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Review

A Review of Energy Industry Chain and Energy Supply Chain

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Abstract: The reduction of carbon emissions from the energy industry chain and the coordinated development of the energy supply chain have attracted widespread attention. This paper conducts a systematic review of the existing literature on the energy industry chain and energy supply chain. Based on the analytical results, this paper finds that research gaps exist in the studies of energy consumption structure and resource consumption in energy industry chain. In addition, the studies of coordinated operation mechanisms, risk control and the impact of government policies on the energy supply chain still have some shortcomings. Furthermore, this paper shows that the exploitation and utilization of renewable energy and the sustainable development of the energy industry chain and supply chain have become the major focus of scholars and governments in recent years. Accordingly, this article finally presents the future research prospects and provides managerial insights for policy makers and enterprise managers to accelerate the development of renewable energy resources and to achieve green, low-carbon, coordinated and sustainable development.

Keywords: energy industry chain; energy supply chain; coal; natural gas; oil; new energy; energy structure; sustainable development

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1. Introduction

With the rapid growth of the global economy, energy, as a necessary material basis for the development of the national economy, together with capital, labor, land, etc., constitutes an essential production input factor for the development of modern society. Since Rasche and Tatom (1977) first added energy as a factor of production into the Cobb–Douglas production function [1], academia began to carry out extensive research on energy economic theory and energy digital governance.

With the rapid development of traditional energy resources such as coal and natural gas, the quantity of traditional resources has been sharply reduced due to the continuous exploitation and utilization of coal, natural gas, oil and other fossil energies. The growing shortage of traditional energy has seriously restricted the development of the global economy. In addition, the consumption of fossil energy destroys the balance of the ecological environment, causing serious global environmental pollution and extreme global climate change. According to statistics, between 1995 and 2007, international procurement resulted in an increase of 110 million tons of global carbon dioxide emissions [2]. Additionally, energy consumption in transnational transport further aggravated global carbon emissions. Considering the great amount of pollutants and the deterioration of human settlements, environmental governance of the energy industry chain and supply chain has gradually become a hot topic among governments and academic circles. Under the promotion of the United Nations Environment Programme (UNEP), more than 130 countries, including the vast majority of developing countries, have agreed to establish the Belt and Road Initiative International Green Development Coalition (BRIGC) in order to achieve global green trade and spread global green production technology. The Fifth Plenary Session of the 18th

Central Committee of the Communist Party of China also points out that adhering to green development and sustainable development is an important choice and strategic direction for China's economic development in the new era.

Therefore, extensive research has been conducted on the energy industry chain and energy supply chain in recent years. Exploring the resource and environmental impact factors of the energy industry chain and the industrial coordination relationship is an important way to formulate energy industry development and ecological environmental protection strategies and promote high-quality regional development. However, limited research has been conducted on the systematic summary and overview of the reduction of carbon emission in the energy industry chain and the coordinated development of the energy supply chain.

Based on this, this article presents a systematic review of the research of the energy industry chain and energy supply chain. This paper also clarifies the research progress and frontiers, and discusses the existing research gaps and possible research directions in order to provide useful reference for the research of global energy industry chain and energy supply chain and the corresponding environmental impact. This study also presents several recommendations for policy makers and enterprise managers to achieve sustainable development.

As shown in Figure 1, the study of low-carbon emission reduction in the energy industry chain mainly focuses on two aspects: the definition and structure of the energy industry chain and its environmental impact. As regards coordinated optimization of the energy supply chain, current studies mainly focus on three dimensions; coordinated operation mechanisms, risk control and the intervention of government policies.

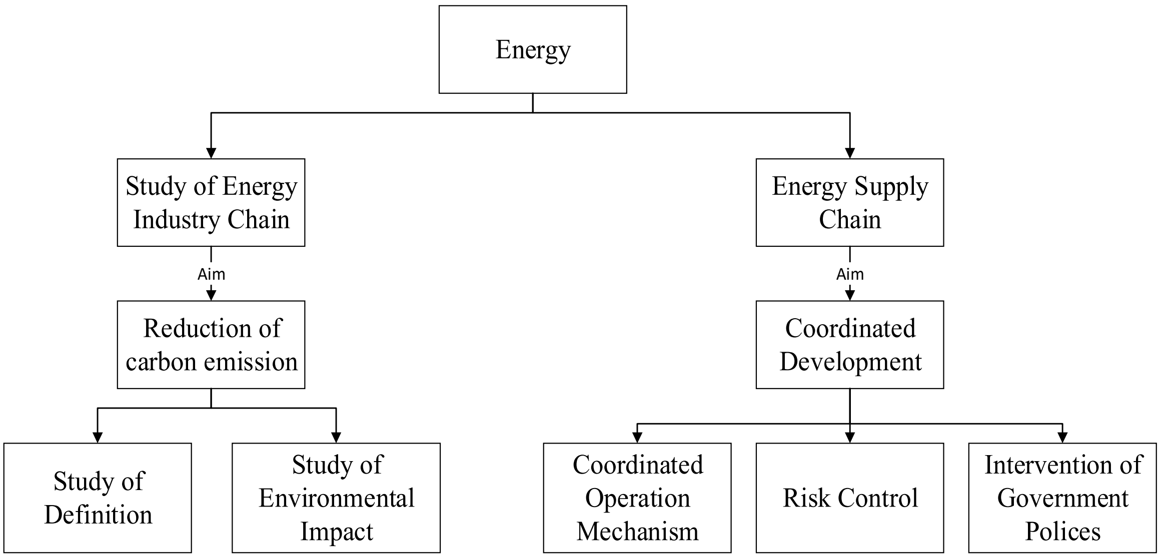

Figure 1. Structure of the Literature Review.

The remainder of the paper is structured as follows. Section 2 provides a brief overview of studies on low-carbon emission reduction of the energy industry chain. Section 3 gives a general review of research on the coordinated development of the energy supply chain. Section 4 summarizes the key findings and presents interesting directions for future investigation.

2. Energy Industry Chain

In recent years, an increasing number of researchers have begun to study energy conservation and emission reduction of traditional energy industry chains, such as coal and natural gas, and the development and utilization of new energy industry chains. Given the continuous economic growth and environmental deterioration, the development of the energy industry chain is increasingly restricted by the environment, and the construction of a low-carbon economy has gradually become a popular research topic. As shown in Figure 2, some scholars have studied the operation mechanisms of the industrial chain and the sources of pollution from the perspective of the definition of the energy industrial chain. Others focused on the characteristics of the energy industry chain, such as the consumption structure, industrial structure, water resource consumption and the associated carbon emission.

