Research on the Risk Warning about the Investment & Construction of China's Overseas Coal-fired Power Projects

——Country-specific Research on Indonesia

GREENPEACE 绿色和平

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Expert Recommendation

Southeast Asian countries have always been hot areas for overseas investment of Chinese enterprises. Among them, Indonesia enjoys promising population base dividends and economic development expectations, a special 35GW encouragement policy, as well as a comprehensive two-part tariff policy. Indonesia, together with Pakistan and Bangladesh, has become the top priority for overseas power investment by Chinese enterprises in recent years.

Indonesia's resource endowment and national policy determine its foreign power policy, mainly on coal-fired power. In recent years, Chinese enterprises have been increasingly building new coal-fired power projects around the world in the form of equity investment. This trend has also caused Chinese enterprises and financial institutions to take more long-term risks from overseas coal-fired power projects. Therefore, it is urgent to provide Chinese developers, debt capital, and regulatory authorities with a realistic forecast and risk analysis on coal-fired power investment in Indonesia. In such case, the *Research on the Risk Warning about the Investment & Construction of China's Overseas Coal-fired Power Projects: Country-specific Research on Indonesia* jointly conducted by the international environmental protection organization Greenpeace and Shanxi University of Finance and Economics is launched at the right time and is of great practical significance.

Building on the methodology of the National Energy Administration for risk warning about coal-fired power planning and construction, this report mainly makes analysis on the investment and construction of coal-fired power projects from three aspects: redundancy of coal-fired power installed capacity, economy of coal-fired power investment and construction and resource constraints.

The redundancy of installed capacity is the fundamentals: China's thermal power investment in Indonesia has been near its peak, making it difficult to reasonably determine when Indonesia will face a power surplus like Pakistan. The report is of good scientificity by focusing on the percentage reserve of the power system and making analysis based on the actual data of Indonesia. Its conclusions on the redundancy in different regions are also consistent with the cognition of many front-line developers.

The economy of coal-fired power projects is the internal motivation: Without relying on the common one-part tariff mechanism in China, the report analyzes, in accordance with the reality of Indonesia, the economy problems based on the two-part tariff mechanism from the perspectives of rate of return and factors affecting the rate of return.

Resource constraint is a significant factor influencing risk aversion guidelines and future trends: This section will be focused by host countries, investors, financing banks, environmental institutions, and other stakeholders before choosing their own future policies.

In general, I think this report is a work that combines theory with practice because it combines the actual situation under the Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) of Indonesia and the concerns of Chinese enterprises going global. It is also a good research report which adopts appropriate research methods and reasonable data, draws highly reliable conclusions, and make actionable policy recommendations.

Greenpeace has issued several influential reports previously. Without feature-length dogmatic preaching regarding energy conservation and emission reduction, this report makes an objective and comprehensive analysis on the "less environmental-friendly" sector of Indonesian coal-fired power, and indirectly guides pragmatic practitioners to pay attention to and support environmental protection. This is also a great wisdom of Greenpeace.

Tong Gang, head of No.1 Investment and Financing Department, PowerChina International Group Limited

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Executive Summary

Since Indonesia successively implemented two power development plans of 10GW and 35GW, its domestic installed capacity of coal-fired power has risen rapidly, greatly improving the widespread power shortages in Indonesia from the end of last century to the beginning of this century. During this period, Chinese-funded power enterprises also actively participated in the construction of coal-fired power in Indonesia, continuously expanding the installed capacity of coal-fired power projects invested in the local areas. As of 2018, the coal-fired power projects of more than 7 GW invested by Chinese power enterprises were still under contract or under construction. However, with the rapid development of Indonesia's power industry and the substantial increase in grid coverage, the following three questions need to be paid more attention to and discussed:

1) The development scale of Indonesia's power market in the future;
2) The profitability of coal-fired power in the future and the possibility of achieving the desired rate of return by continued investment in coal-fired power;
3) With the increasingly severe environmental issues, whether Indonesia's resource and environmental conditions allow continued construction of a large number of new coal-fired power projects.

The above three problems are analyzed and discussed in this report. According to the RUPTL of Indonesia, the country is divided into five major regions in this report, namely Java-Bali, Kalimantan, Sulawesi, Sumatra and Maluku-Papua. In addition, this report analyzes the status quo of the three indicators: redundancy of coal-fired power installed capacity, economy of coal-fired power investment and construction and resource constraints in the five major regions in 2017, and also makes a scenario prediction for the changes of three indicators in 2022 from the aspects of high economic growth (GDP growth of 5.9%, Scenario 1) and low economic growth (GDP growth of 5.2%, Scenario 2).

- **Analysis on the redundancy of installed capacity of coal-fired power**

The reserve margin[1] of power system is used in this report as the basis for judging whether the coal-fired power capacity in each region is excessive. It is considered as overcapacity when the actual reserve margin of power system in a region is greater than a reasonable reserve margin. On the basis of measuring the reserve margin of power systems in the five major regions of Indonesia in 2017, this report makes a scenario prediction and warning analysis on the reserve margin of power systems in each region in 2022.

In high economic growth scenario (Scenario 1), in 2022, except that the actual reserve margins of power systems in Sulawesi and Maluku-Papua regions are lower than the reasonable reserve margin, the actual reserve margins of power systems in Java-Bali, Kalimantan and Sumatra regions are all greater than the reasonable reserve margin, indicating that in this scenario, coal-fired power overcapacity will occur in these three regions, with the excess capacity of 6,686 MW, 164 MW and 128 MW respectively. Compared with 2017, the actual reserve margins of power systems in the five major regions will rise by different degrees. Except for a small rise in Sulawesi region, the other four regions have risen over 100%. In general, due to the large installed power generation capacity between 2018 and 2022, it is difficult to achieve rapid growth in power demand. Therefore, with the smooth implementation of the RUPTL of Indonesia, even if Indonesia can achieve a faster economic development, there will be severe coal-fired power overcapacity in the Java-Bali region in 2022, and a slight coal-fired power overcapacity in the Kalimantan and Sumatra regions.

1 The reserve margin of a power system is the percentage of the equivalent available installed power capacity over the maximum power load demand

In low economic growth scenario, that is, when Indonesia's economy grows at a relatively low rate (5.2%), coal-fired power overcapacity in each region will worsen further. The coal-fired power overcapacity in Java-Bali, Kalimantan and Sumatra regions will further increase to 8,164 MW, 460 MW and 891 MW respectively. Meanwhile, the coal-fired power overcapacity will occur in the Maluku-Papua region.

- **Economic analysis on coal-fired power investment and construction projects**

Based on the existing two-part tariff mechanism in Indonesia, an internal rate of return (IRR) indicator is used in this report to assess the economy of the coal-fired power projects invested and constructed by Chinese enterprises and financial institutions in different regions of Indonesia, and make a scenario prediction of the economy of coal-fired power projects in 2022 based on two scenarios of high and low economic growths.

In high economic growth scenario, the tariff in Indonesia is basically unchanged, while the annual utilization hours of coal-fired power show a slight decline. The prediction result shows that in 2022, the IRR of coal-fired power projects in Sumatra and Sulawesi regions will be higher than 10%, but lower than the IRR of general projects (12%); the IRR in Java-Bali and Kalimantan regions will be below 10%, which is not suitable for coal-fired power project investment due to insufficient attraction and small profit margin. In low economic growth scenario, the growth of Indonesia's power demand tends to slow down, the tariffs will fall, and the annual utilization hours of coal-fired power will also decline sharply. Compared with the high economic growth scenario, the power demand in the Maluku-Papua region reduces, the power supply is relatively abundant, the investment economy also reduces, and the return on investment also decline; the IRR of coal-fired power projects in Sumatra, Kalimantan, Sulawesi and Java-Bali regions is lower than 10%, which is not suitable for coal-fired power project investment in the future due to relatively centralized installed capacity and weak investability. In addition, under the premise of assuming that the rigid payment of Indonesia's take-or-pay clauses is broken, this report also makes a sensitivity analysis on the IRR of coal-fired power projects for the sensitive indicators. According to the analysis, the main sensitive indicators affecting the IRR of Indonesia's coal-fired power projects are the estimated annual utilization hours, the feed-in tariff of coal-fired power and the estimated standard coal price.

- **Analysis on resource constraints**

This report analyzes the resource and environmental constraints imposed on Indonesia's coal-fired power projects from three aspects: water resources, air pollution and climate change. The water resource constraints and air pollution faced by different regions are evaluated using the indicators of baseline water stress of the World Resources Institute (WRI) and $PM_{2.5}$ concentration respectively; while climate change is characterized by carbon dioxide emissions, which are calculated using the default methods provided in the IPCC Guidelines for National Greenhouse Gas Inventories in 2006. Due to the limitation of data availability, the year in which data are used in the three-aspect evaluation also differs.

The evaluation results for water resources, air pollution and climate change are as follows:

1) In 2010, Indonesia had abundant water resources throughout the country, with less water stress, but the regional distribution was severely uneven. Among them, Java-Bali was in the high water stressed region, with the baseline water stress of 55%. In 2020, the baseline water stress in the Java-Bali region will rise to 59%, and water resource pressure is relatively high.
2) In 2016, the air quality in Sumatra region was the worst, with an average annual $PM_{2.5}$ concentration of 29.44 μg/m^3, missing the target in the transitional phase 2 of the World Health Organization (WHO) International Standard. The annual average $PM_{2.5}$ concentrations in Kalimantan and Java-Bali regions were better than that in Sumatra region, but missed the target in the transition phase 3.

3) From 2010 to 2017, the annual carbon dioxide emissions in Java-Bali region were the largest, account for 59% of the total in the country; Sumatra region was the second, accounting for 22%.

As for the warning system, this report establishes an Indonesian coal-fired power investment and construction risk warning index system consisting of two warning indicators: redundancy of coal-fired power installed capacity and economy of coal-fired power investment and construction. The former indicator reflects the redundancy of local coal-fired power installed capacity, and the latter reflects the economy of the construction of local self-use coal-fired power projects, providing decision-making references for investment and construction of coal-fired power projects. The final risk warning result, which is determined by the highest ratings of the two indicators, aims to provide systematic and detailed evaluation data for government policy-making departments, coal-fired power investment enterprises, financial institutions and other investors to further improve the policy and decision.

The risk warning indicator in this report has two ratings: red and orange. Red indicates that there is an ultra-high risk of coal-fired power investment and construction in 2022, and orange indicates that there is a high risk of coal-fired power investment and construction. The warning standard for the redundancy of coal-fired power installed capacity in this report is: Orange indicates that the actual reserve margin of power system is higher than the reasonable reserve margin, and the excess part is greater than the corresponding reserve margin of a local single large-sized coal-fired power unit, but lower than the corresponding reserve margin of the installed capacity required for the annual increase of local electrical load; while red indicates that the actual reserve margin of power system is higher than the reasonable reserve margin, and the excess part is greater than the corresponding reserve margin of the installed capacity required for the annual increase of local electrical load. The warning standard for the economy of investment and construction in this report is: Red indicates that the IRR is below 10%, and orange indicates that the IRR is from 10% to 12%.

It can be seen from the comprehensive warning results that the comprehensive warning results of Java-Bali and Kalimantan regions in the high economic growth scenario are both red, indicating that coal-fired power investment and construction in these two regions will face higher risks and these two regions are greatly constrained by various indicators. In the low economic growth scenario, the warning results of Sumatra, Java-Bali, Kalimantan and Sulawesi regions are all red, indicating that the coal-fired power investment and construction in these regions will face higher risks. Among them, the comprehensive warning result of Sulawesi region is changed from orange to red, indicating that the investment risk in terms of economy in Sulawesi region is higher than that in the high economic growth scenario. The comprehensive warning result of Maluku-Papua region rises to orange, indicating that the investment risks in terms of redundancy of installed capacity and economy become higher; and the comprehensive warning result of Sumatra region keeps unchanged, but the investment risks in terms of redundancy of installed capacity and economy are higher than that in the high economic growth scenario. In general, it will be highly risky to invest and construct coal-fired power projects in Indonesia in 2022. In addition to the regions with red and orange warning, investors also need to be on the alert for the potential future risks of coal-fired power investment in other regions.

Based on the analysis result above, the policy recommendations are made as follows:

1) China's relevant government decision-making and management departments should establish a risk warning system for China's overseas coal-fired power investment in the major host countries, and guide and urge enterprises to fully consider factors that may affect the long-term operation of coal-fired power projects in their early investment decision-making plans. In addition, they should also manage the new coal-fired power projects in the overseas high-risk regions through the rational use of public funds and the policy regulations of warning systems.
2) Equity investment enterprises should establish and improve long-term risk evaluation systems for the projects, and gradually improve their awareness and ability to control long-term risks such as global energy transition and climate changes.
3) Banks, insurance companies and other financial institutions should improve their understanding and risk evaluation capabilities of the long-term operating market of overseas coal-fired power projects, identify high-risk projects, and strictly control financing or guarantees for high-risk projects.
4) Indonesian government should fully consider the medium-/long-term impact of excessively rapid growth of power supply construction, energy transition and environmental & resource constraints on coal-fired power investment, promptly stop approving newly established coal-fired power projects in high-risk regions, and improve its own energy development planning capabilities and the reasonability and stability of its energy policies to carry out energy transition from coal to renewable energy.

Contents

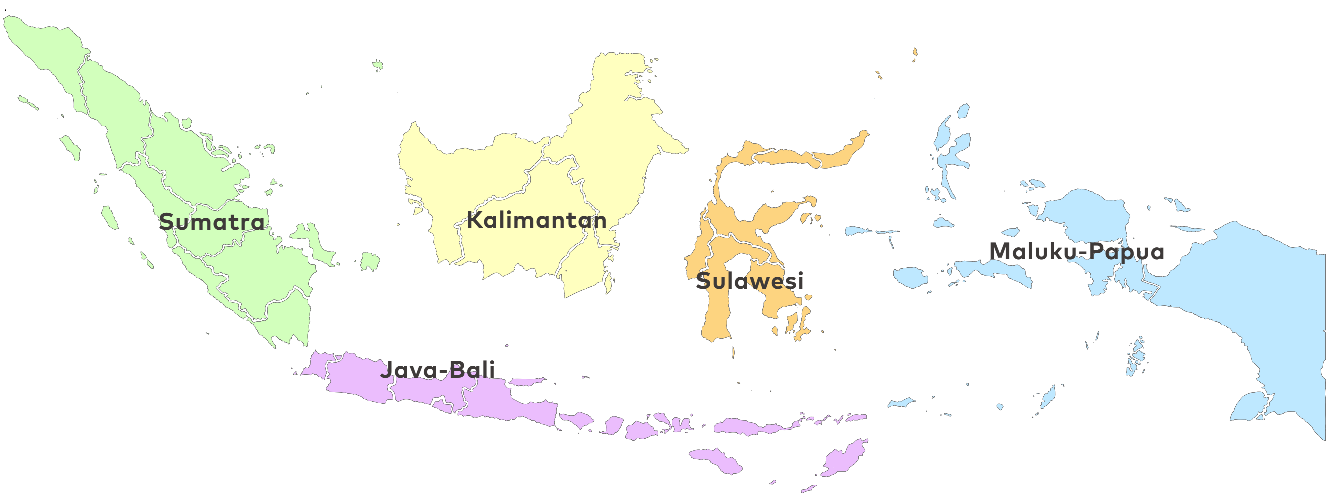
Preface

Since the early 1990s, Chinese enterprises, especially coal-fired power enterprises dominated by state-owned enterprises and with significant technological advantages, have gradually quickened the pace of "going-out". As a country rich in coal resources, China's coal-fired power industry has flourished in the past forty years, producing a number of advanced technologies in terms of coal-fired power generation and terminal pollutant abatement. With the maturity of technology and the accumulation of experience, Chinese coal-fired power enterprises have become the main force in the global coal-fired power market. In recent years, China has continuously strengthened power cooperation with other countries, and exported more technologies, equipment and capitals. Coal-fired power has also become an important part of China's overseas power investment. However, facing the complex market environment and the fragile natural environment in the host countries of investment, China's overseas coal-fired power investment may face various risks in policy, environment and economy. On one hand, the lack of energy planning experience and the relatively weak financial support system of the host countries have become the main reasons of business risks for China's overseas coal-fired power investment enterprises. On the other hand, subject to local economic and social development levels, environmental capacity constraints and related policies and systems, Chinese enterprises and financial institutions will face potential environmental and ecological risks. Therefore, China urgently needs to establish a set of powerful country risk evaluation and warning mechanism to detect and avoid the risks of overseas coal-fired power investment as soon as possible. Since the release of the *Notice on the Establishment of Risk Warning Mechanism for Coal-fired Power Planning and Release of Risk Warning for Coal-fired Power Planning and Construction* in 2016, the National Energy Administration has established a risk warning index system for domestic coal-fired power planning and construction, effectively putting forward countermeasures for how to avoid potential risks in coal-fired power construction from the perspectives of redundancy of coal-fired power installed capacity, economy of coal-fired power investment and construction and resource constraints. Such a warning system can be used in China's overseas coal-fired power investment to help Chinese enterprises and financial institutions identify and avoid risks.

