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Unlocking the investment impact of biomass energy utilization on environmental degradation for an isolated island

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Abstract

Purpose – Discussions on environment-friendly production connected with the concerns of growing biomass emissions have gained much attention. In this regard, this study aims to explore the issue of biomass energy consumption and its related emission effects on the economic and environmental well-being of the economy of Cyprus.

Design/methodology/approach – This study sources time series data on specific variables from the Global Material Flow and the World Bank's World Development Indicators (WDI, 2020) between 1990 and 2016. The Robust least square (ROB-L^2) in conjunction with Pesaran autoregressive distributed lag (ARDL) methodology analysis techniques was used in addition to the Granger causality tests to examine the direction of causality flow between the variables under consideration.

Findings – The results indicate that biomass energy usage in the long run reduces pollution and negatively correlates with CO_2 emissions level. Also, the decline of emission is influenced by increased foreign direct investment (FDI), thus, activities of foreign investors contribute to combating emission in the country. According to empirical results, non-renewable energy consumption showed both positive and negative influences on increased emission level, whereas economic growth is increasing carbon dioxide emission for the case of Cyprus.

Declarations.

1. Ethical approval.
Answer: not applicable.
2. Consent of Participate.
Answer: not applicable.
3. Consent to publish.
Answer: not applicable.
4. Availability of data.
Answer: the data for this study will be available upon a reasonable request.
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Divine Q. Agozie: writing- original draft, conceptualization.
Murad A. Bein: supervision, validation.
Festus Victor Bekun: supervision, validation.
Festus Fatai Adedoyin: writing- original draft, conceptualization.

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Originality/value – This study applies current reliable data that offers renewed insights and sheds light on the state of affairs on biomass utilization from a developing country perspective. Additionally, it extends the discourse on the impact of biomass utilization on CO_2 emissions by considering the impact of FDI, trade flow and energy consumption in a carbon-income function built on the liner version of the environmental Kuznets curve hypothesis. Although this is by no means exhaustive, the study pioneers the discourse on how FDI with biomass utilization among other relevant variables influences carbon dioxide emission.

Keywords Biomass energy, Economic growth, Carbon reduction, Environmental sustainability, Non-renewable energy, Cyprus

Paper type Research paper

HIGHLIGHT

- We explore the combined impact of FDI, economic growth, trade flow, CO_2 emission and renewables on the environmental quality in Cyprus.
- Unlike non-renewable energy, an increase in biomass energy utilization does not increase CO_2 emissions within the study's context.
- FDI decreases environmental degradation in the long run in Cyprus.
- Environmental sustainability will be achieved by investing in renewable energy (biomass energy utilization) for the Cyprus economy.

1. Introduction

The consequences of depending on fossil fuel energy sources and the need to reduce greenhouse gas (GHG) emissions motivate the need to explore bio-based reserves. Recent reports on developments in the renewable energy domain highlight biomass energy as a viable alternative to fossil fuel supplies (Hess *et al.*, 2016; Meyer, 2017). Coupled with this assertion, the market volatility of fossil fuels and the increasing GHG pollution heightens the urgency with which economies must turn to the utilization of green energy such as biomass and biofuels (Meyer, 2017). For instance, China has hastened initiatives to facilitate the wider utilization of sustainable energy sources through the introduction of massive taxation opportunities to investors engaged in biomass and waste anaerobic digestion schemes in China (Energy Information Administration, 2016). Similarly, India also introduced similar initiatives and fiscal incentives to encourage the use of biofuels (Energy Information Administration, 2016).

Among European states, the European Union (EU) has also set goals for 2020 (Europe, 2030 energy target) with a view of mitigating environmental degradation through the reduction in GHG emissions by 20% from the rates of 1990, raising the proportion of European energy intake from clean energy by 20% and boosting energy performance also by 20%. In the long run, the future objective for European states by 2050 (Europe, 2050 official report) is to reduce GHG pollution by 80%–95%.

However, orthodox and renewable energy sources (RESs) account for about 81% and 14% of the world's expected availability of main energy sources, respectively (IEA, 2017). Oil, carbon and natural gas largely constitute the inputs of non-renewable energy resources, whereas RESs include biomass, sunlight, wind, hydro and geothermal energy sources. The literature largely suggests sustainable energies account for some 14% of the world's energy source (IEA, 2017), with traditional biomass emerging as one of the key RESs, particularly among emerging economies. REN21 (2016) reports biomass energy accounted for about 9% of RES. This low level of generation and utilization of biomass energy has also estimated energy to reach a 50% level globally by the year 2050 (EU, 2050; Mondal and Denich, 2010). The bio-mix is mainly derived from three sources: plant residues, forest residues and energy crops (Guta, 2012). Biomass is usually obtained from rice straw, agricultural residues, animal waste, and municipal waste, among others (Hossen *et al.*, 2017). Discussions on biomass conversion to bioenergy for electricity generation has mainly emerged from two perspectives: specific vaporization and gasification (Mondal and Denich, 2010). Direct use of fire, primarily used for many rural settings in most developing economies, contradicts the global expectations of biomass energy development and utilization as a means to reducing emissions. Thus, the increased development of biomass could adversely affect the environment; however, its increased effective development by use of advanced technologies or procedure can lead to sustainable environments through the reduction of pollutants energy (Hossen *et al.*, 2017). This in other words calls for increased direct investments into biomass production technology. In that, where development procedure improve biomass generation is likely to increase and subsequently reduce environmental degradation.

Evidence from Cyprus suggests that fossil pollutions from the region were 6,872,427 tons in 2016 suggesting a 3.7% increase in emission over the previous period of 2015 (WDI, 2020). CO_2 per capita in Cyprus was equivalent to 5.87 tons per person (based on the population of 1,170,187) in 2016, which also shows an increase of 0.17% over 5.71 tons per person in 2015. Nevertheless, the country contributed 0.02% of the world CO_2 emissions, which has been consistent from 1993 to 2016 (WDI, 2020).

