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RESEARCH ARTICLE

RENEWABLE ENERGY IN THE KINGDOM OF MOROCCO: EXPLORING THE IMPACT OF TECHNOLOGICAL INNOVATIONS ON CARBON DIOXIDE EMISSIONS"

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Abstract

Morocco is aligning with the global shift towards renewable energy, strategically investing in locally available sources to enhance economic independence and sustainable development. This study investigates the pressing issue of carbon emissions, examining the interplay between renewable energy sources, information and communication technology (ICT), governance, and GDP in Morocco through a time-series analysis using the ARDL model. The results underscore the pivotal role of renewable energy (solar, wind, hydroelectric), ICT, and effective governance as key factors in curbing carbon emissions. The findings have far-reaching implications for long-term carbon emission reduction and inform Morocco's policy framework in the fight against climate change.

Introduction:-

Environmental degradation is making the world unaware of how to handle environmental concerns. Undoubtedly, in the 21 century,taking urgent actions has become a significant challenge,considering the increase of extreme events that emerge around the world such as floods, melting glaciers, droughts increasing levels of temperature levels.The Paris agreement clarifies its objective to keep the global temperature increased to well under 2 C and warming below 1.5 C to raise the target of 2030 greenhouse gas emission reduction (IEA, 2020). Under the Environmental Kuznets Curve hypothesis, many researchers acknowledged that any extra use of fossil fuels increases the level of emissions in the environment(N. Apergis, I. Ozturk, 2015).

Thus,Countries attempting to promote their economy through clean energy regarding environmental regulations seem to be matching the global energy standards. However, countries relying on non-renewable sources are lagged behind the perspective (Olawuyi, 2021). Consequently, low emissions from energy sources promote emerging economic opportunities and facilitate energy technology and innovations, with energy distribution development (D. Zillman, L. Godden,2018). Early actions have been implemented before 2030 targets. Alternative renewable energy has been undertaken for fostering environmentally friendly policies across European countries and has contributed to reducing carbon emissions so far(N. Apergis, I. Ozturk, 2015). In addition, In the core of renewable energy sources, Morocco's aim regarding clean energies began in 2009, in consequence, the kingdom's renewable capacity tripled to 711M in solar resources and raised 1.22 GW in wind capacity by 2018 (Kousksou, et al., 2018). The present study answers the following questions. Morocco is the first North African country to produce renewable energy technologies such as solar and wind . Second, the current study will examine factors under investigation for CO_2 emissions. Third, due to the political instability in the last decade, it will be interesting to further inquire if governance has any possible linkage with CO_2 emissions in the study region.

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Kingdom Needs of Energy:
Morocco faces a substantial energy challenge, heavily relying on imported oil and gas with a dependency rate of 94.5% in 2020. Fossil fuels dominate the energy mix, with petroleum supplying 41% and coal and peat 17%. Despite a surge in primary energy demand, the government aims to reduce consumption by 15% from 2016 levels by 2030 through energy efficiency measures. The nation's electricity sector, marked by a 37.08% reliance on coal in 2021, aims for a significant shift towards renewables. However, disruptions caused by the pandemic have impacted renewable energy projects, hindering progress toward the Paris Agreement target. The Moroccan government, optimistic about reaching 52% renewables by 2030, supports initiatives through the Moroccan Agency for Sustainable Energy. Legislative amendments demonstrate a commitment to enhancing the regulatory framework and promoting private sector engagement in renewable energy, signaling Morocco's determination to address its energy landscape challenges.

Solar energy:
Morocco strategically leverages its abundant solar resources, receiving an average solar radiation of 4.7 to 5.6 kWh/m2/day, with a substantial annual sunshine duration. The ambitious Moroccan Solar Plan, initiated in 2009, focuses on harnessing this potential. The Moroccan Agency for Solar Energy (MASEN) oversees its implementation, coordinating various projects outlined in Table 2, totaling a US$ 9 billion investment until 2020. Notably, the Ouarzazate plant, a pivotal part of this plan, receives European co-financing and comprises Noor 1, Noor 2, Noor 3, and Noor 4. These plants, employing diverse technologies, contribute significantly to Morocco's renewable energy landscape. The Noor 1 plant, utilizing parabolic-cylinder concentrated solar thermal power (CSP), stands as one of the world's largest with a capacity of 160 MW. Among CSP technologies, the parabolic trough collector (PTC) with thermal oil and molten salt storage, exemplified by the Noor 1 plant's Rankine cycle, emerges as a mature and efficient choice. Location selection for CSP plants is guided by global distribution of direct normal radiation (DNI), and to be commercially viable, they must maintain a DNI of at least 2000–2800 kWh/m²/year.

