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*Article*

# Factors of Renewable Energy Consumption in the European Countries – the Bayesian Averaging Classical Estimates Approach

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**Abstract:** The aim of the paper is to identify the most likely factors that determine the demand for Renewable Energy Consumption (R.E.C.) in European countries. Although in Europe a high environmental awareness is omnipresent, countries differ in scope and share of R.E.C. due to historical energetic policies and dependencies, investments into renewable and traditional energetic sectors, R&D development, structural changes required by energetic policy change, and many other factors. The study refers to a set of macroeconomic, institutional, and social factors affecting energetic renewable policy and R.E.C. in selected European countries in two points of time: i.e., before and after the Paris Agreement. The Bayesian Average Classical Estimates (BACE) is applied to indicate the most likely factors affecting R.E.C. in 2015 and 2018. The comparison of the results reveals that the G.D.P. level, nuclear and hydro energy consumption were the determinants significant in both analyzed years. Furthermore, it became clear that in 2015 the R.E.C. depended strongly on the energy consumption structure, while in 2018, the foreign direct investment and trade openness played their role in increasing renewable energy consumption. The direction of changes is positive and complies with sustainable development goals (S.D.G.s).

**Keywords:** renewable energy; economic; institutional; and social factors; Bayesian Average Classical Estimates (BACE), Paris Agreement

## 1. Introduction

Since the last decade of the 20th century, renewable energy (RE) has got attention across the globe among the different parts of society. The main reason for this popularity is environmental damage, biodiversity change, land loss, global warming, rapid increase in population, higher fuel prices, geopolitical and military conflicts, and ultimate affect all other sectors of the economy. Renewable energy consumption (R.E.C.) has climbed by 16.1% in Europe and Euro-Asia, 19.9% in Middle Eastern countries, 26.8% in Africa, 27.7% in North America, 35.1% in Asia-Pacific, and 50.5% in South and Central America in the last two decades. On the other hand, global non-renewable energy use climbed by only 1.25%. It indicated small rises in regions such as Africa (2.9%) and the Middle East (3.6%), as well as negative growth in the European Union (E.U.), Europe, and Euro-Asian countries (-1.7%, -0.9%, and -0.6%, respectively) [1].

Identifying the R.E.C. determinants and understanding which factors drive new energy sources are critical for policymakers and government authorities. The appropriate selection of determinants for the R.E.C. plays a crucial role in mechanizing suitable policies to find an efficient alternative solution to tackle the increasing energy demand. Moreover, it helps to control carbon emissions and further achieve the climate change targets. It also assists them in shifting their energy demand from fossil fuel to renewable energy to achieve sustainable development goals in the long run.

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The current study examines economic, social, and institutional determinants of renewable energy consumption in selected European countries. The energy consumption structure is included in the analysis. All European countries were taken into account at the very beginning, but the data availability limited the selection. Finally, 28 countries were considered, including 25 members of the E.U., Norway, Switzerland, and the United Kingdom. The outcomes of this study are crucial in defining and implementing appropriate energy policies to increase the share of renewable energy sources in total energy consumption. As a result, this research can significantly impact policy recommendations and practice in the EU-28. Finally, this study contributes to the existing empirical literature by identifying the factors driving renewable and non-renewable energy demand in the EU-28.

The methodology is based on the BACE method. The main advantage of the BACE is to rank the factors according to the probability when the number of potential variables is fairly large. Furthermore, it ensures comparativeness results and suggests the most likely model specifications among a vast range of competing ones [2,3]. The current study is based on encompassing approach by incorporating the different sets of determinants of R.E.C.

In the research, we concentrated on the newest data, which seems to be the most reliable. This is due to the huge increase in renewable energy use in recent years. From the energetic policy perspective, the Paris Agreement prepared in 2015 and signed in 2016 was the milestone to prevent climate change and limit global warming. What is essential, 194 countries and the E.U. ratified the document, which means a strong interest of different parties in climate resilience. The goals of the Paris Agreement are strongly related to the low greenhouse gas emissions development, which can be done by changing the structure of energy production and consumption. Consequently, our analysis was prepared in two separate years, i.e., 2015 and 2018, conducted separately for cross-sectional data. The approach considered in the current study is strongly supported by The Intergovernmental Panel on Climate Change (IPCC) report issued on August 9th, 2021[1], which confirmed the role of the human in climate change affecting many kinds of weather and climate extremes.

The research questions are whether implementing more restricted policies for environment protection and against climate change could help to increase the impact of renewable energy sources on total energy consumption. The answer to such a question is provided using descriptive statistical analysis with the coefficient of variation and a more advanced BACE approach.

The novelty of the current research lies in a direct comparison of the renewable energy consumption factors in two years and finding the incentives for the R.E.C. in the European countries. Furthermore, a few causal models useful for implementing appropriate energy policy in terms of energy usage patterns are suggested. As a result, this research can significantly impact policy recommendation and practice in the European countries, taking into account their current development and the scale of R.E.C. Finally, this study adds to the existing empirical literature by identifying the factors driving renewable energy demand in Europe. To the best of our knowledge, no empirical study incorporates and investigates a large set of R.E.C. determinants using the BACE approach at the regional level.

The rest of the paper is organized as follows. Section 2 reports the relevant literature review. Section 3 provides materials and methods. Section 4 presents the empirical results. Section 5 provides a discussion of the results. The final section 6 concludes the paper and discusses policy implications.

## 2. Literature Review

[1] https://www.ipcc.ch/assessment-report/ar6

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In the literature, several studies analyzed the relationship between economic growth and renewables deployment [4-7], and there is some agreement on how they interact. It seems obvious that the factors like G.D.P. or G.D.P. per capita reflect the country's wealth and play a considerable effect in deciding the use of renewables. Moreover, a surplus revenue implies a greater possibility for RE growth or more resources to support it. Increased income allows countries to cover developing RE technologies, while also ensuring more support for the costs of government policies promoting and regulating RE. Several studies have focused on the determinants of R.E.C. in the economic literature [8-10].

According to [11], RE technologies are relatively expensive and cannot compete with traditional energy technologies without government support. Several studies [12-14] emphasized how public policies are one of the primary motivators of RE growth in this context. Subsidies, quota rules, direct investment, research and development (R&D), feed-in tariffs, and green certificates are some of the most frequent public policy initiatives to boost renewables. [15] investigated the relationship between RE, terrorism, fossil fuels, commerce, and economic growth for France. Their findings suggested that trade openness and R.E.C. are linked in both directions (bidirectional causality).

Some authors (e.g., [11, 12,16, 17]) explicitly consider the effects of political factors on R.E.C. On the other hand, other studies focus exclusively on the factors that influence RE use without separating the impact of various policy instruments [5,18-21]. Political, socioeconomic, and country-specific issues are all included in the models of these studies [ 11,16]. Most studies have revealed that real income is one of the key drivers of R.E.C. [5, 18, 21,22]. Furthermore, because high-income countries can readily fund costly RE investments and give incentives due to abundant sources, countries may use more renewables as their G.D.P. rises [11,16, 17].

