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Sustainable Development of Power Retailers and Industrial Parks in China's Belt and Road Initiative

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Abstract: Energy infrastructure construction is a top priority and focus for the Belt and Road Initiative (BRI), and this drives dramatical demand for significant energy consumption growth and investment funds in BRI countries. In response, the concept of a regional power grid of an industrial park (RPGIP) has emerged as a new energy infrastructure, where the industrial power supply, load, and grid are integrated to form a balanced and independent regional power grid. Moreover, dramatically increased market competition on the retail side of the electricity market challenges developing countries striving to achieve sustainable development of power retailers. This paper proposes that power retailers transform into energy saving companies (ESCOs) to participate in the electricity management of an RPGIP. By using a financing scheme realized by asset securitization, power retailers can smoothly participate in the construction and operation of a power system of BRI that contributes to accelerating energy infrastructure construction, the electricity management of the RPGIP, and sustainable development of power retailers in BRI countries. Furthermore, this study provides a game analysis for achieving maximum benefits of power retailers and industrial consumers in the implementation of the financing scheme.

Keywords: Belt and Road Initiative; power retailer; regional power grid of industrial park; asset securitization; game analysis

1. Introduction

Effective energy utilization is a key to driving economic development as the power industry rapidly develops. The United States Energy Information Administration indicates that world energy consumption will grow by 52% from 2010 to 2040 [1]. The energy use in developing countries was 16% higher than that in developed countries in 2010, and developing countries are likely to consume 88% more energy than developed countries by 2040 [2]. The "Belt and Road Initiative" (BRI) is a strategic plan proposed by China, greatly contributing to the prosperity and development of BRI countries [3,4]. For developing countries along China's Belt and Road Initiative (BRI), the industry sector is the main consumer of electric power and energy resources. However, it is difficult to achieve effective energy utilization in developing countries, and these countries have high carbon emissions and low energy efficiency [5]. For example, insufficient energy utilization, such as low utilization of thermal power equipment and a large amount of wasted renewable energy, has resulted in thermal power overcapacity in China [6]. In India, due to ongoing theft, corruption, and an artificially depressed pricing structure, the private sector is expected to make a full and positive competition in the electricity market [7]. An insufficient national power infrastructure has resulted in limited transmission lines in Mexico [8]. Thus, the private sector has been encouraged by the government to participate in the power industry to help unbundle generation, transmission, and distribution services, which is desirable from a governmental perspective in terms of deregulated electricity markets, renewable energy sources integration, and promotion of power utilization efficiency [9,10].

An industrial park plays a main role in economic and energy development [11], and reasonable use of an industrial park is key to developing the energy infrastructure and improving energy utilization efficiency. A regional power grid of an industrial park (RPGIP) can effectively integrate both energy resources and local industrial *prosumers*—entities that both produce and consume energy. An RPGIP is a balanced and independent regional power grid composed of an integrated power supply, load, and grid. The Chinese government has launched a pilot project of an RPGIP in Shanxi province to demonstrate how an independent regional power grid works [12]. Similarly, a novel conceptual architecture, which can efficiently integrate agents, such as generators, consumers, and storage, is raised to effectively use renewable energy and distributed energy resources [13]. To effectively and efficiently integrate prosumers into competitive electricity markets is a strategic challenge for both policymakers and planners [14]. Although active distribution networks facilitate energy resources use, local generation, and consumption, it is difficult to effectively manage numerous industrial prosumers [15]. Additionally, the construction of an industrial park needs substantial funds and a stable power grid, which is the main challenge to investors and managers in BRI countries.

The electric power industry is gradually evolving toward marketization, where power retailers make buy and sell bids to conduct power trading more smoothly and effectively. Private investors, local government investors, and foreign investors are encouraged by many governments to invest in electric power generation plants in BRI countries, and this has improved efficiency in electricity markets significantly. For instance, efficient market operation enables Germany's balanced power market to utilize traditional energy and renewable energy effectively [16]. The Chinese government has released Relative Policies on Deepening the Reform of Power Industry (No. 9 Document), further improving marketization [17], and Vision and Actions on Jointly Building Silk Road Economic Belt and 21st-Century Maritime Silk Road [18] that emphasizes the significance of cooperation in the connectivity of energy infrastructure and an integrated industrial chain of energy and resource cooperation. Since then, power retailers have been able to offer customized electricity services regarding energy efficiency to customers [19,20]. Before the electricity market reform, there was no motivation in the monopolized electricity market to conduct energy efficiency programs for electricity consumers [21]. Nevertheless, an appropriate market and investment mechanism is urgently required due to various risks resulted by electric power investments [22]. The West Bengal state government of India pursues electricity liberalization to improve efficiency of the power industry [23]. Developed countries like Germany, which have established a proper market mechanism, have achieved a high efficiency trading system of the power market so effectively that they not only reap economic benefits, but also establish sustainable development in the electrical power system [24,25]. Development of electric power markets in developed countries provides valuable experiences to draw from for development and establishment of electricity markets in developing countries. For BRI countries, using diversified financial services and instruments is a sustainable means to develop their electricity markets towards marketization.

In electricity markets, the power retailer plays the role of an energy resource agent that negotiates with power suppliers on behalf of power consumers. Given an RPGIP mechanism properly designed by power retailers, more consumers can be attracted to participate in an industrial park project. Power retailer involvement in the electricity market means the private sector is encouraged by governments to enter the market. Furthermore, power retailers provide advanced metering data for consumers and ensure power trading more efficiently [26]. As the retail side of the electricity market develops, market competition, external influence, and service quality enhances simultaneously. However, for a certain number of developing countries, the liberalization of the electricity market faces influences from the public sector and fails to meet expectations [23,27–29]. In the realistic expectation of the electricity market reform, the desirable function of power retailers is expected to reduce the electricity price of power suppliers and the electricity cost of consumers, to prevent the monopolization of grid enterprises, and to achieve the marketization in the power industry. However, in practice, the power retailer lacks rationality to obtain economic benefits from the electricity price differences between consumers and power suppliers. As a result, operation and power consumption efficiency of the electricity market are not improved as effectively as the expectation.

Asset securitization, an advanced financing method, draws great attention from countries all over the world. Substantial overseas experience has proven that asset securitization works well when applied to the electric power industry. Asset securitization leases and power purchase agreements can significantly raise capital while reducing project financing costs and risks [30]. Securitization of solar assets is a viable low-cost financing mechanism to improve the financing efficiency of solar photovoltaic (PV) projects [31]. As a vast majority of power companies and customers enter into long-term contracts, the huge economic benefit of asset securitization has increasingly attracted more attention of the power companies [32]. Hyde and Komor [33] pointed out that securitization not only reduces financing costs for distributed solar PV, but also acts as a market-based means to supplement the lack of policy. Therefore, the promotion of asset securitization deserves more promotion by governments and to be used in more industries, which demonstrates the future development of the electricity market. Thus, asset securitization can be applied as a financing method to construct RPGIP in order to avoid financing costs and risks, which accelerates the construction of energy infrastructure in BRI countries.