Table 2
Major solar projects.

Plant/Site	Production capacity	Technology	Commissioning year
Ain Beni Mather	472 MW	CSP/PV	2011
Ourazazatte	580 MW	CSP/PV	2018
Foum Al Oued	500 MW	CSP/PV	2020
Boujdour	100 MW	PV	2018
Sbkhat –Tah	500 MW	CSP/PV	2020
NOOR Tafilalt	120 MW	PV	2019
NOOR Atlas	200 MW	PV	2020
NOOR Argane	200 MW	PV	After 2020

Table 1:- Renewable energy sources in Morocco.
Source: Ministry of energy, and environment.

Wind Energy
Morocco, blessed with a geographically advantageous position, boasts a significant wind energy potential estimated at around 6000 MW. Key windy regions, including the Tangier-Tetouan, Essaouira, and southern Atlantic areas, exhibit average wind speeds exceeding 8 m/s. As part of its robust energy strategy, Morocco ambitiously pursues a wind energy program, aiming to reach 2,000 MW installed capacity by 2020 and further elevate it to 2,600 MW by 2030. Notably, the Giant wind terminal stands as Africa's largest wind power project, with a 2015 total capacity of 300 megawatts. Beyond electricity production, Morocco's wind program emphasizes industrial integration, research, development, and technical training, fostering a comprehensive approach to sustainable energy development. Table 3 highlights commissioned wind power plants, while outlines projects in various stages of development, reflecting Morocco's commitment to advancing renewable energy.

Table 3
Commissioned wind power plants.

Project	Capacity	Year of commissioning
Amgdoul	60 MW	2007
Tanger I	140 MW	2009
Koudia Al Baida/Toress	50 MW	2000
Cimar	5 MW	2011
Lafarge	32 MW	2009
Trfaya	300 MW	2014
Akhfenir	100 MW	2014
Akhfenir 2	100 MW	2016
Foum Al Oued	50 MW	2014
Haouma	50 MW	2014
Jbel Khalladi	120 MW	2018
Aftissat	200 MW	2018
PEI 85 — MIDELT	180 MW	2019
PEI 850 — BOUJDOUR	100 MW	2019
Law 13-09 – OUALIDIA	36 MW	2019
PEI 850 — TISKRAD	300 MW	2020
PEI 850 — TANGER II	70 MW	2020
PEI 850 — JBEL LAHDID	200 MW	2020
Total	2,093 MW	

Table 3:- Renewable energy sources in Morocco. Source: Ministry of energy, and environment.

Hydropower programmer

Morocco's energy strategy charts a course for hydropower to contribute 14% to the country's energy production by 2020, increasing installed capacity from 1,730 MW in 2008 to 2,000 MW. The plan involves constructing new hydroelectric dams and pumped storage stations (PETS). Currently, with 1,770 MW hydroelectric capacity, including 464 MW in PETS mode, challenges arise due to Morocco's semi-arid nature. Water tank levels, crucial for optimal production, fluctuate. Hydroelectric turbines also balance electricity production with irrigation needs. While global hydropower production often falls below installed capacity, Morocco anticipates PETS as storage for solar and wind energy, enhancing hydraulic capacity to 2,120 MW by 2020. Future plans include sixty large dams, primarily for water resource management. To propel renewable energy, diversifying financing models and encouraging private sector investment is crucial, alongside tapping into biomass potential through immediate, concrete projects. Table 5 details the current hydropower projects, while Table 6 outlines future endeavors, emphasizing the need for diversified funding and private sector involvement in Morocco's renewable energy landscape.

