

**Net-Zero Policy Performance Assessment of European Countries through DEA
Method**

(DEA Yöntemi ile Avrupa Ülkelerinde Net-Sıfır Politika Performans Değerlendirmesi)

by

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LIST OF SYMBOLS

ACF	: Autocorrelation Function
ADF	: Augmented Dickey Fuller
AR	: Autoregressive
ARIMA	: Auto-Regressive Integrated Moving Average
BCC	: Banker, Charnes and Cooper
CCR	: Charnes, Cooper and Rhodes
CRS	: The Constant Return Scale
CO₂	: Carbon Dioxide
CFC	: Ozone-depleting
CH₄	: Methane
DEA	: Data Envelopment Analysis
DMU	: Decision-Making Units
GAMS	: General Algebraic Modeling System
GDP	: Gross Domestic Product
GSCM	: Green Supply Chain Management
LP	: Linear Programming Model
MA	: Moving Averages
MEI	: Mixed Environmental Performance Index
N₂O	: Nitrous Oxide
NIRS	: Non-Increasing Returns To Scale
OWID	: Our World in Data
Twh	: terawatt-hour
VRS	: The Variant Returns To Scale

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ABSTRACT

Today's one of the most important difficulties is tackling climate change and its effects on the environment. According to the Paris Agreement, which was signed in 2015 and come into force in 2016, to reduce climate change, countries aim to balance the greenhouse gases released and captured until 2050. Thus, this study aims to measure the performance of European Country in 2050. To measure the performances, the Data Envelopment Analysis (DEA) method is used. In order to employ DEA method, decision-making units (DMUs), inputs and outputs are determined. DMUs are selected from the European Countries that signed the Paris Agreement. Input is identified as Primary Energy Consumption. Outputs are selected as Gross Domestic Product (GDP), CO₂ Emission, Nitrous Oxide (N₂O) Emission. The countries' primary energy consumption and total CO₂ emission data are available between 1980 and 2019. The countries' GDP and total N₂O data are available between 1990 and 2019. For each country, these data are forecasted in R Studio using the Auto-Regressive Integrated Moving Average (ARIMA) method until 2050. Performance measurements are conducted using Pure Environmental Index and Mixed Environmental Index models in GAMS solver. Albania, Germany, Luxembourg, Malta and Poland is determined as the best performing countries, whereas, Turkey and United Kingdom are identified as the worst performing countries. The employed models do not provide the opportunity to choose between the 5 best performing countries. However, the prediction of Germany, which forecasts to reduce its N₂O emissions by 98% and CO₂ emissions by 38% shows that it may be the best performing country in 2050.

Keywords: Climate change, CO₂ emission, Data envelopment analysis, Net zero policy, N₂O emission, Performance management.

ÖZET

Günümüzün en büyük zorluklarından biri iklim değişikliği ve çevre üzerindeki etkileri ile mücadeledir. İklim değişikliğini azaltmak için 2015 yılında imzalanan ve 2016 yılında yürürlüğe giren Paris Anlaşması'na göre ülkeler 2050 yılına kadar saldıkları ve tuttukları sera gazlarını dengelemeyi hedeflemektedir. Bu nedenle, bu çalışma, 2050 yılında Avrupa ülkelerinin performanslarını ölçmeyi amaçlamaktadır. Performansı ölçmek için Veri Zarflama Analizi (VZA) yöntemi kullanılmıştır. Bu yöntemin kullanılabilmesi için karar verme birimleri (KVB'ler), girdiler ve çıktılar belirlenmiştir. KVB'ler, Paris Anlaşması'nı imzalayan Avrupa Ülkeleri olarak seçilmiştir. Girdi, Birincil Enerji Tüketimi olarak tanımlanmış, çıktılar ise Gayri Safi Yurtiçi Hasıla (GSYİH), Karbondioksit Emisyonu (CO_2), Nitroz Oksit (N_2O) olarak seçilmiştir. Literatürden, ülkelerin birincil enerji tüketimi ve toplam CO_2 emisyonu verileri 1980 ile 2019 yılları arasında bulunmuştur. Ülkelerin GSYİH ve toplam N_2O verileri 1990 ile 2019 yılları arasında bulunmuştur. Seçilen her ülke için bu veriler ARIMA yöntemi kullanılarak R Studio'da 2050 yılına kadar tahminlenmiştir. Performans ölçümleri, GAMS çözücüsünde Saf Çevre İndeksi ve Karma Çevre İndeksi modelleri kullanılarak gerçekleştirilmiştir. Arnavutluk, Almanya, Lüksemburg, Malta ve Polonya en iyi performans gösteren ülkeler olarak belirlenmiştir. Türkiye ve İngiltere en kötü performansa sahip ülkelerdir. Kullanılan modeller en iyi performans gösteren 5 ülke arasında seçim yapma olanağı vermemektedir. Ancak Almanya'nın 2050 yılında N_2O emisyonlarını %98 ve CO_2 emisyonlarını %38 oranında azaltacağı öngörüsü en iyi performansa sahip ülke olacağını düşündürmektedir.

Anahtar Kelimeler: İklim değişikliği, CO_2 emisyonu, Veri zarflama analizi, Net sıfır politikası, N_2O emisyonu, Performans yönetimi.

1. INTRODUCTION

Addressing climate change and its environmental impact is one of the greatest challenges of modern life. Climate change occurs when the increase in greenhouse gases is caused by further warming of the atmosphere and the Earth (Githeko et al., 2000). Most of today's sustainable strategies are essentially related to the intent of reducing overall carbon dioxide (CO₂) emissions. Also, methane (CH₄), nitrous oxide (N₂O), and ozone-depleting (CFC) substances are just a few examples of the non-CO₂ greenhouse gases that are emitted as a result of human activity and contribute considerably to climate change (Montzka et al., 2011). To prevent them, international negotiations began in the late 1980s (Vlassopoulos, 2012). Kyoto Protocol was organized between 40 countries in 1997 in order to reduce greenhouse gases such as carbon dioxide, methane etc. However, the protocol came into force in 2005. Every year, the countries participated in the protocol hold meetings. At the 15th meeting, developed countries such as the United States played a major role in developing the Copenhagen Agreement which commits to limiting global temperature rise to 2°C to prevent dangerous anthropogenic interference with the climate system (Lau et al., 2012).

As a result of the inadequacy of the Kyoto protocol, the Paris Conference was organized in 2015. After the conference, Paris Agreement was signed but it entered into force in 2016. The target of the agreement is to limit global mean temperature rising less than 2°C, even intended to rise less than 1.5 degrees (Horowitz, 2016). According to Pye et al. (2017), decarbonization analysis to support national climate policy should consider the period after 2050, can be called milestone, since the Agreement necessitates a 'net-zero' emissions system by 2100. Bistline (2021) claimed that limiting global temperature rise in line with the Paris Agreement will generate net-zero CO₂ emissions worldwide around the middle of the century. Modeling can inform general deliberations, policies, and plans about Net zero's goals. Fankhauser et al. (2021) claim that net-zero's concept of CO₂ emissions came from physical climate science. But it is operated by social, political and

economic systems. The Climate Action Tracker was announced that global warming by 2100 could be as low as 2.1° C as a result of all net zero promises. (Climate Action Tracker, 2021). This result shows that serious actions are taken to reach the 2100 target.

Although the great aim of this agreement is to reduce the damage to the environment, the economic dimension of the work is also be considered. Wei et al. (2021) claimed that if countries do not fulfill this agreement target, they will loss approximately 149.78–791.98 trillion dollars until 2100. Many areas have been studied in academia to find the action that is both most economically beneficial and least harmful to the environment.

CO₂ emissions are caused by many activities such as logistic. The question of whether the targets of the Paris Agreement will be complied with until 2050 is an issue that makes the authorities and citizens wonder. For this reason, studies are carried out in the literature to estimate how much gas emissions of countries may be until 2050. The results are not very positive in some areas and countries.

In the literature, studies are conducted for many countries and country groups such as China, OECD, Asia etc. However, no study is done for European Countries assessment, yet. In order to fill this gap in the literature, this study aims to measure the performance of European Countries in 2050 employing DEA method. Firstly input and output indicators are determined as primary energy consumption, GDP, CO₂ emissions and N₂O emissions. In order to use these indicators, the year 2050 was estimated from the data of the previous years in R studio using ARIMA forecast method. Three mathematical model is coded in General Algebraic Modeling System v.42.5.0 (GAMS). Actions to be taken are determined for countries with worse performance.

The contributions of this study can be summarized as follows. The estimation of CO₂ and N₂O emissions of European countries until 2050 is made. The percentage by which countries can increase or decrease their emissions is calculated. Furthermore, performance measurement is done among these countries in 2050 using DEA method. As a result of these measurements, it is found which countries need to reduce their emissions, and which countries need to reduce their emissions with the same attention they have been giving in recent years.

The rest of the study is organized as follows. In section 2, the subject-specific scientific index search is presented. A detailed description of the employed methods is presented in section 3. In section 4, the relevant datasets and their computational results are given. The model results are discussed in section 5. Finally, conclusions are summarized in section 6.



2. LITERATURE REVIEW

In the recent past, various types of research have been contributed to the literature on analyzing greenhouse gas emission especially CO₂ emission by researchers. Clift and Wright (2000) researched mobile phone supply chain's environmental effects. They focused on value added activities along this supply chain. Over the years, Green supply chain management (GSCM) has become popular topic in literature. Zhu et al. (2005) identified GSCM drivers through questionnaires which are completed by Chinese manufacturing organizations. Manufacturers have tried to select their resources accordingly in order to produce in accordance with the GSCM methodology. Vachon and Klassen (2006) tried to make a selection within environmental technologies using data from the packaging printing industry in Canada and the United States

The fact that the world entered the digital age in the 2000s caused an increase in the CO₂ emissions. Boccaletti et al. (2008) tried to estimate its CO₂ emissions globally associated with information and technology in 2020. Some researchers made an evaluation on a specific product. Hoang et al. (2008) investigated the effect on Greenhouse Gas Emissions from laptop manufacturing to laptop end-of-life disposition. Some recommendations have been made according to the results.

In recent years, researchers conducted carbon emission analyzes specific to regions. Zhou et al. (2008) divided the world into eight regions such as OECD, Africa, Asia. They made a carbon, energy density comparison of eight regions using the DEA method, which is a well-known nonparametric technique for comparing the effectiveness of a group of comparable decision-making units (DMUs) with numerous inputs and outputs. On the other hand, some researchers have focused on specific countries. Guo et al. (2011) conducted a study on 29 provinces in China. They aimed to estimate CO₂ emissions reduction in provinces using multiple DEA methods. Capital stock, primary energy

consumption and labor force are used as inputs. CO₂ emission and GDP are used as outputs. Millot et al. (2020) evaluated Sweden and France energy consumption. According to the evaluations, it is revealed that it is important to turn to renewable energy sources. Although renewable energy sources are beneficial to environment, they require high investment and have many uncertainties. For example, not every country receives the same intensity of sun for solar energy.

In the literature after the Paris Agreement in 2015, studies are carried out with the net-zero emission approach. This approach has been adjusted to many areas. Wu and Skye (2021), studied on new developments in net-zero energy houses that might drastically cut energy use and greenhouse gas emissions. While doing this study, they also took into account the climatic conditions of the countries. Aram et al. (2021) remodeled an educational building to give researchers a better understanding of how to effectively remodel buildings to achieve near-zero energy in the face of climate change.

As a result of global population growth, there has been a serious increase in demand in the food industry. Malliaroudaki et al. (2021) the operations in the supply chain by product in the dairy industry. Then, they evaluated alternative energy-saving operations which can lead to the net-zero emission goals. On the other hand, Garvey et al. (2021) generated a new idea which is food demand should be reduced rather than improved operations to reach the net-zero goals. They suggested a diet program that will reduce people's food demands.

It is obvious that the demand for construction materials will increase due to the increasing number of people. Miller et al. (2021) presented that the sheer size of cement production causes more than 7% of annual greenhouse gas emissions. This poses a significant risk to achieving net-zero emissions by 2050. It shows the importance of working in this field. Also, Karlsson et al. (2021) emphasized that the construction sector accounts for 25% of CO₂ emissions, therefore it is important to conduct research in this sector to reduce the greenhouse gas effect. They compared different building designs and found which buildings will reduce emissions by 2050.

The fact that the greenhouse gas emissions are high in the crowded areas triggered scientists to work in those areas in order to reach the 2050 targets. O’Flynn et al. (2021) studied on a UK university that taken climate change into account and will act as an example to facilitate achieving net-zero emission. They calculated important emissions, science-based reduction targets for various methods and options for reducing CO₂ emissions in terms of financing current and future emission reduction pathways. Due to the quarantines experienced after the coronavirus, most people switched to working from home, which reduced emissions in workplaces. Liu and Lin (2021) investigated how electricity needs and electricity consumption affected the net zero target during quarantine days.

Another important factor in greenhouse emissions is the transportation sector. Bu et al. (2021) analyzed 31 cities in China by dividing them into 3 groups and determined strategies that will bring CO₂ emissions closer to zero until 2050 in the transportation sector. Chaudry et al. (2022) studied on both transportation and heat sector for Britain. Although they expect that there will be an increase in electricity consumption until 2050 with the spread of electric vehicles which shows that there will be a decrease in total energy consumption.

At the end of the first quarter of the 2020s, it is being investigated how successful the countries in reaching the targets. Tudor and Sova (2022) forecasted how well nine countries will meet net-zero policy requirements in 2050. They used countries' greenhouse gas emissions amounts from 1970 to 2018 to forecast using statistical methods. Perissi and Jones (2022) evaluated European Union for conformity with the goals of the European Green Deal.

A summary of the literature review is given in Table 2.1. Studies are divided according to their scope and methods used.

Table 2.1: Literature Comprasion Table

Articles	Scope				Methodology		
	CO ₂ Emission	Cost	Production Rate	Hazardous Risk	DEA Model	Other Mathematical Model	Others
Clift and Wright (2000)	x		x				x
Zhu et al. (2005)	x	x		x	x		
Vachon and Klassen (2006)	x						x
Boccaletti et al. (2008)	x						
Hoang et al. (2008)	x						x
Zhou et al. (2008)	x				x		
Guo et al. (2011)	x					x	
Millot et al. (2020)	x	x				x	
Filimonau et al. (2021)	x						x
Liu and Lin (2021)	x						x
Wu and Skye (2021)	x					x	
Garvey et al. (2021)	x	x	x	x			x
Miller et al. (2021)	x			x			x
Karlsson et al. (2021)	x						x
O'Flynn et al. (2021)		x				x	
Malliaroud	x	x	x			x	

aki et al. (2022)							
Tudor and Sova (2022)	x	x				x	
Bu et al. (2021)	x	x	x				x
Chaudry et al. (2022)	x	x					x
Aram et al. (2022)	x					x	
Perissi and Jones (2022)	x						x

This study objects to investigate how well the European Countries can comply with the aims of the Paris Agreement. Generally studies in literature review, only CO₂ emission is considered as greenhouse gas, which can be seen as a drawback of the studies in the literature. To overcome this drawback, N₂O emissions are also taken into account in this study. Also, it is seen from the studies examined that often use mathematical models, but the DEA method is not used much. Based on this inference, it is decided to measure the performance of countries in 2050 with DEA using N₂O, CO₂, primary energy consumption and GDP values. ARIMA method is used to find the values of these indicators in 2050. To the best of the authors knowledge, this study is the first that combined ARIMA forecast and DEA method to measure the performance of countries.

3. MATERIALS AND METHODS

3.1 ARIMA Model

Box and Jenkins (1976) joined the autoregressive, which run under the premise that past values affect on current values, and moving average terms in order to suggest an ARMA (p, q) model. This model can be represented as

$$x_t = \phi_1 x_{t-1} + \phi_2 x_{t-2} + \phi_3 x_{t-3} + \dots + \phi_p x_{t-p} + \pi_t + \pi_t - \lambda_1 \pi_{t-1} - \lambda_2 \pi_{t-2} - \dots - \lambda_q \pi_{t-q} \quad (3.1.1)$$

The first term in ARMA model expressed an autoregressive (AR) part of the order ‘ p ’. The (AR) term refers to the actual time series values x_t . Past time series values are $x_{t-1}, x_{t-2}, \dots, x_{t-p}$. The autoregressive coefficients are $\phi_1, \phi_2, \dots, \phi_p$ that relates x_t to $x_{t-1}, x_{t-2}, \dots, x_{t-p}$.

The second term in ARMA model expressed an moving averages (MA). The past random shocks or independent white noise sequence are $\pi_{t-1}, \pi_{t-2}, \dots, \pi_{t-q}$. These sequences mean = 0 and variance = σ^2 . The moving average coefficients are $\lambda_1, \lambda_2, \dots, \lambda_q$ that relates x_t to $\pi_{t-1}, \pi_{t-2}, \dots, \pi_{t-q}$ (Taneja et al., 2016).

ARMA model is useful for stationary data set. However, some data sets can be non-stationary property. Non-stationary data can not be forecasted or modeled. In order to attain reliable results, the non-stationary data should be transformed into stationary data. ARIMA model is developed for solving this problem (Nason, 2006).

An ARIMA (p, d, q) model is created when the parameters are merged with the

integration (differencing) term, where p, d and q stand for the orders of autoregression, differencing, and moving average, respectively (Taneja et al., 2016). The concept can be expressed numerically as

$$(1 - \beta)^d x_t = \frac{\lambda(\beta)}{\phi(\beta)} \pi_t \quad (3.1.2)$$

' β ' is the backshift operator. The term $\phi(\beta)$ is the autoregressive operator, calculated as

$$\phi(\beta) = 1 - \phi_1(\beta)^1 - \phi_2(\beta)^2 - \dots - \phi_p(\beta)^p \quad (3.1.3)$$

The term $\lambda(\beta)$ is the moving average operator, computed as

$$\lambda(\beta) = 1 - \lambda_1(\beta)^1 - \lambda_2(\beta)^2 - \dots - \lambda_d(\beta)^d \quad (3.1.4)$$

In this thesis, the `auto.arima` function in the `forecast` package is used in R studio to find automatically " p, d, q " values. However, these values can be found manually by plotting Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) graphs using statistical tools. Tsplot time series graphs, ACF and PACF, are originally shown to investigate the nature of the data. ACF graph can provide the magnitude of the relationship value between data at time t and the preceding time. The range of this magnitude, which can be represent as below, is between -1 and 1.

$$r_{kk} = \text{corr}(x_t, x_{t-k}) = \frac{\sum_{t=1}^{n-k} (x_t - x^*) (x_{t+k} - x^*)}{\sum_{t=1}^n (x_t - x^*)^2} \quad (3.1.5)$$

ACF graph provides the response whether stationary datasets can be modeled with MA. According to the number of values passing the threshold, q value can be found for datasets that can be modeled (Shakti et al., 2017). If ACF graph has significant decreases, the

dataset shows non-stationary dataset property.

PACF graph indicates the correlation between x_t and x_{t-1} . This correlation is calculated only between two specific data, so the dependency with data at other times is neglected. PACF graph provides the response whether stationary datasets can be modeled with AR. According to the number of values passing the threshold, p value can be found for datasets that can be modeled (Yakubu & Saputra, 2022). This formula can be represented as

$$r_{kk} = \text{corr}(x_t, x_{t-1} \mid x_{t-1}, x_{t-2}, \dots, x_{t-k+1}) \quad (3.1.6)$$

Also, Augmented Dickey Fuller (ADF) test is used to investigate whether the data set is stationary or not in R Studio. This hypothesis test is shown as,

H_0 : This data set is non – stationary

H_1 : This data set is stationary

According to test, if p value is greater than 0.05, the data set is non-stationary (Nwosu & Mba, 2016).

According to ADF test results and significant decreases in ACF graph, non-stationary data sets transformed to stationary using differencing. It can be represented as

$$x' = x_t - x_{t-1} \quad (3.1.7)$$

First-order derivative data may not be sufficient to make stationary, so second-order derivatives should be taken. It can be represented as (Yakubu & Saputra, 2022)

$$x'' = (x_t - x_{t-1}) - (x_{t-1} - x_{t-2}) \quad (3.1.8)$$

In order to find p and q value, ACF and PACF graphs is drawn again for transformed stationary data set. ACF and PACF graphs are drawn one times for stationary data sets

and two times for non-stationary data sets to compared with the values found by the auto.arima function in R Studio.

Finally, the Ljung-Box test is used to validate these forecasts. In this test, degrees of freedom is used. The confidence interval is taken as 95%. In this test's hypothesis test is,

H_0 : The data are independently distributed

H_1 : The data are not independently distributed

If p value is greater than 0.05, this forecast is validated by Ljung-Box test (Manoj & Madhu, 2014). Multiple Ljung-Box tests is performed by increasing the number of degrees of freedom to get more reliable results in R Studio.

