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Research on Economic Evaluation Methods and Project Investment Strategies for Gas Power Generation Based on the Natural Gas Industry Chain and Gas–Electricity Price Linkage in China

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Abstract: In recent years, due to the spike in natural gas spot prices, gas-fired power corporations' operating costs have skyrocketed. Traditional power generation corporations have gradually been withdrawing from gas power generation investment, replaced by oil and gas enterprises with upstream resources. The development of gas-fired power plants helps to maintain the stability of the power grid and has a positive effect on the realization of carbon neutrality goals. At present, most of the financial evaluation methods for gas power generation projects tend to focus on the static tariffs of the project itself and lack consideration for the overall contribution to the industry chain and the latest "gas–electricity price linkage" mechanisms in China, leading to oil and gas enterprises reducing investment in gas-fired power plants due to yield constraints. In this paper, a financial evaluation methodology for gas power generation projects based on the industrial chain and the "gas–electricity price linkage" mechanism was proposed. The investment return characteristics of specific gas power generation projects under the "gas–electricity price linkage" mechanism in different provinces were revealed through this methodology. Considering the characteristics and industrial development trends in major provinces in China, investment and operation strategies for gas power generation were proposed. These studies provide oil and gas enterprises with references and suggestions for future investment decisions for new gas power generation projects.

Keywords: gas–electricity price linkage mechanism; marginal contribution; gas power generation; financial evaluation methods; industrial chain

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1. Introduction

With the large number of offshore wind and photovoltaic installations in China, the stability and security of China's power grid is under serious threat. There is an urgent need to install a peaking power supply to safeguard the grid. Gas power generation (GPG) has the characteristics of instantaneous use [1,2], adjustable availability [3], strong peak shifting capability [1,4], large gas consumption [5], etc., and has been an indispensable and important part of the country's construction of a new type of power system mainly based on new energy sources in China [6,7]. In the power industry, GPG is a bridge between traditional energy sources and the new zero-carbon energy world, and is an indispensable "regulator" of the new power system [7]. GPG also plays an important role in the field of natural gas peaking, which is a "stabilizer" for the natural gas industry chain to strengthen, solidify and stabilize the chain [8].

In recent years, under the guidance of new policies, China's new installed capacity for natural gas has remained above 4 million kilowatts, with overall fluctuating change [9]. In 2020–2021, China suffered multiple rounds of low-temperature cold weather. While there

was a simultaneous tightening of supply of all types of resources, domestic natural gas resource enterprises continued their efforts to increase supply and support power plants in peak power generation, helping to maintain energy supply across the country [10]. In 2021, China's new installed capacity for GPG reached its peak, with the new installed capacity reaching 10.57 million kilowatts. China's National Development and Reform Commission (NDRC) and the National Energy Administration (NEA) issued the "14th Five-Year Plan for a Modern Energy System". By 2025, annual domestic natural gas production will reach more than 230 billion cubic meters, and the total installed capacity of power generation will reach about 3 billion kilowatts. The energy reserve system will be more complete, and the ability to supply energy independently will be further enhanced in China [11,12]. With China's "carbon neutral" policies continuing to be promoted, it is expected that China's GPG installed capacity will maintain a steady growth through the middle of this century, reaching a peak of 300–400 million kilowatts around 2050, and will then remain stable. China's GPG has a lot of space for future development [13,14].

With the international situation characterized by a confluence of turmoil, international natural gas prices maintain a high level [15,16]. At this stage, GPG still lacks sufficient competitiveness [17,18], and all parties have taken measures to safeguard the revenue of power plants [19,20]. In terms of policy, the provinces with large installed capacity of GPG, such as Guangdong Province, Jiangsu Province, and Zhejiang Province, have implemented "gas–electricity price linkage" subsidies for GPG feed-in tariffs, to alleviate the losses caused by rising costs [21,22]; on the corporate side, traditional power producers are actively working with natural gas, upstream oil, and gas enterprises [23]. They smoothed out the risk of natural gas price fluctuations by signing long-term purchase and sales contracts or participating in each other's shares [24].

Oil and gas enterprises have a unique resource advantage in GPG. Compared with traditional power generation enterprises, the development of GPG helps oil and gas enterprises increase the capacity for consumption of liquid natural gas (LNG), providing a basis for bigger and stronger resource pools [25,26]. In terms of market share, the development of GPG helps oil and gas enterprises to stabilize and increase their local market shares in gas and electricity. With regard to the "gas–electricity price linkage" mechanism, the development of GPG helps oil and gas enterprises to effectively expand their space for maneuvering, and has a positive effect on stabilizing and regulating the storage capacity of LNG resources and enhancing the bargaining power of LNG [27,28]. For power plant operations, oil and gas enterprises have multiple types of resources, such as LNG and domestically produced gas, and they can guarantee the stability of power plant costs through effective resource deployment [29,30].

