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Prediction of Energy Consumption by Using Regression Model

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Keywords

Energy System,
Renewable energy,
Regression.

Abstract

Energy crisis is one of the problems that lead to different changes for countries. Increasing this matter in different countries has made them substitute alternative and renewable energies instead of other resources. Which in turn has brought about development that contributes to sustainability In this work, we analyzed the energy supply and demand in Germany for describing energy consumption in each sector. Considering the energy balance sheet data, the correlation between energy consumption and some basic parameters such as GDP, population growth, and industrial growth rate is analyzed through a regression model. Regarding the model, energy consumption in 2022 is predicted as 209018.1 Mtoe. According to the model, a significant decrease in energy consumption is obtained which is the consequence of renewable energy use in each sector.

1. Introduction

Energy is one of the most important topics in the past, present, and future of mankind. The complexity and importance of the issues related to it have never been as it is today. There are the very different issues related to energy management and programming which make it difficult to get a catch on energy matters. For instance, complexity in supply and demand indicators, global and regional markets status, and environmental impacts are such subjects which make it sophisticated to simply discuss energy related matters as well [1].

Economic growth and global energy demand augmentation caused oil and gas prices increase and also decrease the reliance on these sources for energy. Therefore, other resources replacement is one of the best choices for primary energy [2].

One of the most controversial debates is fossil fuels consumption in developed countries which have increased in recent years. Therefore, the matter of emissions and existence of resources related to fossil fuels, roll as a basic concerning in many countries.as for the solution, renewable energies can get a good result. In order to replace renewable energies, recognizing energy demand trend is one of the most important targets [3].

This article aims to analyze energy consumption in Germany. Electricity consumption in various sectors incorporates industry, residential, and transportation is investigated. Then, with using forecasting tools, the best regression model is presented and applied for 2022 energy consumption prediction. Subsequent examination of regression shows the impact of basic parameters on energy demand together. Parameters include GDP, population growth, and industrial growth rate which can influence on energy consumption individually.

2. Literature Review

2.1. Country Situation

Germany is one of the central Europe countries, with an area of 357121. 41 Km^2 by 2015. According to the statistics, it has 79,758,764 inhabitants and is the most populous country in Europe (with 223 Km^2 population density) [4]. The country has a temperate climate and is the third largest exporter of goods and services in the world. Also, Germany has the third largest economy in the world and the first in Europe. On the other hand, it is the sixth country taking into account energy consumption which is extremely dependent on exports. Around 60% of its energy supplied from other countries. Because of the central location, it is called transportation node in order to link countries. Approximately, about a third of energy consumption is consumed in industry. Whereas, transportation and residential sectors consume about a quarter of energy consumption [3].

The use of renewable energy saved 30 billion euro compared with consumption patterns without the presence of renewable energy in the years 2011 to 2013 [5]. Almost a

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third of all solar panels and more than half wind turbines of the entire world are made by Germany [3]. Figure1 shows the share of energies in Germany compared in 3 individual years. Thus, the share of renewable energies is increased with nuclear fading.

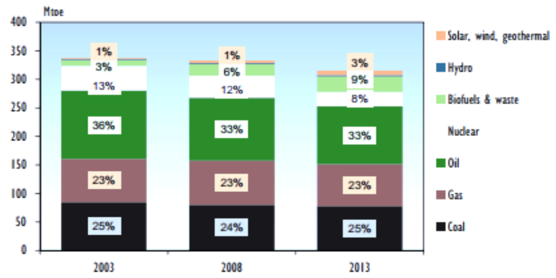

Figure 1. the share of energies in Germany compared in 3 individual years [3]

2.2. Germany's Energy Balance Analysis

Based on Germany's energy balance, the total primary energy supply (TPES) in 2013 considered as 317 Mtoe which has increased about 2% compared with last year. This rise is caused by an increase in imports. Primary energy is supplied from resources such as coal (25% of production and imports), oil (30% of imports), natural gas (23% of imports), nuclear energy (8% of production), and biodiesel (9% of production) [3].

2.2.1. Production

A number of renewable energies production is reported 33680 Mtoe in 2013 (12% of total energy consumption). Total energy production is presented 35% which 20% is related to renewable energies. Figure 2 depicts the share of renewable energies in 2015.