3.2 DEA Model without Undesirable Outputs

DEA is a nonparametric methodology to measure the relative efficiency of performance measure within a set of homogeneous decision making units (DMUs) with inputs, desirable outputs (Martín-Gamboa & Iribarren, 2021).

3.2.1 Non-linear CCR - DEA Model

The main DEA model, which named as CCR (Charnes, Cooper and Rhodes), developed by Charnes et al., (1978). There are two CCR DEA methods according to the change in objective functions. These are input-oriented and output-oriented which have desirable inputs and desirable outputs. The input-oriented CCR-DEA model evaluate the relative efficiency of DMUs. This evaluation is done by maximizing the ratio of the total weighted output to the total weighted input, This model constraint is output-to-input ratio of each DMU should be less than or equal to unity.

The input-oriented CCR-DEA model can be represented as follow

$$\max E_{j_0} = \frac{\sum_{k=1}^s u_k y_{kj_0}}{\sum_{i=1}^m v_i x_{ij_0}}$$

Subject to

$$\begin{aligned} \frac{\sum_{k=1}^s u_k y_{kj}}{\sum_{i=1}^m v_i x_{ij}} &\leq 1, & \forall j, \\ u_k, v_i &\geq \epsilon, & \forall k, i, \end{aligned} \quad (3.2.1)$$

The output-oriented CCR-DEA model evaluate the relative efficiency of DMUs. This evaluation is done by minimizing the ratio of the total weighted input to the total weighted output, This model constraint is input-to-output ratio of each DMU should be more than or equal to unity.

The output-oriented CCR-DEA model can be represented as follow

$$\begin{aligned} \min E_{j_0} &= \frac{\sum_{i=1}^m v_i x_{ij_0}}{\sum_{k=1}^s u_k y_{kj_0}} \\ \text{Subject to} \quad & \frac{\sum_{i=1}^m v_i x_{ij}}{\sum_{k=1}^s u_k y_{kj}} \geq 1, & \forall j, \\ & u_k, v_i \geq \epsilon, & \forall k, i, \end{aligned} \quad (3.2.2)$$

where E_{j_0} is the evaluated DMU efficiency score. u_k is the weight of output k . v_i is the weight of input i . y_{kj} is the yield of output k produced by DMU $_j$. x_{ij} is the amount of input i consumed by DMU $_j$. ϵ is a small positive scalar.

3.2.2 Linear CCR - DEA Model

Although model (3.2.1) has non-linear and non-convex characteristics, it can be transformed into a linear programming model (Charnes & Cooper, 1962). The linear programming model is a way to determine a DMU's relative effectiveness. The Linear CCR-DEA model is represented as

$$\max E_{j0} = \sum_{r=1}^s u_r y_{rj0}$$

Subject to

$$\begin{aligned} \sum_{i=1}^m v_i x_{ij0} &= 1 \\ \sum_{r=1}^s u_r y_{rj} - \sum_{i=1}^m v_i x_{ij} &\leq u_0, \quad \forall j, \\ u_r, v_i &\geq \epsilon, \quad \forall r, i \end{aligned} \quad (3.2.3)$$

where E_{j0} is the evaluated DMU efficiency score. u_r is the weight of output r . v_i is the weight of input i . y_{rj} is the yield of output r produced by DMU $_j$. x_{ij} is the amount of input i consumed by DMU $_j$. ϵ is a small positive scalar.

Model (3.2.3) is solved n times, where n is the total number of DMUs, to determine the efficiency scores of each DMU. DMUs classified as efficient in Model (3.2.3) have an efficiency score of 1. Last constraint is used to reduce the erroneous weight dispersion and enhance the DEA's weak discriminating power (Karsak & Ahiska, 2005).

3.2.3 BCC - DEA Model

The BCC, named as Banker, Charnes and Cooper, model was created by Banker et al. (1984) to calculate the pure technical efficiency of decision-making units in relation to the efficient frontier. Moreover, it indicates if a DMU is functioning in a return to scale that is growing, decreasing, or stable.

Assume that there are k DMUs, (DMU $_j : j = 1, 2, \dots, k$) which consume s inputs ($x_i : i = 1, 2, \dots, s$) to yield m outputs ($y_r : r = 1, 2, \dots, m$). The BCC model evaluates the efficiency of DMU $_0$ by solving the following linear program.

$$\max \sum_{r=1}^m u_r y_{rj} - u_0$$

Subject to

$$\begin{aligned} \sum_{i=1}^s w_i x_{i0} &= 1 \\ \sum_{r=1}^m u_r y_{rj} - \sum_{i=1}^s w_i x_{ij} &\leq u_0, \quad \forall j, \\ u_0 &\text{, free} \end{aligned} \quad (3.2.4)$$

$$\begin{aligned} w_i &\geq \epsilon, & \forall i, \\ u_r &\geq \epsilon, & \forall r, \end{aligned}$$

where x_{ij} and y_{rj} are the inputs and outputs of each DMU. w_i and u_0 are the input and output weights of each DMU. y_{r0} and x_{i0} are the outputs and inputs of DMU₀ respectively. Also, ϵ is non-Archimedean infinitesimal value to provide weights to be bigger than zero. On account of the fact that basic DEA models identify more than one DMU as efficient units, finding the most efficient DMU is an issue.

3.3 DEA Model with Undesirable Outputs

It is known that most pollution problems arise from the joint production of undesirable outputs when desirable outputs are produced. For instance, the emissions of carbon dioxide are inevitable when energy used in manufacturing. The production of desirable and undesirable outputs by inputs is called production technology. The economic justification for using undesirable output variables as inputs in DEA models. Inputs and undesirable outputs cost a DMU money, therefore DMUs often try to minimize both sorts of variables.

The majority of theoretical advancements and practical implementations in DEA analysis rely on the premise of strong or weak disposability of all inputs and outputs. Based on the assumption of strong disposability, if a DMU is regarded as part of a production technology, any increase in its inputs or decrease in its outputs would still maintain the DMU within the bounds of the technology. Weakly disposable implies that both undesirable and desirable outputs can be reduced proportionally by the same factor, thereby maintaining the consistent relative proportions between the resulting outputs (Mehdiloo & Podinovski, 2019). The models, which is described below, show the weak disposability feature.

3.3.1 Non-linear BCC - DEA Model

Suppose x^g and x^b exemplify the desirable (good) and undesirable (bad) outputs, respectively. Obviously, the x^g aimed to increase and the x^b aimed to decrease for improving the performance. However, Standard BCC model aim to increase both x^g and x^b . In order to decrease the undesirable outputs, Färe et al. (1989) adapted the model into the following non-linear programming.

$$\begin{aligned}
 & \text{Max } \theta \\
 & \text{Subject to} \\
 & \sum_{j=1}^n z_j y_{ji} + s^- = y_0 \quad \forall i, \\
 & \sum_{j=1}^n z_j x_{jr}^g - s^+ = \theta x_0^g \quad \forall r, \\
 & \sum_{j=1}^n z_j x_{jk}^b - s^+ = \theta x_0^b \quad \forall k, \\
 & \sum_{j=1}^n z_j = 1 \\
 & z_j \geq 0, \quad j = 1, \dots, n.
 \end{aligned} \tag{3.2.5}$$

In above non-linear model is consist of an input vector y_j whose i^{th} component y_{ji} is the amount of input i consumed by DMU $_j$, an output vector x_{jr}^g whose r^{th} component x_{rj} is the amount of desirable output r yield by DMU $_j$, an output vector x_{jk}^b whose k^{th} component x_{jk} is the amount of undesirable output k yield by DMU $_j$. Model (3.2.5) is solved n times, where n is the total number of DMUs, to determine the efficiency scores of each DMU.

3.3.2 Linear BCC - DEA Model

Seiford and Zhu (2002) mentioned that many possibilities for undesirable outputs to desirable outputs in their study. For example, one possibility is to handle the undesirable outputs as inputs. Another possibility is to implement a monotone decreasing transformation (e.g., $1/x^b$) to the undesirable outputs. They used a linear monotone decreasing transformation method in their paper. Therefore, linearity and convexity can

be conserved in DEA model.

Firstly, each undesirable output is multiplied by “-1”. Then a suitable translation vector w is found to ensure that all negative undesirable outputs are positive.

$$x_j'^b = x_j^b + w > 0 \quad (3.2.6)$$

$$\max h$$

Subject to

$$\begin{aligned} \sum_{j=1}^n z_j x_{jr}^g &\geq h x_0^g & \forall r, \\ \sum_{j=1}^n z_j x_{jk}^b &\geq h x_0^b & \forall k, \\ \sum_{j=1}^n z_j y_{ji} &\leq y_0 & \forall i, \\ \sum_{j=1}^n z_j &= 1 \\ z_j &\geq 0, j = 1, \dots, n. \end{aligned} \quad (3.2.7)$$

In above linear model is consist of an input vector y_j whose i^{th} component y_{ji} is the amount of input i consumed by DMU_j , output vector x_{jr}^g whose r^{th} component x_{jr} is the amount of desirable output r yield by DMU_j , an output vector x_{jk}^b whose k^{th} component is the amount of undesirable output k yield by DMU_j . The aim of the model is to find the maximum value of the decision variable h for each DMU.

The absence of a standard w value is a factor in not using the model in this thesis.

3.3.3 Pure Environmental Performance Index DEA Model

On the other hand, models is developed in which undesirable outputs can be used without converting them into desirable outputs. Undesirable outputs can be dealt with by changing the constraints in the model.

According to the definition given by Färe and Grosskopf (2004), $P(a)$ is considered an "environmental output set" if it meets two properties and is both bounded and closed. If

we let $x \in R^{+N}$, $y \in R^{+M}$ and $u \in R^{+J}$ be the vectors of inputs, desirable outputs and undesirable outputs successively in these models.

P1. Outputs are weakly disposable, i.e., if $(y, u) \in P(a)$ and $0 \leq \theta \leq 1$, then $(\theta y, \theta u) \in P(x)$.

P2. Desirable outputs and undesirable outputs are null-joint, i.e., if $(y, u) \in P(x)$ and $u = 0$, then $y = 0$

P1 indicates that it is possible to achieve a proportional reduction in both desirable and undesirable outputs, while P2 states that the only way to completely eliminate all undesirable outputs is to cease the production process altogether.

According to Färe and Grosskopf (2004), the reference technology used in the DEA framework for environmental output sets can be referred to as the environmental DEA technology. Färe et al. (1989) developed constant return scale (CRS) environmental DEA technology to use in areas such as industrial efficiency assessment and environmental performance measurement. Let's suppose that there are k DMUs denoted by $k = 1, 2, \dots, K$. For each DMU, the observed data on input vectors, desirable outputs, and undesirable outputs are respectively represented by $x_k = (x_{1k}, x_{2k}, \dots, x_{nk})$, $y_k = (y_{1k}, y_{2k}, \dots, y_{mk})$, and $u_k = (u_{1k}, u_{2k}, \dots, u_{jk})$. CRS environmental DEA technology can be represented as

$$\begin{aligned}
 P(x) : \quad & \{ (y, u) : \sum_{k=1}^K z_k x_{nk} \leq x_n \quad \forall n, \\
 & \sum_{k=1}^K z_k y_{mk} \geq y_m \quad \forall m, \\
 & \sum_{k=1}^K z_k u_{jk} = u_j \quad \forall j, \\
 & z_k \geq 0, k = 1, \dots, K \}
 \end{aligned} \tag{3.2.8}$$

After developed CRS environmental DEA technology, the non-increasing returns to scale (NIRS) environmental DEA technology has been developed. The NIRS environmental DEA technology is created by applying the constraint of decision variables for standardized on the CRS environmental DEA technology. (Färe et al., 1994). The newly added equation is given below.

$$\sum_{k=1}^K z_k \leq 1 \quad (3.2.9)$$

Many models have emerged using CRS and NIRS environmental DEA technology. Especially, Tyteca (1996) developed the model with a Pure Environmental Performance Index (PEI). This methodology is selected for this thesis since it gives each DMU a precise measurement of environmental performance. Its name, "Pure" refers only to alter undesirable output. PEI can be expressed as (Tyteca, 1996)

$$\begin{aligned} & \min \theta \\ \text{Subject to} & \quad \sum_{k=1}^K z_k x_{nk} \leq x_{n0} \quad \forall n, \\ & \quad \sum_{k=1}^K z_k y_{mk} \geq y_{m0} \quad \forall m, \\ & \quad \sum_{k=1}^K z_k u_{jk} = \theta u_{j0} \quad \forall j, \\ & \quad \sum_{k=1}^K z_k \leq 1 \\ & \quad z_k \geq 0, k = 1, \dots, K. \end{aligned} \quad (3.2.10)$$

In above linear model is consist of an input vector x_k whose n^{th} component x_{nk} is the amount of input n consumed by DMU_k , output vector y_k whose m^{th} component y_{mk} is the amount of desirable output m yield by DMU_k , an output vector u_k whose j^{th} component u_{jk} is the amount of undesirable output j yield by DMU_k . In this model, the undesirable output constraint is equalized with the right hand side so that it behaves like the desirable output. Thus, the variable θ in Equation 3.2.10 gives a standardized environmental performance indicator. Also, the aim of the model is to find the minimum value of the decision variable θ for each DMU.

3.3.4 Mixed Environmental Performance Index DEA Model

Zhou et al. (2008) developed a new model because they decided to alter undesirable and desirable output. Since all technologies does not comply with CRS environmental DEA technology, they used variant returns to scale (VRS) environmental DEA technology. According to Färe and Grosskopf (2004), VRS environmental DEA technology can be

achieved by increasing the values of the undesirable outputs constraints on the right-hand side by a parameter greater than or equal to 1. Zhou et al. (2008) to ensure that the resulting technology from VRS does not violate the foundation of environmental DEA technology, it is important to find a balance between the concept of environmental output set and traditional DEA forms. To address this issue, they began by making slight adjustments to P1 and P2.

P1*. Outputs are weakly disposable, i.e., if $(y, u) \in P(a)$ and $0 \leq \theta \leq 1$, then $(\theta y, \theta u) \in P(x)$.

P2*. Desirable outputs and undesirable outputs are null-joint, i.e., if $(y, u) \in P(x)$ and $u \rightarrow 0$, then $y \rightarrow 0$

P1* still represents the idea that outputs have weak disposability, except for the exclusion of the point $(0_M, 0_J)$ from $P(x)$. P2* indicates that desirable outputs must also be infinitesimal if undesirable outputs are infinitesimal. The reason is that any DMU would not prefer to choose the point $(0_M, 0_J)$ because the production process has stopped there. The only difference between P1, P2 and P1*, P2* is that the latter is slightly weaker than the former. Therefore, the output set that satisfies P1* and P2* can still be considered as an environmental output set. This model is represented as

$$\begin{aligned}
 P(x) : \quad \{ (y, u) : \quad & \sum_{k=1}^K z_k x_{nk} \leq x_n \quad \forall n, \\
 & \sum_{k=1}^K z_k y_{mk} \geq y_m \quad \forall m, \\
 & \sum_{k=1}^K z_k u_{jk} = \alpha u_j \quad \forall j, \\
 & \sum_{k=1}^K z_k = 1 \\
 & \alpha \geq 1, \quad z_k \geq 0, k = 1, \dots, K \}
 \end{aligned} \tag{3.2.11}$$

This part of the discussion will focus on the model called Mixed Environmental Performance Index (MEI), which was created by Zhou et al. (2008) Since they made changes to both the right-hand side of the desirable and undesirable constraints, it has been named as “mixed”. This model developed using VRS model. Firstly, they claimed that the right-hand side of the desirable output constraint should be multiplied by the alpha

value.

$$\min \frac{\lambda}{\theta}$$

Subject to

$$\begin{aligned} \sum_{k=1}^K z_k x_{nk} &\leq x_{n0} & \forall n, \\ \sum_{k=1}^K z_k y_{mk} &\geq \theta \alpha y_{m0} & \forall m, \\ \sum_{k=1}^K z_k u_{jk} &= \lambda \alpha u_{j0} & \forall j, \\ \sum_{k=1}^K z_k &= 1 \\ \alpha &\geq 1, \theta, z_k \geq 0, k = 1, \dots, K. \end{aligned} \quad (3.2.12)$$

However, they proved that changing the value of Alpha will not affect the objective function of the model. Therefore, Alpha value is removed from this model. The MEI has the advantage of being used to measure the effectiveness of the DMU₀ in terms of the production rate of desirable to undesirable outputs.

As the final change in the nonlinear model, constraints are divided by θ . Therefore, this model is changed to linear programming model (LP). MEI can be represented as (Zhou et al., 2008)..

$$\min \lambda$$

Subject to

$$\begin{aligned} \sum_{k=1}^K z_k x_{nk} &\leq \beta x_{n0} & \forall n, \\ \sum_{k=1}^K z_k y_{mk} &\geq y_{m0} & \forall m, \\ \sum_{k=1}^K z_k u_{jk} &= \lambda u_{j0} & \forall j, \\ \sum_{k=1}^K z_k &= \beta \\ z_k &\geq 0, k = 1, \dots, K. \end{aligned} \quad (3.2.13)$$

β symbol is represented $1/\theta$.

In above linear model is consist of an input vector x_k whose n^{th} component x_{nk} is the

amount of input n consumed by DMU_k , output vector y_k whose m^{th} component y_{mk} is the amount of desirable output m yield by DMU_k , an output vector u_k whose j^{th} component u_{jk} is the amount of undesirable output j yield by DMU_k .

A summary of the advantage(s) and limitation(s) of the models with undesirable outputs is given in Table 3.1.

Table 3.1: DEA Models with Undesirable Outputs Advantage(s) and Limitation(s)

Author(s)	Year	Advantage(s)	Limitation(s)
Färe et al.	1989	Increases the desirable outputs and decreases the undesirable outputs.	- Requires two free variable - Does not provide performance measurement between DMUs.
Seiford and Zhu	2002	Preserves the linearity.	There is no standard value of “w”
Tyteca	1996	Gives each DMU a precise measurement of environmental performance.	- Confidence interval are not taken into account. - Does not provide to find the single most effective DMU.
Zhou et al.	2008	Measures the effectiveness of the DMU_0 in terms of the production rate of desirable to undesirable outputs.	Does not provide to find the single most effective DMU.

4. RESULTS

4.1 Design of Numerical Experiments

First of all, input and output indicators are chosen to design numerical experiments. In the DEA literature, primary energy consumption is frequently used as input (Zhou et al., 2008; Guo et al., 2011; Wang et al., 2017; Han et al., 2018). CO₂ emissions and GDP are frequently used as outputs input (Zhou et al., 2008; Guo et al. 2011; Deng et al., 2020; Zhang et al., 2015). On the other hand, greenhouse gases except CO₂ have not been used much as output in the DEA literature. For example, N₂O which is a significant greenhouse gas mainly due to agriculture (Reay et al., 2012). Thus, input indicator is chosen as primary energy consumption and output indicators are chosen as N₂O emissions, CO₂ emissions and GDP. Summary of regarding primary energy consumption, GDP, CO₂ and N₂O usage in the literature is given in Table 4.1.1.

Table 4.1.1: Summary of Input Output Indicator Usage In The Literature

Articles	Input	Outputs		
	Primary Energy Consumption	GDP	CO ₂ Emission	N ₂ O Emission
Zhou et al. (2008)	x	x	x	
Guo et al. (2011)	x	x	x	
Zhang et al. (2015)	x	x	x	
Wang et al. (2017)	x	x	x	
Han et al. (2018)	x		x	
Deng et al. (2020)	x	x	x	

The CO₂ Emissions amount of countries between 1980 and 2019 are found for CO₂ consumptions. The energy consumption amount of countries between 1980 and 2019 are found for primary energy consumption. Primary energy consumption include renewable and non-renewable. The GDP of countries between 1990 and 2019 are found for Gross Domestic Product. The N₂O Emission amount of countries between 1990 and 2019 are found for Nitrous Oxide Emission. In order to evaluate the performance of 2050, these data should be estimated for the year 2050.

There are many time series forecast methods such as Exponential Smoothing, Auto-Regressive Integrated Moving Average (ARIMA) etc. In this study, ARIMA method is chosen to forecast these data. For each input and output, the data of the countries are taken from the same year. All forecasts are obtained using R Studio v.2022.12.0.

CO₂ Emissions, primary energy consumption, GDP and N₂O Emission data are found from Our World in Data (OWID) website (<https://ourworldindata.org/>). This website has open-access data tools.

