MASTEROPPGAVE

Course code: ORG5009

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Comparative study on the path of clean energy transition between Germany and the United States under the background of global energy transition

Date: 2022.05.14

Total number of pages: 49

NORD universitet

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Summary

This thesis compares the differences between Germany and the United States in clean energy transition from the perspectives of goal and path, analyzes the reasons for the different paths of clean energy transition between the two countries by using PEST model, and makes an in-depth excavation and analysis from the four aspects of politics, society, technology and economy, so as to get the reasons for the different paths of clean energy development between the two countries.

The biggest difference between Germany and the United States in the transition of clean energy is that Germany has launched a phase out plan of nuclear energy with the development of renewable energy as the core; However, the United States vigorously develops nuclear energy and natural gas (including shale gas) as important transitional energy, and also attaches importance to renewable energy production. I explore the reasons for the differences between the two countries from four aspects. From the political level, the German ruling parties put environmental protection at the core and gives legal support to renewable energy; The United States puts national energy security and energy independence first, followed by environmental protection. From the social perspective, the German public opinion survey shows that most people have high support for renewable energy production and infrastructure expansion; In the United States, most Americans support expanding solar and wind energy and there is an increasing tendency to purchase electric vehicles. From the perspective of technology, German renewable energy technology is at the leading level in the world and has a high degree of technological maturity; After a long period of development and innovation, hydraulic fracturing and horizontal well technologies in the United States have a higher maturity than those in other countries. From the economic perspective, due to the maturity of renewable energy technology, the production cost of renewable energy in Germany is decreasing, and the production cost of some renewable energy is lower than that of traditional fossil fuels; Due to the mature shale gas exploitation technology, low shale gas development cost and high income, the United States vigorously exploits shale gas.

To sum up, Germany and the United States have chosen different goals and paths of clean energy transition due to their different economic, political, social and technological situations. This can provide reference for the transition and development of clean energy in other countries.

Preface and acknowledgments

This thesis is the last part of my master's study in global management at the Business School of Nord University in Bodø, Norway. This major is a master's project jointly trained by East China Normal University and Nord University. The reason why I choose this topic is because of current global climate change. Clean energy transition is currently a problem studied by most countries. By analyzing and comparing the reasons for different clean energy transition paths in different countries, it can provide reference for other countries to choose appropriate energy transition paths. In addition, during my one-year study in Bodø, I deeply understood the importance of environmental protection and energy transition.

I want to thank my supervisor Andreas Raspotnik for patiently answering and guiding my confusion. I would like to thank Nord and all my teachers in China for their valuable help in determining the topic of my thesis.

Abstract

In the context of energy transition, Germany and the United States have vigorously developed clean energy, which is representative in the world's clean energy transition. Taking wind energy, solar energy and other renewable energy as the development core, Germany has issued and revised the renewable energy law (EEG) for many times, launched the phase out plan of nuclear energy, and put environmental protection in the primary position of energy development. While developing renewable energy, the United States takes nuclear energy and natural gas (including shale gas) as important transitional energy and vigorously develops them, reflecting the political goal of taking energy independence and energy security as the core.

Through the PEST analysis framework, this thesis analyzes the reasons for the different paths of clean energy transition in Germany and the United States from the four levels of politics, society, technology and economy, and draws a conclusion according to the survey data and relevant literature analysis. From the political perspective, the United States places energy independence and energy security in a priority position over environmental protection; Germany's policies such as eliminating nuclear energy reflect that the ruling parties place environmental protection at the core, followed by energy security. From the social perspective, the German authoritative public opinion survey shows that the vast majority of people support renewable energy production and infrastructure expansion, especially in solar energy and offshore wind energy; In the United States, most Americans support expanding solar and wind energy and there is an increasing tendency to purchase electric vehicles. In terms of technology, the hydraulic fracturing and horizontal well technology in the United States is more mature than that in other countries, and the shale gas exploitation technology is higher; Germany's renewable energy technology is at the world's leading level and is in a technologically advantageous position in the production of offshore wind and solar energy. From the economic perspective, the United States has made great efforts to exploit and develop shale gas because of its low cost and high income due to technical reasons; The cost of renewable energy

exploitation in Germany is gradually reduced, and the cost of some renewable energy is even lower than that of traditional fossil fuel exploitation. The income shows a gradual upward trend and the income is considerable.

To sum up, Germany and the United States have their own characteristics in these four aspects, resulting in the two countries choosing different development paths in the transition and development of clean energy.

Table of contents

1 Introduction

In this chapter you will be introduced to the background of the topic of the thesis, its purpose and selection of the two countries.

1.1 Motivation and choice of problem statement

In December 2019, the European Commission announced the "European Green Deal" to deal with climate change and promote sustainable development, promoting the "green development" of the EU. The agreement proposes that by 2050, Europe will become the world's first "carbon neutral" region, that is, the net emission of carbon dioxide will be reduced to zero. The EU has developed a detailed road map and policy framework for this purpose. At the level of industrial policy, the EU focuses its development on clean energy, circular economy, digital technology and other aspects. Policies and measures cover almost all economic fields such as industry, agriculture, transportation and energy, so as to accelerate the transition of the EU economy from the traditional model to the sustainable development model. Renewable energy in EU countries has developed rapidly, such as solar energy in Germany and wind energy in France. As one of the EU Member States, Germany has always been in a leading position in energy transition and clean energy development. Under the condition of gradually reducing its dependence on nuclear energy, Germany takes renewable energy dominated by solar energy and wind energy as the development core, and has formulated detailed energy development policies.

The development path of clean energy in the United States is very different from that in Germany and other EU countries. The large-scale exploitation of shale gas in the "shale revolution" and the rapid development of renewable energy in the United States have injected new vitality into the energy transition of the United States. Therefore, the energy transition of the United States takes nuclear energy and natural gas as the transitional energy, and also develops renewable energy. Overall, Germany and the United States have different directions and paths in energy transition. Germany is transforming to renewable energy and the United States is transforming to

clean energy (renewable energy, natural gas and nuclear energy).

By comparing the differences of clean energy development strategies between Germany and the United States, and excavating the deep-seated reasons and specific conditions behind the differences of energy paths between Germany and the United States, we can better understand the energy transition in Europe and the United States, and provide reference for other countries with similar energy development backgrounds as Germany or the United States.

1.2 Research gap

Firstly, scholars generally believe that the EU has strong representation and leadership in energy transition and global climate governance. Capros et al. (2018) said that the role of electricity is crucial to the EU's energy transition, and energy efficiency and renewable energy are the core pillars. ETS (European Trading Scheme) mechanism and bottom-up policy measures provide significant greenhouse gas emission reduction required for decarbonization of EU energy system. Flamos (2015) pointed out that in recent years, Europe has achieved a world leading position in many renewable energy technologies. Li Xinlei (2020) compared the clean energy diplomacy of Germany, the United States, Japan and India, and pointed out that Germany and the United States have different core interests in energy transition. The United States takes energy independence as the core and Germany takes climate and environmental protection as the core. Zhu Tong (2016) made a comparative analysis of the process of energy transition between Germany and the United States. Lin Lv et al. (2017) pointed out the innovation of the energy transition policies of Germany and the United States.

Secondly, scholars believe that the commercial exploitation of shale gas mainly driven by the "shale revolution" in the United States has gradually achieved energy self-sufficiency in the United States, and renewable energy has also developed rapidly. Fu Jingyun (2019) proposed that after the "shale revolution", the change of the role of the United States in the energy market will trigger the "systematic effect" of the world

energy market and geopolitics. The United States is not only taking advantage of the shale revolution to become the world's largest natural gas producer, but also using new energy power to change the game rules of the natural gas market, so as to reshape the global energy geopolitical pattern. Energy is used as an important tool to strengthen US global leadership. Zhang Jifeng (2016) believes that the "shale oil and gas revolution" has strengthened the dominance of the United States in energy diplomacy and climate change. Xue Yuze and Zhang Mingyuan (2020) believe that the focus of U.S. energy policy has gradually shifted from "energy independence" to "energy dominance". In the United States, there has been a surge in wind and solar power generation in recent years. Downie (2019) proposed that among all commercially viable renewable energy sources today, wind and solar energy have the greatest potential to change the energy sector.

In short, there are little domestic and foreign literatures comparing the energy transition and clean energy strategies of Germany and the United States. The relevant literatures only point out the differences in the development of clean energy between the two countries. However, as for why these two countries follow different paths, no research has yet been conducted comprehensively based on my research. In view of this research gap, this thesis explores the reasons for the different paths of energy transition between the two countries from four perspectives- political, social, technological, economical perspective.

1.3 Research question

The research question of this thesis is to analyze the four perspectives' reasons (political, social, technological, and economical) of different goals and paths in clean energy transition between Germany and the United States.

2 Theoretical perspectives

This chapter introduces what is energy transition, defines the meaning and scope of clean energy, and introduces PEST analysis model.

2.1 Theoretical concepts

2.1.1 Energy transition

The World Energy Council (2019) describes energy transition as a multidimensional, nonlinear and complex long-term structural evolution of the energy system. There is a common method to judge whether a country has completed its energy transition, "In the process of a country's transition from one energy source to another, if new energy accounts for 5% of the total energy consumption, it is considered to be the sign of the beginning of the transition of the energy system. If this new energy accounts for more than 50% or the largest proportion of the total energy consumption, it can be considered to be the sign of the completion of this energy transition." In the history of human development, most experts and scholars believe that two energy transitions have been completed (Jensen, 2011). At present, we are in the primary stage of the third energy transition. In the first industrial revolution in the mid-18th century, the technological transition of steam engine changed the main energy from firewood to coal. The second industrial revolution at the end of the 19th century, the reform of electric power technology and internal combustion engine technology, made oil the leading energy. At the end of the 20th century, due to the change of contemporary computer information technology and the pressure of ecological environment, the leading energy gradually shifted from oil and gas resources to clean energy. However, the technical requirements and cost of clean energy are relatively high. At present, the existing clean energy is only an important supplement to the fossil energy system. The energy transition needs some time, and the clean energy transition is in the initial development stage.