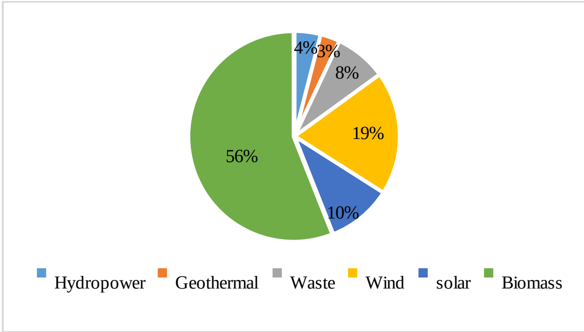

Figure 2. Share of renewable energies in 2015

2.2.2. Consumption

Total energy consumption is reported 218 Mtoe in 2011, 220 Mtoe in 2012 (1% increase), and 224 Mtoe in 2013 (1% increase). Figure 3 represents the share of energy consumption by sectors in 2011-2013. This trend is shown that the energy consumption in different parts of Germany is relatively stable and completely under control [3].

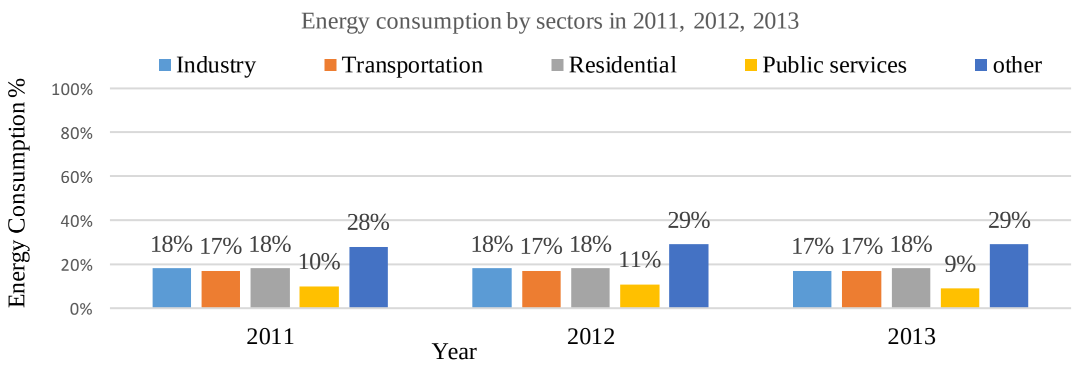

Figure 3. The share of energy consumption by sectors in 2011-2013 [3]

2.3. Germany's Electricity Consumption Analysis

Electricity consumption has surged over the past 10 years (Figure 4) [3]. The use of renewable energies reduces electricity prices in recent years [5]. In recent years, renewable power installed capacity has increased in Germany and reached 76 thousand MW by the end of 2012 [6]. Figure 5 plots the share of power generation by each resource in 2014.

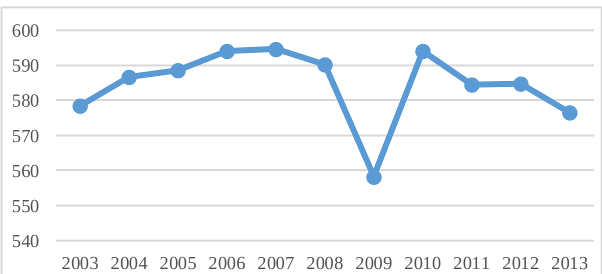

Figure 4. Electricity consumption over the past 10 years

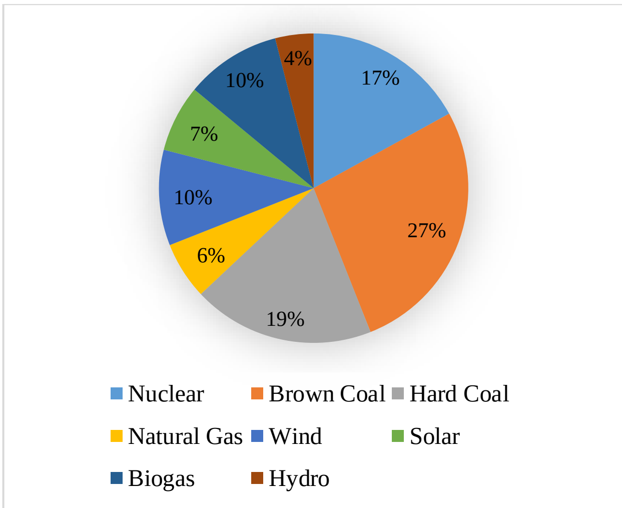

Figure 5. Share of power generation by each resource in 2014 [7]