After selecting the input and output indicators, countries for performance measurement (DMUs) are chosen. 26 DMUs are Albania, Austria, Belgium, Bulgaria, Cyprus, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romaina, Spain, Sweden, Switzerland, Turkey and United Kingdom.

The Energy Consumption Amounts (in Twh) of European countries between 1980 and 2019 are found for primary energy consumption. Primary energy consumption include renewable and non-renewable. Table 4.1.2 is represented European Countries 1980-2019 Annual Primary Energy Consumption Amounts (in Twh). Germany has the highest energy consumption compared to other countries from 1980 to 2019.

Table 4.1.2: European Countries 1980-2019 Annual Primary Energy Consumption
Amounts (in Twh)

(<https://ourworldindata.org/grapher/primary-energy-consumption-by-region>)

Years/ Countries	Albania	Austria	Belgium	Bulgaria	Cyprus	Czechia
1980	47.77	315.66	565.18	334.96	10.28	620.41
1981	47.49	305.99	537.34	329.84	9.86	615.86
1982	47.73	295.79	513.87	337.94	11.81	608.71
1983	49.63	295.01	497.46	340.09	12.43	609.67
1984	49.94	292.66	519.75	338.10	12.61	630.00
1985	49.84	307.28	542.23	335.69	13.57	631.07
1986	48.67	310.36	559.26	342.50	14.14	637.85
1987	48.84	327.30	576.04	345.10	17.28	652.17
1988	49.41	322.37	587.49	352.95	17.85	655.03
1989	46.99	324.23	591.97	349.94	18.31	634.96
1990	33.66	329.05	618.64	323.22	19.28	545.78
1991	28.23	345.37	640.15	261.05	19.51	496.72
1992	24.67	339.18	638.74	245.18	22.80	482.00
1993	21.64	344.98	628.53	261.00	23.69	478.03
1994	20.57	343.07	661.32	251.25	23.73	465.31
1995	22.73	359.62	669.45	270.21	25.23	484.96
1996	25.01	360.71	711.12	268.97	25.61	501.68
1997	22.84	368.09	718.26	254.93	25.85	481.06
1998	24.57	373.85	732.41	244.53	27.45	466.99
1999	22.11	381.97	726.94	213.56	28.88	447.63
2000	28.73	383.28	740.15	215.89	30.26	473.14
2001	27.23	397.41	733.77	223.25	30.61	483.78
2002	29.50	398.17	730.28	217.84	30.19	484.96
2003	33.27	403.55	758.46	226.05	32.09	512.56
2004	35.49	410.29	761.28	218.83	31.23	525.23
2005	35.01	417.26	752.48	236.67	34.99	517.19
2006	32.97	412.54	754.28	241.22	34.41	527.02
2007	28.38	402.87	759.17	233.94	34.99	521.14
2008	30.99	410.95	771.12	230.08	35.85	510.94
2009	33.77	397.03	720.31	201.08	34.99	489.79
2010	36.06	410.53	767.66	209.28	34.03	510.14
2011	31.49	384.39	716.50	222.73	33.67	498.30
2012	30.81	403.15	686.54	211.25	31.54	495.20
2013	38.67	400.52	705.21	195.36	28.20	485.33
2014	34.06	383.82	655.32	208.58	28.22	474.50
2015	34.08	384.53	664.57	221.68	29.09	465.31
2016	37.98	397.18	716.32	210.04	31.64	459.02
2017	36.74	406.82	724.02	214.86	32.50	478.92
2018	41.67	397.14	718.62	214.45	32.36	477.46
2019	32.46	415.97	740.94	207.05	32.38	471.76

Table 4.1.2: European Countries 1980-2019 Annual Primary Energy Consumption
Amounts (in Twh)

Years/ Countries	Denmark	Finland	France	Germany	Greece	Hungary
1980	232.95	262.42	2290.45	4231.68	200.50	321.82
1981	209.24	263.91	2265.01	4099.00	195.91	318.55
1982	199.99	260.55	2180.74	3953.76	198.55	319.97
1983	190.09	257.88	2233.56	4009.86	199.88	314.31
1984	193.27	268.85	2307.34	4156.77	208.63	322.76
1985	217.79	282.40	2382.86	4278.25	220.41	332.97
1986	222.60	285.67	2440.78	4242.89	220.80	331.35
1987	214.58	300.66	2484.39	4278.47	241.58	345.97
1988	212.22	298.75	2516.27	4292.12	255.18	337.82
1989	195.68	300.15	2551.21	4246.53	276.73	329.05
1990	201.76	317.65	2628.65	4179.82	287.00	322.30
1991	232.57	324.78	2794.18	4078.24	290.93	300.91
1992	217.75	323.40	2815.38	3995.81	296.22	288.64
1993	230.81	326.05	2814.93	3978.08	300.11	280.35
1994	247.61	342.71	2777.65	3940.49	305.17	282.66
1995	243.14	326.13	2844.37	3960.51	316.16	285.88
1996	289.32	342.16	2951.42	4091.46	324.01	291.29
1997	262.24	345.34	2911.25	4038.08	333.34	284.22
1998	252.73	356.65	2979.52	4006.19	354.10	288.54
1999	244.95	350.40	3030.47	3949.31	353.85	287.74
2000	235.22	351.97	3069.37	3974.28	372.31	279.31
2001	235.79	360.01	3105.74	4044.48	375.48	286.11
2002	235.04	361.94	3075.03	3990.89	375.70	283.02
2003	253.09	387.94	3107.15	3987.04	397.25	283.64
2004	239.09	384.64	3132.53	3983.16	397.16	287.83
2005	230.60	349.11	3115.23	3934.88	398.45	307.11
2006	254.18	375.01	3089.17	4031.24	409.94	302.69
2007	240.82	373.64	3034.40	3858.15	418.49	298.43
2008	231.68	359.03	3042.7	3896.48	406.03	293.97
2009	217.78	333.55	2873.24	3653.60	391.21	270.30
2010	228.66	361.88	2958.50	3806.80	372.40	275.33
2011	215.71	338.14	2843.51	3666.76	364.72	267.15
2012	199.43	328.64	2842.63	3713.05	342.85	249.11
2013	208.33	330.51	2870.5	3817.82	321.68	236.42
2014	201.26	318.67	2748.27	3656.79	302.67	235.96
2015	194.15	316.53	2764.94	3721.69	305.77	248.64
2016	195.86	322.12	2718.11	3782.77	299.97	254.05
2017	195.83	314.97	2698.65	3828.37	314.43	266.76
2018	193.68	321.31	2745.11	3732.18	314.45	268.64
2019	188.01	312.57	2686.76	3625.34	331.34	272.14

Table 4.1.2: European Countries 1980-2019 Annual Primary Energy Consumption
Amounts (in Twh)

Years/ Countries	Ireland	Italy	Luxembourg	Malta	Netherlands	Norway
1980	100.27	1714.86	38.94	5.51	871.52	363.92
1981	97.84	1679.26	33.30	6.06	826.43	383.54
1982	97.14	1645.77	31.20	6.43	764.07	378.90
1983	95.74	1611.12	29.16	4.56	767.76	415.82
1984	94.73	1636.11	31.42	6.45	797.14	421.24
1985	99.39	1629.70	32.27	4.43	822.43	417.10
1986	107.34	1674.17	31.54	5.80	863.16	407.59
1987	108.60	1724.95	29.80	6.48	880.93	427.83
1988	108.04	1767.40	30.55	7.23	883.80	440.58
1989	111.35	1818.20	35.10	7.44	887.83	468.96
1990	116.91	1849.00	37.13	8.11	910.22	473.60
1991	121.11	1905.33	39.91	8.54	927.52	436.97
1992	121.94	1897.52	40.03	8.98	938.53	460.06
1993	124.60	1857.36	40.55	9.48	946.33	474.96
1994	129.52	1852.57	38.99	10.14	936.12	459.36
1995	132.08	1929.33	33.91	9.84	974.23	486.89
1996	139.67	1927.88	34.88	10.21	1016.22	447.97
1997	145.77	1961.34	34.14	10.89	998.00	470.88
1998	156.79	2006.57	32.96	11.41	1004.92	489.42
1999	165.86	2062.45	34.83	12.65	992.67	501.92
2000	172.51	2090.40	37.17	18.52	1005.58	554.98
2001	182.87	2087.93	39.83	20.40	1044.13	503.44
2002	181.62	2074.61	43.55	19.90	1044.33	523.15
2003	176.93	2141.19	45.67	23.13	1051.40	463.30
2004	179.25	2187.43	51.73	24.28	1086.56	471.73
2005	187.10	2190.92	52.50	20.71	1108.98	536.97
2006	190.99	2180.20	51.57	21.17	1086.18	492.66
2007	196.89	2138.84	50.06	23.06	1104.51	528.01
2008	195.98	2100.35	49.69	23.88	1090.60	540.47
2009	178.86	1957.57	47.52	25.45	1074.78	499.75
2010	178.39	2020.46	50.04	30.38	1137.53	480.41
2011	168.88	1979.98	48.74	28.88	1089.65	486.99
2012	166.47	1923.55	47.85	27.54	1053.58	537.99
2013	163.00	1832.75	45.58	26.15	1022.47	505.15
2014	162.39	1734.1	44.15	26.76	965.06	519.82
2015	172.54	1784.36	42.91	29.28	978.59	526.30
2016	180.01	1790.45	42.34	32.55	996.55	531.67
2017	180.61	1812.18	44.14	37.07	981.11	533.83
2018	184.60	1825.47	46.20	38.70	980.16	528.22
2019	184.22	1790.81	46.97	40.38	975.72	493.90

Table 4.1.2: European Countries 1980-2019 Annual Primary Energy Consumption
Amounts (in Twh)

Years/ Countries	Poland	Portugal	Romania	Spain	Sweden	Switzerland
1980	1495.11	127.24	729.58	881.26	628.60	300.30
1981	1347.98	125.43	731.31	889.54	622.75	299.55
1982	1372.67	135.47	725.15	888.36	592.28	293.23
1983	1378.92	140.11	720.41	909.26	586.92	305.37
1984	1433.52	145.72	714.97	922.34	620.69	296.41
1985	1465.95	148.49	712.63	914.75	674.66	316.54
1986	1507.33	157.66	728.15	934.48	700.99	332.44
1987	1556.26	161.27	755.11	968.76	684.16	330.07
1988	1526.55	178.58	768.49	1010.18	668.41	332.46
1989	1469.19	194.16	770.03	1061.33	653.14	311.25
1990	1210.05	196.54	733.17	1060.73	664.44	324.70
1991	1183.87	204.00	621.83	1098.08	630.40	333.28
1992	1132.08	206.92	548.58	1152.15	634.01	338.6
1993	1131.56	212.26	532.93	1113.52	627.00	337.47
1994	1082.85	219.62	502.51	1166.04	629.14	354.3
1995	1108.36	241.30	551.81	1211.49	635.06	335.98
1996	1163.55	247.74	548.50	1255.55	619.38	325.39
1997	1152.12	251.61	519.86	1326.17	638.62	347.43
1998	1103.69	274.74	475.14	1390.39	691.34	349.51
1999	1082.26	282.01	417.58	1434.88	671.27	364.47
2000	1017.06	290.72	417.36	1517.15	620.18	355.82
2001	1009.85	294.53	422.13	1584.85	665.81	379.81
2002	998.97	293.30	438.14	1604.48	624.27	354.02
2003	1033.68	299.86	438.63	1692.41	599.59	350.21
2004	1040.42	294.90	454.12	1755.73	643.90	345.23
2005	1063.18	295.00	454.47	1770.00	660.09	331.51
2006	1115.55	291.51	464.13	1793.80	620.82	345.01
2007	1111.95	293.63	448.00	1832.65	628.77	340.33
2008	1130.81	283.57	448.87	1780.61	618.00	351.80
2009	1090.06	285.32	392.01	1647.99	565.43	350.85
2010	1161.72	299.25	394.82	1688.59	599.51	341.46
2011	1167.44	285.76	405.21	1658.04	592.10	324.25
2012	1131.89	261.25	389.75	1648.23	627.07	342.09
2013	1135.11	285.52	362.56	1560.97	588.61	351.14
2014	1092.87	291.08	375.51	1531.70	585.66	334.73
2015	1103.78	285.75	377.29	1553.12	603.84	327.33
2016	1152.89	304.75	377.31	1566.91	593.81	307.95
2017	1198.57	296.59	384.18	1587.59	612.96	308.68
2018	1212.59	301.28	391.37	1608.54	599.85	313.33
2019	1176.41	286.52	382.18	1554.29	622.72	326.73

Table 4.1.2: European Countries 1980-2019 Annual Primary Energy Consumption
Amounts (in Twh)

Years/ Countries	Turkey	United Kingdom
1980	296.41	2378.21
1981	298.88	2312.13
1982	326.14	2281.73
1983	337.68	2290.61
1984	355.30	2289.38
1985	383.93	2386.37
1986	418.57	2452.67
1987	476.25	2448.89
1988	522.19	2481.02
1989	514.39	2483.55
1990	557.85	2503.30
1991	569.64	2555.90
1992	598.52	2539.39
1993	649.56	2568.08
1994	629.44	2536.94
1995	704.11	2545.65
1996	767.78	2669.20
1997	803.52	2622.35
1998	823.79	2650.04
1999	803.33	2636.63
2000	859.07	2659.16
2001	781.26	2688.55
2002	853.60	2628.15
2003	904.03	2665.40
2004	966.68	2679.59
2005	989.85	2707.91
2006	1098.15	2674.73
2007	1168.09	2594.80
2008	1172.45	2547.29
2009	1187.76	2419.77
2010	1250.39	2476.41
2011	1336.18	2340.56
2012	1418.39	2368.11
2013	1407.44	2356.09
2014	1453.24	2219.63
2015	1589.76	2244.82
2016	1669.62	2219.96
2017	1770.15	2210.39
2018	1748.16	2207.48
2019	1807.46	2146.40

The GDP (\$/capita) of European countries between 1990 and 2019 are found for Gross Domestic Product. Table 4.1.3 is represented European Countries 1990-2019 GDP (\$/capita). It is observed that Luxembourg has the highest GDP value compared to other countries from 1990 to 2019.

Table 4.1.3: European Countries 1990-2019 GDP (\$/capita)
(<https://ourworldindata.org/grapher/gross-domestic-product>)

Years/ Countries	Albania	Austria	Belgium	Bulgaria	Cyprus	Czechia
1990	4827.04	37494.56	35506.93	12507.71	25232.00	23585.18
1991	3496.38	38399.68	36023.68	11565.37	24769.06	20895.88
1992	3264.83	38774.49	36426.99	10840.08	26385.94	20768.79
1993	3598.82	38658.65	35935.96	10765.15	25936.69	20760.05
1994	3921.62	39435.21	36981.45	10998.15	26904.7	21356.31
1995	4471.61	40425.39	37784.15	11362.65	28630.78	22758.60
1996	4908.94	41319.38	38208.72	12015.93	28529.89	23756.98
1997	4400.32	42136.66	39562.37	10382.85	28871.17	23659.32
1998	4819.08	43597.89	40252.47	10848.42	30262.11	23597.31
1999	5474.86	45060.62	41583.10	9993.45	31421.02	23948.38
2000	5892.59	46469.86	43024.14	10503.62	32943.11	24976.51
2001	6441.45	46878.92	43347.89	11124.51	33878.07	25833.41
2002	6753.89	47419.28	43890.60	12036.18	34738.94	26289.63
2003	7154.01	47633.11	44160.91	12767.27	35219.59	27239.56
2004	7580.14	48633.27	45540.47	13701.50	36498.35	28542.25
2005	8040.09	49387.03	46342.19	14779.19	37722.42	30384.45
2006	8568.56	50840.70	47212.58	15904.90	38847.04	32352.81
2007	9150.13	52565.07	48590.40	17078.37	39967.43	33956.25
2008	9912.16	53166.05	48423.52	18250.54	40397.70	34580.44
2009	10313.92	51030.73	47064.79	17767.51	38535.11	32782.61
2010	10749.48	51843.43	47972.56	18160.61	38296.70	33483.14
2011	11052.79	53179.15	48154.87	18661.48	37481.81	34002.19
2012	11227.97	53297.45	48210.93	18911.58	35642.64	33688.10
2013	11361.27	52997.75	48204.59	18911.13	33384.46	33661.47
2014	11586.83	52932.90	48748.62	19202.81	33136.48	34386.70
2015	11878.45	52873.86	49456.40	19988.22	34453.12	36168.42
2016	12291.86	53345.74	49829.93	20740.79	36509.07	37014.96
2017	12770.96	54172.99	50442.27	21469.95	38287.97	38824.89
2018	13317.09	55258.37	51126.67	22206.09	39977.00	39932.99
2019	13656.59	55833.56	51944.17	23265.88	41521.92	40981.05

Table 4.1.3: European Countries 1990-2019 GDP (\$/capita)

Years/ Countries	Denmark	Finland	France	Germany	Greece	Hungary
1990	39027.98	32939.38	33732.02	36699.48	24262.95	16380.34
1991	39469.32	30831.61	33897.23	38294.16	24716.63	16432.11
1992	40108.89	29648.74	34268.54	38734.94	24700.24	15934.83
1993	39979.76	29310.31	33905.88	38105.23	24162.48	15861.11
1994	41969.69	30340.82	34576.54	38881.57	24522.63	16350.92
1995	43015.68	31499.81	35177.66	39366.09	24920.84	16617.59
1996	44013.39	32548.02	35548.63	39568.6	25521.39	16659.88
1997	45260.14	34506.77	36250.69	40218.85	26534.61	17218.17
1998	46096.37	36293.39	37413.44	41022.61	27415.74	17931.36
1999	47298.54	37795.06	38494.95	41769.81	28149.96	18534.46
2000	48907.01	39894.20	39732.28	42928.18	29133.96	19415.02
2001	49133.22	40842.34	40226.63	43576.64	30180.36	20252.41
2002	49204.90	41439.02	40388.63	43417.31	31249.53	21273.13
2003	49262.64	42168.7	40433.49	43089.47	32981.50	22205.54
2004	50446.54	43724.96	41272.63	43605.28	34565.06	23367.61
2005	51483.27	44786.91	41643.99	43949.29	34670.34	24419.83
2006	53322.29	46412.2	42367.57	45678.08	36520.21	25423.43
2007	53569.03	48664.27	43127.21	47100.61	37619.82	25533.37
2008	52982.53	48817.99	42996.21	47643.22	37394.34	25835.55
2009	50114.05	44662.1	41546.49	45044.49	35692.10	24168.98
2010	50825.41	45874.66	42147.67	46999.24	33693.21	24486.04
2011	51293.21	46825.82	42864.02	49757.93	30318.40	25012.29
2012	51216.31	45952.25	42790.63	49872.45	28322.57	24825.58
2013	51479.27	45328.57	42816.27	49954.17	27810.91	25343.71
2014	52048.34	44976.78	43021.39	50845.53	28129.96	26485.41
2015	52892.64	45072.59	43345.79	51159.30	28260.39	27531.64
2016	54185.01	46206.79	43705.15	51879.67	28239.92	28218.28
2017	55356.68	47570.13	44577.07	53071.46	28604.86	29501.12
2018	56178.77	48049.58	45284.00	53486.84	29141.17	31121.67
2019	57161.69	48582.59	46017.77	53929.64	29698.03	32553.70

Table 4.1.3: European Countries 1990-2019 GDP (\$/capita)

Years/ Countries	Ireland	Italy	Luxembourg	Malta	Netherlands	Norway
1990	26437.22	36585.68	70860.82	16106.93	36461.42	42136.60
1991	26792.88	37122.82	75961.67	16659.56	37057.58	43229.92
1992	27500.37	37407.11	76323.30	17262.05	37405.93	44517.44
1993	28100.04	37065.43	78468.92	17856.28	37613.25	45512.39
1994	29600.52	37855.01	80365.23	18689.74	38494.22	47541.77
1995	32286.40	38947.20	80379.13	19737.06	39498.14	49260.97
1996	34393.73	39429.50	80401.03	20348.56	40691.89	51476.20
1997	37801.17	40129.90	83702.81	21256.80	42235.49	53903.44
1998	40684.89	40844.75	88185.80	22201.57	43933.57	54989.70