Since the private sector is encouraged to participate in the power industry, and marketization of the power industry develops rapidly, it is desirable to design a new financing scheme that improves the sustainable and diversified development of the industry and BRI. Furthermore, the power retailer and RPGIP require more specific methods to achieve long-term development. The main contributions of this paper can be summarized as follows:

- We identify the main factors that have resulted in the development dilemma and constraint of power retailers in this emerging market.
- We design a new financing scheme to construct a regional power grid financed by asset securitization, and present the development of asset securitization. Based on asset securitization, the construction of RPGIP in BRI countries can be accelerated, and the power retailer established by either the private or public sector can participate in electricity management of the RPGIP. According to the financing scheme, the power retailer can transform into an energy service company (ESCO), which effectively enhances the utilization efficiency of electric power and energy resources, and promotes sustainable development of the power retailer and the RPGIP in BRI countries.
- We provide a game analysis of the proposed financing scheme. It provides the method how to achieve the maximum benefit of power retailers and industrial consumers in the RPGIP project.

The organization of the paper is as follows: Section 2 describes the current status of marketization in China's power industry. Section 3 presents the process of power retailers to establish a RPGIP financed by asset securitization and participate in the electricity management of RPGIP in BRI countries. Section 4 illustrates the game analysis related to the economic benefits of industrial consumers and power retailers. Section 5 provides conclusions.

2. Current Status of Marketization in China's Power Industry

As the "No. 9 Document" released in 2015 discusses, a new round of reform has taken place in China to improve marketization of the electricity market [34]. The document is a valuable reference, worthy of some deep analysis by developing countries. Additionally, the rapid expansion of financial markets in China represents an inevitable trend of cooperation in the electricity market and the financial market. In light of local power generation, power retailers sell electricity as a product from the generation side to end-use consumers. As power retailers participated in the electricity market, the electricity traded in China's electricity market exceeded 10,000 terawatt-hours (TWh) in 2016. The average price per kilowatt-hour (kWh) decreased to 0.0723 CNY, saving consumers more than 57.3 billion CNY. The electricity traded on the market in the State Grid Corporation of China area increased by 58.8% in 2016. However, as more power retailers are established, market competition increases dramatically. As a result, many power retailers have no ability to gain market share, due to the fierce market competition.

Figure 1 shows that there were 3512 power retailers established by the end of 2016. It also shows the distribution of power generation and power retailers in eight regions, based on the division of geographical regions. In general, power retailers are mainly located in regions that have more power generation, such as the Southwestern region, the Eastern region, a part of the Southern region next to the Eastern region, and a part of the Northern region next to the Central region. Illogically, a number of power retailers were established in some provinces or cities where there are neither rich power generation resources nor a large power consumption demand. Figure 2 illustrates the distribution proportions of power generation and power consumption, as well as the number of power retailers in each province or city in China. It also shows that the distribution of power retailers is far more than the distribution of power generation and consumption in 15 provinces or cities (Anhui in the Eastern region; Guangdong and Hainan in the Southern region; Hunan in the Central region; Beijing, Tianjin, Hebei, and Shanxi in the Northern region; Qinghai, Shaanxi, and Gansu in the Northwestern region; Sichuan, Yunnan, and Chongqing in the Southwestern region; and Jilin in the Northeastern region), especially in the Northern region (Beijing, Tianjin, Hebei, and Shanxi) and the Southwestern region (Sichuan and Yunnan). This means that a certain amount of power retailers lack a sustainable development strategy and face an over-competition in the electricity market. For example, there are more than 8% (286) of China's power retailers in Hebei province; however, Hebei province accounts for only 4.53% (2617 TWh) of the total power generation and 5.46% (3265 TWh) of the total power consumption in China, which means that the amount of power retailers fails to match Hebei's power generation and power consumption. Furthermore, the State Grid Corporation of China, China Southern Power Grid, and five other large generation enterprises can also participate in the electricity market as power retailers, which threatens the development of other comparatively small-scale power retailers. Addressing the development dilemma and constraint of power retailers is crucial for marketization in China's power industry. Therefore, power retailers need to consider future development and improve their competitiveness in the electric power industry.

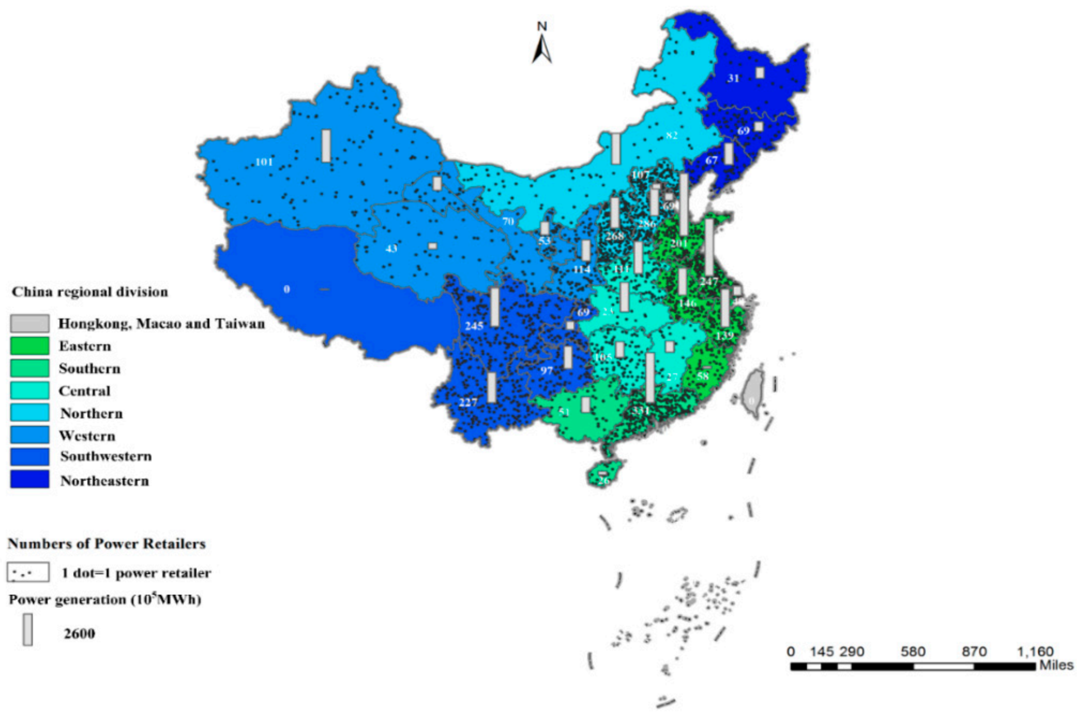

Figure 1. Distribution of power retailers and power generation in China in 2016. Data source: http://shoudian.bjx.com.cn/news/20161216/797415-2.shtml; China Electricity Council (2016).

