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Research article

Networked sustainable business model innovation and sustainable energy transitions: A case study of incumbent Chinese manufacturers in 2010–2022

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A B S T R A C T

The sustainability transition literature has paid scant attention to incumbent generation equipment manufacturers, constituting a complementary element in electricity systems. To fill this research gap, this study develops the concept of networked sustainable business model innovation (SBMI) as an analytical framework to explore how incumbent manufacturers change business models in response to changes in incumbent power generators and how these changes influence transitions in electricity systems. Based on case studies of three major Chinese incumbent power generation equipment manufacturers, our findings reveal that the networked SBMI by incumbent power generators and power generation equipment manufacturers can accelerate transitions to RES-E-based electricity systems in the segments where incumbent power generation equipment manufacturers have the capabilities to reorient and gain a competitive edge in the market. However, incumbent power generators can resume coal power projects unless incumbent power generation equipment manufacturers completely scrap coal power equipment production capacities.

1. Introduction

Recent transition studies have revealed that the traditional perception of incumbents as homogeneous groups that are "locked-in" socio-technical regimes, intensifying economic and political struggles to resist, slow down, and prevent transition efforts do not hold. Incumbent actors are distinguishable from regimes and are not homogeneous at company and industry levels. Some incumbent companies organize coalitions to invest in more advanced technology in their core businesses (Lowes et al., 2020) to reinforce incumbency. They may even increase lobbying to push transitions back and block the scope and speed of change from increasing and their technologies from declining (Markard, 2018), leading to transition backlash (Pel, 2021). Others reorient themselves toward

Abbreviations: BMI, business model innovation; BRI, Belt-and-Road Initiative; CSP, concentrated solar power; DEC, Dongfang Electric Corporation; EPC, engineering, procurement construction; FiT, feed-in tariff; FYP, Five-year plan; HEC, Harbin Electric Corporation; IPP, independent power producer; JV, joint venture; M&A, merger and acquisition; OEM, original equipment manufacturing; PERC, Passivated Emitter and Rear Cell, PV, photovoltaic, R&D, research and development; RES-E, renewable energy sourced-electricity; RPS, renewable portfolio standards; SC, supercritical; SBM, sustainable business model, SBMI, sustainable business model innovation, SEC, Shanghai Electric Corporation; SOEs, state-owned enterprises; UHV-DC, ultra-high voltage, direct current; USC, ultra-supercritical.

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innovation and new business models and reorganize to diversify their activities. However, contestation and power struggles within incumbents have rarely been analyzed (Magnusson and Werner, 2022). In addition, the implications of the sustainability-related activities of incumbent firms have not been adequately assessed (Kungl, 2024).

An organization study proposes theory-based categories of incumbent firms' behaviors and motives in sustainability transitions by combining the innovating/defending and collaborating/competing spectra: capable compound, networked change agent, institutional constituent, and path-dependent specialist (Magnusson and Werner, 2022). The categorization enables us to propose an organizational strategy to unpack path dependency. However, the categories frame firms as coherent units with bounded resources and distinct identities, limiting us from understanding organizational boundaries' multi-dimensional and dynamic nature. Incumbent firms can change ownership, merge and acquire other firms, and divest in response to landscape developments.

The incumbency research has expanded the scope to overcome the inadequate assessment and the limitations. First, it incorporates incumbent firms' business model innovations (BMIs), referred to as creating new systems rather than developing individual technologies (Bocken et al., 2014). The expansion unpacks path dependency into limited resources and capabilities, and dissatisfaction of top management and managers in the core business units, providing practical implications (Sund et al. 2021). The multiplicity of incumbent actor types, their strategies, the transient nature of their strategic positioning, and the various resources they deploy to support transformative changes (Turnheim and Sovacool, 2020) can diverge their positioning, triggering regime destabilization (Steen and Weaver, 2017) and accelerating energy transition processes.

Second, the research pays attention to collective network actions throughout supply chains. Analyses of upstream, downstream, and adjacent industrial manufacturers confirm that a transition in the focal sector creates transformation pressure on manufacturers and technology suppliers throughout the value chain. Firms in the focal sectors and upstream, downstream, and adjacent industrial manufacturers diversify their businesses and thus enhance collaboration and competition (Andersen and Gulbrandsen, 2020). Given that these manufacturers can potentially bring resources and expertise that generate significant differences for further development, how they build coalitions and critically change business models affects sectoral reconfiguration and transitions (Ruggiero et al., 2021).

Power generation equipment manufacturers are adjacent industrial manufacturers in the electricity system transitions. The traditional electricity system supply chain begins with fuel exploitation and transportation, electricity generation, transmission, and distribution to the final consumers (Schwarz, 2018). However, power generators can procure renewable energy sources-based electricity (RES-E) technologies from dedicated manufacturers. Incumbent manufacturers may compete with dedicated manufacturers by reorienting their businesses to supply RES-E technologies. Whether their technologies satisfy incumbent power generators and gain a competitive edge with dedicated RES-E manufacturers remains unpredictable. Anxiety pushes them to supply their technologies to become developers of RES-E projects. This diversification strategy creates a dilemma between collaboration and competition: Incumbent manufacturers collaborate with power generators as technology suppliers but compete with the latter as power developers.

BMI research focuses primarily on incumbent power generators (Wainstein and Bumpus, 2016). Few studies have explored how incumbent power generation equipment manufacturers build coalitions, change business models and the state of coopetition (Christ et al., 2017), and affect the speed and direction of the electricity system transitions. Various actors in the traditional supply chain and connected industries strive for improved collaboration and their impacts on sustainability transitions (Melander, 2017). While Hellström et al. (2015) analyzed distributed energy ecosystems, Rossignoli & Lionzo (2018) analyzed network collaboration, and Planko et al. (2019) analyzed coopetition strategies in the electricity sector, none of these studies have analyzed the multiplicity and heterogeneity of responses of incumbent power generation equipment manufacturers.

To fill this research gap and deepen our understanding of the impact of incumbent power generation equipment manufacturers on energy transitions, we pose two research questions:

- How do incumbent power generation equipment manufacturers change their business models in response to the BMI of incumbent power generators?
- How do networked BMIs from incumbent power generators and equipment manufacturers influence sustainable transitions in electricity systems?

We first conduct a literature review of sustainable BMI (SBMI) in supply networks and develop coopetition as an analytical framework for power generation equipment manufacturers. We then consider three major incumbent Chinese power generation equipment manufacturers as cases to provide answers.

This study makes three main contributions to the literature. Theoretically, it provides a granular understanding of how networked SBMIs can overcome the incumbency in electricity system transitions. Methodologically, it provides an analytical framework for investigating how networked SBMIs are generated among complementary elements and advance sustainable transitions in electricity systems. Previous literature on networked SBMI has focused mostly on the circular economy (Oskam et al., 2018; Pieroni et al., 2019) and sustainable supply chain management (Geissdoerfer, Morioka, et al., 2018). Empirically, it provides novel findings on China's climate and energy policy paradox of simultaneous increase in domestic coal power and renewable energy (Malz et al., 2023; Mori and Takehara, 2018).