Moreover, according to the Cyprus Drafted Integrated National Energy and Climate Plan from 2021 to 2030, the dependence on fossil electricity supplies by Cyprus possess some significant challenges. For its energy requirements, Cyprus relies on imports of fossil fuels and spends over 8% of its gross domestic product (GDP) on energy. In the EU-28, the island has witnessed the fastest increase in energy usage, from 1.6 million tons of oil (Mtoe) to 2.3 Mtoe in 2015 suggesting an increase by 41% from 1990.

Furthermore, the RESs target of 13% is for wind turbines, photovoltaic (PV) systems, solar-thermal and biomass and biogas plants to be generated by 2020. RES has contributed 8.4% of the energy generation in 2016, according to the latest statistics. In 2016, the RES production improved by 6%, mainly because of the high performance of private PV systems compared to 2015. In 2016, wind farms accounted for nearly 55% of RES electricity, whereas private PV system production increased by almost 15% between 2015 and 2016 [1].

This proportion has been growing and the growth in PV is expected to extend facilities to reach or even exceed the 288 MW solar PV goal in 2020, competitively and sustainably. All the oil utilized comes from imports, even though unsustainable since 1990, has increased by more than 35% from 1990 to 2015. For the case of solid fuels, total intake rose by 85% around 1990 and 2004 because of the development of the building industry. From 2004 to 2008, solid fuel utilization remained constant, until after 2008 where solid fuel usage declined significantly to the 1990 stage.

Although the actual amount of energy generated from renewables has risen by more than 310% since 2006 (Figure 2), clean energy only contributes just 8.6% to the overall production. Proportionally, the energy generation mix in Cyprus seems to be fewer emissions strenuous from 2008, when the very first combined-cycle energy production unit was operationalized and the impact of renewable inputs began to be substantial.

Moreover, in total, there has been significant growth in Cyprus' electricity generation from 1990 to 2015. Over time, renewables have dramatically expanded the share of primary energy supply to about 6.07% in 2016 in Cyprus. About 68% of the renewable energy produced is provided by solar thermal and biomass. In 1990, biofuels saw the biggest growth increase from 0% to about 6% in 2016 (Figure 1).

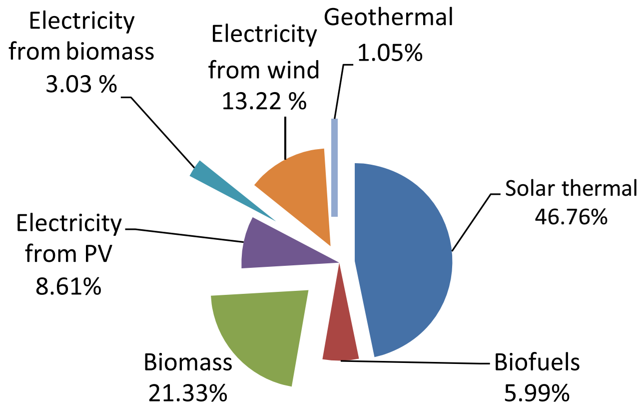

Figure 1. Cyprus existing renewable energy share between technologies as of the end of 2016

Based on the 2016 estimates, Cyprus, like any other EU states, has a big obstacle to meet the latest RESs 2020 goals. Cyprus's target is 13% of total energy intake to be from renewable sources by 2020[2] (Figures 2 and 3).

Although the information presented suggests that energy utilization within the country seems to contribute a steady proportion of pollution over the years, CO_2 emission for this development is opposed to the country's efforts to achieve its target of a sustainable environment and energy security determined by its Council of Ministers in 2015 (the Paris Accord) [2]. For the EU and the global economy to achieve the environmental targets on emissions, it is paramount that each country can achieve its target on emission to sustain the global target (EU, 2030).

On this basis, this study seeks to explore the influence of biomass energy utilization on environmental degradation. Giving the assertion that biomass energy emerges as a viable RES that, when developed with appropriate technology could reduce ecological degradation.

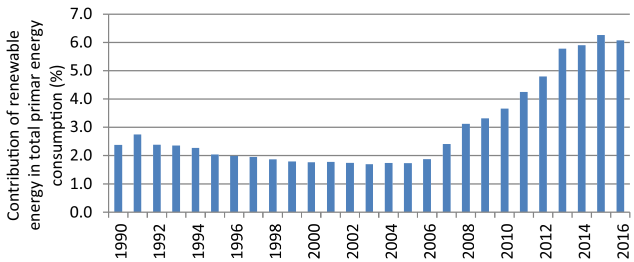

Figure 2. Share of renewable energy in total primary energy consumption in percentage, 1990–2016

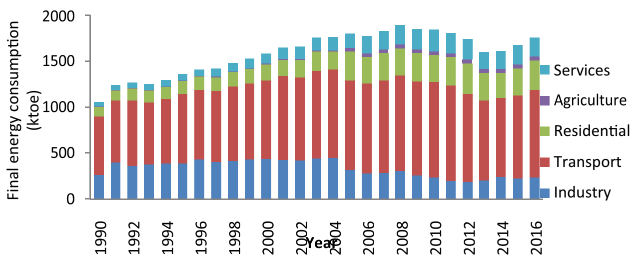

Figure 3. Final energy consumption by sector in Mtoe, 1990–2016

The study empirically considers the role of foreign direct investments (FDIs) and economic growth, non-renewable energy, trade and biomass energy utilization on carbon dioxide emission. That is, to establish the hypothesis that the effective development and utilization of biomass for energy generation can reduce CO_2 emission and contribute to sustainable development. To the best of knowledge from our literature search, several studies have investigated the impact of biomass on ecological degradation without considering the effect of FDI. In the opinion of this study, a significant influence of FDI on biomass energy development would shape the government's decisions on which areas to direct or incentivize FDI initiatives for renewable energy generation and utilization. To effectively assess the study's objective, the examination accesses both the long- and short-run effects of CO_2 emission on environmental degradation using the Robust least squares (ROB-L^2) and autoregressive distributed lag (ARDL) methodology, respectively, whereas the Granger causality test was used to check the causality relationship of the variables.

The remainder of this study is structured as follows: a literature summary is provided in Section 2. Econometric methods and information are presented in Section 3. Section 4 focuses on empirical analysis, whereas Section 5 contains conclusion and policies from policymakers.