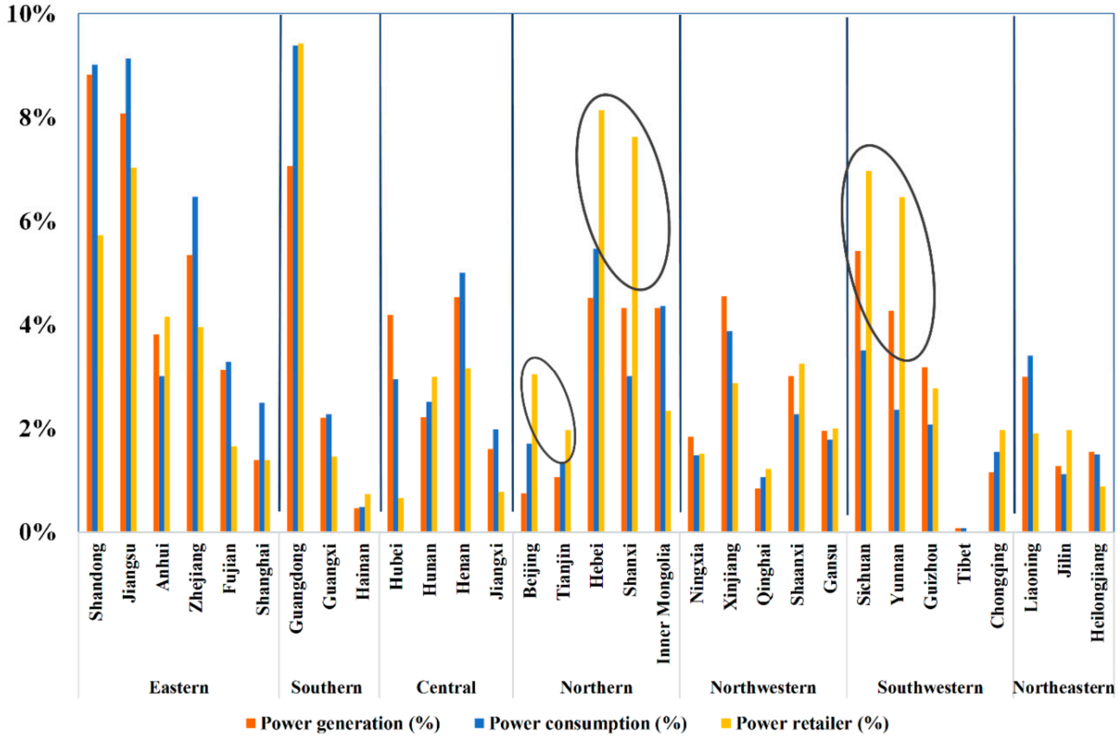

Figure 2. Comparison among the distribution proportions of China's power generation, power consumption, and numbers of power retailers in its Eastern, Southern, Central, Northern, Northwestern, Southwestern, and Northeastern regions in 2016. Data source: China Electricity Council (2016); http://shoudian.bjx.com.cn/news/20161216/797415-2.shtml.

3. Methods

3.1. Asset Aecuritization in Developing Countries

In the 1990s, asset securitization was designed to be a reliable financing method in the United States. It isolates a part of favorable assets, which brings stable future cash flow but lacks liquidity, from a financial institution or corporation. A Special Purpose Vehicle (SPV), an independent financial institution established to raise funds, accepts the favorable assets transferred from the original owner. It is used in a large number of public–private partnership projects to raise funds [35,36], and it plays an essential role in the process of asset securitization. Governments of developing countries value the development of asset securitization and support the participation of SPVs in various industries [28–30]. In late 1998, Pemex Finance Ltd. started to finance capital expenditures as an SPV in Mexico. The Chinese government mentions that proper financial methods can effectively accelerate the development of the BRI. In December 2016, asset-backed note guidelines of the National Association of Financial Market Institutional Investors added SPV as a financing vehicle in China, as a means of asset securitization that has strong government support.

Asset securitization is an effective financing method to utilize financial assets, improve funds utilization efficiency, and avoid credit risks. Although the development of asset securitization is strongly supported by governments, there are few studies regarding asset securitization in the energy industry. Thus, this study focuses on using asset securitization in the energy industry. Figure 3 shows the asset securitization financing process. The first step in the process of asset securitization is to prepare an asset pool, which is the future cash flow produced by a project over a certain period. Subsequently, the originator sells this asset pool to an SPV that is in charge of issuing the securities to obtain funds from a security market and transfers the funds to an originator. Additionally, the asset pool implements credit enhancement granted by a guarantee company and pursues a higher credit rating than that assigned by a rating agency in the financing process. The whole security issuance process is regulated by a supervisory department.

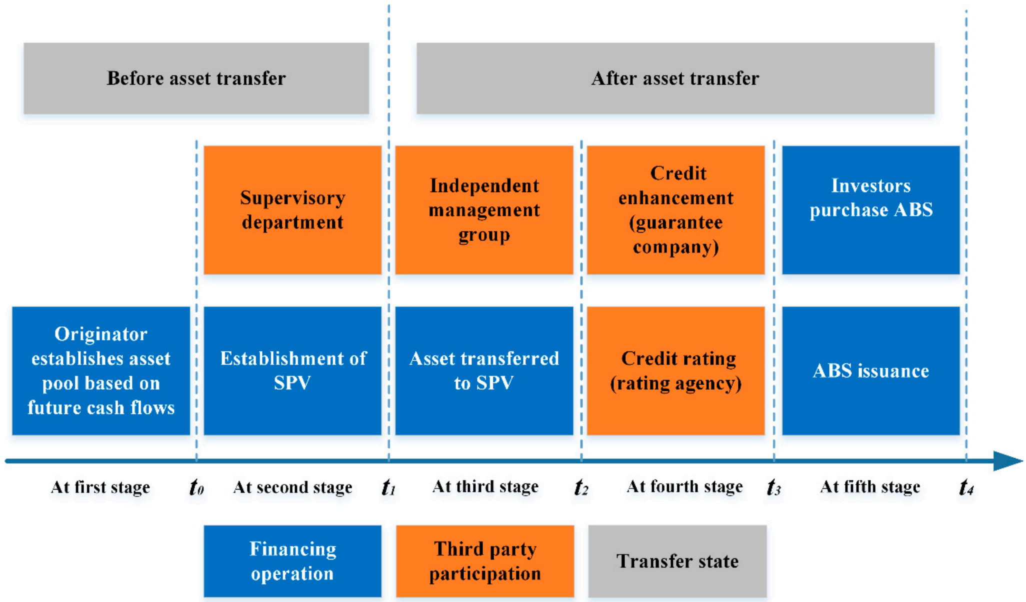

Figure 3. The asset securitization financing process.

