			
Accclkg	-1.751*	-1.698*		0.00583***	-1.751*	-1.698*
	(-2.13)	(-2.37)		-16.97	(-2.13)	(-2.37)
L.acclkg	-1.264	-1.553			-1.264	-1.553
	(-1.46)	(-1.47)			(-1.46)	(-1.47)
D.acclkg			-0.916			
			(-0.36)			
InvestEne	1.61E-09	-5.93E-10		1.82e-11***	1.61E-09	-5.93E-10
	-0.18	(-0.06)		-25.55	-0.18	(-0.06)
L.investEne	3.13E-09	6.48E-09			3.13E-09	6.48E-09
	-0.74	-1.34			-0.74	-1.34
D.investEne			-4.87E-09			
			(-0.19)			
Ei	65.36*	71.96		0.415***	65.36*	71.96
	-1.98	-1.86		-152.67	-1.98	-1.86
L.ei	-1.813	-16.16			-1.813	-16.16
	(-0.10)	(-0.44)			(-0.10)	(-0.44)
Rec	-0.281	-1.781		0.0509***	-0.281	-1.781
	(-0.18)	(-0.83)		-68.65	(-0.18)	(-0.83)
L.rec	-4.614	-3.312			-4.614	-3.312
	(-0.94)	(-0.82)			(-0.94)	(-0.82)
LD.rec			22.34			
			-0.15			



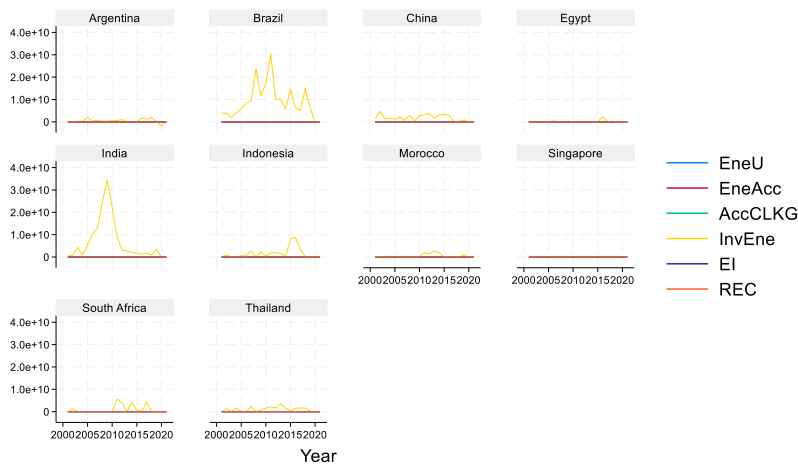
_cons	97.53	36.55	-74.29		97.53	36.55
	-0.86	-0.38	(-0.37)		-0.86	-0.38
N	190	200	180	210	190	200

t statistics in parentheses\* p < 0.05, \*\* p < 0.01, \*\*\* p < 0.001 Source. Author’s estimations.

**Table 4.** General cross-section dependence Test

Variable CD-test p-value	corr abs(corr)
eneu 30.06 0.000	0.978 0.978
eneacc ++	++
accclkg ++	++
investEne ++	++
ei 27.34 0.000	0.889 0.889
rec 28.01 0.000	0.911 0.911
Notes: Under the null hypothesis of independence $CD \sim N(0,1)$	cross-section
	+=No observations

Source’s Estimations



Graphs by Country

**Figure 1.** Panel Graphs of the variables Source. Author’s estimations.

From figure 1. is the panel graph display of the variables. The panel graph indicates that the study economies have progressed minimally in other indicators regarding achieving SDG 7. However, they have progressed substantially concerning investments in energy in the private sector, especially regarding RES investment. Brazil takes the commanding lead of all the

countries, next to India. India, the most populous country, has in 2019 a total installed generation capacity of 373 721MW [71].

Furthermore, India is the third-largest energy consumer due to rising earnings levels and lifestyle advancements. The energy demand doubled in the 2000s, with 80% of energy use coming from coal, oil and biomass[72]. According to[72], India now spends about 3% of its gross domestic product to clean energy financing; the majority of it goes to clean energy financing. Hence, the reason it placed second in energy investments. From 2010, South Africa saw an increase in its REIPPP, geared toward attracting private sector participation. The program has attracted private resources and expertise to grid-connected renewable in the country at affordable tariff rates [73]. Despite China's significant investment in domestic energy and its global leadership in consumption, energy investment remains predominantly controlled by state or quasi-state institutions [74]. Curiously, Singapore, the developed economy of the study units, does not have data on investment in energy with private sector participation. Thailand, as well as Indonesia, are increasing their investments in energy with private sector private participation.