Oil and gas enterprises are gradually becoming the main investment force in GPG projects in China [31,32]. With the national high-quality city gas projects having been divided up, vehicle and ship refueling business volumes are small, and are facing electric replacement; more and more oil and gas enterprises have begun to involve themselves in the field of GPG in order to strengthen the natural gas industry chain terminal. CNOOC has been vigorously developing its GPG business in recent years, and currently has 10 GPG projects in operation, with a total installed capacity of 11.21 million kilowatts, including the Hainan Yangpu Power Plant Project and the Zhongshan Jiaming Power Project [33]. CNPC also actively participates in track competition, mainly laying out the Kunlun GPG project and the Southwest Oil and Gas Field Rongshan differential pressure power generation project, etc. [34]. SINOPEC's GPG projects mainly include the Sinopec Southwest Bureau Gas Field Booster Station GPG project.

Based on this, this study thoroughly researched the tariff mechanisms of "gas–electricity price linkage" in different provinces. Combining the "gas–electricity price linkage" mechanism, with the characteristics of the oil and gas enterprise industry chain, a financial evaluation method for GPG based on the GPG industry chain was proposed. The methodology was used to analyze the investment return characteristics of specific GPG projects under the "gas–electricity price linkage" mechanism in different provinces. Combined

with this characteristic, tariff mechanisms, and industrial development characteristics of major provinces in China, investment and operation strategies for GPG were proposed. These studies provide oil and gas enterprises with references and suggestions for future investment decisions and project operations for new GPG projects.

2. Method for the Evaluation of GPG Based on the Natural Gas Industry Chain

Combined with the characteristics of "gas–electricity price linkage" mechanisms, a financial evaluation methodology for GPG based on the industrial chain of GPG is proposed in this section. The incremental values of the new GPG project to the whole industry chain were taken into account in the economic evaluation method, and a financial evaluation model was developed to calculate the overall value increment in the industry chain of oil and gas enterprises.

2.1. The Theory of Marginal Contribution (In Economics)

Marginal contribution, also known as marginal profit, is an important concept and theory in management accounting and an important ingredient in principal-volume profit analysis [35]. It is the amount remaining after the revenue from the sale of the products of the enterprise, minus the variable costs of products involved. This is the balance after the total variable costs incurred are compensated for by the sales revenue of the product, which is called the marginal contribution. The formula for marginal contribution is as follows:

$$\text{Marginal Contribution} = \text{Sales Revenue (excluding taxes)} - \text{Variable Costs}$$

Sale Revenue is the sales price of the product minus the portion of VAT included therein, i.e., the sales price without tax. Variable Cost is the change in the amount of cost within a certain range as the volume of business changes.

We extended the marginal contribution analysis to the financial evaluation of the industry chain. Herein, we regarded the industrial chain as a complete product line, the investment amount generated by adding a single investment as the Variable Costs, the resulting change in the overall income of the industrial chain as the Sales Revenue, and the resulting incremental economic benefits of the whole industrial chain as the marginal contribution, with the following formula:

$$TR = \sum_{m}^{n} (\Delta TS - \Delta TC) \quad (1)$$

TR is the total benefit of the industry chain. m is the total number of links in the industry chain. n is the nth link. ΔTS is the change in total sales of a single link. ΔTC is the change in total cost of a single link.

2.2. Natural Gas Industry Chain

China's natural gas industry chain involves natural gas production, trade, transportation, storage, and the marketing of multiple links [36]. The natural gas industry chain can be split into upstream, midstream, downstream, and end users. Regarding upstream gas sources: China's natural gas sources are mainly imported gas (including imported pipeline gas and imported LNG) and domestically produced natural gas, which are generally extracted or imported by domestic oil and gas corporations. In the midstream storage and transportation chain, imported pipeline gas enters China and is transported together with self-produced gas through the pipeline to each province, and then accesses municipalities through provincial pipelines, at which time the pipeline gas is processed in liquefaction plants to become LNG and is transported by tanker trucks to areas where no pipelines have been laid. Meanwhile, after LNG enters the Chinese market through the receiving terminal, it is partly vaporized into the backbone pipeline, and partly transported to the distribution facility through tanker trucks, which are set up for natural gas storage and peaking in this segment. In the downstream distribution chain, pipeline gas enters into mu-

nicipalities and then becomes accessible to downstream users through municipal pipelines. LNG transported by tanker trucks is sold to downstream automobile and industrial users through refueling stations, of which GPG is one of the important end-users in the natural gas industry chain.