2. Related literature review

This study highlights the contribution of bioenergy expansion in decreasing emissions, rising energy instability, agricultural advancement to the downside of biodiversity, intensive water usage, deforestation and increasing energy cost (Burg *et al.*, 2018; He *et al.*, 2018; Shao and Rao, 2018). Bioenergy, in particular compost, besides biomass, is a sustainable energy source that takes green management into justification (Baležentis *et al.*, 2019). The study evaluated both the positive and negative effects of energy generation on environmental pollution. For instance, Katircioglu (2015) evaluated the connection between biomass energy and GHGs sensitivity in Turkey using the ARDL technique, and reports that biomass energy inhibits corrosion. Bilgili (2012) also noted that biomass development helps to mitigate GHG emission in the USA. In a pre-defined evaluation, Bilgili *et al.* (2016) used a wavelet consistency analysis to understand how biomass energy reduces CO_2 emission in the USA. Shahbaz *et al.* (2017) implied nearly equivalent assumptions for the US economic activity through the ARDL bounding investigational process. One of the seminal studies on biomass production was that of Dogan *et al.* (2017), who investigated the connection between biomass intake and the output of carbon dioxide in biomass-major states and described the important contribution of biomass electricity in the lessening of climate pollutants. Baležentis *et al.* (2019) confirmed that biomass energy lessens GHG compared to other energy sources. Shahbaz *et al.* (2019) also examined the influence of biomass electricity on foreign investments and CO_2 emission across the Middle East and North African states using the generalized method of moments (GMM) methodology and developed a measurable impact of biomass intake on the mitigation of toxic substances. Danish Wang (2019) then used the GMM technique to address the component of biomass energy in lessening carbon dioxide production, in addition to confirming that biomass energy reduces biodiversity stress in the BRICS societies. Using a groundbreaking quantitative approach, specifically the vigorous ARDL, Sarkodie *et al.* (2019) measured the effect of biomass intake on climate change mitigation and the country's development and determined that biomass energy decreases emission.

Few studies did not support the positive effect of biomass energy on the prevention of pollution (Mahmood *et al.*, 2019; Shahbaz *et al.*, 2018) and Ahmad *et al.* (2016) reported that biomass energy inputs had a negligible impact on the output of CO_2. At the same time, certain explanatory variables in CO_2 pollution, which include foreign exchange and FDI, had already been described in the verification to avoid any damage to the prerequisite. Ren *et al.* (2014) argued that global trade and FDI in the Chinese manufacturing segment have worsened ecological efficiency, even though Al-Mulali *et al.* (2015) noted that global trade meaningfully decreases carbon dioxide pollution across Europe. Liobikien and Butkus (2018) observed the same result on behalf of a team of 147 nations. However, study assums that free import and export would increase carbon dioxide emissions. Zhang and Zhang (2018) noticed that the money system had a detrimental impact on CO_2 GHGs in China. The predictive findings of Hille *et al.* (2019) have shown that FDI decreases CO_2 emissions. However, in a survey of numerous areas, Shahbaz *et al.* (2015) reported the contrary effect of FDI in carbon dioxide GHGs, underpinning the toxicity hypothesis that the presence of FDI is a pollutant.

A few other findings have shown that, as biomass energy utilization declines, economic growth has expanded, which means that sustainable success is a good indication that the use of biomass energy will be discouraged (Victor and Victor, 2002). In some cases, greater energy use means a decrease in generators, particularly at the household level. For example, Foster *et al.* (2000) confirmed that households had lessened their total energy use by other methods where energy usage could yield effective results. However, many developing markets have shown lower GDP per capita, and these countries rely mostly on renewable resources that are not clean compared to other countries in advanced countries, such as the G-20 (IEA, 2016).

3. Data and method energy

3.1 Data

This study examined the impact of biomass energy consumption on CO_2 emissions in Cyprus using the most recent available data from 1990 to 2016. The data for biomass energy was obtained from Global Material Flow database, whereas CO_2 pollution, economic growth, non-renewable energy utilization, FDI and trade are all sourced from the World Bank's World Development Indicators (WDI, 2020). Specifically, the variables are measured as follows: biomass energy utilization (BM) in tons per capita, CO_2 emissions also in metric tons per capita, real GDP is measured in constant 2010 US$ and denoted as GDP and non-renewable energy utilization is measured in the proportion of per cent total energy and denoted as NREC. Finally, FDI is measured in BoP, current US$ and denoted as FDI and trade, measured as a percentage of GDP and denoted as trade as outlined (TRD). This information is summarized in Table 1. The selection of the variables was based on the sustainable development goals (SDGs) 7 and 13 (UN, 2015). Resource use – in addition to associated infrastructure, energy supply plays a key role in economic growth and therefore

Name of indicator	Abbreviation	Proxy/scale of measurement	Source
Carbon dioxide emissions per capita	CO_2	measured in metric tonnes	WDI
Gross domestic product	GDP	Constant 2010 US$	WDI
Foreign direct investment	FDI	BoP, current US$	WDI
Non-renewable energy	NREC	Percentage of total energy	WDI
Trade	TRD	Percentage of GDP	WDI
Biomass energy utilization	BM	Tons per capita	GMF

Source: Author's compilation

Table 1. Description of variables

in environmental growth (SDG 7) and climate change mitigation relies on prudent energy use and output choices and associated infrastructure (SDG 13). The variables analyzed have been used in their logarithmic natural order to mitigate heteroscedasticity problems.

3.2 Methods

Similar to the works of Danish Wang (2019), Mahmood *et al.* (2019), Shahbaz *et al.* (2019) and Gyamfi *et al.* (2020b, 2021a), the study analyzes the relationship between real GDP, biomass energy and CO_2 emissions while considering FDI and trade from an economic point of view of the Republic of Cyprus. The research model has expressed an equation:

$$CO_2 = f(BM, GDP, NREC, FDI, TRD) \quad (1)$$

where CO_2 represent carbon emission, GDP denotes gross domestic product, NREC as non-renewable energy consumption, FDI as foreign direct investment and TRD as trade openness. The logarithmic transformation has been performed to enable the variables in this study to maintain constant variance across all the series, which is presented as follows:

$$LnCO_{2t} = \alpha_0 + \beta_1 LnBM_t + \beta_2 LnGDP_t + \beta_3 LnNREC_t + \beta_4 LnFDI_t + \beta_5 LnTRD_t + \mu_t \quad (2)$$

where α is the constant term and β s are slope perimeters that need to be examined.