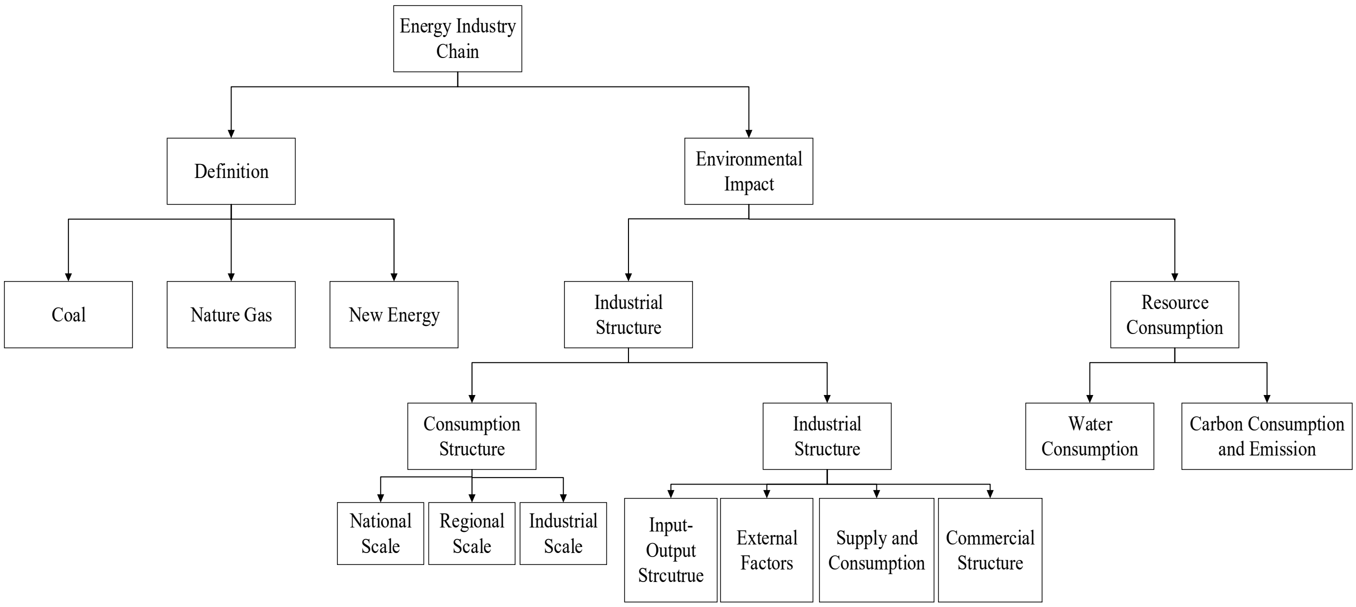

Figure 2. Structure of Study on Energy Industry Chain.

2.1. *The Definition of Energy Industry Chain*

The energy industry chain is a complex, giant system, which includes not only raw coal, crude oil, natural gas, hydropower, nuclear power and other related primary energy sources [3], but also the process of thermal power generation, heat production, the production of various petroleum products and coal-based products [4]. At present, the academic community has not yet formed a unified definition of the energy industry chain. Most researchers hold the view that the energy industry chain consists of energy suppliers (the upstream), energy production departments (the midstream), and energy sales and consumption departments (the downstream) [5–7].

As shown in Figure 3, the energy industry chain starts from energy and natural resources and ends in the energy consumption market, and has upstream and downstream relationships and value exchanges. The upstream supplier contains two functions: raw material acquisition and storage and transportation. The midstream producer contains two activities: production and storage and transportation. The downstream consumer has the activity of sale and use of energy resources. The upstream link delivers products or services to the downstream link, and the downstream link feeds back information to the upstream link, showing typical value attributes and structural attributes [8,9]. Therefore, most scholars focus on top-down or bottom-up single chain research when conducting research on the energy industry chain [10,11]. Currently, the academic research on the energy industry chain mainly focuses on the coal energy industry chain, the natural gas industry chain and the new energy industry chain.

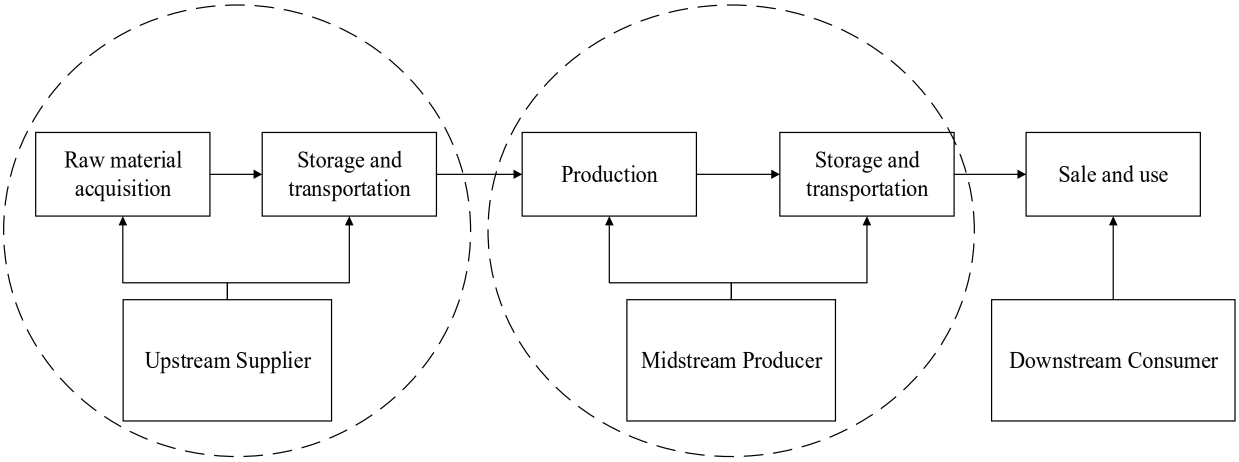

Figure 3. General framework of the energy industry chain.