The remainder of this paper is organized as follows: In Section 2, we review the literature on SBMI and networked SBMI and identify coopetition as a key driver of sustainability transitions in supply chain networks. This concept was developed to build an analytical framework. The methodology for the case studies and the logic behind the case selection are presented in Section 3. In Section 4, we present the results; in Section 5, we discuss the role of the manufacturing element of complementarity in transitions in electricity systems. Finally, Section 6 concludes.

2. Analytical framework

2.1. Sustainable business model innovation and sustainability transitions

The multilevel perspective on sustainability transitions argues that landscape developments and the subsequent destabilization of existing regimes create space for novelties to scale. In this process, novelty improves price performance, helps gain support from powerful groups, and entails struggles with rivals and regime actors over regulations (Smith and Raven, 2012). A multilevel perspective focuses on the development and diffusion of new artifactual technologies, but it overlooks the micro-level of innovating actors (Markard and Truffer, 2008).

In contrast, BMI is a type of organizational innovation often intertwined with technology and complements product and process innovation (Zott et al., 2011). It describes the reconfiguration of existing value propositions, means of value creation, and value capture or the introduction of entirely new ones (Massa et al., 2017). It includes the mobilization of resources and the creation of legitimacy. SBMI is thus a business model innovation aimed at (a) sustainable development or positive, respectively reduced, negative impacts on the environment, society, and the long-term prosperity of the organization and its stakeholders, or (b) adopting solutions or characteristics that foster sustainability in its value proposition, creation, and capture elements or its value network (Geissdoerfer et al., 2018).

Value proposition refers to the value and benefits created for users based on technology. It identifies the products, services, production processes, and market segments for which the value proposition is intended to benefit customers. The sustainability value proposition provides measurable ecological and social value, together with economic and commercial value (Boons and Leke-Freund, 2013).

Value creation emphasizes key activities of businesses' actions and interactions (Bocken et al., 2014), and the content, structure, and governance of transactions designed (Zott and Amit, 2010) to create deliverables for customers/users and provide them in the market. It develops core products, services, and technologies; enhances the value chain position to attract new customers and niche technology experts; and expands the network by developing relationships with relevant stakeholders, such as new industries, new and current customers, and collaboration partners. Value delivery highlights customer interfaces such as customer segments, relationships, and channels (Planko and Cramer, 2021). Sustainable value creation changes and develops products, services, production, technology, value chains, market segments, customers, and networks to align with sustainable value propositions (Beers et al., 2021).

Value capture relates to how a firm earns revenue when providing customers and users goods, services, or data/information (Teece, 2010). It includes new revenue mechanisms for a firm, its ability to be a revenue risk-sharing partner, and competitive strategies that maintain competitive advantages over competitors (Holtström, 2022). SBMs capture economic value, ecosystem services, and social value, such as customer loyalty (Beers et al., 2021), and maintain or regenerate natural, social, and economic capital beyond organizational boundaries (Schaltegger et al., 2016). A firm is motivated to create sustainable value if it identifies value capture potential and perceives greater economic benefits, including attractiveness as a value chain partner, innovation capabilities, reputation, and brand value (Laukkanen et al., 2021).

Incumbent firms tend to develop business models different from those of startups. Startups tend to develop business models with a high customer orientation and a strong digital component, or high ecological components. Incumbent firms pursue a greater number of business model archetypes and develop business models with complex value creation and delivery structures and high capital intensity (Palmié et al., 2021). To expand the boundaries of their businesses, incumbent firms employ transformation, diversification, and acquisition (Ruggiero et al., 2021). Transformation refers to the development of resources and capabilities by self-financing in-house development and leveraging existing capabilities to reorient innovation to capture value in new niche sectors in domestic and international markets (Steen and Weaver, 2017), new market segments through servitization (Holtström, 2022), and gaining larger market shares (Achtenhagen et al., 2017). Mergers and acquisitions provide a quick means of enhancing skill sets and hedging in new environments (Pickl, 2019).

Diversification includes various forms of collaborative strategies, ranging from joint ventures (JVs) to strategic alliances, aimed at accessing other companies' resources for the increased utilization of joint resources (Das and Teng, 2000). The new knowledge and resources obtained through strategic alliances can benefit a firm's customers if a sustainable value proposition is developed (Holtström, 2022).

There are three types of diversification strategies: geographical, vertical, and horizontal (Kenner and Heede, 2021; Mori, 2021a). Geographical diversification refers to entering new markets while retaining core businesses in the original or home country or completely relocating them (Mori, 2021c). This strategy may demand adjustment of the products to local needs and contexts but does not require changes in the core businesses. Horizontal diversification adds new products and technologies to their line-ups to serve purposes that other products may not fulfill. Incumbent companies engage in sector coupling or integration of new and old technologies. Vertical diversification expands core businesses vertically along the value chain to internalize added value and develop an integrated marketing strategy (Löhr and Mattes, 2022). Successful vertical diversification requires matching the capabilities of core and new businesses (Leonard-Barton, 1992), and reorganization for innovation and production. JVs and social contact with new entrants (Heiskanen et al. 2018) may be adopted to advance diversification. They can enhance a firm's skillset to manage new challenges and provide hedges in a new environment (Pickl, 2019).

SBMs drive sustainability transitions in three ways (Bidmon and Knab, 2018). First, as non-technological niche innovations, they foster the upscaling of niche innovations without relying on technological innovation. Scalability is a measure of transformative potential. As part of their market strategies, SBMs may help firms overcome significant barriers (Sarasini and Linder, 2018).

Second, as intermediates between the technological niche and socio-technical regime, they reconfigure regime rules, facilitating the stabilization process of technological innovation and its breakthrough. SBMs may create visions and expectations that motivate a diverse set of stakeholders, as part of strategic and tactical activities to demonstrate the viability, sustainability, and legitimacy of innovation (Sarasini and Linder, 2018). The SBM realigns system components around a new value (Bolton and Hannon, 2016). Changes in the elements of the sociotechnical regime such as market structures, institutions, technologies, and user practices offer new opportunities for SBMs to emerge from niches to wider applications. However, this regime is an obstacle for SBMs (Bidmon and Knab, 2018; Hannon et al., 2013). Firms evolve their business models into SBMs only when wider institutional, discursive, practical, and relational developments are associated with a specific transition pathway for scaling SBMs (Beers et al., 2021).

Third, as part of the socio-technical regime, existing business models hamper transitions by reinforcing the current regime's stability.