4. Econometric methodology

In line with Engle and Granger (1987), the result from a regression becomes spurious when there is no evidence of stationarity among the variables. Based on this, the error correction model (ECM) is used to check both the error correction and cointegration among the variables.

We, therefore, base the long-term relationship on ROB-L^2, as used by Costa *et al.* (2019) for forecasting Brazil's natural gas and ARDL techniques are used to check the short-run effects of the variables. The ARDL approach possesses several econometric strengths compared with the conventional time-series data models. For instance, it could fix endogeneity problems at the same time handle either short- or long-term parameters. The ARDL cointegration method is also capable of taking into account variables in a combined integration order, such as level (I (0)) and first difference (I (1)) but not second difference (I (2)). Pesaran *et al.* (1999) also highlight the pool mean group estimator to be accurate, resilient and high to lag orders and outliers. Finally, the pairwise Granger causality tests were used to examine the causal relationship of the variables.

Based on the studies of Emir and Bekun (2019) and Mikayilov *et al.* (2020), we primarily carried out a stationary test to ensure that we identified the maximum level of detailed estimates and the asymptotic characteristics of the variables under study. The augmented Dicky–Fuller (ADF), Philip and Perron (PP) and Kwiatkowski–Phillips–Schmidt–Shin tests were used to determine the root unit so that the approximations of the variables would not produce bias regressions estimates. Additionally, Engle and Ganger ECM checks both cointegration and spurious of variables. However, the possibility of a long-run equilibrium relationship was established through Johansen–Fisher cointegration test. The ROB-L^2 was also carried out to access the long-run association equilibrium of the variables. This estimation can provide a robust standard error and coefficient for determining long-run associations. The short-run association regarding the variables was assessed using the ARDL test and finally, the causality test was carried out by Granger causality tests to obtain the causal relationships between the variables. The causality checks provide effective and consistent estimations even in the case of a mixed order of integration between variables (Figure 4).

4.1 Results

4.1.1 Pre-estimation diagnostic. The summary statistics of the analysis of the data drawn for this study is presented in Table 2. The summary statistic reveals that FDI has the highest mean, median, maximum and minimum and CO_2 emissions have the least variables mean, median, maximum and minimum. The variance inflation factor (VIF) or tolerance factor, which is the inverse of VIF, resonates the position of Pearson correlation analysis (see Appendix for VIF/I/VIF results). In examining the variable associations, the correction matrix (Table 3) provides proofs that biomass is negatively correlated with carbon emission and real GDP positively correlates with carbon pollution. Biomass energy is negatively

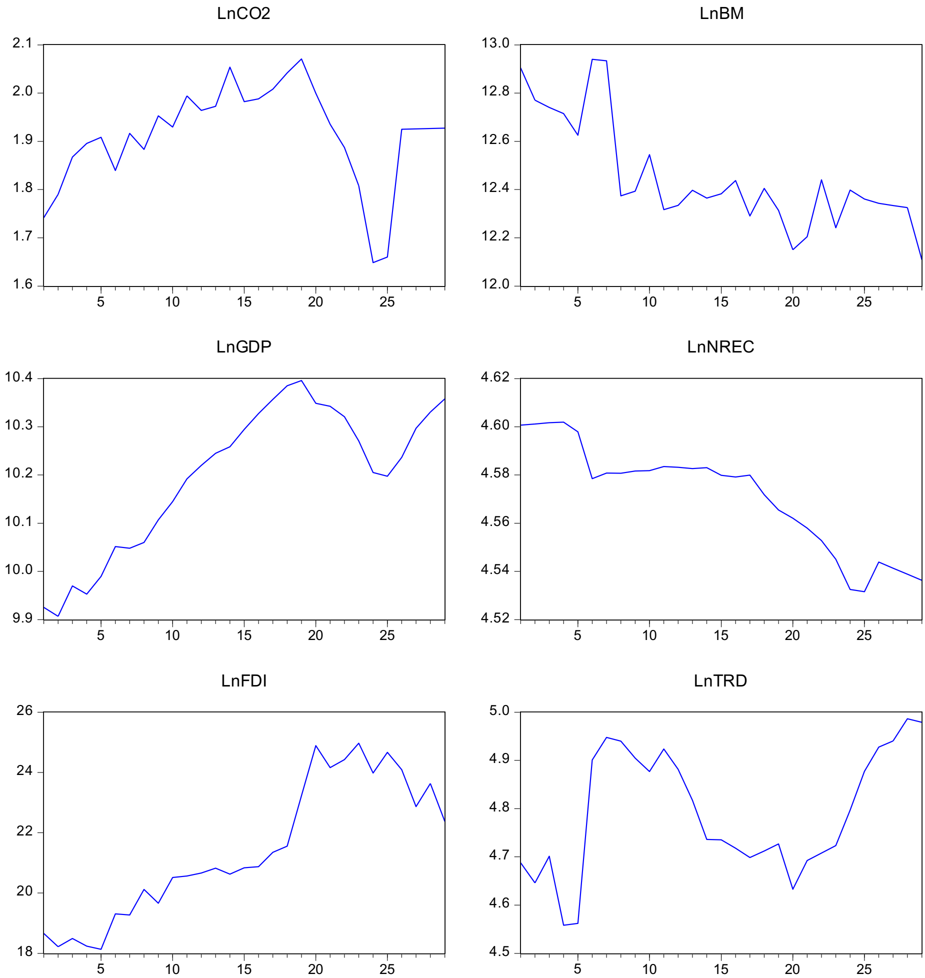

Figure 4.
The movement pattern of the series. NB: The plot shows the dynamics of the biomass energy, nonrenewable energy, FDI and trade relative to carbon dioxide emissions of Cyprus from 1990 to 2016

associated with real GDP and FDI but negatively correlated with non-renewable energy. Real GDP on the other hand negatively correlates with non-renewable energy and positively correlates with FDI. Finally, non-renewable energy negatively correlates with both FDI and trade.

