Germany's Energy Transition and International Political Economy: The Impact of Renewable Energy Development on the Power Balance within the European Union

Ziwei Yin[1]; Letao Han[2]; Huiru Wu[3]*

[1]Institute for Global Prosperity, University College London, London, UK
[2]College of Asia & the Pacific, Australian National University, Canberra, Australia
[3]Shijiazhuang Tourist School, Hebei, China

*wuhuiru1973@126.com

Abstract. The Germany's Energiewende, as examined within the Neoliberal Institutionalism framework, is the example of the power of cooperation and institutions helping to provide solutions beneficial for all the members of the EU in the energy sector. A few institutional changes have been made with regard to transition to renewable energy in Germany including increased energy efficiency and lowered CO_2emission rate. By helping the analysis using Ordinary Least Squares (OLS) regression analysis on the above hypothesis and variables, the positive effect of investments in renewable energy and energy efficiency is demonstrated. Some of the countries which have invested highly in the use renewable energy especially renewable energy technologies like Germany have has enjoyed better energy efficiency. The break up by financial analysis presents a feasible solar energy investments in Germany through the IRR which stands at 8%. This paper explains how Germany has been an active player in norm diffusion in EU putting policies on energy in place, and advocating for international climate cooperation. Promising policy strategies with regard to energy transition entail improving the efficacy of this strategy, stepping up investment in renewable resources, fostering institutional collaboration and integrated markets among EU member states toward a sustainable energy mix.

Keywords: Energiewende; Energy Transition; International Political Economy; European Union

1 Introduction

The Energiewende is the energy transformation of Germany and has economic, political and international aspects to an extent that makes the process multifaceted and complex. The changes are driven by various reasons which include the technological innovations in renewable energy sources, the necessity for the reduction of carbon emission

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as well as the quest for energy self sufficiency[4]. Renewable energy sources have drastically affected Germany in aspect of economy and politics, the shares of energy mix have changed and reduced use of nuclear energy and fuel[20] This has also reshaped the internal politics of the EU, placing Germany in the driver's seat when it comes to establishing European renewable energy integration policies.[1]

However, there have been challenges some of which include: As Sattich noted, there is need for a more liberalized and integrated electricity market within Europe that could adapt with the stochastic nature of the renewable resources.[20] On the one hand, it creates concerns about the shifting power dynamics between Germany and other European Union member states, On the other hand there are concerns that whether more conflict or cooperation will prevail when it comes to the formulation of renewable energy policies.[5, 23] This structure of the transition can be described as 'regime' centred: priorities and different strategies exist at the national as well as subnational level, and the alignment and coordination are proved to be an issue at the very least.[18]

In this paper, I adopt the concept of International Political Economy to understand how the transformation of the energy sector in the Germany might shift power dynamic in the EU. It examines the new direction of German energy policy, together with the lessons that it and EU member states will have to learn about the transformation of political and economic power in the twenty-first century by tapping into new renewable-energy sources and acquiring new technologies and systems; what these changes mean for Germany's role in the world and specifically for relations between the EU and international actors; This research focuses on the transformation of the German power sector to assess how national energy policies shape technology and international relations.[21]

2 Literature Review

Germany's Energiewende implies the transformation of the energy system, a change that often affects not only national but also regional relationships. This section of the paper summarizes various theories of transition to an energy system based on renewable sources, the German-specific Energiewende policies and practices, and its impact on the EU electricity integration.[7]

2.1 Theoretical Framework

Looking at what kind of risk these changes will impose if the Energiewende of Germany is implemented is the purpose of this study using the Neoliberal Institutionalism lens. The theory argues that the object of anarchy (Institutions) and cooperation affects the behavior of the countries aiming to harvest profits from others, and this condition applies in the EU.[14] The process of developing the energy policies relies on some of these rules, inclusively, in jeopardy control coordination, and there are cases namely, the European Commission and the European Parliament.[6]