Some studies found that carbon emissions increase REC [5,11,18-22]; others found that carbon emissions negatively impact [11,12,17]. Concerns about the environment, particularly global warming, are highlighted as key factors in reducing fossil fuel consumption and increasing R.E.C. [5,11,21,22]. Because the main cause of global warming and climate change is the release of large amounts of greenhouse gases into the atmosphere [16], emissions are used in models to account for environmental concerns. Increases in emissions may be associated with increased use of renewables to meet emissions targets set by international agreements [17,19,20]. Other important factors influencing R.E.C. include energy prices, which have been found to have statistically significant effects in some studies [5,17,18,20-22]. Other energy sources, particularly fossil fuels, might be considered alternatives for renewables. As fossil fuel prices rise, it will increase the consumption of RE [5,16-18, 20-23].

Furthermore, because there is a close relationship between energy prices and inflation and inflation and economic growth, the use of RE can reduce the cost-push inflationary pressures caused by price increases in fossil fuels and the risk of stagflation, according to [20]. Furthermore, [12] and [17] stressed the importance of policy consistency and clarity for RE investments. The relevance of institutions, such as E.U. membership, is highlighted by [16]. Common targets and E.U. energy policy may boost renewable deployment in the case of E.U. membership.

According to [11], if a country has serious energy security issues, it may be compelled to rely extensively on fossil fuels, lowering its RE share. Changes in energy consumption, especially electricity consumption, may negatively or positively impact R.E.C. [11,12,16]. Previous research has found that trade openness [21], and international trade [22], economic growth [24] have statistically significant and positive effects on R.E.C.

In recent debates around the world, the importance of RE in economic development and its environmental benefits in climate risk management has piqued interest. Increasing RE production and consumption investment could be more cost-effective and practical than using non-renewable energy [25,26]. According to [27], RE can be a crucial tool in climate change adaptation and mitigation. It is commonly known that CO2 emissions from RE sources are lower than those from traditional energy sources.

In [5] there was discovered that in the G7 countries, higher real G.D.P. per capita leads to higher R.E.C. per capita. While CO2 emissions have a positive effect, increasing oil prices has a smaller but negative impact. In another study, authors discovered a similar beneficial influence of real G.D.P. per capita on R.E.C. per capita for 18 emerging economies [24]. [21] found the same influence of real G.D.P. per capita on R.E.C. per capita for a panel of 64 countries. The study also discovered that trade openness influences R.E.C. per capita.

From 1995 to 2011, [28] utilize a panel data model to investigate the determinants of RE investment in the (EU-27) in solar and wind scenarios. Their findings imply that a robust regulatory perception negatively impacts solar energy investment, with decreased sunshine hours catalyzing increased investment in wind energy in the EU-27. Between 1990 and 2014, [29] investigated the impact of macroeconomic and social variables on RE usage in the G7 countries. The study shows that research spending (as a percentage of G.D.P.), the human development index, and energy imports positively impact RE use.

Between 2003 and 2014, [30] investigated if RE stimulates economic growth in (EU-28) countries. The findings show that RE (biomass, hydropower, geothermal, wind, and solar) contributes favorably to energy growth in EU-28 countries, with biomass having the most significant impact. It was claimed that a 1% increase in primary RE output results in a 0.05 to 0.06 percent rise in G.D.P. per capita. There is also a unidirectional causal relationship between sustainable energy growth and primary RE output in the medium and long run.

The study [31] analyzed the determinants for 53 countries by using the W.D.I. data set from 1990-2017. The study used the variables (e.g., R.E.C. (hydroelectricity terawatt-hour) and non-renewable energy consumption (daily consumption of barrels oil) as dependent variables and human capital (average years of schooling population) and non-renewable energy price (barrel price of oil constant 2016 U.S. $) as independent variables. The selection of this study is consistent with the previous studies (e.g., [32-35]). The study found a positive and statistically significant relationship between the non-renewable energy price and the two types of energy consumption.

Similarly, [36] examined variables relating to RE production and the financial sector using panel data for 119 non-OECD countries. The study discovered that the Kyoto Protocol and commercial banking have a positive effect on RE. On the other hand, [37] examined the RE capacity, global knowledge stock, G.D.P per capita, electricity consumption growth rate, Kyoto protocol, and alternative energy source production in 26 OECD countries. The study discovered that while ratification of the Kyoto Protocol and the deployment of nuclear and hydroelectric energy technologies improves RE, energy security, fossil fuel production, future electricity demand, and national RE policies have no effect.

In conclusion, the relationship between different variables (e.g., economic growth, carbon emissions, and RE generation) is not consistent across nations or estimating methods, as evidenced by the above review.

## 3. Materials and Methods

### *3.1. Data Sources and Descriptive Statistics*

The currents study uses cross-sectional data on the R.E.C. and its determinants in selected European countries in 2015 and 2018. The study is based on the secondary data sources, including World Development Indicators (WDI-2019); Statistical Review of World Energy (BP-2019); International Monetary Fund (I.M.F.); Energy Information Administration (E.I.A.); Worldwide Governance Indicators (W.G.I.); International Renewable Energy Agency (IRENA) and the International Energy Agency (I.E.A) consisting of annual observations on selected European countries. The list of countries is given in Table 1.

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**Table 1.** The list of selected countries.

| Countries | Codes | Countries | Codes | Countries | Codes | Countries | Codes |
|---|---|---|---|---|---|---|---|
| Austria | AUT | Finland | FIN | Latvia | LVA | Romania | ROU |
| Belgium | BEL | France | FRA | Lithuania | LTU | Slovak Republic | SVK |
| Croatia | HRV | Germany | DEU | Luxembourg | LUX | Slovenia | SVN |
| Cyprus | CYP | Greece | GRC | Netherlands | NLD | Spain | ESP |
| Czech Republic | CZE | Hungary | HUN | Norway | NOR | Sweden | SWE |
| Denmark | DNK | Ireland | IRL | Poland | POL | Switzerland | CHE |
| Estonia | EST | Italy | ITA | Portugal | PRT | United Kingdom | GBR |

Over the last three decades, one can observe a substantial increase in renewable energy consumption (R.E.C.) in all European countries; however, the scale of the increase differs significantly. The renewable energy consumption across countries and years is presented in Figure A1 in the appendix. A remarkable disparity between highly developed European and developing economies justifies a dummy variable corresponding to this division.

The study aims at finding determinants of increasing renewable energy consumption. Taking into account the literature review, many economic, institutional, and energy variables were specified. They can be divided into the following subgroups:

(1) Economic: G.D.P. and G.D.P. per capita, FDI net inflow, unemployment, trade openness.
(2) Disaggregate energy consumption: oil, coal, gas, nuclear and hydro energy consumption.
(3) Social: Education index, Life expectancy index, School enrollment, tertiary (% gross)
(4) Institutional: political stability absence & absence of violation, control of corruption, the rule of law.
(5) Demographic: Surface Area.
(6) Dummies: Top developed countries group of world's advanced economies and wealthiest liberal democracies, former members of the Eastern Block, and G7 countries.