2.1.1. Coal Energy Industry Chain

In the study of the coal energy industry chain, many researchers define the composition of the energy industry chain as coal production (power consumption), coal transportation (oil consumption, power consumption), power production (coal consumption, oil consumption), power transport (loss of power) and users (power consumption) [6,12,13]. Magazzino (2016) defines the energy industry chain as the 'coal, electricity and oil transportation' energy supply chain [14]. Wang (2019) further defines the multi-link input–output relationship between coal and electricity as the energy industry chain, and analyzes the impact of vertical integration of China's coal-electricity industrial chain on enterprise TFP [15]. Gao et al. (2012) define the energy industry chain as an industrial cluster formed by coal industry, thermal power industry, coal chemical industry and coal power chemical industry [16]. Zhu et al. (2020) further think it can be extended to the 'coal mining—thermal power generation—high load energy industry chain' and 'coal mining—coal chemical industry—building materials industry chain,' with coal as the upstream, and 'coal mining—thermal power generation—building materials industry chain' [17]. When considering low-carbon development mechanism, Bishan (2019) defines the coal energy industry chain as a single chain that includes coal suppliers, logistics providers, coal chemical industry manufacturers and product users, and applies the 0–1 integer programming method to establish the structure optimization model and analyze the low-carbon mechanism of the coal energy industry chain [18].

2.1.2. Natural Gas Industry Chain

Regarding the natural gas industry chain, many scholars define the natural gas industry chain as a top-down energy industry chain with three stages: upstream (natural gas supplier), midstream (infrastructure such as natural gas pipelines) and downstream (natural gas market dominated by industrial gas) [18–20]. Based on this definition, Liu et al. (2020) studies the current situation and market structure of the energy market at the two levels of the industrial chain and points out the development path for the gas and electricity industry to implement the vertical integration strategy [21]. Ma et al. (2022) present an optimization model of the natural gas industry chain that integrates natural gas producers, natural gas suppliers and pipeline network transportation in order to design a collaborative optimization scheme for the natural gas industry chain [22].

2.1.3. New Energy Industry Chain

Regarding the new energy industry chains, many scholars define new energy as clean and pollution-free alternative energies, such as solar energy, wind energy, biomass energy, geothermal energy and nuclear energy [22,23]. Based on this, Xu and Lin (2018) and Liu et al. (2019) point out that the new energy industry chain refers to the industrial chain of equipment manufacturing, application products and technical research and development services, derived from the development and utilization of non-traditional energy [24,25]. Han also summarizes that the new energy industry chain is a high-tech industry chain that realizes the industrialization of non-traditional energy, such as solar energy, geothermal energy, wind energy and ocean energy [26]. When studying marine renewable energy industry, Salem (2016) and Animah et al. (2022) regard solar energy, wind energy and other renewable energy industry chains as a single chain from top to bottom, and present the techno-economic feasibility evaluation model accordingly [27,28]. From the perspective of the industrial development stage, the new energy industry chain is an industrial chain formed by the transformation of new energy technology to productivity [5,28,29]. The development of the new energy industry chain is mainly divided into the following stages: Research and development stage; Technical demonstration stage; The initial stage of commercialization, that is, 'scale cost reduction' along the learning curve; and the stage of commercialization maturity, which is the stage of large-scale promotion [30].

2.2. The Environmental Impact of Energy Industry Chain

As for the research on the industrial structure of the energy industry chain, the existing research is mainly carried out considering the dimensions of the energy consumption structure and energy industry structure.

2.2.1. Energy Consumption Structure

Research of the energy consumption structure (ECS) mainly focuses on the proportion of primary energy consumption (such as coal, oil, natural gas, nuclear power and other renewable energy) relative to the total energy consumption [31–33]. Many scholars use correlation analysis to study relationships between energy industrial structure and economic growth, environmental emissions and other factors from the national scale, regional scale, and industrial scale.

Regarding the national scale, Feng et al. (2009) find that there exists a long-term equilibrium relationship among China's ECS, economic structure and energy intensity [34]. Based on this, Dong et al. (2017) further predict the future trajectory of China's ECS under multiple policy scenarios [35]. Zhang et al. (2011) and Wang et al. (2011) evaluate the development trend of Chinese ECS and find that ECS in China experienced only slow and limited improvement [36,37]. As a result, many researchers use different methods to optimize China's energy consumption structure. Sun et al. (2018) designs the ECS measurement model based on the data envelopment analysis (DEA) method to optimize China's ECS [38]. Zeng et al. (2021) propose 17 influencing factors that hinder the China's ECS based on historical data from 1980 to 2019, and employ the Copula function to develop an optimization model of ECS [39]. As for the study of foreign energy consumption structures, Lawrence et al. (2013) study the global probability distribution of global per capita energy consumption [40]. Sebri et al. (2014) examines the causal relationship between renewable ECS and trade openness in BRICS countries [41]. Combining empirical data from Italy, Magazzino et al. (2016) evaluates the bidirectional relationship between ECS, economic growth and carbon emissions [14]. The existing literature mainly focuses on the ECS of a single country and ignores the mutual influence of the ECS in multiple countries; therefore, the mechanism of global ECS needs further investigation.

As for the regional scale, Dong and Deng (2019) analyze the relationship between the diversification of ECS and regional haze pollution in the Yangtze River Economic Belt, and propose that the diversification of the gasoline and electricity consumption structure can help reduce regional air pollution [42]. Based on this, Xia et al. (2021) further constructed an extended LMDI model to examine the impact of regional ECS on regional industrial pollution emissions, and proved that improving regional ECS is the core driver to develop green economics and decrease regional pollution emissions [43]. Current studies have found that numerous regional factors have great impact on the regional ECS, such as regional population structure [44], regional economic growth and energy intensity [45];

regional GDP per capita and regional economic structure [46]; the level of regional green finance development [47] and the level of regional innovation [48].

Regarding the industrial scale, current research mainly focuses on industries with high energy consumption, such as the iron and steel industry. He and Wang (2017) provide a brief overview of energy use and consumption by the global steel industry [49]. For China's iron and steel industry, Peng et al. (2014) construct a prediction model to forecast the output and energy consumption [50], Chen et al. (2014) develop a system dynamics model and a bottom-up energy system model, TIMES (The Integrated MARKAL-EFOM System), to evaluate energy consumption and CO2 emissions from China's steel industry [51]. For iron and steel industry in foreign countries, Ansari and Seifi (2012) build a system dynamics model to assess steel demand, production and energy consumption in Iran [52]. Based on the industry sector energy efficiency modeling (ISEEM) modeling framework, Karali et al. (2014) develop a bottom-up model to compute the efficiency of energy consumption of iron and steel industry in U.S. [53]. The existing literature mainly analyzes industries with high energy consumption, but in the process of analysis, the analysis perspective is mainly based on the proportion of primary energy consumption; there is limited research on the proportion of renewable energy consumption.