Chinese enterprises have had years of experience in overseas coal-fired power projects investment by involvement types of equity investment, financial support, EPC (Engineering, Procurement, and Construction), or equipment export. Judging from the total capacity of projects involved, Indonesia is one of the countries with the largest overseas coal-fired power investment by Chinese enterprises, and is also the largest energy producer and consumer in Southeast Asia. Therefore, Indonesia is selected for country-specific research in this report. By analyzing the coal-fired power investment environment and risks in Indonesia, this report aims to establish a risk warning system for coal-fired power investment to help Chinese enterprises and financial institutions avoid the potential risks of coal-fired power investment in Indonesia to the greatest extent.

This report will make warning analysis on the risks of investment and construction of coal-fired power projects in Indonesia. According to the RUPTL of Indonesia, the country is divided into five major regions in this report, namely Java-Bali, Kalimantan, Sulawesi, Sumatra and Maluku-Papua, as shown in Figure 0.1. In combination with the economic growth, geographical characteristics and power supply and consumption in these five regions, this report makes a comprehensive evaluation on the possible risks of the coal-fired power investment and construction in these five major regions in 2022, and gives the comprehensive warning results of coal-fired power investment and construction. The warning target year is mainly set based on the two aspects:
1) Short-term prediction is more accurate and reliable than long-term prediction;
2) The three-year short-term warning model developed by the National Energy Administration of China for domestic coal-fired power projects has become more mature and can be used as a reference for other countries. This report mainly conducts risk prediction and warning research on coal-fired power investment and construction projects in the five major regions of Indonesia from the aspects of redundancy of installed capacity, economy and resource constraints. Among them, the redundancy of installed capacity reflects the redundancy of local coal-fired power installed capacity; the economy reflects the economy of coal-fired power projects, providing decision-making references for investment and construction of coal-fired power projects; and resource constraint reflects the degree of resource and environmental impacts on the planning and construction of local coal-fired power projects. The three indicators can comprehensively cover the risk sources of coal-fired power investment in terms of economic benefits, market space and environmental carrying capacity. On this basis, this report makes risk warning and targeted policy recommendations for Chinese government departments, enterprises and financial institutions to invest and construct coal-fired power projects in Indonesia.

Figure 0.1 **Schematic diagram of five major regions in Indonesia**



01 Overview of Power Development in Indonesia

As the most populous country in Southeast Asia, Indonesia has a population growth of about 1.31%, with over half of the population living in the western region. It has the largest power market in Southeast Asia[1]. According to the data of the Construction Sector of Indonesia in 2017, the per capita power consumption in Indonesia is still at a low level, which is about 1/4 of that of Malaysia and has a large room for growth[2].

1.1 Coal resource conditions in Indonesia

Indonesia boasts good conditions for coal-fired power projects due to its high coal production and vast land. According to the energy statistics of British Petroleum Company (BP), Indonesia's proven reserves of coal reached 22.598 billion tons in 2017, ranking 10th in the world, and accounting for about 2.2% of the world's total reserves. However, due to the vast production and export of coal, the coal reserves/production ratio in Indonesia is merely 49, which is significantly lower than the global average of 134.

Indonesia's proven reserves of coal are mainly distributed in Sumatra and Kalimantan regions, especially the central and southern regions of Sumatra and the central, eastern and southern regions of Kalimantan. Most of the coal mines in Indonesia are open-pit ones with good mining conditions, and the commercial recoverable reserves amount to 4.45 billion tons. The reserves of coal in Indonesia are mainly lignite and sub-bituminous coal[3], accounting for 58.68% and 26.60% respectively, and featuring high moisture, low ash content, low sulfur content, and high volatility.

1.2 Power construction in Indonesia

At the beginning of this century, Indonesia began to reform its domestic power system. However, under the influence of various international and domestic factors, the power supply seriously lagged behind the power demand, limiting its economic development. In order to get out of the predicament of power insufficiency, Indonesia began to implement a new national power master plan in 2006, which was formulated by the state-owned electric utility, Indonesian Perusahaan Listrik Negara (hereinafter referred to as PLN). Since then, Indonesia had successively introduced multiple "10GW Plans"[4] to increase the installed power generation capacity. The then President Joko Widodo proposed the "35GW Plan"[5] after he came to power in 2014, that is, an additional 35 million kilowatts of installed power generation capacity would be added during the 2015-2019 period.

However, Indonesia's average annual economic growth has not reached the target of 7% in the past few years, and the power demand has not experienced the expected substantial increase. As a result, the "35GW Plan" was progressing slowly, and it is expected that only 50% will be completed by the end of 2019, the remaining 50% will be completed during 2023 and 2025. Therefore, the expected increase in power demand and the planned additional installed power generation capacity in the RUPTL (2018-2027) are reduced compared to that in the RUPTL (2017-2026), with a view to controlling the installed power generation capacity to prevent excess power.

According to the statistics in the RUPTL (2018-2027), as of the end of 2017, Indonesia's total power generation capacity was 55,925.96 MW, and is expected to reach 91588.96 MW in 2022[6]. From the perspective of geographical distribution, the power development in the five major regions of Indonesia is extremely uneven. The installed capacity of Java-Bali region accounts for about 74.2% of the total of the country, Sumatra region accounts for 16.7%, and the remaining regions account for 9.1%. From the perspective of supporting facilities, due to the constraints of the objective geographical environment, Indonesia has not yet formed a unified power grid system. Except for the largest Java-Madura-Bali Electricity Grid in the country and the Sumatra Power Grid under accelerated construction, the power grids or power stations in other regions are small in size or isolated, and the overall grid system is backward. For the 46,831 km supporting power grid proposed in the "35GW Plan", only 6,819 km has been completed and put into use at the end of 2017, accounting for only 15%, and leaving a large amount of power grids to be constructed.

On the whole, with the strong support of the Indonesian government for the power industry, the country's installed power generation capacity has increased rapidly in recent years. As of December 2017, Indonesia's total installed power generation capacity was 55,925.96 MW, the power generation capacity was 290 TWh, the total national power consumption was 247 TWh, and the per capita power consumption was 978.74 kWh[6]. The access to electricity nationwide in Indonesia is 93.08%.

02 Risk evaluation of coal-fired power investment in the five major regions of Indonesia

The Chapter 2 and Chapter 3 of this report analyze the status quo of coal-fired power investment and construction risks in the five major regions of Indonesia in 2017 from three aspects [2]: redundancy of installed capacity, economy and resource constraints, and predict the investment and construction risks in 2022, thus establishing a risk warning system for coal-fired power investment and construction in Indonesia in 2022.

2 The Notice on the Establishment of Risk Warning Mechanism for Coal-fired Power Planning and Release of Risk Warning for Coal-fired Power Planning and Construction released by the National Energy Administration was referenced for the establishment of the evaluation system.

2.1 Analysis on the redundancy of installed capacity of coal-fired power

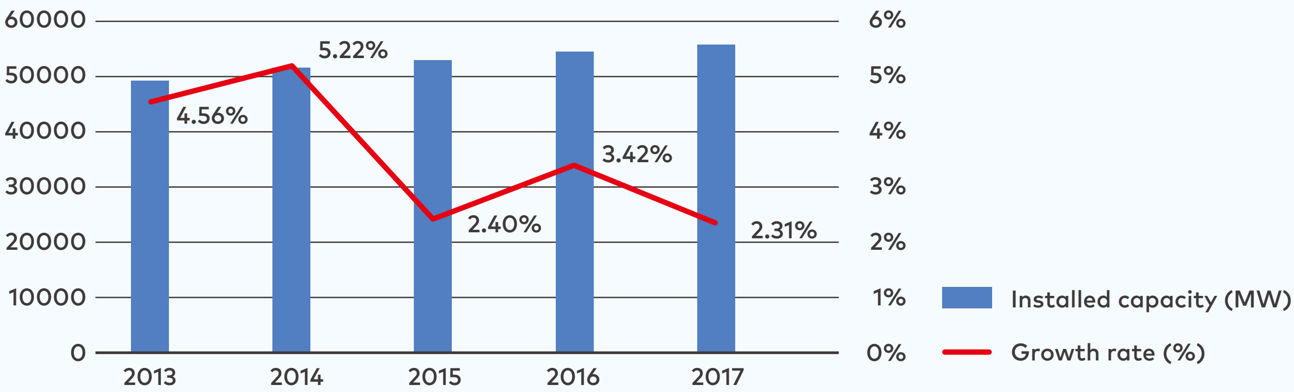
2.1.1 Status quo of the redundancy of coal-fired power investment and construction

Indonesia's power industry is developing rapidly, and the current power structure is dominated by coal-fired power. Its renewable energy is mainly hydropower, geothermal and biomass power generation, with a small amount of photovoltaic and wind power installed, which develops slowly on the whole. According to the statistics of the PLN Annual Report (2017), by the end of December 2017, PLN and its subsidiaries had 5,389 sets of generating units with a total installed capacity of 39,651.79 MW, of which 28,725.53 MW (72.44%) were located in the Java-Bali region. The installed capacity of various types of generating units are: steam turbine: 19,530.50 MW (49.26%), combined cycle: 9,022.54 MW (22.75%), diesel: 3,880.02 MW (9.79%), hydropower: 3,583.15 MW (9.04%), gas turbine: 3,075.83 MW (7.76%), geothermal: 550.89 MW (1.39%), and solar and wind power: 8.86 MW (0.02%). Together with the installed capacity of independent power producers (IPPs) and leased power stations, the total installed capacity of power generation in Indonesia is 55,925.96 MW, an increase of 2.31% compared with that by the end of December 2016. Among them, the installed capacity of IPPs and leased power stations was 23.73% and 5.37%, respectively. The PLN's share of installed capacity decreased in relation to that in 2016, but still reached 70.90% [7].

PLN is in charge of power generation, power grid and energy planning across Indonesia. Its functions are similar to those of the former State Power Corporation of China. Indonesia needs to import complete sets of large-scale power equipment due to its lagging industrial and manufacturing system. Therefore, in order to reduce construction costs, Indonesia has gradually opened its power generation market. Some power projects were introduced to IPPs through international tendering, and the power produced by IPPs was sold to PLN through the signing of long-term power purchase agreements (PPAs). Although PLN's current share of installed capacity has dropped to 70.90%, the grid share is still 100% [8].

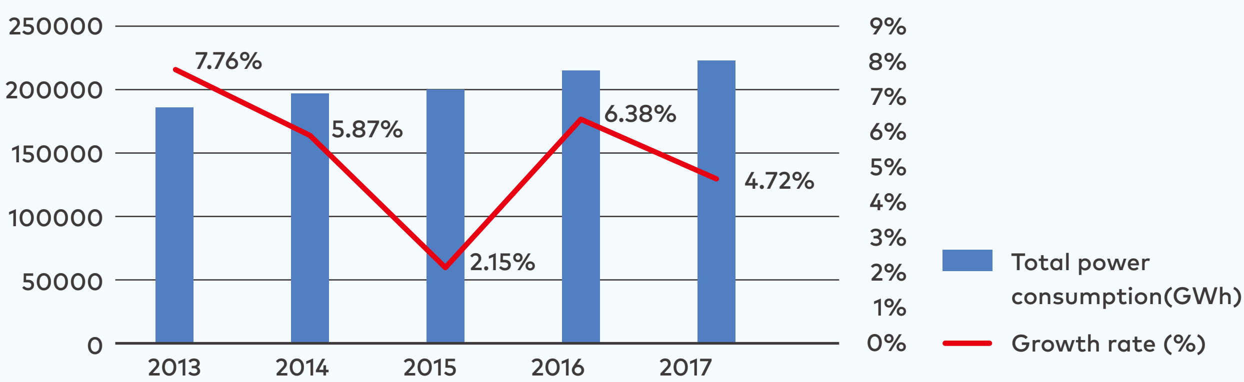
From 2013 to 2017, Indonesia's total installed power generation capacity increased at an average annual growth of 3.58%, lower than the GDP growth in the same period, and the growth of total installed capacity was lower than that of power demand during the same period except 2015. After two years of rapid growth, Indonesia's installed power generation capacity nationwide began to decline sharply in 2015. There are two main reasons for the small decrease in the growth of installed power generation capacity: 1) the previous two "10GW Plans" have basically been implemented; 2) in spite of the "35GW Plan" proposed by the new president Joko Widodo in 2014, the power stations need to be put into use after three to five years due to the long construction cycle, thus resulting in the low growth of the installed power generation capacity nationwide from 2013 to 2017.

Figure 2.1 Installed power generation capacity and its growth of Indonesia from 2013 to 2017



Source: PLN Annual Report (2013-2017) [9]

Figure 2.2 Total power consumption and its growth of Indonesia from 2013 to 2017

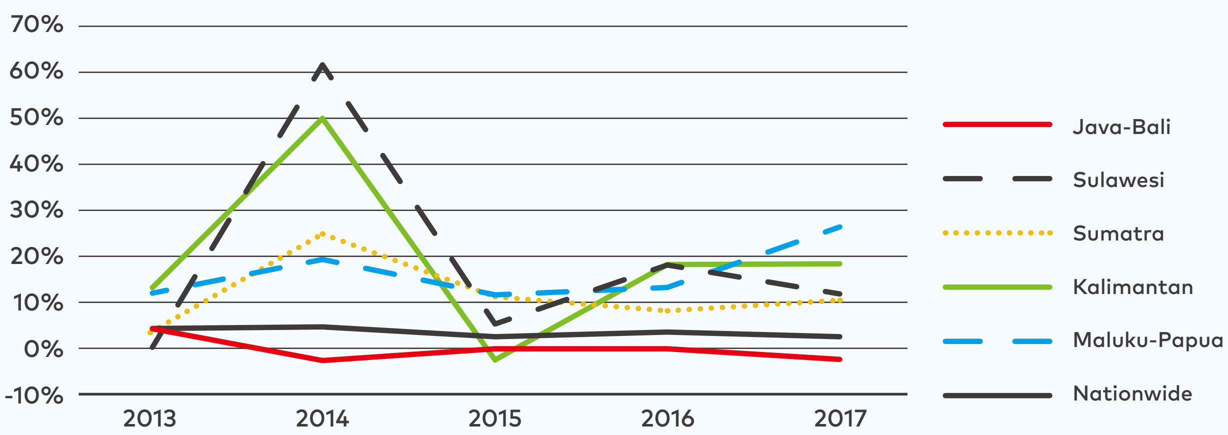


Source: PLN Annual Report (2013-2017) [9]

From the perspective of GDP growth [6], as the global economy had not yet recovered, the continued weakness of the international market in 2015 affected the export of Indonesia's staple commodities, resulting in the decrease in the growth of domestic consumption and foreign investment. In order to curb high inflation and currency depreciation, Indonesia adopted a tight monetary policy, leading to a drop in GDP growth to 4.88% in 2015. The drop in GDP growth further resulted in a sharp decline in the total power consumption, especially the growth of power consumption in the industrial sector, which was only 2.15% in 2015. The GDP growth in 2016 was 5.04%, and the growth of the total power consumption was 6.4%. The GDP growth remained basically unchanged in 2017, but the growth of the total power consumption declined to 4.72%, indicating that Indonesia's power consumption elasticity declined. This phenomenon could be attributed to changes in Indonesia's economic structure, which were mainly reflected by the gradual increase in the contribution ratio of the commercial sector to GDP. The relatively low demand for power by the commercial sector and no obvious increase of the industrial sector's share in GDP led to the decline in the elasticity of power consumption[7]. In addition, the expected growth of Indonesia's power demand in the RUPTL over the years was higher than the actual growth. Formulating a power supply construction plan based on such over-estimated power demand growth may cause the oversupply problem.

(1) Power supply in the five major regions

Figure 2.3 Growth of installed power generation capacity in the five major regions of Indonesia from 2013 to 2017



Source: PLN Annual Report (2013-2017) [8]

As seen from the growth of installed power generation capacity in the five major regions of Indonesia from 2013 to 2017:

- The growth of installed power generation capacity in the Java-Bali region is basically consistent with the growth trend of the installed capacity nationwide. However, except for the high growth of installed capacity in 2013, the growth of installed capacity in remaining years was lower than the national average, and the growth of installed capacity in 2014 and 2017 even showed negative values, indicating that the number of obsolete generating units in the region was slightly greater than the number of newly added generating units, thus resulting in a basically equal installed capacity.