3.2. Electricity Asset Securitization

Although industrial parks, which are significant energy infrastructure projects on the BRI, facilitate the use of energy resources, local generation, consumption, and management of numerous industrial prosumers (entities that both produce and consume energy) with different requirements is challenging. Besides, as increasingly more power retailers participate, market competition among them increases. Owing to the fierce business competition, power retailers must consider a sustainable development of the electricity market. An energy service company (ESCO) is a company that provides advanced energy efficiency-related services, and for which energy saving performance contracting (ESPC) is a core offering of its energy efficiency services business. In an energy saving performance contract, the ESCO guarantees energy savings, and obtains revenue by mitigating customers' unpredictable risks [37]. The BRI countries urgently need energy efficiency and low-carbon technologies to develop their power industries [38], which could be realized by ESCOs. If the functions of power retailers and ESCOs can be combined to use in the power industry, the marketization in power industry and energy resource utilization efficiency of industrial park could be improved dramatically. For developing countries, a government grant is a main financing method for an energy infrastructure project to access funds. Most energy projects have relied greatly on the investment of public sectors, which results in a shortage of capital and other financial problems of governments [39]. A public–private partnership (PPP) is another financing method used in the power industry. According to the cooperation between the private investor and the government, the energy infrastructure project construction could be effectively accelerated. However, a bunch of failed PPP cases shows that many risks need to be addressed and more policy support is required to construct a successful PPP energy project [40,41]. Compared to other financing methods, asset securitization could significantly reduce project risks and financial burdens of governments. Therefore, this paper proposes a financing scheme to obtain funds and other benefits based on asset securitization. It primarily aims at achieving sustainable development of power retailers, accelerating the construction of an RPGIP, and promoting marketization of the electric power industry in BRI countries. As shown in Figure 4, the industrial consumer and the power retailer sign long-term electricity contracts. The power retailer sells the long-term electricity contract to an SPV as a kind of transferable asset. Then, the SPV issues an asset-backed security (ABS) supported by the long-term electricity contract to investors on a power exchange. While these investors receive interest periodically, the SPV transfers the funds from security investors to power retailers. Supervisory departments supervise the series of financial operations. The advantage of financing by the asset securitization method is that it eliminates the financing constraint of the originator. The transferred assets can receive a higher credit rating, so that the credit ceiling is broken, and the financing cost is reduced by asset securitization. Moreover, since the asset is transferred to the SPV, it no longer belongs to the originator, even in the case of bankruptcy. This sort of transfer is called a "true sale" in general. Furthermore, if the power retailer goes bankrupt, the creditor cannot pursue the future cash flow produced by the long-term electricity contract. This method demonstrates that the rights and interests of investors can be entirely protected. In summary, asset securitization protects the independence and security of financing.

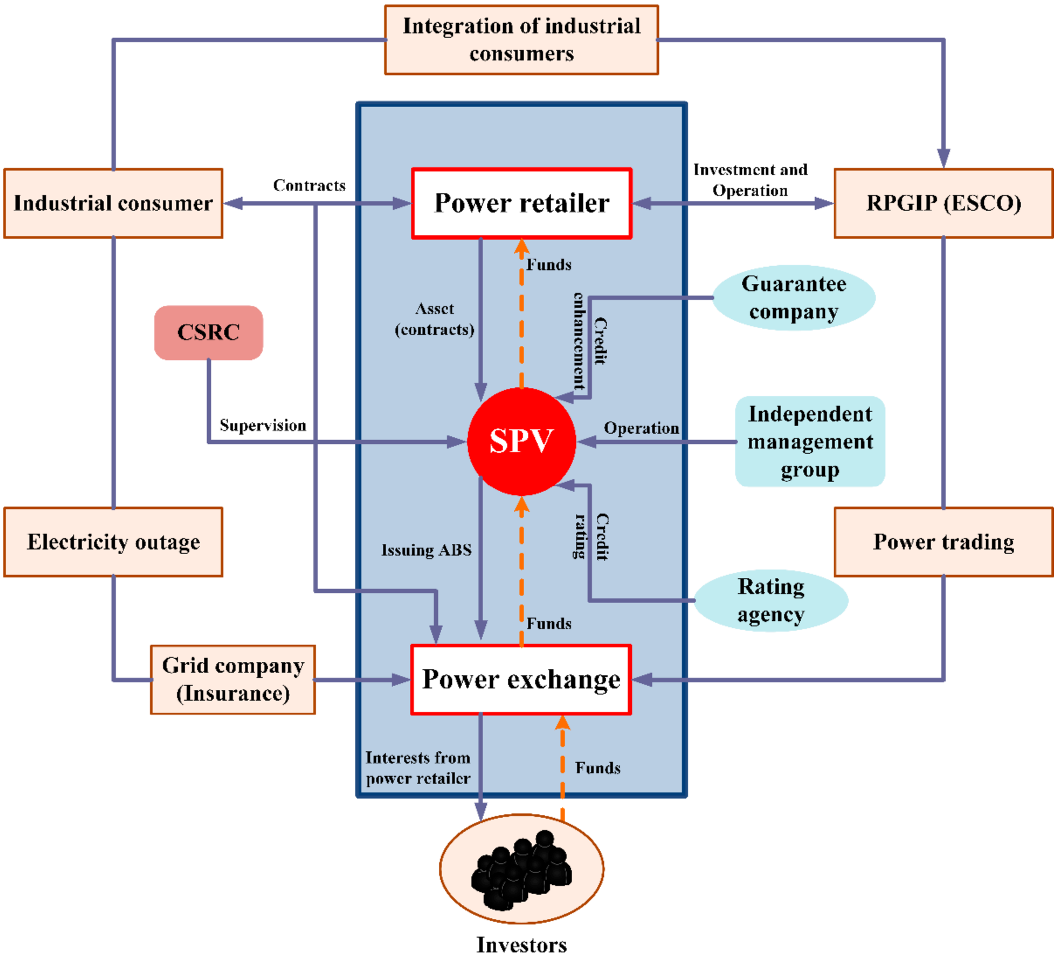

Figure 4. Financing scheme based on asset securitization. Note: SPV, special purpose vehicle; ESCO, energy service company; RPGIP, regional power grid of an industrial park; CSRC.

Pursuing an external credit enhancement to improve the rating level of an ABS by the rating agency is a required step for asset securitization. It not only reduces the financing cost and the credit risk of investors, but it also improves investor confidence and passion, as well as the originators' financing efficiency. In short, a better credit rating comprehensively enhances the whole financing process. After the credit enhancement, the credit rating is a step to measure the credit risk of asset securitization and asset solvency for the originator. It also discloses the credit risk of an ABS for investors and provides the details regarding the financing process for regulators. Through this series of steps, an SPV can obtain funds from investors and transfer these funds to the power retailer smoothly. Then, the power retailer invests the funds in the construction of an RPGIP to acquire the management rights of the electrical power system. Consequently, the power retailer and industrial consumers are the main investors and managers of the RPGIP that contributes to the development of energy infrastructure and power industry in BRI countries.

