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Coal Repowering in China

Governance Challenges and Possible Solutions

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Introduction

This briefing paper provides **a panoramic overview of the electricity governance in China,** with specific emphasis on its policy, regulatory and institutional settings (*Sections 1 to 3*). Building on this review, *Section 4* delves into the key challenges that are likely to affect the prospects for coal repowering in China. *Section 5* further extends this discussion to explore potential solutions to address these challenges. For further details about the theoretical and analytical frameworks supporting the analysis in this briefing paper, please refer to *Appendix A.* It's important to note that nuclear power-related issues (e.g., waste treatment), though significant, are not addressed in this paper, yet they may also affect the pursuit of repowering in China.

Summary of contents

01. Policy Settings

The current policy settings in China predominantly focuses on building a clean power system with renewable energy as its backbone.

In the Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy (the Working Guidance thereafter), which serves as the blueprint for China's climate strategy, stringent objectives are outlined to strictly limit the increase in coal consumption over the 14th Five-Year Plan period (2021-2025) and phase it down thereafter. In addition, the Working Guidance emphasises strict control over the development of coal-fired power generation projects. To replace coal power in meeting rising electricity demand, the Working Guidance supports the deployment of non-fossil energy sources, with particular emphasis on renewable energy (NDRC, 2021).

To translate these guiding objectives into action, the 14th Energy Five-Year Plan (2021-2025), the country's strategic planning document for energy sector development, sets a target to increase the share of non-fossil generation to around 39% by the end of the planning period (NEA, 2022). Following the release of this document, the National Development and Reform Commission (NRDC), the country's macroeconomic planning agency, announced the plan on renewable energy development in June 2022, outlining a set of specific targets on renewable generation and capacity utilisation (see **Table 1** in **Appendix B**). This plan emphasises the development of large utility-scale renewable energy bases, particularly in resource-rich western regions, along with distributed renewable energy systems in eastern city-clusters (NDRC, 2022).

The primary focus for nuclear energy development is on capacity expansion in coastal areas, whereas repowering has garnered scant attention.

The 14th Five-Year Plan aims to 'actively, securely and steadily' advance coastal nuclear power construction, with a target of reaching installed capacity of 70GW by 2025 (NEA, 2022) – an approximately 25% increase from the 2022 levels at 56 GW. The 14th Five-Year Plan also explicitly identifies several advanced nuclear technologies to be deployed, including two third-generation technologies (Hualong One, and Guohe One), along with high-temperature gas-cooled reactors featuring a demonstration project in Shandong, marking the country's first fourth-generation reactors (Sandalow et al., 2022).

02. Regulatory Settings

Guided by the aforementioned policy settings, a diverse array of regulatory incentives has been introduced to support the uptake of renewable energy and complementary technologies, such as battery storage.

The 13th Five-Year Plan on Renewable Energy, issued by NDRC in 2016, set a target to achieve 680 GW of renewable energy capacity by 2020 (NDRC, 2016). The Plan was implemented with generous feed-in tariffs (FiTs), access to capital from policy banks, and other incentives (Sandalow et al., 2022). Starting in 2021, FiTs were phased out for new wind and solar projects and replaced by market-based incentives, including competitive auctioning, voluntary green certificate trading, and renewable portfolio standards (Zhou et al., 2022).

In the realm of energy storage, NDRC released policy guidelines in 2021 to expedite the development of energy storage, outlining a target of achieving more than 30 GW non-hydro energy storage capacity by 2025 (Bian, 2023). Later, over 20 provinces announced plans to support the deployment of energy storage systems, with a combined capacity exceeding 40 GW (Yi, 2022).

Capacity payments have been provided to coal power generators to facilitate their transition toward a supportive role within the power system – an immediate solution to address the shortages of system flexibility. The National Energy Administration (NEA) indicated at the Two Sessions in 2022 that while new coal power projects exclusively for electricity generation will not be permitted in principle, there's scope for constructing 'supportive units' of a 'certain scale' to ensure supply sufficiency and reliability (China Dialogue, 2022). Additionally, the Report on the Work of the Government 2022 called for a transformation of coal power to provide flexibility services, supporting higher levels of renewable penetration, as well as to provide heating to reduce the use of emissions-intensive loose coal (State Council, 2022).