- In the Kalimantan region, except for the negative growth of installed capacity in 2015, the growth in other years was higher, with an average annual growth of 19.79% over five years. The centralized implementation of the "10GW Plan" greatly increased the installed capacity in 2014, with a growth of up to 50.71%. This also caused a blank period of new installed capacity in 2015, leading to a decline in the growth of installed capacity. Such situation was improved after 2016, and the growth of installed capacity rebounded to a high level from 2016 to 2017. On the whole, the installed power generation capacity in the Kalimantan region had been greatly improved under a series of tendentious policy guidance of the Indonesian government.

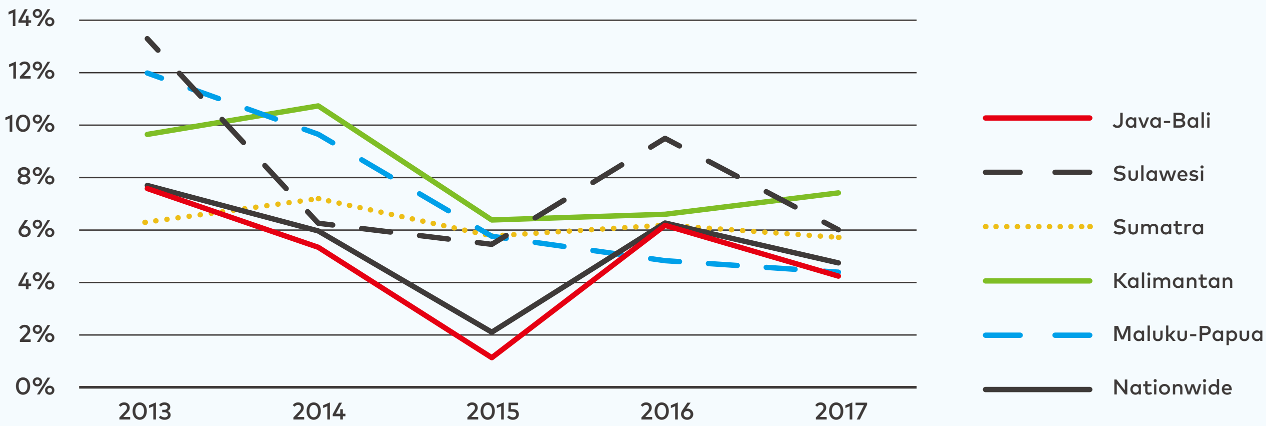
- The average annual growth of installed power generation capacity in Sumatra region from 2013 to 2017 was 12.09%, higher than the national average. The trend of the growth of installed capacity from 2013 to 2014 was the same as that in the Kalimantan region. The implementation of the previous power station construction plan made the installed capacity growth at a high level of 25.02% in 2014. Due to prosperous economy and large development potential in the Sumatra region, Indonesia National Electric Power Corporation had gradually abandoned the plan for the high-voltage DC submarine cable project in Sumatra-Java region, and solved the power supply problem by increasing the installed power generation capacity in the region. Therefore, different from Kalimantan region, the growth of installed capacity in Sumatra region remained relatively high after 2014.

- The installed power generation capacity in the Maluku-Papua region showed a significant upward trend during 2013 and 2017, with an average annual growth of 16.77%. After a periodical high growth in 2014, the growth of installed capacity in the region fell slightly, but then rose to a new high of 26.82% in 2017. It should be noted that due to the small base of installed power generation capacity in the Maluku-Papua region, a small amount of new installed capacity could lead to a large change in the growth of installed capacity. As of 2017, the total installed power generation capacity in the region was still less than 1,000 MW.

- Similar to other regions, the installed power generation capacity in Sulawesi increased significantly in 2014, with a growth of 63.02%. Then the growth fell sharply to 5.25% in 2015 and rose again to some extent from 2016 to 2017. In general, the average annual growth of installed power generation capacity in Sulawesi region reached 19.85% from 2013 to 2017, higher than the growth of power demand during the same period.

(2) Power demand in the five major regions

Figure 2.4 Growth of power demand in the five major regions of Indonesia from 2013 to 2017



Source: RUPTL (2018-2027) [6]

As seen from the growth of power demand in the five major regions of Indonesia from 2013 to 2017:

- The growth of the total power consumption in the Java-Bali region showed a sharply declining trend. The average annual growth of the total power consumption in the region during the five years was 4.92%, which was lower than the national average of the same period. The growth in the Java-Bali region was relatively low compared with the other four regions. Specifically, the growth of the total power consumption in the region fell rapidly from 2013 to 2015, and fell to the lowest of only 1.09% in 2015. The growth rebounded to 6.26% in 2016 but fell again to 4.33% in 2017 mainly due to following two reasons:

  1) the poor global economic situation restrained the rise in power demand;

  2) with the rapid development of the power industry in the Java-Bali region, the electrification rate rose to a relatively high point, limiting the space for rising and making it difficult to boost power demand by increasing the number of power users [9].

- The total power consumption in the Kalimantan region showed a downward trend during the five years, with an average annual growth of 8.14%, which was slightly higher than the other four regions and higher than the national average annual growth of the total power consumption in the same period. Specifically, the growth of the total power consumption in the region remained at about 6.5% after 2014, and accelerated from 2015 to 2017 due to the following two factors: The investment and construction of the Indonesian government's power infrastructure had gradually improved the substations and regional power grids, greatly resolving the problem of insufficient power supply in terms of transmission and distribution. In addition, due to the long-term low electrification rate in this region, the improvements in power transmission and distribution had also effectively released the demand [10]. In addition, the accelerated development of mineral resources and the construction of pithead plants also contributed to the increase in the growth of the total power consumption in the region.

- The average annual growth of the total power consumption in the Sumatra region during the five years was 6.2%, which was higher than the national average annual growth of the total power consumption in the same period. In terms of the absolute amount, the average annual growth of the actual total power consumption in the region was relatively low and stable. Therefore, the high growth of installed power generation capacity might cause excess power supply in the region.

- The average annual growth of the total power consumption in the Maluku-Papua region during the five years was 7.36%, which was higher than the national average annual growth of the total power consumption in the same period. However, the growth of the total power consumption in the region fell rapidly during the five years. From 2016 to 2017, the growth remained at only about 4.5%, which was far lower than the growth of installed capacity during the same period. In addition, the overall level of economic growth of Maluku-Papua region dominated by agriculture was low and developed slowly. In addition, the historical contradictions between religions and races further slowed the development, and the contribution of regional economy to GDP was only about 2%. Furthermore, the geographical condition of the Maluku-Papua region which was mainly composed of multiple small islands severely limited the power grid construction[10]. The above problems made it difficult for the region to solve the dilemma of power transmission and distribution in the short term. It is expected that the growth of the total power consumption in the region would still remain low in the future.

- The average annual growth of the total power consumption in the Sulawesi region during the five years was 8.08%, which was at the forefront compared with other regions, and higher than the national average annual growth of the total power consumption in the same period. However, the growth of the total power consumption in the region gradually decreased during the five years. For example, it dropped sharply in 2014 after a high growth in 2013. The growth remained at about 5.8% from 2014 to 2017 (except a high growth of 9.57% in 2016). On the whole, except for 2013 and 2015, the growth of installed capacity in other years was much greater than the growth of demand. According to the current plan of the Indonesia National Electric Power Corporation, it is expected that the growth of installed capacity in the region will remain at a high level by 2022. In the case where no new demand growth point is found, there may be an excessive supply of power in the region.

2.1.2 Evaluation method of the redundancy of installed coal-fired power capacity

From the perspective of resource redundancy, the reserve margin of power system is used in this report as the basis for judging whether the coal-fired power capacity in each region is excessive. It is considered as overcapacity when the actual reserve margin of power system in a region is greater than a reasonable reserve margin. This report assumes that, in the calculation, non-thermal power can be used preferentially, and the overcapacity is coal-fired power capacity, that is, the installed coal-fired power capacity that exceeds the part corresponding to a reasonable reserve margin of power system is considered as coal-fired power overcapacity in the region[11]. The formula for calculating coal-fired power overcapacity is as follows:

$$CE=IC-MP\times(1+RM) \qquad (2.1)$$

Where, CE is the equivalent overcapacity of coal-fired power, IC is the equivalent available installed capacity of each energy source, MP is the maximum power load, and RM is the reasonable reserve margin of the power system. Refer to the appendix for the setting method of the reasonable reserve margin of the power system in each region.
The actual reserve margin of power system (RM') in each region is calculated as follows:

$$RM'=\frac{IC}{MP}-1 \qquad (2.2)$$

Where, the equivalent available installed capacity of each energy source (IC) is calculated as follows:

$$IC=AC\times DC\mp OD/RE \qquad (2.3)$$

In the above formula, AC is the existing installed capacity of each energy source, DC is the contributing factors to each energy capacity, and OD and RE are sending and receiving power across provinces respectively. Considering that the backward development level of the Indonesian power grid and little power transmission among regions, this report ignores the cross-region power transmission in the calculation. Table 2.1 shows the capacity contribution factors of various energy types.

It should be noted that there is no uniform international standard for the contribution factors of the maximum load of various power sources, and Indonesia also lacks relevant research literature. Considering the low reliability of the Indonesian units, the unit availability discount was 5% in the analysis on this report. The contribution factors of wind power and photovoltaic have been controversial. The contribution factors of wind power and photovoltaic were assigned as 15% and 40% (ground mounted fixed photovoltaic panel) to 60% (ground mounted tracking photovoltaic panel) on the US's PJM power market for conducting a resource redundancy evaluation. In this report, 10% and 25%[12] are set respectively for the sake of robustness. Considering the low proportion of Indonesia's hydropower and the existing low installed hydropower capacity, and in combination with the opinions of relevant industry experts, the contribution factor of hydropower is set to 25% in this report.

Table 2.1 Capacity Contribution factors of each power type

Power Type	Coal-fired power	Hydropower	Wind power	Photovoltaic power	Non-coal thermal power
Capacity contribution factor	85%	25%	10%	25%	85%

2.1.3 Analysis on the redundancy of installed capacity of coal-fired power

The redundancy of installed power generation capacity in each region is calculated based on electric power balance in this report. Due to the different hours of utilization for different generation energy sources, the power generation efficiency of different installed energy unit capacity also varies. Under the premise of no significant fluctuations in the proportion of hours of utilization of various types of power generation energy, in order to facilitate the research on the power supply capacity, the installed power generation capacity of each energy type is converted into equivalent installed coal power capacity in this report for calculation[13]. Table 2.2 shows the calculation results of the reserve margins of the power systems in the five major regions of Indonesia in 2017.

Table 2.2 Reserve margins of the power systems in the five major regions of Indonesia in 2017

Region	Actual reserve margin	Reasonable reserve margin[3]
Sumatra	40.94%	80%
Java-Bali	14.70%	15%
Kalimantan	49.66%	80%
Sulawesi	28.26%	60%
Maluku-Papua	28.02%	75%

In general, due to the differences in power grid construction, geographical environment, economic development and other factors, the actual reserve margins of power systems in different regions of Indonesia are quite different.

- In terms of absolute value, the actual reserve margin of power system in the Java-Bali region was the lowest at 14.70% in 2017, while the actual reserve margins in the other four regions were higher, of which the Kalimantan region had the highest actual reserve margin of 49.66%.

- In terms of relative value, although the actual reserve margin of power system in the Java-Bali area was low, it was very close to a reasonable reserve margin. Due to its relatively complete power grid and relatively reasonable installed structure, the existing scale of installed capacity can fully guarantee the power supply to the region. If additional installed capacity continues to be added in the region in accordance with the planning in the future, it is very likely to face risks of overcapacity. Although the actual reserve margins are higher in the Maluku-Papua, Sumatra, Kalimantan, and Sulawesi regions, they are far below the reasonable reserve margins, leaving some room for investment. However, considering the gradual tightening of resource constraints and the increasingly serious environmental situation, new investment in the future should give priority to replacing coal-fired power generating units with clean energy.

3 Refer to the appendix for the calculation method of the reasonable reserve margin.

2.1.4 Prediction of the redundancy of installed coal-fired power capacity

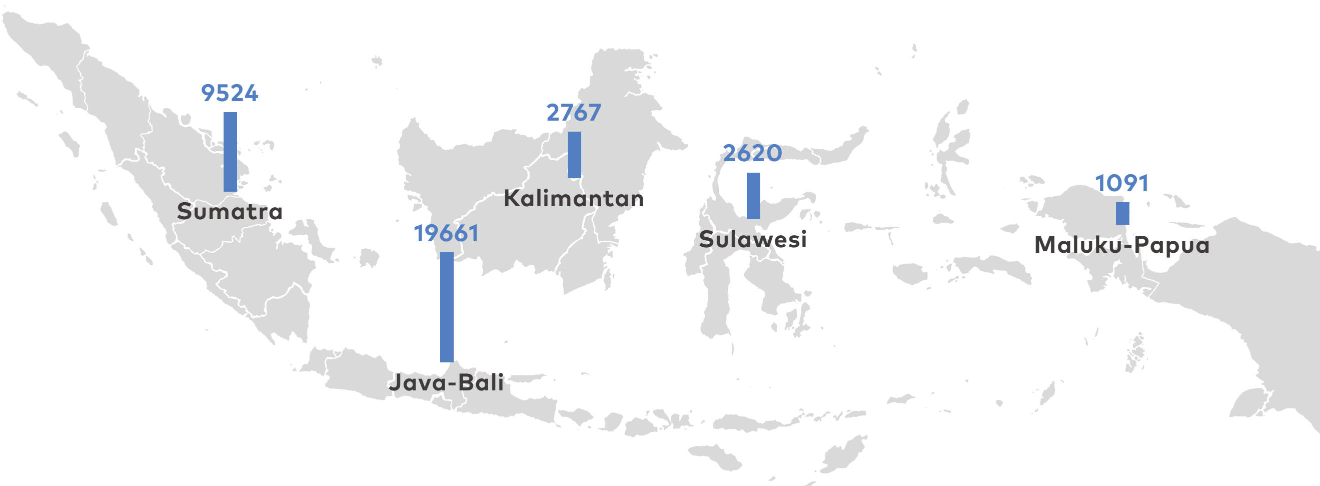
The same methodology is used for the prediction and status quo analysis on the redundancy of Indonesia's installed coal-fired power capacity in 2022, and each variable in the formula is replaced by the predicted value in 2022. For the maximum power load demand in each region in 2022, this report calculates the power consumption growth based on the GDP growth and power consumption elasticity coefficient of each region from 2018 and 2022, and assumes that the growth of maximum power load demand during the same period is the same as the growth of power consumption. This report will conduct a scenario research on the GDP growth from 2018 to 2022. The elasticity of power consumption in each region will be based on the average value of the elasticity of power consumption in each region from 2013 to 2017 as an approximate value. Table 2.3 shows the elasticity of power consumption in each region from 2013 to 2017.

In terms of installed capacity, although the "35GW Plan" proposed by the Indonesian government in 2014 made slow progress due to the slower-than-expected economic growth and power demand growth[14], a large number of power stations would still be under construction or planning during the period of 2018 and 2022. According to the RUPTL (2018-2027), Indonesia will add 35,663 MW of installed power generation capacity from 2018 to 2022. Figure 2.5 shows the new installed capacity in each region.
In the current policy background, the installed power generation capacity of the country in 2022 is expected to reach 91,588.96 MW.

Table 2.3 Elasticity of power consumption in each region

Region	Sumatra	Java-Bali	Kalimantan	Sulawesi	Maluku-Papua
Elasticity of power consumption	1.22	0.96	1.59	1.58	1.44

Figure 2.5 Estimated new installed capacity (MW) in each region of Indonesia from 2018 to 2022



In order to evaluate the future power supply and demand situation in Indonesia, this report sets high and low power demand growth scenarios based on the GDP growth predicted by the Indonesian National Development Planning Agency, to explore Indonesia's national and regional development status of the power industry at different economic development rates in Indonesia. The specific scenarios are set are as follows:

Scenario 1: Assume that the GDP growth of Indonesia from 2018 to 2022 is the same as the average annual GDP growth predicted by the Indonesian National Development Planning Agency, that is, the average annual GDP growth is 5.9%, and the GDP growth of each region is also the same as expected. It should be noted that the growth predicted by the Indonesian National Development Planning Agency is based on optimistic expectations of the world economic recovery, that is, the steady rise in staple commodity prices, the increase in international trade growth, and the increasing confidence of enterprises and consumers.

Scenario 2: Assume that the GDP growth of Indonesia is difficult to reach the value predicted by the Indonesian National Development Planning Agency[4], that is, the world economic recovery is relatively stable, and the average annual GDP growth of Indonesia from 2018 to 2022 (5.2%) is slightly higher than that of 2018, which is used as the basis for lowering the average annual GDP growth of each region from 2018 to 2022.