The selection of variables is based on both the environmental economics fundamentals [38] and empirical literature review. The selected variables, G.D.P per capita, oil price, and oil consumption, were used by [22]; Foreign direct investment, net inflows (% of G.D.P) by [39]; Rule of Law, Control of Corruption, Political Stability & Absence of Violence/Terrorism by [40]; Education index by [41]. The description of all variables and their units is given in Table A1 in the appendix.

Table A2 presents descriptive statistics for the population of selected European countries in the years 1995, 2000, 2005, 2010, 2015, and 2018. It confirms the general change in the structure of the energy consumption from different sources. On average, the consumption of oil, gas, nuclear, and particularly coal in Europe decreases gradually while hydro and renewable energy use increases substantially. The most substantial reduction is observed in coal energy consumption, which amounts to almost 39% between 1995 and 2018. On the other hand, the increase in renewable energy consumption was over 2200% from the average 0.2409 in 1995 to 5.7405 in 2018. Values of standard deviation (S.D.) shows that dispersion is really huge, and coefficients of variation exceed 100 percent. In Figure A2, the coefficients of variation for energy consumption from different sources are shown. They inform about the general tendency towards convergence among the countries in energy consumption [42]. The convergence is observed for oil and gas energy consumption. The remained energy sources reveal rather a divergence, which confirms huge variability among the countries. The empirical distributions are positively skewed and leptokurtic.

### *3.2. Methodology*

One potential problem in the linear model selection procedure is finding a significant set of explanatory variables among all potential determinants. The problem is not trivial

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if we imagine that for the sake of this analysis, we have 18 potential variables with 262,144 linear combinations; some of them are equally likely with similar explanatory power. To overcome this problem, we decided to use BACE—Bayesian Averaging of Classical Estimates introduced in [2], which is essential for the credibility and conclusiveness of presented results. Briefly speaking, BACE parameter estimates are obtained by applying Ordinary Least Squares (O.L.S.) and then averaged across all possible combinations of models, given their explanatory power. Therefore, we do not only make inferences on the "best" single model, but we take into account the uncertainty of all models. Consequently, we can easily identify significant determinants of a dependent variable based on a whole model space without specific knowledge [3]. The latest review of model averaging techniques and their implementation is presented in [43].

The construction of the BACE model methodology is explained by equations (1-6).

Let us consider the following linear regression model for cross-sectional dataset:

$$M_j: y = \alpha \iota_N + X_j \beta_j + \epsilon, j = 1, \dots, 2^K \quad (1)$$

where $K$ denotes the total number of potential explanatory variables, $2^k$ is a total number of possible linear combinations, $\iota_N$ is a $(N \times 1)$ vector of ones, $y$ is $c$ vector of observations, $X_j$ is $(N \times k_j)$ matrix containing the set of regressors included in the model $M_j$, $\beta_j$ is $(k_j \times 1)$ vector of unknown parameters, $\epsilon$ is $(N \times 1)$ a vector of errors, normally distributed, $\epsilon \sim N(0_N, \sigma^2 I_N)$. Notation $N(\mu, \Sigma)$ denotes a normal distribution with location $\mu$ and covariance $\Sigma$.

Based on [2], we can use O.L.S. estimates to calculate the approximation of the posterior probability of every model $M_j S$ using the following formula:

$$\Pr(M_j \mid y) \approx \frac{\Pr(M_j) N^{-\frac{k_j}{2}} SSE_j^{-\frac{N}{2}}}{\sum_{i=1}^{2^K} \Pr(M_i) N^{-\frac{k_i}{2}} SSE_i^{-\frac{N}{2}}} \quad (2)$$

where $SSS_j$ and $SSS_j$ are the O.L.S. sum of squared errors, $k_j$ and $k_{is}$ are the number of regression parameters $\beta_j$ and $\beta_i$, $P_r(M_j)$ and $P_r(M_i)$ are prior probabilities of models $M_j$ and $M_i$.

In our case, we use the popular binomial model prior [44]:

$$\Pr(M_j) = \theta^{k_i}(1-\theta)^{K-k_i}, \theta \in [0,1] \quad (3)$$

We know that we only need to specify a prior expected model size $E(\Xi) = K\theta$ to set the prior probability for all competitive models from binomial distribution properties. For example, if $\theta = 0.5$, then the prior expected model size equals the average number of potential regressors, and all models have an equal prior probability.

In the BACE approach, we can also obtain the averages of parameters estimates $\beta$ based on the whole model space [2, 45]:

$$E(\beta \mid y) \approx \sum_{i=1}^{2^K} \Pr(M_i \mid y) \hat{\beta}_i \quad (4)$$

$$\mathrm{Var}(\beta \mid y) \approx \sum_{i=1}^{2^K} \Pr(M_i \mid y) \mathrm{Var}(\beta_i) + \sum_{i=1}^{2^K} \Pr(M_i \mid y) \left(\hat{\beta}_i - E(\beta \mid y)\right)^2 \quad (5)$$

where $\hat{\beta}_i$ and $Var(\beta_i)$ are the O.L.S. estimates of $\beta_i$ from model $M_i$.

Another useful and popular characteristic in model averaging is so-called posterior inclusion probability (P.I.P.), which is defined as the posterior probability that the independent variable $x_i$ is relevant in explaining the dependent variable [46, 47]. In our case, the P.I.P. is calculated as the sum of the posterior model probabilities for all of the models that include a specific variable:

$$\Pr(\beta_i \neq 0 \mid y) = \sum_{i=1}^{2^K} \Pr(M_i \mid \beta_i \neq 0, y) \quad (6)$$

Thus P.I.P. can be understood as the importance of each variable for explaining the dependent variable.

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## 4. Results

The study takes into account a group of independent variables that represent potential factors responsible for renewable energy consumption (R.E.C.) in 28 European economies (see Table A1). Referring to the environmental policy adopted in Europe after the Paris agreement in 2015, we considered two points of time:

(a) the year 2015, just before the Paris Agreement ratification;
(b) the year 2018, after the Paris Agreement ratification.

It should be mentioned that the E.U. and all its members individually ratified the Paris agreement in 2016.

The research question was whether implementing a more restricted policy for environment protection and against climate change could cause a substantial change in the determinants of R.E.C. in European countries.

In order to identify determinants of R.E.C., we used the BACE selection procedure, which enables searching all possible combinations of potential variables and selecting the most probable candidates. The BACE also enables calculations of the averages of the coefficient means and standard deviations of parameters and the explanatory power of competitive models. We used the BACE 1.1 package[2], which is available in the gretl program as open-source software.