The regional power grid combines power supply, power grid, and the power consumer as an integration to self-balance electricity supply and demand with an independent operation system. It also helps to decrease electricity price and high load operation of power generators, and establishes self-adjustment and a self-monitoring operation system. The purpose of the asset securitization is to quickly construct an RPGIP in a few years that contributes to development of the electric power industry, and even government energy planning strategies. Based on the financing scheme, the power retailer, which is providing funds for the construction of the RPGIP, could use this funding support as leverage to participate in the electricity management of the regional power grid. According to the electricity management participation, the power retailer transforms into an ESCO to realize energy saving, and to improve energy utilization efficiency of the RPGIP. Moreover, D'Adamo and Rosa [42] mentioned that proper analyses from political and operational levels could promote management of renewable energy. Malakar et al. [43] found that proper load management could result in more profits for the hybrid system due to advanced power management based on an integrated load scheduling. Motivated by these benefits, the power retailer participating in electricity management could provide a professional analysis and better manage load for the RPGIP because of its information-collection capacity and market sensitivity. Electricity derivatives would play an important role in the electricity market [44], and power retailers could rely on their own market capability to avoid market price risk as the electricity managers of the RPGIP. Additionally, industrial customers have a huge potential to enhance demand response resource and renewable energy utilization [45]. Thus, RPGIP as an integration of industrial customers could effectively contribute to the development of demand response. In short, the proposed financing scheme accelerates the construction of an RPGIP towards promoting economic prosperity of BRI countries and regional economic cooperation, and strengthens exchanges and mutual learning between different civilizations.

Today, consumers bear the economic loss caused by power outage risk, and the official encouragement to prevent power outage is not reliable [46]. Performance-Based Regulation and Reward–Penalty Scheme are used to maintain the balance of power supply reliability and expense, and pay compensation to consumers [47]. Furthermore, financial insurance is a potential development direction for the electric power industry. If the grid company, which controls the operation of the electrical power system, was to provide reliability insurance to unbundle delivery and reliability services, and enable consumers to receive differentiated reliability based on their preferences, outage risk could be allocated to the grid company instead of consumers [48]. Consumers could pay insurance fees to decrease their outage risk, and insurance companies could obtain economic benefits through taking the outage risk [49]. Such insurance would not only benefit consumers, but also indirectly improve electricity consumption efficiency. This paper designs reliability insurance to be traded on a power exchange that can be conveniently supervised. Meanwhile, the comprehensive system would improve the market position of power retailers.

In the past, although governments have released several incentives to improve energy efficiency management, there is still a huge potential in terms of energy utilization [50]. As energy efficiency management represents a global issue, more private sectors, such as ESCOs, are required to participate in energy efficiency projects [51]. Ge et al. [52] proposed that power retailers can upgrade their functions becoming energy managers; according to energy efficiency programs, as a sort of power retailers' services, power retailers can avoid the fierce competition with other power retailers, and in the meantime improve energy utilization efficiency of customers—however, how to realize the role transformation is a challenge. The financing scheme enables the power retailer to participate in managing the industrial park's electricity, which provides an opportunity for the power retailer to transform into an ESCO that improves the sustainable development of power retailers. The National Energy Administration encourages the ESCO to become an entity that can provide energy efficiency services and electricity trade services for customers [53]. Power retailers obtain benefits by making customers' energy utilization more efficient, which decreases the investment on energy infrastructure [54–57]. Their electricity management ability improves electricity use, and their professional market analysis ability enhances trading operation efficiency. A function of a power retailer is to avoid excessive power use to market demand and strengthen energy resource utilization. These advantages are designed to alleviate electricity waste and ultimately improve energy utilization efficiency. Consequently, the participation of power retailers in electricity management of an RPGIP could stimulate the adequate utilization of energy resources, increase power supply reliability, and realize the detailed control of electricity consumption. Moreover, the improvements regarding energy utilization efficiency depend on the technology and industry. There are 12 case studies about energy efficiency technologies used by ESCOs (see Table 1).

The advantages of this financing scheme are summarized as follows:

- The information of regional electricity consumption can be integrated according to the electricity management of power retailers.
- The power retailer can achieve sustainable and diversified development as an ESCO. Meanwhile, it provides advanced energy efficiency technologies for the electricity management and power utilization.
- By using asset securitization, developers of an RPGIP can obtain sufficient funds in a short period of time. It effectively accelerates the development of the electric power industry in BRI countries.
- Asset securitization promotes the marketization of the electric power industry and enhances the relation between the financial market and the electricity market.
- As long-term electricity contracts are used for financing, utilization efficiency of funds is increased.

3.3. Financial Analysis of the Financing Scheme Implementation

When industrial consumers have their own regional power grid and self-generation plant, they can achieve significant electricity cost savings. Based on the financing scheme presented in Section 3, with the investment of a power retailer, a regional power grid can be constructed quickly, in few years. Once the RPGIP is built, the industrial consumer generates electricity on its own. Although the electricity cost drops dramatically, the apparent value does not represent the present value of the cost saving. Thus, considering the time value of the electricity cost saving, the net present value (NPV) of the electricity cost saving should be calculated by proper financial methods.

This paper uses the capital asset pricing model (CAPM) and weighted average cost of capital (WACC) as financial models to estimate the NPV of the RPGIP. CAPM focuses on market risk and WACC focuses on capital structure, respectively. These models are effectively utilized to evaluate the practical value of the projects because they consider market risk and capital structure together. Investors usually use the WACC model to make capital budgeting decisions in financial analysis of new projects [61]. Ondraczek et al. [62] used the WACC model to determine the discount rate of the project of the PV power industry in different countries. CAPM is often used to measure the firm's systematic risk [63]. Combing their advantages to calculate NPV of RPGIP makes the evaluation more convincing. As long as the estimation of NPV is positive, the RPGIP project is feasible. It directly and quickly shows the result for the industrial customer and power retailer, which makes them aware of the project's economic benefits. In short, using CAPM and WACC is a reliable, accurate approach to evaluating the RPGIP project. To estimate net present value, three main parts must be calculated: (1) Initial investment for the regional power grid; (2) the present value of the cost saving during the lifespan of the regional power grid; and (3) the residual value of regional power grid.

Table 1. The 12 case studies of energy efficiency technology used by ESCOs.