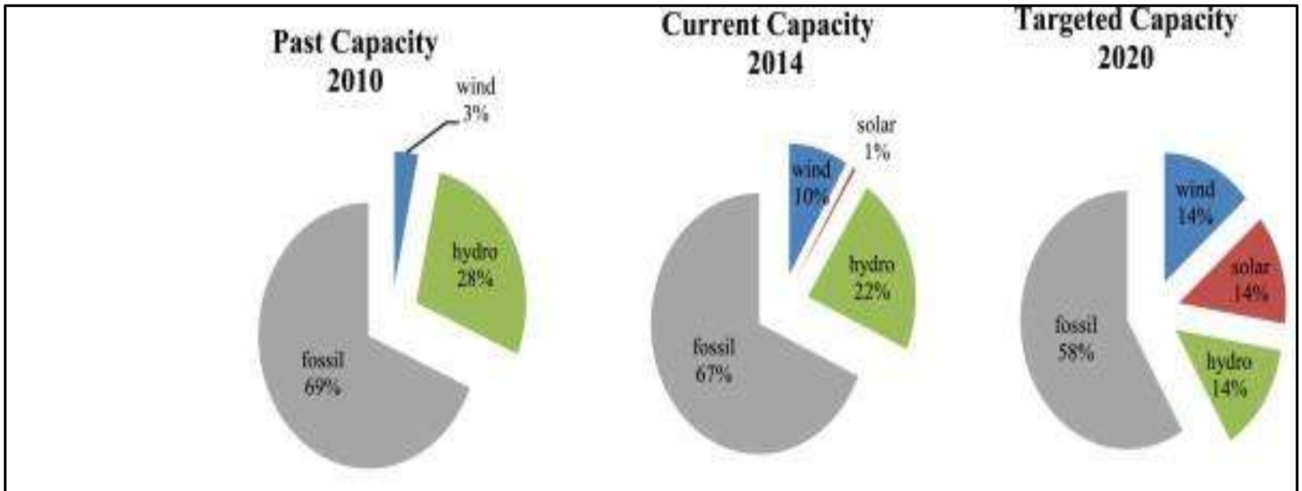
Table 5
Current situation of the hydro projects by Mars 2020.

Project	Capacity
PETS Afourer	464 MW
Diverses usines	337 MW
Al Wahda	240 MW
Allal El Fassi	240 MW
Bin El Ouidane	135 MW
Al Massira	128 MW
Afourer	94 MW
Ahmed El Hansali	92 MW
Tanafnit	40 MW
Total	1,770 MW

Table 6
Future hydropower projects in Morocco.

Project	Location	Capacity	Situation
Afrer	Agadir	465 MW	Under construction
Step Abdelmoumen	Agadir	350 MW	Under construction
Ifhsa	Oued Laou	300 MW	Under construction
M'dez El Mnzel	Sefrou	300 MW	Under construction
Khenifra	Khenifra	125 MW	Under construction
BarOuender	Taounate	30 MW	Under construction
Tamejout	Beni Mellal	30 MW	Under construction
Tillougit I	Beni Mellal	26 MW	Under construction
Boutferda	Azilal	18 MW	Under construction
Tillougit II	Beni Mellal	8 MW	Under construction

Table 4 and Table 5:- Renewable energy sources in Morocco.
Source: Ministry of energy, and environment.



	2010				2014				2020			
	wind	Solar	hydro	fossil	wind	solar	hydro	fossil	wind	solar	hydro	fossil
Installed capacity [MW]	221	0	1770	4352	780	35	1770	5392	2000	2000	2000	8500
Energy generated/ estimated [GWh]	659	0	3631	18410	2087	77*	3631	22804	5964	4380*	4103	35949
Share of total energy [%]	3	0	16	81	8.1	0.3	12.6	79	12	9	8	71

Fig. 1:- Table renewable energy sources in Morocco.
Source: Ministry of energy, and environment.

Green hydrogen H2

Morocco is strategically advancing its green economic and industrial sector, focusing on hydrogen, ammonia, and methanol to facilitate a sustainable energy transition and reduce emissions. With a decade of renewable energy experience, Morocco aims to become a regional leader in green hydrogen, contributing around 4% of global demand. Establishing economic sectors around these green energy sources is anticipated to cut emissions by approximately 20%, enhancing partner countries' carbon neutrality. The national demand for green hydrogen is projected to reach 4 TWh by 2030, escalating to 40 TWh by 2050, with corresponding renewable energy capacities. Morocco's comprehensive roadmap involves cost reduction, research and innovation centers, local industrial integration, and measures for financing, export facilitation, storage, and domestic market development. This initiative not only fosters economic growth and carbon neutrality but also secures energy independence by locally producing essential materials like ammonia, contributing to long-term sustainability.