The whole model space in the regression model (excluding intercept) was equal to $2^{18} = 262{,}144$. The total number of Monte Carlo iterations was 1,000,000 (including 10% burn-in draws). The correlation coefficient between the analytical and numerical probabilities of the top models was above 0.99, which means that convergence of simulation was confirmed. Model prior was set to uniform, which means that all possible specifications were equally likely.

The posterior results are given in the following Table 2. It shows posterior inclusion probabilities, the average value of the coefficient (parameter estimate overall considered models), and the corresponding average standard error. The posterior inclusion probability (P.I.P.), equalled at least 0.7, shows a high probability of being included in the model. Although there is no formal requirement for high posterior probability, it is reasonable to assume that it is at least higher than 0.5 and treat the results higher than 0.7 as reliable.

[2] The BACE 1.1 package is available at http://ricardo.ecn.wfu.edu/gretl/cgi-bin/gretldata.cgi?opt=SHOW_FUNCS and was developed by [48]

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**Table 2.** Posterior estimates of renewable consumption determinants in 2015 and 2018.

| | 2015 | | | 2018 | | |
|---|---|---|---|---|---|---|
| Variable | PIP | Avg. coefficient | Avg. std. error | PIP | Avg. coefficient | Avg. std. error |
| const | **1.0000** | 6.3989 | 14.5596 | **1.0000** | 10.9202 | 15.5713 |
| NC | **0.9992** | -0.2503 | 0.0767 | **1.0000** | -0.3141 | 0.0634 |
| GDP | **0.9808** | 0.0119 | 0.0042 | **0.8834** | 0.0099 | 0.0056 |
| FDI_BOP | 0.3705 | -0.0028 | 0.0055 | **0.9186** | 0.0184 | 0.0088 |
| TO | 0.4940 | -0.0077 | 0.0110 | **0.8550** | -0.0203 | 0.0126 |
| HC | **0.7368** | -0.1845 | 0.1607 | **0.7770** | -0.1481 | 0.1294 |
| GC | **0.9933** | -0.5105 | 0.1646 | 0.4701 | -0.1247 | 0.2003 |
| OC | **0.9196** | 0.2859 | 0.1728 | 0.4443 | 0.0673 | 0.1206 |
| CC | 0.2480 | 0.0058 | 0.0305 | 0.4036 | 0.0258 | 0.0452 |
| TDC | 0.5894 | 7.1765 | 9.1039 | 0.3741 | -0.5901 | 6.9248 |
| SURF | 0.6361 | 0.000006 | 0.000006 | 0.3274 | 0.000001 | 0.000004 |
| SET | 0.3528 | -0.0108 | 0.0224 | 0.3048 | 0.0082 | 0.0208 |
| PSA | 0.1980 | 0.0586 | 0.8835 | 0.2994 | 0.6116 | 1.5392 |
| LEI | 0.4445 | -10.1697 | 16.4292 | 0.2966 | -5.8818 | 15.5512 |
| FEBC | 0.3009 | -0.0741 | 1.4099 | 0.2430 | -0.2563 | 1.0624 |
| UNEMP | 0.3690 | -0.0628 | 0.1405 | 0.2291 | 0.0091 | 0.1133 |
| CCUR | 0.4248 | -0.9699 | 1.8046 | 0.2136 | -0.1381 | 0.8091 |
| RL | 0.2933 | 0.4730 | 1.7139 | 0.2083 | 0.1680 | 1.0496 |
| EI | 0.2326 | 0.4600 | 7.8276 | 0.1901 | 0.0202 | 5.8023 |

Note: Bold font indicates P.I.P. values greater than 0.7.

The results in Table 2 exhibited a substantial difference between factors of R.E.C. in European countries in 2015 and 2018. The results for 2015 indicated nuclear and hydro energy consumption, oil and gas energy consumption, and the value of G.D.P. The signs of parameters for N.C., H.C., and G.S. were negative, which means that there was a competition between specified energy sources in Europe depending on hitherto resources, infrastructure, and long-term contracts. The G.D.P. denotes the country's economic position and readiness for renewable infrastructure investments. The average coefficient of 0.0119 shows that increasing G.D.P. by 1000 USD will result in increasing renewable energy consumption by 11.9 Mtoe, keeping all other factors unchanged.

The results for the year 2018 revealed that the following factors are the most likely: nuclear and hydro energy consumption, G.D.P., FDI net inflow, and trade openness. What is more interesting the signs of the mean parameters are in line with the knowledge and intuition. G.D.P. and FDI_BOP have positive parameter estimates signs, while nuclear and hydro energy consumption have negative signs. Additionally, the value for the G.D.P. is less than in 2015, but the positive value of FDI_BOP supports it. The trade openness has a negative parameter estimate. Such variables focus on the economic and energy factors that mostly influence renewable energy consumption in European countries. The G.D.P. and FDI support investments in the renewable energy sector; thus, their positive impact aligns with economic logic.

On the other hand, nuclear and hydro energy consumption compete with the renewable energy sector[3]. However, the recent findings support renewable energy as much faster in building the infrastructure as compared with the nuclear one[4]. The trade openness, measured as the sum of a country's exports and imports as a share of that country's G.D.P. (in %), shows a negative sign, which is in line with the findings presented in the literature [31,49].

[3] https://energypost.eu/renewable-energy-versus-nuclear-dispelling-myths/ (accessed 24.07.2021)

[4] 2019 World Nuclear Industry Status Report, available at https://www.worldnuclearreport.org/-World-Nuclear-Industry-Status-Report-2019-.html (accessed 24.07.2021).

Three important issues need to be clarified. Firstly, European countries gradually introduced renewable energy sources, and after ratifying the Paris agreement, they were ready to fight against climate change. Secondly, countries in Europe are diversified concerning the infrastructure in the energy sector. Thirdly, the European countries are quite homogenous as concern social and institutional environment; therefore, the variables included into social and institutional groups did not impact renewable energy consumption.

Table A3 and A4 include the top three models according to their posterior probabilities for 2015 and 2018, respectively. The total probability of the presented models is 0.0270 (2015) and 0.0258 (2018), so it is easy to see that the best models have a very low posterior probability. It means that there is no one dominant specification, and inferences based on only one model can be very misleading, because each of them has very low explanatory power. The top three models consist of 7 – 12 variables, and some of them are significant in a single regression. Still, due to the small explanatory power of the model, they have low P.I.P. values and thus do not significantly impact the dependent variable. That means our results justify the necessity of using the model averaging (BACE) approach instead of a single model selection procedure. There is one more important remark on the example models. In 2015 the division into top developed countries and former Eastern bloc was significant across all models, while in 2018, the dummies are less likely or insignificant.

**5. Discussion**

Application of the BACE procedure provides a reliable result as it allows to search the entire model space to find the most likely determinants of renewable energy consumption. The most important advantages of the model averaging were indicated in [2,50]. The first one is including the model uncertainty into the model selection procedure, which reduces overconfidence in a single model. Furthermore, it avoids the all-or-nothing mentality that is associated with classical hypothesis testing, where a model is either accepted or rejected wholesale. BACE gracefully updates its estimates as the data accumulate and the resulting model weights are continually adjusted. Finally, BACE is relatively robust to model misspecification. The successful application of BACE is possible for different databases as cross-sectional data, time-series data, and panel data [51-53].