To support the transition of coal power, NDRC issued a notice in 2023 establishing a capacity payment mechanism for coal power (NDRC, 2023). This mechanism alleviates the financial strains on coal power generators, reducing the immediate pressure for more distant options (e.g., repowering) to decarbonise. This is especially so when considering the high fuel expenses witnessed in recent years, which have led many coal power generators to operate at a loss. It is reported that in 2021 alone, China's large coal power generators incurred losses exceeding 120 billion yuan (about US$16.6 billion). Although there was some improvement in the following two years, financial losses still exceeded 10 billion yuan (about US$1.4 billion) in the first half of 2023, with some plants having a debt ratio over 75% (People's Daily, 2023).

03. Institutional Settings

The Institutional settings in China are fragmented and major policy decisions typically result from extensive negotiations involving central ministries, local authorities, and large state-owned enterprises (SOEs).

Unlike the conventional perception of China as a unitary state, often labelled as 'developmental state' or 'environmental authoritarianism' (Beeson, 2014, 2010), the country's institutional settings are fragmented, marked by diverse and sometimes conflicting interests among actors involved in the decision-making process, including central ministries, SOEs, local authorities, etc (Gilley, 2012). An illustrative overview of the institutional structure for the electricity sector in China is provided in **Figure 1** in **Appendix B.**

In this context, it becomes apparent that decisions regarding technical pathways (including repowering via nuclear energy) for electricity transition is not simply a top-down, authoritarian process where decisions are unilaterally made by the central government and implemented by a subservient bureaucracy. Instead, the decisions are influenced by the intricate interplay between central directives and localised, sectoral considerations and interests.

Large generation SOEs play an important role in the governance process. Prior to 1985, China's electricity industry was publicly owned, vertically integrated, and operated through SOEs under the administrative supervision of the Ministry of Electric Power Industry (MEPI). Beginning in 1997, major steps were taken to separate government functions from the operational management of publicly owned energy enterprises, primarily due to concerns regarding their poor financial performance (Andrews-Speed, 2012). The establishment of the State Power Corporation (SPC) in 1997 marked a significant milestone in this process, as it assumed operational management from the MEPI and acquired electricity assets from local Bureaus of Electric Power (BEPs) (Xu and Chen, 2006).

Further restructuring ensued in 2002, whereby the SPC's generation assets were divided among five major companies, namely, Huaneng, Huadian, Guodian, Datang, and China Power Investment (Xu and Chen, 2006). The structural reform initiated in 1997 led to the creation of large and relatively autonomous electricity SOEs (Downs, 2016), whose market dominance has been further solidified through subsequent rounds of mergers and acquisitions.

By the end of 2022, the total installed capacity of major central generation SOEs, often referred to as "Five Bigs and Four Smalls", exceeded 1,360 GW, representing over half of the country's total capacity. Local generation SOEs also maintain substantial shares in their respective regional markets, with several, such as Zhejiang Provincial Energy Group, Guangdong Energy Group and Beijing Energy Group, boasting installed capacities comparable to central SOEs.

Figure 1: Share of total installed capacity owned by major Central SOEs

Source: Ember (2024)

04. Governance Challenges

Based on the preceding discussion, several issues affecting the scope for the pursuit of coal repowering in China can be identified. These include:

Lack of awareness of coal repowering in the current policy settings: The current policy settings in China predominantly focuses on building a clean power system with renewable energy as its backbone, supplemented by storage technologies, and more flexible market trading mechanisms. Within this framework, nuclear energy is viewed as a vital complement to renewable energy, and the focus for its development is on capacity expansion in coastal areas. Coal repowering via nuclear energy has yet to receive significant attention.