2.2. Networked SBMs

Business models with a broad value orientation, broad stakeholder network, and reflexive orientation show transformative potential, thus advancing system transformation (Proka et al., 2018). Networked SBMs can help firms in a network structure align their efforts to shape a more sustainable system. SBMs require new skills, resources, and capabilities as well as new institutional arrangements with external partners to integrate diverse knowledge. However, the created ecological and social values do not always bring economic value or enhance firms' competitive advantage. Networked SBMs enable firms to benefit from collective network actions throughout the value chain and with multiple actors, while spreading the risk of SBMI among them (Bocken et al., 2014).

Collective network actions enable them to create standards for compatible technology development, change legislation, shift the minds of users or potential users, pool knowledge and resources to co-create new products and services, develop them to be commercially viable, share infrastructure, embrace collective marketing, and bundle forces to compete with other technologies (Planko et al., 2019; Planko and Cramer, 2021). These benefits flow back into the value propositions of individual firms' business models through better marketing communication and customer relationships. System resources created by the network are accessible to individual firms and thus affect their value-creation processes. In practice, collective network actions enable manufacturers to effectively address the obligatory extended producer liability, which requires networked SBMIs: SBMIs strategically engaged by multiple actors in the entire lifecycle (Planko and Cramer, 2021).

Therefore, firms incorporate system-building goals as a sustainable value proposition if they perceive greater benefits from system-building activities than system-building costs. Sustainable value creation is extended to include system-building activities for product development and optimization, market creation, sociocultural changes, and coordination among multiple actors. Each consists of a set of system-building activities collectively implemented by the network actors (Planko et al., 2016). Firms choose different constellations of actors and networks based on the system-building goals they want to achieve; thus, their participation patterns evolve (Rossignoli and Lionzo, 2018). A variety of actors can be network actors, such as technology and service producers, suppliers, policymakers, user groups, financial institutions, or any other type of ecosystem actor.

Conversely, firms face the risk of crucial information leakage, dependencies, or loss of first-mover advantage from collective network actions. In particular, startups and small firms face risks when collaborating with large firms, such as incumbent utilities. Incumbent utilities prefer integrating activities through mergers and acquisitions to bundling activities that contribute to decarbonization, but in a manner that reinforces the efficiency and lock-ins of their traditional business models (Pereira et al., 2022). To increase the benefits and mitigate the risks of collective network actions, trust development, investment in collaboration, common vision and goals, goal alignment, clear boundaries for information sharing, clear boundaries for joint technology development, a neutral entity in charge of coordination, clear collaboration structures, creation of a "common playing field," careful composition of partners in pilot projects, and fair collaboration between large and small firms are indispensable (Planko et al., 2019).

Firms that perceive higher risks in collaborative network actions prefer competition to collective action. Most SBMs prioritize the economic dimension among environmental, social, and economic sustainability; thus, they are not inherently better able to overcome tensions across these three dimensions (Alonso-Martinez et al., 2021). They develop products or services for specific target groups and market segments as the process approaches the consumer (Bengtsson and Kock, 2000). While sustainability-related coopetition strategies— the simultaneous use of high levels of competition and sustainability-related cooperation—can improve economic and environmental performance at the system level, they cannot always overcome tradeoffs between them within a firm or between firms in collaboration (Manzhynski and Figge, 2020). These strategies can be overtaken by competitive considerations and the need for greater independence of each firm as the economic situation changes (Christ et al., 2017).

2.3. Networked SBM and sustainability transitions in the electricity sector

Based on these arguments, we build an analytical framework for the causal effect between the SBMI in a networked SBM and sustainability transitions in the electricity sector. As explained in the multilevel perspective framework, incumbent power generators select and take novelty to stabilize the regime when they encounter landscape developments and the subsequent destabilization of the existing regime. They choose novelties that can fix the destabilized regime and fit better with their firm-specific, socioeconomic, and infrastructural factors (Mori, 2021a). They choose renewable energy, such as wind and solar power, when they are required to place ambitious climate and renewable targets. Alternatively, they can select efficient coal power with pollution abatement technologies when they require efficiency targets and pollution control. They may switch to natural gas if it is available and affordable.

These responses triggered competition among power generation manufacturers (Fig. 1a). Dedicated wind and solar photovoltaic manufacturers build internal momentum through learning processes, thereby improving the price and performance of breakthroughs.

Competition emerges between incumbent power generators and dedicated wind and solar photovoltaic (PV) manufacturers when the latter diversify their businesses to develop wind and solar power projects and provide operational and maintenance services.

Conversely, incumbent power generation equipment manufacturers may collaborate with incumbent power generators to prevent niche innovators from emerging, delay radical changes, and even move back to a weaker reorientation. This happens especially when policymaking actors and structures are subsumed in a deeper and wider “multiplex” of “deep incumbency,” which transcends the sociotechnical regime (Johnstone et al., 2017). This is because they are characterized by sunk investments, long operating lifetimes, and complementary capital investments; although the extent is less than that of power generation (Schmidt et al., 2017; Kim et al., 2022). In addition, they are locked in traditional arms-length relationships with electricity companies under the vertically integrated fossil fuel-based electricity supply system, which produces customized products on an engineer-to-order basis or standard products in a make-to-order mode because electricity companies take the initiative in the development of power generation technologies (McGovern and Hicks, 2004). These characteristics make them adhere to their core businesses, continuing the production of their core products, such as boilers for coal power and turbines for coal and hydropower. They tend to capitalize on historically accumulated capabilities—knowledge, prior experience, organizational culture, and asset positions—and competitive advantage to pursue multiple technological paths (Bergek and Onufrey, 2014). They incrementally invest in more advanced technologies for their core businesses and use pragmatic blending and appropriate clean rhetoric traditionally associated with emerging technologies to attain policy targets and regulations (Patala et al., 2019). Although these activities may intensify collaborations with incumbent power companies, they are likely to diffuse mature technologies with low technical risk (Nemet, 2009; Onufrey and Bergek, 2021), strengthen lock-ins to mature technologies (Lee et al., 2022), and retard sustainability transitions.

Coopetition strategies become broader and more intensive when innovations such as wind and solar power technologies and development and original equipment manufacturing (OEM) by dedicated renewable technology manufacturers gain momentum in the market to overthrow the existing regime (Fig. 1b). Incumbent power generators must collaborate with dedicated manufacturers to secure a supply of wind and solar power technologies as competition for electricity supply becomes fiercer. Enhanced collaboration causes the traditional businesses of incumbent power generation equipment manufacturers to collapse. They must revisit previous arm’s length relationships with incumbent electricity generators to change their business models. Unbundling and market deregulation further prompt incumbent manufacturers to make changes (McGovern and Hicks, 2004). For this reason, those with high intentions and asset positions adopt vertical diversification strategies, capitalizing on external networks and intensive external relationships to integrate external knowledge and technologies and advance eco-innovative activities (Cai and Zhou, 2014; Cainelli et al., 2015). These activities are not limited to the manufacture of nuclear, wind, and solar power technologies that support incumbent power generators in attaining new climate and renewable energy targets. They expand their maintenance, retrofit, and refurbishment businesses for installed plants, develop service capabilities, and provide sophisticated technical services such as real-time remote-control systems, customer service, and technical support, including product upgrades (McGovern and Hicks, 2004). They also provide integrated services that arrange finance, engineering, procurement, and construction contracts between power generators and independent power producers (Mori, 2020). These activities intensify the competition in the power market between incumbent manufacturers and dedicated renewable energy ones.