Morocco's per capita CO_2 emissions

Morocco's CO_2 emissions per capita are less compared with the top CO_2 emitter countries and regions such as China, India, Europe, and the world. Morocco's dependency on cement manufacturing and consumption of fossil fuels are still a huge source of CO_2 emissions in the country. The country is significantly dependent on a huge portion of import energy to meet its growing energy demand (D. Zillman, L. Godden,2018), which raised an annual average ratio of 6.5% between the years 2002 to 2020. Moreover, Morocco has announced an aspiring goal of significantly improving its renewable energy consumption from environmentally friendly sources, heading to generate the nation's total renewable energy output by 52% in the upcoming years (K. Choukri, A. Naddami, 2017). From Fig. 3, it is clear that Morocco is the leading country to transfer its main source of energy consumption from non-renewable energy to renewable energy utilization. In addition, the country's per capita CO_2 emissions are far less than China, India, the US, the EU, and the world. Therefore, Morocco faces problems of governance and political instability during that period.

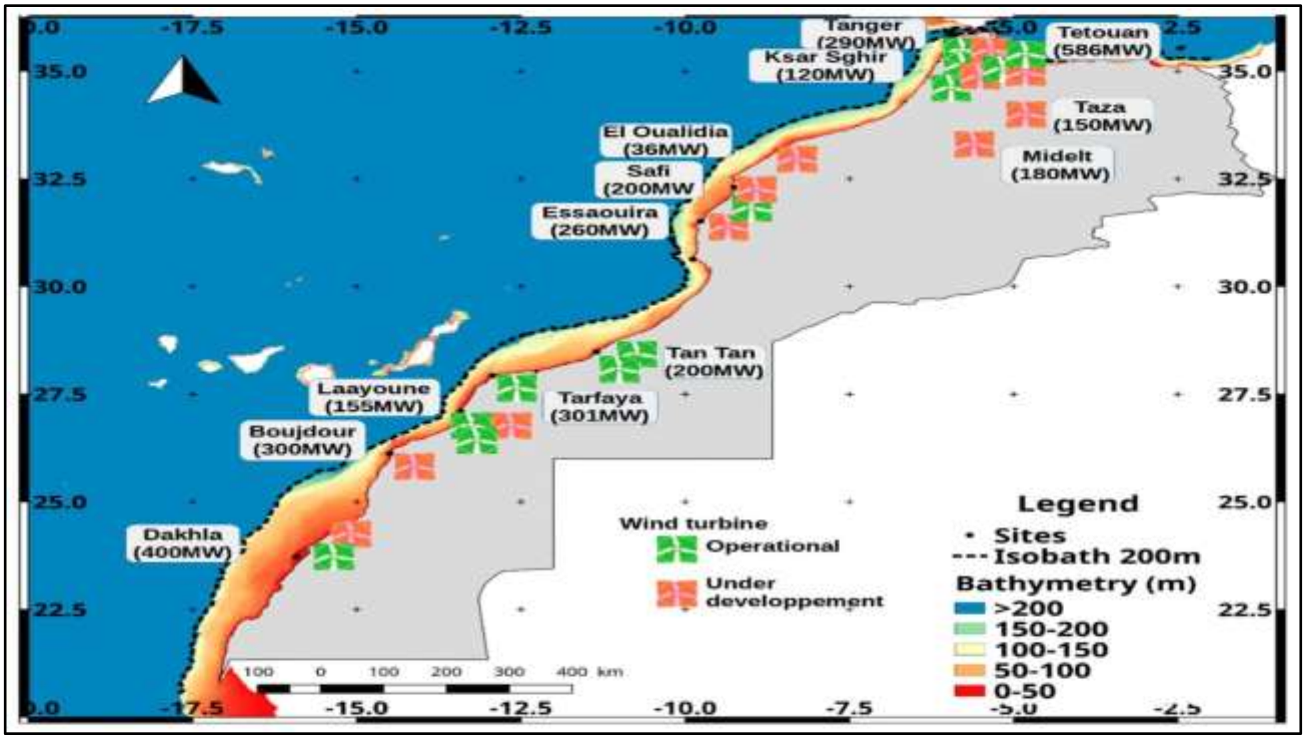


Fig. 2:- Represents renewable energy sources in Morocco.
Source: Ministry of energy, and environment.