From those previous energy transitions, we can find that they present some commonalities. Firstly, from the perspective of the motivation of energy transition, the transition of leading energy is caused by the joint action of economic, political policy, science and technology, environment and other factors. Among them, technological progress has always been the internal driving force of energy transition, and technological innovation has always run through energy development. The economic

level, investment direction and intensity of a country are the key factors affecting the speed of energy development and the success of energy transition, and economic security is indispensable (Wang Zhuoyu, 2019). Policy support provides upper level guidance and accelerates energy transition. The pressure of ecological environment forces the transition and development of leading energy towards sustainable and clean direction from the outside. Secondly, in terms of the performance of energy transition, leading energy replacement is an important symbol of energy transition. In the first energy transition, coal replaced firewood as the leading energy. In the second energy transition, coal was replaced by oil. Since the 21st century, clean energy has gradually sprung up and developed in various countries, which is expected to replace oil and gas resources as the leading energy in the future. Third, from the perspective of the goal of energy transition, in the three energy transitions, the leading energy has changed from firewood—coal—oil to clean energy, and the energy is gradually developing towards improving use efficiency and reducing carbon emissions. "Sustainable, clean and efficient" is the main direction of energy transition (Wang Zhuoyu, 2019).

The current energy transition also has some distinctive characteristics. First, energy transition is characterized by unbalanced development among regions. Due to differences in resource endowments and economic development levels among countries, different countries are at different stages of energy transition. While developed regions represented by European and American countries are committed to developing low-carbon and efficient clean energy, some underdeveloped countries have not yet achieved the second energy transition, lack of modern energy services and face energy poverty. Second, there are differences in the path of energy transition. For example, the United States has successfully realized large-scale exploitation of shale gas by using technical means, and developed biodiesel and corn ethanol with its own advantages (Li Penghui, 2016). Iceland relies on its geographical advantages to vigorously develop geothermal energy to reduce its dependence on oil imports. Germany has invested heavily in its own wind power projects, expanded the supply of renewable energy such as wind and solar energy, and is about to reduce the import of

oil and gas resources from Russia. Norway relies on its natural advantages to develop hydropower. Third, alternative energy has diversified characteristics. There are many kinds of new energy, but it is difficult for any single energy to occupy the dominant advantage. At present, the diversification of energy transition is mainly reflected in the power system. There are many choices of power sources, such as wind energy, solar energy, nuclear energy, oil and gas resources, coal, etc. different countries have also introduced different policies according to local conditions to guide power enterprises to make appropriate power supply energy choices (IRENA, 2020). Fourth, energy transition is difficult. Although most clean energy has the advantages of environmental protection, high efficiency and sustainability, due to the limitation of the current technical level, the price and production cost of clean energy are often higher than fossil energy, so we have to rely on government policies and subsidies to promote and develop (EEG, 2021). In addition, the infrastructure of fossil energy has spread all over transportation, construction, industry and other industries. While transforming fossil energy into clean energy, the energy consumption mode and structure of the whole industry and commerce need to be changed. For example, in the transportation industry, if the public transportation is changed from fuel transportation to electric transportation, it needs to lay matching energy pipelines and other equipment and facilities, which not only has high technical requirements, but also needs high economic costs.

In the third energy transition, Germany and the United States, as typical clean energy transitional countries, chose different energy transition paths. Germany has abandoned nuclear energy and vigorously developed renewable energy dominated by wind and solar energy. With the help of technological innovation, the United States exploits shale gas on a large scale, and also pays attention to the development of biomass energy, wind energy and other energy. The energy transition of the two countries is relatively representative and successful.

2.1.2 Clean energy

Different experts and scholars have different definitions of the concept of clean energy. Modern Chinese Dictionary (2019) defines clean energy as energy that does not produce or produces little pollutants in the process of development and utilization. China 360 encyclopedia website (2022) interprets clean energy as green energy, that is, energy that does not emit pollutants and can be directly used in production and life, including nuclear energy and renewable energy.

About whether natural gas is a form of clean energy, scholars hold different views. Li Yinghua (2017), deputy director of the oil and natural gas Department of the National Energy Administration of China, proposed to cultivate natural gas into one of the main energy sources of China's modern clean energy system, and it can be introduced to classify natural gas as clean energy. Jensen et al. (2011) pointed out that natural gas is an attractive energy, clean and easy to distribute. Tong Xiaoguang (2010) argues that compared with coal and oil, natural gas has less carbon dioxide emissions and it belongs to clean energy. R. Weijermars et al. (2011) pointed out that natural gas is a relatively clean fossil fuel. Jing Wei et al. (2021) proposed that compared with coal, natural gas is a relatively clean energy with the advantages of high calorific value and low carbon emission. It plays an important role in the transition from high-carbon energy to low-carbon energy and is a bridge for the development of low-carbon energy in the future. However, some scholars hold opposing view. Global Doctor Organization representative office in Beijing (2020) think natural gas burned by household stoves and boilers will also increase carbon dioxide emissions and exacerbate global warming.

Besides, shale gas is a kind of unconventional natural gas, which is composed of methane. Wang Chao (2021) thought that shale gas is a clean and efficient new energy resource. With the progress of technology, the prospect of clean energy development and utilization represented by shale gas will be broader and broader. Han Xiaoping (2013) said that natural gas energy, including shale gas, is a kind of clean energy.

Combustion produces water and carbon dioxide. Chinese Baidubaike website (2022) argues shale gas, mainly composed of methane, is a clean and efficient energy resource and chemical raw material. Francis and Sergey (2012: 05) found that the production of shale gas and specifically, the associated hydraulic fracturing operations have not materially altered the total GHG emissions from the natural gas sector.

But some experts think shale gas is not clean enough. Margaret et al. (2013:01) pointed that high-volume horizontal hydraulic fracturing, a controversial new mining technique used to drill for shale gas, is being implemented worldwide. Chemicals used in the process are known neurotoxins, carcinogens, and endocrine disruptors. People who live near shale gas drilling sites report symptoms that they attribute to contaminated air and water. Rajmund and Alina (2014) argued that some chemicals in hydraulic fracturing fluid used in shale gas exploitation are highly toxic and pose a potential threat to the environment.

We can see that scholars have different views on whether shale gas is a form of clean energy. Summing up their views above, scholars who believe that shale gas belongs to clean energy mainly because there is less pollution in the “use process” of shale gas, while opponents believe that the chemicals used in the “production process” of shale gas have a great possibility of polluting the environment.

Summing up the views of a large number of experts and scholars, it can be found that the difference in the definition of “clean energy” mainly lies in whether natural gas (including shale gas) belongs to clean energy. Compared with traditional fossil fuels such as coal and oil, conventional natural gas does not emit harmful nitrogen and sulfur compounds in the process of production and combustion, and the emission of carbon dioxide is much lower than that of coal and oil. However, compared with emerging energy sources such as solar energy, nuclear energy and wind energy, natural gas still produces carbon dioxide and emits greenhouse gases in the process of production and utilization, and the carbon emission of these emerging energy sources

is almost zero. Therefore, natural gas can be considered as a transitional energy between traditional fossil energy (coal and oil) and new clean energy (renewable energy and nuclear energy). In addition, after inquiry, the development plans related to natural gas are basically mentioned in the clean energy development policies and documents formulated by various countries, such as Germany, U.S., China and so on. As for shale gas, its use process hardly releases carbon dioxide. Although the production process has the possibility of potentially harming the environment, the degree of harm needs to be studied. Just like the manufacturing, transportation and installation of wind turbines also may endanger the environment.

In view of the low carbon dioxide emission of natural gas and the comprehensive views of experts and scholars, this thesis lists natural gas (including shale gas) as a form of clean energy. To sum up, this thesis interprets "clean energy" as: energy that does not produce or produces less pollutants and greenhouse gases in the process of development and utilization, and can be directly used in production and life, including solar energy, wind energy, marine energy, hydrogen energy, bioenergy, geothermal energy, water energy, nuclear energy and natural gas (including shale gas).

Clean energy has incomparable advantages over traditional fossil energy. Especially in the context of global ecological pressure and climate warming, clean energy, as an environment-friendly energy, not only has less pollution to the ecological environment, but also has high energy production efficiency. Fossil energy is non-renewable and limited in total, and will eventually be exhausted. However, most clean energy such as solar energy and wind energy are renewable and can achieve sustainable economic and social development. Although there are many advantages of clean energy, due to the current technical constraints, its energy cost and energy price are generally higher than that of fossil energy such as coal and oil. And in some industries, such as transportation, compared with fuel vehicles, electric vehicles have some defects, such as insufficient power and short endurance time. Natural gas has both the high efficiency of fossil energy and the low-carbon advantages of clean energy. Therefore,

most countries take natural gas as an important transitional energy when formulating clean energy policies and plans. At the same time, they increase technological innovation, continuously reduce the production cost of clean energy and promote the acceleration of energy transition.

2.1.3 Overview of German and U.S. energy transition

According to IRENA (2020) data, Germany, Italy and Spain are the top three countries on the renewable energy installed capacity aspect in Europe, and the United States, Brazil and Canada are the top three countries in the Americas. Germany and the United States are typical representatives in the transition of clean energy.

Since the Green Party and the Social Democratic Party won the general election in the 1990s, Germany has taken the transition of renewable energy as an important goal (Li Xinlei, 2020). Since the promulgation of the first renewable energy law (EEG) in Germany in 2000, the renewable energy fixed price on grid policy (FIT) has been promoted nationwide. The renewable energy law has undergone six amendments. In 2017, the renewable energy power generation bidding system (FIP) was revised and the bill was introduced to promote the promotion and development of clean energy. In 2010, Germany put forward the "energy vision" to explain Germany's medium and long-term energy strategy. In 2011, Germany launched the energy transition plan, which defined the goal of energy transition by 2050. It is expected that renewable energy power generation will account for more than 80% in 2050. At present, Germany is "abandoning nuclear power" and using renewable energy such as wind energy and solar energy to reduce the proportion of fossil energy in energy consumption. On March 31, 2022, Russian President Vladimir Putin signed a document requiring Russian natural gas transactions with foreign buyers in rubles, resulting in Germany reducing its natural gas imports from Russia. Even if Germany wants to get rid of its dependence on Russian energy, it will take some time to completely get rid of its dependence on Russian natural gas imports due to rising energy prices and high investment costs in energy transition.

Due to the success of the "shale revolution", the United States has realized a large number of unconventional natural gas exploitation. While meeting its domestic energy demand, it has even been sold abroad. The U.S. has changed from an energy demander to an important global energy supplier. At the same time, the United States is also developing clean energy projects such as nuclear energy, using technological advantages to develop corn ethanol and biodiesel, so as to promote the diversification of energy supply. And Department of Energy (DOE) moved at lightning speed toward clean energy goals (DOE, 2021). It is making efforts to achieve 100% zero carbon power supply by 2050 in the U.S.