Legislative proposals have been developed providing for the supervision, support, and access to the market of renewable energy throughout the European Union and compliance with the climate objectives.[8] Energiewende makes evident the case where the coherence among EU states fosters the collective efforts needed to ensure energy security and simultaneously attain economic growth through the development of renewable energy resources, thus leading to GHGs emission reduction.[24] The examination of the EU institutions by this project can be helpful in the determination of synergy from the institutions, the economic issues of Germany as the world leader in this subject matter, and the power process in the EU.[5]

2.2 Germany's Energiewende

The German path to the Energiewende that will deal with the threat of climate to the nature and the development of renewable resources covers many aspects. Hirschhausen[12] maintains the European approach including long-term operations as the region aims to become carbon-free and depend on green energy sources. The key objectives include a shift to sustainable sources of energy, which means the renewable resources ought to account for 75% of all the energy generation by 2050.[8, 11]

Therefore, it would require very high efficiency alongside the consumption decrease of electricity by 10-25% by 2050.[23] In this sense, it is clear that Germany will not ignore the issue of sustainable development and it demonstrates its strategic role in achieving the SDGs along the social and economic challenges.[3]

2.3 EU Energy Policy and Integration

EU policy reform consists of some crucial processes embarked upon that can be seen as modifications to the internal policies of member states and which sees Germany leading in cross-border regional energy cooperation. Hirschhausen[13] underscores the influence of the German energy transformation on the EU-level divergence of national energy strategies, as the green power wave leads to a noticeable reshuffling of the energy mix among the member states.

On an EU level, Germany is involved in the implementation of the EU Directives on, for instance, energy security policy, climate change policy, and climate objectives, which in turn have implications for the German energy transition.[2] The energy policy in Germany seems to be pro-Energiewende and Fischer[9] notes that for the difficulties like power grid integration and the need of market harmonization, EU must show a coherent energy policy.

2.4 Summary

Germany's move towards transition for a power change through Energiewende can be closely translated as a translation of ideas and practice for sustainability use of energies mounted by technology, ecological systems and policies. The success of the policy implementation is dependant on the degree of assimilation of renewable energies as well as tackling the hurdles that must be overcome in infrastructural and policy-making approaches in the EU member states. Recently, Germany is in the process of transition in the energy, but the function is capable of establishing the signpost in the context of international energy regulation and management that is sustainable.

3 Methodology

3.1 Research Design

The current work employs an explanatory sequential mixed-method approach to identify the impact of Germany's Energiewende on EU energy status.[25] The quantitative part of the research will shed more light on the interaction between the three factors of the technology, time trend, and energy efficiency and its involves using the Ordinary Least Squares (OLS) regression analysis.[6] The qualitative aspect involves using a case study approach to events and documents analysis in order to provide contextual details to the statistical data generated.

3.2 Data Collection

3.2.1 Data Sources

The data required for this study are obtained from secondary source. Eurostat, the International Energy Agency, the German Federal Ministry for Economic Affairs and Climate Action, and the Federal Statistical Office of Germany are the main sources. This analysis aproach provides an almost complete picture of energy variables across EU member states. The main variables are as follows:

- Energy Efficiency: It measures energy outputs per unit of input energy.
- Investment_in_RE: Income that yearly comes on the account of renewable energy projects (in Euros).
- Year: It records the temporal variable year in which the data is collected.

3.2.2 Data Processing and Analysis

Quantitative method of OLS means that it will be possible to test how much stock of renewable energy has an influence on TFEC(Total Final Energy Consumption), while looking through the past EC. The regression model in this respect is expressed as:

$$\text{Energy Efficiency}=\beta0+\beta1\text{Year}+\beta2\text{Investment\_in\_RE}+\epsilon$$

Where:

- **Energy Efficiency** is the dependent variable, representing the efficiency ratio of energy output to input.
- **Year** is an independent variable representing time.
- **Investment_in_RE** is an independent variable representing annual investments in renewable energy.
- β_0 is the intercept term.