Review of the literature: CO2 connection, renewable energy, governance, and ICT

Since the warming that was seen throughout the early stages of environmental changes until the current rapid speed, climate change has become a topic of controversy (A. Reisinger, J. Canadell, 2017). The relationship between climate change and the various contributing elements, such as energy use, renewable energy, FDI, trade, finance, and urbanization, has been noted from both theoretical and empirical perspectives (K. Khan, J. Teng, 2019). In order to characterize how sociolectal institutions affect a country's economic performance, the notion of governance was developed. Governance include not only the government but also businesses and other establishments that carry out legal activities, including the application of laws.

Carbon is mitigated by the relationship between renewable energy and CO2 emissions. Regarding the crucial role that the use of renewable energy plays in lowering CO2 emissions, researchers are generally in agreement (Khan, T. Hassan, 2021). According to Zhang, B. Wang's 2017 study, which examined Pakistan's CO2 emissions and renewable energy use from 1970 to 2012, using more renewable energy has a significant impact on the nation's CO2 emissions. The most recent study by Ref (Shahbaz, 2021) used the ARDL model to examine the short- and long-term associations among the variables and discovered that, in the short run, increased use of renewable energy contributes to the decrease of CO2 emissions in the case of China. On the other hand, According to the study of Ahmad (2019), using renewable energy sources to mitigate CO2 emissions is ineffective in the cases of Pakistan, Turkey, and Thailand, in that order.

The effect of government efficiency on reducing CO2 emissions

According to the study by Ref (Fredriksson, 2003), which included political instability and corruption in its theoretical model, the variables had a detrimental effect on environmental policy. Furthermore, different aspects have varied effects on CO2 emissions. For instance, empirical research indicates that democracy has a beneficial effect on CO2 emissions, which may be guaranteed given a country's high economic levels. However, when democracy and corruption were combined, the outcomes changed to show a negative influence due to the high degree of corruption. (H. Song, T. Hassan, 2021). Environmental quality is associated with social and democratic aspects in terms of the rule of law and an efficient regulatory system, which might result from improvements in social wealth, fairness, and education (Mehmood, 2021). Apart from the above mentioned aspects, renewable energy sources can effectively offer decentralized and cooperative development models. Therefore, incorporating appropriate implementation and cooperative management of environmental governance could enhance trust and credibility metrics (Canadell, et al., 2007).

ICT's effect in reducing CO2 emissions

Additionally, the efficacy of governance in achieving favorable outcomes is a determining factor in how policies are implemented. Because of this, the effectiveness of government has to take into account possible means of advancing the apparatuses involved in implementing policies and making decisions. A prevailing trend that affects our way of life is the growing usage of digital technology. As a result, it significantly improves government transparency and structural transformation (Durkiewicz, 2018). As a result, it is essential to note the degree of environmental impact and whether an influence is direct or indirect when examining how various factors affect CO2 emissions. First, developed nations' perspectives on rising technology have revealed how the ICT sector affects CO2 emissions.

According to research studies, ICT is responsible for 2% of all carbon dioxide emissions caused by humans. These emissions are produced by conventional energy sources, freight and railroads, and economic drivers. Any quantity of CO2 emissions prompted by intermediary inputs can affect the ICT sector. Stated differently, the integration of ICT goods and services into source sectors makes them an indirect polluting industry. Nevertheless, several studies found that employees' direct use of ICT could help other companies (Chatti, 2021).

Model description and methodology

Using time-series data from 2000 to 2020, a number of econometric tests and analyses were carried out to look at how CO2 emissions affect renewable energy sources, ICT, and governance in Morocco.

Data description

Table:- Data description.