Table 2.4 Average annual GDP growth of each region in Indonesia from 2018 to 2022

Region	Scenario 1	Scenario 2
Sumatra	5.94%	5.24%
Java-Bali	5.48%	4.77%
Kalimantan	5.06%	4.34%
Sulawesi	6.64%	5.96%
Maluku-Papua	6.68%	6.00%
Nationwide	5.90%	5.20%

Based on the above assumptions, this report calculates the system reserve margins of installed power generation capacity in Indonesia and different regions in 2022. Table 2.5 shows the results.

Table 2.5 Forecast Reserve capacity of power system in each region of Indonesia in 2022

Region	Scenario 1	Scenario 2	Reasonable reserve margin[5]
Sumatra	81.76%	88.56%	80%
Java-Bali	31.69%	36.07%	15%
Kalimantan	90.30%	100.82%	80%
Sulawesi	29.52%	36.02%	60%
Maluku-Papua	72.50%	80.46%	75%

4 According to the historical data[15], the previous GDP growth rates predicted by the Indonesian National Development Planning Agency were generally about 1% higher than the actual growth rate, indicating a big prediction error.

5 Refer to the appendix for the prediction method of the reasonable reserve margin.

In Scenario 1, except that the actual reserve margins of power systems in Sulawesi and Maluku-Papua regions are lower than the reasonable reserve margin, the actual reserve margins of power systems in Java-Bali, Kalimantan and Sumatra regions are greater than the reasonable reserve margin, indicating that in this scenario, coal-fired power overcapacity will occur in these three regions in 2022, with the excess capacity of 6,686 MW, 164 MW, and 128 MW respectively. Compared with 2017, the actual reserve margins of power systems in the five major regions will rise by different degrees in 2022. Except for a small rise in Sulawesi region, the other four regions realize a rise of over 100%. In general, due to the large installed power generation capacity between 2018 and 2022, it is difficult to achieve rapid growth in power demand. Therefore, with the smooth implementation of the RUPTL of Indonesia, even if Indonesia can achieve a faster economic development, there will also be severe coal-fired power overcapacity in the Java-Bali region in 2022, and a slight coal-fired power overcapacity in the Kalimantan and Sumatra regions.

In Scenario 2, that is, when Indonesia's economy grows at a relatively low rate (5.2%), the coal-fired power overcapacity in each region will worsen. Compared with Scenario 1, except that the actual reserve margin of power system in Sulawesi region is at a reasonable level, there will be coal-fired power overcapacity at different degrees in the other four major regions. The coal-fired power overcapacity of 60 MW will occur in the Maluku-Papua region, while the coal-fired power overcapacity in Java-Bali, Kalimantan and Sumatra regions will further increase to 8,164 MW, 460 MW and 891 MW respectively.

To summarize, the average annual GDP growth from 2018 to 2022 is negatively correlated with Indonesia's coal-fired power overcapacity in 2022, and the degree of coal-fired power overcapacity in different regions varies greatly. The growth of power demand in the newly released RUPTL each year has been adjusted downward, it is still apparently overestimated. If Indonesia continues to add new capacity according to the current RUPTL, and the economic growth has not accelerated, it is expected that the problem of coal-fired power overcapacity will further intensify in the Java-Bali, Kalimantan and Sumatra regions in 2022, and even may occur in the Maluku-Papua region.

3 Refer to the appendix for the calculation method of the reasonable reserve margin.

2.2 Economic analysis on coal-fired power investment and construction projects

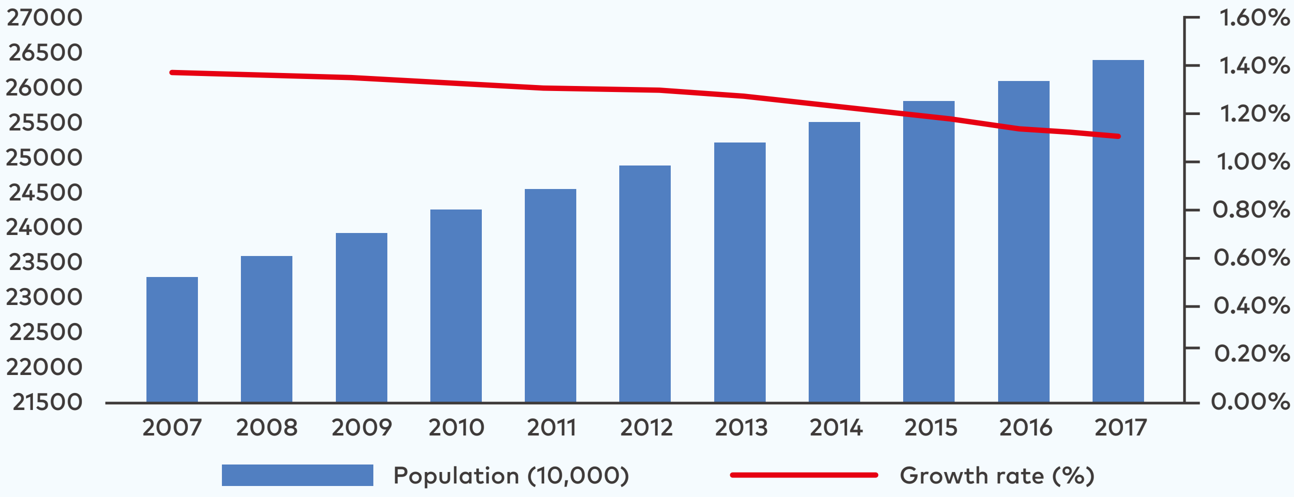
2.2.1 Status quo of the economy of coal-fired power investment and construction

As the largest economic entity in Southeast Asia, Indonesia's economy has developed rapidly and its GDP has risen steadily, with an average annual growth of around 5% [15] in recent years, thus having a unique advantage in attracting foreign investment. In addition, Indonesia is the fourth most populous country in the world, with a population growth of about 1.30% in the past decade. The population in 2017 was 266 million, accounting for 3.5% of the world's population. Indonesia is rich in resources and has a broad market. In recent years, its political situation has been stable and legal system has been gradually improved, attracting many foreign investors. Since the international financial crisis in 2008, the growth of foreign investment in Indonesia has maintained an average annual rate of over 13% [16]. The launch of the "35GW Plan" has attracted close attention from many large power enterprises around the world, which have actively participated in the development of Indonesia's power market.

Up to now, Chinese-funded enterprises that have directly participated in investment in Indonesia's energy projects include China Huadian Corporation, China Datang Corporation, former Shenhua Group, Power Construction Corporation of China (PowerChina), China Energy Engineering Group, which focus on the development of coal-fired power, gas-fired and other thermal power projects. In addition, China National Machinery Import & Export Corporation, SEPCO Electric Power Construction Corporation, China Chengda Engineering Co., Ltd. and other power construction units have also participated in the Indonesia's Electric Power Engineering Procurement Construction (EPC) projects. Apart from Chinese-funded enterprises, Japan's Mitsubishi, Marubeni, Mitsui and other enterprises are also following the development of large-scale coal-fired and gas-fired projects; Electricite de France and France Gas Turbine Group have also paid close attention to and actively followed up gas-fired projects and other energy projects[17].

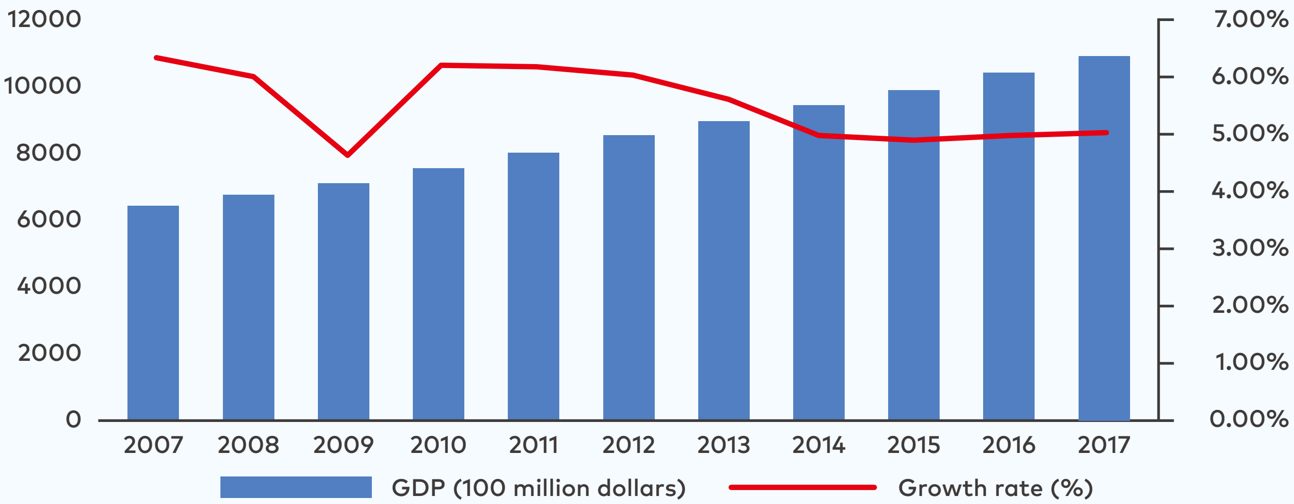
In the past few years, Indonesia's population and GDP have generally shown a trend of continuous growth. Indonesia's population continued to grow between 2007 and 2017, leading to a growing demand for power. During this period, Indonesia's population growth had maintained a relatively stable and slowly declining trend, as shown in Figure 2.6. Between 2007 and 2011, Indonesia's GDP showed a significant growth trend, the economy developed rapidly, and the growth fluctuated greatly. Between 2012 and 2017, due to the influence of domestic and foreign factors, Indonesia's GDP resumed a steady growth trend after a slight decline, and the economic growth slowed slightly, with slight fluctuation, as shown in Figure 2.7.

Figure 2.6 Population growth in Indonesia from 2007 to 2017



Source: Global Macroeconomic Data Platform [18]

Figure 2.7 GDP of Indonesia from 2007 to 2017



Source: Global Macroeconomic Data Platform [19]

2.2.2 Evaluation method of the economy of coal-fired power investment and construction

Indonesia manages the national power industry through PLN. In accordance with Decree No. 15 of 1985 and the implementation regulations, PLN is a state-owned enterprise designated by the Indonesian government with power control rights. It will maintain its market monopoly position for a long time and independently operate the power transmission and transformation business nationwide, and is the only enterprise that sells electricity to end consumers (regardless of individuals or enterprises). All IPPs need to sell power to PLN only and sign a PPA with PLN which has a business that guarantees power supply in its concession area. The benefits of IPP are largely realized through PPA guarantees, in which the "Take-or-pay" agreement is the core of all clauses, providing electricity sellers with guaranteed income and cash flows that are unrelated to the demand of electricity purchasers, thus attracting investment from many power enterprises.

An internal rate of return (IRR) indicator is used in this report to assess the economy of the coal-fired power projects invested and constructed by Chinese enterprises and financial institutions in the five major regions of Indonesia, and make a prediction of the coal-fired power projects in 2022 based on different scenarios. IRR indicates the expected rate of return for a project investment. Its advantage is that it can link the return of a project during its operation period with its total investment, and it is easy to compare with the benchmark rate of return on investment of the same industry to determine whether the project is worth investment and construction.

The IRR of investment and construction of coal-fired power projects in Indonesia is calculated as follows:

$$NPV=\sum_{t=0}[(A+P_d\times C)-CO]_t(1+IRR)^{-t}=0 \qquad (2.4)$$

Where, NPV refers to the project's net present value, which is the difference between the discounted value (cash inflow) of future cash flows generated by a project investment and the project investment cost (cash outflow), reflecting the profitability of the project investment. The discount rate when the net present value is zero is the IRR of the project. In normal circumstances, an IRR greater than or equal to the benchmark IRR indicates that the project is feasible.

A represents the capacity income of the coal-fired power project, which is the generation revenue corresponding to the capacity price. Capacity price refers to the fixed tariff collected regularly on the premise that the electricity seller and purchaser, sign an electricity purchase agreement to determine the power generation capacity of the power plant by using the agreed reliable net capacity of the power plant as the basis for calculation. The capacity price mainly reflects the fixed cost, which is mainly investment cost and is implemented at the tariff approved by the government. It is essentially a payment for the ability of a generating unit to provide power to a power grid, so the settlement of the capacity price is closely related to the availability of the generating unit.

P_d represents the energy price, which refers to the tariff charged based on the on-grid electric quantity actually transacted by a power generation enterprise, reflecting the maintenance and operation costs of a coal-fired power project. It mainly includes various costs during the project operation and maintenance such as variable operation and maintenance costs and standard coal prices (P_{ca}), generating unit coal consumption (R_{ca}) and other fuel costs.

C represents the power generation amount, which is the product of the actual annual utilization hours (T_v) of a project and the installed capacity. It should be noted that the cash inflow is the product of the feed-in tariff of a power generation enterprise(P) and the power generation amount. However, in order to reflect the idea of the two-part tariff system in Indonesia, this report splits the IRR calculation formula into two parts: capacity revenue and energy revenue. The sum of the capacity price and the energy price determined by the power generation enterprises and the PT. PLN through negotiation is the feed-in tariff of the power generation enterprises, and the revenue of the power generation enterprises is calculated based on the power generation.

CO represents cash outflow, including fixed asset investment, current asset investment, income tax, etc. Parameters such as the dynamic investment per kW (C_E), depreciation rate (k_{zj}), loan proportion (r), loan interest rate (k_{ll}), etc. are involved for calculation.

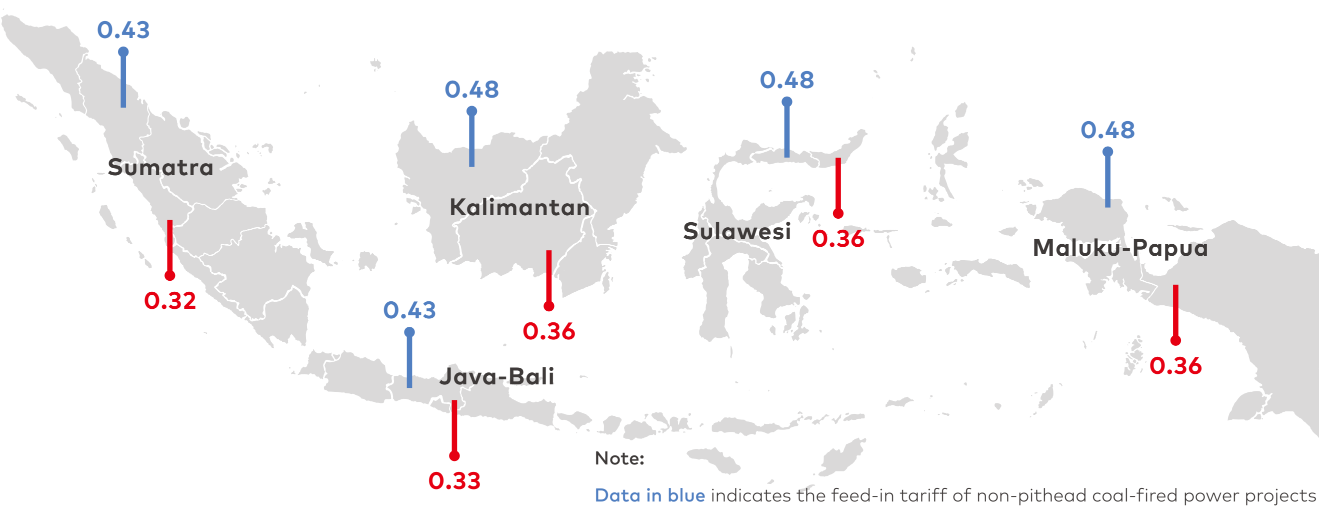
This report uses the data in terms of the above-mentioned economic indicators in the five major regions of Indonesia for 2012-2017 and the prediction data for 2018-2022 to calculate the IRR on investment and construction of coal-fired power projects in the five major regions of Indonesia. Some parameters involved in the calculation are as follows:

(1) Feed-in tariff for coal-fired power projects (denoted as P, excluding tax, in "yuan/kWh") represents the calculation price of the electricity and energy purchased by the PLN from power generation enterprises when they are connected to the main grid. This report adopts the regional feed-in tariff under the tariff policy of Biaya Pokok Pembangkitan (BPP) in Power in Indonesia: Aksin (PLN) [20]. Figure 2.8 shows the detailed feed-in tariffs.