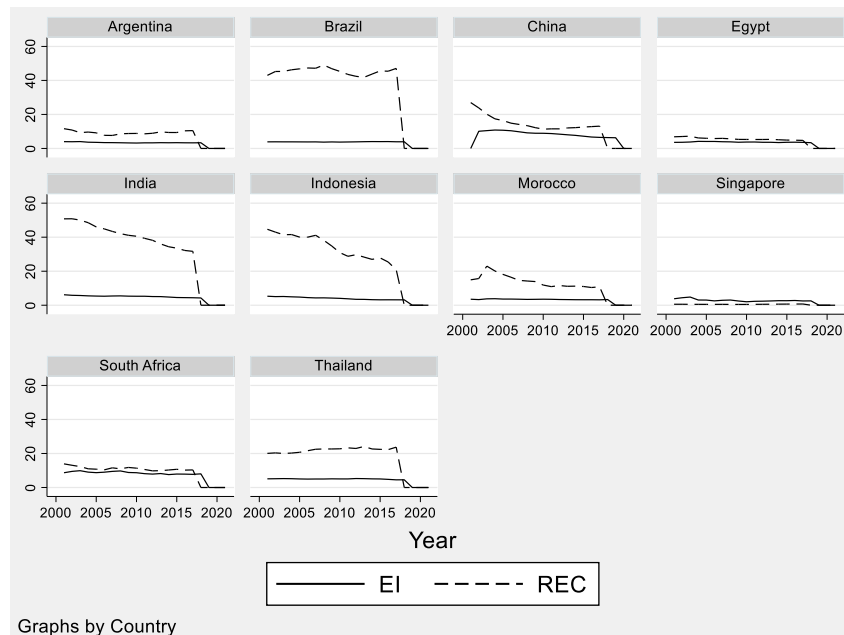


Figure 2. Graph of REC and EI. Source. Author's estimations.

Figure two depicts the variables of renewable energy consumption of primary energy (REC) and energy intensity (EI). The essence of this graph is to reveal the trend REC has followed since the implementation of the SDG 7 in 2015. It is clear that there has been a decline in REC consumption across most countries following the implementation of SDG 7. Indonesia and Brazil have also seen a rise, and RES makes up over 48% of final energy consumption in Brazil [75]. On the other hand, Morocco experienced a decline in REC; in China there was also a decline and a further increase in REC. South Africa experienced its EI and REC increase in the same direction. Its EI is as high as a 10% rate. Notably, Singapore, the developed economy among the study countries, consumes a very insignificant amount of RES as part of its total primary energy consumption. The fact is, REC Consumption as part of primary energy consumption has declined in most countries after the passage of SDG 7. Meanwhile, these economies are signatories to the Paris Agreement and explicitly stated it in their Nationally Determined Contributions (NDCs) as their national targets in achieving SDG 7.

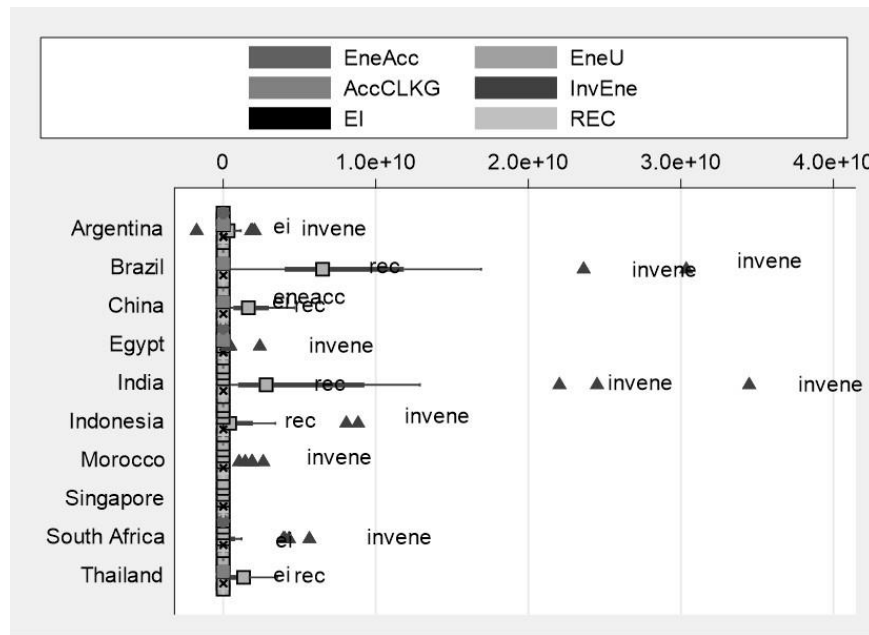


Figure 3. Boxplot of the variables and Countries.