European countries tend to realize sustainable energy plans. Although between 2015 and 2018, the total primary energy consumption in Europe has increased by 2.7% from 1996.8 to 2050.7 (Mtoe) but the production of fossil fuels was reduced. The total oil production was reduced by 2.16%, and gas production decreased by 4.22% from 2015 to 2018. The most significant reduction was observed in coal production (reduction by 9.19%) and consumption (decreased by 9.46%). Europe is in one of the top positions in renewable energy consumption, fluctuating from 141.5 to 172.2 Mtoe from 2015 to 2018, which indicates a 21.70% change [54].

As it was mentioned, the renewable energy plans require new investment and changing the structure of the energy sector by replacing old energy infrastructure with a new one. It is related to closing traditional industries, local environment changing, and new energetic complexes construction. As comes from the results of this study, there is a divergence concerning R.E.C. in Europe. Increasing G.D.P. and FDI inflow can help to activate the changes, particularly in less advanced countries, like Croatia, Cyprus, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia. The presence of trade openness in 2018 as the factor influencing renewable energy consumption aligns with the results presented in [15].

However, there remains a social context of the changes. [55] prepared a literature review on the social acceptance of renewable energy projects (R.E.P.) in European countries. They found that social acceptance is a significant barrier in the implementation of R.E.P. They argued that governments must consider the general trends in local acceptance and create a framework that will increase the probability of local acceptance

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and reduce the chances of an opposition network that will hinder the development of a R.E.P. Trust in principal actors remains a significant driver in local acceptance. It has been demonstrated that to foster acceptance of renewable energy projects; the public must gain trust in local authorities and developers. To achieve the goal, full transparency of the project is recommended.

Basing on the experience of the current study the further research plans are fostered. The next attempt is to consider determinants of the R.E.C. from a worldwide perspective. The panel data approach is also planned. The final step of the research is to combine renewable energy consumption and production with the green economic growth indicator.

## 6. Conclusions

In the current study, we put the research question on determinants of renewable energy consumption in European countries. The European countries belong into two groups developed and developing ones. Using the BACE approach, substantial differences between factors observed in 2015 and 2018 were found. The applied BACE approach is robust against a single model concept. In 2018 G.D.P. supported by the FDI and Trade Openness are responsible for the country's investments in the renewable energy sector. A qualitative change comes directly from the Paris agreement ratified in 2016. The strong warnings on the climate change effects resulted in the energy policy change in European countries. Although renewable energy requires both new investments in infrastructure and social acceptance, the increase of the R.E.C. in Europe is visible.

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## Appendix A

**Table A1.** Variable Descriptions

| No. | Variable Abbreviation | Variable name | Proxy/Scale of measurement | Data source |
|---|---|---|---|---|
| | | | **Energy based variables** | |
| 1 | REC | Renewable Consumption | million tonnes of oil equivalent to exajoules (Mtoe) | BP-2019 |
| 2 | OC | Oil consumption | million tonnes of oil equivalent to exajoules (Mtoe) | BP-2019 |
| 3 | GC | Gas consumption | million tonnes of oil equivalent to exajoules (Mtoe) | BP-2019 |
| 4 | CC | Coal consumption | million tonnes of oil equivalent to exajoules (Mtoe) | BP-2019 |
| 5 | HC | Hydro consumption | million tonnes of oil equivalent to exajoules (Mtoe) | BP-2019 |
| 6 | NC | Nuclear consumption | million tonnes of oil equivalent to exajoules (Mtoe) | BP-2019 |
| | | | **Economic based variables** | |
| 7 | GDP | GDP | Data are in constant 2010 U.S. dollars. | WDI-2019 |
| 8 | TO | Trade Openness | Trade Openness= Exports of goods and services (% of G.D.P.)+ Imports of goods and services (% of G.D.P.). | WDI-2019 |
| 9 | FDI_BOP | Foreign direct investment, net inflows (BOP) | Foreign direct investment refers to direct investment equity flows in the reporting economy. It is the sum of equity capital, reinvestment of earnings, and other capital. Data are in current U.S. dollars. | WDI-2019 |
| 10 | UNEMP | Unemployment, total | Unemployment refers to the share of the labor force that is without work but available for and seeking employment. Measured in (% of the total labor force) | WDI-2019 |
| | | | **Social based variables** | |
| 11 | P.S.A. | Political stability and absence of violence | Political Stability and Absence of Violence/Terrorism measures perceptions of the likelihood of political instability and/or politically-motivated violence, including terrorism. | WGI-2020 |
| 12 | RL | Rule of Law | Reflects perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence. | WGI-2020 |
| 13 | CCUR | Control of corruption | Reflects perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests. | WGI-2020 |
| 14 | EI | Education Index | Education index is an average of mean years of schooling (of adults) and expected years of schooling (of children), both expressed as an index obtained by scaling with the corresponding maxima. | http://hdr.undp.org/en/indicators/103706 |
| 15 | LEI | Life Expectancy Index | Life expectancy at birth expressed as an index using a minimum value of 20 years and a maximum value of 85 years. | http://hdr.undp.org/en/indicators/103206 |
| 16 | SET | School enrollment, tertiary | Gross enrollment ratio is the ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. measured in (% gross). | WDI-2019 |
| | | | **Other variables** | |
| 17 | SURF | Surface area | Surface area is a country's total area, including areas under inland bodies of water and some coastal waterways. measured in (sq.km). | WDI-2019 |
| | | | **Dummy Variables** | |
| 18 | TDC | Top Developed Countries | Dummy variable if country is a member of the G-7, group of world's advanced economies and wealthiest liberal democracies. | authors elaboration |
| 19 | FEBC | Former Eastern Bloc | Dummy variable if country was a member of the Eastern Bloc. | authors elaboration |