We summarized the industry chain where GPG is located by dividing it into four main links, which are natural gas trading, natural gas transportation, power generation/co-generation, and the purchase/sale of electricity/heat as shown in Figure 1. Each of the four links is implemented by four operating entities. They are gas trading companies, infrastructure-operating companies, power plants, and electricity sales companies.

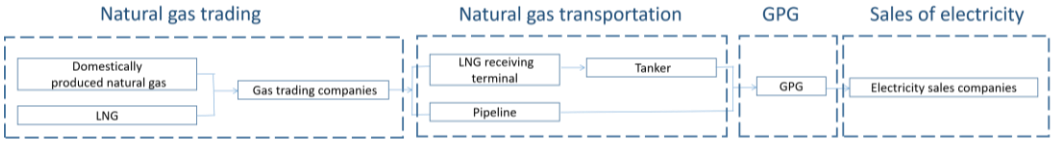


Figure 1. GPG Industry Chain.

2.3. Financial Evaluation Model

According to the marginal contribution analysis method, the GPG project is regarded as an incremental product of the industry chain; the incremental revenue brought by this incremental product to each link of the industry chain is calculated, and the total incremental revenue is regarded as the revenue of the industry chain for financial evaluation. The cash flow statement of the GPG was used as the basis, and the incremental cash flow of each link was used to verify the cash flow statement of the industry chain, in order to analyze the industry chain's financial internal rate of return (FIRR) (shareholder's investment amount) [37]. The GPG industry chain benefit formula is as follows, with specific sub-segment modeling shown in Supplementary S2:

$$\sum_{t=1}^{n}(CI - CO)_t \times (1 + FIRR)^{-t} = 0 \quad (2)$$

$FIRR$ is the financial internal rate of return of the gas power plant industry chain. CI is the incremental total cash inflow of the industry chain in the t year. CO is the incremental total cash outflow of the industry chain in the t year. n is the project calculation period. The basic parameters of the industrial chain are shown in Table S9 of the Supplementary Materials.

3. Results of the Revenue Characterization Study of GPG Projects in Key Provinces of China

We assumed that oil and gas enterprise A was the main body of the project investment, as the enterprise has a complete natural gas industry chain. The shares of the enterprise in the industry chain links are shown in Table 1. Taking enterprise A's investment in a GPG project in different regions of China as an example, we explored the revenue characteristics of GPG projects in different regions. Herein, we simplify the influencing factors, and we mainly explore in this section the factors that have the greatest impact on GPG projects, such as local GPG utilization hours, feed-in tariffs, and "gas–electricity price linkage" policies (Supplementary S1). We assumed that natural gas trade costs are tied to JCC (LNG prices are linked to JCC, and pipeline gas prices remain constant), feed-in tariffs are tied to gas price (specific formulas are shown in Supplementary S1.1.2, S1.2.2, and S1.3.2), and various expenses such as natural gas processing costs, pipeline costs, and labor costs are consistent across regions, controlling for their non-critical factors, and exploring the impact of the major factors on the revenue of the GPG project.

Table 1. Share ratio of enterprise A in the link.

Links of the Chain	Shares in the Link
Gas trading companies	100%
Receiving terminal	30%
Pipelines	100%
Power plants	70%
Electricity sales companies	100%

The investment and operational period of power plant B are 2 and 20 years, and the total evaluation period is 22 years. Ancillary service revenues are measured over a 10-year operating period. The construction investment of the project is USD 34,290,000, including USD 35,620,000 of value-added tax during the construction period. The investment plan for construction investment is 50% in the first year and 50% in the second year. The depreciable life is 18 years, and salvage rate is 5%. The amortization period is 10 years, and the salvage rate is 0%. Basic parameters are detailed in Table S10 of the Supplementary Materials.