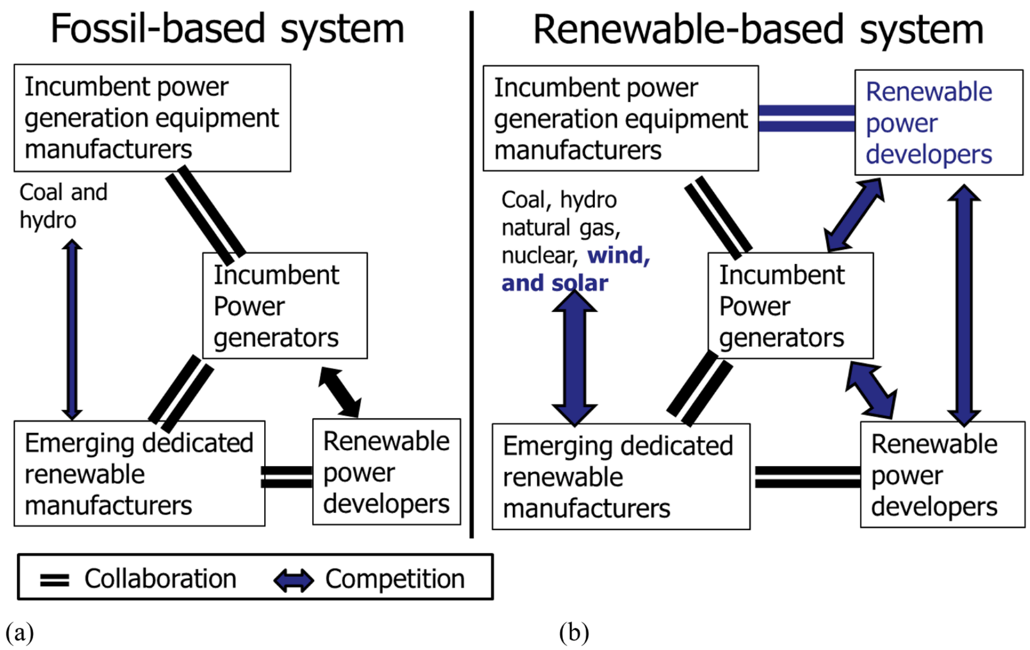

Fig. 1. Coopetition between incumbent power generators, incumbent power generation equipment manufacturers, and dedicated RES-E manufacturers in fossil fuel-based and RES-E systems.

The analytical framework implies that SBMIs in upstream manufacturers can generate networked SBMs with power generators and advance system-level sustainability transitions in the electricity sector when they are sufficiently competitive in terms of both environmental and economic gains. The question is: Under what contexts and conditions do SBMIs in upstream manufacturers make this happen?

3. Methodology and data

3.1. Case selection

Given that coopetition strategies among power generators were analyzed in Mori (2021a), this study focuses on those among power generation equipment manufacturers. The study selected three major incumbent state-owned Chinese power generation equipment manufacturers for three reasons. First, the Chinese government mandated incumbent power generators to attain an increasing number of climate, energy, and environmental targets (Mori and Takehara, 2018). These targets and policy instruments have disrupted the dominant value chain of the electricity system. In response, incumbent state-owned enterprises have taken a more aggressive stance on low-carbon transitions than private power generators (Zhang and Andrew-Speed, 2020), as in the European Union (Steffen et al., 2022).

Second, incumbent state-owned power generation equipment manufacturers must compete with private manufacturers under China's fragmented authoritarianism (Gilley, 2012; Sheng, 2020). State-owned enterprises are argued to be risk-averse and gain lower returns from R&D investments than private companies (Zhou et al., 2017). Private companies have taken advantage of business opportunities under fragmented authoritarianism to enhance their competitiveness in low-carbon industries (Sheng, 2020). This holds particularly true for dedicated wind and solar power manufacturers.

Third, the three incumbent power generation equipment manufacturers have provided heterogeneous responses despite being state-owned enterprises in a country with a top-down and non-participatory approach to public policy-making (Gilley, 2012). Their heterogeneous responses may make it difficult to take collective action to influence public policies, thus unlocking institutional barriers to reorienting businesses (Mori, 2021a).

Three manufacturers—Dongfang Electric Corporation (DEC), Harbin Electric Corporation (HEC), and Shanghai Electric Corporation (SEC)—dominate the supply of thermal and hydropower generation equipment. The DEC was established as a central government-administered entity, one of the largest manufacturers of boilers, turbines, and generators for power generation, and a contractor of engineering, procurement, and construction (EPC) for international power projects. This accounts for two-fifths of domestic hydropower and one-third of domestic thermal power generation equipment production. The DEC has diversified its manufacturing processes to include desulfurization, denitrification, nuclear reactor pressure vessels, wind turbines, hydrogen fuel cells, and high-voltage large-power frequency converters (DEC, 2015).

The HEC was established in 1994 by consolidating several state-owned entities, including the former Harbin Electric Machinery Works, Harbin Boiler Works, and the Harbin Turbine. It mainly produces boilers, turbines, generators, and control equipment for coal, hydropower, and gas power (webpage).

The SEC was established in 1954 as a department of the Shanghai government, reorganized as a corporate group in the 1990s, and converted into a listed corporation in 2005 (SEC, n.a.). The SEC began manufacturing fossil-fueled power-generating boilers and turbines.

We chose the period from 2010 to 2020. Since the 12th Five-Year Plan (2011–15), the Chinese government has set energy and carbon intensity reduction targets. The *Action Plan on Prevention and Control of Air Pollution* was issued in 2013 to accelerate the replacement of small-scale coal power plants, commercial boilers, industrial plants, non-utility power generation plants, and district heating plants with large and efficient ones. The Chinese government has also prohibited power generators from installing new coal plants in coastal regions and imposed a cap on the consumption of primary energy and coal.

Concurrently, the government has implemented favorable policies for RES-E and nuclear power (World Nuclear Association, 2022). The wind and solar power targets set in the 12th Electricity Development Five-Year Plan encouraged more ambitious targets for the generation capacity of hydro, onshore wind, solar PV, and concentrated solar power (CSP) in the 13th Electricity Development Five-Year Plan (Gosens et al., 2017).