Guided by these policy settings, large generation SOEs have actively diversified their portfolios, with little attention devoted to repowering. In recent years, there has been a noticeable trend among large generation SOEs in China to expand into the renewable energy sector. This has been facilitated by the establishment of dedicated subsidiaries, with substantial capital expenditure (capex) allocated to renewable energy projects through these entities (Dong et al., 2023). Additionally, large generation SOEs also play a crucial role as investors in battery storage projects. As of June 2023, there were 325 battery storage projects under construction, with nearly half of them supported by the 'Five Bigs' generation SOEs (China Electricity Council, 2023).

This trend of diversification can be attributed to robust regulatory and financial incentives (see Section 2 for details) aimed at promoting the adoption of renewable energy and energy storage technologies. These incentives, which include better access to capital, and green certificates, create value-adding opportunities for generation SOEs.

Coal-fired power plant, cooling towers and river surface reflection, Jiangxi, China

The aforementioned lack of awareness of coal repowering cannot be solely attributed to insufficient information and knowledge, especially considering that repowering initiative in other countries have been recognised by energy-related organisations such as China Atomic Energy Authority (CAEA, 2024). It may also be a result of conscious decision-making, influenced by the following factors:

- **Policy support for coal power flexibilisation mitigates the immediate need for seeking more distant solutions.** China's increasing reliance on renewable generation creates a significant demand for system flexibility to manage its intermittency. Coal power offers an immediate solution to this challenge, especially considering the limitations and challenges faced by alternative technologies such as battery storage, green hydrogen, and pumped hydro, which are not yet deployable at the scale required for effective renewable integration. In addition, while deeper market reforms hold promise in unlocking additional flexibility within the existing system, their implementation encounters significant challenges, failing to provide short-term solutions.

  Against the backdrop of major power crises in recent years, ensuring energy security becomes paramount. As a proven technology, coal power flexibilisation offers an immediate solution. To support the transition to ancillary and backup capacity providers, capacity payments have been provided to coal power generators, reducing their financial pressure. This also mitigate the immediate need for them to conduct more distant search for decarbonisation solutions, including repowering via nuclear energy.

- As the pressure for decarbonisation continues to intensify, large generation SOEs will begin seeking more distant solutions. However, repowering's attractiveness may be affected by:

The lack of nuclear energy-related capabilities by large generation SOEs

Currently, only three generation SOEs operate nuclear power assets in China: China National Nuclear Corporation (CNNC), China General Nuclear Power Group (CGN), and State Power Investment Corporation (via its nuclear power subsidiary, State Nuclear Power Technology Corporation, SNPT). Due to their limited proficiency in nuclear energy-related operations, other generation SOEs may not prioritise repowering their facilities with nuclear energy. Instead, they are more likely to explore alternative solutions, such as carbon capture and storage (CCS), that better align with their existing capabilities and operational needs.

This inclination is understandable if one notes that incumbent actors are often well-equipped to diversify into 'adjacent' or 'related' sectors, leveraging their historically accumulated skills and knowledge to gain a competitive edge in the emerging markets over new entrants (Breschi et al., 2003; Neffke et al., 2011) . This viewpoint is supported by empirical studies indicating that firm-level diversification into related sectors tends to be more successful than unrelated diversification (Helfat, 2002; Shin and Jalajas, 2010).

Potential impact on the coal-electricity ecosystem

The coal-electricity regime in China is a complex ecosystem that encompasses various interconnected sectors, including coal production and supply, the coal chemical industry, power generation, and the manufacturing of relevant equipment and facilities. This extensive network underscores the intricate interdependencies and dependencies among these sectors, suggesting that actions taken by one entity (coal generators to repower their facilities, in our instance) will inevitably affect other interconnected entities.