Table 2.6 Warning indicators for the economy of coal-fired power construction

Indicator name	Indicator code	Indicator unit
Net present value	NPV	yuan
Capacity revenue	A	yuan
Energy price	P_d	yuan /kWh
Power generation	C	kWh
Cash outflow	CO	yuan
Feed-in tariff of coal-fired power projects	P	yuan /kWh
Dynamic investment per kW	C_E	yuan /kW
Estimated annual utilization hours	T_v	hour
Depreciation rate	k_{zj}	%
Ratio of loans to total investment	r	%
Loan interest rate	k_{ll}	%
Coal consumption in power generation	R_{ca}	gce/kW
Estimated standard coal price (including tax)	P_{ca}	yuan /ton

Figure 2.8 Regional feed-in tariff under the tariff policy of BPP in 2017



Note:

Data in blue indicates the feed-in tariff of non-pithead coal-fired power projects (including customs duties).

Data in red indicates the feed-in tariff of pithead coal-fired power projects (including customs duties).

Source: Power in Indonesia [20]

The above data is based on the statistics of the tariffs in the five major regions under the Indonesian BPP policy (Table 2.7). In 2017, the Indonesian Ministry of Energy and Mineral Resources (MEMR) introduced new rules for PLN's power purchase price (referred to as feed-in tariff). Ceiling prices were introduced based on different parameters for the feed-in tariffs for pithead coal-fired power plants, non-pithead coal-fired power plants, fuel gas power plants, micro fuel gas power plants, and hydropower plants with different energy types and installed capacity.

Table 2.7 Price composition of coal-fired BOT projects in Indonesia[7]

Tariff composition	Segmentation of tariff composition	Name	Definition
Capacity price	Part A	Return on unit capital cost (CCR) (for power plant)	It refers to the annual average return on fixed capital cost per kW for a power plant during the whole operation period, in INR/kilowatt-year.
	Part B	Unit fixed operation & maintenance cost ratio (FOMR)	It refers to the annual average return on fixed capital cost per kW for a power plant during the whole commercial operation period, in INR/kilowatt-year.
Energy price	Part C	Coal price per kWh (ECR)	It refers to the coal price per kWh during the billing period, in INR/ kilowatt-hour.
	Part D	Variable operation & maintenance cost per kWh (VOMR)	The rate of return on the variable operation & maintenance cost per kWh, in INR/kilowatt-year.
Supplementary tariff	Part E	(Outgoing circuit) Return on unit capital cost (CCRT)	It refers to the annual average return on fixed capital cost per kW for an outgoing circuit during the whole commercial operation period, in INR/kilowatt-year.

Based on the market norms of the two-part tariff system in Indonesia, the feed-in tariff mainly consists of capacity price and energy price. The capacity price is formulated based on the average investment cost of various types of generating units participating in the competition within the regional power market or power dispatch trading center. It is mainly used to calculate costs, determine and fix the expected return rate for the next few decades. Its electricity energy cost mainly includes return on own funds, loan return, depreciation, fixed cost, labor cost and other parts, and is a key indicator for negotiating coal-fired power project investment with PLN. The energy price is mainly formed by various costs during the operation and maintenance period, such as variable operation and maintenance costs and fuel costs such as coal price and coal consumption. Among them, the coal cost is currently borne by PLN, thus having no impact on the return on investment and investment decisions of project investors[21]. However, if the rigid payment of the take-or-pay clauses is broken, the risks of increased fuel costs and reduced utilization hours will also be borne by the project investors.

Although the Indonesian government has issued the price ceiling order for different feed-in tariffs for different types of energy and different installed capacity, it is not similar to the "benchmark price" implemented in China. The tariff of an IPP project is mainly quoted by the investor based on the construction and operation costs and investment return prediction. After winning the bid from competing with different bidders, the investor will sign a power purchase and sales agreement with PLN to determine the feed-in tariff during the operation period. Therefore, the tariff level of each IPP project will vary depending on the investor and the construction cost level. The final feed-in tariff shall be subject to the power purchase and sales agreement signed by both parties.

(2) Dynamic investment per kW (denoted as C_E, in "yuan/kW") represents the capital required for constructing each kilowatt of installed capacity by a power plant, and is calculated by dividing the total investment by the installed capacity. The indicator data used in this report is calculated based on the specific power plant project and is divided by the project region.

The projects involved in the calculation are distributed in four major regions, including coal-fired and coal mine-mouth (CMM) power generation projects in the Java-Bali, Kalimantan, Sulawesi and Sumatra regions. The data of coal-fired power projects in the Maluku-Papua region is not available (Table 2.8).

Table 2.8 Dynamic investment per kW in Indonesia

Project name	Installed capacity (10,000 kW)	Type	Location	Dynamic investment per kW (yuan/kW)
Jawa-9 & 10	200	Coal-fired	Banten	10647
Meulaboh-3 & 4	40	Coal-fired	Aceh	8505
Sumut-2	60	Coal-fired	North Sumatera	9450
Kalbar-2	20	Coal-fired	West Kalimantan	9450
Sumbagsel-1	30	Coal-fired	Southern Sumatera	9450
Sulbagut-3	10	Coal-fired	Northern Sulawesi	9450
Jawa-6	200	Coal-fired	West Java	2363
Jambi I	60	CMM	Jambi	9450
Kaltim-5	20	CMM	East Kalimantan	9450
Kalselteng-3	20	CMM	South/Central	9450
Kaltim-3	20	CMM	East Kalimantan	9450
Kaltim-6	20	CMM	East Kalimantan	9450
Sumsel-6	60	CMM	South Sumatera	9450
Riau-1	60	CMM	Riau	9450
Jambi II	60	CMM	Jambi	9450
Kalselteng-4	20	CMM	South/Central	9450
Kalselteng-5	20	CMM	South/Central	9450
Jawa 7	200	Coal-fired	Banten	5935

Source: PwC Power in Indonesia Investment and Taxation Guide [22]; Sina Finance [23]

(3) Estimated annual utilization hours (denoted as T_v in "hours") refer to the average time of full load operation of a generating unit in a year. The power industry is an investment-intensive industry. After deducting necessary downtime for equipment maintenance, etc., the higher the number of hours of power generation, the higher the economic value created by the equipment. This report uses the regional official data released by the Indonesian MEMR as a reference for indicator prediction. The calculation formula is:

Annual utilization hours of power generation equipment = Power generation during the report period/ Annual average capacity of power generation equipment during the report period

(2.5)

Table 2.9 Annual utilization hours of coal-fired power generation equipment in Indonesia

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015
Annual utilization hours	7375	7014	7237	6858	5525	5450	5383	5497	5394

Source: RUPTL (2018-2027)[6]

Table 2.10 Power balance sheet of Indonesia in 2017

Region	Installed power generation capacity (MW)	Power generation amount (GWh)	Annual utilization hours (h)
Sumatra	5776.72	32748	5669
Java-Bali	32047.36	169663	5294
Kalimantan	1568.84	8028	5119
Sulawesi	1603.75	9439	5888
Maluku-Papua	351.37	2157	6145

Source: PLN Annual Report (2017) [24]

(4) Loan interest rate (denoted as k_{ll} in "%") refers to the ratio of interest amount to principal amount during the term of loan. According to the reference value summarized from the data of investment projects by domestic power enterprises such as China Shenhua Guohua Power and some Japanese enterprises in Indonesia, the estimated loan interest rate adopted in this report is 6.46% (Table 2.11).

Table 2.11 Loan interest rate of coal-fired power investment projects in Indonesia

Project name	Total cost (million dollars)	Loan (million dollars)	Equity (million dollars)	Ratio of loans to equity	Interest rate
Shenhua-Guohua Power Plant	331	231.7	99.3	233%	NA
Java Island No.7 Power Station	NA	NA	NA	NA	6M Libor + 3%
Weighted average of Plants in PwC's survey	NA	NA	NA	76%	6.46%

Source: Securities Times [25]; China.org.cn [26]; PWC Alternating Currents: Indonesian Power Industry Survey 2018[27]

(5) Coal consumption in power generation (denoted as R_{ca} in gce/kWh) represents the amount of coal consumed for power generation of each kWh by a coal-fired power plant. Due to the large differences in the coal consumption for production of different projects, this report uniformly converts the sample coal into standard coal in order to facilitate the calculation and comparison. The reference value of coal consumption for power supply of typical conventional coal-fired generating units is adopted in this report as the coal consumption data of power generation.

Table 2.12 Comparison of energy consumption indicators between Indonesian coal and Chinese coal [28]

Project	Power generation (10,000 kWh)	Running time (h)	Average load (MW)	Generating unit load coefficient (%)	Coal consumption for power generation (Standard coal (g)/kWh)
Indonesian coal	1875.85	72	260.05	78.80	306.72
Chinese coal	1895.85	72	263.31	79.79	308.31
Difference	-20.00	0	-3.26	-0.99	-1.59

Table 2.13 Reference value of coal consumption for power supply of typical conventional coal-fired generating units

Type of generating unit		Designed coal consumption for power supply of new generating units (Standard coal (g)/kWh)	Coal consumption for power supply of the existing generating units	
			Average level	Advanced level
1 million kW-grade ultra-supercritical	Wet-cold	282	290	285
	Air-cold	299	317	302
600,000 kWh-grade ultra-supercritical	Wet-cold	285	298	290
	Air-cold	302	315	307
600,000 kWh-grade supercritical	Wet-cold	303	306	297
	Air-cold	320	325	317
600,000 kWh-grade subcritical	Wet-cold	-	320	315
	Air-cold	-	337	332
300,000 kWh-grade supercritical	Wet-cold	310	318	313
	Wet-cold	327	338	335
300,000 kWh-grade subcritical	Wet-cold	-	330	320
	Wet-cold	-	347	337

Source: Action Plan for the Transformation and Upgrading of Coal Power Energy Conservation and Emission Reduction (2014–2020)[29]

(6) Estimated standard coal price (denoted as P_{ca}, including tax, in yuan/ton). This indicator uses the monthly data of Indonesian thermal coal released by Indonesia Investment Coal Price from 2012 to 2018, and the thermal coal price is uniformly converted into the standard coal price. In addition, the data is weighted with reference to the China Thermal Coal Price Index over the past three years, and the weights are taken as 0.5, 0.3 and 0.2 from the near to the distant. Taking into account the abnormal fluctuations of coal prices in 2016, and in combination with the judgments of other institutions and scholars on the future coal price trends, this report appropriately increases the calculation weight of coal prices in the fourth quarter of 2016 in the average annual price in 2016. The standard coal price is calculated as follows:

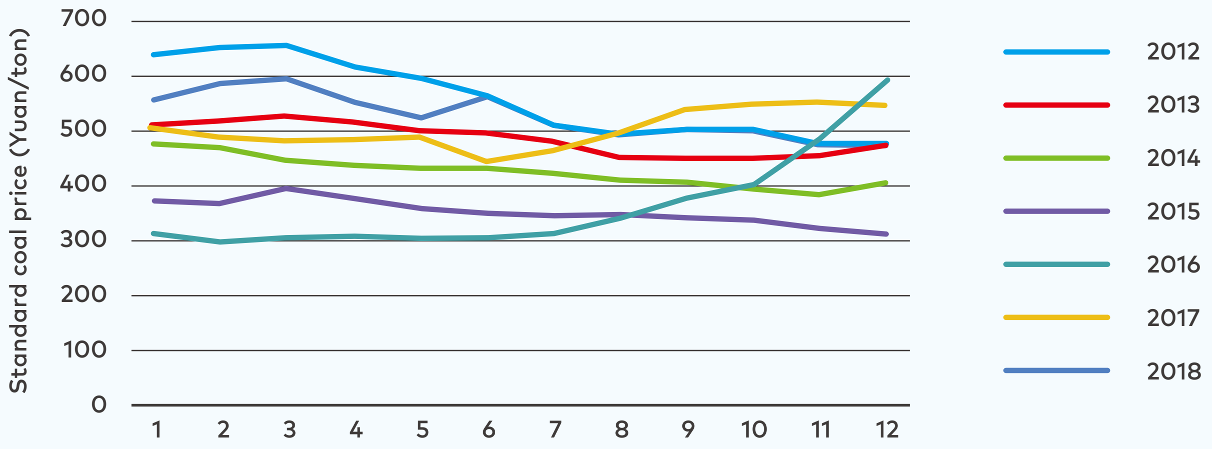
$$UCSC=UCRA\times ECSC$$

$$ECSC=ACES/7000 \qquad (2.6)$$ [30]

Where, UCSC indicates the unit price of standard coal, that is the price of steam coal that could generate the same amount of heat; UCRA indicates the unit price of steam coal; ECSC indicates the energy conversion standard coal coefficient, and ACES indicates the actual calorific value of steam coal[6], in Kcal/kg.

The calculation results of the standard coal price show that there are certain seasonal characteristics of coal prices in Indonesia. For example, the standard coal prices are higher in some seasons such as spring and winter. As shown in Figure 2.9, the average coal price in Indonesia during 2012 and 2018 was between 320-450 yuan/ton. This period will be used as a reference for economic analysis in the following economy evaluation and prediction. It is noted that the calculated price of standard coal is the price of steam coal that could generate the same amount of heat under Indonesia standard, which is lower than the price of low-heating value steam coal, resulting in a more conservative evaluation and prediction result for economic analysis.

Figure 2.9 Standard coal price in Indonesia from 2012 to 2018



Source: Indonesia Investment Coal Price[33]

6 In the calculation, according to the calorific value of fuel coal by the current thermal coal price, that is, the average monthly price of under the HBA index, and the indicator benchmark of 6322 kcal for the high calorific value, as well as 8% of total water, 15% of ash, and 0.8% of sulfur, the energy standard coal coefficient is 0.9, and then the current standard coal price is calculated under the exchange rate of 1: 6.5 (USD to Yuan).

(7) Other variable operation and maintenance costs. Land is privately owned in Indonesia. Neither foreigners nor foreign companies can own land in Indonesia, but foreign direct investment enterprises can have the following three restricted rights:

1) building tenancy, allowing the investors to construct on the land and own the building for 30 years. If necessary, the investors can apply to the Badan Koordinasi Penanaman Modal Republik Indonesia (BKPM) for approval for an extension of 20 years;
2) the right to use, allowing the use of land for specific purposes for 25 years, with an available extension of another 20 years;
3) development right, allowing land development for multiple purposes such as agriculture, fishery and animal husbandry, with a trial period of 35 years and an available extension of another 25 years.

It is relatively easy to obtain (lease or purchase) land in Indonesia, and land prices vary greatly depending on factors such as the completeness of infrastructure, and public security conditions in the region. The survey results by the Central Bank of Indonesia show that the average price of industrial land in the downtown Jakarta is about USD 330/m^2, and is USD 190/m^2 in Bogor, Bekasi and Karawang, while the average price of industrial land in Medan, Semarang, Yogyakarta and other cities is relatively low. Some industrial plots are sold at higher prices, such as the Pulogadung Industrial Park in eastern Jakarta, where the land price is as high as USD 630/m^2. This shows that the current price of industrial land in Indonesia is already higher than that in other Southeast Asian countries (USD 119/m^2 in Bangkok, Thailand; USD 52-102/m^2 in Manila, Philippines; and USD 20-25/m^2 in Kuala Lumpur, Malaysia), which may make it less attractive for foreign enterprises to invest in coal-fired power projects in Indonesia.

As a high water consumption industry, the operation and maintenance costs of the coal-fired power industry are affected by local water prices, which are closely related to the country's economic development level, the reserves of water resources, and social systems. As shown in Table 2.14, the water price was IDR 4,900/m^3 (yuan 2.42/m^3) for the industrial water consumption within 10 m^3 in Jakarta in 2017; the water price was IDR 6,000/m^3 (yuan 2.96/m^3) for the water consumption of 11-20 m^3; and the water price was IDR 7,450/m^3 (yuan 3.67/m^3) for the water consumption exceeding 20 m^3. In 2017, Beijing's industrial water price was yuan 9.2/m^3 (including yuan 4.20 for water, yuan 2.30 for water resource fee, and yuan 3 for sewage treatment). Compared with Beijing, the water cost in Indonesia is relatively low, and the water price has less constraints on the coal-fired power enterprises.

Table 2.14 Water price of Jakarta in 2017

User type	Price (IDR/m^3)		
	0-10m^3	11-20m^3	> 20m^3
I	1050	1050	1050
II	1050	1050	1575
III	3550	4700	5500
IV	4900	6000	7450
V	6825	8150	9800
VI	12550	12550	12550
VII	14650	14650	14650

Source: Economic and Commercial Counsellor's Office of the Embassy of the People's Republic of China in the Republic of Indonesia
I. Religious sites; II. Government and hospitals; III. Residential housings; IV. Industrial enterprises; V. Diplomatic missions; VI. Starred hotels; VII. Special purposes

2.2.3 Economic analysis on coal-fired power investment and construction projects

Based on the above indicators and data, this report will substitute reasonable predicted data and fixed parameters to calculate the expected IRR of the coal-fired power projects in the five major regions of Indonesia, and make an evaluation and prediction of the economy of the coal-fired power project investment and construction in Indonesia in 2022 according to different scenarios.