4.1.2 Unit root results. The need to explore time-series properties of variables is pertinent to avoid spurious analysis. Especially, the error of modeling variables integrated of order 2. Thus, the need to investigate the time-series properties is presented in the study with both unit root and stationarity test presented in the subsequent section:

$$\Delta Yi = \beta 1 + \beta 2 + \beta 3 + \beta 4 + \beta 5 + \ \delta Yt - 1 + \sum_{i=1}^{m} \alpha t \Delta Yi - t + \in t \qquad (3)$$

This approach was also critical to assess the likely implementation of the factors for the analysis. In this case, we have enacted three various approaches (Pesaran and Shin, 1998; Perron, 1988: Kwiatkowski, 1992) with a probabilistic variable and a tendency to evaluate the potential of unit root affiliated with variables. These techniques were suitable because they are capable of identifying heterogeneity and cross-sectional dependence between modules.

These strategies are determined to provide the ability to resolve the problem of low strength produced by the pseudo-stationary data set and to exploit the extra information

Variables	$LnCO_2$	LnBM	LnGDP	LnNREC	LnFDI	LnTRD
Mean	1.911884	12.45139	10.19787	4.570956	21.42070	4.790975
Median	1.926670	12.38251	10.23631	4.579861	20.83556	4.736239
Maximum	2.070690	12.93989	10.39591	4.601917	24.97137	4.986376
Minimum	1.648620	12.10883	9.906736	4.531591	18.13532	4.558250
Std. dev	0.104010	0.226764	0.151097	0.022265	2.248683	0.126831
Skewness	−0.973167	0.912487	−0.554269	−0.391929	0.154471	−0.057821
Kurtosis	3.675739	2.888639	2.013308	1.973121	1.733513	1.817612
Jarque–Bera	5.129184	4.039378	2.661255	2.016605	2.053484	1.705458
Observations	29	29	29	29	29	29

Table 2. Summary statistics

Variables	$LnCO_2$	LnBM	LnGDP	LnNREC	LnFDI	LnTRD
$LnCO_2$	1.0000					
Prob.	–					
LnBM	−0.3503[c]	1.0000				
Prob	(0.0624)	–				
LnGDP	0.4919[a]	−0.8141[a]	1.0000			
Proc	(0.0067)	(0.0000)	–			
LnNREC	0.2296	0.6091[a]	−0.6379[a]	1.0000		
Prob	(0.2309)	(0.0005)	(0.0002)	–		
LnFDI	−0.0548	−0.7259[a]	0.7620[a]	−0.8914[a]	1.0000	
Prob	(0.7777)	(0.0000)	(0.0000)	(0.0000)	–	
LnTRD	−0.0311	−0.1693	0.1591	−0.4477[b]	0.1802	1.0000
Prob	(0.8730)	(0.3799)	(0.4097)	(0.0149)	(0.3495)	–

Note: [a, b] and [c] represent 1, 5 and 10% significant levels, respectively

Table 3. Correlation matrix analysis

given by the integrated cross-section time series for robust test results. The findings in Table 4 show that the variables are combined in the order I (1), i.e. the same number. It is also a measure of the non-stationarity of the parameters at the point, but at the first stationary difference, the difference, e.g. CO_2, is observed to be stationary at [I (1)] under the heterogeneity variance system. The unit root test in Table 4 also demonstrates that most of the variables were not stationary at the level but were stationary at the first difference, indicating that the variables were suitable for analysis and that the results are generalizable.

4.1.3 Error correction model. After accessing the stationarity of all the variables, the ECM is further used to check the spurious level of the variables and cointegration among them. The general form of the ECM of the unit is given as follows:

$$\Delta C_t = \alpha 0 + \varrho 1 C_{t-1} + \beta 0 \Delta Y_t + \theta 1 Y_{t-1} + u_t \quad (4)$$

where ΔY_t is stationary, C_t and Y_t cointegrated (thus together I (0)), then u_t must be I (0).

From Table 5, it is observed that the t statistics of the ADF and Adj t statistics of the PP are greater than all the test critical values at 1%, 5% and 10% levels, respectively, which proves that the variables are not spurious, which make the variables stationary at either level or first difference. Thus, the significant level at both ADF and PP shows sufficient cointegration among the variables.

4.1.4 Cointegration test outcome. After determining stationarity among the variables, the analysis proceeds to identify the probability of cointegration to access the long-run equilibrium among the variables. The Johansen–Fisher cointegration test by Johansen (1992) was used. It was observed that the variables were not significant at both $r \leq 4$ and $r \leq 5$, which proofs a rejection of the null hypothesis by concluding that the variables are cointegrated (Table 6).

Table 4.
Unit root test

	PP		ADF		KPSS	
Variables	Level	First diff	Level	First diff	Level	First diff
$LnCO_2$	−2.5015	−4.7468[a]	−2.4246	−4.7611[a]	6.8001[a]	0.041
LnBM	−2.1566	−11.526[a]	−2.3693	−3.3572[b]	12.45[a]	−0.028
LnGDP	−1.5161	−3.3594[b]	−2.0968	−3.3594[b]	10.198[a]	0.015[b]
LnNREC	−0.3314	−4.3636[a]	−0.3863	−4.4203[a]	4.5709[a]	−0.002[b]
LnFDI	−1.2668	−5.7945[a]	−1.2599	−5.8081[a]	21.421[a]	0.132
LnTRD	−1.5433	−4.6219[a]	−1.5433	−4.6483[a]	4.791[a]	0.010

Note: [a, b] and [c] represent 1, 5 and 10% significant levels, respectively

Table 5.
Engle–Granger error correction model test

	t statistic	p value		Adj. t stat	p value
Augmented Dickey–Fuller test statistic	−4.0578[a]	(0.0041)	Phillips–Perron test statistic	−3.9891[a]	(0.0049)
Test critical values			*Test critical values*		
1% level	−3.6892		1% level	−3.6892	
5% level	−2.9719		5% level	−2.9719	
10% level	−2.6251		10% level	−2.6251	

Note: [a, b] and [c] represent 1, 5 and 10% significant levels, respectively

4.2 Estimation results

Table 7 shows the long run ROB-L^2 estimations in four models where the authors add and drop some variables to confirm their robustness. From the estimation, it was identified that BM was negatively significant in both Models 1 and 4 at a 10% level, which identified that an increase in CO_2 emission will decrease BM (Model 1) by 0.1395% and (Model 4) by 0.1378%. This proves that utilization of biomass in Cyprus in the long run help minimizes ecological degradation and can help the country to achieve the reduction of pollutants target for 2030. It affirms the analysis of Bilgili *et al.* (2016), Shahbaz *et al.* (2017), Dogan *et al.* (2017) and Gyamfi *et al.* (2020b, 2021a) that BM reduces CO_2 emissions.