3.1. Guangdong Province

The local GPG utilization hours in Guangdong Province showed a relatively smooth fluctuation from 2019 to 2022 (Supplementary S1.1.1). Herein, we chose the average of the annual utilization hours from 2019 to 2022 as the annual utilization hours of power plant B. The project's feed-in tariff was 2.557 billion kWh and gas consumption was 485.56 million Nm^3, and the cost of natural gas was linked to the feed-in tariff along with the JCC price. The results of B yield IRR variation with oil price JCC are shown in Figure 2. It is shown that when JCC increases, the overall trend in project IRR changes for different LNG content resources is similar, with all showing three phases. In phase 1, when the oil price is at a low level (USD 50–60), the project IRR (Figure 2a), IRR_{chain} (Figure 2b) and the industry chain shareholder $IRR_{chain\text{-}shareholder}$ (Figure 2c) are at a high level, and the decline is slow. In phase 2, when oil prices continue to grow (USD 60–80), the rate of decline increases. In phase 3, when the oil price grows above USD 80 to 100, the project IRR continues to decrease and enters a loss state, while the IRR_{chain} and $IRR_{chain\text{-}shareholder}$ decrease slows down but remains at a low level. This is due to the fact that when the oil price is at a high or low level, the gas price is also at a correspondingly high or low level, triggering the Guangdong Province's "gas-to-electricity price linkage" to mitigate the changes in the rate of return caused by changes in the costs of the GPG project. The "gas-to-electricity price linkage" mechanism cannot be triggered when the oil price is in the middle of the range, where an increase in the oil price leads to a significant drop of IRR. It is suggested that the "gas-to-electricity price linkage" mechanism in Guangdong Province focuses on subsidizing situations where gas prices are highly volatile. Through the results of the model calculations, it can be seen that the "gas-to-electricity price linkage" mechanism is able to subsidize the changes in fuel costs caused by changes in the price of gas. However, its cost-sparing effect is not particularly effective, and all IRRs show a downward trend as the price of oil increases.

Comparing the IRR of different LNG contents, it is shown that resources with higher LNG contents are able to achieve higher yields when oil prices are at low levels. Initially, with the gradual increase in oil prices, the difference in resource yields for different LNG contents was not significant. As oil prices continue to increase, resources with lower LNG content enter a slow decline phase earlier. It is suggested that low-value domestic gas is highly supportive of this project, as well as chain yields at high oil prices.

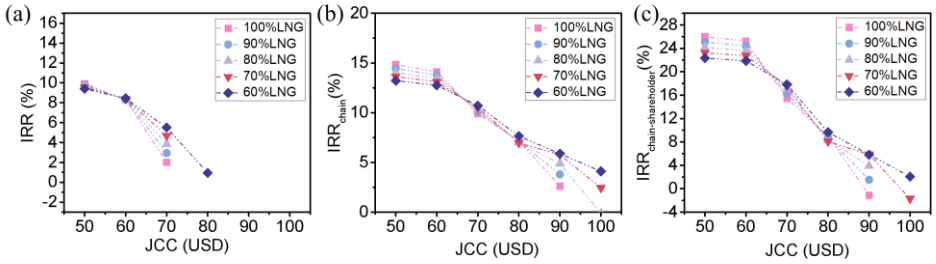


Figure 2. IRR of power plant B with different JCC prices in Guangdong Province. (**a**) The project IRR of power plant B with different JCC prices; (**b**) The project IRR_{chain} of power plant B with different JCC prices; (**c**) The project $IRR_{chain\text{-}shareholder}$ of power plant B with different JCC prices.

Comparing the project IRR, IRR_{chain}, and $IRR_{chain\text{-}shareholder}$, it can be seen that the IRR_{chain} and $IRR_{chain\text{-}shareholder}$ are significantly higher than the project IRR. It is suggested that investing in the GPG project by oil and gas enterprises can increase the economic benefits of the whole industry chain, while oil and gas enterprises across the whole industry chain are more able to withstand the risk of high oil prices compared to power generation companies alone. For oil and gas enterprises with multiple upstream resources, they can cope with gas price fluctuations through different resource ratios. This reveals the reason that a large amount of GPG plants in Guangdong Province have either sold off their assets or partnered with companies with a stable upstream gas supply in recent years.

All in all, the Guangdong "gas-to-electricity price linkage" mechanism is not suitable for the survival of GPG projects with pure LNG resources in Guangdong Province. Investment in GPG projects in Guangdong Province need to match pipeline gas. A variety of gas sources should be included under the regulation, in order to better cope with fluctuations in natural gas prices, to protect the project or the entire industrial chain of expected returns. The use of multiple sources of gas regulation can better cope with fluctuations in natural gas prices and safeguard the expected returns of the project or the entire industrial chain. GPG was developing fast in Guangdong Province, with high annual utilization hours of power generation and a strong regional advantage. Although the cost-reducing effect of the "gas-to-electricity price linkage" mechanism is relatively weak, the expected returns of the project and the industry chain can be guaranteed by matching the corresponding upstream resources.