3.2. Research design

We employed a case study method with multiple designs and variations. A case study method is suitable for testing internal validity and answering questions about the correctness of inferences and rival explanations. It is also relevant for testing external validity and acknowledging analytical generalization (Yin, 2014). Multi-case study designs with variations in type are desirable to provide strong evidence of the relevance of the initial set of propositions (Sovacool et al., 2018). We then applied the SBM framework to analyze the changes in business strategies and coopetition.

3.3. Data source

We relied on holistic data collection strategies. We used data from secondary sources such as academic books, articles, business journals, and daily newspapers. We collected information from publicly available documents, including news releases and annual reports. We checked the annual reports from 2010 to 2023 for the DEC, 2006, 2011 to 2023 for the HEC, and 2006, 2008, and 2011 to

2023 for the SEC and compiled the data to analyze business strategies, cost and revenue structure, and financial performances.

To complement these sources, documents were collected from business magazines, online news, and other publicly accessible sources by searching for company names. We did not conduct interviews with key stakeholders in the companies because of the detention of an increasing number of Chinese and foreign nationals on suspicion of espionage and the wide-ranging update to anti-espionage legislation by the Chinese government (Chen, 2023).

The COVID-19 pandemic and the revised Counter-espionage Law made it extremely difficult for international researchers and researchers outside mainland China to access key informants to obtain primary data in China. The inaccessibility confined our data to document-based.

4. Results

4.1. Business strategies of the incumbent manufacturers

The three manufacturers have upgraded their in-house technological capabilities to satisfy the needs of their main customers, that is, incumbent power generators facing increasingly stringent energy and environmental policies. While they acquired technological capabilities to invest in R&D for more efficient supercritical (SC) and ultra-supercritical (USC) steam turbines and boilers, they fostered technological collaboration with incumbent power generators when upgrading power generation and control technologies (Table A.1, A.2, A.3). While they did not possess knowledge or prior experience in manufacturing nuclear, gas, wind, or solar power equipment, they created subsidiaries for manufacturing wind power equipment. They entered the wind power industry in 2005 (Zhao et al., 2009), and solar PV in 2010, several years later than dedicated manufacturers, with the perception that long-term experience in manufacturing steam and hydro turbine generators could compensate for the lack of technological capabilities to develop wind turbines (Korsnes, 2020).

They also sought to collaborate with international manufacturers to upgrade their technological capabilities for coal, gas, nuclear, wind, solar PV, and CSP. They developed large-scale SC and USC steam turbines and boilers through JVs (Table A.1), licenses, and OEM by the 2010s (Tables A.2 and A.3). While they might have accepted the division of labor for the supply of generation equipment for large-scale hydropower projects between DEC and HEC, there are few if any collaborations for upgrading technological capabilities among the three manufacturers.

Tougher energy–environment–climate policies hit the three incumbent manufacturers. Their market share plummeted from 82 % of the power generation equipment production in 2009 (BJX, 2010) to 70 % in 2020 (CMIF, 2021). Although they provided nearly all large-scale SC and USC steam turbines and boilers in China (Yue, 2012) and earned large profits (Figure A.1), they lost legitimacy in maintaining this business model as incumbent power generators shifted their investments from coal power. They perceive onshore wind power as a promising and important substitute for coal power in the long run (Zhu et al., 2019). They also perceived nuclear and solar power as future profit opportunities in power generation equipment manufacturing and integrated services such as international EPC, financial facilities, and operations and maintenance.

The DEC and HEC developed technological capabilities for large and medium-sized hydropower generators, which they supplied for the Three Gorge Dam project and the Hohhot and Pushihe pumped-storage projects (Hydro Review, 2006). Their dominance in large-scale coal power and hydropower equipment markets brought them high operational profits, which were invested in R&D of nuclear, gas, wind, and solar power. The HEC stepped into joint R&D with Huaneng—the largest incumbent power generator—for steam generators and helium ventilators for nuclear plants, and supercritical CO_2 cycle coal power generation. The DEC collaborated with the China Three Gorges Corporation to conduct joint R&D for 10 MW offshore wind turbines (Yuki, 2020b) and 13 MW.

The DEC and HEC struggled with changing business models when encountering financial distress in 2016. The HEC shifted its business model toward management reform for better quality, and RES-E (Li and Zhou, 2019; Yu, 2021). Nonetheless, the HEC remained inert by expanding its business to electric motor manufacturing and geographically diversifying engineering services. While international business achieved stable growth in 2014–17 (Figure A.2), it did not generate sufficient revenue to compensate for the reduced revenue from thermal power generation and hydropower equipment (Fig. 2), failing to generate large profit margins in the late 2010s (Fig. 3). Weak financial capabilities restrict the HEC from allocating resources for R&D (Figure A.3) and enhancing technological capabilities to diversify businesses. Consequently, the HEC witnessed a widening gap in total assets, revenue, and profits with the DEC and SEC during the 2010s (Fig. 4).

The DEC shifted its focus in business to nuclear power, offshore wind, logistics, financial services, and international business. The rapid growth of logistics and EPC services compensated for the declining revenue from power generation equipment in 2018–2020, keeping total revenue intact (Fig. 3). The revenue from hydro and wind power in 2020 also compensated for the declining revenue from thermal power generation equipment (Fig. 2).

In contrast, the SEC organized a JV with Mitsubishi Electric to enter elevator production in the 1990s. This success made the company proactive in its R&D investments and international collaborations as instruments for acquiring and developing new manufacturing capabilities. Capitalizing on its strong in-house technological capabilities and large market potential, the SEC has upgraded collaborations with Siemens to enhance technological capabilities for high-efficiency coal, gas, nuclear, and wind power generation equipment (Emerging Markets Business Information News, 2010). In parallel, the SEC acquired a 40 % stake in Ansaldo to overcome technical barriers to developing gas turbine manufacturing (Power Engineering International, 2014).

Boundary spanning shifted the SEC's main revenue sources from thermal power generation equipment to wind power (Fig. 2), industrial equipment, and integrated services (Fig. 3), and increased total equity (Fig. 4). A 4–5 % net profit margin in the 2010s enabled the company to finance sufficient investments in R&D (Figure A.3) and JVs, fostering an energy storage business that