Moreover, the estimations prove that the effect of real GDP is positively significant in all the three models at a 1% level. This result is inconsistent with Ulucak (2020), but affirms the findings of Gyamfi *et al.* (2021b, 2020a, 2021c) and Adedoyin *et al.* (2021). From the Chines energy/economy, Ulucak (2020) found a negative long-run significant association regarding real GDP and pollution. This analysis shows that a 1% rise in CO_2 emission will increase real GDP by 0.5246%, 0.7293%, 0.6609% and 0.5257%. The environmental Kuznets curve (EKC) hypothesis is not supported by this study, as economic growth in the long run positively and significantly relates to carbon dioxide pollution. Besides, NREC was found not be significant from the first model when the entire set of the variable was examined

Hypothesis no. of CE(S)	Eigenvalue	Trace statistic	Critical value	Prob.
$r \leq 0$	0.883871[a]	149.7704	95.75366	(0.0000)
$r \leq 1$	0.775278[a]	91.63797	69.81889	(0.0004)
$r \leq 2$	0.567131[b]	51.32995	47.85613	(0.0227)
$r \leq 3$	0.482158[c]	28.72233	29.79707	(0.0661)
$r \leq 4$	0.333400	10.95403	15.49471	(0.2143)
$r \leq 5$	0.000140	0.003786	3.841466	(0.9497)

Note: [a, b] and [c] represent 1, 5 and 10% significant levels, respectively

Table 6. Johansen–Fisher cointegration test

Variables	Model 1 ROB-L^2	Model 2 ROB-L^2	Model 3 ROB-L^2	Model 4 ROB-L^2
LnBM	−0.1395[c]	–	–	−0.1378[c]
Prob	(0.0734)	–	–	(0.0561)
LnGDP	0.5246[a]	0.6609[a]	–	0.5257[a]
Prob	(0.0001)	(0.0000)	–	(0.0000)
LnNREC	−0.1845	−0.8110[a]	0.3760[a]	−0.2179
Prob	(0.6542)	(0.0005)	(0.0025)	(0.5750)
LnFDI	−0.0330[a]	−0.0368[a]	0.0128[c]	−0.0338[a]
Prob	(0.0001)	(0.0001)	(0.0852)	(0.0000)
LnTRD	−0.0284	−0.0668	−0.0117	–
Prob	(0.7305)	(0.4491)	(0.9258)	–
R^2	0.4332	0.4219	0.0473	0.4493
ADJ-R^2	0.3388	0.3526	−0.0260	0.3832
Rn^2 stat	35,074.36[a]	29,343.67[a]	14,348.01[a]	39,247.78[a]
Prob	(0.000000)	(0.000000)	(0.000000)	(0.000000)

Note: [a, b] and [c] represent 1, 5 and 10% significant levels, respectively

Table 7. Robust least squares (ROB-L^2) long-run relationship

together. However, after BM was dropped in the second model, it showed a negative significant effect at 1%. Indicating that a percentage rise in CO_2 emissions will decrease NREC by 0.8110%, when the real GDP variable was dropped in addition to BM, then the significant change from negative to positive at 1% level was attained. Indicating a percentage increase in CO_2 emission will increase NREC by 0.3760%.

Nevertheless, the result from the table shows a robust negative long-run association between FDI and CO_2 emissions. This analysis is in line with the finding of Hille *et al.* (2019) who affirms that FDI reduces CO_2 emission. Similarly, this analysis confirms that an increase in FDI will decrease CO_2 emissions by 0.0330%, 0.0368% and 0.0338%. This outcome is healthy for the country because funds from outside sources in the form of FDI are effectively used for setting up better energy infrastructure, which helps in reducing CO_2 pollution.

4.2.1 Short-run relationship Table 8 presents the short-run estimations of the ARDL (3, 2, 2, 2, 1, 2) of the variables. From the analysis, it was observed that there is a negative short-run association regarding the lagged value of CO_2 ($LnCO_2$ (−2), $LnCO_2$ (−3)) and CO_2 emissions in the current period. It was clear that lagged value of CO_2 reduces CO_2 emission by 0.41% and 0.355% in the current period. Furthermore, the lagged value of BM (LnBM (−1), LnBM (−2)) has a positive short-run association with emission at 0.41% and 0.278% in the current period. Moreover, the lagged value of real GDP (LnGDP (−2)) confirms a negative association with CO_2 emissions at 2.349% in the current period. NREC lagged value (LnNREC (−2)) on the other hand has a positive association with CO_2 emission at 16.36% in the current period. Nevertheless, for the FDI, both the log value and the lagged value (LnFDI, LnFDI (−1)) confirm a positive association with emission at 0.041% and 0.11% in the current period. Finally, TRD confirmed a negative association with CO_2