3.2. Jiangsu Province

The GPG utilization hours in Jiangsu Province maintained relatively stable fluctuations from 2019 to 2022 (Supplementary S1.2.1). Herein, we chose the average of the annual utilization hours from 2019 to 2022 as the annual utilization hours. The project's feed-in terms of the tariff is 2.551 billion kWh, and gas consumption was 494.29 million Nm^3, and the cost of natural gas was linked to the feed-in tariff along with the JCC price. The result of the IRR of power plant B with the JCC oil price is shown in Figure 3. It can be seen that, from the known data, the IRR of the projects all show a positive correlation with the JCC. This shows that under the "gas-to-electricity price linkage" mechanism in Jiangsu, it can well channelize the changes in the cost of the GPG project caused by changes in natural gas prices. At the same time, it is shown that as the LNG content decreases, its slope, with increasing JCC, becomes larger. In other words, with a high percentage of domestically nature gas and a high oil price, the project can earn a high return. Interestingly, as the LNG content increases, there will be a C_0, and with a C_0 ration, the IRR will be almost constant regardless of oil price movements.

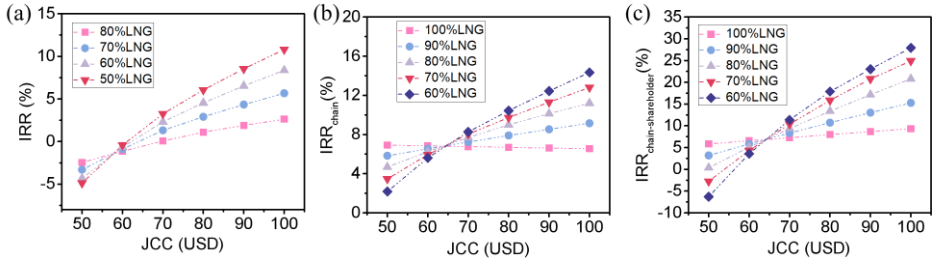


Figure 3. IRR of power plant B with different JCC prices in Jiangsu Province. (**a**) The project IRR of power plant B with different JCC prices; (**b**) The project IRR_{chain} of power plant B with different JCC prices; (**c**) The project $IRR_{chain\text{-}shareholder}$ of power plant B with different JCC prices.

With LNG content exceeding 80%, the project's IRR is negative regardless of oil price. Therefore, in this subsection, it is not possible to calculate the change in IRR for a high percentage of LNG content. In absolute terms, a larger percentage of LNG is associated with lower project IRR. It is suggested that the GPG project in Jiangsu Province with 100% LNG will be unprofitable. Therefore, investment in GPG projects in Jiangsu must be coupled with low-priced domestic gas resources.

Similarly, we compared the IRR (Figure 3a), IRR_{chain} (Figure 3b), and $IRR_{chain\text{-}shareholder}$ (Figure 3c) with different JCC prices. It can be seen that both IRR_{chain}, and $IRR_{chain\text{-}shareholder}$ show the same trend as the project IRR. As with the project IRR, there still appears a $C_{0\text{-}chain}$; by calculating the $C_{0\text{-}chain}$ as 98.7%, it is shown that the IRR_{chain}, and $IRR_{chain\text{-}shareholder}$, is positively correlated with the change in JCC. Comparing IRR, IRR_{chain}, and $IRR_{chain\text{-}shareholder}$, it can be seen that IRR is negative at some specific oil prices, but both IRR_{chain} and $IRR_{chain\text{-}shareholder}$ are positive. For these situations, oil and gas enterprises should choose whether or not to invest in the project. Although the project may not be profitable, it can increase the overall revenue of the natural gas industry chain and expand the market share of the terminal.

In conclusion, investment in GPG projects in Jiangsu Province needs to be matched with diversified upstream gas sources. Investments need to be supported by domestic gas to effectively cope with natural gas price fluctuations, so that the chain of oil and gas companies can achieve higher returns. In Jiangsu province, oil and gas enterprises with multiple sources of gas have a strong competitive advantage over power plants with a single source of gas.

3.3. Zhejiang Province

The GPG utilization hours in Zhejiang Province underwent a sudden change in 2021. This is due to the policy of driving up the utilization hours of GPG plants. In 2022, compared to 2021, although there was a slight decrease, the fluctuations were not significant. The annual utilization hours in 2022 declined slightly compared to 2021, but the fluctuations were not significant (Supplementary S1.3.1). Herein, we chose the average of the annual utilization hours of 2021 and 2022 as the annual utilization hours of project B. The project's feed-in tariff is 1.773 billion kWh and gas consumption is 336.6 million Nm^3, and the cost of natural gas is linked to the feed-in tariff along with the JCC price. The result of the IRR of power plant B with the oil price JCC is shown in Figure 4. Unlike both Guangdong Province and Jiangsu Province, the project IRR is positively correlated with the change in JCC, and the slope of the positive correlation increases as the LNG content increases. When the LNG content becomes zero, IRR does not vary with the JCC price. In other words, as long as there is LNG in the resource pool, the IRR of the projects increases with the increase in JCC, indicating that the "gas-to-electricity price linkage" mechanism in Zhejiang Province has played a better role in price diversion. However, in terms of the absolute value of the IRR of the project, the return of the project in Zhejiang Province is relatively stable and at a lower value.