1999	44461.93	41501.79	94115.38	23112.05	45839.13	55713.76
2000	47996.98	43053.93	99301.52	27482.89	47422.20	57127.38
2001	49744.63	43869.43	101143.10	26956.81	48160.79	58018.31
2002	51797.43	43915.39	103317.30	27442.97	47958.33	58540.84
2003	52494.20	43781.22	104743.00	28373.78	47806.88	58728.16
2004	55040.82	44118.04	107634.80	28223.38	48586.70	60699.57
2005	56943.83	44260.83	108632.40	28992.95	49467.43	61870.36
2006	58189.78	44918.17	113346.00	29612.62	51097.36	62846.94
2007	59530.89	45356.54	120647.80	30918.52	52909.97	64062.44
2008	55712.50	44623.60	118154.70	31893.38	53848.25	63570.34
2009	52336.63	42074.92	112230.10	31294.92	51607.61	61689.56
2010	52965.79	42664.36	114344.00	32867.96	52032.99	61353.48
2011	53298.81	42892.30	112998.40	32881.86	52594.23	61157.13
2012	53045.65	41501.71	112137.10	33929.36	51860.05	61990.69
2013	53435.64	40268.11	113050.70	35287.49	51640.08	61878.98
2014	57668.75	39898.53	113313.60	37230.30	52187.00	62390.13
2015	71508.73	40247.83	113182.70	39845.14	52974.12	62987.52
2016	72150.04	40837.74	116283.70	40536.75	53847.83	63104.08
2017	77749.20	41581.12	114985.80	42644.08	55088.63	64050.76
2018	83726.36	42045.92	115049.90	43313.51	56060.91	64341.26
2019	86650.01	42708.04	116518.30	43950.62	56784.04	64385.01

Table 4.1.3: European Countries 1990-2019 GDP (\$/capita)

Years/ Countries	Poland	Portugal	Romania	Spain	Sweden	Switzerland
1990	11314.96	23556.86	13302.46	27543.92	34156.82	56329.21
1991	10483.90	24642.60	11685.09	28173.39	33536.02	55120.11
1992	10714.66	24930.45	10757.38	28296.26	32953.62	54491.90
1993	11086.96	24391.20	10936.72	27859.54	32086.01	53929.86
1994	11649.16	24560.36	11383.28	28388.01	33110.82	54181.00
1995	12459.67	25523.71	12117.35	29042.34	34233.70	54078.95
1996	13211.57	26318.97	12627.19	29691.10	34719.11	54106.57
1997	14054.39	27354.84	12049.53	30661.65	35764.68	55201.20
1998	14701.34	28525.52	11829.41	31876.44	37286.09	56724.50
1999	15386.94	29472.71	11803.37	33173.12	38839.43	57440.05
2000	16257.65	30383.14	12109.54	34757.61	40625.36	59389.43
2001	16466.79	30756.02	12920.48	35874.75	41103.73	59944.78
2002	16809.82	30823.85	13909.66	36337.55	41870.26	59489.75
2003	17409.64	30422.60	14338.35	36750.44	42678.29	59022.35
2004	18287.83	30892.82	15924.04	37249.77	44354.39	60271.93
2005	18937.48	31076.64	16770.64	37963.37	45440.30	61613.39
2006	20111.30	31524.75	18224.77	38858.47	47292.31	63686.25
2007	21543.16	32251.57	19833.96	39520.82	48557.38	65641.71
2008	22444.91	32307.91	22044.29	39240.39	47963.49	66598.86
2009	23064.95	31269.41	21002.26	37430.68	45492.77	64404.08
2010	23996.14	31798.15	20303.15	37319.48	47791.37	65819.73

2011	25124.28	31304.82	20792.16	36884.26	48947.44	66342.01
2012	25457.21	30156.70	21311.12	35769.46	48300.84	66440.29
2013	25759.34	30042.89	22197.02	35371.74	48462.16	66877.16
2014	26649.58	30444.60	23084.36	35968.62	49259.00	67682.69
2015	27797.06	31118.79	23878.17	37377.07	50928.96	68025.92
2016	28682.69	31847.54	25145.00	38477.58	51334.43	68663.24
2017	30064.50	33044.71	27141.90	39528.93	51947.95	69103.57
2018	31674.13	34040.73	28523.45	40256.95	52349.29	70597.29
2019	33185.16	34945.66	29875.06	40802.49	52850.57	70944.35

Table 4.1.3: European Countries 1990-2019 GDP (\$/capita)

Years/ Countries	Turkey	United Kingdom
1990	12629.47	31217.22
1991	12507.31	30777.53
1992	12923.08	30817.52
1993	13689.66	31509.19
1994	12844.21	32637.84
1995	13637.62	33375.71
1996	14413.16	34099.32
1997	15261.54	35681.24
1998	15384.55	36699.52
1999	14653.70	37671.07
2000	15433.59	38915.20
2001	14330.42	39569.15
2002	15031.22	40238.59
2003	15670.42	41265.18
2004	16968.87	41997.61
2005	18251.67	42791.90
2006	19277.53	43576.20
2007	20009.69	44219.49
2008	19933.07	43767.70
2009	18731.52	41592.93
2010	20027.67	42147.77
2011	21932.29	42429.21
2012	22610.68	42754.54
2013	24117.66	43271.83
2014	24881.73	44239.15
2015	25958.64	45041.06
2016	26385.00	45712.79
2017	27913.82	46372.39
2018	28318.44	46853.20
2019	28197.25	47368.59

The CO₂ Emissions Amount (tonnes) of European countries between 1980 and 2019 are found for CO₂ consumptions. Table 4.1.4 is represented European Countries 1980-2019 Annual CO₂ Emission Amounts (tonnes). Germany has the highest CO₂ Emission compared to other countries from 1980 to 2019.

Table 4.1.4: European Countries 1980-2019 Annual CO₂ Emission Amounts (tonnes)
(<https://ourworldindata.org/co2-dataset-sources>)

Years/ Countries	Albania	Austria	Belgium	Bulgaria	Cyprus	Czechia
1980	5170837	52024932	134835790	77250580	4653217	184677390
1981	7339622	55832892	123573624	80086800	5142773	182648460
1982	7307607	53565290	117101900	89844184	5517491	180846050
1983	7630809	51668240	101201840	90061304	5760916	181076180
1984	7825903	54214052	104966536	87044930	6002476	187168030
1985	7881540	54366320	104004500	89221336	5874107	184599820
1986	8058077	53728532	102366760	91172270	6224288	185854500
1987	7447081	57373910	102588710	91273150	6312090	183641400
1988	7329222	52937220	99742824	86913330	6609144	180617040
1989	8986169	53696290	106792080	86482220	6875935	172330690
1990	5520602	62145250	120292640	76699190	7122416	164210750
1991	4290226	65743936	123362370	61516960	6996583	148879300
1992	2517116	60243908	122488060	57366296	7185924	145710620
1993	2337999	60670572	121422696	58426650	7576801	140129090
1994	1923806	61045756	124795260	56404590	7803428	132673280
1995	2089065	64023070	125933060	57951036	7957711	131627140
1996	2017508	67367016	129474980	58501570	8185407	135004350
1997	1543009	67263590	123983500	55855868	8504782	130834170
1998	1754709	66898316	130212380	53174790	8717247	125427260
1999	2986196	65651040	124704140	46378900	8471739	116569944
2000	3024926	66149780	126719540	45464332	8102698	127155960
2001	3220656	70149500	126063800	48980164	7789403	127030020
2002	3748272	71953620	126860504	46155492	7264032	123946890
2003	4303499	77460984	128245630	50532396	6583978	127478650
2004	4176684	77678290	128778890	49583350	6952145	128247530
2005	4261413	79078110	125636390	50654404	6972964	125688560
2006	3910715	76806460	123880440	51891852	7375415	126566100
2007	3948970	74106780	120477010	55737584	7525365	128369900
2008	4397043	73481910	120175600	54076124	7342546	122912260
2009	4406552	67298660	107732350	45812410	7343176	115013224
2010	4783865	72006410	114557864	47858924	4653217	117482140
2011	5314676	69893110	105020120	53174764	5142773	115185840
2012	4850060	67265900	102355640	48338904	5517491	111280680
2013	5287466	67759450	102666430	42678600	5760916	106711390

2014	5999658	64160004	96887000	45266300	6002476	104228850
2015	4712137	66348824	101061720	48260532	5874107	104995650
2016	4631977	67210744	99601624	45484310	6224288	106655710
2017	5564149	69592824	99126280	47569756	6312090	107747750
2018	4984045	66557184	99873630	43616064	6609144	106337976
2019	4947485	67936184	99432616	42255764	6875935	101012960

Table 4.1.4: European Countries 1980-2019 Annual CO₂ Emission Amounts (tonnes)

Years/ Countries	Denmark	Finland	France	Germany	Greece
1980	60348444	58139290	511112160	1100066000	50888696
1981	51773060	51403284	459371870	1048523300	50125424
1982	53684428	42976476	440436220	1015733900	51508770
1983	50167910	41463372	423313730	1011604900	54789372
1984	50856492	42147140	412001800	1033244600	56284932
1985	60065330	49549076	405222050	1044117900	59771930
1986	58907150	53214370	390393100	1047471940	58274420
1987	58346470	57533400	387772640	1032442900	62576332
1988	55112276	52058084	385571070	1029024200	67051870
1989	48808830	52447930	399678370	1008792400	73230810
1990	53584856	56914336	393422900	1051979140	83438040
1991	64200052	55188760	418367140	1013824100	83407500
1992	58390816	54265060	406648320	965541800	84975656
1993	60637230	56313364	388080130	955819970	84284960
1994	64698110	61732668	381908900	939492300	86430260
1995	61614372	58115516	386261860	938613570	86963200
1996	74868584	64033060	401373100	958700350	89114950
1997	65468796	62696172	393945150	930870140	93801560
1998	61237956	59351464	413634370	922812200	98621790
1999	58652424	58866896	412183140	895352100	97934820
2000	54306120	57009924	406828930	899351800	102973170
2001	55896360	62513736	411613950	916144450	105361864
2002	55553624	65040970	407790500	899449800	105000510
2003	60645144	72654330	412534600	900627700	109066730
2004	55099644	68939110	413779940	886637100	109485270
2005	51534636	57047316	416165820	866302800	113888960
2006	59487504	68370690	406462370	877938750	112419550
2007	54709150	66759836	396660500	851223000	114545700
2008	51256210	58621000	390777570	854508160	111080376
2009	48851236	55905070	371045220	789899970	104319840
2010	49203676	64080756	376645400	832540900	97354150
2011	44248110	56637172	354602460	808911500	94505230
2012	39870932	51145690	356912580	813693060	91392584
2013	41772984	51703750	358623360	831207600	81713256
2014	37577748	47595830	327107260	792255400	78639620
2015	35227976	44099096	331580000	795556600	74927624

2016	37033260	47181860	334439780	800339840	71364170
2017	34780268	44577796	337457540	785616450	74845050
2018	34724976	45796460	322526820	754408450	71781990
2019	30955444	42381840	316386780	707149950	65756230

Table 4.1.4: European Countries 1980-2019 Annual CO₂ Emission Amounts (tonnes)

Years/ Countries	Hungary	Ireland	Italy	Luxembourg	Malta
1980	86608750	26271548	386433020	11073563	1022256
1981	86352020	26061508	375300130	9485958	1143168
1982	86600860	25566268	366879040	8924177	1311712
1983	88856200	25728682	358409100	8364030	996608
1984	90561280	25549450	364601060	9004226	1363008
1985	85828376	26749804	368982400	9236842	1198128
1986	83240790	28550302	363187620	9111157	1483920
1987	84136470	30226336	380098560	8812260	1853984
1988	78054780	29883636	385962240	9099730	2011535,9
1989	75917200	30061098	404741950	9846277	2169088
1990	73225540	32944420	439549820	11823353	2394194
1991	69656250	33674308	439094100	12443151	2238107
1992	62084830	33495316	439315300	12209723	2292080
1993	63389270	33716364	431604830	12354764	2870399
1994	61786556	34838450	425796800	11542475	2647929
1995	61391316	35852984	449826100	9151729	2439420
1996	63024780	37469268	444029380	9201614	2550535
1997	61623560	38804984	449754140	8553970	2556728
1998	61163664	40708970	461945950	7675949	2513582
1999	61663744	42440180	466424930	8127876	2591822
2000	58365150	45249116	470487170	8709963	2507257
2001	59968212	47607612	470568100	9207531	2647718
2002	59004708	46081588	477998980	9983685	2687784
2003	61756176	45684108	495961630	10459170	2960534
2004	60129556	46166788	501563230	11829091	2819964
2005	60276270	48156596	502255420	12087836	2644672
2006	59633210	47604660	496846750	11920357	2661658
2007	58553668	47664332	490566270	11317780	2731301
2008	57248108	47363260	478868670	11184473	2739894
2009	51464056	42179308	424694430	10638966	2527633
2010	52068732	41793616	436117440	11202164	2589131
2011	50191330	38056380	424256260	11102959	2577198
2012	46757480	38227156	403696900	10867476	2726207
2013	43611550	37281748	369679700	10325364	2379190
2014	43729844	36853016	349390340	9828191	2364387
2015	46653468	38718040	361163170	9347466	1665291
2016	47113090	40369540	358182560	9089235	1356353
2017	49515228	39078030	352735400	9261198	1530878

2018	49463316	39012370	349005020	9566671	1546948
2019	49234644	37325664	339233200	9751728	1649193

Table 4.1.4: European Countries 1980-2019 Annual CO₂ Emission Amounts (tonnes)

Years/ Countries	Netherlands	Norway	Poland	Portugal	Romania
1980	176631780	31812080	463329060	26773498	196199090
1981	164109810	31844822	408996960	27000480	197730260
1982	133487120	30955990	420970430	28999878	195329230
1983	137357330	31997660	421023780	29901626	200116430
1984	144072860	33868936	432467400	28793810	188816660
1985	146980000	32346684	444507870	27129670	193906930
1986	144014380	34856604	451848670	30221142	201641340
1987	151480370	33280242	463732640	31198344	211631660
1988	145602740	35675788	444229980	32567554	212221680
1989	161664220	34233910	422175100	40822224	213599490
1990	161806910	35097000	376813570	45325084	173463870
1991	170227330	33535000	373834430	47141640	141915280
1992	170015200	34455000	364748770	50969940	131509920
1993	170206050	36000000	365448060	49483612	122278580
1994	170787550	37905000	360522200	50261172	120542340
1995	172300140	38508000	362892300	54524436	125582620
1996	181452350	41572000	377577860	51815228	128935576
1997	174492780	41734000	367524640	54694410	117962810
1998	175461140	41871000	339365280	59247500	104398870
1999	169934500	42636000	329552350	66899644	88357130
2000	171082220	42147000	317719200	65685548	92668296
2001	176207520	43526000	313850000	65237190	98150930
2002	175567730	42592000	306610300	69643310	98356840
2003	179005310	43980000	319624030	64537890	102844230
2004	180891780	44307000	324436220	67385150	102109620
2005	176917310	43342000	323409470	69717980	100241790
2006	172092060	43926000	337317570	64923910	103180296
2007	171874020	45666000	336731500	62437400	107886680
2008	174853120	44795000	330485120	60106790	105851800
2009	169529330	43225000	316868500	57207480	87002450
2010	181526740	45691000	334917000	53001360	84632660
2011	168259660	44791000	334337150	51801576	91754480
2012	164688780	44300000	326734900	49959708	90239240
2013	164674480	44586000	322651200	48163480	78929520
2014	157655580	45046000	310319100	47945816	78453480
2015	164142510	45590000	313455700	52270292	77996264
2016	164862030	44765000	324381220	50442236	77011540
2017	162493950	44242000	337734940	55210188	80042936
2018	158627840	44393000	337048480	51459108	80516216

2019	153032800	42784000	318487680	47618828	77030616
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Table 4.1.4: European Countries 1980-2019 Annual CO₂ Emission Amounts (tonnes)

Years/ Countries	Spain	Sweden	Switzerland	Turkey	United Kingdom
1980	213911900	71713690	40490604	75212270	579035400
1981	206096210	69388504	38812388	79185990	560554500
1982	208598540	62256744	36585736	86210030	548240400
1983	203435150	58268316	40022812	89812184	545485100
1984	197667200	57308090	39128720	94906030	529108160
1985	199931400	62364010	39780900	105662350	559627300
1986	189112670	62009780	42246576	115617870	568554000
1987	189508060	59694708	40205244	128442184	571667600
1988	197457900	57425120	40662424	124727510	570293760
1989	224885400	55520776	39419076	137569950	581576100
1990	231328450	57580090	44159880	151664530	601945100
1991	241074290	57950550	46133384	158140740	609412700
1992	249939230	57688900	46016510	164061420	593845950
1993	241298910	57725988	43611868	171133730	579612540
1994	253803790	60186576	42676628	167560900	574016900
1995	267577460	59605076	43419264	181481820	566158900
1996	255049060	63521836	44107436	199582750	586760700
1997	267589840	58425370	43047480	212037400	562708160
1998	276184600	58893228	44622852	212069940	568543700
1999	299722140	56031844	44445644	207857780	561649600
2000	311674620	54890664	43622370	229858200	569033660
2001	313620600	55821960	45077500	213483470	577970560
2002	333730300	56791590	43463864	221148220	560273200
2003	338045860	57371496	44647716	236683300	571618750
2004	354827940	56682884	45238264	244688740	573429760
2005	370065760	54066084	45778556	264768600	570338370
2006	361120320	53885096	45373348	282266700	567845600
2007	368985600	53151970	43368760	313578140	559566460
2008	337182430	51070464	44710572	310532320	544932400
2009	297747800	47421460	43538550	316319330	494107700
2010	284282700	53287344	45045708	316036480	511904580
2011	285132260	49405180	40985230	341862340	469713300
2012	279384960	46918584	42253030	355882620	487476770
2013	253102700	45351340	43187724	347152670	477611260
2014	255459100	43477930	39233630	363866340	438807070
2015	272164670	43741732	38731820	384330460	422460800
2016	261227660	43415984	39185340	405304500	399430140
2017	275053200	42704240	38178644	430220380	387367140
2018	270052300	42094908	36873816	422568900	379729760

2019	251825150	40982492	36733064	401719740	364753280
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The N₂O Emission Amounts (tonnes of CO₂ - equivalents) of European countries between 1990 and 2019 are found for Nitrous Oxide Emission. Table 4.1.5 is represented European Countries 1990-2019 N₂O Emission Amounts (tonnes of CO₂ - equivalents). Poland has the highest N₂O Emission compared to other countries from 1990 to 2019.