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**Table A2.** Descriptive Statistics for Energy Consumption According to Different Sources in European Countries

| Source | Oil Consumption | | | | | |
|---|---|---|---|---|---|---|
| Years | 1995 | 2000 | 2005 | 2010 | 2015 | 2018 |
| Mean | 25.5868 | 26.4246 | 27.2254 | 25.1221 | 22.8585 | 23.5671 |
| S.E | 6.7471 | 6.7588 | 6.6116 | 6.0195 | 5.4955 | 5.5243 |
| Med | 11.2194 | 10.8897 | 11.0132 | 10.7220 | 10.0999 | 10.5758 |
| S.D. | 35.7025 | 35.7644 | 34.9852 | 31.8520 | 29.0794 | 29.2317 |
| Kurt | 3.3606 | 2.5040 | 1.6758 | 1.8892 | 2.6849 | 2.2979 |
| Skew | 2.0038 | 1.8380 | 1.6656 | 1.6737 | 1.8107 | 1.7290 |
| Range | 138.9582 | 134.1266 | 126.1889 | 118.0561 | 112.6862 | 111.6916 |
| Min | 1.3299 | 1.1655 | 1.4394 | 1.4336 | 1.4848 | 1.5026 |
| Max | 140.2881 | 135.2921 | 127.6283 | 119.4897 | 114.1710 | 113.1941 |
| Obs | 28 | 28 | 28 | 28 | 28 | 28 |

| Source | Gas Consumption | | | | | |
|---|---|---|---|---|---|---|
| Years | 1995 | 2000 | 2005 | 2010 | 2015 | 2018 |
| Mean | 11.9391 | 14.2396 | 16.0359 | 16.1486 | 12.9957 | 14.2033 |
| S.E | 3.5395 | 4.2928 | 4.6006 | 4.5435 | 3.6295 | 4.0108 |
| Med | 3.0019 | 4.0149 | 4.1146 | 4.5813 | 3.8785 | 4.2757 |
| S.D. | 18.7294 | 22.7155 | 24.3439 | 24.0421 | 19.2053 | 21.2232 |
| Kurt | 3.3539 | 4.1808 | 2.9618 | 2.6442 | 2.5919 | 2.9565 |
| Skew | 2.0433 | 2.2053 | 1.9877 | 1.9135 | 1.9006 | 1.9648 |
| Range | 66.8421 | 87.1382 | 85.4571 | 84.6886 | 66.1682 | 75.9176 |
| Min | 0 | 0 | 0 | 0 | 0 | 0 |
| Max | 66.8421 | 87.1382 | 85.4571 | 84.6886 | 66.1682 | 75.9176 |
| Obs | 28 | 28 | 28 | 28 | 28 | 28 |

| Source | Coal Consumption | | | | | |
|---|---|---|---|---|---|---|
| Years | 1995 | 2000 | 2005 | 2010 | 2015 | 2018 |
| Mean | 12.7343 | 11.2384 | 11.0827 | 9.7995 | 9.1320 | 7.7798 |
| S.E | 4.0922 | 3.6148 | 3.4981 | 3.3070 | 3.1943 | 2.8294 |
| Med | 4.8950 | 3.9199 | 3.8506 | 3.7908 | 3.2514 | 3.0665 |
| S.D. | 21.6539 | 19.1275 | 18.5103 | 17.4990 | 16.9028 | 14.9718 |
| Kurt | 7.0533 | 8.6580 | 7.9418 | 8.9482 | 11.3421 | 10.6100 |
| Skew | 2.6952 | 2.8583 | 2.7512 | 2.9604 | 3.2493 | 3.2712 |
| Range | 90.5155 | 85.2689 | 81.2447 | 77.0423 | 78.6773 | 66.3859 |
| Min | 0.1070 | 0.0360 | 0.0440 | 0.0147 | 0.0033 | 0.0133 |
| Max | 90.6225 | 85.3049 | 81.2887 | 77.0569 | 78.6806 | 66.3992 |
| Obs | 28 | 28 | 28 | 28 | 28 | 28 |

| Source | Hydro Consumption | | | | | |
|---|---|---|---|---|---|---|
| Years | 1995 | 2000 | 2005 | 2010 | 2015 | 2018 |
| Mean | 3.9275 | 4.3418 | 3.8380 | 4.2364 | 4.1194 | 4.1456 |
| S.E | 1.2203 | 1.3679 | 1.2593 | 1.1868 | 1.2995 | 1.2958 |
| Med | 0.9256 | 0.9559 | 1.0466 | 1.0880 | 1.1500 | 1.1514 |
| S.D. | 6.4572 | 7.2384 | 6.6636 | 6.2802 | 6.8763 | 6.8567 |
| Kurt | 6.0942 | 7.5019 | 9.6198 | 4.7663 | 8.3324 | 8.6433 |
| Skew | 2.3838 | 2.5596 | 2.8797 | 2.0801 | 2.6703 | 2.6869 |
| Range | 27.4992 | 32.0899 | 30.7028 | 26.4176 | 31.0680 | 31.3382 |
| Min | 0 | 0 | 0 | 0 | 0 | 0 |
| Max | 27.4992 | 32.0899 | 30.7028 | 26.4176 | 31.0680 | 31.3382 |
| Obs | 28 | 28 | 28 | 28 | 28 | 28 |

| Source | Renewable Consumption | | | | | |
|---|---|---|---|---|---|---|
| Years | 1995 | 2000 | 2005 | 2010 | 2015 | 2018 |
| Mean | 0.2409 | 0.5116 | 1.2068 | 2.4582 | 4.8355 | 5.7405 |
| S.E | 0.0667 | 0.1470 | 0.3936 | 0.7882 | 1.5340 | 1.8756 |
| Med | 0.0700 | 0.1095 | 0.3433 | 0.7046 | 2.0728 | 2.2679 |
| S.D. | 0.3528 | 0.7778 | 2.0829 | 4.1707 | 8.1170 | 9.9248 |
| Kurt | 4.9283 | 4.5466 | 10.2783 | 9.7951 | 10.7530 | 11.5624 |
| Skew | 2.0445 | 2.0316 | 2.9772 | 2.9885 | 3.0497 | 3.1839 |
| Range | 1.4979 | 3.2366 | 9.6991 | 19.0421 | 38.3485 | 47.2298 |
| Min | 0 | 0 | 0.0002 | 0.0165 | 0.0750 | 0.1049 |
| Max | 1.4979 | 3.2366 | 9.6993 | 19.0586 | 38.4235 | 47.3347 |
| Obs | 28 | 28 | 28 | 28 | 28 | 28 |

| Source | Nuclear Consumption | | | | | |
|---|---|---|---|---|---|---|
| Years | 1995 | 2000 | 2005 | 2010 | 2015 | 2018 |
| Mean | 7.1857 | 7.7039 | 8.1038 | 7.4965 | 6.9924 | 6.7636 |
| S.E | 3.2612 | 3.5624 | 3.8111 | 3.5740 | 3.5644 | 3.3637 |
| Med | 0.4546 | 0.9821 | 1.0807 | 0.4491 | 0.4614 | 0.3953 |
| S.D. | 17.2567 | 18.8502 | 20.1666 | 18.9117 | 18.8611 | 17.7989 |
| Kurt | 16.4649 | 17.2537 | 18.7523 | 19.9556 | 22.8416 | 22.7416 |
| Skew | 3.8487 | 3.9592 | 4.1321 | 4.2727 | 4.6172 | 4.5977 |
| Range | 85.3580 | 93.9408 | 102.1698 | 96.9636 | 98.9790 | 93.4905 |
| Min | 0 | 0 | 0 | 0 | 0 | 0 |
| Max | 85.3580 | 93.9408 | 102.1698 | 96.9636 | 98.9790 | 93.4905 |
| Obs | 28 | 28 | 28 | 28 | 28 | 28 |

**Note:** Med: Median; S.E.=Standard Error; S.D.= Standard deviation; Kurt= Kurtosis; Ske= Skewness; Min=Minimum; Max=Maximum; Obs= Observations.