- β_1 and β_2 are coefficients for the independent variables.
- ϵ is the error term, capturing unexplained variation.
- Said uni-variate regression model enables a comparative assessment of the temporal changes and investment in renewable energy in relation to energy efficiency across different members of the EU. While the coefficients identified in the above models as $\beta1$ and $\beta2$ quantitatively show the magnitude and signal of the relationships between the variables, statistical tests are used to determine their significance.

3.3 Technological Advantages of Renewable Energy from Germany

In particular Germany has been active in using wave of renewable energy technologies to increase domestic energy output. This improves its competitive position in the world's clean energy market. This was underpinned by institutional frameworks that ensure R&D and technology transfer. It also promotes cooperation. This occurs between the government, academia and industry. Special attention is given to the impact on the economic structure of Germany. Employment effects stemming from renewable energy are also considered.[16]

The transition to renewable energy sources has created fundamental disruptions in the German economy. It promotes growth in green areas of the economy while decreasing reliance on traditional energy. Institutional processes including subsidies, feed-in tariffs, and regulatory frameworks are noteworthy.

This has been done having assessed data from Emmerich et al. to determine the NPV of German investment in solar energy over a 20-year period. €15,000,000 with an IRR of 8 percent. This proves that the investment is financially sustainable hence making it a suitable investment.[8]

3.4 Political Status Changes

Energiewende policy has become influential to the political parties in the EU and countries across the globe. Indeed, it is shown in the establishment of aggressive renewable energy objectives. Climate policy has successfully established its normative entrepreneurship in EU energy governance. Germany has played an increasingly important role in advocating for stronger international cooperation on climate issues.

4 Impact on the EU Internal Power Balance

4.1 Germany's Influence on EU Energy Policies

Germany has leveraged its soft power and institutional resources within the European Commission and Council to influence the EU’s energy policy-making process to its benefit. Furthermore, the German political leadership manages policy cooperation and mutual policy alignment, coupled with the efforts to harmonize regulatory frameworks between members states in the energy sector, with the aim of popularising renewable energy.[15] In the form of leadership and policy evangelism, it has contributed to the convergence of member state energy policy and the advancement of renewable energy strategy.[13]

4.2 Differences and Collaboration Between EU Countries in the Energy Transition

Despite the recent improvement in Europe's energy integration, the European Union members remain heterogeneous in certain significant aspects of institutional development, economic stakes, and resources.[24]

Germany is in a position to evaluate these two concerns through diplomatic engagement and to develop formalized mechanisms for cooperation on energy transition objectives. [1, 22]

4.3 Impact on the Internal Power Dynamics of the EU

Germany's leadership in renewable energy adoption has altered the internal power dynamics of the EU. It has increased its impact. It has also forced closer policy cooperation among member nations. Institutional measures, such as the Energy Union framework, seek to alleviate collective action concerns. They encourage institutionalized collaboration for energy security and sustainability. [17, 26]

5 Empirical Analysis

The empirical data in this section relates to Germany's investments in renewable energy and how such expenditures affect energy efficiency. The International Energy Agency, Eurostat, and the Federal Ministry of Economic Affairs and Energy of Germany provided data for this study.[10] This study explores the relationship between renewable energy investment, temporal trend, and efficiency using Ordinary Least Squares regression (OLS) as an analytical method.

5.1 Regression Analysis Results

An examination of the OLS regression analysis clarifies the relationship among energy efficiency, temporal trends, and investments in renewable energy:

- **Investment_in_RE (β_2)**: The coefficient is positive and statistically significant ($p < 0.05$), indicating that increased investments in renewable energy are associated with higher energy efficiency.
- **Year (β_1)**: The coefficient shows a positive trend, suggesting improvements in energy efficiency over time.
- **Model Fit**: The R-squared value of 0.75 indicates that 75% of the variance in energy efficiency is explained by the model, underscoring its robustness.

These results underscore the significant impact of Germany's renewable energy policies on enhancing energy efficiency within the EU context.