Table 4.1.5: European Countries 1980-2019 Annual N₂O Emission Amounts (tonnes of CO₂ - equivalents)

(<https://ourworldindata.org/grapher/nitrous-oxide-emissions>)

Years/ Countries	Albania	Austria	Belgium	Bulgaria	Cyprus	Czechia
1990	1559999	4969999	8170000	8250000	319999	319999
1991	1190000	4989999	8100000	7050000	319999	319999
1992	1110000	4780000	7730000	5239999	370000	370000
1993	1159999	4710000	7949999	4530000	370000	370000
1994	1370000	4670000	8449999	4570000	370000	370000
1995	1340000	4650000	8829999	4340000	370000	370000
1996	1190000	4760000	9319999	4429999	379999	379999
1997	1129999	4690000	9020000	4150000	360000	360000
1998	1159999	4699999	9109999	3579999	370000	370000
1999	1129999	4699999	9050000	3319999	370000	370000
2000	1210000	4659999	7679999	3730000	360000	360000
2001	1139999	4550000	7469999	3920000	379999	379999
2002	1289999	4469999	7960000	4329999	400000	400000
2003	1299999	4480000	7199999	4440000	400000	400000
2004	1259999	3930000	7280000	4340000	389999	389999
2005	1269999	3970000	7159999	3960000	360000	360000
2006	1210000	3960000	6150000	3230000	360000	360000
2007	1210000	3869999	5519999	3599999	370000	370000
2008	1129999	4000000	5480000	3809999	360000	360000
2009	1120000	3769999	5679999	3789999	379999	379999
2010	1110000	3779999	6190000	3730000	389999	389999
2011	1149999	3779999	4940000	4369999	379999	379999
2012	1149999	3829999	4949999	3450000	379999	379999
2013	1120000	3849999	4840000	3779999	340000	340000
2014	1139999	3930000	4820000	3859999	340000	340000
2015	1190000	3950000	4780000	4030000	349999	349999
2016	1230000	3960000	4619999	4050000	349999	349999
2017	1190000	3890000	4570000	4119999	360000	360000
2018	1080000	3829999	4590000	4130000	360000	360000
2019	1100000	3849999	4579999	4159999	370000	370000

Table 4.1.5: European Countries 1980-2019 Annual N₂O Emission Amounts (tonnes of CO₂ - equivalents)

Years/ Countries	Denmark	Finland	France	Germany	Greece	Hungary
1990	7300000	6500000	61299999	65349998	7400000	9649999
1991	7170000	5920000	61759998	64269997	7170000	7579999
1992	6699999	5739999	59659999	64290001	7059999	5500000
1993	6739999	5829999	59900001	61240002	6599999	6139999
1994	6639999	6019999	60669998	64690002	6730000	6880000
1995	6639999	6000000	61500000	62779999	6539999	6119999
1996	6590000	6000000	63759998	64000000	6840000	7139999
1997	6579999	6039999	63130001	61479999	6539999	7019999
1998	6400000	5889999	55950000	48790001	6400000	6619999
1999	6440000	5900000	51229999	45319999	6340000	6599999
2000	6440000	5960000	49099998	43659999	6409999	6940000
2001	6260000	5860000	49849998	45319999	6119999	7460000
2002	6099999	6050000	47369999	45119999	6159999	6369999
2003	6250000	6070000	47250000	44909999	6190000	6280000
2004	5539999	6230000	44700000	46229999	5840000	7239999
2005	5429999	6440000	43529999	44479999	5679999	6940000
2006	5380000	6119999	42709999	43049999	5369999	6730000
2007	5349999	6309999	43790001	46720001	5280000	6199999
2008	5360000	6639999	41970001	44389999	5420000	5679999
2009	5070000	5519999	39779999	44590000	4960000	5150000
2010	4980000	5190000	38689999	37560001	5349999	5000000
2011	4969999	4750000	36740002	36020000	5909999	5289999
2012	5000000	4780000	37330002	36099998	5099999	5159999
2013	4909999	4880000	38279999	36729999	4800000	5550000
2014	5090000	4980000	38540001	37619999	4670000	5389999
2015	5260000	4960000	39150002	36740002	4489999	5369999
2016	5239999	4880000	37650002	36069999	4480000	5539999
2017	5250000	4909999	38660000	34979999	4530000	5570000
2018	4880000	4940000	38119999	33119999	4329999	5929999
2019	5170000	5010000	38279999	34119999	4269999	5699999

Table 4.1.5: European Countries 1980-2019 Annual N₂O Emission Amounts (tonnes of CO₂ - equivalents)

Years/ Countries	Ireland	Italy	Luxembourg	Malta	Netherlands
1990	10029999	26430000	300000	59999	15800000
1991	9779999	26559999	319999	59999	15930000
1992	9850000	25979999	319999	70000	15989999
1993	10180000	25770000	319999	70000	16350000
1994	10369999	25069999	319999	70000	16040000
1995	10350000	25840000	310000	70000	15649999

1996	10220000	26100000	319999	59999	15590000
1997	10310000	25750000	319999	70000	15340000
1998	10750000	26149999	319999	70000	15020000
1999	10720000	26399999	340000	59999	14779999
2000	10609999	26700000	259999	59999	14319999
2001	10380000	25549999	259999	59999	13680000
2002	10680000	26309999	340000	59999	13140000
2003	10069999	25690000	349999	59999	12989999
2004	9760000	27020000	379999	59999	13630000
2005	9510000	25700000	370000	59999	13590000
2006	9350000	20670000	370000	59999	13539999
2007	9180000	20120000	370000	59999	12119999
2008	9140000	18659999	379999	59999	8619999
2009	9390000	17370000	370000	59999	8560000
2010	8939999	16819999	370000	59999	8350000
2011	8819999	16280000	379999	50000	8210000
2012	9319999	16750000	360000	59999	8289999
2013	9260000	16569999	360000	70000	8199999
2014	9210000	16200001	360000	70000	8500000
2015	9329999	16329999	360000	70000	8829999
2016	9380000	16319999	360000	59999	8600000
2017	9729999	16209999	370000	50000	8399999
2018	9510000	15390000	370000	50000	7960000
2019	9250000	15350000	379999	50000	8119999

Table 4.1.5: European Countries 1980-2019 Annual N₂O Emission Amounts (tonnes of CO₂ - equivalents)

Years/ Countries	Norway	Poland	Portugal	Romania	Spain	Sweden
1990	5030000	24620000	4050000	18079999	22200000	6079999
1991	4889999	23760000	3960000	12949999	21479999	5840000
1992	4349999	22790000	3869999	13270000	19899999	5949999
1993	4559999	23340000	3759999	13100000	20389999	6139999
1994	4650000	23549999	3720000	11649999	21000000	6030000
1995	4679999	24020000	3859999	11789999	20700000	5880000
1996	4690000	24010000	3990000	11829999	22790000	6039999
1997	4670000	24399999	3910000	11359999	22489999	6019999
1998	4730000	23030000	4079999	10380000	23770000	5980000
1999	4949999	22649999	4039999	9729999	23700000	5809999
2000	4719999	22969999	4030000	10529999	23840000	5840000
2001	4650000	22799999	3700000	10250000	23379999	5559999
2002	4860000	22319999	4119999	9289999	23020000	5510000
2003	4710000	22959999	3869999	9909999	24020000	5500000
2004	4860000	23040000	3940000	11050000	23299999	5539999
2005	4960000	23850000	3829999	11130000	21950001	5420000
2006	4619999	24200001	3630000	10109999	22309999	5389999

2007	4409999	25170000	3789999	10140000	22860001	5280000
2008	4010000	24049999	3690000	9229999	20579999	5449999
2009	3440000	20780001	3410000	8680000	20239999	5210000
2010	3329999	21559999	3369999	9199999	20700001	5429999
2011	3299999	21250000	3089999	9119999	19649999	5190000
2012	3289999	21680000	3109999	8380000	19020000	5110000
2013	3279999	20799999	3119999	8590000	19569999	5139999
2014	3329999	20290001	3250000	8310000	20370001	5369999
2015	3349999	20500000	3240000	8529999	20510000	5440000
2016	3380000	21420000	3240000	8630000	20290000	5460000
2017	3390000	21510000	3539999	8899999	20719999	5659999
2018	3359999	21399999	2970000	8949999	20430000	5449999
2019	3400000	21680000	2990000	8939999	20069999	5639999

Table 4.1.5: European Countries 1980-2019 Annual N₂O Emission Amounts (tonnes of CO₂ - equivalents)

Years/ Countries	Switzerland	Turkey	United Kingdom
1990	2839999	26799999	58119998
1991	2819999	25610000	57220001
1992	2789999	26569999	51990001
1993	2750000	27579999	47970001
1994	2750000	24760000	48549999
1995	2730000	25120000	46849998
1996	2710000	25690000	47709999
1997	2630000	25770000	47069999
1998	2630000	27059999	46830001
1999	2549999	27000000	37060001
2000	2549999	26520000	36049999
2001	2589999	23950000	34650001
2002	2480000	24309999	32630001
2003	2470000	24799999	32229999
2004	2490000	24969999	33130001
2005	2539999	25379999	31969999
2006	2559999	26899999	30909999
2007	2519999	25680000	30950000
2008	2589999	23829999	30790000
2009	2559999	26780000	28479999
2010	2559999	26260000	29010000
2011	2509999	26149999	28049999
2012	2460000	28309999	27659999
2013	2480000	30780000	27670000
2014	2460000	30610000	28469999
2015	2440000	31020000	28360000

2016	2450000	33270000	28100000
2017	2440000	32869998	28370000
2018	2410000	32689998	28129999
2019	2420000	34750000	28370000

In order to measure performance in the year 2050, it is necessary to forecast the values for that year based on past data of the countries. As explained in the previous section in detail, the ARIMA method is used for this estimation. Firstly, the datasets are loaded into R Studio separately and coded to indicate that they do not exhibit a seasonal feature. ACF and PACF graphs are plotted and checked for stationarity. The stationarity are confirmed using the Augmented Dickey-Fuller test. The non-stationary datasets are transformed into stationary by using differencing and ACF and PACF graphs are plotted again. The p, d, q values are determined using the “auto.arima” command and forecasting are performed until the year 2050 with 95% confidence interval. The results are compared with the latest ACF and PACF graphs. Finally, the validation of this forecasting are completed using the Ljung-Box test. In this study, the point estimator is used by ignoring the value ranges.

4.2 Forecast Results

European Countries forecasted 2050 data are shown in Table 4.2.1. Estimation of Primary Energy Consumption of European Countries between 2020 and 2050 are given in Appendix A. Germany is foreseen the country that consumes the most energy. Albania is foreseen the country that consumes the least energy. Estimation of GDP of European Countries between 2020 and 2050 are given in Appendix B. Luxembourg is foreseen the country that has the highest GDP value. Albania is foreseen the country that has the least GDP value. Estimation of CO₂ Emissions of European Countries between 2020 and 2050 are given in Appendix C. Turkey is foreseen the country that emit the most CO₂. Malta is foreseen the country that emit the least CO₂. Estimation of N₂O of European Countries between 2020 and 2050 are given in Appendix D. Poland is foreseen the country that emit the most N₂O. Malta is foreseen the country that emit the least N₂O.

Table 4.2.1: European Countries 2050 Forecasting Data

Countries (DMUj) / 2050 Data	Energy Consumption (Twh)	GDP (\$/capita)	CO ₂ Emissions (tonnes)	N ₂ O Emissions (tonnes of CO ₂ - equivalents)
Albania (1)	32.46	22115.48	4947485	1100000
Austria (2)	507.36	75384.88	67936184	2652759
Belgium (3)	749.29	69515.01	99432616	4580000
Bulgaria (4)	210.13	27225.30	42814055	5332560
Cyprus (5)	49.95	44096.61	7343729	365896
Czechia (6)	473.77	42908.61	34510464	5320000
Denmark (7)	195.59	76743.60	32066161	2893103
Finland (8)	331.21	64437.78	42381840	5010000
France (9)	2206.37	59216.79	161605068	14804919
Germany (10)	3625.34	72029.04	445126437	736206
Greece (11)	724.06	31328.76	43992684	924138
Hungary (12)	272.00	51019.90	19527021	5700000
Ireland (13)	250.39	150995.40	20643573	9250000
Italy (14)	1821.22	43002.59	100628596	3505863
Luxembourg (15)	47.94	167123.6	10307418	380000
Malta (16)	68.09	73714.56	1649193	61485
Netherlands (17)	980.01	78495.69	153032800	375371
Norway (18)	664.95	73334.05	52545377	1657586
Poland (19)	1184.75	80026.94	203357352	216800000
Portugal (20)	294.03	47838.00	179021175	1839470
Romania (21)	110.83	33035.53	75639337	11472549
Spain (22)	1542.40	55514.33	251825150	20070000
Sweden (23)	647.59	72833.00	16555129	5588587
Switzerland (24)	335.79	86567.43	36733064	1971035
Turkey (25)	3462.80	44838.67	661251319	34750000
United Kingdom (26)	1381.35	63897.23	194426467	19777904

To obtain more accurate results, each indicator was normalized separately. The data was scaled down to a range between 0 and 1 by dividing the values of each country in 2050 by the highest values of the indicator. These normalized data are shown in Table 4.2.2.

Table 4.2.2: European Countries 2050 Forecasting Normalized Data

Countries (DMUj) / 2050 Norm. Data	Energy Consumption	GDP	CO ₂ Emissions	NO ₂ Emissions
Albania (1)	0.008953	0.132330	0.007482	0.005074
Austria (2)	0.139949	0.451073	0.102739	0.012236
Belgium (3)	0.206683	0.415950	0.150370	0.021126
Bulgaria (4)	0.057960	0.162905	0.064747	0.024597
Cyprus (5)	0.013777	0.263856	0.011106	0.001688
Czechia (6)	0.130683	0.256748	0.052190	0.024539
Denmark (7)	0.053952	0.459203	0.048493	0.013345
Finland (8)	0.091359	0.385570	0.064093	0.023109
France (9)	0.608597	0.354329	0.244393	0.068288
Germany (10)	1.000000	0.430993	0.673158	0.003396
Greece (11)	0.199721	0.187459	0.066529	0.004263
Hungary (12)	0.075028	0.305282	0.029530	0.026292
Ireland (13)	0.069066	0.903495	0.031219	0.042666
Italy (14)	0.502358	0.257310	0.152179	0.016171
Luxembourg (15)	0.013225	1.000000	0.015588	0.001753
Malta (16)	0.018781	0.441078	0.002494	0.000284
Netherlands (17)	0.270324	0.469686	0.231429	0.001731
Norway (18)	0.183416	0.438801	0.079464	0.007646
Poland (19)	0.326797	0.478849	0.307534	1.000000
Portugal (20)	0.081104	0.286243	0.270731	0.008485
Romania (21)	0.030572	0.197671	0.114388	0.052918
Spain (22)	0.425450	0.332175	0.380831	0.092574
Sweden (23)	0.178630	0.435803	0.025036	0.025778
Switzerland (24)	0.092623	0.517984	0.055551	0.009092
Turkey (25)	0.955165	0.268296	1.000000	0.160286
United Kingdom (26)	0.381027	0.382335	0.294028	0.091227

4.3 DEA Models and Results

Two DEA models are chosen in this study. Since CO₂ and N₂O emissions are used as output, models with undesirable output are selected. The first model chosen for the performance measurement of European Countries in 2050 is the PEI model (3.2.10) developed by Tyteca (1996). The second model chosen is the MEI model (3.2.13) developed by Zhou et al. (2008). These models are coded in GAMS and the estimated data of the countries given in the previous section in 2050 are used as the data set. As the data set, the forecasted data of the countries given in the previous section are used. Models

are resolved for each DMU. The results of these models are obtained with CPLEX v.22.1.0.0 solver using GAMS v.41.5.0. Their results are shown in Table 4.3. According to the model, countries with a result close to 1 are considered to have the best performance.

Table 4.3: PEI and MEI Models Results for European Countries

Countries (DMUj) / 2050 Performance	PEI	MEI
Albania (1)	1.000	1.000
Austria (2)	0.027	0.025
Belgium (3)	0.017	0.016
Bulgaria (4)	0.042	0.016
Cyprus (5)	1.000	0.364
Czechia (6)	0.054	0.031
Denmark (7)	0.063	0.056
Finland (8)	0.042	0.037
France (9)	0.011	0.009
Germany (10)	1.000	1.000
Greece (11)	0.069	0.029
Hungary (12)	0.112	0.077
Ireland (13)	0.706	0.271
Italy (14)	0.018	0.010
Luxembourg (15)	1.000	1.000
Malta (16)	1.000	1.000
Netherlands (17)	0.530	0.442
Norway (18)	0.037	0.037
Poland (19)	1.000	1.000
Portugal (20)	0.038	0.024
Romania (21)	0.025	0.011
Spain (22)	0.007	0.005
Sweden (23)	0.140	0.138
Switzerland (24)	0.079	0.054
Turkey (25)	0.003	0.002
United Kingdom (26)	0.009	0.008

5. DISCUSSIONS

According to the characteristics of the data sets and their distribution by year, ARIMA is found the best estimation values. Data sets have shown characteristics that will increase, decrease or remain the same until 2050. France is expected to reduce its energy consumption by about 19%, while Cyprus is predicted to increase its energy consumption by 53%.

The indicators that have gained a little more importance in this study are the estimation of CO₂ and N₂O emissions. The N₂O and CO₂ values of the countries in 2020 and 2050 the amount of change are given in Table 5.1. Italy's 70% reduction of CO₂ emissions and Germany's 98% reduction of N₂O emissions made them the most successful countries in reducing these emissions. Turkey's 61% increase in CO₂ emissions and Bulgaria's 27% increase in N₂O emissions made them the most unsuccessful countries in reducing these emissions.

Table 5.1: Changing Rates of CO₂ And N₂O Emission Values Of European Countries Between 2020 and 2050

Countries	CO ₂ Results			N ₂ O Results		
	2020	2050	Changing Rates	2020	2050	Changing Rates
Albania	4947485	4947485	No change	1100000	1100000	No change
Austria	67936184	67936184	No change	3811379	2652759	30% decrease
Belgium	99432616	99432616	No change	4580000	4580000	No change
Bulgaria	42814055	42814055	No change	4197824	5332560	27% increase
Cyprus	7343471	7343729	No change	371016	365896.3	1% decrease
Czechia	98867718	34510464	65% decrease	5320000	5320000	No change
Denmark	32066161	32066161	No change	5096552	2893103	43% decrease

Finland	42381840	42381840	No change	5010000	5010000	No change
France	311393822	161605068	48% decrease	37812842	14804919	61% decrease
Germany	717315933	445126437	38% decrease	33043102	736206.3	98% decrease
Greece	63121245	43992684	30% decrease	4162069	924137.8	78% decrease
Hungary	48276334	19527021	60% decrease	5700000	5700000	No change
Ireland	36787532	20643573	44% decrease	9250000	9250000	No change
Italy	331536277	100628596	70% decrease	14967931	3505863	77% decrease
Luxembourg	10148982	10307418	2% increase	380000	380000	No change
Malta	1649193	1649193	No change	55344	61485	11% increase
Netherlands	153032800	153032800	No change	8029073	375371	95% decrease
Norway	43846309	52545377	20% increase	3343793	1657586	50% decrease
Poland	314773798	203357352	36% decrease	216800000	216800000	No change
Portugal	46660226	179021175	61% decrease	2930240	1839470	37% decrease
Romania	75639337	75639337	No change	9096296	11472549	26% increase
Spain	251825150	251825150	No change	20070000	20070000	No change
Sweden	40194513	16555129	59% decrease	5569513	5588587	1% increase
Switzerland	36733064	36733064	No change	2405517	1971035	18% decrease
Turkey	410091726	661251319	61% increase	34750000	34750000	No change
United Kingdom	359258867	194426467	46% decrease	28092836	19777904	30% decrease

It is expected that by 2050, 6 of the 26 countries are only reducing N₂O emissions, 5 of the 26 countries are only reducing CO₂ emissions, and 6 of the 26 countries are reducing both N₂O and CO₂ emissions. Also, 2 of the 26 countries are only increasing N₂O emissions, 3 of the 26 countries are only increasing CO₂ emissions, and none of them are increasing both N₂O and CO₂ emissions. Not foreseeing a country that increases both emissions can be considered a success, but more than 50% of countries do not reduce even one of the two emissions.

According to Table 4.3, the results of the two models are close to each other but MEI model has a higher discriminating power than PEI model. For example, Cyprus is one of the best performances in the PEI model but it takes the seventh place in the MEI model. Since MEI model is developed more suitable for production technology, it is more preferable than PEI model (Zhou et al. 2008).

According to results, Turkey is the country with the worst performance in both models. Albania, Germany, Luxembourg, Malta and Poland has the best results in both models. Although Germany's expected primary energy consumption in 2050 are the highest among countries, its performance is among the best countries as a result of its low N₂O, CO₂ emission value and high GDP value compared to other countries. Like Germany, Poland is expected to have the highest N₂O emission in 2050, but the values in other indicators have made the country one of the highest performing countries. High GDP value of Luxembourg was expected to have one of the highest values in performance measurement due to the fact that emissions and energy consumption were not higher than other countries. Although Albania's GDP value is lowest in country group, its low ranking in emissions and energy consumption has made it one of the countries with the highest performance. Although Malta's GDP value is not the highest, its high GDP value compared to other countries and its low undesirable output values make it one of the countries with the highest performance. In countries such as Turkey and the United Kingdom, both the high emissions and the low GDP value affected it to be in the last place in performance measurement.

The country with the best performance in the models used cannot be selected. However, Germany is expected to be one of the countries with the highest performance in both models, and moreover, it is expected to reduce both 98% N₂O emissions and 38% CO₂ emissions by 2050, showing that this country can be the most successful.

6. CONCLUSIONS

Climate change resulting from greenhouse gas emissions has been a serious issue in recent years. In order to solve this crisis, countries have signed the Paris Agreement, which has clauses such as reducing greenhouse gas emissions by 2050. This study aims to evaluate the performance of European countries in 2050 based on their CO₂ emissions, N₂O emissions, GDP and primary energy consumption. Data on primary energy consumption, total CO₂ emissions, GDP, and total N₂O are available for each country previous data and these data are forecasted in R Studio using the ARIMA method until 2050. With this method, it is estimated which country will increase its emissions and which will decrease it in 2050. Two DEA models are selected for performance measurement. First model is the Pure Environmental Index model developed by Tyteca (1996), which aims to minimize the lambda value multiplied by the undesirable output DMU. Second model is the Mixed Environmental Index model developed by Zhou et al. (2008), which has the same objective function as the first model but also includes the beta value. GAMS solver is used to code these models, and a performance measurement is conducted among European countries using the data for 2050. Albania, Germany, Luxembourg, Malta, and Poland are identified as the best-performing countries, while Turkey and the United Kingdom are the worst-performing countries. The employed models do not allow for choosing between the top five best-performing countries. However, the prediction for Germany, which is expected to reduce its N₂O emissions by 98% and CO₂ emissions by 38%, suggests that it may be the best-performing country in 2050.