Variables	Description	Source
CO2	CO2 emissions (metric tons per capita)	WDI
RE	Renewable energy consumption (% of total solar, wind, and hydroelectric consumption)	WDI
ICT	Individuals using the Internet (% of population)	WDI
GE	Govt. effectiveness (estimate of governance ranges from 2.5 (weak) to þ2.5 (strong) governance.	WDI
GDPPC	GDP per capita (current US$)	WDI

Table 7 presents the results of correlation and descriptive statistics. CO2 emissions were reported to have a mean value of 1.29 and a standard deviation of 0.36. Renewable energy has a mean value of 1.18 and a standard deviation of 0.10. In a similar vein, ICT reported a mean value of 0.92 with a 0.69 standard deviation. Furthermore, the government effectiveness mean value was recorded as 0.11, with a 0.05 standard deviation. The data was equally distributed, as shown by our examination of the data's normality distribution, which is further supported by the probability values. Additionally, the correlation matrix's results showed that there was a strong but negative association between CO2 emissions, renewable energy, ICT, and and governance suggesting that these elements can greatly lower CO2 emissions. Model description and methodology.

Table 7:- Descriptive statistics and correlation summary.

Statistics	CO_2	RE	ICT	GE	GDPPC
Mean **Median** **Max** **Min** **Std. Dev.**	1.29 1.2 1.85 0.79 0.36	1.18 1.20 1.36 1.01 0.10	0.92 0.45 1.92 0.13 0.69	0.11 0.09 0.03 0.27 0.05	3.25 3.21 3.50 2.82 0.19
Skewness **Kurtosis**	0.23 1.57	0.37 1.83	0.25 1.22	0.92 4.73	0.20 1.88
Jarque-Bera	3.35	2.90	5.12	9.65	2.13
Probability	0.18	0.23	0.07	0.01	0.34
Obs.	36	36	36	36	36
CO_2	1				

RE	0.87*** (-10.39)	1			
ICT	0.95*** (18.95)	0.77*** (-7.23)	1		
GE	0.26 (1.62)	0.39** (-2.47)	0.21 (1.29)	1	
GDPPC	0.95*** (19.59)	0.78*** (-7.47)	0.93*** (15.1)	0.15 (0.88)	1

*p<0.05; **p<0.01; ***p<0.001.

Where CO2 signifies carbon dioxide emissions, t represents time; RE is the total output of renewable energy sources, ICT denotes the total number of internet users, GE is the government effectiveness, and GDP is the gross domestic product per capita. In contrast, in equation (2) a0 signifies constant in the model. Moreover, $\beta 1$, $\beta 2$, $\beta 3$, $\beta 4$, and $\beta 5$ represent the coefficients of the independent variables.

$$CO2_t = \alpha_0 + \beta_1 RE_t + \beta_2 ICT_t + \beta_3 GE_t + \beta_4 GDP_t + u_t \ (2$$

Co-integration test

The unit root test is used to identify which variables are mutually stationary. With the use of the following equation, all the chosen variables were joined at the standard unit orders of 1(0) and 1(1), demonstrating that is uniform with the sufficient of the dynamic simulated ARDL model especially for our study (Dickey, 1988).

$$\Delta CO2_t = \phi_0 + CO2_{t-i} + \phi_1 RE_{t-i} \phi_2 ICT_{t-1} + \phi_3 GE_{t-1} + \phi_5 GDP_{t-1} (3)$$

The first difference in the equation above is represented by the letter CO2, which stands for carbon dioxide emissions. The other symbols in the equation are for time (t), renewable energy (RE), internet users (ICT), government effectiveness (GE), and gross domestic product (GDP) per capita. Moreover, the variables t and i represent the optimal lag's duration as ascertained by the Akaike Information Criterion (AIC)., $\emptyset_1$, $\emptyset_2$, $\emptyset_3$, $\emptyset_4$, $\emptyset_5$, and β_1, β_2, β_3, β_4, β_5, exploring the long-run relationship respectively(Khan, Teng.2019)Thus, we design our null and alternative hypothesis based on the ARDL model:

H0=∅1 = ∅2 = ∅3 = ∅4 = ∅5 = 0 while

H1≠∅1≠∅2≠∅3≠∅4≠∅5≠0

Distribution with Autoregressive Lag (ARDL)

Refs. made the initial proposal for the ARDL model (Pesaran., 2001). A number of studies, including C. ShuKai and T. Hassan (2021), highlight the benefits of the ARDL paradigm. To the best of our knowledge, explanatory variables and a lag duration of response can be used with the ARDL co-integration model. For this reason, in this work, we utilize the long-run ARDL model.