The following table summarizes the main results of research and empirical studies in respect to ECS (Table 1). The results indicate that the development and utilization of new energy will help reduce carbon emission, optimize the energy consumption structure and achieve sustainable development.

Table 1. The results of empirical studies on ECS.

Article	Model	Data Used	Main Results	Optimization Approach
[38]	Fixed-sum input model and ECS assessment model	2016 China City Statistical Yearbook.	The development of a secondary industry greatly influences the ECS	Reduce high carbon energy and increase gas and oil consumption
[39]	Multi-factor dynamic support vector regression (MFD-SVR) model	1980 to 2019 China Statistical Yearbook" and "China Energy Statistical Yearbook"	The adjustment of energy prices, higher rural income can increase the consumption and reproduction of green products	Promote the development of clean energy
[40]	Cumulative Probability Distribution Function	1980–2010 U.S. Energy Information Administration (EIA)	Carbon emission from fossil fuel has great impact on global ECS	Reorient the global economy toward renewable energy
[41]	Vector error correction model	1971–2010 annual time series of real gross domestic product in BRICS countries over the period	The bi-directional Granger causality exists between economic growth and renewable energy consumption	Promote the development of renewable energy
[42]	Spatial econometric model	Panel data of 11 provinces in China from 2001–2015	The influence of energy consumption on haze pollution depends on the combined action of energy consumption scale and diversification of ECS	Promote the development and utilization of clean and new energy sources to optimize the ECS
[43]	Extended LMDI model	Panel data of China's 30 provinces from 1998 to 2017	Effect of FER, the reciprocal of industrial pollution control investment per unit GDP and economic development are the main factors leading to the change of national and regional ECS	Promote the development of renewable energy to optimize ECS
[45]	Complete decomposition model	The panel data of the gross domestic product (GDP) and the total energy consumption in 30 provinces in China	Economic growth has a significant driving effect on ECS	Promote China's economic growth transfer from the extensive growth mode of high input and high consumption to the low input and low consumption of the intensive growth pattern
[47]	System GMM model.	Data from 30 provinces (autonomous regions) except Tibet Autonomous Region from 2007 to 2017 from China Statistical Yearbook	The development of green finance is positively correlated with the ECS	Actively develop alternative energy and renewable energy to broaden the supply channels of green finance and promote the optimization of ECS
[48]	Coefficient panel model and a Hansen panel threshold model	Panel data of nine regions in China from 2005 to 2015	The marginal effect of regional innovation capability shows obvious heterogeneity when promoting the upgrading of ECS	Promote the utilization of renewable energy and innovation-driven development strategy
[50]	The whole life cycle model	1949–2010 China Steel Industry Statistical Yearbook Data	Energy saving technology and new energy technology can promote ECS and emission reduction in China's steel industry	Promote the production route adjustment, steel recyclability and technologies of energy conservation and emission reduction

2.2.2. Energy Industry Structure

Regarding energy industry structure, the academic community has carried out a series of research on the input-output structure, the impact of external factors on different energy industries, the dual structure of supply and consumption and the commercial structure of the energy industry. By using the energy input-output analysis, the energy flows according to processes of energy conversion and use [54,55], as well as energy inputs and consumption patterns [56,57], can be clearly evaluated. On the one hand, many scholars have found that energy efficiency is greatly affected by external factors in various industries, such as the public lighting industry [58], building energy service industry [58] and energy technology and engineering (ETE) industry [59]. On the other hand, numerous researchers have explored ways to achieve carbon emission reduction by studying the dual structure of supply and consumption in different industries, including the heating and power industries [60,61], transportation industry [62] and energy-intensive industries [63]. As for the commercial structure of the energy industry, the existing research mainly focuses on the business structure of the renewable energy industry. Aslani and Mohaghar (2013) study the seven core areas of business structure in renewable energy industry, such as the strategic area, resource area, technology area, feasibility analysis area, customer and market area, stakeholder area, and value creation area [7]. However, the internal relationship system between various primary energy and extended industries, and the sorting and quantitative analysis of the impact of these related structural characteristics on the ecological environment need further investigation.

2.2.3. Water Resource Consumption

For instance, Liu and Liu (2016) study the high-water consumption of coal coking, coal gasification and coal liquefaction industry and introduce new water saving methods in the coal chemical industry in order to solve the problem of high-water consumption in the coal chemical industry [64]. Vidic et al. (2013) systematically analyze the influence of shale gas development on regional water resource quality [65], Vengosh et al. (2014) further point out that with hydraulic fracturing becoming the main core technology for shale gas, water consumption and wastewater discharge have become a new research hotspot [66]. Xu et al. (2018) propose an integrated water and waste load allocation model to support the analysis of trade-offs between economic growth, resource utilization and environmental protection in the coal chemical industry [67]. Li et al. (2021) conduct a case study of water consumption in China's coal power industry in order to solve the problems of high water consumption and serious pollution by the coal chemical industry [68].

2.2.4. Carbon Emission

In the process of secondary energy production and the processing and conversion of various energy products, a large amount of energy is consumed and a large amount of carbon emissions are generated. Given the global concern regarding carbon emissions and environmental impact, the accounting of carbon emissions has become an important topic in the research of energy consumption. Based on the life-cycle analysis, Xia et al. (2010) and Xu (2013) propose an econometric evaluation model on carbon emission of China's coal-energy chain [69,70]. Yu et al. (2014) further estimate the influence of carbon emission on environment by computing the coefficient of carbon emissions in China's coal-to-energy chains [71]. Proietti et al. conclude that carbon footprint can be an improved indicator to assess the direct and indirect GHG emissions from a life-cycle perspective, and can be an effective tool for industry-chain planning [72]. Combining the life-cycle assessment and ASPEN Plus tool, Qin (2016) develops a hierarchical attribution management approach to calculate the carbon footprint of the coal-to-methanol chain [73]. Zhou et al. (2020) further construct a trinity resource utilization system of coal mining to promote the safe production and economic benefits of coal mines in China [74].