The feed-in tariff of coal-fired power$P$ is calculated based on the annual industry data. The average value of the industry is selected as the reference tariff of the five major regions, and the overall assessment is conducted for the national feed-in tariff ranging from yuan 0.37 to 0.42 /kWh. The average value is selected by unit type as the coal consumption for power generation R_{ca} according to the reference value of typical conventional coal-fired power generation units and the existing cases. The average low and high values of the standard coal price changes in the past two years are selected as the estimated standard coal priceP_{ca} , which is 320 yuan/ton and 450 yuan/ton respectively based on the exchange rate of USD to yuan (1: 6.5). The estimated annual utilization hours (T_v) is calculated while referring to the annual utilization hours in Indonesia, with the estimated value ranging from 5,300 to 6,200 hours. The dynamic investment per kW C_E is valued by investigating the existing coal-fired power projects in Indonesia. The value in most of the regions is yuan 9,450/kWh, while the value in the Java-Bali region is higher at about yuan 9,700/kWh. In addition to the above indicators, the basic evaluation data of the remaining indicators are from domestic coal-fired power enterprises and their projects. The depreciation rate is k_{zj} valued as 6.25% based on a 16-year depreciation period. The ratio r of power project loans to the total investment is valued as 80% of the official value. The loan interest rate k_{ll} is valued as 6.46% with reference to the official loan interest rate provided by major domestic banks for overseas project investments.

The GDP growth of Indonesia was 5.2% in 2018. Under this growth, commodity prices increased steadily and the growth of international trade improved, thus gradually enhancing the business and consumer confidence. Therefore, the IRR of coal-fired power projects is related to the GDP growth. Table 2.15 shows the calculation results of the IRR of the coal-fired power projects in the five major regions of Indonesia from 2018 to 2019.

Table 2.15 IRR of the coal-fired power projects in Indonesia from 2018 to 2019

Region	On-grid electricity power (P) (yuan/kWh)	Coal consumption for power generation (R_{ca} gce/kWh)	Estimated standard coal price (P_{ca}, yuan/ton)	Estimated annual utilization hours (T_v, h)	Dynamic investment per kW (C_E, yuan/kW)	IRR
Sumatra	0.35/0.39	320	320/450	5669	9450	10.32%-10.88%
Java-Bali	0.36/0.40	320	320/450	5400	9700	9.27%-9.78%
Kalimantan	0.38/0.40	320	380/450	5300	9450	9.44%-9.9%
Sulawesi	0.38/0.40	320	380/450	5600	9450	11.22%-11.72%
Maluku-Papua	0.39/0.41	325	380/450	5900	9450	14.14%-14.75%
Nationwide	0.38/0.41	320	350/450	5500	9450	11.90%-12.44%

According to the stress test research method [32], this report, in combination with the uncertainty of power demand and assuming that the rigid payment of Indonesia's take-or-pay clauses is broken, conducts a sensitivity analysis on the IRR the coal-fired power projects in Indonesia. The sensitivity indicators analyzed include the feed-in tariff of coal-fired power projects, the estimated standard coal price, and the estimated annual utilization hours. In addition, a comparison is made on the corresponding IRR results and the national IRR benchmark value (12.44%) in Table 2.16 to analyze the amount of variation.

Table 2.16 Sensitivity analysis results

Sensitivity factors	Amount of variation	IRR	Variation of IRR
Tariff	5% up	14.98%	20% up
Coal price	20% up	9.39%	25% down
Utilization hours	20% up	19.92%	60% up

The above-mentioned sensitivity coefficient analysis shows that among the factors that affect the return on investment of coal-fired power projects, the most sensitive factor is the estimated annual utilization hours, followed by the feed-in tariff, and then the standard coal price.

2.2.4 Prediction on the economy of coal-fired power investment and construction

In recent years, the investment environment in Indonesia has improved, and the domestic economic growth has accelerated, basically remaining at about 5%. The expansion of the population size has promoted the increase in the level of electrification, leading to the increasing demand for power. Occupying a large proportion in Indonesia's RUPTL, the coal-fired power industry has certain potential for further development in the future, but also faces great challenges.

On one hand, in the face of pressure to achieve the goal of energy structure adjustment, Indonesia will vigorously develop renewable energy to optimize the power structure. In 2019, Indonesia's renewable energy accounts for only 11.4% of the country's energy structure, which is far from the target (23%) in 2025 set by the government. Compared with the power demand prediction in the RUPTL (2018-2027), the power demand growth in the RUPTL (2019-2028) is adjusted from 6.86% to 6.42%. The estimated new installed power capacity in Indonesia from 2019 to 2028 is 56.4 GW, and renewable energy will account for 30% of the total new installed power capacity[33].

On the other hand, Indonesia has introduced new PPA regulations[34] based on its own circumstances: In the event of force majeure such as policy or supervision, PLN does not need to assume the responsibility of "take-or-pay" and can renegotiate again to adjust the PPA, which will undoubtedly further increase the risk of IPP projects and also reduce the attractiveness of investment in the power industry. In addition, Indonesia's ceiling price limit policy requires that 85% of the national average or regional power supply cost (BPP) be used as the price limit threshold for new projects, which will make some IPP projects economically further worse.

Faced with the development of renewable energy and the risk of cancellation of the "take-or-pay" clauses, the utilization hours and feed-in tariff of the coal-fired power projects in Indonesia will tend to decrease. In addition, as coal resources in Indonesia are unevenly distributed, and the coal-fired power generation costs in relatively resource-rich regions are relatively low. With the further expansion of coal-fired power generation, regional excess risks may occur due to imbalances in regional power development. In this regard, this report makes an analysis from the following two scenarios:

In Scenario 1, Indonesia's tariff is basically unchanged, and the annual utilization hours declines slightly. Assuming that the average annual GDP growth of Indonesia from 2018 to 2022 is 5.9%, which is the same as the average annual GDP growth expected by the Indonesian National Development Planning Agency. In addition, assuming that the standard coal price is maintained in the range of 320-450 yuan/ton. In this scenario, the return on investment of coal-fired power projects in Indonesia in 2022 ranges differently. Among them, the IRR of coal-fired power projects in the Java-Bali and Kalimantan regions is relatively low, with weak investment attractiveness in power projects as the installed coal-fired power capacity in these two regions are large and the reserve margin is relatively high.

Table 2.17 Calculation of expected IRR of coal-fired power projects in Indonesia in 2022 (Scenario 1)

Region	On-grid electricity power (P) (yuan/kWh)	Coal consumption for power generation (R_{ca} gce/kWh)	Estimated standard coal price (P_{ca}, yuan/ton)	Estimated annual utilization hours (T_v, h)	Dynamic investment per kW (C_E, yuan/kW)	IRR
Sumatra	0.35/0.39	320	320/450	5569	9450	9.75%-10.3%
Java-Bali	0.36/0.40	320	320/450	5303	9700	8.72%-9.22%
Kalimantan	0.38/0.40	320	380/450	5140	9450	8.51%-8.95%
Sulawesi	0.38/0.40	320	380/450	5500	9450	10.62%-11.11%
Maluku-Papua	0.39/0.41	325	380/450	5678	9450	12.71%-13.29%
Nationwide	0.38/0.41	320	350/450	5400	9450	11.27%-11.79%

In Scenario 2, the growth of Indonesia's power demand has slowed down, causing a reduction in tariff and sharp decline in the coal-fired power annual utilization hours. Assuming that the average annual GDP growth of Indonesia from 2018 to 2022 is 5.2%, which is slightly higher than that in 2018 but lower than that expected by the Indonesian National Development Planning Agency. In addition, assuming that the standard coal price is maintained in the range of 320-450 yuan/ton. In this scenario, the economy of coal-fired power investment in Indonesia is poor. Compared with Scenario 1, the power demand in each region reduces, the power supply is relatively abundant, the investment economy reduces, and the return on investment also declines; only a certain return can be got from the investment in the Maluku-Papua region. The IRR in the other four major regions is relatively low. Therefore, there is small investment space in these four regions due to relatively centralized installed capacity and high electrification rate.

Table 2.18 Calculation of expected IRR of coal-fired power projects in Indonesia in 2022 (Scenario 2)

Region	On-grid electricity power (P) (yuan/kWh)	Coal consumption for power generation (R_{ca} gce/kWh)	Estimated standard coal price (P_{ca}, yuan/ton)	Estimated annual utilization hours (T_v, h)	Dynamic investment per kW (C_E, yuan/kW)	IRR
Sumatra	0.34/0.38	320	320/450	5469	9450	7.97%-8.49%
Java-Bali	0.35/0.39	320	320/450	5206	9700	7.08%-7.54%
Kalimantan	0.37/0.39	320	380/450	4981	9450	6.54%-6.95%
Sulawesi	0.37/0.39	320	380/450	5400	9450	8.80%-9.27%
Maluku-Papua	0.38/0.40	325	380/450	5550	9450	10.61%-11.15%
Nationwide	0.37/0.40	320	350/450	5300	9450	9.44%-9.93%

Generally, in high economic growth scenario, Indonesia's coal-fired power market will still have some profit margins in 2022. However, with the increase of coal-fired power investment projects, the development space of Indonesia's coal-fired power market will gradually shrink, and some regions will approach or be in a state of saturation in coal-fired power construction. Taking Java-Bali and Kalimantan regions as examples, the former develops rapidly in the power projects with concentrated power stations, which may lead to weak investability; the latter has difficulty in increasing power demand in a short period of time, and thus is not suitable for continued investment in coal-fired power projects.

In low economic growth scenario, the economy and IRR of coal-fired power investment in the Maluku-Papua region decline; the IRR of coal-fired power projects in the Sumatra, Kalimantan, Sulawesi, and Java-Bali regions are relatively low due to relatively large installed capacity and weak investability, thus it is not suitable to invest in coal-fired power projects in these four regions.

To summarize, in both scenarios, there are risks and possible loss of investment in coal-fired power projects in the Java-Bali and Kalimantan regions. There are risks of investment and construction in coal-fired power projects in the Sumatra region due to relatively low IRR. In the scenario of high economic growth, there are certain profit margins for investment in coal-fired power projects in the Sulawesi region due to higher IRR. However, when the economy develops at the current growth, it will not be suitable for additional investment in coal-fired power projects in this region. It is suitable for power project investment in the Maluku-Papua region which has a high IRR and a large investment space, as well as a large demand for power stations due to a small base.

2.3 Analysis on the resource and environmental restraints of coal-fired power investment and construction

Due to the characteristics of high water consumption, high pollution and high carbon emissions of coal power projects, the construction and investment in these projects are constrained by resource and environmental conditions such as water shortages, environmental pollution and climate changes. Indonesia is located in Southeast Asia, which is one of the regions with the highest air pollution in the world. Due to the extreme weather caused by climate changes, the investments in coal-fired power projects in Indonesia face more prominent resource and environmental risks. This report analyzes the resource and environmental constraints imposed on Indonesia's coal-fired power projects from three aspects: water resources, air pollution and climate change.

2.3.1 Status quo and predictive analysis on water resources environment

With the economic development and population growth, human demand for water resources continues to increase. Coupled with the irrational exploitation and use of water resources by human beings, many countries and regions have experienced water shortages to different degrees. Furthermore, the uneven distribution among regions has further exacerbated the tension of water resources.

As a country with the fifth largest water resources in the world, Indonesia has abundant water resource reserves. In 2017, Indonesia's water resource reserves were 2.02 trillion cubic meters with an annual water production capacity of 390 million cubic meters [35]. However, a large amount of Indonesia's natural water resources is not available, and there is a serious uneven distribution of water resources among regions. The available water supply in the Java-Bali, Sulawesi, Sumatra, Maluku-Papua and Kalimantan regions accounts for 6.1%, 6.2%, 20.1%, 32.0% and 35.5% respectively of the country's total.

As Indonesia crosses the equator and has a typical tropical rain forest climate, there is a shortage of water during the dry seasons, which may result in drought due to long periods of no rain. In the rainy seasons, the water absorption of limestone hills is low, leading to frequency floods. Special climatic conditions and resource endowments, as well as soil erosion caused by forest destruction, have made Indonesia's surface water and drinking water become scarce resources. The coal-fired power industry which requires a large amount of surface water as cooling water will face risks such as water shortage and water use competition.

The baseline water stress of the World Resources Institute (WRI) is used in this report as an indicator for assessing and predicting water resource constraints in different regions of Indonesia in 2017 and 2022, respectively[36]. The baseline water stress is the ratio of the annual water withdrawal to the average available water resources in a drainage basin. The higher the value, the greater the competition pressure for water use. A high water stressed region has a baseline water stress value ranging from 40% to 80%, and an ultra-high water stressed region has a baseline water stress value greater than 80%.

The WRI baseline water stress data was used for evaluating the data in 2010 and predicting the data in 2020, 2030 and 2040. According to preliminary analysis, with the development of population, economy and industry, Indonesia's water consumption increases year by year, resulting in the year-by-year decrease in the amount of available water resources and year-by-year increase of the baseline water stress. Limited by the availability of data, this report uses the water stress of different regions in Indonesia in 2010 for a status analysis. The actual water stress in different regions in Indonesia in 2017 should be higher than this result. The table below shows the measurement results of water stress in the five major regions of Indonesia in 2010:

Table 2.19 Water stress in the five major regions of Indonesia in 2010

Region	Available water (100 million m^3)	Total water consumption (100 million m^3)	Baseline water stress	Indicator level
Sumatra	6888.79	334.91	5%	Low (<10%)
Java-Bali	2081.72	1146.99	55%	High (40%-80%)
Kalimantan	12159.92	68.48	1%	Low (<10%)
Sulawesi	2133.65	127.86	6%	Low (<10%)
Maluku-Papua	10970.04	15.44	0%	Low (<10%)
Nationwide	34234.12	1693.68	5%	Low (<10%)

Source: Waterway Chart of the WRI[36]

The calculation results show that Indonesia has abundant water resources with low water stress throughout the country, but the distribution among regions is severely uneven. Among them, the baseline water stress in the Java-Bali region is 55%, which is in a high water stressed region which faces great pressure on water resources. This is mainly due to drought without rain, inadequate water supply, as well as serious pollution, population base and large water resources consumption, etc. The baseline water stress in the other four regions are relatively low, indicating that the local economic development is hardly restricted by water resources.

This report uses currently available water stress in different regions of Indonesia in 2020 for predictive analysis, so the results are conservative. The estimated water stress in different regions in Indonesia in 2022 should be higher than this result. According to the analysis results (Table 2.22), the predicted national water stress in Indonesia in 2020 is 6%, indicating that the pressure on water resources is relatively low, but there are obvious differences among regions. The baseline water stress in the Java-Bali region is 59%, which is a high water stressed region; the baseline water stress in the Sumatra, Kalimantan, Sulawesi, and Maluku-Papua regions are 5%, 1%, 6%, and 0% respectively, indicating low pressure on water resources[36].