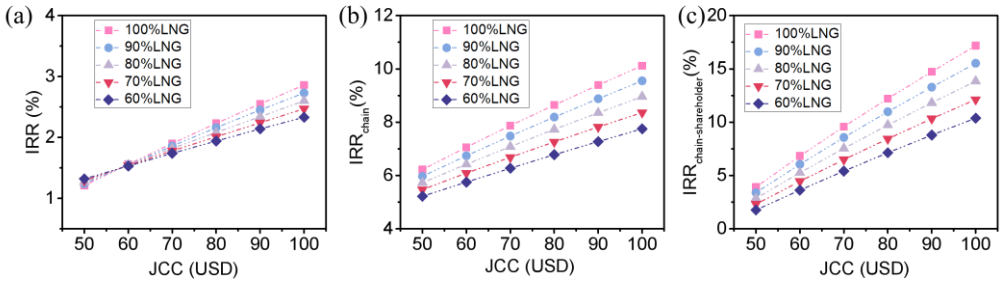


Figure 4. IRR of power plant B with different JCC prices in Zhejiang Province. (**a**) The project IRR of power plant B with different JCC prices; (**b**) The project IRR_{chain} of power plant B with different JCC prices; (**c**) The project $IRR_{chain\text{-}shareholder}$ of power plant B with different JCC prices.

Comparing the IRR (Figure 4a), IRR_{chain} (Figure 4b), and $IRR_{chain\text{-}shareholder}$ (Figure 4c) under different JCC prices, it is shown that both IRR_{chain} and $IRR_{chain\text{-}shareholder}$ show the same trend as the project IRR, although the project IRR is at a lower value, and the IRR_{chain} and $IRR_{chain\text{-}shareholder}$ are both higher.

In conclusion, investing in GPG projects in Zhejiang Province requires less upstream resources, and a project using 100% LNG resources can still be profitable. However, the overall yield is at a low level due to the low utilization hours of GPG projects in the region. The province's well-established "gas-to-electricity price linkage" mechanism can be utilized to effectively guard against the impact of natural gas price fluctuations on project yields. At the same time, the project has a sizable incremental profit in the industry chain, and the region is suitable for investors without upstream resources to invest in GPG projects.

3.4. Research on "Gas-to-Electricity Price Linkage" Mechanisms in Different Regions

In order to more intuitively compare the effects of the "gas-to-electricity price linkage" mechanism in the three regions, we use the control variable method to assume that the annual utilization hours of power generation in each region are 3000 h, and all other conditions remain unchanged, to explore the project and industry chain yield situation in each region under different oil price conditions. The results are shown in Figure 5. It is suggested that the trends in IRR (Figure 5a,d,g), IRR_{chain} (Figure 5b,e,h), and $IRR_{chain\text{-}shareholder}$ (Figure 5c,f,i) in the three regions do not change with the change in utilization hours. Comparing the IRR, IRR_{chain}, and $IRR_{chain\text{-}shareholder}$ absolute values for the project, the rate of return in Zhejiang Province has a smaller variation and is in a higher range, followed by Jiangsu Province, where the rate of return fluctuates more, and lastly Guangdong Province, where the rate of return fluctuates the most.

Oil and gas enterprises with diverse gas sources are more competitive in Guangdong Province and Jiangsu Province. Enterprises lacking upstream gas sources are more suitable for investment for GPG projects in Zhejiang Province. Due to the weak diversion effect of "gas–electricity price linkages" in Guangdong Province and Jiangsu Province, only a portion of the rising cost of fuel has been diverted. Investments in Guangdong and Jiangsu Province need to be matched with diversified upstream gas sources. The process of operating the GPG project requires domestic gas to effectively cope with natural gas price fluctuations, so that the chain of oil and gas enterprises can achieve higher returns. Investing in Zhejiang Province requires less upstream resources and requires the utilization of power sales companies to develop downstream customers and improve annual utilization hours.