From the perspective of the objectives of clean energy development of the two countries, Germany attaches importance to the environmental protection demands of clean energy, and the United States attaches importance to the guarantee function of clean energy on energy independence and energy security. The following chapters will make a detailed comparative analysis of the objectives and paths of clean energy development of the two countries, and explore the reasons behind the differences between the two countries.

2.2 Analytical tool

In order to analyze the four aspects' reasons, this thesis will use PEST analysis model (Thomas, 2016), which is briefly introduced below.

PEST analysis is mainly a macro environment analysis model, including P (politics), E (economy), S (society) and T (technology). The political aspect mainly includes political system and system, policies, laws and regulations, etc. Economic aspects include economic growth rate, government subsidies, inflation rate, business cycle, etc. Social aspects include residents' consumption tendency, lifestyle, social welfare, income distribution, population growth rate, education, etc. Technology includes the speed and maturity of technology renewal, information technology reform,

government research expenditure, etc. (Jianshu, 2020). PEST framework can be used to conduct a more comprehensive and comprehensive analysis of the research object.

3 Methodology

3.1 Data

When doing a research, we need to collect data in many ways. Due to the macro purpose of this topic and the limitation of time and resources, the data sources of this study are all based on secondary data, that is, the information on official websites such as the national energy Administration, published academic literature, books and journals. Compared with primary data, secondary data has the advantages of convenient collection and sorting, high efficiency, and can continue to do further research or innovation based on the basic views of previous experts and scholars.

This thesis has a wide range of data sources, including annual reports collected from the official website of the National Energy Agency, such as Energiewende, a German energy transition website, and the National Energy Administration of the United States; Data collected from energy agencies, such as IRENA and IEA; Collect relevant materials from professional energy academic journals, mainly on Google scholar and CNKI (China National Knowledge Internet) ; In addition, information is collected from energy related newspapers and news websites, and these materials are carefully selected, representative and authentic.

Some of these data are used to compare the differences in energy transition paths and objectives between Germany and the United States. Most of the data are analyzed with PEST framework to specifically analyze the reasons for the different clean energy transition paths between Germany and the United States from four aspects: politics, economy, society and technology.

3.2 Selection of study

In this thesis, I choose to use the qualitative analysis method, which is more suitable

for comprehensive cause analysis, because the qualitative analysis method focuses on "what", "why" and "how to do" (Joachim Haugen, 2019), and the research problem of this paper is exactly "why". However, the quantitative analysis method focuses more on the digital analysis of "how many", so the qualitative analysis method is more suitable in this paper.

The research design of this paper is as follows: firstly, this paper constructs a theoretical framework, explains the meaning of energy transition, defines the scope of clean energy, and introduces PEST model. Secondly, collect data from official websites such as the national energy Administration and academic journals, sort out and compare the differences between Germany and the United States in the goal and path choice of clean energy transition. Next, based on the collected data, this paper uses PEST model and framework to analyze in detail the reasons for the different paths of clean energy transition in Germany and the United States from the four perspectives of politics, technology, society and economy. Finally, a conclusion is drawn based on the analysis.

3.3 Quality of the research

In order to judge the research quality of this paper, we need to look at the credibility and effectiveness of this thesis.

3.3.1 Reliability and validity

"Reliability is used as consistency or stability in measurements" (Svartdal 2018). Reliability is all about how trustworthy the data we collected is. Can others get the same results after analyzing according to the analysis framework of this paper? If the results are very different, the credibility of the article needs to be questioned (Joachim Haugen, 2019).

Most of the information and data come from the national energy website, energy organizations and public opinion survey institutions. Because most of the institutions and organizations are non-profit, the data are more authoritative and authentic.

However, some errors are not excluded. For example, there may be some errors in whether the samples and objects selected by the public opinion survey institutions are representative and whether the number of respondents is sufficient. However, given that the selected survey institutions have a high reputation in Germany or the United States and have a long operation time, they are more credible. In addition, some materials are selected from representative journals and literature, belonging to SCI (Science Citation Index) and CSSCI (Chinese social science citation index) categories. SCI--The citation database founded and published by the American Institute of Scientific Information (ISI) in 1961 covers comprehensive Retrieval Publications in life sciences, clinical medicine, physical chemistry, agriculture, biology, veterinary science and engineering technology. The collection range is an important international journal in that year. Especially its citation index shows unique scientific reference value and occupies an important position in the academic community (Hongsi Academy of Sciences, 2019). CSSCI-- Developed by China social science research and evaluation center of Nanjing University, it is a key project of the State and the Ministry of education. CSSCI follows the law of bibliometric and adopts the method of combining quantitative and qualitative evaluation to select journals with strong academic and standardized editing from more than 2700 Chinese academic journals of Humanities and Social Sciences in China as the source journals. At present, it contains more than 500 academic journals in 25 categories, including law, management, economics, history and political science, with nearly 1 million source documents and more than 6 million citations. At present, the Ministry of Education in China has taken CSSCI data as an important assessment index in the evaluation of institutions and bases of colleges and Universities across the country, achievement evaluation, project approval, talent training and so on (Hongsi Academy of Sciences, 2019). Therefore, these resources have high reliability.

"The validity is to what extent one can draw valid conclusions about what one has set out to investigate, based on the result of an experiment or a study" (Dahlum 2018). In view of the typicality and representativeness of the data collected, the reasons for the

different paths of clean energy transition in Germany and the United States can be comprehensively analyzed through PEST framework analysis.

3.3.2 Study limitations

Because the selection of data and data comes from secondary data, the research has some limitations. The first limitation is the lack of primary information. The data year may not be new enough, and there is no field interview with relevant staff. The accuracy of the information needs to be improved. The second limitation is that only qualitative analysis is used. Quantitative analysis is only mentioned in the public opinion survey. Using more quantitative analysis can improve the accuracy of the research results.

4 Comparison of clean energy strategies between Germany and the United States

Before analyzing the differences of the Germany and United States in the clean energy transition, we need to firstly watch the differences. This chapter explains and introduces the differences of clean energy development goals, selection of clean energy types, attitude towards nuclear energy, clean energy policy, main motivation of energy transition, types of energy transition in these two countries. Finally I make a table to clearly compare and see these different parts.

4.1 Comparison of clean energy development goals between Germany and the United States

Germany issued the renewable energy law in 2000, and then revised and supplemented it six times (EEG2004, EEG2009, EEG2012, EEG2014, EEG2017 and EEG2020). Judging from the frequency of revision almost every three years, Germany has full patience in the transition of clean energy.

Thirty years ago, under the influence of climate change, energy security and other factors, Germany began its energy transition (Li Xinlei, 2020). Supporting the

development of renewable energy with fixed electricity price has become the main line of formulating energy law for a period of time. In 1991, Germany officially implemented the power grid access law (StrEG), which requires grid operators to purchase renewable energy power at a fixed price. On this basis, Germany launched the renewable energy law in 2000, in which the fixed price policy of differentiation, long-term implementation and regular adjustment is the main content of this law. At the same time, the law provides power grid operators with a surcharge standard and sharing mechanism, and collects subsidies from consumers in the form of surcharges. After the EU renewable energy power directive was put forward, the revised EEG2004 in Germany set a specific target: in 2010, renewable energy power generation will account for 12% of the total power generation; 20% by 2020. Due to the rapid expansion of Germany's renewable energy industry, the target requirements for the proportion of renewable energy power generation are realized in advance, and the subsidy policy has disadvantages, EEG2009 has set up the adjustment and reduction mechanism of fixed on grid electricity price and put forward relevant market-oriented provisions. EEG2012 proposes to achieve the goal that the proportion of renewable energy power generation in the total power generation will reach 80% by 2050. Due to excessive government subsidies and high subsidy costs, EEG2014 launched reform measures to transform the long-term fixed price acquisition system into a market-oriented bidding system. While implementing the electricity price support policy, remove the excessive subsidy policy to provide transition time for renewable energy power suppliers. With the government's support for renewable energy power for many years, Germany's onshore wind power and photovoltaic power generation technologies are relatively mature and have the strength to participate in market-oriented competition. In this context, EEG2017 has fully introduced the bidding system. EEG2021 proposes a new goal to achieve carbon neutrality in all power industries and power terminals by 2050. By 2030, the proportion of renewable energy power generation in the total power generation will reach 65%, the cumulative installed capacity of onshore wind power will reach 71GW, offshore wind power will reach 20GW, photovoltaic power generation will reach 100GW and biomass power

generation will reach 8.4GW.

The goal of clean energy transition in the United States is different from that in Germany. In 2015, the Obama Administration proposed the "clean energy plan" to promote the transition of hybrid energy dominated by renewable energy, natural gas and nuclear energy (Xu Xiaoming, 2018). However, President Trump abolished the "clean energy plan" during his term of office, and all States independently set clean energy development goals under the guidance of the government (Zhou Qi and Fu Suixin, 2017). After President Biden took office, he put forward the goal of reducing carbon emissions in the United States by 50% by 2030, achieving 100% clean electricity by 2035 and achieving net zero emissions by 2050. By the end of 2021, a total of 31 states and the District of Columbia had formulated renewable energy portfolio standards (RPS) and clean energy standards (CES), and 20 states had set the development goal of 100% clean electricity by 2050. In 2021, Delaware, Oregon, North Carolina and Illinois updated their clean energy development goals. In February 2021, Delaware set a goal to achieve renewable energy power generation accounting for 40% of electricity sales by 2035. In July 2021, Oregon proposed that the proportion of clean energy sales should reach 100% by 2040. In September 2021, Illinois raised the overall goal of CES to 50% of electricity sales from renewable energy by 2040. In October 2021, North Carolina set the CES target of carbon neutral power generation accounting for 100% of power sales by 2050. At the same time, the United States continues to promote the large-scale exploitation and production of shale gas. The U.S. Department of Energy pointed out that shale gas is an important part of the balanced and sustainable national energy strategy of the United States (DOE, 2021).

As can be seen from the clean energy development goals of Germany and the United States, Germany has formulated and continuously improved the renewable energy law from the national level and the legal level, focusing on the development of renewable energy dominated by wind and solar energy. The new goal proposes that the power

generation from renewable energy will account for 65% of the total power generation by 2030, and the power industry will be carbon neutral by 2050. For the time being, the United States has not formulated a clear clean energy bill. The energy transition mainly starts from the state level and implements the state level quota system (RPS). Each State formulates independent clean energy development goals according to its own energy development.

4.2 Comparison of clean energy development paths between Germany and the United States

4.2.1 Transitional energy options

Although both the United States and Germany follow the path of clean energy development, the path is different, especially in the choice of transitional energy.