2.4. Germany's Industrial Energy Consumption

In 2013, the most important primary energy which is used to supply energy demand in the industry reported the electricity (33%). According to Germany's energy balance, it is obtained that the share of coal, biodiesel, oil product and heat is 4%, 32%, 11%, and 14% respectively. Furthermore, data is shown that the use of renewable energies and their production capacity is rising during recent years.

2.5. Germany's Residential Energy Consumption

The country is gradually reducing its dependence on fossil fuels, thus turning more and more to renewable technologies. It is much obvious in residential part with using geothermal energy as a point of view. On the other hand, the use of fossil fuels is still noticeable where natural gas and oil products are 38% and 23% respectively [3]. To be exact, 60% of total energy is used for space heating, 15% for water heating, and 17% for equipment. As regards renewable energy, about 5% of buildings equipped with solar water heaters in 2012. Among 2000 to 2008, around 20% energy efficiency added which is refer to the residential sector. Further, this number increased 5% during 2009-2012 [3].

2.6. A Comparison Between Residential and Industry Sectors

According to energy balance data in 10 years, the industrial and residential trend is plotted (Figure 6). Regarding the industrial trend, it is almost constant during this period. While there are 2 reductions in residential energy consumption [3].

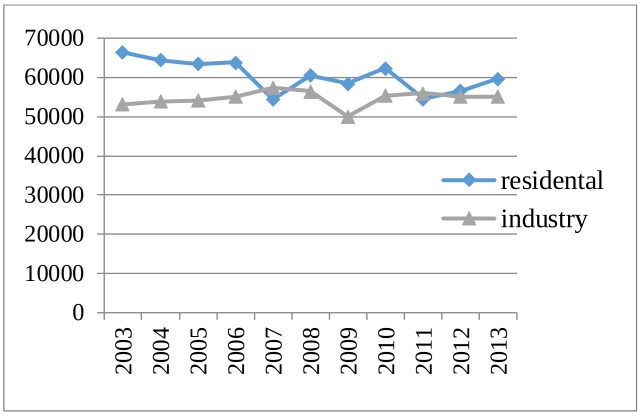

Figure 6. Industrial and residential consumption trends during 10 years [3]

2.7. Germany's transportation energy consumption

Oil products are considered as the main resource for transportation demand which comprises 92% in 2013. Bioenergy is used as 5%, thus remain are natural gas and electricity. According to statistics, there existed no change in 2012, although total energy consumption increased in 2013. Furthermore, 5.4% of the energy needs in transport sector were covered by renewables in 2014 (Figure 7) [8].