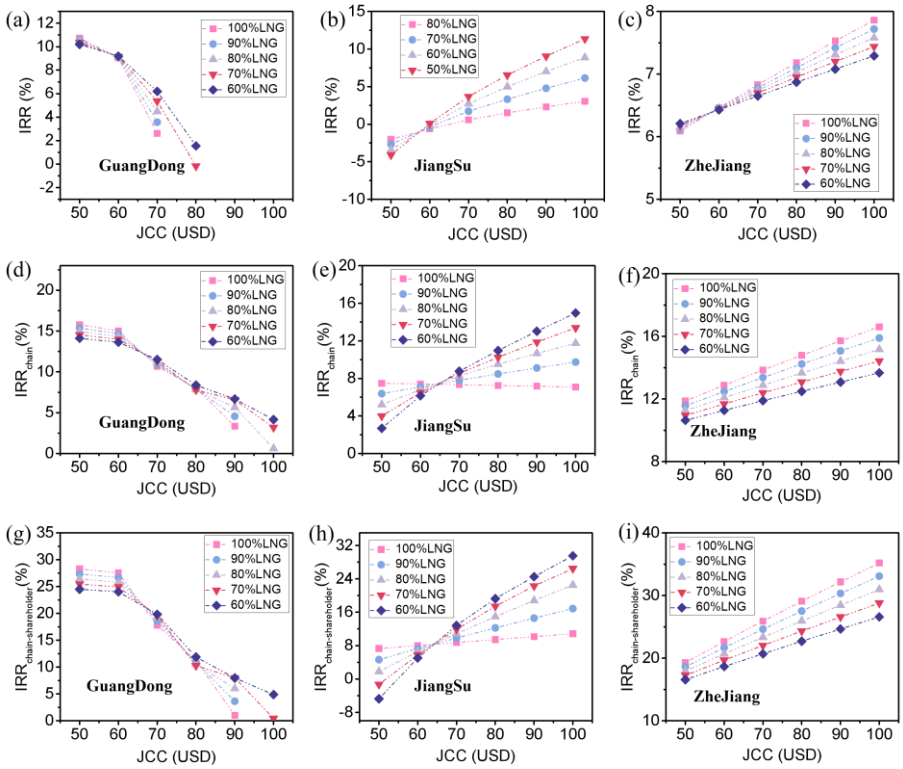


Figure 5. IRR of power plant B at 3000 h. (**a**) The project IRR of power plant B with different JCC prices in Guangdong Province; (**b**) The project IRR of power plant B with different JCC prices in Jiangsu Province; (**c**) The project IRR of power plant B with different JCC prices in Zhejiang Province; (**d**) The project IRR_{chain} of power plant B with different JCC prices in Guangdong Province; (**e**) The project IRR_{chain} of power plant B with different JCC prices in Jiangsu Province; (**f**) The project IRR_{chain} of power plant B with different JCC prices in Zhejiang Province; (**g**) The project $IRR_{chain\text{-}shareholder}$ of power plant B with different JCC prices in Guangdong Province; (**h**) The project $IRR_{chain\text{-}shareholder}$ of power plant B with different JCC prices in Jiangsu Province; (**i**) The project $IRR_{chain\text{-}shareholder}$ of power plant B with different JCC prices in Zhejiang Province.

4. Strategy

4.1. Investment Strategy

(1) For oil and gas enterprises, there is a natural resource advantage in the field of gas power plant investment, compared with traditional power generation enterprises. The anti-risk properties of oil and gas enterprises are stronger, and resource rationing can be utilized to better cope with the risk of rising fuel costs caused by rising gas prices.

(2) Oil and gas enterprises have a complete natural gas industry chain, and investment in gas power generation can effectively grow the natural gas industry chain's upstream trade profits. It is recommended that oil and gas enterprises actively invest in or participate in the use of gas-fired power plants. The gas power plant projects will drive regional natural gas sales, so as to seize the regional market, and enhance the overall profits of the industry chain. At the same time, oil and gas companies can invest in gas power plants to enhance the bargaining power of natural gas trade and safeguard the upstream revenue.

(3) In the industry chain, investment in gas-fired power generation can lead to significant incremental revenue in the infrastructure and pipeline sector. However, the natural gas trading sector is characterized by high risks and high returns. Therefore, oil and gas enterprises can choose the share ratio of each sector of the industry chain according to risk appetite. Investors with a high risk appetite are advised to increase the share ratio in the natural gas trading sector. Investors with a low risk appetite are advised to increase the share ratio in the infrastructure sector.

(4) Investment of oil and gas enterprises in GPG projects needs to effectively utilize the advantages of the "gas-to-electricity price linkage" mechanism in different regions. These enterprises can improve the overall industry chain profitability through resource allocation.

(5) Regarding "gas-to-electricity price linkage" mechanisms in different provinces:

In Zhejiang Province, the "gas-to-electricity price linkage" mechanism has a more obvious cost-reducing effect, and projects are less dependent on low-priced domestic gas resources. It is suitable for enterprises lacking upstream gas resources in the region to invest in GPG projects. However, the utilization hours of power generation in Zhejiang Province are low, and the driving effect on the industrial chain is not as good as that of the other two provinces. At present, the Zhejiang Provincial Government plans to implement a number of policies to increase the annual utilization hours of GPG. Once the annual utilization hours has risen, Zhejiang Province will become a high-quality GPG project investment region.