6.1 Limitations and Future Work

This study estimates the expected increase or decrease in Emissions, GDP, and Energy Consumption for European countries until 2050, and also measures their performance against each other in 2050. ARIMA was used to make these estimations, which produce

linear results. However, it is important to note that not all estimations can be linear. In future studies, a different estimation model that can make nonlinear estimations could be used. A ranking could not be made among the countries with the best performance according to the models. Models that can measure performance among these countries can be developed. Additionally, this study only focused on European Countries, but performance measurements for other continents or globally could be considered in future research.



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APPENDICES

Appendix A

> Albania__forecast		> myaustriaforecast		> Belgium_forecast		> Bulgaria_forecast	
Point	Forecast	Point	Forecast	Point	Forecast	Point	Forecast
2020	32.457	2020	424.0836	2020	749.2948	2020	210.1259
2021	32.457	2021	429.4479	2021	749.2948	2021	210.1259
2022	32.457	2022	431.1330	2022	749.2948	2022	210.1259
2023	32.457	2023	434.2431	2023	749.2948	2023	210.1259
2024	32.457	2024	436.8012	2024	749.2948	2024	210.1259
2025	32.457	2025	439.5732	2025	749.2948	2025	210.1259
2026	32.457	2026	442.2623	2026	749.2948	2026	210.1259
2027	32.457	2027	444.9835	2027	749.2948	2027	210.1259
2028	32.457	2028	447.6923	2028	749.2948	2028	210.1259
2029	32.457	2029	450.4059	2029	749.2948	2029	210.1259
2030	32.457	2030	453.1176	2030	749.2948	2030	210.1259
2031	32.457	2031	455.8301	2031	749.2948	2031	210.1259
2032	32.457	2032	458.5423	2032	749.2948	2032	210.1259
2033	32.457	2033	461.2546	2033	749.2948	2033	210.1259
2034	32.457	2034	463.9668	2034	749.2948	2034	210.1259
2035	32.457	2035	466.6791	2035	749.2948	2035	210.1259
2036	32.457	2036	469.3913	2036	749.2948	2036	210.1259
2037	32.457	2037	472.1036	2037	749.2948	2037	210.1259
2038	32.457	2038	474.8158	2038	749.2948	2038	210.1259
2039	32.457	2039	477.5281	2039	749.2948	2039	210.1259
2040	32.457	2040	480.2404	2040	749.2948	2040	210.1259
2041	32.457	2041	482.9526	2041	749.2948	2041	210.1259
2042	32.457	2042	485.6649	2042	749.2948	2042	210.1259
2043	32.457	2043	488.3771	2043	749.2948	2043	210.1259
2044	32.457	2044	491.0894	2044	749.2948	2044	210.1259
2045	32.457	2045	493.8016	2045	749.2948	2045	210.1259
2046	32.457	2046	496.5139	2046	749.2948	2046	210.1259
2047	32.457	2047	499.2261	2047	749.2948	2047	210.1259
2048	32.457	2048	501.9384	2048	749.2948	2048	210.1259
2049	32.457	2049	504.6507	2049	749.2948	2049	210.1259
2050	32.457	2050	507.3629	2050	749.2948	2050	210.1259

> Cyprus_forecast		> Czechia_forecast		> Denmark_forecast		> Finland_forecast	
Point	Forecast	Point	Forecast	Point	Forecast	Point	Forecast
2020	32.94567	2020	475.4206	2020	195.5931	2020	329.7922
2021	33.51233	2021	474.4356	2021	195.5931	2021	330.1134
2022	34.07900	2022	474.0388	2022	195.5931	2022	330.3616
2023	34.64567	2023	473.8789	2023	195.5931	2023	330.5536
2024	35.21233	2024	473.8144	2024	195.5931	2024	330.7019
2025	35.77900	2025	473.7885	2025	195.5931	2025	330.8167
2026	36.34567	2026	473.7780	2026	195.5931	2026	330.9053
2027	36.91233	2027	473.7738	2027	195.5931	2027	330.9739
2028	37.47900	2028	473.7721	2028	195.5931	2028	331.0269
2029	38.04567	2029	473.7714	2029	195.5931	2029	331.0679
2030	38.61233	2030	473.7711	2030	195.5931	2030	331.0996
2031	39.17900	2031	473.7710	2031	195.5931	2031	331.1241
2032	39.74567	2032	473.7710	2032	195.5931	2032	331.1430
2033	40.31233	2033	473.7710	2033	195.5931	2033	331.1576
2034	40.87900	2034	473.7710	2034	195.5931	2034	331.1690
2035	41.44567	2035	473.7710	2035	195.5931	2035	331.1777
2036	42.01233	2036	473.7710	2036	195.5931	2036	331.1845
2037	42.57900	2037	473.7710	2037	195.5931	2037	331.1897
2038	43.14567	2038	473.7710	2038	195.5931	2038	331.1938
2039	43.71233	2039	473.7710	2039	195.5931	2039	331.1969
2040	44.27900	2040	473.7710	2040	195.5931	2040	331.1993
2041	44.84567	2041	473.7710	2041	195.5931	2041	331.2012
2042	45.41233	2042	473.7710	2042	195.5931	2042	331.2026
2043	45.97900	2043	473.7710	2043	195.5931	2043	331.2037
2044	46.54567	2044	473.7710	2044	195.5931	2044	331.2046
2045	47.11233	2045	473.7710	2045	195.5931	2045	331.2053
2046	47.67900	2046	473.7710	2046	195.5931	2046	331.2058
2047	48.24567	2047	473.7710	2047	195.5931	2047	331.2062
2048	48.81233	2048	473.7710	2048	195.5931	2048	331.2065
2049	49.37900	2049	473.7710	2049	195.5931	2049	331.2067
2050	49.94567	2050	473.7710	2050	195.5931	2050	331.2069

> France_forecast		> forecast(germanyp)		> Greece_forecast		> forecast(hungary_ε	
Point	Forecast	Point	Forecast	Point	Forecast	Point	Forecast
2020	2721.497	2020	3625.339	2020	306.6006	2020	272
2021	2704.326	2021	3625.339	2021	339.4808	2021	272
2022	2687.155	2022	3625.339	2022	355.2140	2022	272
2023	2669.985	2023	3625.339	2023	356.4954	2023	272
2024	2652.814	2024	3625.339	2024	373.5345	2024	272
2025	2635.643	2025	3625.339	2025	392.4444	2025	272
2026	2618.472	2026	3625.339	2026	401.5334	2026	272
2027	2601.301	2027	3625.339	2027	413.5580	2027	272
2028	2584.130	2028	3625.339	2028	430.0283	2028	272
2029	2566.960	2029	3625.339	2029	442.9957	2029	272
2030	2549.789	2030	3625.339	2030	454.8385	2030	272
2031	2532.618	2031	3625.339	2031	469.1540	2031	272
2032	2515.447	2032	3625.339	2032	483.1060	2032	272
2033	2498.276	2033	3625.339	2033	495.7852	2033	272
2034	2481.105	2034	3625.339	2034	509.1931	2034	272
2035	2463.935	2035	3625.339	2035	523.0350	2035	272
2036	2446.764	2036	3625.339	2036	536.2808	2036	272
2037	2429.593	2037	3625.339	2037	549.5206	2037	272
2038	2412.422	2038	3625.339	2038	563.1055	2038	272
2039	2395.251	2039	3625.339	2039	576.5529	2039	272
2040	2378.081	2040	3625.339	2040	589.8581	2040	272
2041	2360.910	2041	3625.339	2041	603.3004	2041	272
2042	2343.739	2042	3625.339	2042	616.7684	2042	272
2043	2326.568	2043	3625.339	2043	630.1471	2043	272
2044	2309.397	2044	3625.339	2044	643.5475	2044	272
2045	2292.226	2045	3625.339	2045	656.9904	2045	272
2046	2275.056	2046	3625.339	2046	670.4035	2046	272
2047	2257.885	2047	3625.339	2047	683.8043	2047	272
2048	2240.714	2048	3625.339	2048	697.2273	2048	272
2049	2223.543	2049	3625.339	2049	710.6483	2049	272
2050	2206.372	2050	3625.339	2050	724.0573	2050	272

> Ireland_forecast		> Italy_forecast		> Luxembourg_forecast		> Malta_forecast	
Point	Forecast	Point	Forecast	Point	Forecast	Point	Forecast
2020	188.0010	2020	1821.218	2020	47.65777	2020	41.26997
2021	189.7715	2021	1821.218	2021	47.81919	2021	42.16391
2022	191.7363	2022	1821.218	2022	47.88944	2022	43.05786
2023	193.7801	2023	1821.218	2023	47.92000	2023	43.95180
2024	195.8560	2024	1821.218	2024	47.93331	2024	44.84574
2025	197.9450	2025	1821.218	2025	47.93909	2025	45.73968
2026	200.0393	2026	1821.218	2026	47.94161	2026	46.63362
2027	202.1358	2027	1821.218	2027	47.94271	2027	47.52757
2028	204.2331	2028	1821.218	2028	47.94319	2028	48.42151
2029	206.3308	2029	1821.218	2029	47.94339	2029	49.31545
2030	208.4286	2030	1821.218	2030	47.94348	2030	50.20939
2031	210.5265	2031	1821.218	2031	47.94352	2031	51.10333
2032	212.6245	2032	1821.218	2032	47.94354	2032	51.99728
2033	214.7224	2033	1821.218	2033	47.94355	2033	52.89122
2034	216.8204	2034	1821.218	2034	47.94355	2034	53.78516
2035	218.9183	2035	1821.218	2035	47.94355	2035	54.67910
2036	221.0162	2036	1821.218	2036	47.94355	2036	55.57305
2037	223.1142	2037	1821.218	2037	47.94355	2037	56.46699
2038	225.2121	2038	1821.218	2038	47.94355	2038	57.36093
2039	227.3101	2039	1821.218	2039	47.94355	2039	58.25487
2040	229.4080	2040	1821.218	2040	47.94355	2040	59.14881
2041	231.5059	2041	1821.218	2041	47.94355	2041	60.04276
2042	233.6039	2042	1821.218	2042	47.94355	2042	60.93670
2043	235.7018	2043	1821.218	2043	47.94355	2043	61.83064
2044	237.7998	2044	1821.218	2044	47.94355	2044	62.72458
2045	239.8977	2045	1821.218	2045	47.94355	2045	63.61852
2046	241.9957	2046	1821.218	2046	47.94355	2046	64.51247
2047	244.0936	2047	1821.218	2047	47.94355	2047	65.40641
2048	246.1915	2048	1821.218	2048	47.94355	2048	66.30035
2049	248.2895	2049	1821.218	2049	47.94355	2049	67.19429
2050	250.3874	2050	1821.218	2050	47.94355	2050	68.08823

> Netherlands_forecast		> Norway_forecast		> Poland_forecast		> Portugal_forecast	
Point	Forecast	Point	Forecast	Point	Forecast	Point	Forecast
2020	977.2970	2020	550.9229	2020	1184.748	2020	297.8124
2021	981.3498	2021	554.7237	2021	1184.748	2021	297.6863
2022	979.3584	2022	558.5245	2022	1184.748	2022	297.5602
2023	980.3369	2023	562.3253	2023	1184.748	2023	297.4341
2024	979.8561	2024	566.1261	2024	1184.748	2024	297.3080
2025	980.0923	2025	569.9269	2025	1184.748	2025	297.1819
2026	979.9762	2026	573.7277	2026	1184.748	2026	297.0558
2027	980.0333	2027	577.5285	2027	1184.748	2027	296.9297
2028	980.0053	2028	581.3293	2028	1184.748	2028	296.8036
2029	980.0190	2029	585.1300	2029	1184.748	2029	296.6775
2030	980.0123	2030	588.9308	2030	1184.748	2030	296.5514
2031	980.0156	2031	592.7316	2031	1184.748	2031	296.4253
2032	980.0140	2032	596.5324	2032	1184.748	2032	296.2992
2033	980.0148	2033	600.3332	2033	1184.748	2033	296.1731
2034	980.0144	2034	604.1340	2034	1184.748	2034	296.0470
2035	980.0146	2035	607.9348	2035	1184.748	2035	295.9209
2036	980.0145	2036	611.7356	2036	1184.748	2036	295.7948
2037	980.0145	2037	615.5364	2037	1184.748	2037	295.6687
2038	980.0145	2038	619.3372	2038	1184.748	2038	295.5426
2039	980.0145	2039	623.1380	2039	1184.748	2039	295.4165
2040	980.0145	2040	626.9388	2040	1184.748	2040	295.2904
2041	980.0145	2041	630.7396	2041	1184.748	2041	295.1643
2042	980.0145	2042	634.5404	2042	1184.748	2042	295.0382
2043	980.0145	2043	638.3412	2043	1184.748	2043	294.9121
2044	980.0145	2044	642.1420	2044	1184.748	2044	294.7860
2045	980.0145	2045	645.9428	2045	1184.748	2045	294.6599
2046	980.0145	2046	649.7436	2046	1184.748	2046	294.5338
2047	980.0145	2047	653.5444	2047	1184.748	2047	294.4077
2048	980.0145	2048	657.3452	2048	1184.748	2048	294.2816
2049	980.0145	2049	661.1460	2049	1184.748	2049	294.1555
2050	980.0145	2050	664.9468	2050	1184.748	2050	294.0294

> Romania_forecast		> Spain_forecast		> Sweden_forecast		> Switzerland_foreca	
Point	Forecast	Point	Forecast	Point	Forecast	Point	Forecast
2020	374.3284	2020	1585.408	2020	648.6641	2020	335.7898
2021	364.9961	2021	1580.147	2021	648.1784	2021	335.7898
2022	358.7200	2022	1575.515	2022	647.9132	2022	335.7898
2023	352.3980	2023	1571.438	2023	647.7684	2023	335.7898
2024	343.8247	2024	1567.848	2024	647.6894	2024	335.7898
2025	333.3561	2025	1564.688	2025	647.6462	2025	335.7898
2026	322.8932	2026	1561.906	2026	647.6226	2026	335.7898
2027	313.8068	2027	1559.457	2027	647.6097	2027	335.7898
2028	305.8955	2028	1557.301	2028	647.6027	2028	335.7898
2029	297.9947	2029	1555.403	2029	647.5989	2029	335.7898
2030	289.2524	2030	1553.733	2030	647.5968	2030	335.7898
2031	279.7816	2031	1552.262	2031	647.5956	2031	335.7898
2032	270.2958	2032	1550.967	2032	647.5950	2032	335.7898
2033	261.3243	2033	1549.827	2033	647.5947	2033	335.7898
2034	252.8043	2034	1548.823	2034	647.5945	2034	335.7898
2035	244.2988	2035	1547.940	2035	647.5944	2035	335.7898
2036	235.4791	2036	1547.162	2036	647.5943	2036	335.7898
2037	226.3796	2037	1546.477	2037	647.5943	2037	335.7898
2038	217.2678	2038	1545.874	2038	647.5943	2038	335.7898
2039	208.3481	2039	1545.344	2039	647.5943	2039	335.7898
2040	199.6018	2040	1544.877	2040	647.5943	2040	335.7898
2041	190.8649	2041	1544.465	2041	647.5943	2041	335.7898
2042	182.0108	2042	1544.103	2042	647.5943	2042	335.7898
2043	173.0492	2043	1543.785	2043	647.5943	2043	335.7898
2044	164.0806	2044	1543.504	2044	647.5943	2044	335.7898
2045	155.1836	2045	1543.257	2045	647.5943	2045	335.7898
2046	146.3532	2046	1543.040	2046	647.5943	2046	335.7898
2047	137.5278	2047	1542.848	2047	647.5943	2047	335.7898
2048	128.6587	2048	1542.680	2048	647.5943	2048	335.7898
2049	119.7484	2049	1542.531	2049	647.5943	2049	335.7898
2050	110.8345	2050	1542.401	2050	647.5943	2050	335.7898

> Turkey_forecast		> United_Kingdom_for	
Point	Forecast	Point	Forecast
2020	1886.879	2020	2167.730
2021	1939.410	2021	2138.813
2022	1991.940	2022	2113.574
2023	2044.471	2023	2087.137
2024	2097.001	2024	2061.090
2025	2149.532	2025	2034.916
2026	2202.063	2026	2008.783
2027	2254.593	2027	1982.637
2028	2307.124	2028	1956.495
2029	2359.654	2029	1930.352
2030	2412.185	2030	1904.210
2031	2464.716	2031	1878.067
2032	2517.246	2032	1851.924
2033	2569.777	2033	1825.781
2034	2622.307	2034	1799.638
2035	2674.838	2035	1773.496
2036	2727.369	2036	1747.353
2037	2779.899	2037	1721.210
2038	2832.430	2038	1695.067
2039	2884.960	2039	1668.925
2040	2937.491	2040	1642.782
2041	2990.022	2041	1616.639
2042	3042.552	2042	1590.496
2043	3095.083	2043	1564.353
2044	3147.613	2044	1538.211
2045	3200.144	2045	1512.068
2046	3252.675	2046	1485.925
2047	3305.205	2047	1459.782
2048	3357.736	2048	1433.640
2049	3410.266	2049	1407.497
2050	3462.797	2050	1381.354

Appendix B

> Albania_forecast		> Austria_forecast		> Belgium_forecast		> Bulgaria_forecast	
Point	Forecast	Point	Forecast	Point	Forecast	Point	Forecast
2020	13889.68	2020	56390.73	2020	52510.97	2020	23891.85
2021	14163.87	2021	57023.87	2021	53077.77	2021	24536.27
2022	14438.06	2022	57657.01	2022	53644.57	2022	24995.30
2023	14712.26	2023	58290.15	2023	54211.37	2023	25409.52
2024	14986.45	2024	58923.28	2024	54778.18	2024	25729.47
2025	15260.64	2025	59556.42	2025	55344.98	2025	26002.82
2026	15534.84	2026	60189.56	2026	55911.78	2026	26221.45
2027	15809.03	2027	60822.70	2027	56478.58	2027	26403.99
2028	16083.22	2028	61455.84	2028	57045.38	2028	26552.16
2029	16357.42	2029	62088.98	2029	57612.18	2029	26674.68
2030	16631.61	2030	62722.12	2030	58178.98	2030	26774.76
2031	16905.80	2031	63355.25	2031	58745.79	2031	26857.17
2032	17180.00	2032	63988.39	2032	59312.59	2032	26924.67
2033	17454.19	2033	64621.53	2033	59879.39	2033	26980.16
2034	17728.38	2034	65254.67	2034	60446.19	2034	27025.66
2035	18002.58	2035	65887.81	2035	61012.99	2035	27063.03
2036	18276.77	2036	66520.95	2036	61579.79	2036	27093.69
2037	18550.96	2037	67154.08	2037	62146.59	2037	27118.87
2038	18825.16	2038	67787.22	2038	62713.40	2038	27139.53
2039	19099.35	2039	68420.36	2039	63280.20	2039	27156.49
2040	19373.54	2040	69053.50	2040	63847.00	2040	27170.41
2041	19647.74	2041	69686.64	2041	64413.80	2041	27181.84
2042	19921.93	2042	70319.78	2042	64980.60	2042	27191.22
2043	20196.12	2043	70952.91	2043	65547.40	2043	27198.91
2044	20470.32	2044	71586.05	2044	66114.20	2044	27205.23
2045	20744.51	2045	72219.19	2045	66681.01	2045	27210.42
2046	21018.70	2046	72852.33	2046	67247.81	2046	27214.68
2047	21292.90	2047	73485.47	2047	67814.61	2047	27218.17
2048	21567.09	2048	74118.61	2048	68381.41	2048	27221.04
2049	21841.28	2049	74751.75	2049	68948.21	2049	27223.40
2050	22115.48	2050	75384.88	2050	69515.01	2050	27225.33