From this perspective, coal repowering is likely to encounter limitations in addressing all interconnected regime elements and associated interests. For example, the reduction in coal generation resulting from repowering efforts may precipitate a decline in coal mining activities. This decline, in turn, can have cascading effects on associated economic activities, such as equipment manufacturing and transportation, which rely heavily on the coal mining sector for demand. Additionally, the coal chemical industry, which depends on coal as a feedstock, may also experience disruptions due to changes in coal consumption patterns.

05. Possible Solutions

This paper does not aim to take a stance for or against nuclear energy. Instead, it is motivated by the urgent need to facilitate the decline of the coal-electricity regime to mitigate the worst impact of climate change. Repowering presents a potential option for achieving this goal, particularly given the considerable uncertainty surrounding technological development. Innovative technologies, such as CCS, although promising, are not yet mature and deployable at scale. Should their development fail to meet expectations, repowering serves as insurance for an uncertain future. It is found that if the current rate of deployment continues, the carbon storage capacity by 2050 would only reach about 700 million tons per year, just 10% of what is required (Martin-Roberts et al., 2021),

To promote coal repowering as a safeguard against future uncertainty in China, two possible pathways can be explored. The **first, top-down pathway** starts with an international consensus acknowledging repowering as a viable option for phasing down coal power, probably facilitated through the implementation of demonstration projects. Subsequently, repowering may be incorporated into central policy guidelines in China, incentivising generation SOEs to actively pursue repowering initiatives.

The **second, bottom-up pathway** involves promoting trial projects in regions on the peripheral of the coal-electricity ecosystem in China. Particular attention should be given to areas (e.g., Guangdong) experiencing rapid electricity demand growth and having limited local coal resources. In such areas, reliance on electricity imports from neighbouring provinces may prove inadequate to meet rising demand due to long lead times in interconnectivity projects and protracted negotiations over pricing and trading arrangements. Repowering local coal-fired power plants may provide a viable option for complementing renewable energy and ensuring supply adequacy. Local coal power generators are also more likely to consider repowering given their limited connections with the coal-electricity ecosystem, due to the lack of local coal resources.

06.
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07.
Appendices

Appendix A

A-1: Theoretical backdrop

In the broadest sense, governance can be considered as 'all the ways in which groups of people collectively make choices' (Florini, 2003). It is through this process that the potential for coal repowering can be articulated, cross-cutting issues and underlying trade-offs can be discussed, and a possible reconciliation between differing viewpoints, perspectives and interests regarding its application can be facilitated.

This paper considers repowering as a potential pathway for facilitating a major change in the coal-electricity regime, based on the argument that coal power is deeply embedded within a broader coal-electricity regime, encompassing coal production and supply, coal chemical industry, power generation, and the manufacturing of relevant equipment and facilities. The interdependence and interconnectedness within this network extend across various domains, including technical, socio-economic, regulatory, and market aspects.

In such settings, the extent to which coal repowering can find policy and political acceptance in the governance process hinges largely on its ability to address the tensions and conflicts arising from the coal-electricity regime change while advancing the transition agenda.

The nature of regime change

The field of transition studies has increasingly grown in prominence, as evidenced by the exponential growth of studies devoted to the topic (Köhler et al., 2019). These studies conceptualise an energy system as a socio-technical regime, where technologies, human agency, and social structures converge to meet societal demands for energy, such as for industrial heating, street lighting, and powering electrical appliances (Geels, 2005). From this standpoint, energy transition is construed as a regime change process, characterised by deep-structural changes in the overall configuration of the energy system, involving multiple actors and levels (Geels, 2002; Geels and Schot, 2010; Verbong and Loorbach, 2012).

Transition studies are particularly well-known for introducing the Multi-Level Perspective (MLP), a 'global' framework that provides a useful guidance for understanding the entire regime change process (Kanger et al., 2020). The MLP envisions this process as an outcome of co-evolutionary interplay between three distinct levels: niche innovations, socio-technical regime, and macro landscape (Geels, 2002). Within this framework, successful innovations, initially nurtured in small, protected niches, gradually mature and start to challenge the dominant, incumbent regime. When landscape pressures are sufficient, these challenges pave the way for niche innovations to achieve breakthroughs (Geels, 2011), leading to a 'regime shift' (Kemp et al., 1998).