The Boxplot depicts another perspective of the variables concerning the individual countries and explains these countries' progress in attaining the SDG 7. The Boxplots define India as a bit ahead of Brazil regarding investments in energy with private sector participation. Argentina has progressed well regarding clean cooking. And that EI is more accentuated in India, South Africa, Egypt, and Morocco. In contrast to China, where energy investment is primarily led by the state, in India, Brazil, and South Africa, the private sector dominates energy investment [74]. These economies need to electrify their energy intensive industries to speed up the decarbonization of these sectors [76].

## Conclusion

The study analyzed the progress of the Association members of IEA to determine the sustainable development goal seven. The aim of the SDG 7 is to provide affordable, and sustainable energy for all by 2030, as enshrined in the Paris Agreement. The study analyzed the indicators used to measure the countries' progress in achieving the SDG 7 in the study published by Sustainable Energy for ALL (SE4All). The study period was from 2001-2021. The analysis realized that the least square estimation of fixed effects and random effects are biased and not consistent due to endogeneity concerns. An instrumental approach can lessen the endogeneity concerns. Thus, the System GMM, difference GMM, and Poisson fixed effect (PFE) were applied to conduct this empirical analysis of these Association member countries' progress in achieving SDG 7. These dynamic panel approaches were analyzed by adding their lagged values to the dependent variables to give robust and consistent estimates.

The results proved that the Association member countries have progressed significantly concerning access to clean cooking solutions as this variable is significant within the Difference GMM model, the system GMM model, and the Poisson fixed effect model (PFE). Another indicator used in tracking the performance of countries on their progress on the SDG 7 is energy intensity. The significance of this variable implies these countries have not reduced their energy intensity levels. It correlated moderately within the correlation matrix too. This strong outlook of EI calls on member countries to reduce EI levels to acceptable levels, preferably near zero, by electrifying the EI sectors of their various economies. South Africa and China are the most EI economies in the study unit. Contrarily, Singapore, the most developed economy in the study

unit, has the least EI rate. There is a need for these countries to decouple energy consumption from GDP growth.

In a similar vein, energy consumption played a substantial role, indicating that the significance of energy use has grown in driving economic development. Of greater significance is the meaningful increase in private sector involvement in energy investments among the countries examined. This is a promising indication, as the realization of SDG 7 hinges upon the accessibility of financial resources from both the private and public domains. This necessitates the promotion and utilization of financial resources to enhance investments in emerging technologies. It is imperative that they maintain the current momentum in the direction of augmented investment in the energy sector, particularly in renewable energy sources.

Moreover, the analysis also affirms that the implementation of SDG 7 has resulted in a decrease in renewable energy consumption as a percentage of total primary energy in certain countries. Indeed, the study countries have progressed on the indicator of energy access since most of the countries have attained universal access to electricity. But the concern is whether this near-universal access is from sustainable energy sources.

The following are the policy implications; It is imperative to implement specific policies and programs aimed at expediting the reduction of energy intensity and the promotion of renewable energy sources. Examples of specific actions encompass implementing structural transformations and technological advancements within industrial sectors. It is imperative for nations to develop comprehensive resource strategies that prioritize the implementation of renewable energy. The allocation of resources to improve transmission and distribution networks. Additionally, there is a need to enhance the grid infrastructure in order to accommodate contemporary renewable energy technologies. The importance of promoting increased private sector involvement in energy investments cannot be overstated. It is imperative for governments to establish favorable conditions for private investments through the provision of financial incentives and regulatory assistance. The continuous monitoring and evaluation of progress towards indicators for SDG 7 are indispensable. This encompasses periodic evaluations of energy accessibility, energy efficiency, utilization of renewable energy, and financial investments to ensure compliance with SDG 7 objectives.

The study highlights the substantial progress made by members of the IEA Association in key areas necessary for achieving SDG 7. Nevertheless, there is a requirement for continuous and intensified endeavors, specifically in the

realm of decreasing energy intensity and augmenting the utilization of renewable energy sources. Through the implementation of comprehensive policies, the promotion of private sector investments, and a focus on technological advancements, these countries have the potential to accelerate their progress towards achieving universal access to sustainable energy by 2030. Future studies can expand to include other Sustainable Development Goals and different regions to assess their progress in relation to the Paris Agreement.

### Statement on Ethical Conduct

**Data availability:** The data that supports the findings of this study are openly available on request.

**Competing interests:** The author has no relevant financial or non-financial interests to disclose.

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**Author Contributions:** David Alemzero contributed to conceptualization, methodology, formal analysis, data curation, writing, project, review, and editing.

worldbank.org/source/world-development- Data Availability Statement: The data that support the findings of this study are openly available on request and was downloaded from <https://databank> indicators.

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