Table 2.20 Prediction of water stress in the five major regions of Indonesia in 2020

Region	Available water (100 million m^3)	Total water consumption (100 million m^3)	Baseline water stress	Indicator level
Sumatra	7092.59	367.98	5%	Low (<10%)
Java-Bali	2177.33	1284.17	59%	High (40-80%)
Kalimantan	10018.88	70.95	1%	Low (<10%)
Sulawesi	2277.13	138.64	6%	Low (<10%)
Maluku-Papua	8432.90	16.15	0%	Low (<10%)
Nationwide	29998.82	1877.89	6%	Low (<10%)

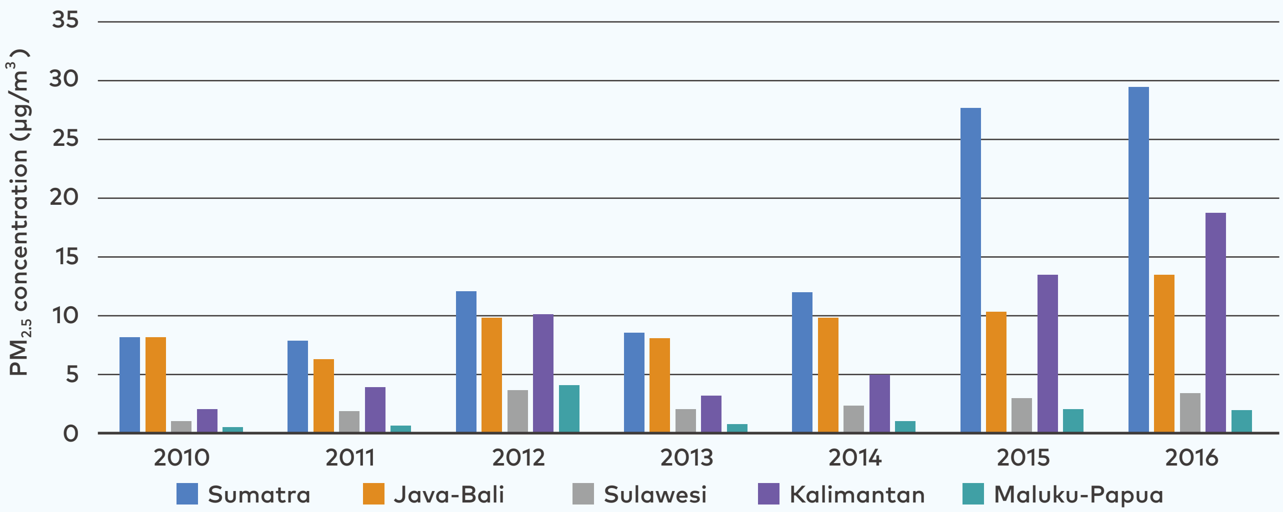
Source: Waterway Chart of the WRI[36]

2.3.2 Status quo and analysis on air environment pollution

Since 1990s, Indonesia's economy has developed rapidly, along with prominent environmental problems, in which air pollution is the most serious problem. Take Jakarta as an example, it has encountered with serious air pollution problems in recent years, with the main emission sources of transportation, industry and residential buildings. Due to the backward construction of roads and the increase in the use of cars, traffic jams often occur in Jakarta, causing emissions of a large amount of black smoke. According to a survey jointly conducted by Australian international aid organizations and the Indonesian Environmental Management Center, the most serious air pollutants in Jakarta are sub-micron particles, namely, particles with the particle diameter of below 2.5 microns. $PM_{2.5}$ particles in black smoke account for 50% of the total number of particles, and carcinogens are adsorbed on particles with a weight of about 20μg per cubic meter, which damages the human respiratory system[37]. In addition, eight coal-fired power plants within 100 kilometers around Jakarta are also one of the main sources of $PM_{2.5}$ emissions[38]. Official data shows that in 2012, 28% of $PM_{2.5}$ emissions in Jakarta came from the industry, and this proportion will reach 32% in 2020[39]. According to the Jakarta Post, in September 2015, the air pollution index of Pekanbaru, the capital of Riau Province, Sumatra, reached a new record of 984 points, reaching a level that seriously endangered health, causing thousands of local residents to escape[40].

The profound impact of air pollution on Indonesia and surrounding residents will also affect and restrict the development of the high-polluting coal-fired power industry to a certain extent. Meanwhile, the operation of coal-fired power stations will also emit $PM_{2.5}$, nitrogen oxides, sulfur oxides and other pollutants, further exacerbating air pollution problems in different regions. Figure 2.10 shows the $PM_{2.5}$ concentrations in five major regions of Indonesia from 2010 to 2016. It can be seen that the overall $PM_{2.5}$ concentration in different regions of Indonesia shows an upward trend from 2010 to 2016, further deteriorating the air pollution situation.

Figure 2.10 Annual average $PM_{2.5}$ concentration in five major regions of Indonesia from 2010 to 2016



Source: NASA's Earth Observing System Data and Information System (EOSDIS)[41]

This report uses $PM_{2.5}$ to assess the impact of ambient air quality on coal-fired power investment and construction in different regions of Indonesia. $PM_{2.5}$ refers to particles with an aerodynamic equivalent diameter less than or equal to 2.5 microns in the atmosphere, also known as particulates that which can go directly to the alveoli of the lungs, and has an important impact on air quality and visibility. $PM_{2.5}$ contains a large amount of toxic and harmful substances, and features long residence time in the atmosphere and long transportation distance, which may pollute the atmospheric environment and endanger human health.

For $PM_{2.5}$ concentration limits, the standards differ in different countries and regions. From the current academic research situation, there is no absolute safe concentration limit for $PM_{2.5}$. Studies conducted in the United States and Western European countries have shown that even low concentrations above background concentrations (3-5 μg/ m³) may have adverse effects on human health [42].

a. $PM_{2.5}$ standard of World Health Organization (WHO). The standard $PM_{2.5}$ given by the World Health Organization is a gradual goal rather than a safety limit, aiming to guide regions around the world to realize lower $PM_{2.5}$ concentrations. As both short-term and long-term exposure to $PM_{2.5}$ may have impact on health, this gradual goal is divided into a 24-hour and an annual mean value. The ultimate goal set by the WHO is that the annual mean value is less than 10 μg/m³ and the 24-hour mean value is less than 25 μg/m³. As this goal is difficult to achieve for some countries in the short term, the WHO also provides three-level transition target values (see Table 2.21).

b. Standard $PM_{2.5}$ concentration value adopted in China. In February 2012, the Ministry of Environmental Protection of China issued the Ambient Air Quality Standard (GB3095-2012), which added a $PM_{2.5}$ concentration limit, that is, the annual average concentration limit is lower than or equal to 35 μg/m^3, and the 24-hour average concentration limit is lower than or equal to 75 μg/m^3. This concentration limit is the same as the target value of the transition phase 1 set by the WHO.

c. Standard $PM_{2.5}$ concentration value adopted in the United States. In 1997, the National Ambient Air Quality Standards issued by the United States added the upper limit of $PM_{2.5}$ concentration. In 2006, the United States revised its air quality standards and proposed stricter standards for $PM_{2.5}$ concentration, that is, the upper limit of the average daily and annual $PM_{2.5}$ concentration is 35 μg/m^3 and 15 μg/m^3, respectively, which are approximately equivalent to the target value of the transition phase 3 set by the WHO.

Table 2.21 International standard $PM_{2.5}$ concentration value set by the WHO

Reference standard	Annual average concentration (μg/m^3)	24-hour average concentration (μg/m^3)
Target value of transition phase 1 /Chinese standard	35	75
Target value of transition phase 2	25	50
Target value of transition phase 3 /American standard	15	37.5
Air Quality Guideline (AQG)	10	25

Source: WHO[42]

Table 2.22 $PM_{2.5}$ concentration (μg/m^3) in five major regions of Indonesia in 2016

Region	Minimum annual concentration	Maximum annual concentration	Annual average concentration
Sumatra	1.89	89.90	29.44
Java-Bali	2.70	39.09	13.65
Kalimantan	3.00	79.59	18.86
Sulawesi	1.50	18.29	3.65
Maluku-Papua	1.00	8.50	2.11

Source: NASA's Earth Observing System Data and Information System (EOSDIS) [41]

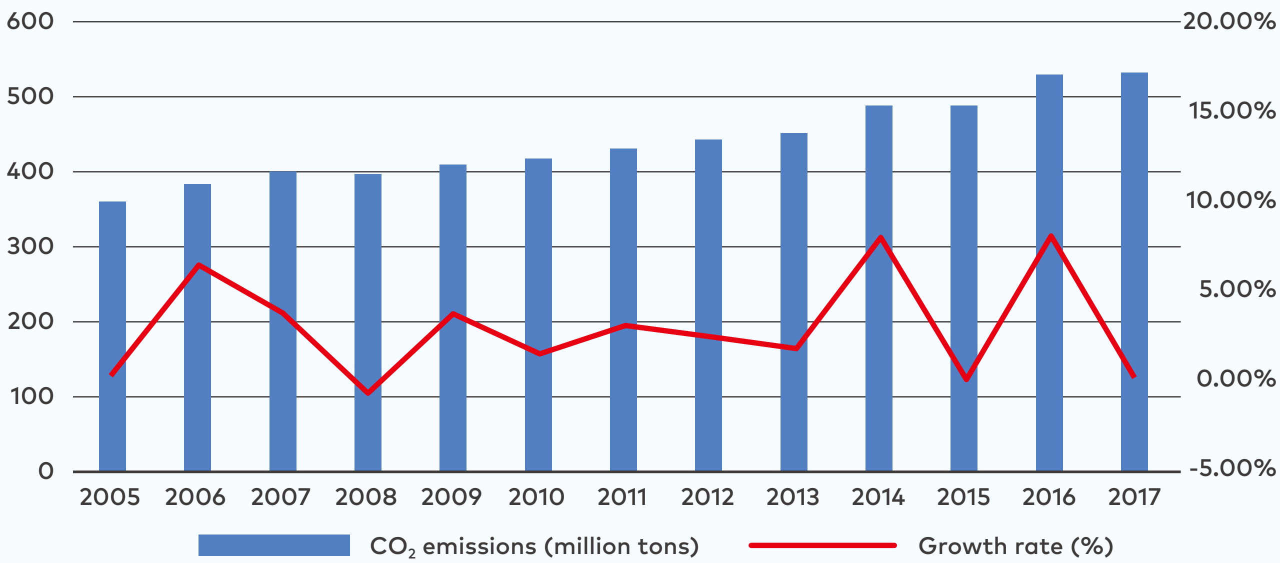
Based on the satellite images taken by NASA, this report analyzes $PM_{2.5}$ concentrations in the five major regions of Indonesia in 2016. The results are shown in Table 2.22. Comparing the standards published by WHO, the Ministry of Environmental Protection of China, and the U.S. National Ambient Air Monitoring Agency, the annual average $PM_{2.5}$ concentrations in the five major regions of Indonesia in 2016 were lower than the annual average $PM_{2.5}$ threshold issued by the Ministry of Environmental Protection of China. The annual average $PM_{2.5}$ concentration in the Sumatra region was 29.44 μg/m^3, which was within the target value range of the transition phase 1 set by WHO, indicating that the air quality was poor and had a great impact on human health and atmospheric environmental pollution. The annual average $PM_{2.5}$ concentration in the Kalimantan region was 18.86 μg/m^3, which was within the target value range of the transition phase 2 set by WHO, and higher than the upper limit of the annual average standard concentration released by the United States, indicating that the air quality was relatively poor. The annual average $PM_{2.5}$ concentration in the Java-Bali region was 13.65 μg/m^3, which was within the target value range of the transition phase 3 set by WHO, but failed to meet the WHO's AQG. In spite of relatively good air quality, relevant departments still need to improve the atmospheric environment. The annual average $PM_{2.5}$ concentrations in the Sulawesi and Maluku-Papua regions are 3.65 μg/m^3 and 2.10 μg/m^3, respectively, reaching the value recommended by WHO.

2.3.3 Status quo and analysis on carbon dioxide emissions

In December 2015, nearly 200 parties resolved to pass the Paris Agreement, promising to control the global average temperature rise to within 2°C by the end of the 21st century, and strive to further control it within 1.5°C. As one of the contracting parties, Indonesia must consider the constraints of resources and environment on economic development when dealing with a series of problems in terms of the extensive use of various resources and the deterioration of the ecological environment, etc.

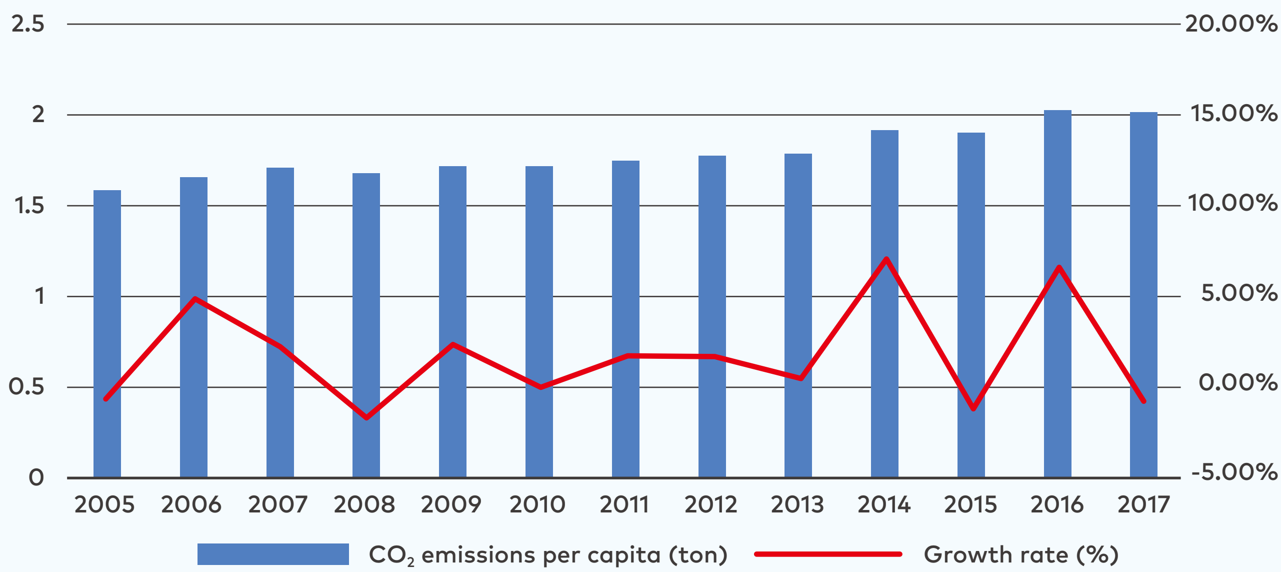
According to the Emission Database for Global Atmospheric Research (EDGAR), Indonesia's carbon dioxide emissions in 2017 were 532 million tons, ranking 12th in the world, and the cumulative total carbon dioxide emissions for the year accounted for 1.43% of the world's total emissions[43]. In addition, Indonesia's total carbon dioxide emissions have grown rapidly at an annual average growth of nearly 3.3%, leading to the increase of carbon emissions per capita at an annual average growth of 2%. In Sumatra and Kalimantan, the CO_2 emission is mainly from deforestation.

Figure 2.11 CO_2 emissions in Indonesia from 2005 to 2017



Source: Emission Database for Global Atmospheric Research (EDGAR)[43]

Figure 2.12 CO_2 emissions per capita in Indonesia from 2005 to 2017



Source: Emission Database for Global Atmospheric Research (EDGAR)[44]

This report uses CO_2 emissions to assess climate change constraints faced by Indonesia's coal-fired power industry. CO_2 emissions refer to the carbon dioxide emissions directly or indirectly generated by humans in production activities, and mainly refer to the emissions generated during the production, transportation, use and recycling of commodities. CO_2 is the main component of greenhouse gases. A large amount of CO_2 emissions may cause problems such as global warming, global redistribution of precipitation, melting of glaciers and frozen soils, and rising sea levels, which not only endanger the balance of natural ecosystems, but also threaten human food supply and living environment.

To facilitate the calculation of the CO_2 emissions generated by the five major regions of Indonesia by region, this report, in accordance with the default method provided in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, uses the CO_2 emissions generated by primary energy consumption (mainly coal, oil, and natural gas) in different regions of Indonesia as an estimated value of Indonesia's CO_2 emissions. The calculation formula is as follows[45]:

$$Eco_2 = F \times COEco_2 \tag{2.7}$$

Where, Eco_2 indicates the amount of CO_2 emissions from the consumption of fossil fuels, F indicates the amount of fossil fuel consumption, and $COEco_2$ indicates the CO_2 emission coefficient. Table 2.23 shows the CO_2 emission coefficients of various energy sources.

Table 2.23 CO2 emission coefficient of various energy sources [46]

Energy source type	Coal	Oil	Natural gas
CO_2 emission coefficient (tons of CO_2/tce)	2.744	2.138	1.628

Table 2.24 Consumption of various types of primary energy sources from 2011 to 2017

Energy type \ Year	2010	2011	2012	2013	2014	2015	2016	2017
Coal (million tons)	64.00	66.00	67.00	72.00	76.00	86.00	82.13	79.34
Oil (million tons)	103.54	105.96	108.31	108.22	110.17	106.61	105.42	109.23
Natural gas (million tons)	54.32	55.99	56.12	54.26	54.39	52.80	51.12	50.57

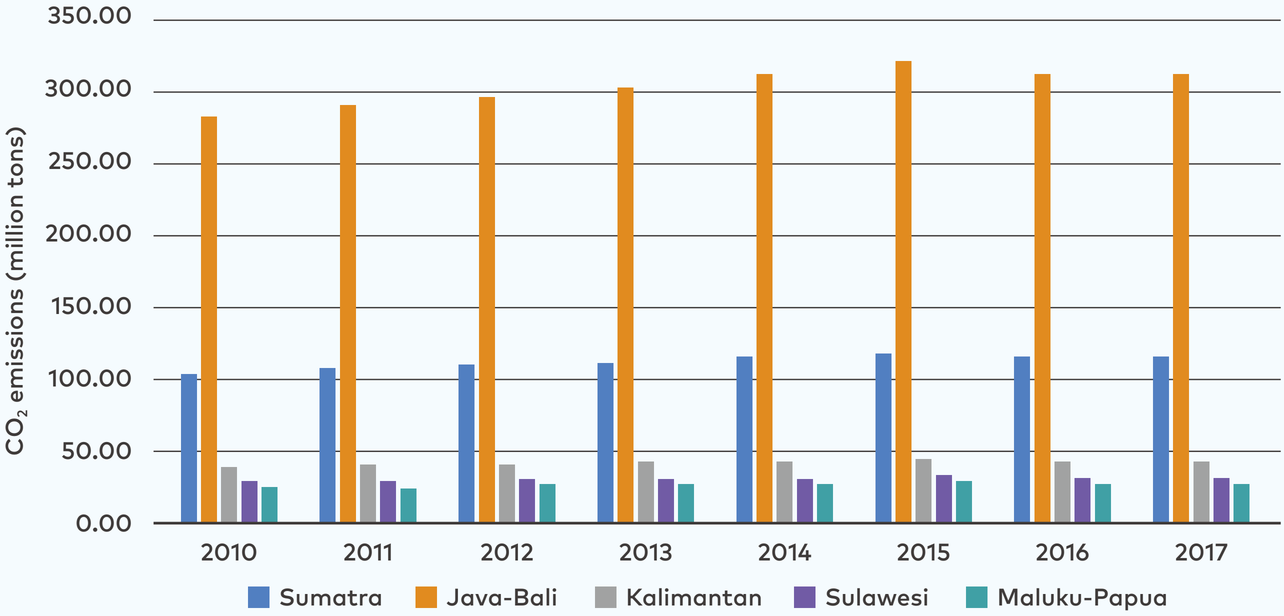
Source: Statistical Yearbook of Indonesia 2011-2018[47]

Unit: million tons of standard coal

As shown in Table 2.24, the consumption of various types of primary energy sources in Indonesia from 2010 to 2017 showed a volatile upward trend. Among them, oil consumption accounted for the largest proportion (45%) of the country's primary energy consumption annually; coal consumption accounted for the second (32%); and natural gas consumption accounted for the lowest proportion (23%).