While earlier transition studies tend to focus on the emergence and diffusion of niche innovations, considering them as the main drivers for regime change, more recent studies have increasingly turned their attention to the dynamics of incumbent regime (Ford and Newell, 2021; Fuenfschilling and Truffer, 2014; Geels, 2014; Leipprand and Flachsland, 2018; Ting and Byrne, 2020) , often referred to as the 'flipside of energy transition' (Turnheim and Geels, 2012). This shift in focus reflects a growing recognition that merely empowering niche innovations will not be sufficient to facilitate the transition towards a clean energy future. Additional efforts are also needed to transform the incumbent regime, particularly through destabilisation and phasing out its emissions-intensive components (Leipprand and Flachsland, 2018). This realisation is substantiated by empirical evidence, such as the 'coal conundrum' in

Germany (Jungjohann and Morris, 2014), and the phenomenon of 'more renewables, more coal' observed in China (Myllyvirta, 2023).

Regime change via incumbent diversification

Some transition studies emphasise the deep embeddedness of dominant regime technologies, such as coal-fired power plants and their associated supply chains, within a 'whole complex of scientific knowledge, engineering practices, production process technologies, product characteristics, skills and procedures, established user needs, regulatory requirements, institutions and infrastructure' (Hoogma et al., 2005, p 211). Consequently, these studies suggest that the dominant regime is 'locked in and stabilized on several dimensions' (Geels, 2010), resulting in regime change being a protracted process, often spanning several decades or more. This perspective aligns with Vaclav Smil's observation that 'all energy transitions have one thing in common: They are prolonged affairs that take decades to accomplish'(Smil, 2010, pp 141).

In these studies, regime lock-in is often ascribed to the resistance of incumbent actors (Hess, 2020; Lockwood et al., 2020, 2019a; van Mossel et al., 2018), portraying them as 'villains' who systematically impede transition efforts, owning to their shared and deep attachment to the dominant regimes (Turnheim and Sovacool, 2020). This viewpoint often garners support from empirical observations indicating that incumbent actors resist policy support and regulatory changes necessary for facilitating a higher level of clean alternative integration (Ford and Newell, 2021; Geels, 2014; Hess, 2016; Lee and Hess, 2019).

Beyond portraying incumbent actors solely as resistant to change, some studies adopt a more nuanced perspective on regime change. Here, incumbent actors may also actively pursue diversification into emerging clean energy sectors, primarily to seize the windows of opportunity for new value creation (Geels et al., 2016; Lockwood et al., 2019b; Smink et al., 2015). This is especially so when external pressures, such as increased difficulties in securing financial support for fossil fuel assets, or more ambitious targets for decarbonisation, accumulates. gradually weakening their commitment to the dominant regime (Turnheim and Geels, 2013). The diversification process can potentially enhance the credibility of novel technologies, promote technological variety and innovation, facilitate knowledge and resource transfer (Erlinghagen and Markard, 2012), and most importantly, weaken regimes' 'grip on firms-in-industries', paving the way for regime change (Turnheim and Geels, 2013).

A-2: Analytical framework

This paper aims to develop an understanding of the governance challenges faced by coal repowering in China, transcending the prevailing technology-centric considerations primarily focused on its technical potential, economic feasibility, and externalities (e.g., impact on local economy and jobs). To achieve this objective, an inductive case study approach, as proposed by Sovacool and Valentine (2012), is adopted. This approach entails first gathering extensive data and information describing the socio-economic and energy contexts within which coal repowering is expected to occur in China. Then, leveraging the strength of this data to inform conclusions drawn from the study.

This approach differs from deductive methods as it does not rely on predetermined hypotheses, enabling a broader understanding of the subject matter that extends beyond testing existing theories (Sovacool and

Valentine, 2012). Given the scarcity of prior research on coal repowering, an inductive approach is particularly suitable for uncovering novel insights.