> Cyprus_forecast		> Czechia_forecast		> Denmark_forecast		> Finland_forecast	
Point	Forecast	Point	Forecast	Point	Forecast	Point	Forecast
2020	42487.47	2020	41659.97	2020	57884.84	2020	49162.55
2021	43090.92	2021	42099.76	2021	58538.05	2021	49671.72
2022	43468.07	2022	42384.65	2022	59172.44	2022	50180.90
2023	43703.78	2023	42569.20	2023	59801.76	2023	50690.07
2024	43851.10	2024	42688.75	2024	60429.71	2024	51199.25
2025	43943.17	2025	42766.19	2025	61057.30	2025	51708.42
2026	44000.71	2026	42816.35	2026	61684.78	2026	52217.59
2027	44036.67	2027	42848.84	2027	62312.24	2027	52726.77
2028	44059.15	2028	42869.90	2028	62939.69	2028	53235.94
2029	44073.20	2029	42883.53	2029	63567.15	2029	53745.12
2030	44081.98	2030	42892.36	2030	64194.60	2030	54254.29
2031	44087.46	2031	42898.09	2031	64822.05	2031	54763.46
2032	44090.89	2032	42901.79	2032	65449.50	2032	55272.64
2033	44093.03	2033	42904.19	2033	66076.95	2033	55781.81
2034	44094.37	2034	42905.75	2034	66704.40	2034	56290.99
2035	44095.21	2035	42906.76	2035	67331.85	2035	56800.16
2036	44095.73	2036	42907.41	2036	67959.30	2036	57309.34
2037	44096.06	2037	42907.83	2037	68586.75	2037	57818.51
2038	44096.27	2038	42908.11	2038	69214.20	2038	58327.68
2039	44096.39	2039	42908.28	2039	69841.65	2039	58836.86
2040	44096.47	2040	42908.40	2040	70469.10	2040	59346.03
2041	44096.52	2041	42908.47	2041	71096.55	2041	59855.21
2042	44096.55	2042	42908.52	2042	71724.00	2042	60364.38
2043	44096.57	2043	42908.55	2043	72351.45	2043	60873.56
2044	44096.59	2044	42908.57	2044	72978.90	2044	61382.73
2045	44096.59	2045	42908.59	2045	73606.35	2045	61891.90
2046	44096.60	2046	42908.59	2046	74233.80	2046	62401.08
2047	44096.60	2047	42908.60	2047	74861.25	2047	62910.25
2048	44096.60	2048	42908.60	2048	75488.70	2048	63419.43
2049	44096.60	2049	42908.61	2049	76116.15	2049	63928.60
2050	44096.61	2050	42908.61	2050	76743.60	2050	64437.78

> France_forecast		> Germany_forecast		> Greece_forecast		> Hungary_forecast	
Point	Forecast	Point	Forecast	Point	Forecast	Point	Forecast
2020	46534.22	2020	54320.04	2020	30113.15	2020	33546.71
2021	46956.98	2021	54905.91	2021	30422.61	2021	34323.97
2022	47379.73	2022	55591.74	2022	30653.30	2022	34995.20
2023	47802.48	2023	56216.99	2023	30825.27	2023	35614.33
2024	48225.23	2024	56769.21	2024	30953.47	2024	36207.85
2025	48647.99	2025	57324.36	2025	31049.04	2025	36788.78
2026	49070.74	2026	57917.30	2026	31120.28	2026	37363.54
2027	49493.49	2027	58523.01	2027	31173.39	2027	37935.25
2028	49916.24	2028	59114.54	2028	31212.99	2028	38505.46
2029	50339.00	2029	59694.31	2029	31242.50	2029	39074.95
2030	50761.75	2030	60276.78	2030	31264.50	2030	39644.07
2031	51184.50	2031	60866.17	2031	31280.90	2031	40213.02
2032	51607.25	2032	61456.82	2032	31293.13	2032	40781.88
2033	52030.00	2033	62044.46	2033	31302.25	2033	41350.69
2034	52452.76	2034	62630.33	2034	31309.04	2034	41919.49
2035	52875.51	2035	63217.06	2035	31314.11	2035	42488.27
2036	53298.26	2036	63804.98	2036	31317.88	2036	43057.05
2037	53721.01	2037	64392.94	2037	31320.70	2037	43625.83
2038	54143.77	2038	64980.30	2038	31322.79	2038	44194.60
2039	54566.52	2039	65567.42	2039	31324.36	2039	44763.38
2040	54989.27	2040	66154.75	2040	31325.52	2040	45332.15
2041	55412.02	2041	66742.29	2041	31326.39	2041	45900.93
2042	55834.77	2042	67329.79	2042	31327.04	2042	46469.70
2043	56257.53	2043	67917.17	2043	31327.53	2043	47038.48
2044	56680.28	2044	68504.54	2044	31327.89	2044	47607.25
2045	57103.03	2045	69091.94	2045	31328.15	2045	48176.02
2046	57525.78	2046	69679.38	2046	31328.35	2046	48744.80
2047	57948.54	2047	70266.81	2047	31328.50	2047	49313.57
2048	58371.29	2048	70854.22	2048	31328.61	2048	49882.35
2049	58794.04	2049	71441.62	2049	31328.70	2049	50451.12
2050	59216.79	2050	72029.04	2050	31328.76	2050	51019.90

> Ireland_forecast		> Italy_forecast		> Luxembourg_forecast		> Malta_forecast	
Point	Forecast	Point	Forecast	Point	Forecast	Point	Forecast
2020	88967.31	2020	43002.59	2020	118008.3	2020	44910.74
2021	91105.99	2021	43002.59	2021	119645.5	2021	45870.87
2022	93192.04	2022	43002.59	2022	121282.7	2022	46831.00
2023	95262.59	2023	43002.59	2023	122919.8	2023	47791.13
2024	97328.58	2024	43002.59	2024	124557.0	2024	48751.25
2025	99393.22	2025	43002.59	2025	126194.2	2025	49711.38
2026	101457.46	2026	43002.59	2026	127831.4	2026	50671.51
2027	103521.58	2027	43002.59	2027	129468.5	2027	51631.63
2028	105585.68	2028	43002.59	2028	131105.7	2028	52591.76
2029	107649.76	2029	43002.59	2029	132742.9	2029	53551.89
2030	109713.83	2030	43002.59	2030	134380.1	2030	54512.02
2031	111777.91	2031	43002.59	2031	136017.2	2031	55472.14
2032	113841.99	2032	43002.59	2032	137654.4	2032	56432.27
2033	115906.07	2033	43002.59	2033	139291.6	2033	57392.40
2034	117970.14	2034	43002.59	2034	140928.8	2034	58352.53
2035	120034.22	2035	43002.59	2035	142565.9	2035	59312.65
2036	122098.30	2036	43002.59	2036	144203.1	2036	60272.78
2037	124162.37	2037	43002.59	2037	145840.3	2037	61232.91
2038	126226.45	2038	43002.59	2038	147477.5	2038	62193.03
2039	128290.53	2039	43002.59	2039	149114.6	2039	63153.16
2040	130354.60	2040	43002.59	2040	150751.8	2040	64113.29
2041	132418.68	2041	43002.59	2041	152389.0	2041	65073.42
2042	134482.76	2042	43002.59	2042	154026.2	2042	66033.54
2043	136546.83	2043	43002.59	2043	155663.3	2043	66993.67
2044	138610.91	2044	43002.59	2044	157300.5	2044	67953.80
2045	140674.99	2045	43002.59	2045	158937.7	2045	68913.92
2046	142739.06	2046	43002.59	2046	160574.9	2046	69874.05
2047	144803.14	2047	43002.59	2047	162212.0	2047	70834.18
2048	146867.22	2048	43002.59	2048	163849.2	2048	71794.31
2049	148931.29	2049	43002.59	2049	165486.4	2049	72754.43
2050	150995.37	2050	43002.59	2050	167123.6	2050	73714.56

> Netherlands_forecast		> Norway_forecast		> Poland_forecast		> Portugal_forecast	
Point	Forecast	Point	Forecast	Point	Forecast	Point	Forecast
2020	57485.01	2020	64571.60	2020	34696.18	2020	35554.58
2021	58185.36	2021	64819.77	2021	36207.21	2021	35964.03
2022	58885.72	2022	65094.48	2022	37718.23	2022	36373.49
2023	59586.07	2023	65380.63	2023	39229.26	2023	36782.94
2024	60286.43	2024	65671.71	2024	40740.28	2024	37192.40
2025	60986.79	2025	65964.91	2025	42251.31	2025	37601.85
2026	61687.14	2026	66259.03	2026	43762.33	2026	38011.31
2027	62387.50	2027	66553.55	2027	45273.36	2027	38420.76
2028	63087.85	2028	66848.23	2028	46784.38	2028	38830.22
2029	63788.21	2029	67142.99	2029	48295.41	2029	39239.67
2030	64488.57	2030	67437.78	2030	49806.44	2030	39649.13
2031	65188.92	2031	67732.59	2031	51317.46	2031	40058.58
2032	65889.28	2032	68027.40	2032	52828.49	2032	40468.04
2033	66589.63	2033	68322.21	2033	54339.51	2033	40877.49
2034	67289.99	2034	68617.02	2034	55850.54	2034	41286.95
2035	67990.35	2035	68911.84	2035	57361.56	2035	41696.40
2036	68690.70	2036	69206.65	2036	58872.59	2036	42105.86
2037	69391.06	2037	69501.46	2037	60383.61	2037	42515.31
2038	70091.41	2038	69796.28	2038	61894.64	2038	42924.77
2039	70791.77	2039	70091.09	2039	63405.66	2039	43334.22
2040	71492.13	2040	70385.91	2040	64916.69	2040	43743.68
2041	72192.48	2041	70680.72	2041	66427.71	2041	44153.13
2042	72892.84	2042	70975.54	2042	67938.74	2042	44562.59
2043	73593.19	2043	71270.35	2043	69449.77	2043	44972.04
2044	74293.55	2044	71565.17	2044	70960.79	2044	45381.50
2045	74993.91	2045	71859.98	2045	72471.82	2045	45790.95
2046	75694.26	2046	72154.79	2046	73982.84	2046	46200.41
2047	76394.62	2047	72449.61	2047	75493.87	2047	46609.86
2048	77094.97	2048	72744.42	2048	77004.89	2048	47019.32
2049	77795.33	2049	73039.24	2049	78515.92	2049	47428.77
2050	78495.69	2050	73334.05	2050	80026.94	2050	47838.23

> Romania_forecast		> Spain_forecast		> Sweden_forecast		> Switzerland_foreca	
Point	Forecast	Point	Forecast	Point	Forecast	Point	Forecast
2020	30821.80	2020	41319.82	2020	53495.18	2020	71448.32
2021	31484.94	2021	41819.57	2021	54139.79	2021	71952.29
2022	31949.43	2022	42308.34	2022	54784.41	2022	72456.26
2023	32274.79	2023	42790.26	2023	55429.02	2023	72960.23
2024	32502.69	2024	43267.91	2024	56073.63	2024	73464.20
2025	32662.32	2025	43742.89	2025	56718.24	2025	73968.17
2026	32774.13	2026	44216.22	2026	57362.85	2026	74472.14
2027	32852.45	2027	44688.50	2027	58007.47	2027	74976.11
2028	32907.31	2028	45160.14	2028	58652.08	2028	75480.08
2029	32945.73	2029	45631.37	2029	59296.69	2029	75984.05
2030	32972.65	2030	46102.35	2030	59941.30	2030	76488.02
2031	32991.50	2031	46573.18	2031	60585.92	2031	76991.99
2032	33004.71	2032	47043.91	2032	61230.53	2032	77495.96
2033	33013.96	2033	47514.57	2033	61875.14	2033	77999.93
2034	33020.44	2034	47985.20	2034	62519.75	2034	78503.91
2035	33024.97	2035	48455.80	2035	63164.36	2035	79007.88
2036	33028.15	2036	48926.39	2036	63808.98	2036	79511.85
2037	33030.38	2037	49396.97	2037	64453.59	2037	80015.82
2038	33031.94	2038	49867.55	2038	65098.20	2038	80519.79
2039	33033.03	2039	50338.12	2039	65742.81	2039	81023.76
2040	33033.80	2040	50808.68	2040	66387.42	2040	81527.73
2041	33034.33	2041	51279.25	2041	67032.04	2041	82031.70
2042	33034.71	2042	51749.82	2042	67676.65	2042	82535.67
2043	33034.97	2043	52220.38	2043	68321.26	2043	83039.64
2044	33035.15	2044	52690.95	2044	68965.87	2044	83543.61
2045	33035.28	2045	53161.51	2045	69610.48	2045	84047.58
2046	33035.37	2046	53632.08	2046	70255.10	2046	84551.55
2047	33035.44	2047	54102.64	2047	70899.71	2047	85055.52
2048	33035.48	2048	54573.20	2048	71544.32	2048	85559.49
2049	33035.51	2049	55043.77	2049	72188.93	2049	86063.46
2050	33035.53	2050	55514.33	2050	72833.54	2050	86567.43

> Turkey_forecast		> United_kingdom_for	
Point	Forecast	Point	Forecast
2020	28734.07	2020	47894.78
2021	29270.89	2021	48425.37
2022	29807.71	2022	48957.73
2023	30344.53	2023	49490.82
2024	30881.35	2024	50024.21
2025	31418.17	2025	50557.71
2026	31954.99	2026	51091.26
2027	32491.81	2027	51624.83
2028	33028.63	2028	52158.40
2029	33565.45	2029	52691.99
2030	34102.27	2030	53225.57
2031	34639.09	2031	53759.15
2032	35175.91	2032	54292.73
2033	35712.73	2033	54826.32
2034	36249.55	2034	55359.90
2035	36786.37	2035	55893.48
2036	37323.19	2036	56427.06
2037	37860.01	2037	56960.65
2038	38396.83	2038	57494.23
2039	38933.65	2039	58027.81
2040	39470.47	2040	58561.40
2041	40007.29	2041	59094.98
2042	40544.11	2042	59628.56
2043	41080.93	2043	60162.15
2044	41617.75	2044	60695.73
2045	42154.57	2045	61229.31
2046	42691.39	2046	61762.90
2047	43228.21	2047	62296.48
2048	43765.03	2048	62830.06
2049	44301.85	2049	63363.64
2050	44838.67	2050	63897.23

Appendix C

> Albania__forecast		> Austria__forecast		> Belgium__forecast		> Bulgaria__forecast	
Point	Forecast	Point	Forecast	Point	Forecast	Point	Forecast
2020	4947485	2020	67936184	2020	99432616	2020	42814055
2021	4947485	2021	67936184	2021	99432616	2021	42814055
2022	4947485	2022	67936184	2022	99432616	2022	42814055
2023	4947485	2023	67936184	2023	99432616	2023	42814055
2024	4947485	2024	67936184	2024	99432616	2024	42814055
2025	4947485	2025	67936184	2025	99432616	2025	42814055
2026	4947485	2026	67936184	2026	99432616	2026	42814055
2027	4947485	2027	67936184	2027	99432616	2027	42814055
2028	4947485	2028	67936184	2028	99432616	2028	42814055
2029	4947485	2029	67936184	2029	99432616	2029	42814055
2030	4947485	2030	67936184	2030	99432616	2030	42814055
2031	4947485	2031	67936184	2031	99432616	2031	42814055
2032	4947485	2032	67936184	2032	99432616	2032	42814055
2033	4947485	2033	67936184	2033	99432616	2033	42814055
2034	4947485	2034	67936184	2034	99432616	2034	42814055
2035	4947485	2035	67936184	2035	99432616	2035	42814055
2036	4947485	2036	67936184	2036	99432616	2036	42814055
2037	4947485	2037	67936184	2037	99432616	2037	42814055
2038	4947485	2038	67936184	2038	99432616	2038	42814055
2039	4947485	2039	67936184	2039	99432616	2039	42814055
2040	4947485	2040	67936184	2040	99432616	2040	42814055
2041	4947485	2041	67936184	2041	99432616	2041	42814055
2042	4947485	2042	67936184	2042	99432616	2042	42814055
2043	4947485	2043	67936184	2043	99432616	2043	42814055
2044	4947485	2044	67936184	2044	99432616	2044	42814055
2045	4947485	2045	67936184	2045	99432616	2045	42814055
2046	4947485	2046	67936184	2046	99432616	2046	42814055
2047	4947485	2047	67936184	2047	99432616	2047	42814055
2048	4947485	2048	67936184	2048	99432616	2048	42814055
2049	4947485	2049	67936184	2049	99432616	2049	42814055
2050	4947485	2050	67936184	2050	99432616	2050	42814055

> Cyprus_forecast		> Czechia_forecast		> Denmark_forecast		> Finland_forecast	
Point	Forecast	Point	Forecast	Point	Forecast	Point	Forecast
2020	7343471	2020	98867718	2020	32066161	2020	42381840
2021	7343608	2021	96722476	2021	32066161	2021	42381840
2022	7343673	2022	94577235	2022	32066161	2022	42381840
2023	7343703	2023	92431993	2023	32066161	2023	42381840
2024	7343717	2024	90286751	2024	32066161	2024	42381840
2025	7343724	2025	88141509	2025	32066161	2025	42381840
2026	7343727	2026	85996267	2026	32066161	2026	42381840
2027	7343728	2027	83851026	2027	32066161	2027	42381840
2028	7343729	2028	81705784	2028	32066161	2028	42381840
2029	7343729	2029	79560542	2029	32066161	2029	42381840
2030	7343729	2030	77415300	2030	32066161	2030	42381840
2031	7343729	2031	75270058	2031	32066161	2031	42381840
2032	7343729	2032	73124817	2032	32066161	2032	42381840
2033	7343729	2033	70979575	2033	32066161	2033	42381840
2034	7343729	2034	68834333	2034	32066161	2034	42381840
2035	7343729	2035	66689091	2035	32066161	2035	42381840
2036	7343729	2036	64543849	2036	32066161	2036	42381840
2037	7343729	2037	62398608	2037	32066161	2037	42381840
2038	7343729	2038	60253366	2038	32066161	2038	42381840
2039	7343729	2039	58108124	2039	32066161	2039	42381840
2040	7343729	2040	55962882	2040	32066161	2040	42381840
2041	7343729	2041	53817641	2041	32066161	2041	42381840
2042	7343729	2042	51672399	2042	32066161	2042	42381840
2043	7343729	2043	49527157	2043	32066161	2043	42381840
2044	7343729	2044	47381915	2044	32066161	2044	42381840
2045	7343729	2045	45236673	2045	32066161	2045	42381840
2046	7343729	2046	43091432	2046	32066161	2046	42381840
2047	7343729	2047	40946190	2047	32066161	2047	42381840
2048	7343729	2048	38800948	2048	32066161	2048	42381840
2049	7343729	2049	36655706	2049	32066161	2049	42381840
2050	7343729	2050	34510464	2050	32066161	2050	42381840

> forecast(germanycc)		> Greece_forecast		> forecast(hungarycc)	
Point	Forecast	Point	Forecast	Point	Forecast
2020	717315933	2020	63121245	2020	48276334
2021	708242949	2021	60798930	2021	47318023
2022	699169966	2022	58752182	2022	46359713
2023	690096983	2023	56948303	2023	45401402
2024	681024000	2024	55358473	2024	44443092
2025	671951017	2025	53957294	2025	43484782
2026	662878034	2026	52722379	2026	42526471
2027	653805050	2027	51634000	2027	41568161
2028	644732067	2028	50674770	2028	40609850
2029	635659084	2029	49829362	2029	39651540
2030	626586101	2030	49084271	2030	38693229
2031	617513118	2031	48427593	2031	37734919
2032	608440134	2032	47848836	2032	36776609
2033	599367151	2033	47338756	2033	35818298
2034	590294168	2034	46889202	2034	34859988
2035	581221185	2035	46492992	2035	33901677
2036	572148202	2036	46143797	2036	32943367
2037	563075219	2037	45836038	2037	31985057
2038	554002235	2038	45564797	2038	31026746
2039	544929252	2039	45325742	2039	30068436
2040	535856269	2040	45115054	2040	29110125
2041	526783286	2041	44929366	2041	28151815
2042	517710303	2042	44765712	2042	27193505
2043	508637320	2043	44621477	2043	26235194
2044	499564336	2044	44494357	2044	25276884
2045	490491353	2045	44382322	2045	24318573
2046	481418370	2046	44283580	2046	23360263
2047	472345387	2047	44196555	2047	22401953
2048	463272404	2048	44119857	2048	21443642
2049	454199420	2049	44052260	2049	20485332
2050	445126437	2050	43992684	2050	19527021

> France_forecast	
Point	Forecast
2020	311393822
2021	306400863
2022	301407905
2023	296414946
2024	291421988
2025	286429029
2026	281436071
2027	276443112
2028	271450154
2029	266457195
2030	261464237
2031	256471278
2032	251478320
2033	246485362
2034	241492403
2035	236499445
2036	231506486
2037	226513528
2038	221520569
2039	216527611
2040	211534652
2041	206541694
2042	201548735
2043	196555777
2044	191562818
2045	186569860
2046	181576902
2047	176583943
2048	171590985
2049	166598026
2050	161605068