Technologies	Range of Application	Investment Cost	Energy Saving (Ton of Standard Coal Equivalent)/yr	CO_2 Emission Reduction (ton)/yr
1. Low concentration gas power generation technology in coal mines	Coal industry	20.96 million CNY; eight 500 megawatts (MW) power generation units	3000	30,000
2. High efficiency pulverized coal boiler system technology	Coal industry	11 million CNY; 20 ton/yr pulverized coal boiler retrofit	3102	8188
3. Belt conveyor frequency conversion energy efficiency system technology	Coal industry	3 million CNY; a set of belt conveyor frequency conversion energy efficiency system for 200t coal mine	6000	15,840
4. Flue gas-integrated optimization system heat recovery technology	Coal-fired power plant	9.65 million CNY; 300 MW power generation units retrofit	3900	Unknown
5. Draft fan and steam-driven technology of super critical and ultra-super critical unit	Thermal power plant	33.5 million CNY; draft fan retrofit of 1000 MW power generation units	4829	Unknown
6. Waste incineration power generation technology	Power generation	340 million CNY; annual 114 million kWh power generation project	30,261	Unknown
7. Steam turbine flow modernized retrofit technology	Steam turbine in power industry	38.43 million CNY; 300 MW unit retrofit	4000	10,560
8. Steam turbine steam seal modification	Steam turbine in power industry	30 million CNY; six 300 MW units retrofit	20,000	52,800
9. Energy-saving and efficiency of electrostatic precipitation control technology	Power industry	2.7 million CNY; 300 MW unit retrofit	1400	3696
10. Transformation of pure condensing steam unit to combined heat and power	Pure condensing steam unit	16 million CNY; two 200 MW pure condensing steam units	14,000	36,960
11. Intelligent optimization and online coking early warning system of utility boiler	Power industry	1.8 million CNY; utility boiler retrofit of 1000 MW power generation plant	1315	3472
12. Flue gas waste heat recovery and fan operation optimization technology for flue gas desulfurization	Power industry	43.7 million CNY; two 1000 MW flue gas desulfurization system	29,000	76,560

Data source: [58–60].

The operation periods of the regional power grid are set as {1, ..., N}. The initial investment cost occurs at period n = 0, which is invested by the power retailer. Thus, it does not consider the discount rate.

Part A is the initial investment:

$$A = \text{Initial Investment} \tag{1}$$

Part B is the calculation of the present value of cost saving per year, as follows:

$$B = PV = \sum_{t=1}^{n} CF_n (1 + R_{WACC})^{-n} \tag{2}$$

where CF_n is the electricity cost saving per year during the lifespan of the regional power grid, and R_{WACC} is the discount rate (%), which can be interpreted as the opportunity cost of capital (the maximum return of capital in an alternative investment). It is used to measure the feasibility of projects, which can be seen by estimation of this parameter in Equation (4).

Part C is the calculation of the residual value:

$$C = \frac{TV_n}{(1 + R_{WACC})^n} \tag{3}$$

where TV_n denotes the terminal value of the regional power grid.

As long as the NPV is positive, the regional power grid is deemed feasible and worthwhile. Combining Equations (1)–(3) to calculate the project's NPV, when NPV $= -\text{A} + \text{B} + \text{C} \geq 0$ is obtained, the project is acceptable.

In Equation (3), R_{WACC} is the discount rate and the minimal expected return. Therefore, the determination of its proper value is vital in the project value estimation. The WACC model is:

$$R_{WACC} = \frac{E}{E+D} \times R_E + \frac{D}{E+D} \times R_D \times (1 - T_c) \tag{4}$$

In this model, where E is equity capital, D is debt capital. The investment cost includes R_E and R_D, which are the cost of equity capital and the cost of debt capital, respectively. T_c is the tax rate. In this paper, the vast majority of funds is financed by asset securitization. ABS is the main financing tool and its interest rate is the cost of debt capital, R_D. The value of R_E is calculated by CAPM. The CAPM is:

$$R_E = R_F + \omega \times (R_M - R_F) \tag{5}$$

where R_E denotes the cost of equity capital. R_F represents the risk-free rate, which normally is recognized as the return rate of long-term treasury bonds in China. R_M is the expected return on the market portfolio. The difference (R_M–R_F) is often called *market risk premium*. ω is the systematic risk that reflects the sensitivity of an industry or a company to the market risk. For an individual company, the value of ω is calculated as follows:

$$\omega_{Individual} = \frac{COV(R_I, R_M)}{VAR(R_M)} = \frac{\sigma_{I,M}}{\sigma_M} \tag{6}$$

where $\sigma_{I,\,M}$ is the standardized covariance of the stock return rate of the individual company and the return rate of market portfolio, and σ_M is the variance of the return rate of the market portfolio. For an industry, the calculation of ω is different. By a certain amount of collection on systematic risks from list companies, the average value of ω is calculated as an industry ω [64]. Each ω of these list companies is calculated by Equation (6), and the average value of ω is the industry ω. There is not definitely correct ω, which normally depends a great deal on individual preference in practice. Consequently, the feasibility of the project can be determined based on Equations (1)–(6). When NPV ≥ 0, the project can be accepted; when NPV < 0, the project should be rejected.

Tables 2 and 3 show the financial data related to a new RPGIP in Shandong province, China.

Table 2. The electricity cost before and after constructing the RPGIP, by the regional power grid example.

Cost Items	Cost (Hundred Million Yuan)			
	Before	**After**	**Cost Saving**	**Investment**
Capacity cost	1.66	0	1.66	
Fixed cost per kilowatt-hour	2.17	0	2.17	
Additional cost	7.04	7.04	0	12.3
Generation cost of coal	19.69	18.25	1.44	
Generation cost of gas	0	5.16	−5.16	
Transmission cost	1.69	0	1.69	
Revenue	−0.48	0	−0.48	
Total	31.77	30.45	1.32	12.3

Table 3. The specific project data.

Parameter	Data
Initial investment	12.3 hundred million yuan
Cash flow per year	1.32 hundred million yuan
n	40 years
TV_n	0.615 hundred million yuan
R_{WACC}	5.04%
E	20% ($E + D$)
D	80% ($E + D$)
R_D	3.88%
T_c	25%
R_E	13.54%
R_F	3.4%
R_M	10.3%
ω	1.47