$$CO2_t + \alpha_0 \sum_{i=1}^{q} \sigma_1 RE_{t-i} + \sum_{i=1}^{q} \sigma_2 ICT_{t-i} + \sum_{i=1}^{q} \sigma_3 GE_{t-i} + \sum_{i=1}^{q} \sigma_4 GDP_{t-i} + \varepsilon_t \ (4)$$

The long-run variance in the chosen variables is indicated by the number five in the following equation. Furthermore, we use different Akaike information criterion (AIC) lags lengths for each and every variable. By comparison, the shot-run ARDL model is considered in the subsequent error correction model:

$$CO2_t = \alpha_0 \sum_{i=1}^{q} \beta_1 \Delta RE_{t-i} + \sum_{i=1}^{q} \beta_2 \Delta ICT_{t-1} + \sum_{i=1}^{q} \beta_3 \Delta GE_{t-i} \sum_{i=1}^{q} \beta_3 \Delta GE_{t-1} \sum_{i=1}^{q} \beta_4 \Delta GDP_{t-i} + \varphi ECT_{t-1} + \varepsilon_t \ (5)$$

Dynamic simulations of ARDL

Since the dynamics of the simple ARDL model are unable to assess the short- and long-term effects among the chosen variables, we use the dynamic ARDL simulations model presented by Ref. (Jordan,2021) in this part to assess the long- and short-run effects of various parameters.

$$\Delta CO2_y = \alpha_0 + \theta CO2_{t-1} + \beta_1 \Delta RE_t + \theta_1 RE_t + \beta_2 \Delta ICT_t + \theta_2 ICT_{t-1} + \theta_3 GE_{t-1} + \beta_3 \Delta GE_{t-1} + \theta_4 GDP_{t-1} + \beta_4 \Delta GDP_{t-1} + \varepsilon_t \quad (6)$$

Results and Discussions:-

The outcome shows that economic development and government effectiveness are stationary at level 1(0), while CO2 emissions, renewable energy sources, and ICT have similar integration orders 1(1) and 1(2). During the same sample period, Morocco adopted a number of renewable energy policies throughout the region. The nation is presently working on the development and export of renewable energy technology with a number of other countries and international organizations. Thus, non-linearity in the data series was highlighted by the structural break unit-root estimation.

Table 8:- Unit root tests.

variables	With constant	Constant& Trend	With constant	Constant& Trend	With constant	Constant& Trend
At level	ADF		KPSS		PP	
CO_2	0.25	2.77	0.69	0. 15	0.32	2.76
RE	0.76	2.23	0.59	0.12	0.81	2.23
ICT	0.52	0.96	0.64	0.11	0.62	1.55 3.78***
GE	3.63*	3.77*	0.19**	0.06**	3.60***	2.42
GDP	2.49	2.19	0.69	0.07	2.38	
At differenc e	ADF		KPSS		PP	
CO_2	6.52***	6.44***	0.18***	0.11***	6.55***	6.46***
RE	5.39***	5.33***	0.08***	0.05***	5.37***	5.31***
ICT	4.13**	7.96***	0.16***	0.16***	4.08**	4.03**
GE	6.42***	6.42***	0.05***	0.04***	7.80	7.68
GDP	5.02***	5.12***	0.30***	0.11***	5.01**	5.11**

according to the F-statistics, which show that the F-statistics' value is higher than the upper bound's, or the 1%, 5%, and 10% levels of significance, respectively. The results of the F-statistics are given in Table 9.

Table 9:- ARDL bounds test.

Test statistics	**Value**		**K**	**H1**		**H0**	
F statistics	2.76		4	No level relationship		Relationship exists	
t statistics	2.93						
	F-statistics			t-statistics		P-value F	
	I (0)	I(1)		I (0)	I (1)		
10%	2.45			3.52 2.57 3.66		0.00***0.03**	
5%	3.03			2.86 2.86 3.99		P-value t	
2.5%	3.25			4.49 3.13 4.26			
1%	3.74			5.06 3.43 4.6		0.00***0.00***	

Table 10.The results of dynamic ARDL simulations show that, over the short and long terms, CO2 emissions are significantly and negatively correlated with renewable energy sources. The findings indicate that a 1% increase in renewable energy sources will result in a short- and long-term reduction in CO2 emissions of up to 0.39%. Ref. (Shahbaz.,2021) found similar results for South Asia (Adams, 2018) in the cases of China, Pakistan (Sultan K. Zaman, 2019), and Malaysia (Pata, 2018). On the other hand, Ahmad's (2018) analysis suggests that Pakistan's use of renewable energy sources has not yet resulted in a significant reduction of CO2 emissions.