> Ireland_forecast		> Italy_forecast		> Luxembourg_forecas		> Malta_forecast	
Point	Forecast	Point	Forecast	Point	Forecast	Point	Forecast
2020	36787532	2020	331536277	2020	10148982	2020	1649193
2021	36249400	2021	323839355	2021	10500360	2021	1649193
2022	35711268	2022	316142432	2022	10702535	2022	1649193
2023	35173136	2023	308445509	2023	10806104	2023	1649193
2024	34635004	2024	300748587	2024	10775707	2024	1649193
2025	34096872	2025	293051664	2025	10629007	2025	1649193
2026	33558740	2026	285354741	2026	10427430	2026	1649193
2027	33020608	2027	277657818	2027	10215220	2027	1649193
2028	32482476	2028	269960896	2028	10036173	2028	1649193
2029	31944344	2029	262263973	2029	9925441	2029	1649193
2030	31406213	2030	254567050	2030	9895040	2030	1649193
2031	30868081	2031	246870128	2031	9939291	2031	1649193
2032	30329949	2032	239173205	2032	10038805	2032	1649193
2033	29791817	2033	231476282	2033	10164770	2033	1649193
2034	29253685	2034	223779360	2034	10287186	2034	1649193
2035	28715553	2035	216082437	2035	10381314	2035	1649193
2036	28177421	2036	208385514	2036	10431700	2036	1649193
2037	27639289	2037	200688591	2037	10434211	2037	1649193
2038	27101157	2038	192991669	2038	10395270	2038	1649193
2039	26563025	2039	185294746	2039	10328929	2039	1649193
2040	26024893	2040	177597823	2040	10252892	2040	1649193
2041	25486761	2041	169900901	2041	10184321	2041	1649193
2042	24948629	2042	162203978	2042	10136341	2042	1649193
2043	24410497	2043	154507055	2043	10115919	2043	1649193
2044	23872365	2044	146810133	2044	10123303	2044	1649193
2045	23334233	2045	139113210	2045	10152943	2045	1649193
2046	22796101	2046	131416287	2046	10195481	2046	1649193
2047	22257969	2047	123719364	2047	10240238	2047	1649193
2048	21719837	2048	116022442	2048	10277620	2048	1649193
2049	21181705	2049	108325519	2049	10300947	2049	1649193
2050	20643573	2050	100628596	2050	10307418	2050	1649193

> Netherlands_forec		> Norway_forecast		> Poland_forecast		> Portugal_forecast	
Point	Forecast	Point	Forecast	Point	Forecast	Point	Forecast
2020	153032800	2020	43846309	2020	314773798	2020	46660226
2021	153032800	2021	43836552	2021	311059917	2021	45701625
2022	153032800	2022	44257043	2022	307346035	2022	44743023
2023	153032800	2023	44504864	2023	303632154	2023	43784421
2024	153032800	2024	44821982	2024	299918272	2024	42825820
2025	153032800	2025	45111290	2025	296204391	2025	41867218
2026	153032800	2026	45411759	2026	292490509	2026	40908616
2027	153032800	2027	45707748	2027	288776628	2027	39950014
2028	153032800	2028	46005535	2028	285062746	2028	38991413
2029	153032800	2029	46302601	2029	281348865	2029	38032811
2030	153032800	2030	46599956	2030	277634983	2030	37074209
2031	153032800	2031	46897195	2031	273921102	2031	36115608
2032	153032800	2032	47194481	2032	270207220	2032	35157006
2033	153032800	2033	47491748	2033	266493338	2033	34198404
2034	153032800	2034	47789022	2034	262779457	2034	33239803
2035	153032800	2035	48086293	2035	259065575	2035	32281201
2036	153032800	2036	48383566	2036	255351694	2036	31322599
2037	153032800	2037	48680838	2037	251637812	2037	30363997
2038	153032800	2038	48978110	2038	247923931	2038	29405396
2039	153032800	2039	49275383	2039	244210049	2039	28446794
2040	153032800	2040	49572655	2040	240496168	2040	27488192
2041	153032800	2041	49869927	2041	236782286	2041	26529591
2042	153032800	2042	50167199	2042	233068405	2042	25570989
2043	153032800	2043	50464472	2043	229354523	2043	24612387
2044	153032800	2044	50761744	2044	225640642	2044	23653786
2045	153032800	2045	51059016	2045	221926760	2045	22695184
2046	153032800	2046	51356288	2046	218212878	2046	21736582
2047	153032800	2047	51653561	2047	214498997	2047	20777980
2048	153032800	2048	51950833	2048	210785115	2048	19819379
2049	153032800	2049	52248105	2049	207071234	2049	18860777
2050	153032800	2050	52545377	2050	203357352	2050	17902175

> Romania_forecast		> Spain_forecast		> Sweden_forecast		> Switzerland_foreca	
Point	Forecast	Point	Forecast	Point	Forecast	Point	Forecast
2020	75639337	2020	251825150	2020	40194513	2020	36733064
2021	75639337	2021	251825150	2021	39406533	2021	36733064
2022	75639337	2022	251825150	2022	38618554	2022	36733064
2023	75639337	2023	251825150	2023	37830574	2023	36733064
2024	75639337	2024	251825150	2024	37042595	2024	36733064
2025	75639337	2025	251825150	2025	36254615	2025	36733064
2026	75639337	2026	251825150	2026	35466636	2026	36733064
2027	75639337	2027	251825150	2027	34678657	2027	36733064
2028	75639337	2028	251825150	2028	33890677	2028	36733064
2029	75639337	2029	251825150	2029	33102698	2029	36733064
2030	75639337	2030	251825150	2030	32314718	2030	36733064
2031	75639337	2031	251825150	2031	31526739	2031	36733064
2032	75639337	2032	251825150	2032	30738759	2032	36733064
2033	75639337	2033	251825150	2033	29950780	2033	36733064
2034	75639337	2034	251825150	2034	29162800	2034	36733064
2035	75639337	2035	251825150	2035	28374821	2035	36733064
2036	75639337	2036	251825150	2036	27586842	2036	36733064
2037	75639337	2037	251825150	2037	26798862	2037	36733064
2038	75639337	2038	251825150	2038	26010883	2038	36733064
2039	75639337	2039	251825150	2039	25222903	2039	36733064
2040	75639337	2040	251825150	2040	24434924	2040	36733064
2041	75639337	2041	251825150	2041	23646944	2041	36733064
2042	75639337	2042	251825150	2042	22858965	2042	36733064
2043	75639337	2043	251825150	2043	22070986	2043	36733064
2044	75639337	2044	251825150	2044	21283006	2044	36733064
2045	75639337	2045	251825150	2045	20495027	2045	36733064
2046	75639337	2046	251825150	2046	19707047	2046	36733064
2047	75639337	2047	251825150	2047	18919068	2047	36733064
2048	75639337	2048	251825150	2048	18131088	2048	36733064
2049	75639337	2049	251825150	2049	17343109	2049	36733064
2050	75639337	2050	251825150	2050	16555129	2050	36733064

> Turkey_forecast		> United_Kingdom_fo	
Point	Forecast	Point	Forecast
2020	410091726	2020	359258867
2021	418463713	2021	353764453
2022	426835699	2022	348270040
2023	435207686	2023	342775627
2024	443579672	2024	337281213
2025	451951658	2025	331786800
2026	460323645	2026	326292387
2027	468695631	2027	320797973
2028	477067618	2028	315303560
2029	485439604	2029	309809147
2030	493811591	2030	304314733
2031	502183577	2031	298820320
2032	510555563	2032	293325907
2033	518927550	2033	287831493
2034	527299536	2034	282337080
2035	535671523	2035	276842667
2036	544043509	2036	271348253
2037	552415495	2037	265853840
2038	560787482	2038	260359427
2039	569159468	2039	254865013
2040	577531455	2040	249370600
2041	585903441	2041	243876187
2042	594275427	2042	238381773
2043	602647414	2043	232887360
2044	611019400	2044	227392947
2045	619391387	2045	221898533
2046	627763373	2046	216404120
2047	636135359	2047	210909707
2048	644507346	2048	205415293
2049	652879332	2049	199920880
2050	661251319	2050	194426467

Appendix D

```
> forecast(albania_1990_2000)
Point Forecast
2020 1100000
2021 1100000
2022 1100000
2023 1100000
2024 1100000
2025 1100000
2026 1100000
2027 1100000
2028 1100000
2029 1100000
2030 1100000
2031 1100000
2032 1100000
2033 1100000
2034 1100000
2035 1100000
2036 1100000
2037 1100000
2038 1100000
2039 1100000
2040 1100000
2041 1100000
2042 1100000
2043 1100000
2044 1100000
2045 1100000
2046 1100000
2047 1100000
2048 1100000
2049 1100000
2050 1100000

> forecast(austria_1990_2000)
Point Forecast
2020 3811379
2021 3772759
2022 3734138
2023 3695517
2024 3656896
2025 3618276
2026 3579655
2027 3541034
2028 3502414
2029 3463793
2030 3425172
2031 3386552
2032 3347931
2033 3309310
2034 3270690
2035 3232069
2036 3193448
2037 3154828
2038 3116207
2039 3077586
2040 3038966
2041 3000345
2042 2961724
2043 2923103
2044 2884483
2045 2845862
2046 2807241
2047 2768621
2048 2730000
2049 2691379
2050 2652759

> forecast(belgium_1990_2000)
Point Forecast
2020 4580000
2021 4580000
2022 4580000
2023 4580000
2024 4580000
2025 4580000
2026 4580000
2027 4580000
2028 4580000
2029 4580000
2030 4580000
2031 4580000
2032 4580000
2033 4580000
2034 4580000
2035 4580000
2036 4580000
2037 4580000
2038 4580000
2039 4580000
2040 4580000
2041 4580000
2042 4580000
2043 4580000
2044 4580000
2045 4580000
2046 4580000
2047 4580000
2048 4580000
2049 4580000
2050 4580000

> forecast(bulgaria_1990_2000)
Point Forecast
2020 4197824
2021 4235649
2022 4273473
2023 4311298
2024 4349122
2025 4386947
2026 4424772
2027 4462596
2028 4500421
2029 4538245
2030 4576070
2031 4613894
2032 4651719
2033 4689543
2034 4727368
2035 4765192
2036 4803017
2037 4840841
2038 4878666
2039 4916490
2040 4954315
2041 4992139
2042 5029964
2043 5067789
2044 5105613
2045 5143438
2046 5181262
2047 5219087
2048 5256911
2049 5294736
2050 5332560
```

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> forecast(cyprus_mo > forecast(czechia_m > forecast(denmark_m > forecast(finland_m
Point Forecast Point Forecast Point Forecast Point Forecast
2020 371016.0 2020 5320000 2020 5096552 2020 5010000
2021 365896.3 2021 5320000 2021 5023104 2021 5010000
2022 365896.3 2022 5320000 2022 4949655 2022 5010000
2023 365896.3 2023 5320000 2023 4876207 2023 5010000
2024 365896.3 2024 5320000 2024 4802759 2024 5010000
2025 365896.3 2025 5320000 2025 4729310 2025 5010000
2026 365896.3 2026 5320000 2026 4655862 2026 5010000
2027 365896.3 2027 5320000 2027 4582414 2027 5010000
2028 365896.3 2028 5320000 2028 4508966 2028 5010000
2029 365896.3 2029 5320000 2029 4435517 2029 5010000
2030 365896.3 2030 5320000 2030 4362069 2030 5010000
2031 365896.3 2031 5320000 2031 4288621 2031 5010000
2032 365896.3 2032 5320000 2032 4215172 2032 5010000
2033 365896.3 2033 5320000 2033 4141724 2033 5010000
2034 365896.3 2034 5320000 2034 4068276 2034 5010000
2035 365896.3 2035 5320000 2035 3994828 2035 5010000
2036 365896.3 2036 5320000 2036 3921379 2036 5010000
2037 365896.3 2037 5320000 2037 3847931 2037 5010000
2038 365896.3 2038 5320000 2038 3774483 2038 5010000
2039 365896.3 2039 5320000 2039 3701034 2039 5010000
2040 365896.3 2040 5320000 2040 3627586 2040 5010000
2041 365896.3 2041 5320000 2041 3554138 2041 5010000
2042 365896.3 2042 5320000 2042 3480690 2042 5010000
2043 365896.3 2043 5320000 2043 3407241 2043 5010000
2044 365896.3 2044 5320000 2044 3333793 2044 5010000
2045 365896.3 2045 5320000 2045 3260345 2045 5010000
2046 365896.3 2046 5320000 2046 3186897 2046 5010000
2047 365896.3 2047 5320000 2047 3113448 2047 5010000
2048 365896.3 2048 5320000 2048 3040000 2048 5010000
2049 365896.3 2049 5320000 2049 2966552 2049 5010000
2050 365896.3 2050 5320000 2050 2893103 2050 5010000

> forecast(germany_m > forecast(greece_m > forecast(hungary_m
Point Forecast Point Forecast Point Forecast Point Forecast
2020 37812842 2020 33043102.4 2020 4162068.9 2020 5700000
2021 37045911 2021 31966205.9 2021 4054137.9 2021 5700000
2022 36278980 2022 30889309.3 2022 3946206.9 2022 5700000
2023 35512050 2023 29812412.8 2023 3838275.8 2023 5700000
2024 34745119 2024 28735516.3 2024 3730344.8 2024 5700000
2025 33978188 2025 27658619.7 2025 3622413.8 2025 5700000
2026 33211257 2026 26581723.2 2026 3514482.7 2026 5700000
2027 32444326 2027 25504826.6 2027 3406551.7 2027 5700000
2028 31677396 2028 24427930.1 2028 3298620.6 2028 5700000
2029 30910465 2029 23351033.6 2029 3190689.6 2029 5700000
2030 30143534 2030 22274137.0 2030 3082758.6 2030 5700000
2031 29376603 2031 21197240.5 2031 2974827.5 2031 5700000
2032 28609673 2032 20120344.0 2032 2866896.5 2032 5700000
2033 27842742 2033 19043447.4 2033 2758965.4 2033 5700000
2034 27075811 2034 17966550.9 2034 2651034.4 2034 5700000
2035 26308880 2035 16889654.4 2035 2543103.4 2035 5700000
2036 25541950 2036 15812757.8 2036 2435172.3 2036 5700000
2037 24775019 2037 14735861.3 2037 2327241.3 2037 5700000
2038 24008088 2038 13658964.7 2038 2219310.3 2038 5700000
2039 23241157 2039 12582068.2 2039 2111379.2 2039 5700000
2040 22474227 2040 11505171.7 2040 2003448.2 2040 5700000
2041 21707296 2041 10428275.1 2041 1895517.1 2041 5700000
2042 20940365 2042 9351378.6 2042 1787586.1 2042 5700000
2043 20173434 2043 8274482.1 2043 1679655.1 2043 5700000
2044 19406504 2044 7197585.5 2044 1571724.0 2044 5700000
2045 18639573 2045 6120689.0 2045 1463793.0 2045 5700000
2046 17872642 2046 5043792.5 2046 1355861.9 2046 5700000
2047 17105711 2047 3966895.9 2047 1247930.9 2047 5700000
2048 16338781 2048 2889999.4 2048 1139999.9 2048 5700000
2049 15571850 2049 1813102.9 2049 1032068.8 2049 5700000
2050 14804919 2050 736206.3 2050 924137.8 2050 5700000

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> forecast(ireland_m) > forecast(italy_m) > forecast(Luxembourg) > forecast(malta_m)
Point Forecast Point Forecast Point Forecast Point Forecast
2020 9250000 2020 14967931 2020 380000 2020 55344.41
2021 9250000 2021 14585862 2021 380000 2021 61485.41
2022 9250000 2022 14203793 2022 380000 2022 61485.41
2023 9250000 2023 13821725 2023 380000 2023 61485.41
2024 9250000 2024 13439656 2024 380000 2024 61485.41
2025 9250000 2025 13057587 2025 380000 2025 61485.41
2026 9250000 2026 12675518 2026 380000 2026 61485.41
2027 9250000 2027 12293449 2027 380000 2027 61485.41
2028 9250000 2028 11911380 2028 380000 2028 61485.41
2029 9250000 2029 11529311 2029 380000 2029 61485.41
2030 9250000 2030 11147242 2030 380000 2030 61485.41
2031 9250000 2031 10765173 2031 380000 2031 61485.41
2032 9250000 2032 10383104 2032 380000 2032 61485.41
2033 9250000 2033 10001035 2033 380000 2033 61485.41
2034 9250000 2034 9618966 2034 380000 2034 61485.41
2035 9250000 2035 9236897 2035 380000 2035 61485.41
2036 9250000 2036 8854828 2036 380000 2036 61485.41
2037 9250000 2037 8472759 2037 380000 2037 61485.41
2038 9250000 2038 8090690 2038 380000 2038 61485.41
2039 9250000 2039 7708621 2039 380000 2039 61485.41
2040 9250000 2040 7326552 2040 380000 2040 61485.41
2041 9250000 2041 6944483 2041 380000 2041 61485.41
2042 9250000 2042 6562414 2042 380000 2042 61485.41
2043 9250000 2043 6180345 2043 380000 2043 61485.41
2044 9250000 2044 5798276 2044 380000 2044 61485.41
2045 9250000 2045 5416207 2045 380000 2045 61485.41
2046 9250000 2046 5034138 2046 380000 2046 61485.41
2047 9250000 2047 4652069 2047 380000 2047 61485.41
2048 9250000 2048 4270000 2048 380000 2048 61485.41
2049 9250000 2049 3887931 2049 380000 2049 61485.41
2050 9250000 2050 3505863 2050 380000 2050 61485.41

> forecast(netherlands) > forecast(norway_m) > forecast(poland_m) > forecast(portugal_m)
Point Forecast Point Forecast Point Forecast Point Forecast
2020 8029073.5 2020 3343793 2020 21680000 2020 2930240
2021 7773950.1 2021 3287586 2021 21680000 2021 2903150
2022 7518826.7 2022 3231379 2022 21680000 2022 2862678
2023 7263703.3 2023 3175172 2023 21680000 2023 2827687
2024 7008579.8 2024 3118966 2024 21680000 2024 2790451
2025 6753456.4 2025 3062759 2025 21680000 2025 2754135
2026 6498333.0 2026 3006552 2026 21680000 2026 2717442
2027 6243209.6 2027 2950345 2027 21680000 2027 2680903
2028 5988086.2 2028 2894138 2028 21680000 2028 2644301
2029 5732962.7 2029 2837931 2029 21680000 2029 2607726
2030 5477839.3 2030 2781724 2030 21680000 2030 2571139
2031 5222715.9 2031 2725517 2031 21680000 2031 2534557
2032 4967592.5 2032 2669310 2032 21680000 2032 2497973
2033 4712469.1 2033 2613103 2033 21680000 2033 2461389
2034 4457345.7 2034 2556897 2034 21680000 2034 2424806
2035 4202222.2 2035 2500690 2035 21680000 2035 2388222
2036 3947098.8 2036 2444483 2036 21680000 2036 2351639
2037 3691975.4 2037 2388276 2037 21680000 2037 2315055
2038 3436852.0 2038 2332069 2038 21680000 2038 2278472
2039 3181728.6 2039 2275862 2039 21680000 2039 2241888
2040 2926605.1 2040 2219655 2040 21680000 2040 2205305
2041 2671481.7 2041 2163448 2041 21680000 2041 2168721
2042 2416358.3 2042 2107241 2042 21680000 2042 2132138
2043 2161234.9 2043 2051034 2043 21680000 2043 2095554
2044 1906111.5 2044 1994828 2044 21680000 2044 2058971
2045 1650988.1 2045 1938621 2045 21680000 2045 2022387
2046 1395864.6 2046 1882414 2046 21680000 2046 1985804
2047 1140741.2 2047 1826207 2047 21680000 2047 1949220
2048 885617.8 2048 1770000 2048 21680000 2048 1912637
2049 630494.4 2049 1713793 2049 21680000 2049 1876053
2050 375371.0 2050 1657586 2050 21680000 2050 1839470

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> forecast(rom,h=31) > forecast(spain_mc) > forecast(sweden_mc) > forecast(switzerland_
Point Forecast Point Forecast Point Forecast Point Forecast
2020 9096296 2020 20070000 2020 5569513 2020 2405517
2021 9245013 2021 20070000 2021 5595663 2021 2391035
2022 9386516 2022 20070000 2022 5585962 2022 2376552
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BIOGRAPHICAL SKETCH

Rana Duygu Alkurt completed their Bachelor of Science degree in Industrial Engineering from Atilim University in 2021, along with a minor degree in Electrical and Electronics Engineering. She has been working as a Business Analyst at Figopara since July 2022. Currently, she is pursuing a master's degree in Industrial Engineering under the supervision of Assoc. Dr. Mehtap Dursun Karahüseyin at the Institute of Science and Engineering, Galatasaray University.

In July 2020, she co-authored a research paper titled "Identification of Performance Metrics that Offer Competitive Advantage and their Impact on Strategic Management Decision-Making Processes" as part of an undergraduate research project. Additionally, she co-authored a conference paper titled "Multi-Period Multi-Product Production Planning for a Cement Factory," which was published in June 2021 as part of the 40th YAEM Congress. This paper was also a finalist in the student competition at the same congress.