Variable	Coefficient	Std. error	*t* statistic	Prob.
$LnCO_2(-1)$	−0.020789	0.227063	−0.091555	(0.9293)
$LnCO_2(-2)$	−0.411436[c]	0.204525	−2.011661	(0.0791)
$LnCO_2(-3)$	0.355412[c]	0.172420	2.061320	(0.0732)
LnBM	0.236168	0.130964	1.803306	(0.1090)
LnBM(−1)	0.409771[a]	0.118873	3.447126	(0.0087)
LnBM(−2)	0.278339[a]	0.077578	3.587861	(0.0071)
LnGDP	4.154688[a]	0.951211	4.367789	(0.0024)
LnGDP(−1)	−1.364306	0.887446	−1.537340	(0.1628)
LNGDP(−2)	−2.348723[a]	0.624478	−3.761098	(0.0055)
LnNREC	−2.208674	3.779248	−0.584422	(0.5750)
LnNREC(−1)	−5.132572	4.066642	−1.262115	(0.2425)
LnNREC(−2)	16.35977[a]	4.332557	3.776008	(0.0054)
LnFDI	0.040860[b]	0.015499	2.636332	(0.0299)
LnFDI(−1)	0.106661[a]	0.027289	3.908513	(0.0045)
LnTRD	−0.900167[b]	0.322104	−2.794650	(0.0234)
LnTRD(−1)	0.131842	0.304643	0.432776	(0.6766)
LnTRD(−2)	1.032192[b]	0.318453	3.241267	(0.0119)
C	−59.72418[a]	14.34025	−4.164794	(0.0031)
R^2	0.972239			
ADJ-R^2	0.913248			
F-STATISTIC	16.48104[a]			
F-STAT(PROB)	(0.000204)			

Note: [a, b] and [c] represent 1, 5 and 10% significant levels, respectively

Table 8. ARDL (3, 2, 2, 2, 1, 2) short-run result

emission at 0.9% but the lagged value (LnTRD (−2)) revealed a positive association with CO_2 emission at 1.032% in the current period.

4.2.2 Granger causality tests. Apart from assessing the long- and short-run interconnectedness among variables, it is important to evaluate the legitimacy of the direction of causality among the selected variables. This will help inform policy direction. Table 9 displays the outcomes from the pairwise Granger causality tests.

The outcome of the analysis proofs that there is a one-way causal association between real GDP and CO_2 emission, real GDP and biomass utilization and non-renewable energy utilization and biomass energy utilization. Then biomass energy utilization and trade, non-renewable energy utilization and real GDP, real GDP and FDI, real GDP and trade, FDI and non-renewable energy utilization as well as non-renewable utilization and trade.

5. Discussion of results

The impact of investments in biomass energy usage on carbon emission in Cyprus from 1990 to 2016 is empirically investigated in the present analysis. The study uses numerous dynamic approaches to analyze the interactions that take into account the heterogenic complexity of the variables under analysis. Pollutants have become a big global concern

Null hypothesis	*F* statistic	*p* value	Causality remark
LnBM ↗ $LnCO_2$	0.10548	(0.9003)	No causality
$LnCO_2$ ↗ LnBM	0.35881	(0.7025)	
LnGDP ↗ $LnCO_2$	2.73273[c]	(0.0871)	One-way causality
LnCO2 ↗ LnGDP	0.93752	(0.4067)	
LnNREC ↗ $LnCO_2$	0.30168	(0.7426)	No causality
LnCO2 ↗ LnNREC	1.18640	(0.3241)	
LnFDI ↗ $LnCO_2$	1.43513	(0.2595)	No causality
LnCO2 ↗ LnFDI	2.44309	(0.1101)	
LnTRD ↗ $LnCO_2$	0.65557	(0.5290)	No causality
LnCO2 ↗ LnTRD	1.06875	(0.3606)	
LnGDP ↗ LnBM	5.86715[a]	(0.0091)	One-way causality
LnBM ↗ LnGDP	1.45629	(0.2547)	
LnNREC ↗ LnBM	2.86239[b]	(0.0785)	One-way causality
LnBM ↗ LnNREC	1.04908	(0.3671)	
LnFDI ↗ LnBM	2.22738	(0.1316)	No causality
LnBM ↗ LnFDI	1.24539	(0.3073)	
LnTRD ↗ LnBM	4.68267[b]	(0.0202)	One-way causality
LnBM ↗ LnTRD	0.03840	(0.9624)	
LnNREC ↗ LnGDP	3.80099[b]	(0.0382)	One-way causality
LnGDP ↗ LnNREC	1.19036	(0.3230)	
LnFDI ↗ LnGDP	1.06326	(0.3624)	One-way causality
LnGDP ↗ LnFDI	3.73810[b]	(0.0400)	
LnTRD ↗ LnGDP	3.83253[b]	(0.0373)	One-way causality
LnGDP ↗ LnTRD	0.59980	(0.5577)	
LnFDI ↗ LnNREC	2.49885	(0.1052)	One-way causality
LnNREC ↗ LnFDI	2.69175[b]	(0.0900)	
LnTRD ↗ LnNREC	4.14273[b]	(0.0297)	One-way causality
LnNREC ↗ LnTRD	0.56840	(0.5745)	
LnTRD ↗ LnFDI	0.77481	(0.4730)	No causality
LnFDI ↗ LnTRD	0.59571	(0.5598)	

Notes: [a, b] and [c] represent 1, 5 and 10% significant levels, respectively. ↗ Means do not Ganger cause

Table 9. Result of causality analysis

expressed by various policymakers, stakeholders and nations as a whole. Most governments and environmental sustainability organizations have failed to find answers to these multiple energy consumption problems across economic sectors. For this purpose, this study is conducted to understand the nature of this phenomenon as a whole and propose some measures toward tackling this problem. In this respect, the study analyzes the effect of the use of biomass energy generation on the environment. Also, the study included some significant economic metrics such as real GDP, FDI, non-renewable energy usage and trade to determine the emission effect. The study similar to some prior studies (Bilgili, 2012; Bilgili *et al.*, 2016) establishes an important and negative relationship between the use of biomass energy and CO_2 emissions. This outcome indicates that biomass being a sustainable energy source can reduce the production of GHGs in the ecosystem.