In the United States, the transition from conventional energy to non-conventional energy and natural gas development is inevitable. After 2008, nuclear energy and natural gas play an important role in the energy transition of the United States. According to the statistics of the International Energy Agency (2022), the proportion of coal production in the United States began to decline sharply after 2008, and its proportion of production has been declining from 2008 to 2020. In contrast, the proportion of natural gas production in the United States has continued to rise since 2008. The proportion of renewable energy production has also gradually expanded. By 2020, the share of natural gas production in the United States will account for about 30%, nuclear energy will account for more than 10%, and the sum of natural gas and nuclear energy production will account for more than 40% of total energy production. The proportion of renewable energy such as solar energy and wind energy is relatively small, no more than 10%, but it is still developing gradually compared with before (see Figure 1). It can be seen that in the production structure of clean energy in the United States, the production proportion of nuclear energy and natural gas far exceeds that of renewable energy. It is an extremely important transitional energy in the transition of the United States to the era of clean energy.

Unlike the United States, Germany's energy transition strategy does not choose nuclear energy as a transitional energy, but abandons nuclear energy (Energiewende, 2021). Stopping all nuclear energy production in 2022 is one of the core objectives of Germany's energy transition. The "Phase out nuclear energy" initiative was implemented due to the Fukushima nuclear power leak in 2011. Therefore, since 2011, ten nuclear power plants with nuclear power production of 11GW have been shut down. Another seven nuclear power plants are scheduled to stop operation by 2022. In 2018, Germany's nuclear power generation was 76.0TWh, accounting for about 12% of Germany's total power generation (see Figure 2). As can be seen from the figure, Germany is abolishing the use of nuclear energy and plans to completely stop the production of nuclear energy in 2022. In addition, according to the data of the International Energy Agency, by 2020, Germany's natural gas production accounted for more than 20%, and the production of renewable energy other than solar energy and wind energy accounted for about 10% (see Figure 3).

Compared with the choice of transition energy between the United States and Germany, the United States chose to vigorously develop nuclear energy and natural gas. Germany chose to shut down nuclear power plants in stages and planned to completely stop nuclear power production by 2022.

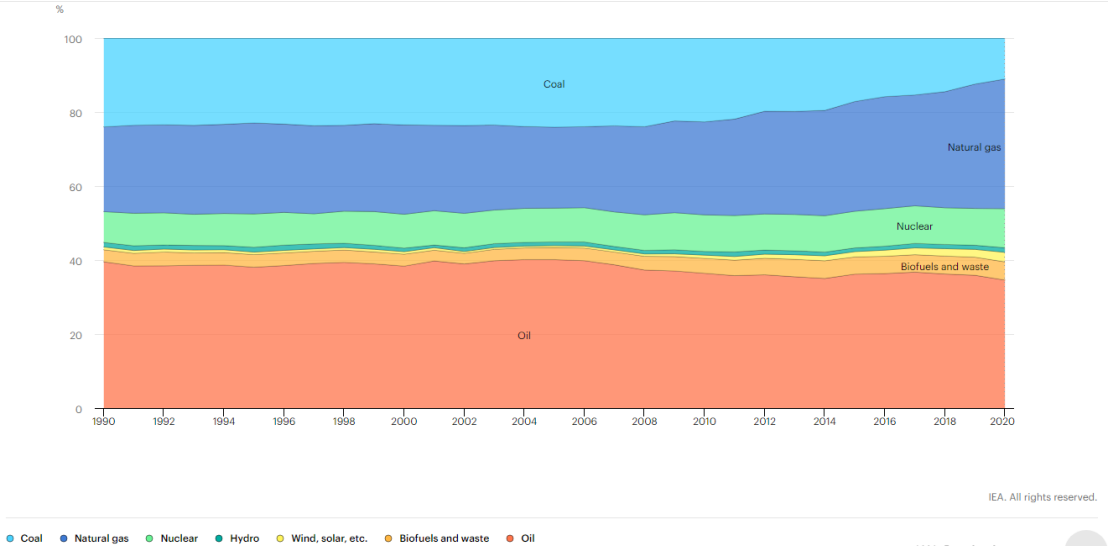

Figure 1 Total energy supply (TES) by source, United States 1990-2020 (IEA, 2022)

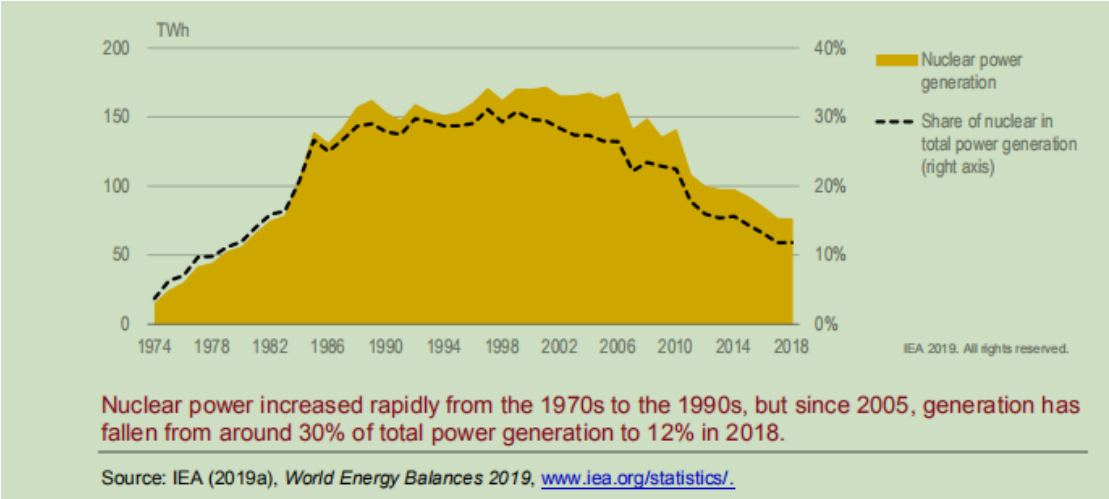

Figure 2 Nuclear power generation and share in electricity generation, 1974-2018 (IEA, 2019)

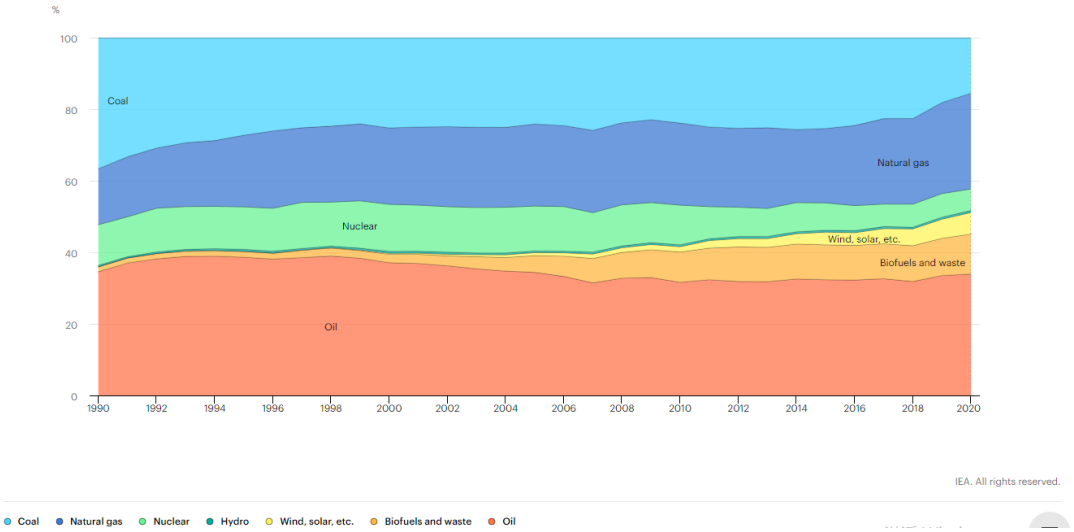

Figure 3 Total energy supply (TES) by source, Germany 1990-2020 (IEA, 2022)

4.2.2 Energy type selection

In terms of the choice of energy types, Germany and the United States have similarities, but the differences are also very obvious. Germany takes the development of "renewable energy" in clean energy as the main direction of energy transition, and is committed to developing renewable energy into the leading energy by 2050. The United States takes "clean energy", including natural gas and nuclear energy, as the main energy for development.

According to the website of Energiewende, the German government takes renewable energy as the main type of energy transition, and puts forward specific targets for

renewable energy consumption by 2050. In contrast, the United States has not proposed renewable energy as the only energy for future energy transition, although the U.S. Department of Energy and some states have a small-scale 100% renewable energy supply experiment. So far, the most explicit goal of energy transformation put forward by the U.S. government is that Obama proposed in his 2011 state of the Union speech that by 2035, 80% of American electricity will come from clean energy composed of renewable energy, natural gas and nuclear energy.

It can be seen that German energy is transforming to renewable energy and the United States is transforming to clean energy.

4.2.3 Main motives and types of energy transition

In 2011, the Bundestag set three energy policy objectives, which are energy security, affordable energy and the supply of energy compatible with the environment, to guide Germany's energy transition. Therefore, the motivation of Germany's clean energy transition is mainly the above three points. However, since Germany began its energy transition in 2000, environmentally compatible energy supply has gradually become the main motivation. Because of the policy decision of phasing out nuclear energy, it reflects that Germany gives priority to reducing and eliminating the possible environmental pollution caused by the risk of nuclear accidents than energy security. If Germany continues to develop nuclear energy, it would be more beneficial to its energy security than simply developing renewable energy and importing energy from other countries. In addition to the elimination of nuclear energy, considering the protection of biodiversity, Germany's tax preference for biofuels has been reduced in recent years, and the output of biofuels has gradually decreased.

The main motivation for the development of clean energy in the United States has always been to consider its own energy security, reduce energy import dependence and gradually realize energy independence. Since the 1970s, the United States has encouraged the development of biofuels and introduced bills and policies to support

the development of ethanol fuels, such as the energy tax act. In order to achieve energy independence, the United States not only develops renewable energy, but also focuses on shale gas, nuclear power, clean utilization of coal and biofuels, and improves energy efficiency. In 2017, the Trump Administration withdrew from the Paris Agreement focusing on addressing climate change, which also means that the United States puts its energy security and energy independence first among environmental protection and energy security.

In short, comparing the main motivation of energy transition between Germany and the United States, it can be concluded that Germany's energy transition is an energy transition type focusing on environmental protection and climate friendliness, while the United States puts energy security first and is an energy transition type dominated by energy independence.