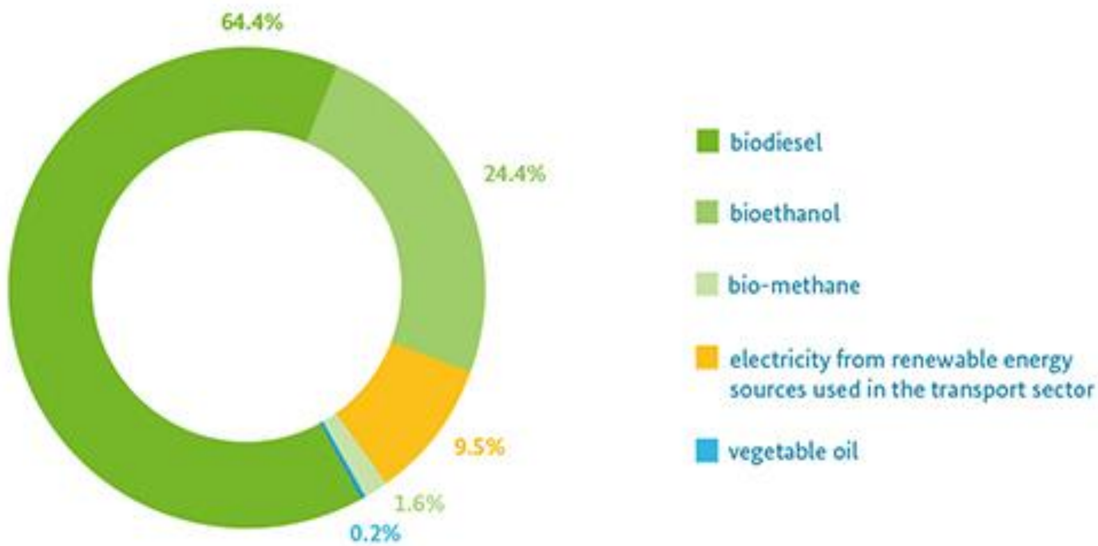

Figure 7. The energy needs in transport sector were covered by renewables in 2014 [8]

3. Forecasting Methods Review

Energy models are standard tool for energy planning. In recent years, efforts have been made for formulation and implementation of energy planning strategies. Therefore, different energy models have identified all around the world. In this study, considering the energy demand trend for each country, the best model is predicted.

4. Energy Forecasting Reviews in Germany

Energy demand prediction is one of the most important concerns all around the world whose solution is evaluated by models and policies in order to take key decisions affecting the economy of a country. Different experiments have been conducted for the estimation of energy demand, in both terms of methodology and estimation [9]. Studies show an error of lower than 2% through a model applied in Spain [10]. A future energy model on the basis of bottom-up system introduced in Germany. The new IKARUS-Model described is a time-step or myopic dynamical bottom-up linear optimization model where each time interval is optimized by itself taking into account the heritage due to results from all periods before. Recent calculations of this model are shown reasonable results [11]. General energy transition time-series based models introduced to evaluate renewable energies consumption and the benefits of this technology replacement with the passages of time [12]. Moreover, an electricity demand response potential model with a high share of renewable energies presented in Germany. In a case study considering a future German power supply system with a share of 70% renewable energies, possible cost reductions achieved by investment [13]. Hence, several models were analyzed and identified as the most accurate. The very common models used in this country are MAED-2, FfE-Gebäudemodell, CDEM, REM, CREEM, ECCABS, REEPS, BREHOMES, LEAP, DECM, CHM, BSM [14-16](see Table 1).