Within the inductive framework, it remains crucial to establish a structured analytical approach. Transition studies on incumbent diversification offer valuable insights for developing such an approach. These studies highlight a wide range of factors influencing the choices of incumbent actors in pursuit of diversification, including repowering. These factors can be categorised into three broad groups:

1.

Policy settings that involve changing energy policy landscapes.

Some studies suggest that the pursuit of diversification by incumbent actors is often triggered by wider policy changes (Hockerts and Wüstenhagen, 2010; Turnheim and Geels, 2013). In the context of coal power, these changes may cause a reduced flow of financial resources to coal power assets (Davidson et al., 2023), changing market conditions with the introduction of carbon pricing that increases the costs of coal generation (Wu et al., 2023), and reduced legitimacy of coal power (Blondeel et al., 2020).

2.

Regulatory settings that include regulatory and market incentives for certain industries, offering opportunities for incumbent generators to diversify their portfolios.

Existing studies suggest that incumbent's strategic decisions regarding diversification are often driven by the perception of opportunities and challenges within emerging sectors (Leipprand and Flachsland, 2018; Steen and Weaver, 2017). This perception arises from expectations regarding the growth or decline of specific technologies and industries relative to others (van Lente, 2012), created by policy incentives aimed at fostering certain technologies and industries (Kivimaa and Kern, 2016).

3.

Institutional settings with specific emphasis on large SOEs, whose choice and preference regarding diversification are influenced by their capabilities and the underlying coal-electricity ecosystem.

Incumbent actors are often well-equipped to diversify into 'adjacent' or 'related' sectors, leveraging their historically accumulated skills and knowledge to gain a competitive edge in the emerging markets over new entrants (Breschi et al., 2003; Neffke et al., 2011). This viewpoint is supported by empirical studies indicating that firm-level diversification into related sectors tends to be more successful than unrelated diversification (Helfat, 2002; Shin and Jalajas, 2010).

Some studies challenge the notion that the pursuit of a particular option for diversification (e.g., repowering) is solely driven by incumbent companies viewing it as beneficial for their own interests. Instead, these studies argue that these decisions are also influenced by the actor-network underpinning the dominant regime. Indeed, incumbent actors often collaborate, resulting in the formation of 'alliances, the collectives and organisations of actors' (de Haan and Rotmans, 2018: 279). This actor-network is characterised by extensive cross-ownership linkages, inter-sectoral connections, and policy coordination mechanisms. It not only grants structural power to the involved actors, providing them with a set of 'relational networks and close contacts' to influence policy outcomes, as suggested by Geels (2014), but also constitutes a 'deep structure' that shapes the behaviours of incumbent actors.

In such settings, the preferences and choices of incumbent actors are inevitably affected by pre-existing relationships and network connections, making them unlikely to operate independently of the underlying actor-network. Consequently, incumbent actors are more likely to pursue diversification options that offer opportunities for all other actors in the network to adapt, thereby helping minimise undesired disruptions to industries and supply chains.