4.2.4 Summary

After analyzing the energy transition and clean energy development goals and paths of Germany and the United States, it is concluded that there are great differences in clean energy development between the two countries, which are sorted out as follows:

Country	Germany	United States
Clean energy development goals	Germany revised the renewable energy law (EEG-2021) to achieve the goal of carbon neutrality in all power industries and power terminals by 2050. By 2030, the proportion of renewable energy power generation in the total power generation will reach 65%.	The Obama Administration announced the "clean energy plan" in 2015 to promote the transition of hybrid energy based on renewable energy, natural gas and nuclear energy. Although Trump's term of office was abolished, green development goals were still set at the state level.
Selection of clean energy types	Renewable energy	Nuclear energy, natural gas (including shale gas), renewable energy, etc.

Attitude towards nuclear energy	Phase out nuclear energy and plan to completely abandon nuclear energy in 2022	Vigorously develop nuclear energy
Clean energy policy	From fixed feed in price system (FIT) to market price + premium subsidy system (FIP) + market-oriented bidding system	State level quota system (RPS)
Main motivation of energy transition	Provide environmentally compatible energy	National energy security
Types of energy transition	Energy transition strategy of climate friendly and environmental governance	Energy transition strategy of partial energy independence

Table 1 Germany and US clean energy development difference

5 Empirical Findings

This chapter uses PEST analysis tool to make a specific analysis of the reasons from four perspectives for the different paths of clean energy transition between the two countries.

5.1 Political perspective: Political interests and objectives

5.1.1 Germany: the ruling parties give priority to environmental protection

While the United States is vigorously developing nuclear energy, Germany has chosen to eliminate nuclear energy and plans to close all nuclear power plants in its territory in 2022. The main political reason is that the German ruling parties give priority to environmental protection, which takes priority over energy security.

In 1998, the German Social Democratic Party and the Green Party won the general election. The Schroeder government and large utility companies reached a "nuclear consensus" agreement to limit the life of nuclear power plants to 32 years. The agreement allocated power generation quotas to each nuclear power plant and allowed them to continue nuclear power production before the nuclear power plant was shut down. In 2009, the Christian Democratic Union / Christian Social Union won the general election and formed an alliance with the Liberal Democratic Party. They

extended the operation life of seven nuclear power plants by 8 years on the basis of the original operation time, and extended the operation time of another 10 nuclear power plants by 14 years to phase out nuclear power. In March 2011, after the Fukushima nuclear power plant leak in Japan, the Merkel Government proposed relevant bills in June of that year. More than 80% of the members of the federal parliament approved the bill, announced the closure of eight nuclear power plants, and planned to close the remaining nine nuclear power plants in 2022. Due to the government's decision and measures to phase out nuclear power, Germany's nuclear power generation accounted for 29.5% of the total power generation in 2000 and decreased to 11.4% in 2020 (Li Xinlei, 2020). Due to the diversified sources of power supply in Germany, in addition to nuclear energy, renewable energy power generation such as solar energy and wind energy also accounts for a large proportion in Germany. Therefore, the phased elimination of nuclear energy will not endanger Germany's power supply, which is feasible. In contrast, France has also proposed a plan to eliminate nuclear energy, but President Macron and some experts expect that the elimination of nuclear energy will lead to a power supply crisis in France (Han Shulin, 2022), so the plan to eliminate nuclear energy has not been implemented like Germany. It can be seen that the German ruling parties gives priority to environmental protection from the political level. Even if the elimination of nuclear energy will have a certain impact on Germany's domestic power supply and even energy security.

In addition, renewable energy exists in a wide range and has the advantages of huge quantity, small clean pollution and renewable. Compared with other energy sources, renewable energy has the least degree of environmental pollution. In order to give priority to environmental protection, in addition to the plan to eliminate nuclear energy, the German ruling parties attach great importance to the development of renewable energy, takes it as the pillar of clean energy transition, and formulates and revises the renewable energy law (EEG) from the legal level for many times. In 2021, the newly revised renewable energy law adjusted the 2030 supply target of renewable energy, increased from 50% of the previous renewable energy to 65% of the total

energy supply, and set specific power supply targets for renewable energy such as wind power (see Table 3). It can be seen that the German government attaches importance to renewable energy in legislation, which also reflects that the German ruling parties put environmental protection in the first place of energy development.

Generation type	2022	2025	2029
Onshore wind power	1.8GW	3.7GW	5.4GW
Offshore wind power	0.5GW	0.7GW	2.9GW
Photovoltaic power generation	4.8GW	4.8GW	5.6GW
biomass power generation	0.2GW	0.5GW	0.5GW

Table 2 Germany EEG-2021 development goals of renewable energies

5.1.2 United States: pursuing energy independence and energy security

After the outbreak of the first oil crisis, the Nixon Administration put forward the energy independence plan, but during his tenure, the energy independence plan was not implemented. According to the 2010 data of the U.S. energy information Administration, the oil energy consumption of the United States accounts for nearly 40% of the total energy consumption. Moreover, the United States has long imported a large amount of oil resources from oil producing countries in the Middle East, Russia and other countries. With the expansion of domestic oil consumption demand, the external dependence of American energy is increasing. Once the relationship between the United States and oil suppliers deteriorates, or oil prices soar, or supply shortage, it will have an incalculable impact on the domestic economic and political leadership of the United States. Politically, over reliance on oil imports has posed a threat to the national security of the United States. In order to reduce dependence on foreign energy, improve the status and voice of the United States in energy diplomacy and ensure its own energy security, the U.S. government has been committed to achieving energy independence for decades.

"Energy independence" refers to reducing the dependence on external energy, which

does not mean completely cutting off energy imports, but increasing the domestic energy supply and raising the energy self-sufficiency rate to a level that can ensure the relative independence of domestic energy, so that the domestic energy market will not be seriously affected by the sharp fluctuations of the international energy market (Li Xinlei, 2020).

Since the beginning of the 21st century, the energy independence policy of the United States has gradually become prominent. With new energy as the core, the Bush Administration formulated energy plans and promulgated relevant energy laws, such as the energy policy act of 1992, which launched strategic oil reserves to ensure the energy security of the United States. The national energy policy issued in 2001 proposes to increase domestic energy supply, reduce energy dependence on foreign countries, develop alternative energy, especially nuclear energy, and promote the diversification of energy supply. Since then, the US government has issued the clean coal power generation plan and the hydrogen fuel plan to accelerate the development of clean coal technology, and increased US $1.2 billion for investment and R&D of hydrogen fuel and hydrogen fuel vehicles (Du Baogui and Zhu Ruonan, 2018). Since then, the United States has gradually increased its domestic oil reserves and improved its energy security. In 2007, the energy independence and security law (also known as the new energy law) was issued, focusing on energy efficiency improvement and the development of alternative energy such as biofuel ethanol. During the Bush Administration, the energy development strategy with energy independence as the core has been relatively complete and achieved initial results.

During Obama's tenure, with the goal of energy independence, he formulated an energy security strategy, which is reflected in the form of energy legislation. The specific contents of the bill include developing alternative clean energy, saving energy and developing new energy, increasing domestic oil production, etc. The blueprint for the future of energy security released by Obama in 2011 pointed out that it is planned to reduce one-third of the current oil consumption of the United States by 2025,

increase the proportion of clean energy in the total energy consumption to 50%, and reduce the oil import of the United States. The Obama Administration's policies on energy independence mainly focus on four aspects. First, improve energy efficiency. In order to double energy efficiency, the Obama Administration has issued the national low-carbon fuel standard (LCFs) and relevant policies and measures to improve vehicle fuel efficiency. Second, expand the development of domestic oil and gas resources and reduce oil imports. The Obama Administration has liberalized the development of oil and gas fields such as the Gulf of Mexico, cooperated with Canada and other countries to build natural gas pipelines, and encouraged the vigorous exploitation of natural gas dominated by shale gas. Third, further develop clean energy such as wind, solar and nuclear energy, and increase the government's financial expenditure on clean energy. Fourth, increase investment in R&D of new energy technologies and support R&D projects of clean energy technologies.

During Trump's Administration, he still adhered to the goal of energy independence, put forward the "US energy priority plan" and accelerated the promotion of us energy independence. The specific contents of the "US energy priority plan" include: increasing the development of domestic fossil fuel oil, shale oil, shale gas and conventional natural gas, and reducing the dependence on foreign energy imports; Cancel the "Climate Action Plan"; Innovate and develop clean coal technology and revitalize the coal industry; Narrow the scope of responsibility of the US Environmental Protection Agency and only protect the ecology of water, air and nature reserves. In addition, during Trump's tenure, he repeatedly proposed to develop domestic energy based on fossil energy on important occasions, led the United States to withdraw from the Paris Agreement, abolished the Obama Administration's clean energy plan and put forward the affordable clean energy plan. In 2019, the United States achieved its first net export of crude oil and petroleum products. Although the trump Administration has put fossil energy in an important position, it has also invested heavily in the development of carbon capture technology to reduce pollutant emissions. It can be seen that the trump Administration has put us energy security in

the first place and energy independence at the core of us energy development.

The Biden Administration has different paths and policies for energy development compared with trump Administration, focusing on the development of clean energy. Biden promised to make the United States achieve a 100% clean energy economy and achieve net zero carbon emissions by 2050. The "clean energy revolution and environment plan" proposed by Biden team has made short-term, medium and long-term quantitative objectives for the development of clean energy. The main contents include: promoting electric vehicles, increasing charging stations and promoting the development of new energy vehicle industry; Increase the construction of clean energy infrastructure such as wind power generation and photovoltaic power generation, and achieve the goal of zero carbon emission in power generation by 2035; The United States rejoined the Paris Agreement. In addition, the Biden government has strengthened cooperation with other countries in climate protection and promoted energy conservation and emission reduction. Although the Biden Administration attaches new importance to the development of clean energy, it still believes that fossil fuels play an important role in the transition from the United States to clean energy, and transitional energy such as shale gas is indispensable in the transition to clean energy. Although the Biden Administration attaches importance to the development of clean energy, energy security and energy independence always run through its energy policy-making, giving priority to environmental protection objectives.

To sum up, since 2000, the United States has been focusing on energy independence and energy security, developing its traditional oil and gas energy and unconventional oil and gas resources, and gradually developing clean energy such as solar energy, wind energy and nuclear energy (see Table 3). Therefore, from the political level, in the transition of clean energy, the United States continues to vigorously develop shale gas and nuclear energy while developing renewable energy. The main political reason is the pursuit of energy security and energy independence.