3. Energy Supply Chain

The energy supply chain is defined as a complicated network of production, supply, transport and storage interconnected through physical and financial infrastructure, information sharing and transmission [72,75,76]. As shown in Figure 4, the study of the energy supply chain can be divided into three aspects: the coordinated operation mechanism, the risk control and the impact of government policies. Currently, the coal–electricity energy supply chain is the core research area and improving the elasticity and resilience of the coal–electricity energy supply chain, as well as ensuring that its security and stability continue to attract industry, government and research experts in the energy field [77]. Most scholars discuss the solution techniques and optimization approaches of the energy supply chain from the following three aspects: the coordinated operation mechanism, the risk management and the intervention mechanism of government policies.

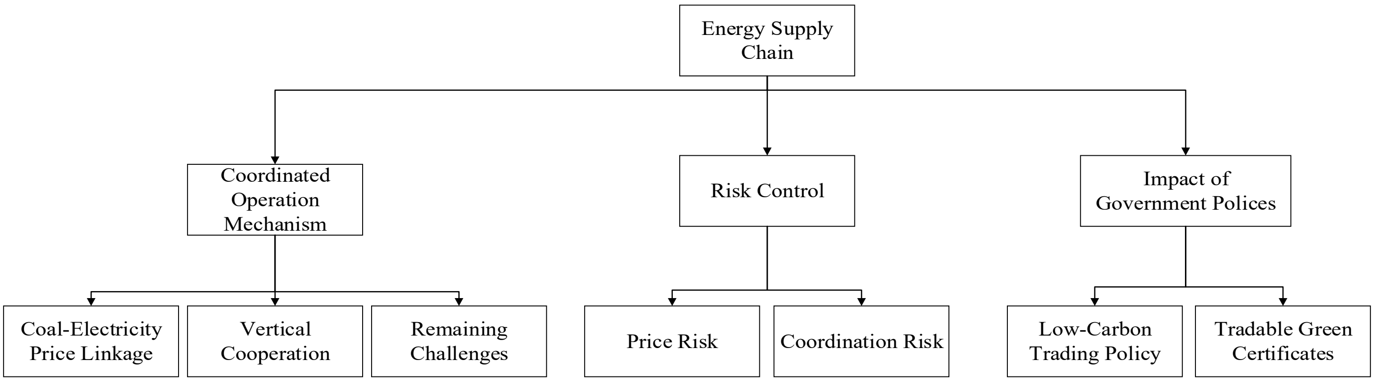

Figure 4. Structure of Study on Energy Supply Chain.

3.1. Coordinated Operation Mechanism of Energy Supply Chain

Currently, the coordinated operation of the supply chain plays an important role in promoting regional economic progress and reducing environmental pollution [78]. With the rapid development of the coal and electricity industries, the existing problems of environmental pollution, overcapacity and poor longitudinal coordination in the coal and electricity industries have become increasingly prominent, which makes promoting the coordination of the coal power energy supply chain become a new focus of social attention [79]. The existing literature mainly focuses on three aspects: the existing challenges, the coal–electricity price linkage mechanism and vertical cooperation of coal–electricity energy supply chain.

3.1.1. Coal–Electricity Price Linkage Mechanism

Regarding the coordinated operation mechanism of the energy supply chain, most of the existing literature focuses on the coal–electricity price linkage mechanism. The coal–electricity price linkage used to be the hotspot and focus of research. Many researchers have developed a series of simulated models, such as game model [80], computable general equilibrium models [81], Stackelberg game model [82] and complex supply chain networks model to establish the dynamic linkage of coal and electricity prices. It is also proven that the price transmission network model can help alleviate the serious contradiction between China's coal price marketization and national electricity price [83,84]. From the perspective of institutional design, the coal–electricity linkage mechanism can indeed reduce the profit loss of coal-fired power generation enterprises and improve business performance when the coal price is increasing [85]. However, the results of the empirical research conducted by Li et al. indicate that the amended scheme of coal–electricity price linkage is a double-edged sword [86]. On the one hand, due to the penalty on highly efficient power plants (over 90% efficiency), the coal–electricity price linkage mechanism will lead to the long-term occupation of the power generation market by low-efficiency power plants, which is not conducive to the development of high-efficiency power plants [87]. On the other hand, the coal–electricity price linkage mechanism has inherent defects such as lower government guide price [88] and cross-subsidies between general industrial and commercial electricity users [89] and large industrial and commercial electricity users. In the coal–electricity price linkage mechanism, the design of electricity prices is based on the electricity price in the downstream, rather than the coal price in the upstream [90]. Table 2 concludes the results of the main empirical studies on the coal–electricity price linkage mechanism.

Table 2. The results of empirical studies on coal–electricity price linkage mechanism.

Article	Model	Data Used	Aim of the Empirical Study	Main Results
[80]	Game model	Numerical study	The impact of the coal-electricity price linkage mechanism on the profit margin of the Chinese power generation company GENCO	The application of coal-electricity price linkage mechanism can reduce the decrease of GENCO's profit margin
[81]	Computable general equilibrium models	China's input–output table of 2005, China's Tax Yearbook 2006 and China's Fiscal Yearbook 2006	The impact of coal price adjustment on China's power industry and the Chinese macroeconomy	Rising coal prices lead to higher costs in the power industry, but the impact fades as coal prices rise
[82]	Stackelberg game model	Numerical study	Profit changes of two coal-electricity price linkage mechanisms caused by different production strategies of coal miners and coal-fired power plants when coal prices rise	Coal-electricity price linkage mechanisms helps reduce the profit losses of coal-fired power plants during periods of rising coal prices
[86]	The stochastic cost frontier models	20 listed coal-fired power plants during 2002–2011	The feasibility and fairness of 2012 amendment to coal-electricity pricing linkage policy in China	Coal-electricity pricing linkage policy encourages the development of less-efficient power plants but greatly hinder the development of highly-efficient power plants
[87]	The price linkage model based on the marginal utility price theory	Q5500 Thermal Coal Commercial Data in Shanxi province, China	Relationship between coal bed gas and coal price	The price linkage relationship exists between coal bed gas and coal price
[88]	The dynamic game analysis model	-	The impacts of different coal or thermal power prices on different markets	Introduction of energy consuming enterprise as the third party can effectively control the unhealthy competition between coal price and electricity price
[89]	Difference-in-differences model	Weekly data of coal price (yuan/ton) and crude oil price (dollar/barrel) from 13 October 2010 to 18 July 2018	Impact of coal sector's de-capacity policy on coal price	The coal sector's de-capacity policy has positive impact on coal price in 2013 and 2016. Furthermore, the impact of coal imports and overcapacity are also the main factors affecting coal prices

It is also found that the inherent defects and inadequate implementation of the coal–power linkage mechanism can led to the loss of the entire power industry [91]. Due to these shortcomings, the coal–electricity price linkage mechanism has lost the power and price basis for implementation and can only be a transitory step to electricity market-oriented reform [92]. As a result, the Chinese government finally decided to abolish the price linkage mechanism and introduce a market-based pricing mechanism in the coal and electricity market.