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**Table A3.** Posterior estimates of top 3 models for renewable consumption determinants in 2015

| Variables | coefficient | std. error | t-stat | p-value |
|---|---|---|---|---|
| | | **Model 1.** Posterior probability: 0.010350 | | |
| Const | 9.2429 | 3.5399 | 2.6110 | 0.0090 |
| NC | -0.3798 | 0.0381 | -9.9660 | < 0.0001 |
| TO | -0.0205 | 0.0077 | -2.6490 | 0.0081 |
| HC | -0.3540 | 0.0979 | -3.6170 | 0.0003 |
| GC | -0.6612 | 0.1026 | -6.4430 | < 0.0001 |
| OC | 0.3574 | 0.1019 | 3.5090 | 0.0005 |
| TDC | 14.5325 | 5.0625 | 2.8710 | 0.0041 |
| SURF | 0.00001 | 0.000004 | 3.1190 | 0.0018 |
| FEBC | -2.3601 | 1.6237 | -1.4540 | 0.1461 |
| UNEMP | -0.3520 | 0.1299 | -2.7090 | 0.0067 |
| CCUR | -2.6847 | 1.0634 | -2.5250 | 0.0116 |
| GDP | 0.0083 | 0.0034 | 2.4630 | 0.0138 |
| | | **Model 2.** Posterior probability: 0.009376 | | |
| Const | 4.5462 | 1.4922 | 3.0470 | 0.0023 |
| NC | -0.3643 | 0.0378 | -9.6470 | < 0.0001 |
| TO | -0.0147 | 0.0069 | -2.1480 | 0.0317 |
| HC | -0.2807 | 0.0866 | -3.2420 | 0.0012 |
| GC | -0.6316 | 0.1038 | -6.0830 | 0.0000 |
| OC | 0.3625 | 0.1051 | 3.4500 | 0.0006 |
| TDC | 13.2797 | 5.1492 | 2.5790 | 0.0099 |
| SURF | 0.00001 | 0.000004 | 2.6740 | 0.0075 |
| UNEMP | -0.2083 | 0.0870 | -2.3940 | 0.0167 |
| CCUR | -1.3370 | 0.5374 | -2.4880 | 0.0129 |
| GDP | 0.0082 | 0.0035 | 2.3740 | 0.0176 |
| | | **Model 3.** posterior probability: 0.007232 | | |
| Const | 8.2507 | 3.5768 | 2.3070 | 0.0211 |
| NC | -0.3950 | 0.0395 | -10.0000 | < 0.0001 |
| TO | -0.0238 | 0.0081 | -2.9460 | 0.0032 |
| HC | -0.3467 | 0.0965 | -3.5920 | 0.0003 |
| GC | -0.6747 | 0.1016 | -6.6390 | < 0.0001 |
| OC | 0.3862 | 0.1030 | 3.7510 | 0.0002 |
| TDC | 17.3483 | 5.4843 | 3.1630 | 0.0016 |
| SURF | 0.00001 | 0.000004 | 3.2710 | 0.0011 |
| FEBC | -2.2588 | 1.6005 | -1.4110 | 0.1581 |
| UNEMP | -0.3235 | 0.1300 | -2.4890 | 0.0128 |
| CCUR | -4.5852 | 1.8667 | -2.4560 | 0.0140 |
| RL | 2.6548 | 2.1589 | 1.2300 | 0.2188 |

| | | | | |
|---|---|---|---|---|
| GDP | 0.0069 | 0.0035 | 1.9710 | 0.0487 |

**Table A4.** Posterior estimates of top 3 models for renewable consumption determinants in 2018

| Variables | coefficient | std. error | t-stat | p-value |
|---|---|---|---|---|
| **Model 1.** Posterior probability: 0.011631 | | | | |
| Const | 2.1936 | 1.0344 | 2.1210 | 0.0340 |
| GC | -0.2202 | 0.0944 | -2.3320 | 0.0197 |
| NC | -0.2864 | 0.0370 | -7.7330 | < 0.0001 |
| HC | -0.1698 | 0.0637 | -2.6670 | 0.0077 |
| TO | -0.0207 | 0.0072 | -2.8640 | 0.0042 |
| OC | 0.1226 | 0.0572 | 2.1440 | 0.0320 |
| GDP | 0.0126 | 0.0025 | 5.0630 | < 0.0001 |
| FDI_BOP | 0.0188 | 0.0050 | 3.7280 | 0.0002 |
| **Model 2.** Posterior probability: 0.009196 | | | | |
| Const | 1.7875 | 1.2368 | 1.4450 | 0.1484 |
| NC | -0.2087 | 0.0323 | -6.4680 | < 0.0001 |
| HC | -0.1499 | 0.0603 | -2.4850 | 0.0130 |
| TO | -0.0184 | 0.0080 | -2.3060 | 0.0211 |
| TDC | -7.7559 | 3.4780 | -2.2300 | 0.0257 |
| GDP | 0.0131 | 0.0010 | 12.5300 | < 0.0001 |
| FDI_BOP | 0.0239 | 0.0050 | 4.8050 | < 0.0001 |
| **Model 3.** posterior probability: 0.004942 | | | | |
| Const | 1.8534 | 1.1568 | 1.6020 | 0.1091 |
| GC | -0.2145 | 0.0977 | -2.1960 | 0.0281 |
| NC | -0.2960 | 0.0392 | -7.5540 | < 0.0001 |
| HC | -0.3334 | 0.1055 | -3.1590 | 0.0016 |
| TO | -0.0187 | 0.0077 | -2.4360 | 0.0148 |
| SURF | 0.00001 | 0.000004 | 1.7460 | 0.0809 |
| GDP | 0.0156 | 0.0023 | 6.9230 | < 0.0001 |
| FDI_BOP | 0.0137 | 0.0056 | 2.4380 | 0.0148 |