As data on primary energy consumption by region is not available, this report conducts a regional distribution of coal, oil and natural gas consumption and calculates the CO_2 emissions of each region based on the GDP share of each region in Indonesia from 2010 to 2017. Figure 2.13 shows the calculation results.

Figure 2.13 CO_2 emissions in the five major regions of Indonesia



The above figure shows that, the overall CO_2 emissions in the five major regions of Indonesia show a fluctuating trend between 2010 and 2017. Among them, the Java-Bali region has the largest CO_2 emissions, accounting for 59% of the national CO_2 emissions annually, which is because the Java- Bali region has a large economy, rapid economic development, and a large primary energy consumption; the Sumatra region has the second largest CO_2 emissions, accounting for 22%; and the Kalimantan, Sulawesi, and Maluku-Papua regions have low CO_2 emissions, accounting for 8%, 6%, and 5%, respectively.

In 2015, based on the current level of CO_2 emissions, Indonesia set its National Determined Contributions (NDC) on CO_2 emissions target in 2030 to 11% reduction in the CO_2 emissions from the energy sector compared to BAU[48]. As the main source of CO_2 emissions, the coal-fired power industry will affect the achievement of the total carbon emission reduction target and will also be constrained by this target.

To summarize, the pressure of water resources has a great environmental constraint on coal-fired power investment and construction in the Java-Bali region. It may face water resource competition in the future and cause potential risks to the investment and construction of coal-fired power stations. In addition, the air pollution problems in Indonesia and the pressure on the achievement of carbon emission reduction targets will also affect the development of the coal-fired power industry to a certain extent, thus posing risks to the investment and construction of coal-fired power projects in Indonesia. Moreover, the coal-fired power projects with high water consumption, high carbon emissions and high pollution will further worsen the environmental conditions in different regions, thus causing more serious air pollution and water stress problems, and affecting the achievement of carbon emission reduction targets.

03 Risk warning for coal-fired power investment and construction in Indonesia

The indicator system of risk warning for coal-fired power investment and construction in Indonesia in 2022 is divided into two indicators: the redundancy of installed coal-fired power capacity and economy of coal-fired power construction. The redundancy warning indicator is a binding indicator, reflecting the feasibility of constructing coal-fired power projects in a region; the economy warning indicator is a suggested indicator, reflecting the economy of constructing coal-fired power projects in a region, thus providing decision-making reference for power plants to invest in coal-fired power projects. The two risk warning indicators are divided into red and orange levels according to the degree of risk. The final risk warning result is determined by the highest rating of the two indicators.

The redundancy warning indicator is divided into red and orange levels based on the reserve margin of the power systems in Indonesia. Orange indicates that the actual reserve margin of power system is higher than the reasonable reserve margin, and the excess part is greater than the corresponding reserve margin of a local single large-sized coal-fired power unit, but lower than the corresponding reserve margin of the installed capacity required for the annual increase of local electrical load; while red indicates that the actual reserve margin of power system is higher than the reasonable reserve margin, and the excess part is greater than the corresponding reserve margin of the installed capacity required for the annual increase of local electrical load. Based on the data of Global Energy Monitor, this report obtains the maximum installed capacity of coal-fired power generation unit expected to run in each region in 2022: 600 MW in Sumatra region, 1,000 MW in Java-Bali region, 150 MW in Kalimantan region, 150 MW in Sulawesi region, and 65 MW in Maluku-Papua region. All calculation results are rounded to an integer.

Table 3.1 Interval division of redundancy warning of installed coal-fired power capacity in each region

Region	Reasonable reserve margin	Orange warning interval	Red warning interval
Sumatra	80%	85-90%	≥90%
Java-Bali	15%	17-20%	≥20%
Kalimantan	80%	85-90%	≥90%
Sulawesi	60%	65-70%	≥70%
Maluku-Papua	75%	80-85%	≥85%

The economy warning indicator is divided into red and orange levels based on the IRR of the coal-fired power projects in Indonesia. A red warning occurs if the IRR is lower than 10%; an orange warning occurs if the IRR is greater than 10% and lower than the common IRR of the projects (usually 12%).

3.1 Redundancy warning of installed capacity

The warning results of the redundancy of coal-fired power installed capacity show that with the centralized implementation of Indonesia's "35GW Plan", the actual reserve margin of power systems in the five major regions will increase in 2022. In Scenario 1 with relatively optimistic economic growth, the actual reserve margin of power system in Java-Bali and Kalimantan regions in 2022 will exceed the reserve margin of power systems corresponding to their respective red warning intervals, indicating that it is highly risky in coal-fired power investment in these regions. In Scenario 2, due to the expected decline in economic growth, the problem of installed coal-fired power overcapacity will arise in more regions. Except for Sulawesi region, the actual reserve margins of power systems in the remaining four regions in 2022 will exceed the reasonable reserve margins: Sumatra and Maluku-Papua regions are in the orange warning interval, indicating high risk in coal-fired investment; the actual reserve margin of power systems in Java-Bali and Kalimantan regions is still in the red warning interval, and the scale of coal-fired power overcapacity further expands.

3.2 Economy warning of investment

The economy warning results of investment show that at different levels of GDP growth, the expected IRR of coal-fired power projects in Indonesia in 2022 will change significantly. In Scenario 1, at a GDP growth of 5.9%, the IRR of coal-fired power projects in Java-Bali and Kalimantan regions in 2022 is less than 10%, which is in the red warning interval, indicating ultra-high risk in coal-fired power investment. The IRR in Sumatra and Sulawesi regions ranges from 10% to 12%, which is in the orange warning interval. In Scenario 2, at a GDP growth of 5.2%, the IRRs of coal-fired power projects in Sumatra, Java-Bali, Kalimantan and Sulawesi regions are all below 10%, which are in the red warning interval; the IRR in Maluku-Papua region ranges from 10% to 12%, which is in the orange warning interval.

3.3 Comprehensive risk warning results of coal-fired power investment and construction

The final risk warning results of coal-fired power investment and construction in the five major regions of Indonesia are determined by the highest ratings among the two indicators: redundancy of coal-fired power installed capacity and economy of coal-fired power investment and construction.

It can be seen from the comprehensive warning results in Scenario 1 that the comprehensive warning results of Java-Bali and Kalimantan regions are both red, indicating that coal-fired power investment and construction in these two regions will face extremely high risks and these two regions are greatly constrained by various indicators. The warning result of Sumatra and Sulawesi regions are both orange, indicating that coal-fired power investment and construction in these two regions will face high risks. In Scenario 2, the warning results of Sumatra, Java-Bali, Kalimantan and Sulawesi regions are all red, indicating that the coal-fired power investment and construction in these regions will face extremely high risks. The warning result of Maluku-Papua region is orange, indicating that coal-fired power investment and construction in this region will face high risk.

Judging from the impacts of the sub-item warning result's change on the comprehensive warning result, in Scenario 2, the investment risk in terms of economy in Sulawesi region is higher than that in Scenario 1 which makes the comprehensive warning result of Sulawesi region change from orange to red. The investment risks in terms of redundancy of installed capacity and economy of Maluku-Papua region become higher, resulting in the comprehensive warning result rises to orange; and the comprehensive warning result of Sumatra region keeps unchanged, but the investment risks in terms of redundancy of installed capacity and economy are higher than that in Scenario 1.

In summary, even if Indonesia's economic growth can reach the expectations of the Indonesian National Development Planning Agency by 2022, the coal-fired power investment and construction in Indonesia will still face high risks. Except for Maluku-Papua region, it is highly risky for coal-fired power investment and construction in the other four regions. Among them, Java-Bali and Kalimantan regions have relatively small space for coal-fired power investment and face extremely high investment risks. At a low economic growth, the risks of coal-fired power investment and construction in Sumatra, Sulawesi and Maluku-Papua regions will further exacerbate.

04 Preventive measures and solutions to risks in coal-fired power investment in Indonesia

Chinese enterprises lack experience in dealing with the long-term risks of overseas coal-fired power investment. In recent years, coal-fired power enterprises going global have gradually accumulated some experience. However, due to the large regional differences in the host countries, the risk evaluation and avoidance of overseas coal-fired power investment requires not only the efforts of involved enterprises and financial institutions, but also the national macro policy guidelines. Therefore, the following suggestions are made in this report:

(1) Governments

China's relevant government decision-making and management departments should establish a risk warning system for China's overseas coal-fired power investment in the major host countries, and guide and urge enterprises to fully consider factors that may affect the long-term operation of coal-fired power projects in their early investment decision-making plans. In addition, they should provide policy guidance and consultation for Chinese coal-fired power enterprises, banks and insurance companies involved in overseas coal-fired power investment, guide public funds and policy-based financial institutions to conduct risk evaluation and prevention of coal-fired power projects in high-risk regions in Indonesia to prevent the risks in overseas coal-fired power investment, and make reasonable use of public funds and policy warning systems to regulate the direction and rhythm of Chinese enterprises' overseas power investment.

(2) Coal-fired power enterprises

Equity investment enterprises should establish and improve long-term risk evaluation systems for the projects, gradually improve their awareness and control capabilities of long-term risks such as global energy transition and climate changes, and comprehensively evaluate long-term risks due to factors such as changes in energy planning and power policy, global energy transition, and excess power capacity in the host countries.

(3) Financial institutions

China has become one of the world's largest investors in coal-fired power projects, and its participation in overseas coal-fired power equity investments has also increased significantly. Banks, insurance companies, and other financial institutions should improve their understanding and risk evaluation capabilities of the long-term operating market of overseas coal-fired power projects, identify high-risk projects, and strictly control financing or guarantees for high-risk projects. Financial institutions should give full play to the guiding role of the capital market in overseas investment, actively promote the positive interaction between financial systems and the energy industry to control the risks in overseas coal-fired power investment. They should also strengthen the risk control and environmental impact management of financial systems, and make reasonable use of public funds and policy warning systems to regulate the direction and rhythm of Chinese enterprises' overseas power investment. In addition, they should constantly improve the supervision and risk control of financial systems.

(4) Indonesian government

The Indonesian government should fully consider the medium-/long-term impact of excessively rapid growth of power supply construction, energy transition and environmental & resource constraints on coal-fired power investment, promptly stop approving new coal-fired power projects in high-risk regions, and improve its own energy development planning capabilities and the reasonability and stability of its energy policies to carry out energy transition from coal to renewable energy.

Appendix

Power system reserve capacity refers to the equipment capacity that needs to be added to the power system in order to ensure the power market demand in the event of equipment repair & maintenance, accidents, and frequency regulation. It usually includes maintenance reserve capacity, accident reserve capacity, and load reserve capacity. Reserve capacity is often determined by the reliability analysis on the power system. Factors such as grid facilities, power supply structure, and power load may affect the size of the reserve capacity. For example, the default planned reserve capacity of the North American Electric Reliability Corporation (NERC) is 15%; in 2015, the average power reserve capacity across China exceeded 35%, leading to a significant power oversupply. Compared with the United States and China, Indonesia has relatively more backward power infrastructure, lower unit reliability, and lower levels of networking (there are a large number of isolated networks and islands), requiring a higher reserve margin of power system. At present, no formal and reliable reserve margin data is available in Indonesia, but taking into account factors such as the level of power grid connectivity, electrical load, power supply structure, unit operating conditions, and equipment maintenance in Indonesia, standards of other countries are not applicable to Indonesia. Therefore, this report determines the reserve margin of Indonesia's power system based on three sub-indicators: load reserve, accident reserve and maintenance reserve.

As for the standard value of the reserve margin of the power system by region, under the principle of balance of electric power and energy and taking into account factors such as grid planning, construction, dispatching operation, and installation structure in different regions, the load reserve, maintenance reserve, and accident reserve of each region are determined separately to obtain a reasonable reserve margin of power system in each region. Considering that the development level of Indonesia's power grid is lagging behind, making it difficult to solve the power shortage problem through interregional power transmission, the three reserve margin levels in each region will be appropriately raised.

(1) Load reserve

Load reserve capacity, also known as operating reserve capacity, is the capacity of equipment added to ensure that the frequency of the power system meets the standards. The load reserve margin (the ratio of the load reserve capacity to the maximum load for power generation by the power system) is related to the total capacity of the power system, the power consumption characteristics of large users in the system, and the nationally prescribed frequency standards. Generally, a large power system adopts a smaller reserve margin and a small power system adopts a larger reserve margin, which needs to be determined based on whether there is an impact load in the system and the load size. Load reserve is in a rotating reserve state, which is generally borne by a hydropower plant or a thermal power plant. In this report, taking into account the lower installed power generation capacity in the Maluku-Papua, Kalimantan, Sulawesi, and Sumatra regions, the load reserve margins in these four regions are raised to some extent for the sake of the reliability level of the units, the status of the network/solitary network and the stability of the power supply.

Schedule 1 Load reserve margin in the five major regions of Indonesia

Region	Sumatra	Java-Bali	Kalimantan	Sulawesi	Maluku-Papua
Load reserve margin	8%	5%	7%	8%	8%

(2) Accident reserve

Power generation equipment in a power system may be temporarily stopped due to some accidents. In order to prevent the power generation equipment from affecting the normal power supply to power users during an emergency shutdown, a certain amount of reserve capacity needs to be set in the power system to replace the power generation capacity during the emergency shutdown. Factors affecting the accident reserve generally include the total installed capacity of the system, the technical level of operating personnel, the service life of the units in the system, the proportion of new and old units, and the quality of equipment maintenance. Due to the low level of power grid construction in Sumatra, Maluku-Papua, Kalimantan and Sulawesi regions, it is difficult to achieve interregional power transmission in the event of an accident, so the level of accident reserve margins in these three regions is slightly raised.

Schedule 2 Accident reserve margin in the five major regions of Indonesia

Region	Sumatra	Java-Bali	Kalimantan	Sulawesi	Maluku-Papua
Accident reserve margin	47%	7%	48%	32%	42%

(3) Maintenance reserve

Regular preventive maintenance is required for units in a power system. It mainly has three types: overhaul, minor repair and accident repair. Accident repair is solved by the accident reserve capacity, while maintenance reserve is only applicable to overhaul and minor repair.

Maintenance reserve capacity mainly depends on factors such as the total capacity of the power system, the size of the stand-alone capacity, the composition ratio of hydropower, thermal power, and nuclear power generation capacity, the health level of power generation equipment in the power system, the maintenance quality, and operation management level. As most of the areas in Sumatra, Sulawesi, Kalimantan, and Maluku-Papua regions are composed of islands and mountains, the power grid development is backward, making it difficult to achieve power transmission within the region.

In addition, according to the existing government planning, small coal-fired power plants in these four regions will be replaced in the future, so a higher maintenance reserve margin is required.

Schedule 3 Maintenance reserve margin in the five major regions of Indonesia

Region	Sumatra	Java-Bali	Kalimantan	Sulawesi	Maluku-Papua
Maintenance reserve margin	25%	3%	25%	20%	25%

By summing up the different reserve margins in each region, a reasonable power system reserve margin by region can be obtained, as shown in the Schedule 4:

Schedule 4 Reasonable reserve margin in the five major regions of Indonesia

Region	Sumatra	Java-Bali	Kalimantan	Sulawesi	Maluku-Papua
Reasonable reserve margin	80%	15%	80%	60%	75%

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