3.1.2. Vertical Cooperation of the Coal–Electricity Energy Supply Chain

There is limited research on the vertical cooperation and integration of the coal–electricity energy supply chain. Joskow (1985) firstly introduced the vertical integration into the coal–electricity energy supply chain [93], Wang et al. (2009) and Kirsch et al. (2013) design theoretical framework for vertical cooperation and value extension of the coal–electricity energy supply chain, they conclude that vertical cooperation can increase the overall benefits of supply chain members and that it is necessary to establish vertical cooperation alliances [94,95]. Sun et al. (2019) establishes a multiple-step multiple mediator model to evaluate the vertical cooperation mechanism in China's coal enterprise. The experimental results indicate that the establishment of vertical cooperation alliances is affected by various factors, such as market structure and policy regulations, and the impact of government regulations on the coal–electricity energy supply chain coordination needs further investigation [96,97].

3.1.3. The Remaining Challenges for the Energy Supply Chain

Coal and electricity are upstream and downstream associated enterprises. The coal produced by upstream coal production enterprises is supplied to downstream coal-fired power generation enterprises to generate electricity [15]. Therefore, the energy supply chain formed by the coal and electricity enterprises is a typical supply chain, and its coordinated operation can have great influence on national energy security and the sustainable development of the economy and society [98]. However, the coordinated operation of the coal power supply chain faces many challenges, such as coal power conflict, environmental pollution and new energy replacement.

Firstly, the coal–electricity conflict has drawn widespread concern. Especially in China, the conflict between market-driven coal prices and state-administered electricity prices has seriously restricted the sustainable development of China's economy [99] and has caused serious consequences, such as uncertainty in the quantity and quality of coal supplies and significant losses of electricity enterprises [100]. In China, the coal power conflict appears in the economic transition process from the planned economy to a market economy [101]. Due to the asymmetry of coal and electricity price reforms and the delay in the electricity marketization reform, when the coal market price fluctuates greatly, the electricity price cannot be adjusted accordingly, leading to the increased costs for coal suppliers and corresponding cyclical conflicts [100,101]. In order to alleviate the serious contradiction between China's coal market price and the state-administered electricity price, researchers have begun to establish cooperative relationships between coal suppliers and electricity utilities by developing Stackelberg game mode [102] or by investigating the price linkage mechanism [82,103].

Secondly, environmental pollution from the field of coal-fired power has drawn great attention. The energy supply chain of coal and electricity involves multiple links, such as coal mining, transportation and generation [104], and each link has a certain degree of pollution, especially in coal-fired power generation, which is one of the major sources of heavy metal pollution in soil [105] and air pollutants by the industrial sector [106]. Therefore, many researchers have begun to explore approaches to control environmental pollution from coal-fired power stations. Oetari et al. (2019) conduct a laboratory evaluation to identify the metal elements in fine and coarse particles from coal-fired power plants in Indonesia. Based on the experimental results, they suggest that air pollution control measures should be designed to manage trace elements associated with coal combustion, such as Na, BE and Sn [107]. Oliveira et al. (2019) apply advanced electron beam and X-ray diffraction techniques to classify the components of coal fires in Colombian coal mines. Based on the GAM model [108], Linnik et al. (2020) design a value approach for large-scale assessment of soil pollution levels and sources of heavy metal pollution [109].

Finally, the application and generation of renewable energy such as hydropower [110], solar power [111], wind power [112] and biomass power [113] has been increasing in recent years, which has posed a certain threat to coal-fired power generation. It is pointed out that coal-fired power generation faces the risk of squeezed market space and partial replacement [114], and an increasing number of countries will expand the production of non-fossil fuel energy [79].

3.2. Risk Control of Energy Supply Chain

Risk control of the energy supply chain mainly focuses on the following aspects: the price risk control, the risk control of supply and demand, the risk control of coordination and the risk control of environmental pollution [97]. As the coal–electricity energy supply chain is a comprehensive network with multiple links, multiple agents, multiple regions and multiple stages, risks to any link may spread to other upstream and downstream links, and even lead to the transmission and extension of chain risks, which can finally cause chain breakage [115]. In order to control the potential risk and prevent the expansion of risk loss, researchers conduct extensive studies on the risk transmission mechanism and risk control approaches, which can be summarized into two aspects: price risk control, and supply chain coordination risk control.

3.2.1. Price Risk Control and Management

Currently, the literature of price risk control and management mainly focus on two aspects: price risk assessment of coal transportation and risk identification and optimization of coal price and electricity price.

The factors affecting the price risk of coal transportation can be divided into the following categories: fuel cost, railway construction cost, external economic cost and environmental cost [116–118]. To analyze the relationship between coal transportation cost and power generation price, and to minimize the price risk in coal transportation, many researchers have developed different coal transportation models, such as the demand-responsive decision support system model [119] and the life cycle greenhouse gas emissions calculation model [116,120].

As for the risk identification of coal price and electricity price, Sadeghi et al. (2006) identify several factors, including time, market conditions and underlying price, that can significantly impact the value of energy transaction [121]. Based on the Bayesian-SV-SGT approach, Chai et al. (2011) conduct the analysis of the risk characteristics of crude oil price fluctuations [122], which can be a reasonable reference for the field of coal and electricity price risk assessment. He et al. (2013) develop a comprehensive electricity price risk assessment model to identify the key risk factors of coal and electricity price. They classify the risk factors into the following categories: regulation policy, market economic, management, development of technology and price of alternative energy [91].