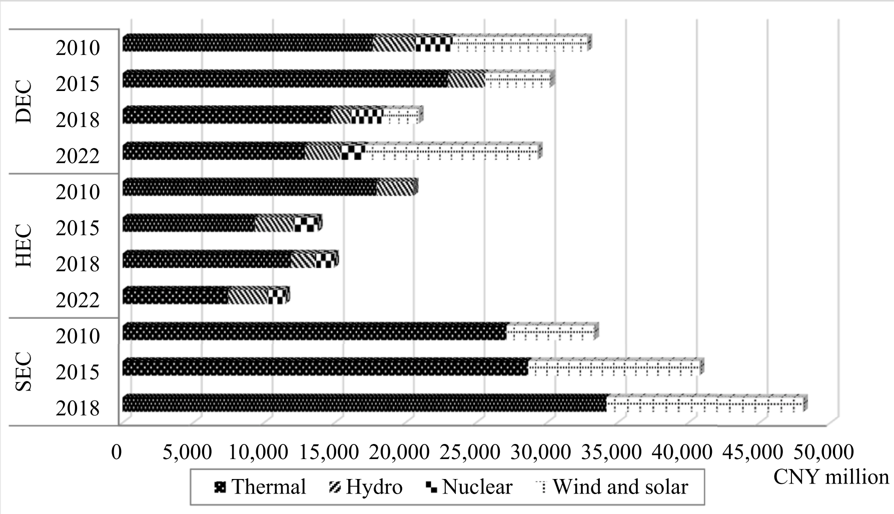

Fig. 2. Revenue structure of the three incumbent manufacturers by type of power generation equipment in 2010–2022
Note 1: Technological breakdown is not available for the SEC after 2019.
Note 2: Wind and solar power in the DEC in 2015, and those in the SEC in 2010, 2015, and 2018 include nuclear power.
Source: Compiled by the authors based on annual reports of the DEC, HEC, and SEC for 2010, 2015, 2018, and 2022.

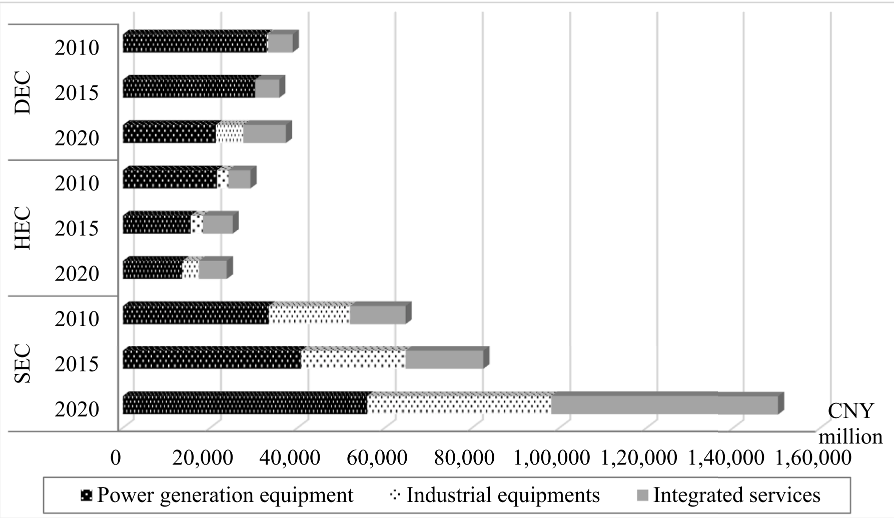

Fig. 3. Revenue structure of the three incumbent manufacturers by type of business in 2010–2020
Source: Compiled by the authors based on annual reports of the DEC, HEC, and SEC in 2010, 2015, and 2020.

mitigated the loss of profits in the COVID-19 and post-feed-in-tariff (FiT) offshore periods.

4.2. Factors behind the heterogeneous responses

To better fit the needs and requirements, the three incumbent manufacturers established closer collaborations with incumbent power generators with technological capabilities, social connections, and networks (Cai et al., 2010) for indigenous innovation, joint R&D, and project development. By enhancing trust and information sharing, incumbent power generators have become key organizational drivers of change (Korsnes, 2020). The closeness varied according to the manufacturer's instructions. The DEC and HEC have developed generation technologies to customize the requirements of incumbent power generators. The success of industrial equipment reduced the SEC's dependence on incumbent power generators.

Conversely, the three incumbent manufacturers rarely competed with incumbent power generators in RES-E generation segments. In the onshore wind and solar PV market, they failed to gain a competitive edge amid fierce competition from RES-E manufacturers and developers (Fig. 5a). In addition to feed-in tariffs that benefited dedicated wind and solar PV manufacturers that emerged as wind and

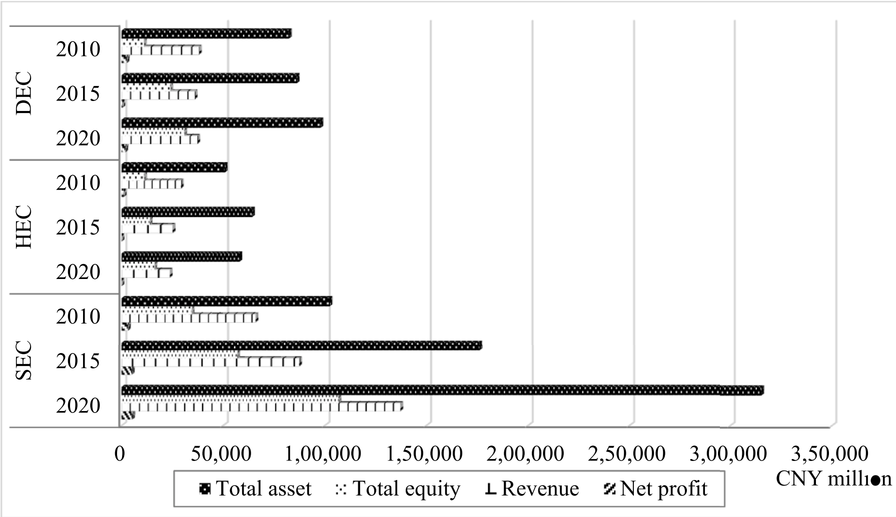

Fig. 4. Financial capabilities of the three incumbent manufacturers in 2010–2020
Source: Same as Fig. 2.

solar power project developers and serious curtailment (Fang et al., 2012; Nature Energy, 2016; Tang et al., 2018), the lack of in-house technological capability prevented them from improving the quality of wind power equipment, leading to corruption, under-performance of operations (Yuan et al., 2015), and devastating reliability. The lack of in-house technological capability and dedicated manufacturers' rapid innovation in solar cells[1] and cell production equipment has kept them behind dedicated solar PV manufacturers (Horii, 2022). The failure to gain legitimacy and support from local governments has widened the technological gap. Consequently, the DEC gave up producing polysilicon (Wang, 2013). Instead, the three manufacturers invested in CSP equipment (DEC, 2021), which benefitted from knowledge accumulated from traditional thermal power equipment manufacturing (CSPPLAZA, 2018). The DEC established a JV with the State Power Investment Corporation, a state-owned incumbent power generator, to build a 200 MW capacity of CSP (Solar Thermal Energy News, 2018).