Table 1. The very common energy models

Model Name	Developer	Model Description
LEAP (Long-range Energy Alternatives Planning)	SEI—Stockholm Environment Institute, Tellus Institute, USA	Integrated modeling tool that can be used for the analysis and evaluation of energy policies and the assessment of climate change mitigation measures across all sectors of an economy (housing, commercial, transportation and industry sectors).
FfE Gebäudemodell (Forschungsstelle für Energiewirtschaft-Gebäudemodel)	Forschungsstelle für Energiewirtschaft e.V. (FfE), Germany	On the basis of available statistical data and distribution keys (floor space per building type, location of buildings, specific energy demand for space heating and hot water provision) this model allows to derive detailed conclusions for the energy demand in the German residential sector.
REM (Regional Engineering Model)	University of Joensuu, Finland	Regional building stock model for assessing the energy demand for space heating and the related GHG emissions and costs. The model was validated using the province of North Karelia, Finland as case study area.
BSM (bottom-up Building-Stock-Model)	Karlsruhe Institute of Technology, Germany	Modular tool for predicting the building stock development (based on deterministic projections of floor space and demolition/refurbishment rates) and the energy demand (based on statistical data for the specific energy demand for space heating). The model is designed for analyzing the German federal government's energy policy targets for the residential sector.
MAED-2 (Model for Analysis of Energy Demand)	International Atomic Energy Agency, Austria	Based on medium- to long-term scenarios of socio-economic, technological and demographic developments this model allows the prediction of the future energy demand. Calculations are performed for the housing, commercial, transportation and industry sectors.
ECCABS (Energy, Carbon and Costs Assessment of Building Stocks)	Chalmers University of Technology, Sweden	Calculation of the annual energy demand, CO2 emissions and energy costs associated with the residential sector. This Model is designed to assess the effects of energy saving measures and CO2 emission mitigation strategies.
CDEM (Community Domestic Energy Model)	Department of Civil and Building Engineering, Loughborough University, UK	Using the core calculation engine BREDEM-8 (Building Research Establishment Domestic Energy Model) this model calculates the monthly energy demand and CO2 emissions in the English residential sector, disaggregating the English housing stock into 47 house archetypes.
CREEM (Canadian Residential Energy End-use Model)	Canadian Residential Energy End-use Data and Analysis Centre, Canada	Calculation of the annual and monthly energy demand and CO2 emissions in the Canadian residential sector. The Software HOT2000 is used as calculation engine.
BREHOMES (Building Research Establishment Housing Model for Energy Studies)	Building Research Establishment (BRE), UK	Disaggregation of the UK housing stock into over 1000 dwelling categories and calculation of the energy demand for each dwelling category with BREDEM-12.
REEPS (Residential End-use Energy Planning System)	Electric Power Research Institute, USA	Evaluation of future trends in energy demand (based on forecasts for appliance installations, operating efficiencies, and utilization patterns for space heating, water heating, air conditioning and cooking) in the US housing sector, taking into account various user-defined assumptions and/or different development scenarios.
DECM(Domestic Energy and Carbon Model)	The Martin Centre for Architectural and Urban Studies, Department of Architecture, University of Cambridge, UK	Prediction of the energy demand and CO2 emissions of the existing English housing stock, using the core calculation engine SAP-2005 (Standard Assessment Procedure). An occupancy pattern is added to this model as a novel feature.
CHM (Cambridge Housing Model)	Cambridge Architectural Research Ltd (CAR), UK	Based on SAP-2009 the model generates estimates for the household energy demand for the UK Government’s Department of Energy and Climate Change (DECC).

5. Analysis of the Relationship between Consumption and Fundamental Economic Variables

5.1. Regression Analysis

Table 2 represents regression results. As a result, the R square is calculated 0.83 which means the high relationship between energy consumption and the parameters above. Therefore, energy consumption prediction is possible considering the equation bellow

$$Y = -1088663.837 - 3.359X_1 + 16128.479X_2 + 494.879X_3 \quad (1)$$

According to Eq. (1), X_1, X_2, X_3 are GDP, population growth and industrial production growth rate factors, respectively.

Table 2. Regression results

Regression Statistics	
Multiple R	0.91117055
R Square	0.83023177
Adjusted R Square	0.745347656
Standard Error	3344.454522
Observations	10
ANOVA	
	df
Regression	3
Residual	6
Total	9
	Coefficients
Intercept	-1088663.837
GDP-billion 2005 USD	-3.359174408
population-millions	16128.47925
Industrial Prodduction Grothe rate	494.8793617
RESIDUAL OUTPUT	

5.1.2. Energy Consumption Prediction

Considering parameter's trend, it is easily possible to predict each amount in one special year. Then, energy consumption is calculated yearly. Equations bellow are shown a linear relationship between year and each parameter.

Year-GDP

$$X_1 = -19.999x + 3433.5 \quad (2)$$

Year- Population growth

$$X_2 = -0.0732x + 82.517 \quad (3)$$

Year- Industrial growth rate

$$X_3 = -0.1939x + 2.6667 \quad (4)$$

Using the above relations, energy consumption is calculated in 2022.

6. Conclusion

Evaluations show a genuine prediction for energy demand from which energy consumption can be controlled and future target scenarios will be reached as well. In this work, energy consumption is predicted taking into account 3 basic parameters such as GDP, population growth, and industrial production rate. Further, Practical solutions and analysis in order to introduce a model is obtained.

With using energy modeling scenarios, sustainable aims, and considering Germany's policy in 2020, renewable energies can fill energy demand's gaps. Moreover, emissions and dependence on other countries reduction are resulted. In future, on the basis of other influenced parameters, environmental consideration, different energy consumption patterns, changes in import and export, international commitment, and technology progressing, study and research in the field of energy will be conducted adequately in Germany.

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