Regarding risk management and optimization of coal price and electricity price, many researchers have carried out modeling research on the risk management and control of the coal–electricity energy supply chain from the risk source level. Wan and Ren (2012) design a Higgins-based risk assessment model and evaluate the resources risk, asset investment risk and inventory risk for the coal and electricity markets [123]. By applying the Monte Carlo simulation method, Boonchuay and Ongsakul (2011) propose an optimal risk bidding model to control and minimize the risk of coal price and electricity price [124]. By combining physical tools of long-term risk management (spot contracts, forward contracts) and financial derivatives (options contracts), Azevedo et al. (2010) establish a price risk optimization framework for electricity generation enterprises to handle price fluctuations [125]. Arnesano et al. (2012) proposes a Nlack–Litterman-based computation model to quantitatively analyze energy production structure and the price risk in Italian energy markets [126]. Gökgöz and Atmaca (2012) design an optimal portfolio to minimize the spot price risks for electricity generation enterprises [127]. Kazempour and Moghaddam (2011) establish the non-linear profit optimization model to estimate the price risks in the electric energy market, reserve market and fuel market [128].

3.2.2. The Coordination Risk Control in Energy Supply Chain

The coordination of risk control of the internal development, transmission and distribution links has an important impact on the control of the overall coordination risk of the coal power energy supply chain. The coordination risk of the coal power energy supply chain mainly exists in the following links: the coordination of power generation and power grid transmission, and the coordination of electricity grid operation and energy user consumption [129]. The insufficient and excessive output of these links may lead to the disruption of the entire supply chain. Therefore, the academic community has carried out extensive research on the above-mentioned links.

Effective coordination between electricity generation, transmission and distribution is conducive to improving the safety, economic and environmental benefits of the entire energy supply chain. Huang et al. (2011) study the grid corporation's cooperative bidding mechanism based on carbon emission reduction scheduling. They conclude that the cooperative bidding mechanism can reduce the coordination risk and promote the stable supply of the electricity market [130]. Zhang et al. (2011) design a single-stage deterministic mode to conduct a game-theoretic analysis of generation and transmission expansion planning [131]. Alizadeh and Jadid (2015) propose a mixed integer nonlinear model to investigate the coordination between generation system expansion and transmission system expansion [132]. Nemati et al. (2018) develop a static model for coordinated generation and transmission expansion planning to mitigate the coordination risk and to reduce the vulnerability of electricity generation system against physical deliberate attacks at the coordination level [133]. Regarding the coordination risk in wind power generation, Zhang et al. (2016) construct a source–grid–load coordination planning model to mitigate the risk of system coordination and to improve the wind power integration capability [134]. Considering the uncertainty of wind generation plants, Hemmati et al. (2016) investigate the risk mitigation approaches in coordinating generation expansion planning and transmission expansion planning [135].

As for the coordination risk for electricity grid operation and energy user consumption, different modes of power grid operation and user energy consumption will have a significant impact on electricity consumption and coal consumption, which, in turn, will affect the demand and supply of coal, and bring certain risks to the coal production and supply links in the coal–electricity energy supply chain. As a result, many researchers have carried out extensive studies to investigate the relationship between coal consumption and the operation mode of the power grid and power consumption. On the one hand, the influence of the power grid link on coal consumption is reflected in the line loss of the power grid; the change of line loss is directly expressed as the power loss of the transmission link, and the change of transmission power loss can be directly converted into power generation coal consumption. Reduction of line loss in the electricity grid is a direct approach to mitigate coordination risk and to improve energy efficiency [136,137]. On the other hand, the changes in user energy consumption patterns will significantly affect the efficiency of energy conservation and coal consumption. Steenhof (2006) compares the changes in the energy consumption intensity of coal, electricity and oil in China, and concludes that the electricity consumption intensity has the greatest impact on the coordination risk of energy consumption [138]. Bannai et al. (2007) establish a financial derivative mathematical model to control the coordination risk from the perspective of energy users [139]. Tan et al. (2009) construct a coal-saving analysis model to study the impact of implementing the time-of-use electricity price. The simulated results indicate that the application of time-of-use electricity pricing will change the time distribution of the power load, and thus, mitigate the coordination risks in energy user consumption and promote coal consumption efficiency in power generation [140].

3.3. The Impact of Government Policies on Energy Supply Chain

The energy supply chain, especially the coal–electricity and renewable energy supply chain involves numerous types of enterprises. Therefore, the operation and management of the energy supply chain are greatly influenced by government policies. The existing literature mainly focuses on the influence of two polices: the low-carbon trading policy and the renewable energy policy.

3.3.1. Impact of Low-Carbon Trading Policy

The primary goal of the low-carbon policy is to reduce greenhouse gas emissions and achieve sustainable development [141]. The object of the low-carbon trading policy is to control carbon emission by constructing a carbon emission trading pricing mechanism [142]. It an effective market-based mechanism for controlling pollutant emissions [143]. Du et al. (2017) and Zhang et al. (2020) both establish the Stackelberg game model to analyze the trade-off mechanism and resource allocation between retailer and manufacture under the low-carbon trading policy. The simulated results indicate that the low-carbon trading policy can help establish a coordination channel and can be an effective tool to achieve a low-carbon economy [144,145]. Duan et al. (2018) evaluate the CO_2 marginal abatement costs of three important industries in 30 provinces in China under the low-carbon trading policy [146]. Qi et al. (2021) further expand the industries range to 33 major industries in China's provinces and construct a Difference-in-Difference-in-Difference (DDD) model to conduct empirical analysis of a low-carbon trading pilot policy. Their results prove that a low-carbon trading policy can improve the development of low-carbon technologies and increase the international competitiveness of major industries [147,148].