The DEC and SEC have emerged as offshore wind turbine OEMs for incumbent power generators, competing with dedicated wind power manufacturers. They became the world's top wind turbine manufacturers as China experienced a rapid expansion in its offshore wind power capacity (CWEA, 2018). They do not compete with incumbent power generators for offshore wind development projects. (Fig. 5b). In addition, the SEC fosters collaboration with innovators in digital applications for system balance, process optimization, and customer orientation to reposition itself at the higher end of the value chain[2] (Zhao, 2019). The action shows sharp contrasts with dedicated manufacturers, such as Goldwind and Minyang, which caught up with European manufacturers to commercialize larger, more efficient, and more cost-effective wind turbines (GWEC, 2022). Conversely, the DEC and SEC invested in a few offshore wind projects (GWEC, 2020).

5. Discussions

Our analysis reveals that two of the three major incumbent power generation equipment manufacturers realigned with incumbent power generators and fostered coopetition only in offshore wind. Conversely, the remaining failed to do so for any of the segments. These different consequences raise two questions: What enabled these two manufacturers to change their business models and achieve networked BMIs, and how do networked BMIs influence sustainable transitions in electricity systems?

5.1. What enabled these two manufacturers to change their business models?

The two incumbent power generation equipment manufacturers successfully explored the offshore wind turbine segment for two reasons. First, the segment was less competitive than onshore wind when momentum was gained. The developments of long-distance ultra-high-voltage transmission lines have substantially reduced the risk of renewable curtailment, directing incumbent power generators toward large-scale hydropower, solar, nuclear, onshore wind, and coal power (Mori, 2021a). The mandated compensation for

[1] Namely, Passivated Emitter and Rear Cell and monocrystalline silicon.

[2] The SEC established a JV with Hong Kong-based BrightSource to win EPC and operational contacts of large-scale CSP projects worldwide. It also established a JV with Hefei Gotion High-tech Power Energy to produce lithium-ion battery energy storage systems (Shanghai Electric Gotion New Energy Technology Co. Ltd., n.a.) and acquired a 28.8% stake in Yinghe Technology for automated lithium-ion battery production equipment within the group (SEC, 2020).

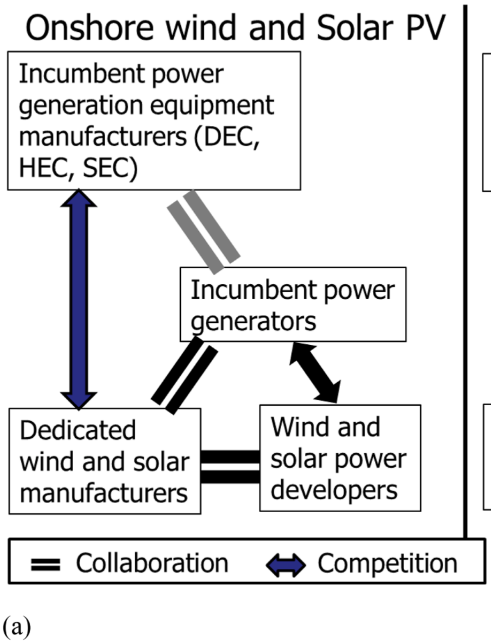

Fig. 5. Coopetition between incumbent power generators, incumbent power generation equipment manufacturers, and dedicated RES-E manufacturers in practice
Note: DEC: Dongfang Electric Corporation; HEC: Harbin Electric Corporation; SEC: Shanghai Electric Corporation.

curtailed electricity pushed grid companies to change their priority to grid connections that favored coal-based power. Dedicated wind power manufacturers capitalized on a better business environment to increase supply; hence, incumbent power generators invested in onshore wind. When the government also implemented provincial renewable portfolio standards to motivate eastern coastal provinces with high electricity consumption to generate RES-E in their jurisdictions, incumbent power generators redirected investments to offshore wind power (Fan et al., 2021). The replacement of premium FiT with competitive tender pricing for offshore wind power with grid connections after 2022 (Yuki, 2020a) accelerated their investments in offshore wind power. However, dedicated wind power manufacturers do not have sufficient capacity to supply wind turbines to the emerging segment. The supply gap created space for the DEC and SEC to venture into wind turbine manufacturing for offshore winds.

Second, the technological barriers for offshore wind turbines were not as severe as those for solar PV in the DEC and SEC. Dedicated wind turbine manufacturers and subsidiary manufacturers of incumbent power generators have supplied conventional high-speed

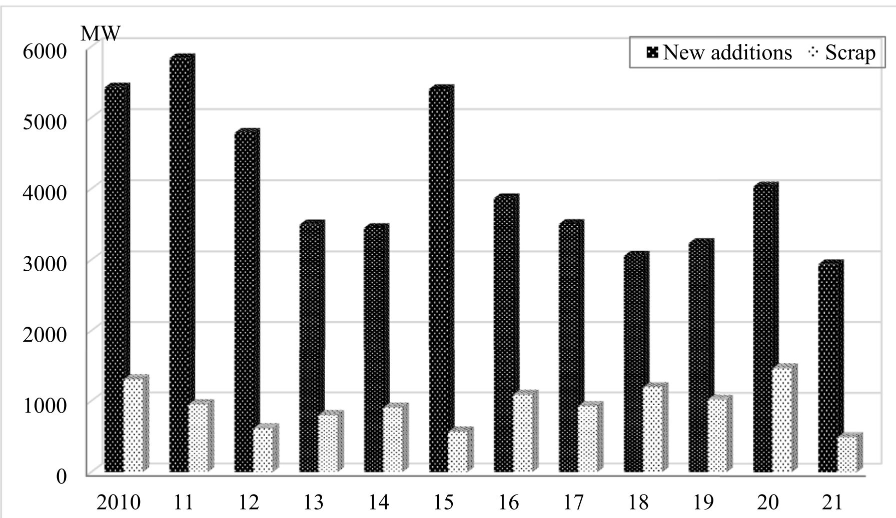

Fig. 6. New additions and scraps of coal power capacity in China in 2010–2021
Source: Compiled by the author based on data from the China Electricity Council (n.a).

wind turbine technologies that have been completely phased out in Europe by 2021 (GWEC, 2022). The government announcement of the FiT phaseout pressurized manufacturers to develop and commercialize large-scale, direct-drive, and medium-speed technologies (Zhao, 2019). The SEC capitalized on technological collaboration with Siemens to catch up with dedicated manufacturers and developed and commercialized large-scale (11 MW) offshore wind turbines (Richard, 2021).

5.2. What retarded business model changes and networked SBMIs?

Conversely, a series of rescues by the Communist Party of China (CPC) enabled the HEC and, to a lesser extent, the DEC to maintain alignment with incumbent power generators and key technological capabilities. The CPC exercised power over personnel to appoint state-owned enterprise leaders with better performance in higher positions in the country's political hierarchy, incentivizing them to comply with government priorities (Kong and Gallagher, 2017). To rescue the HEC's financial distress, the CPC transferred the president of the DEC to the HEC to acquire knowledge and technologies to foster BMI (Yu, 2016). Under the new president, the HEC and DEC were awarded contracts on hydropower, such as the Baihetan Hydropower Projects, and nuclear power projects initiated by incumbent power generators.