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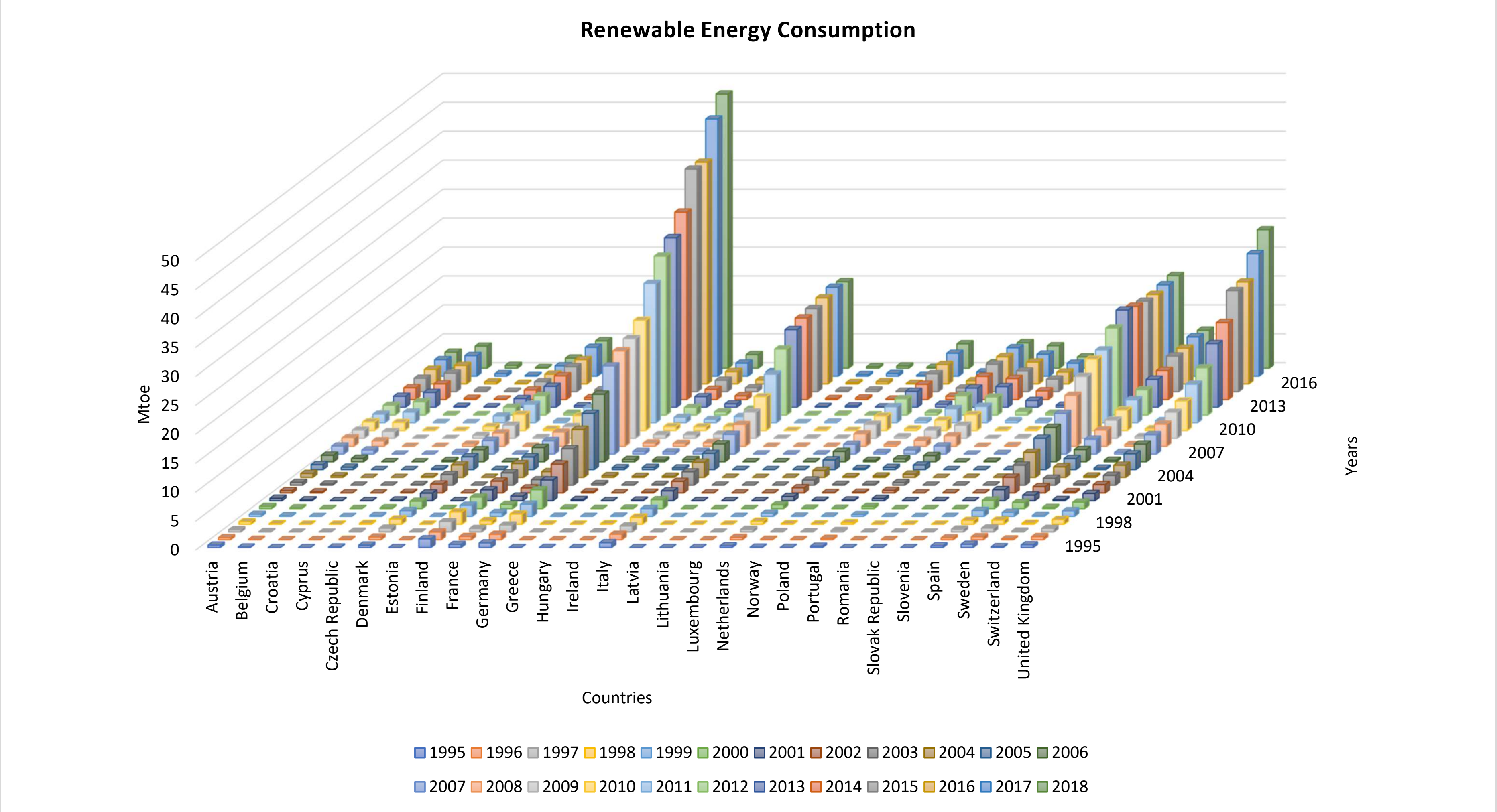


**Figure A1.** Renewable Energy Consumption in European Countries in 1995–2019

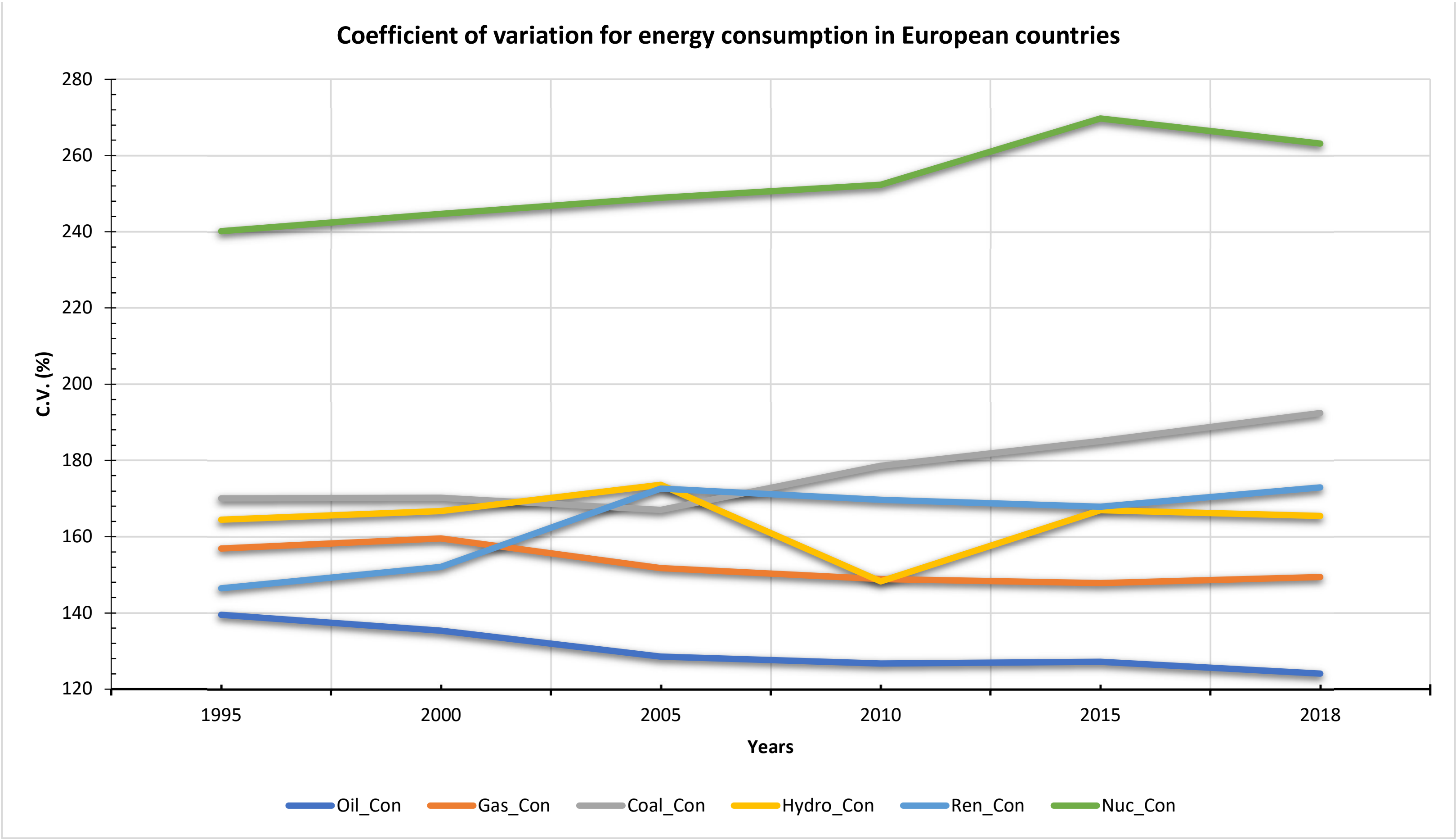


**Figure A2.** Energy Consumption Coefficient of Variation 1995–2018

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