The use of biomass sources is a healthier type of energy to contribute to the pollution reduction in Cyprus. The finding indicates that green sources of energy, including biomass, best support these ecosystems in reducing CO_2 emissions. Moreover, economic growth in the evaluated nation is not a driving force to combat emissions as it helps increase GHG pollution. The EKC philosophy is not validated by this study because long-run economic growth does not contribute to a reduction in CO_2 emission. There was a confirmation from Ulucak (2020) that output is a positive association with pollutants and it does not immediately imply that the country will have a healthy environment or will be exempt from emission if the economy expands. Also, the analysis proof that when Biomass was dropped non-renewable was found significant. It implies that, if the country does not use clean energy for production, it can rely on fossil fuel, which will help in reducing emission in the ecosystem. But after dropping real GDP also to biomass utilization, the outcome from the estimation changed by proofing that non-renewable at this moment is positively significant in producing emission. It can therefore be observed that the expansion of the economy has an impact on fossil fuel in reducing CO_2 emission. FDI, on the other hand, shown from the estimation a negative association with CO_2 emission. Investment from outside the country into the economy helps expand the economy, which in the long run affect the energy sector. This sector always needs fund in areas such as infrastructure expansions, R&D, tannings, subsidizing of taxes and other payments, etc., to have an effective impact on the pollutants emitted into the ecosystem. Therefore, the country is effectively using these fund in good use and the outcome is affirming the finding of Hille *et al.* (2019).

From the short-run association, it was confirmed from the estimations that the lagged value of CO_2 reduces CO_2 emission in the current period. Additionally, the lagged value of biomass energy utilization has a positive association with CO_2 emission. That is, in the current period, biomass energy utilization increases CO_2 emission. Moreover, the lagged value of real GDP confirms a negative association with CO_2 emissions, which implies that economic development on the other hand decreases CO_2 emission in the current state. Nevertheless, non-renewable energy utilization-lagged value has a positive association with pollutants. It indicates that in the current state, non-renewable increases CO_2 emission. Both FDI and it lagged for have a positive relation with CO_2 emission. By this, it implies that FDI increases CO_2 emission in the current period. However, for trade, it has two different significant levels. The normal log form of trade indicated a negative significant relationship with emissions by implying that at this stage, trade reduces CO_2 emission in the current stage but with its lagged value, the significant proofed a positive association with CO_2 emission indication that at this time, trade increases CO_2 emission in the current period.

The outcome of the pairwise Granger causality test analysis proofs that there is a one-way causal association regarding real GDP and CO_2 pollutant, real GDP and biomass utilization. Similarly, non-renewable energy utilization and biomass energy utilization, biomass energy utilization and trade, non-renewable energy utilization and real GDP, real GDP and FDI, real GDP and trade, FDI and non-renewable energy utilization and non-renewable utilization and trade all showed a one-way causal association.

Another essential thing to take into account is that although energy generation from biomass may result in reducing carbon emissions, its efficiency depends heavily on the efficiency of the country's direct investment by investing in energy generation technology and on the amounts of fossil fuel used for manufacturing biomass. Consequently, we could conclude that the technologies used for biomass production in the Republic of Cyprus have a degree of positive effect and that an improved development of biomass energy will minimize these countries' reliance on fossil fuel and find solutions to the environmental problems connected with fossil fuels in the energy mix.

5.1 Conclusion and implications of policies

The impact of biomass energy sources on CO_2 emission for the case of Cyprus examined from 1990 to 2016 was empirically studied in this study. To determine this, the paper applied the ROB-L2 and ARDL techniques. The study concluded that biomass utilization in the Republic of Cyprus is a decent source of energy that aims to minimize CO_2 emission. Here, it should therefore be noted that expansion of the renewable source of energy and the emphasis on renewable sources of energy such as biomass is to the nation's advantage (Bilgili *et al.*, 2016). The higher productivity levels of emission are confirmed by the ever-existing emission loop from conventional energy sources (Owusu and Asumadu-Sarkodie, 2016). This study, derived from the higher inflation of biomass energy generation as a renewable device in CO_2 emissions, however, has gained much greater credibility in this regard. Literature has shown that biomass energy is a renewable energy option that aims to add to the International Energy Agency's emission reductions policy.

It is discovered that the effective utilization of FDI in the economy is a good way to combat environmental damage. Because the outcomes of a negative correlation among FDI and pollution are a strong demonstration of the decent financial influence of foreign countries' funds to reduce pollution. The results of these observations are evidence that global investors' funds are going to support the sustainable environmental movement in the long run. Because this fund is non-country investment money to help expand the economy, the right structures that will contribute to trucking the use of such funds in the economic expansion are incumbent on stakeholders. However, steps to use any portion of the fund to implement and arrest infringements of development awareness on the path to preserve the atmosphere should also be updated in any action or scheme that may have an impact on the long-term output of further emission waste being funded by the fund. The achievement of the SDG 7 for Agenda 2030 will be a disaster without such measures taken in protecting the environment. Given the relation between biomass energy and economic growth, it will be obvious to extend this energy source segment as natural resources are being used well as producing energy for consumption, which would promote industrial growth and expansion.

To promote renewable energy and the effective energy consumption source in their economies, a multilateral agreement should be concluded between North and South Cyprus. It is the responsibility of the authorities on both sides to guarantee that both formal and informal investments in alternative energy sources such as biomass, wind or solar is provided with a pleasant atmosphere. The nation must take advantage of innovation and creativity by sharing knowledge in technological advances and other related key projects conducted by government institutions. Authorities on both sides can also provide an incentive for quick access to the funding of renewable energies, as stated in the Paris COP21 Agreement to promote renewable energy investment partners. The tax holiday is a successful method of funding that raises private-sector investors' participation in the development of renewable energy, which eventually has a ripple effect on final use. Finally, we enter the discussion on the creation of a market for renewable energies and awarding certificates as well as operations of a consolidated clean energy platform that will create more room within the category of sustainable energy.

Notes

1. Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action, amending Regulations (EC) No 663/2009 and (EC) No 715/2009 of the European Parliament and of the Council, Directives 94/22/EC, 98/70/EC, 2009/31/EC, 2009/73/EC, 2010/31/EU, 2012/27/EU and 2013/30/EU of the European Parliament and of the Council, Council Directives 2009/119/EC and (EU) 2015/652 and repealing Regulation (EU) No 525/2013 of the European Parliament and of the Council.
2. Cyprus Drafted Integrated National Energy and Climate Plan for the period of 2021 to 203.

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Appendix

Variables	VIF	1/VIF
LnGDP	2.13	0.470101
LnBM	1.68	0.595926
LnNREC	1 0.46	0.685366
LnFDI	1.75	0.786346
LnTRD	1.52	0.685936
Mean VIF	1.708	

Table A1. VIF estimations

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