The HEC and DEC were also awarded EPC contracts in coal power (Qiáng, 2018) and hydropower projects, and to a lesser extent, joined as independent power producers in the Belt and Road Initiative countries (Mori, 2021c). The contracts helped them export mature technologies with low technical risk and high emissions that no longer met the stringent domestic environmental standards (CREA, 2021), thereby mitigating declining profits in the domestic power equipment market.

The survival of the HEC and, to a lesser extent, the DEC enabled the Chinese government to immediately and again boost investments in new coal power capacity. Stringent energy–climate–environmental targets and policies effectively canceled new coal power projects, while increasing the scrap of existing projects in the 2010s (Fig. 6). Consequently, the net addition of coal power capacity decreased in 2016–2018, was surpassed by wind and solar power in 2020, and was lowest in 2021–2022 (Figure A.4). Despite an increase in the amount of coal power generation, the ratio of total power generation declined from 79 % in 2011 to 61 % in 2021 (Figure A.5). In exchange, the ratio of non-hydro RES-E increased from 2 % in 2011 to 14 % in 2021. Nonetheless, China commissioned 38.4 GW of new coal plants in 2020, which amounted to three times that of the rest of the world (Global Energy Monitor and CREA, 2021) when the State Grid Corporation and China Electricity Council succeeded in relaxing the traffic light alert system in 2020 (Myllyvirta et al., 2020). Nationwide blackouts and electricity rationing over a month in 2021 and severe drought-driven blackouts in 2022 spurred investments in new domestic coal power capacity. The government gave fast-track permissions for 106 GW of new coal power projects by January 2023[3] (CREA and Global Energy Monitor, 2023a), of which 41 GW of new coal power projects will start in the second half of 2022 (Senlen et al., 2023).

5.3. Networked BMI and energy transitions

This discussion has three implications for networked BMI in the transitions of electricity systems. First, networked BMI advances electricity transitions to RES-E systems when both incumbent power generators and power equipment manufacturers embrace BMIs, thus de-aligning coal-based collaborations and realigning RES-E systems. Incumbent power equipment manufacturers can compete with dedicated RES-E manufacturers in collaboration with incumbent power generators and grid companies. Such competition is a strong driving force behind these transitions.

Second, transitions to RES-E systems can be advanced without networked BMI or when incumbent power equipment manufacturers fail to regain a competitive edge with BMIs. Incumbent power generators can foster collaborations with domestically dedicated RES-E manufacturers and international manufacturers to embrace BMI and advance transitions. In this case, domestic incumbent manufacturers go out of business.

Third, incumbent power equipment manufacturers can retard transitions if they possess abundant political and economic assets. Their abundant political and economic assets allow them to undertake geographical and horizontal diversification that aligns with the government's climate-energy policies, maintaining their production capacity. The production capacity enables the government to reverse the transition for national energy security.

These implications contribute to unpacking the rationale behind incumbent firms' heterogeneous responses to landscape developments and sustainable activities. They highlight synchronized changes in the technological elements of complementarities in electricity systems, setting aside firm-specific, socio-economic, and political-institutional factors (Mori, 2021b). Incumbent firms that have relied on incumbent manufacturers for technology supply must wait for their synchronized changes or embrace SBMI to invest in JV to prompt new technologies and create alternative supply chains. The latter choice would weaken the coalition among incumbent firms, increasing heterogeneous responses and overcoming incumbency and lock-ins.

The conceptualization, analytical framework, and findings of networked BMI can be applied to analyses of the third phase of net zero energy transitions. The phase is characterized by synchronized transitions in multiple sectors, particularly energy, industrial, and mineral along the supply chain (Markard and Rosenbloom, 2022). Large-scale integration of intermittent RES-E and distributed energy resources into electric grids and electrification of energy supply requires a new balance between long-term assurances of energy security and short-term flexibility through storage and regional electricity markets. The rebalance triggers whole system changes in

[3] The government gave instructions for increasing coal production capacity, power supply from coal power, and electricity prices from coal power (You, 2021). The severe blackouts in 2022 and 2023 due to serious drought spurred the shift back to increasing new coal capacity (Pak, 2023).

critical minerals and metals sectors throughout supply chains, revisiting existing networks and trade relations (Scholten et al., 2020). Networked BMI helps analyze the transitions throughout the supply chains and multiple system transitions.

6. Conclusions

The incumbency research has expanded the scope to upstream, downstream, and adjacent industrial manufacturers to analyze how a transition in the focal sector creates transformation pressure on manufacturers and technology suppliers throughout the value chain. Incumbent power generation equipment manufacturers are adjacent industrial manufacturers that can affect incumbent power generators' business models and transitions in electricity systems. However, BMI research has not focused on incumbent power generation equipment manufacturers.

To fill the research gap, this study develops the concept of networked SBMI to analyze how incumbent manufacturers change business models in response to changes in incumbent power generators and how their changes influence transitions in electricity systems. To this effect, we take the three major Chinese incumbent power generation equipment manufacturers as cases.

Our findings reveal that the networked SBMI by incumbent power generators and power generation equipment manufacturers can enlarge heterogeneity among incumbents throughout the electricity supply chain, and mitigate incumbency that blocks and retards sustainability transitions in electricity systems without coopetition, but only in the segments where incumbent power generation equipment manufacturers have the capabilities to reorient and gain a competitive edge in the market. Incumbent power generation equipment manufacturers with abundant political and economic assets can maintain the production capacity of coal power generation equipment even if they lag in SBMI. Incumbent power generators can resume coal power projects unless incumbent power generation equipment manufacturers completely scrap coal power equipment production capacities, as seen in the rapid resumption of new coal power projects since 2021.

Our analysis also suggests the applicability of the framework of the networked BMI for the analysis of the third phase of the net zero electricity transitions, which is characterized by synchronized transitions in energy, industrial, and mineral sectors along the supply chain.

This study had two limitations. First, the results and implications are based on a case study of one combination of networked BMIs in electricity systems with a limited number of manufacturers. For example, the vertical integration of coal mining and coal power generation, which has become prevalent in China and Indonesia, encourages coal-power investment and hinders the transition to RES-E systems (CREA and Global Energy Monitor, 2023b). Investigating various combinations will provide more generalized insights into networked BMIs in electrical systems.

Second, the study did not show pathways and strategies for scrapping production capacities of coal power technologies by the laggards. Laggards with abundant political and economic assets can invite government rescues in the name of mitigating adverse economic and social impacts and energy security concerns, retard sustainability transitions. It is worth investigating how to prevent laggers from influencing policy interventions and reinforce incumbency.

CRediT authorship contribution statement

Akihisa Mori: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Keyue Zhang:** Writing – original draft, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.eist.2024.100911.

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