President	Major policies on energy independence and energy security
George Walker Bush （2001-2009）	Start strategic oil reserves, develop alternative energy, especially nuclear energy, and promote the diversification of energy supply
Barack Obama （2009-2017）	Develop alternative clean energy, save energy and develop new energy, and increase domestic oil production
Donald Trump （2017-2021）	Put forward the "American energy priority plan" to develop clean coal technology and carbon capture technology, focusing on the development of fossil fuels
Joseph Biden (2021 present)	Focus on the development of clean energy, increase the construction of wind power and photovoltaic clean energy infrastructure, and promote the development of new energy vehicle industry.

Table 3 Energy security main policy of each American president in 21 century

5.2 Social perspective: People's attitude towards energy transition

5.2.1 Germany: high public support for renewable energy development

The Institute for advanced Sustainability Studies (IASS) conducted a public opinion survey on the theme of German energy transition through the use of forsa.omninet household panel, in the form of online questionnaire survey, investigated and analyzed the attitudes of residents aged 14 and over towards the energy transition and renewable energy development in Germany, and obtained the latest version of Social Sustainability Barometer for the Energiewende：2019 Edition. According to the survey jointly conducted by IASS, innogy foundation and 100% erneuerbar Stiftung foundation every year, the Social Sustainability Barometer for the Energiewende reflects the current public attitudes and concerns about Germany's energy transition.

Research shows that most Germans are willing to bear more costs of climate protection in principle. But low-income families are seeking subsidies to reduce the economic burden of carbon pricing. Most citizens believe that the income from carbon pricing should be earmarked to develop climate friendly transportation systems and renewable energy. Most respondents supported the expansion of offshore

wind energy, the use of geothermal energy, the installation of photovoltaic systems on roofs and other available space, and the construction of biogas plants. Figure 4 and figure 5 show the survey results of German people's support and opposition to the political objectives of German energy transition (Energiewende) and renewable energy technologies in 2017, 2018 and 2019 respectively (see Figure 4 and figure 5).

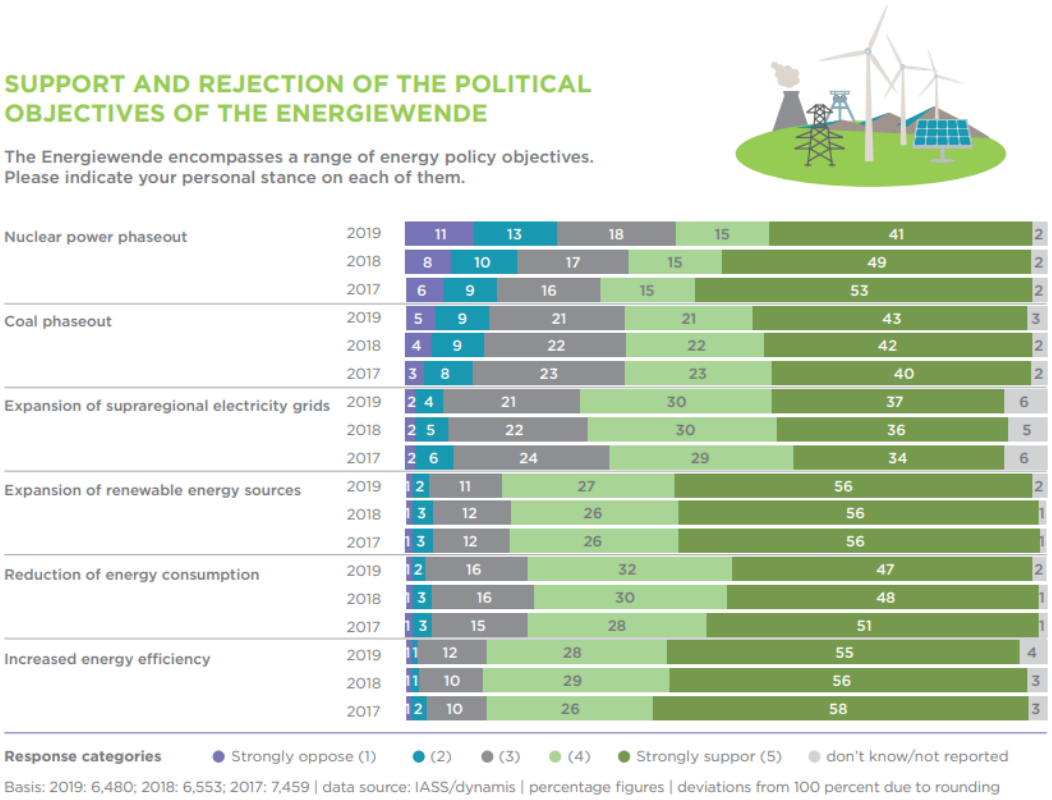

Figure 4 Support and Rejection of the political objectives of the Energiewende (IASS, 2022)

Figure 4 surveys the support and opposition of the German people to the energy political objectives in the German energy transition (Energiewende). According to the data, most respondents (56%) insisted on eliminating nuclear energy in 2019, but their support for the elimination of nuclear energy decreased compared with the previous two years. About two-thirds (64%) of households support coal withdrawal, and their attitude towards coal withdrawal has not changed much in the past three years. 67% of people support the expansion of the power grid, and the support rate is on the rise compared with before. However, considering the existing regional differences in power grid expansion and sustained development rate, it is an important prerequisite for the success of these regional expansion measures. In addition, according to the

figure, there is a broad consensus on three main energy goals: improving energy efficiency (83%), expanding renewable energy (83%) and reducing energy consumption (79%).

In conclusion, most German families support the key political objectives of energy transition. The three political goals of improving energy efficiency, increasing the share of renewable energy and reducing energy consumption have won the highest public support. The public support rate for the energy transition goal of further expanding the power grid and withdrawing from the coal and nuclear energy industry is slightly lower. It can be seen that most German people have strong support for the transition of renewable energy.

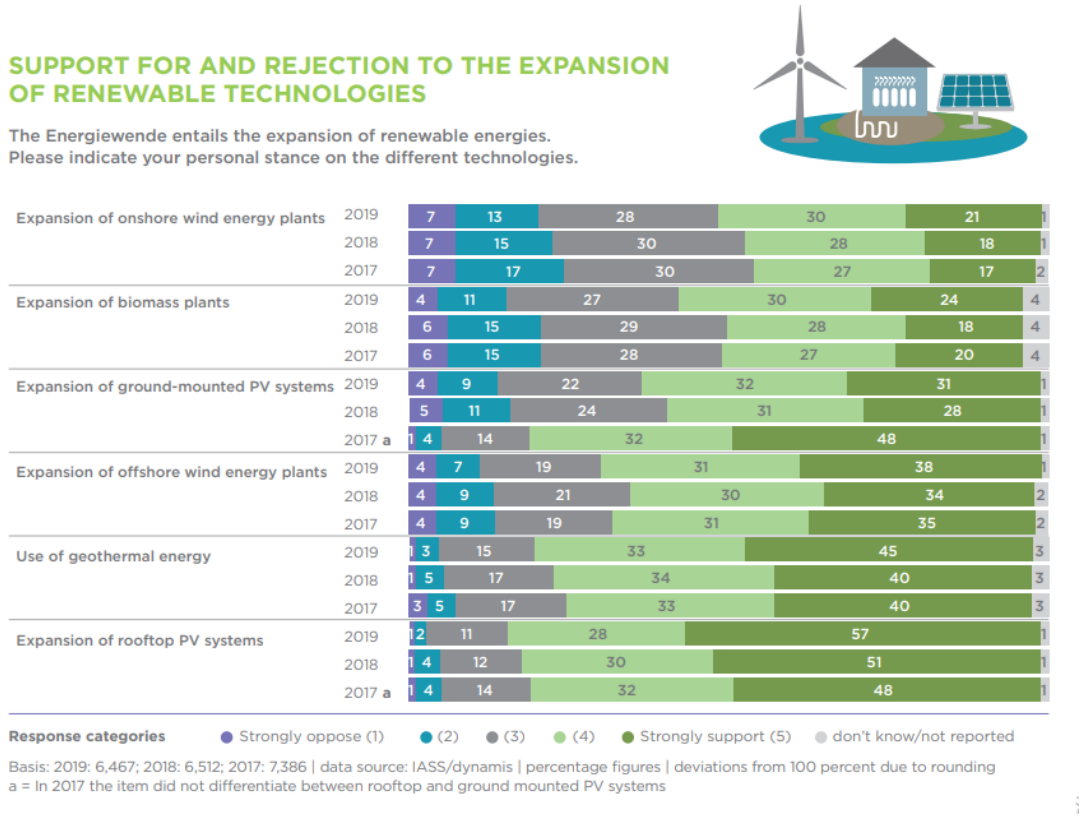

Figure 5 Support for and Rejection to the expansion of renewable technologies (IASS, 2022)

Figure 5 is a poll of the expansion of major renewable energy technologies in Germany. As can be seen from Figure 5, half (51%) of the residents supported the expansion of onshore wind energy in 2019, an increase of 5 percentage points compared with 2018, but 20% of the respondents did not support this goal. Urban and

rural families have different attitudes on this issue, and the attitudes of the East and West are also different. In large cities, the proportion of supporting onshore wind energy is 58%, about one-third higher than that in rural areas. The support rate of the people in the eastern region (39%) is lower than that in the western region (55%). Surprisingly, the opposition rate of residents with nearby wind turbines to the expansion of wind energy on the road (22%) is only 3% higher than that of residents without nearby wind turbines (19%). Since 2018, public support for expanding biomass power generation has increased to 54%. Like the attitude towards wind turbines, most families with biogas digesters nearby and those without biogas digesters nearby support the use of biogas, with support rates of 50% and 56% respectively. In addition, the overwhelming majority of residents supports the expansion of offshore wind energy (69%), increase the use of biomass energy (78%), and install more roof photovoltaic systems (85%), and only a small number of residents oppose it.

In conclusion, the results show that most people support the expansion of renewable energy. The rising popularity of renewable energy related technologies shows that the increasing urgency of the climate crisis and the debate triggered by “Fridays for future” has a positive impact on the public acceptance of climate friendly energy. Democratic scepticism is also declining with regard to the expansion of onshore wind and biomass energy.

To sum up, the German people have a high support rate for the development of renewable energy, which helps to promote the government to formulate and improve energy transition measures and accelerate the process of energy transition in Germany.

5.2.2 United States: Most Americans support expanding solar and wind energy and there is an increasing tendency to purchase electric vehicles.