3.3.2. Impact of Renewable Energy Policy

Regarding renewable energy policy, scholars mainly carry out research on the tradable green certificates (TGC) mechanism. The TGC framework, originated in Netherlands, is a new, market-based, cost-efficient and technology-neutral policy framework intended to stimulate investment in renewable electricity [149,150]. It is the main carrier for market transaction of renewable energy electricity consumption [151]. Currently, European scholars mainly evaluate TGC performance from two aspects: the economics of investment and the design of TGC systems [149]. Studies by Ericsson et al. (2011) and Darmani et al. (2014) indicate that TGC systems can effectively improve the profitability of renewable energy and investment in renewable energy resources [152,153]. Additionally, TGC schemes are technology-neutral [154], indicating that all corresponding renewable energy technologies can obtain the same level of subsidies from government, which stimulate investment in renewable energy [155]. However, some scholars also point out that the uncertainty of fluctuation of certificated price within TGC schemes can hinder renewable energy profitability [156]. As for the design of TGC systems, Jaraitė and Kažukauskas (2013) compare the impact of two different renewable electricity promotion systems (TGC and Feed-in-Tariffs) on the profitability of European electricity production departments and verify that the technology-neutral design of the TGC system can bring additional income to the production sectors [157]. Raadal et al. (2012) further estimate the coordination mechanism between the Quota system and TGC, and prove that the Quota system can be a support mechanism to generate customer-driven demand for renewable electricity [158–160]. In China, Chinese scholars mainly explore the effectiveness and improvement methods of TGC system from three dimensions: the trading mechanism [161–164], the pricing mechanism [165–168] and the impact on new energy enterprise [13,169,170]. The above research mainly considers the influence of TGC on the electricity market equilibrium. However, there are few studies on the policy of renewable energy electricity sales guarantee mechanisms.

4. Conclusions and Recommendations

With the accelerating rate of global warming and climate change, it is of great significance to pay attention to the environmental impact of the energy industry chain and supply chain to achieve sustainable development of the energy economy. Based on the existing research on the energy industry chain and its associated environmental impact, this paper reviews the definition and structure of the traditional energy industry chain (especially coal and natural gas) and the renewable energy industry chain, and discusses the coupling relationship between multi-dimensional regional resource consumption and environmental impact factor. Regarding the energy supply chain, this paper evaluates the impact mechanisms of coordinated operation, discusses the risk transmission mechanism and risk control approaches and estimates the implementation of a low-carbon trading policy and renewable energy policy.

By reviewing and summarizing the literature related to the energy and environmental impact of the industry chain and supply chain, this study presents the following four main findings:

First, extensive research has proven that developing new energy can reduce the dependence on coal and oil, improve the energy consumption structure and resource consumption and achieve sustainable energy production and utilization. Currently, the model algorithm of the energy consumption structure and energy industry structure has been improved, and the existing model can describe the characteristics of the energy consumption structure. However, the environmental factors that influence the energy consumption structure are diverse and random, and there are limited studies on the measurement of combination of multiple environmental indicators, which might contribute to large errors in the evaluation results. In addition, due to the obvious differences in energy structures, production technology and environmental regulation among different economic entities, scant research has been conducted on the combination of energy production structures and regional integration. The impact mechanisms of regional segmentation on new energy consumption structures, new energy production structures and energy industry structures still need to be further explored. Emerging technologies, such as Industrial Big Data's estimation, ecological input–output evaluation and artificial neural network, can be introduced in future studies of renewable energy application. The regional and industrial heterogeneity of the energy industry chain warrants further exploration in future studies.

Second, regarding the study of coordinated operation mechanisms, most studies focus on the coal–electricity price linkage mechanism, and limited research has been conducted on the vertical cooperation mechanism and the mechanism of information communication among coal production enterprises, electricity production enterprises and transportation parties. Moreover, effective logistics management also plays a significant part in the coordinated operation of the energy supply chain, which also lacks in-depth theoretical and quantitative model research. A simulated model still needs to be developed to evaluate the market conditions, income distribution and percentage of increased new income under the cooperation of coal and electricity parties. Furthermore, when implementing vertical integration projects, local governments and energy producers need to consider the choice of cooperation strategies and the influence of changes in market conditions on relevant policies; there is still a gap in the research on the above aspects.

Third, in the study of risk control, the majority of studies focus on the risk control of single risk and several risks within a single link in the coal-power energy supply chain, and limited research has been conducted on evaluating the coordination risk assessment of various links among the energy supply chain. Complex influencing mechanisms exist among coal production, coal transportation, power grid structure, power grid distribution and consumer demand in the coal power supply chain. Especially in China, due to its special market conditions and policy regulation system, the coordination risk problems of coal production, coal transportation, electric power production, electric power transportation, industrial electricity supply chain and other links are more complex than in other countries. The targeted research from domestic and foreign research literature on risk expansion and the transmission mechanism in China are limited and need to be systematically studied by scholars. Therefore, in future research, it will be necessary to put forward research progress on the comprehensive risk control of the coal-power energy supply chain so as to provide empirical analysis on the application of renewable energy with respect to the market in China.

Fourth, in the study of the intervention of government policies, it is proven that the low-carbon trading policy and tradable green certificates policy can optimize the structure of the electricity generation market, protect resources and the environment, improve the coordinated operation efficiency of the energy supply chain, promote the progress of sustainable energy transition and meet the national strategic requirements of adjusting economic structure. However, currently, limited research has been conducted on the evaluation of theoretical and mathematical analysis of vertical decision-making, cooperative revenue calculation and revenue distribution of a renewable energy policy. Regarding empirical research, there are a limited number of studies on the influence mechanism and coupling effect of green certificate trading on the electricity market, which needs further investigation.

The findings of this study are helpful for policy makers to promote sustainable development strategies and relevant enterprise managers to promote the development and utilization of new energy. Based on the analytical results, several managerial recommendations have been presented for policy makers and industry managers. For policy makers, it is recommended to implement market-oriented policies for the development of the energy industry, formulate coordinated industrial development plans, improve the coordination and implementation capacity of the government, strengthen inter-regional development cooperation, establish a mutually beneficial mechanism, strictly restrain energy-intensive enterprises and jointly develop resource-saving industries in order to improve energy efficiency and reduce energy consumption. For the managers of manufacturing enterprises and power generation enterprises, it is suggested to establish the development concept of green, low carbon, energy saving and environmental protection when planning enterprise development. At the same time, it is suggested to strengthen the research and development and application of renewable energy resources and green and clean technologies, accelerate the elimination of backward polluting production technologies, shift the production mode of blind expansion, high pollution and high consumption, and successfully transform the production mode to one of high efficiency, resource saving and pollution reduction. Moreover, it is recommended to develop technological innovation to encourage the utilization of renewable energy, as well as to develop a coordinated regulatory mechanism to control the pollution emissions and reduce the impact of environmental pollution.

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