Table 10:- Results of Dynamic ARDL simulations.

Variable	coefficient	Std. Error	t-Statistic
Constant	1.371**	0.675	2.028
CO_2	0.456***	0.152	2.995
D CO_2	0.219	0.167	1.307
RE	0.221	0.224	0.989
DGE	0.144	0.137	1.052
GDPPC	0.741**	0.24	2.978
DGDPPC	0.112	0.246	0.456
ECT(-1)	0.324***	0.0168	5.243
R-squared	0.99		
N	34		
AIC	3.674		
D-W stat	2.092		
F-stat	0.000***		
Simulations	5000		

*p <0.05; **p <0.01; ***p <0.001 represents significance level, respectively.

Table 11 tabulates the results of various data diagnostics tests. The results of diagnostic tests like the Breusch-Godfrey LM Test show that there isn't any proof of serial correlation between the variables under investigation. According to Ramsey RESET statistics, the model was properly and validly specified. Using Harvey, ARCH, Breusch-Pagan-Godfrey, and other statistics, it was determined that there was no evidence of heteroscedasticity among the variables. According to Jarque Bera statistics, the residuals are reasonable and normal. The F-statistics for the complete data series display probability values that are not significant, indicating that there are no correlation problems among any of the variables.

Table 11:- Diagnostic analysis.

Diagnostic test	F-test	P-value	Outcomes
Breusch-Godfrey LM Test	0.55	0.58	No evidence of serial correlation
Ramsey RESET Test	0.87	0.36	Model specified correctly
Breusch-Pagan-Godfrey	0.52	0.85	No evidence of heteroscedasticity
Harvey	0.79	0.63	No evidence of heteroscedasticity
Jarque Bera	0.23	0.42	Estimated residuals are normal
Glejser	0.61	0.78	No evidence of heteroscedasticity

Conclusions and Policy Recommendations:-

The main driver of climate change is the use of nonrenewable energy sources to support sustained and rapid economic growth. Growing environmental degradation is a problem for developing economies like Morocco. The purpose of this study was to assess how renewable energy sources affect CO2 emissions and how information and communication technology (ICT) and governance functioned in Morocco between 2000 and 2020. The dynamic ARDL simulation model was utilized in the study to monitor the impact of ICT, governance, and renewable energy sources on CO2 emissions in Morocco, both in the short and long term. Nevertheless, in order to investigate the real changes in renewable energy, ICT, and governance and their impact on CO2 emissions—both positive and negative—we employed dynamic ARDL simulations.The primary cause of climate change is the continued and growing use of nonrenewable energy sources for economic growth. Developing economies such as Morocco face challenges from increasing environmental degradation. The aim of this research was to evaluate the impact of renewable energy sources on carbon emissions as well as the functioning of information and communication technology (ICT) and governance in Morocco from 2000 to 2020. The study used the dynamic ARDL simulation model to track the short- and long-term effects of ICT, governance, and renewable energy sources on CO2 emissions in Morocco. Nevertheless, we used dynamic ARDL simulations to look into the actual changes in renewable energy, ICT, and governance and their effect on CO2 emissions—both positively and negatively.According to the results of the dynamic ARDL simulations model, ICT, governance, and renewable energy sources—such as solar, wind, and hydroelectric power—all have a significant impact on how quickly and over time Morocco's CO2 emissions decline.

The results collected indicate that the use of conventional non-renewable energy sources, like oil, nonrenewable energy imports, gas, and coal, increases CO2 emissions in Morocco. The study also took into account the important role that government plays, which is necessary for Morocco's environmental appropriateness. We propose that reducing Morocco's CO2 emissions would be significantly aided by increased government efficacy. Therefore, this study suggests that governments and decision-makers discuss measures that encourage enterprises and families to use renewable energy sources for energy utilization, so contributing to lowering environmental mitigation.

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