Firstly, a non-advocacy and independent polling agency in the United States—Pew Research Center, conducted a poll on the support rate of solar and wind energy (Brian and Alison, 2021). Most U.S. adults continue to support expanding solar panel farms

(84%) and wind turbine farms (77%), but Republicans and Democrats are increasingly divided in views on these two energy sources (see Figure 6), according to a recent Pew Research Center survey (Pew Research Center, 2021:01).

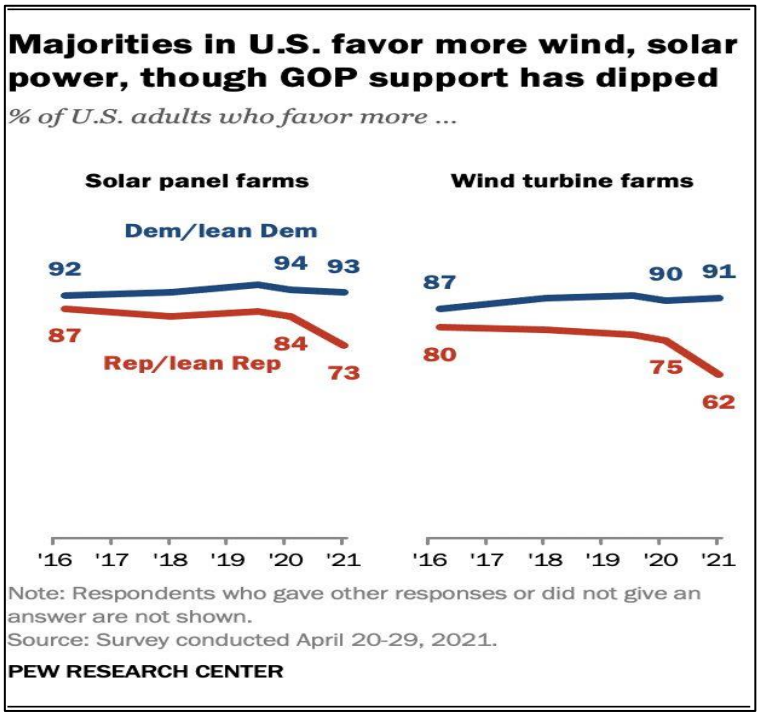

Figure 6 Public opinion on wind and solar power

Secondly, in the process of clean energy transition, the United States has increased the production of renewable energy and vigorously promoted the development of electric vehicle industry. In 2021, Harris poll conducted a survey on the public's purchase tendency of electric vehicles, so as to reflect the American people's acceptance of electric vehicles, their loyalty to automobile manufacturers planning to provide electric vehicles, their main concerns about electric vehicles, and their openness to try new technologies of electric vehicles. Figure 7 is a survey of the current willingness of U.S. residents to buy electric vehicles. The results show that more than 2 / 5 of residents are currently willing to buy electric vehicles. According to the survey results of electric vehicle purchase intention in Figure 8, most urban (74%) and suburban (63%) residents in the United States believe that it is acceptable to buy only electric vehicles before 2040, while residents in rural areas have a relatively low intention to buy electric vehicles before 2040 (46%).

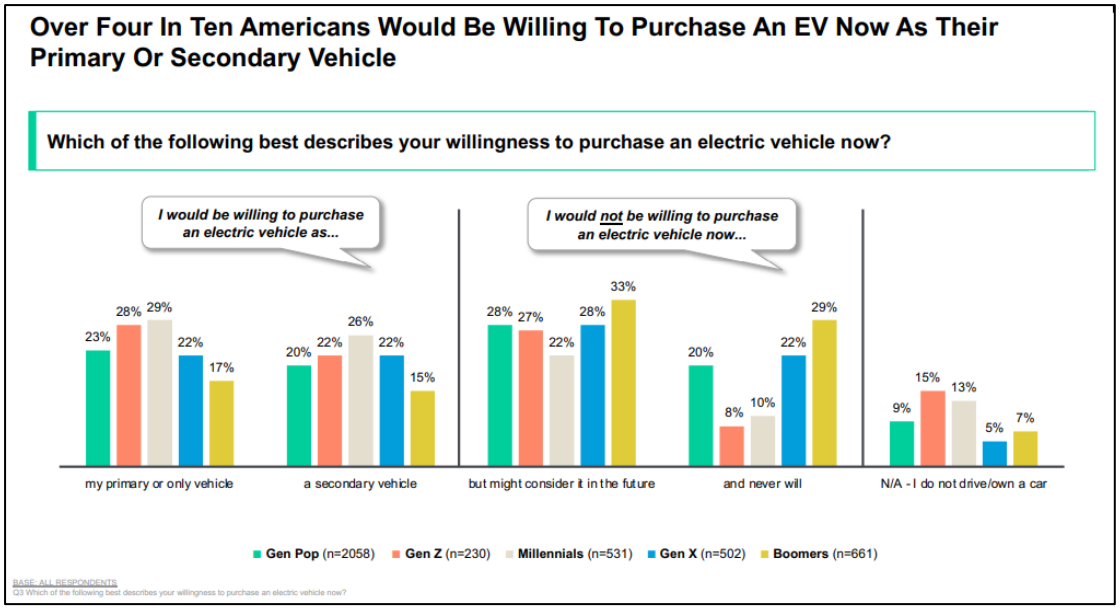

Figure 7 American willingness of purchasing an electric vehicle now (Harris poll, 2021)

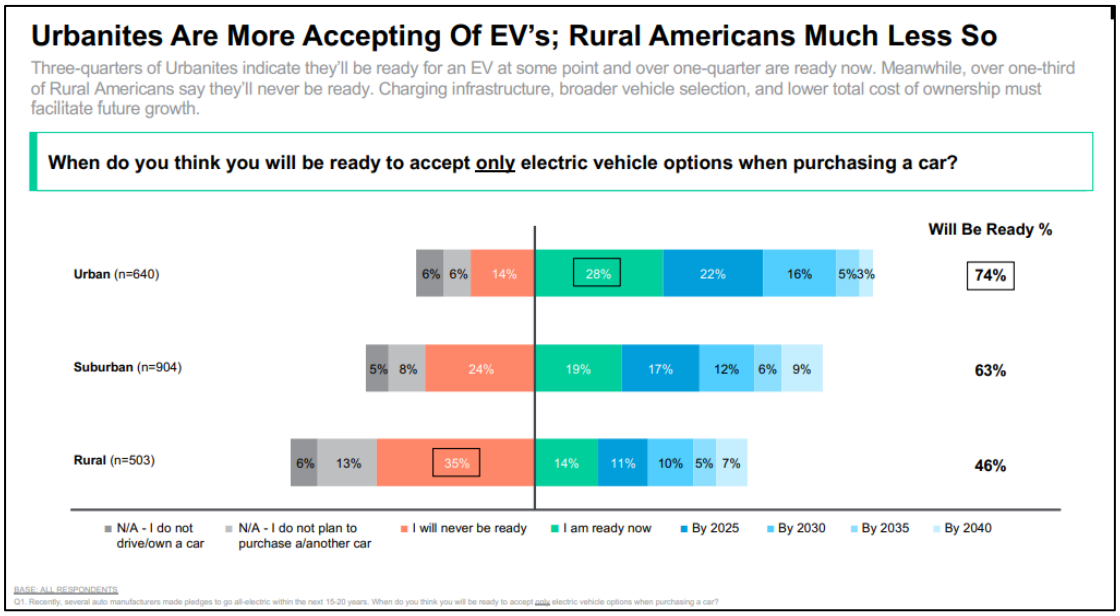

Figure 8 Purchase tendency of American urban, suburban and rural residents to electric vehicles (Harris poll, 2021)

Based on the above data and results, it can be concluded that most Americans support expanding solar and wind energy, and there is an increasing tendency in the U.S. to purchase electric vehicles. They help to promote the production of renewable energy in the United States from the social level, and then promote the transition process of clean energy in the United States.

5.3 Technical perspective: technical maturity

5.3.1 Germany: Renewable energy equipment, power grid expansion capacity and power storage system are being improved

Due to the progress of modern science and technology, the manufacturing technology of photovoltaic panels and wind turbines is becoming more and more advanced, which is conducive to Germany to purchase and lay a large number of relevant photovoltaic power generation equipment and wind power generation equipment, expand photovoltaic power plants and wind power plants, and accelerate the development of solar and wind renewable energy industry in Germany.

Secondly, according to the German energy transition official website (Energiewende, 2021), at present, one-third of Germany's electricity comes from wind, solar and biomass energy. Power grid expansion and transition are the preconditions to ensure sustainable energy supply in Germany, and the power storage system also plays an important role in the development of intelligent power infrastructure. In 2018, Peter Altmaier, German Federal Minister of economy and energy, once said that a successful energy transition requires a modern and perfect power grid and the expansion of renewable energy. In recent years, Germany is strengthening its power grid expansion capacity and trying to keep the power grid transmission system up with the expansion of renewable energy production. In addition, due to technical and space constraints, Germany's power storage capacity needs to be improved. At present, some power is still imported from Norway and other European countries.

5.3.2 United States: hydraulic fracturing and horizontal well technology, shale gas revolution

After decades of technological innovation, the shale gas industry in the United States has developed rapidly, gradually realizing self-sufficiency of natural gas from large natural gas importers, and even exporting it abroad. From the technical level, this great change is inseparable from the development of hydraulic fracturing technology. Hydraulic fracturing technology is a technology that injects high-pressure water into

rock stratum to fracture it. High-pressure water is added with chemicals to improve the permeability of rock stratum. At first, hydraulic fracturing technology was used to transform old wells and improve recovery. Later, due to the emergence of horizontal well technology, this technology was used for shale oil and gas exploitation on a large scale, which greatly promoted the production of shale oil and gas in the United States (Guccione and Zeranski, 2019).

Shale gas in the United States can be divided into three stages from the beginning of production to large-scale development. The first stage is the infancy of shale gas development (1821-1970), the second stage is the development period (1970-2000), and the third stage is the period of large-scale production (after 2000). In the first stage, the first use of shale gas in the United States can be traced back to 1821. The first shale well was drilled in a shale in Chautauqua County, New York, and the extracted natural gas was used to illuminate the town of Fredonia. With this discovery, hundreds of shallow shale wells were drilled along the coastline of Lake Erie, and several shale gas fields were established from the lake to the southeast at the end of the 19th century. In the late 1940s, hydraulic fracturing technology was first used to increase oil and gas wells. In the second stage, the oil crisis in 1973 and 1979 led the U.S. government to look for alternative energy and invest in research and development, including shale gas production technology. In the late 1970s, the US Department of energy (DOE) launched the eastern shale gas project, and energy research institutions such as gas Research Institute and national energy technology laboratory were established one after another. In the third stage, the drilling technology is more advanced. Many shale gas exploration and production companies use advanced drilling technology and hydraulic fracturing technology to find and produce shale gas on a large scale. So far, shale gas exploration and production technology in the United States is relatively mature compared with other countries in the world.