As is shown in Table 2, there is a huge difference in the cost of electricity before and after the RPGIP is constructed. In this example, a 1.32 hundred-million-yuan electricity cost was saved annually by constructing the regional power grid. It should be noted that the costs in Table 2 only depend on the specific region of the project, and they cannot be considered cost standards in China. Table 3 can be calculated by using the data in Table 2 and the financial equations above. This paper adopts a 10-year treasury bond interest rate of R_F (3.4%) [65], and the return rate of the weighted average of component stocks in the Shanghai and Shenzhen 300 index from 2001 to 2016 as R_M (10.3%), and calculates the value of ω (1.47) based on the data of these stocks in the past 60 months. Subsequently, R_E (13.54%) can be calculated by CAPM. In this project, equity capital is 20% and debt cost is 80% of the entire funds, respectively. Lei et al. [66] introduced the normal financing structures and their benchmark yields of the financial leasing project in power net construction, and the optimal ratio of equity to debt is 2:8 in China. Moreover, the lifespan and the residual value of the project are estimated as 40 years and 5% of the initial investment, respectively. The interest rate of ABS is 3.88%, which is a low financing cost compared to financing other ways. Note that the maturity of the first batch of securities is five years, and new securities can be issued when the regional power grid starts to operate by asset securitization. R_{WACC} (5.04%) can be obtained by using the WACC model. Based on Equations (1)–(6), the NPV of this project can be calculated. Consequently, the NPV is 10.31 hundred million yuan, which means that the project is feasible. According to the data from Section 2, too many power retailers are established in the 15 provinces or cities, which results in over-competition in the electricity market. Therefore, power retailers can use the financing scheme as a diversified and sustainable development adding functions of power retailers and decreasing the over-competition in the electricity market. If the data of cost items and parameters in Tables 2 and 3 are collected in these provinces or cities, the NPV of RPGIP projects can be calculated. In summary, based on the financial analysis, the feasibility of implementing the financing scheme and constructing an RPGIP can be determined, which contributes to marketization and sustainable development of the power industry.

4. Game Analysis for the Achievement of Maximum Benefits

As power retailers and industrial consumers jointly invest in and manage the RPGIP, there is a challenge on the benefit allocation between them based on their different effort degree. Game analysis is normally used to realize a win–win cooperation when project participants have different goals and cannot coordinate their actions closely [67]. Due to different demands of power retailers and industrial consumers in the RPGIP project, game analysis for achieving their maximum benefits is needed. Industrial consumers mainly focus on achieving economic benefits and improving energy utilization efficiency. Power retailers focus more on realizing a sustainable development of the industrial park and ensuring the power system's security and stability. A long-term cooperation between power retailers and industrial consumers can increase the RPGIP's future value. Thus, considering the different functions and demands of power retailers and industrial consumers in an RPGIP, a comprehensive plan regarding the benefit allocation between them is designed to increase the RPGIP's future value. According to game analysis, to determine an optimal effort degree and allocation coefficient of power retailers and industrial consumers, the maximum benefits can be achieved as shown below.

First, three assumptions are made to ensure the rationality of the allocation coefficient and effort degree:

Assumption 1: The effort degree of power retailers and industrial consumers determines the economic benefit of the RPGIP. Autrey [68] proposed the team synergy theory for teamwork (the profit function is $c\tau_1^{\delta}\tau_2^{1-\delta}$, τ_1 and τ_2 are the effort degree of the investor and the manager, respectively, δ is the contribution of τ_1's effort to the project, the total contribution of the effort of τ_1 and τ_2 is 1, and c is the correlation coefficient between the investor and manager). Based on the team synergy theory, it is assumed that the power retailer and the industrial consumer have the same contribution of effort in the RPGIP project. The economic benefit of the RPGIP is assumed as:

$$E = \alpha\sqrt{e_P}\cdot\sqrt{e_I} + \varepsilon \tag{7}$$

where, e_P and e_I are the effort degree of power retailers and industrial consumers, respectively, and ε is an external influence and a random variable. Furthermore, the average value and the variance of ε are 0 and σ^2, respectively, in Gaussian distribution. α is the correlation coefficient between power retailers and industrial consumers.

Assumption 2: Power retailers and industrial consumers choose an effort degree based on their economic benefits, and their costs are fluctuated by their effort degree [69]. Moreover, project participants' effort cost is equal to their monetary cost [70]. Thus, the power retailer's cost is:

$$C(P) = 0.5e_P^2 \tag{8}$$

The industrial consumer's cost is:

$$C(I) = 0.5e_I^2 \tag{9}$$

Assumption 3: Power retailers and industrial consumers share economic benefits of the RPGIP project. The benefit allocation coefficient of the industrial consumer and the power retailer are assumed as β ($0 < \beta \leq 1$) and $1 - \beta$, respectively. Additionally, it is assumed that there is no tax or interest in the benefit allocation process.

Based on the individual or collective benefit perspective, different effort degree of power retailers and industrial consumers can be calculated. Section 2 demonstrates that there are numerous power retailers in 15 provinces or cities, such as Beijing, Tianjin, and Hebei. When these power retailers participate in the RPGIP project and cooperate with industrial consumers, they may have different strategies considering the individual or collective benefit perspective. Therefore, different scenarios need to be considered in the game analysis. Four scenarios in the benefit allocation process are demonstrated based on the above assumptions.

Scenario 1: Industrial consumers and power retailers both choose their effort degree from the perspective of individual benefits.

The industrial consumer's expected benefit is:

$$E(I) = \beta\alpha\sqrt{e_P}\cdot\sqrt{e_I} - 0.5e_P^2 \tag{10}$$

The power retailer's expected benefit is:

$$E(P) = (1-\beta)\alpha\sqrt{e_P}\cdot\sqrt{e_I} - 0.5e_I^2 \tag{11}$$

The optimal effort degree of power retailers and industrial consumers, and total benefits are calculated as:

$$\begin{cases} e_P^1 = \frac{\alpha}{2}\sqrt[4]{\beta^3(1-\beta)} \\ e_I^1 = \frac{\alpha}{2}\sqrt[4]{\beta(1-\beta)^3} \end{cases} \qquad \begin{cases} E(P)_1 = \frac{3\alpha^2\beta}{8}\sqrt{\beta(1-\beta)} \\ E(I)_1 = \frac{3\alpha^2(1-\beta)}{8}\sqrt{\beta(1-\beta)} \\ E_1 = E(P)_1 + E(I)_1 = \frac{3\alpha^2}{8}\sqrt{\beta(1-\beta)} \end{cases} \tag{12}$$

Scenario 2: Power retailers and industrial consumers choose their effort degree from the perspective of collective benefits. The expected benefits are:

$$E(e_P; e_I) = \alpha\sqrt{e_P}\cdot\sqrt{e_I} - 0.5e_P^2 - 0.5e_I^2 \tag{13}$$

The optimal effort degree of power retailers and industrial consumers and total benefits are:

$$e_P^2 = e_I^2 = \frac{\alpha}{2} \qquad \begin{cases} E(P)_2 = \frac{\alpha^2\beta}{2} - \frac{\alpha^2}{8} \\ E(I)_2 = \frac{3\alpha^2}{8} - \frac{\alpha^2\beta}{2} \\ E_2 = E(P)_2 + E(I)_2 = \frac{\alpha^2}{4} \end{cases} \tag{14}$$