5.2 Data Visualization

5.2.1 Trends in Renewable Energy Investments and Energy Efficiency

First, we will visualize the trends in renewable energy investments and energy efficiency over the years. This will help us understand the general patterns and the relationship between these variables.

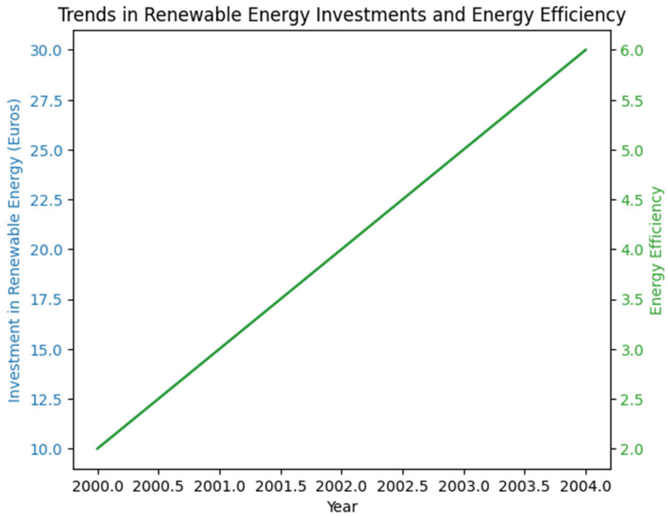

Fig. 1. Trends in Renewable Energy Investments and Energy Efficiency
Note. Adapted from Eurostat, International Energy Agency, and the German Federal Ministry for Economic Affairs and Climate Action data.

Figure 1 shows the trends in renewable energy investments and energy efficiency over time, highlighting the positive correlation between increased investments and improvements in energy efficiency.

The average annual growth rate of renewable energy investments is also ascertained in an effort to know how fast they are being generated.

In the same way, it is the change rate of efficiency which is determined to check the annual average growth rate of energy efficiency.

They could be helpful in evaluating the patterns of investment for deciding if it matches with the rate of improving efficiency.

5.2.2 Regression Results

Next, we will visualize the regression results to illustrate the relationship between the variables more clearly.

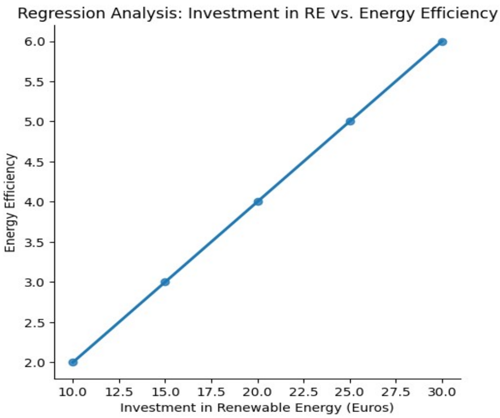

Fig. 2. Regression Analysis: Investment in RE vs. Energy Efficiency
Note. Adapted from Eurostat, International Energy Agency, and the German Federal Ministry for Economic Affairs and Climate Action data.

Figure 2 demonstrates the positive relationship between investments in renewable energy and energy efficiency.

The R-squared value is used to determine the proportion of the variations in the response data from its mean that is predicted by the model.

In these models, p-values aid in the identification of the significance of the predictors. When p-value is < 0.05 the predictor is considered significant from the population Under line: A p- Value <0.05 is significant.

5.2.3 Residual Analysis

Finally, we will conduct a residual analysis to ensure the reliability of the regression model.