Therefore, in terms of technological maturity, the shale gas exploitation technology in

the United States is mature, so natural gas (including shale gas) will be used as an important transitional energy in the transition to clean energy.

5.4 Economic perspective: energy costs and benefits

5.4.1 Germany: lower costs of wind and solar energy

In recent years, technological progress and energy transition so far have greatly reduced the cost of wind and solar power plants. The current bidding results show that the costs of onshore and offshore wind power and photovoltaic systems in open space have converged, with only 5 to 6 cents per KWh. This means that the total cost of renewable energy has been lower than the construction cost of new conventional power plants. In the United States, Australia, China, Chile or Morocco, solar and wind power are now cheaper than nuclear and coal-fired power plants. In 2018, the EEG surcharge on renewable energy generation financing decreased slightly compared with the previous year, although the share of renewable energy in electricity consumption continued to rise. Calculations based on the EEG calculator developed by Germany's Öko-Institut for the energy policy think tank Agora Energiewende show that if the expansion of renewable energy is to be significantly accelerated, there will only be a small amount of additional costs compared with the expansion previously planned by EEG.

According to the analysis of Germany's Öko-Institut data, renewable energy is not necessarily more expensive than traditional oil and gas resources in the future. For Agora Energiewende, Öko-Institut compared the power supply systems of various energy sources and found that renewable energy not only completely covered the power supply of Germany, but also ensured a high level of supply security. If the cost of a ton of carbon dioxide is calculated to be about 50 euros, renewable power systems will usually be cheaper than or as expensive as classical fossil fuel power generation systems by 2050.

5.4.2 United States: shale gas production and solar& wind energy construction costs have reduced

The shale gas exploitation technology in the United States is at an advanced level in the world. In the course of decades of shale gas exploitation, it has carried out exploitation technology innovation and accumulated a lot of experience.

Firstly, from a horizontal perspective, the "shale gas revolution" has made the price of natural gas in the United States lower than that in Europe and Asia for a long time, and the shale gas in the United States has a cost advantage. Secondly, from the vertical point of view, since 2012 US, shale gas wellhead costs have reduced because of technological progress (Médodie et al., 2018). EIA commissioned IHS Global Consulting Company to study the single well cost in Eagle Ford, Bakken, Marcellus and Permian, and separately analyze the Midland basin and Delaware basin of Permian. Survey showed that compared with the highest single well cost in 2012 of the past decade, the upstream cost decreased by 25 ~ 30% in 2015. The development of technology improves the efficiency of drilling and completion, and can obtain high production while reducing the cost of single well (Original oil circle, 2016). Besides, some scholars base on IEA data predict that shale production costs remain moderate by 2040 however favorable scenarios may be (Médodie et al., 2018).

In addition, The Biden administration just approved the country’s first major offshore wind farm and intends to invest in additional offshore wind projects. And construction costs for solar and wind power projects fell dramatically from 2013 to 2018, helping to boost the viability of increased reliance on these sources (Brian and Alison, 2021:01).

6 Discussion and Analytical chapter

Above chapters analyze the four perspective reasons of different clean energy transition goals and paths between Germany and the U.S. By using PEST model, clearly make a relative comprehensive analysis from politics, societies, technology

and economy four aspects.

At present, current journals and literature has not been found an article comprehensively analyzing the reasons for the different paths of clean energy transition in Germany and the United States. In the research gap chapter, the relevant writing situation of the existing literature on this topic has been summarized. Based on this current situation, this thesis analyzes and compares the reasons for the differences between the two countries from four levels, which can fill this research gap. Moreover, Germany is representative in the energy transition of European countries. The development of clean energy in many Western and Northern European countries is similar to that in Germany, because they also have advanced clean energy technology. The United States is also a big country in America. Germany and the United States can well reflect the clean energy transition of other European and American countries.

This thesis comparing with the existing literature has similarities and differences. First, Li Xinlei (2020) proposed that Germany and the United States take environmental protection and energy independence as the core political interests respectively. In terms of politics, after data analysis, this paper also comes to a unanimous conclusion that the two countries have different core interests in the transition of clean energy, but this thesis also analyzes the economic, social and technological reasons to supplement the reasons for the different energy transition paths of the two countries. Second, Lin Lv et al. (2017) put forward the policy practice of Germany's transition to renewable energy, including top-level design, laws and regulations, technology R&D and incentive mechanism; The policy guarantee for the transition of the United States to clean energy includes the implementation of the goal of energy independence, the use of natural gas and nuclear energy as transitional energy, the combination of legal means and economic stimulus, and relevant policies at the state level. Differently, this thesis summarizes the objectives, path, attitude towards nuclear energy, clean energy policy and main motivation of clean energy development in Germany and the United

States, compares them clearly in the form of tables, sorts out the differences between the two countries, and draws the same conclusion: Germany takes the development path with renewable energy as the core, while the United States takes natural gas and nuclear energy as transition energy and develops renewable energy at the same time. In addition, in the cause analysis, the reasons for the differences between the two countries are summarized into four aspects for comparative analysis, which complements the lack of social and cultural reasons above. Thirdly, Jin Leqin (2016) compares the goals and paths of energy transition between the United States and Germany, which is more consistent with the analysis of this paper. Based on the goal and path, this paper analyzes the reasons for the differences between the two countries. Fourth, Zhu Tong (2016) analyzed the political core motivation of the energy transition in Germany and the United States. The conclusion is consistent with this paper. This paper also analyzes it from the social, technical and economic aspects to supplement and improve it. The above articles are most relevant to the theme of this article. Other articles are to compare the differences between the two countries in the transition of clean energy, and some are to analyze the reasons for the differences in a single aspect, such as politics or technology, without a more comprehensive analysis. This paper supplements its content, makes a more comprehensive analysis, fills the gap in the subject literature of this paper, and has a certain innovation.

As for the importance of this article, first of all, due to environmental reasons such as global warming, the transition of clean energy is becoming more and more important. Most countries in the world are formulating plans and schemes for energy transition based on their national conditions. Some countries choose to develop renewable energy and some countries choose to use natural gas as transitional energy to promote energy transition. However, some of these countries have been very successful in energy transition, other countries the progress of energy transition is slow or even stagnant due to high costs or public opposition. So how to make a feasible clean energy development plan? This issue is very important, because the energy development plan guides a country's energy transition. If a country does not formulate

clean energy development goals and paths according to the country's actual political and economic conditions, it is easy to lead to failure or serious difficulties in energy transition. Therefore, if they want to formulate an appropriate energy transition plan, they can refer to other countries with similar national conditions and successful energy transition. For example, although Germany and the United States are carrying out clean energy transition, and both countries are representatives of successful transition, the energy transition paths of the two countries are very different. Therefore, other countries that are undergoing or have not yet started the transition and development of clean energy can compare whether there are similarities in natural factors, politics, economy, culture and technology between themselves and the above two countries, so as to refer to the energy transition path of countries with similar national conditions, the success of their clean energy plans, and combined with their actual situation, Formulate clean energy development goals and paths suitable for their own countries.

Taking China as an example, as one of the largest developing countries in the world and a major producer and consumer of oil and natural gas, how can China draw on the successful experience of developed countries such as Germany and the United States to formulate a clean energy development plan and smoothly realize the transition of clean energy? As we all know, China is rich in oil and gas resources, which is completely different from Germany, which lacks oil and gas resources, and is similar to the United States, which is rich in shale gas resources. Therefore, China can learn from the method of the United States using natural gas as a transitional energy and incorporate it into the clean energy transition plan. However, due to the terrain of China, the shale layer is far from the surface and deep, which makes it difficult and costly to exploit shale gas in China. Therefore, shale gas cannot be exploited on a large scale like the United States. Therefore, conventional natural gas is a more suitable transitional energy for China. In addition, due to the current situation of economic development, China's policies focus on energy security, which is different from Germany, which focuses on environmental protection. Therefore, the elimination

of nuclear energy will not be a measure for China's current clean energy development. In addition, due to the Chinese traditional ideology and culture, the awareness of attaching importance to safety is deeply rooted in the hearts of the people. From the government's measures to deal with COVID-19, we can see that the government puts people's life safety in the first place. The Chinese government and people prefer safe energy. Therefore, China's energy development will take into account the interests of the people to a great extent. In this regard, China and many western countries have different ideas, so the people will be the core in energy policy-making.

This paper analyzes the reasons from four aspects. As for next research step, if we want to further promote the research, we can introduce international factors and analyze it from the international level. For example, Germany is one of the EU countries, and the clean energy transition is also the corresponding EU policies and instructions, or Germany is a member of the Paris Agreement and bears part of the responsibility to solve climate change. In addition, large oil and gas countries such as Russia can be introduced into the ranks of comparative analysis, analyze the current situation of oil and gas countries from the aspects of politics, economy, culture and society, and give relevant suggestions for their development of clean energy.

7 Conclusion

This paper compares the differences between the United States and Germany in the transition of clean energy from the perspective of goal and path, summarizes that the United States mainly takes clean energy including natural gas (including shale gas) and nuclear energy as the main development path, and Germany takes renewable energy as the core development path, and gradually eliminates nuclear energy and coal, and analyzes the reasons for the differences between the two countries from four aspects of politics, society, technology and economy.

From the political perspective, the United States takes energy independence and energy security as the core of clean energy transition and development; The German

government focuses on environmental protection and legislates on policies and requirements related to renewable energy. From a social perspective, most German people support the production of renewable energy and the expansion of infrastructure, especially offshore wind and solar energy; Most Americans support expanding solar and wind energy and there is an increasing tendency to purchase electric vehicles. From the technical and economic point of view, hydraulic fracturing and horizontal well technology in the United States are relatively mature, so the shale gas exploitation cost is low and the income is high; Germany's renewable energy power generation equipment and technology are at an advanced level in the world, and the cost is gradually decreasing. The production cost of some renewable energy is even lower than that of fossil fuels.

In view of the above factors, Germany and the United States have chosen different clean energy transition paths and formulated different clean energy development goals. Other countries can formulate clean energy development goals and plans suitable for their own countries and choose appropriate paths according to the situation and reasons of energy transition in Germany and the United States.

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