Scenario 3: The industrial consumer chooses its effort degree from the perspective of individual benefits. The power retailer chooses the effort degree from the perspective of collective benefits. The optimal degree of the power retailer and the industrial consumer and total benefits are presented below:

$$\begin{cases} e_P^3 = \frac{\alpha}{2}\sqrt[4]{1-\beta} \\ e_I^3 = \frac{\alpha}{2}\sqrt[4]{(1-\beta)^3} \end{cases} \qquad \begin{cases} E(P)_3 = \frac{\alpha^2\beta}{2}\sqrt{1-\beta} - \frac{\alpha^2}{8}\sqrt{1-\beta} \\ E(I)_3 = \frac{3\alpha^2(1-\beta)}{8}\sqrt{1-\beta} \\ E_3 = E(P)_3 + E(I)_3 = \frac{\alpha^2\beta}{8}\sqrt{1-\beta} + \frac{\alpha^2}{4}\sqrt{1-\beta} \end{cases} \tag{15}$$

Scenario 4: The industrial consumer chooses its effort degree from the perspective of collective benefits. The power retailer chooses its effort degree from the perspective of individual benefits. The optimal degree and total benefits are:

$$\begin{cases} e_P^4 = \frac{\alpha}{2}\sqrt[4]{\beta^3} \\ e_I^4 = \frac{\alpha}{2}\sqrt[4]{\beta} \end{cases} \qquad \begin{cases} E(P)_4 = \frac{3\alpha^2\beta}{8}\sqrt{\beta} \\ E(I)_4 = \frac{3\alpha^2}{8}\sqrt{\beta} - \frac{\alpha^2\beta}{2}\sqrt{\beta} \\ E_4 = E(P)_4 + E(I)_4 = \frac{3\alpha^2}{8}\sqrt{\beta} - \frac{\alpha^2\beta}{8}\sqrt{\beta} \end{cases} \tag{16}$$

Based on the game analysis and the result of derivation, the conclusion is summarized as:

(1) When power retailers choose their effort degree from the perspective of individual benefits, according to the comparison between the value of $E(I)_1$ and $E(I)_4$, the result is realized as shown below: When $0 < \beta < 0.411$, industrial consumers choose their effort degree from the perspective of collective benefits; when $0.411 < \beta < 1$, industrial consumers choose their effort degree from the perspective of individual benefits.

(2) When power retailers choose their effort degree from the perspective of collective benefits, according to the comparison the values of $E(I)_2$ and $E(I)_3$, the result is the same as that of **(1)**.

(3) When industrial consumers choose their effort degree from the perspective of individual benefits, according to the comparison between the values of $E(P)_1$ and $E(P)_3$, the result is: When $0 < \beta < 0.589$, power retailers choose their effort degree from the perspective of individual benefits; when $0.589 < \beta < 1$, power retailers choose its effort degree from the perspective of collective benefits.

(4) When industrial consumers choose their effort degree from the perspective of collective benefits, according to the comparison between the values of $E(P)_2$ and $E(P)_4$, the result is the same as that of **(3)**.

In summary, when $0 < \beta < 0.411$, industrial consumers choose their effort degree from the perspective of individual benefits, and power retailers choose their effort degree from the perspective of collective benefits; when $0.411 < \beta < 0.589$, both of them choose their effort degree from the perspective of individual benefits; and when $0.589 < \beta < 1$, industrial consumers choose their effort degree from the perspective of collective benefits, and power retailers choose their effort degree from the perspective of individual benefits. Industrial consumers and power retailers would not choose their effort degree from the perspective of collective benefits. Based on the game analysis, the result is: $E_2 > E_1$; $E_3 > E_1$. Thus, when the value of β is set as $0 < \beta < 0.411$ or $0.589 < \beta < 1$, that makes the benefit of industrial consumers and power retailers approach E_2 or E_3, and the maximum benefits can be achieved.

As Section 2 shows that there are thousands of new power retailers established in the electricity market, these power retailers are struggling with the intense market competition and a single non-sustainable development, especially in Beijing, Tianjin, Hebei, Shanxi, Sichuan, and Yunnan. According to the determination of the benefit allocation coefficient ($0 < \beta < 0.411$ or $0.589 < \beta < 1$) in the RPGIP project, the cooperation between industrial consumers and power retailers can be reliable and realize a win–win situation, and their maximum benefits can be achieved. Consequently, the game analysis provides the RPGIP project an approach based on different effort degree of power retailers and industrial consumers to achieve the maximum benefits.

5. Conclusions

Promoting marketization, sustainable development of power retailers, and cooperation in connectivity of energy infrastructure is an effective motivation for developing BRI. A lack of economic support and low utilization of electric power and energy resource is an increasingly serious problem in developing countries, the result of unreasonable and ineffective marketization planning, waste of electric power, and a series of other factors. This paper proposes to accelerate the construction of energy infrastructure, to enhance the market function of power retailers and the development of industrial parks among different regions in BRI countries, and to promote electricity consumption efficiency. Reasonable use of industrial parks is key to improving energy resources and utilization efficiency. Using a regional power grid of an industrial park can integrate energy resources and local industrial prosumers by the electricity management of power retailers. It also improves the efficiency of power trading and the development of financial market in BRI countries.

As the electricity market develops rapidly in developing countries, increasingly more power retailers participate in that market. As a result, many power retailers have no ability to gain market share and realize a sustainable development due to the fierce competition as the electricity market reform has taken place in China. Power retailers transform into ESCOs that participate in the electricity management of an RPGIP by asset securitization can improve their sustainable development.

The process is straightforward. A power retailer signs a long-term electricity contract with an industrial consumer and sells it to an SPV as a transferable asset. The SPV then issues asset-backed securities to raise funds based on these assets. Subsequently, the power retailer obtains adequate funds to construct an RPGIP in a BRI country, and it takes advantage of these funds to leverage participation in the electricity management of the regional power grid. The power retailer participates in the management of the electric power system in an RPGIP as an ESCO, concentrating on electricity management and electric power sales. This method not only contributes to the sustainable development of power retailers, but it also accelerates the construction of an RPGIP and improves the electricity management and connection among different regions in BRI countries. In the financing scheme, CAPM and WACC are used to estimate the NPV of the RPGIP project as reliable financial models. Moreover, allocating benefits properly between power retailers and industrial consumers is vital for the sustainable development of the RPGIP project. According to game analysis, power retailers and industrial consumers can choose their proper effort degree for achieving the maximum benefits. Finally, a long-term cooperation between power retailers and industrial consumers in the RPGIP project can be realized.

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Abbreviations

BRI	Belt and Road Initiative	RPGIP	Regional power grid of industrial park
ESCO	Energy service company	SPV	Special Purpose Vehicle
ESPC	Energy saving performance contracting	NPV	Net present value
WACC	Weighted average cost of capital	ABS	Asset-backed security
CAPM	Capital asset pricing model	PV	Photovoltaic

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