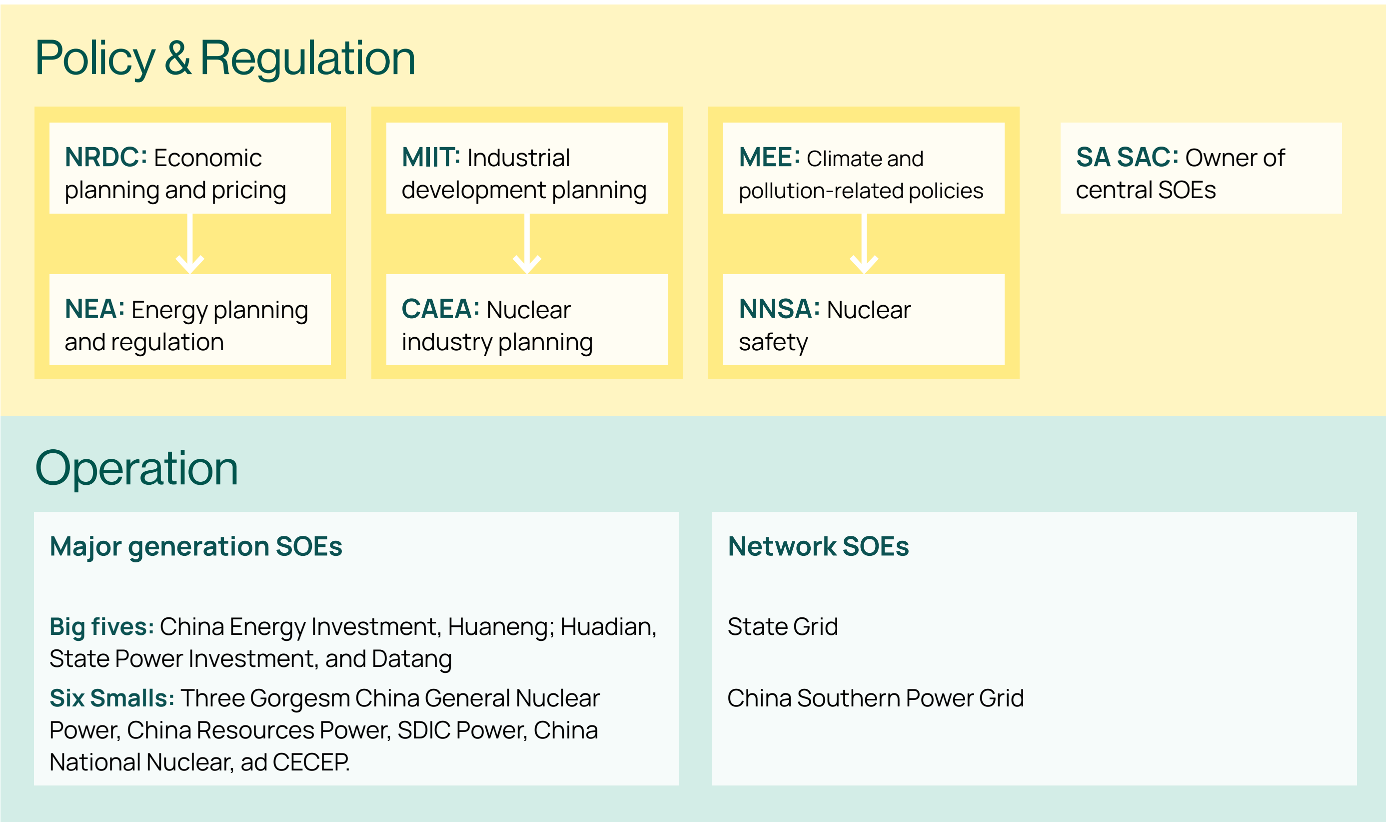
Appendix B

Table 1: Key targets on renewable energy development

	Unit	2020 level	2025 target
Total renewable energy consumption	Billion tonnes of standard coal	0.68	1
Share of renewable electricity consumption	%	28.8	33.0
Share of non-hydro renewable electricity consumption	%	11.4	18.0
Renewable generation	Trillion kWh	2.21	3.30
Non-electric utilisation of renewable energy, including geothermal heating, biomass heating and fuel, and solar heating	Million tonnes of standard coal	-	≥60

Source: NDRC (2022)

Figure 1: Institutional settings of the electricity sector in China



Notes: NRDC – National Reform and Development Commission; NEA – National Energy Administration; MIIT – Ministry of Industry and Information Technology; CAEA – China Atomic Energy Authority; MEE – Ministry of Ecology and Environment; NNSA – National Nuclear Safety Administration; SASAC – State-Owned Assets Supervision and Administration Commission; CECEP – China Energy Conservation and Environmental Protection Group; and SOEs – State-Owned Enterprises.

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