In Jiangsu Province, compared with traditional power generation companies, oil and gas enterprises have more room to maneuver, using the advantage of resource rationing. However, the yield of power generation projects in Jiangsu Province is low. The profitability of these projects is too dependent on domestically produced gas resources. But even if a single project experiences a loss, for the whole industry chain, the driving effect is still very obvious. Therefore, for oil and gas enterprises, the decision-making process for GPG projects in Jiangsu Province should be examined more for its role in driving the industry chain.

In Guangdong Province, although the "gas-to-electricity price linkage" mechanism is not as effective as in the other two provinces, the scale of GPG in Guangdong Province is relatively large. The annual utilization hours of GPG in Guangdong Province are higher, and the IRR of projects is higher with low oil prices. Due to the power shortages throughout the region, there are more investment opportunities in GPG, and higher overall electricity prices in Guangdong Province protect the project's expected returns. Oil and gas enterprises can utilize their resource advantages to participate in the construction of, or merger and acquisition of, some gas-fired power plants. These companies can adjust their operation strategies according to the oil price situation to enhance the profitability of the whole chain.

In addition to the price of electricity and gas, it is necessary to analyze the supply/demand balance, construction costs, and labor costs in the electricity market in the geographic area. This paper only deals with the dimension of "gas-to-electricity price linkage" and "annual utilization hour characteristics" to analyze the IRRs of the individual projects and the industrial chain, to provide a quantitative reference for oil and gas enterprises to make investment decisions.

4.2. Operation Strategy

Resource allocation can be adjusted in conjunction with oil price forecasts to achieve stable or higher yields. It can be seen that there exists a price (P_0) in both Guangdong and Jiangsu. When JCC = P_0, IRR always remains unchanged, no matter how the proportion of LNG resources changes. When JCC > P_0, the proportion of LNG resources needs to be reduced; when JCC < P_0, the proportion of LNG resources needs to be increased, in order to enhance the industrial chain revenue of oil and gas enterprises. However, in Zhejiang province, oil and gas enterprises need to raise the proportion of LNG resources.

5. Conclusions

This study analyzed the current development status, tariff mechanism, and future plans for GPG in the three provinces with the large GPG project installations in China. Combining the characteristics of the natural gas power generation industry chain of oil and gas enterprises, a set of economic evaluation methods based on the industry chain was constructed, on the basis of the cash flow analysis method, combined with the marginal contribution theory. The evaluation methodology was used to analyze the IRR on project investment and the effectiveness of the "gas-to-electricity price linkage" mechanism in

three provinces. The results showed that Zhejiang Province has the best cost-sparing effect from the "gas-to-electricity price linkage" mechanism, followed by Jiangsu Province and finally Guangdong Province. Finally, according to the development policies and market characteristics of GPG projects in different regions, corresponding recommendations are put forward to provide ideas and references for oil and gas enterprises to invest in GPG or the layout of the related industrial chain in the future.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/fuels5040039/s1. Supplementary Materials include Supplementary Notes, Supplementary Tables and Supplementary Figures. Supplementary Notes: S1. Status, Planning, and Policies of GPG in Major Regions of China; S2. Financial evaluation model for GPG in industrial chain; S3. Basic parameters of the industrial chain; S4. Basic parameters of GPG project B. S5. Validation of the financial evaluation model for GPG in the industrial chain. S6. Discussion of carbon capture and storage (CCS). Supplementary Figures: Figure S1: Incremental cash inflows and outflows in the LNG receiving chain. Figure S2. Financial evaluation of Project C and industry chain. Figure S3. Average annual revenue from natural gas-related sectors. Supplementary Tables: Table S1: GPG projects in Guangdong Province, 2019–2022; Table S2. Feed-in tariff level for GPG projects in Guangdong Province; Table S3. Guangdong Provincial Gas and Electricity Linkage Mechanism; Table S4. "14th Five-Year Plan" GPG Key Projects in Guangdong Province; Table S5. GPG in Jiangsu Province, 2019–2022; Table S6. Benchmark feed-in tariff table for GPG units in Jiangsu Province; Table S7. GPG Key Projects during "14th Five-Year Plan" in Jiangsu Province; Table S8. GPG in Zhejiang Province, 2019–2022; Table S9. Basic parameters of the industrial chain; Table S10. Basic parameters of Project B. Table S11. Basic parameters of the industrial chain.

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