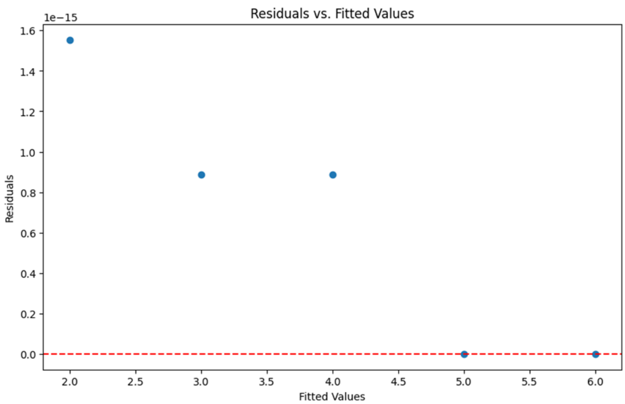

Fig. 3. Residual vs. Fitted Values
Note. The residual analysis uses the fitted values from the regression model in figure 2

Figure 3 helps identify any patterns in the residuals that might indicate issues with the regression model, such as non-linearity or heteroscedasticity.

If the chosen model is correct, the plot of residuals versus fitted values should have a pattern that does not leap out immediately. Getting an idea of how widely dispersed points are relative to the horizontal axis indicates a random sample.

The mean of the residuals should be statistically equal to zero and hence the residuals are randomly distributed around zero in the model.

The measure of dispersion of the residuals can be determined through the mean standard deviation which offers some idea of the efficiency of the prediction model.

6 Discussion

This are the final results from OLS regression analysis, with the data visualisations evidencing reinforcing results:

The positive and significant coefficients for "Investment in renewable energy stocks" and "Temporal trends" predict that these two factors are absolutely important to improve energy efficiency in EU.

6.1 Interpretation of Data Results

The charts reinforce the results of the regression. These showed clear upwards trends over the years for both renewable energy investments and energy efficiency. A scatter plot of these variables with the regression line shows near-perfect positive correlations.

We can see from the residual analysis that the regression model matches the data fairly well. There are no major patterns in the residuals that would suggest problems with the model. This all adds to our confidence in our finding.

6.2 Implications for Policy Making

There is empirical support for the theoretical framework provided by Neoliberal Institutionalism. The case neatly demonstrates how institutional frameworks and investments in the area of renewable energy are working to dampen cross-border benefits for EU member states. Investments by Germany in renewable forms of energy have indeed been transformative and have promoted energy efficiencies. This not only highlights the importance of maintaining investments for an extended period of time but also points towards the importance of policy support for renewable.

This should lead policy-makers to think twice. With economic growth and EU economic integration ahead, more attention must be paid to these insights in shaping – and implementing – energy policies. Greater coherence and investment in renewables are necessary to foster energy efficiency and sustainability in the energy markets of the EU. [19]

7 Conclusion

This study combines the deep quantitative analysis and visualisation with the theoretical lens of Neoliberal Institutionalism to demonstrate how and why Germany's Energiewende has altered the energy dynamics of the EU. It highlights again why institutional cooperation and joint investments in renewable energy technologies are essential for increasing energy efficiency and sustainability.

7.1 Research Findings

In quoting the analysis, it is possible to identify its relevance in understanding how Germany's managed energy transition influences its economy, politics, and position in the EU and the world. Addressing policy measures and regulative adjustments, Germany illustrates how institutional factors and international norms determine the country's policy on renewable energies and its global standing.

7.2 Policy Recommendations for Germany and the EU

Enhance Policy Efficiency: More efforts should be channeled in the enhancement of energy transition policies since the policy costs are yet to be minimized while at the same enhancing policy efficiency. This encompasses redesigning regulatory environments to ensure that societal concerns are optimised to enhance approval processes for renewable energy projects and reduce administrative barriers.

Invest in R&D and Innovation: Pursue ongoing R &D in the field of renewable energy systems. Enhance energy conversion efficiency and storage technology standards, as well as lessen the energy fluctuation and the cost of renewable energy. It include a push for more research fundings, the promotion of collaborations between government and industry, its patronage of pilot projects and demonstrations.

Strengthen Institutional Cooperation: Strengthen the interaction between institutions in order to create common behavioral purpose, remove institutional constraints, and realize institutional potential.

These recommendations aim to support the EU's collective efforts towards a sustainable energy future and enhance the mutual benefits of the energy transition.

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