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Short communication

China's role in scaling up energy storage investments

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ABSTRACT

Accelerating the planning and development of a new power system that is more renewable energy-based is a strategic priority of achieving "dual carbon" goals (peaking carbon emissions before 2030 and becoming carbon neutral before 2060) in China. The large-scale development of energy storage technologies will address China's flexibility challenge in the power grid, enabling the high penetration of renewable sources. This opinion article intends to fill the existing research gap in energy storage technologies through the lens of policy and finance. Results indicate that policy uncertainties in renewable energy might undermine domestic investor confidence in energy storage technologies, while insufficient economic incentives may crowd out private sector participation. Drawing on international best practices, blended concessional finance, supported by development partners, can play a significant role in closing energy storage financing gaps in China and in countries of the Belt and Road Initiative (BRI). To deliver on China's domestic and international climate commitments, this article makes three policy recommendations: (1) moving forward with a carbon pricing agenda that incentivizes energy storage investments in China; (2) tapping the potential of the domestic capital market to close financing gaps for novel energy storage technologies; (3) scaling up energy storage supply chains in BRI countries through multilateral cooperation.

1. Introduction

This study explores the challenges and opportunities of China's domestic and international roles in scaling up energy storage investments. China aims to increase its share of renewable energy to 25% of primary energy consumption by 2030, from 16.6% in 2021, as outlined in its nationally determined contribution [1]. To achieve this target, energy storage is one of the most promising solutions for addressing renewable intermittency issues by balancing electricity demand and supply, which is increasingly a challenge in power systems. The development of energy storage will offer an opportunity to accelerate the energy transition away from coal by providing greater flexibility and reliability to the power grid, thereby enabling high penetration of renewable sources. This particularly contributes to improving energy security in China, particularly given its import dependency on fossil fuels and energy price volatility in the global market.

1.1. Policy-oriented research motivation

The existing literature on energy storage has primarily focused on technological innovation, leaving a research gap to be filled using a policy lens. Through qualitative analysis, this opinion article presents an overview of China's domestic and overseas energy storage policies and investment flows, followed by policy recommendations that encourage policymakers in China to close financing gaps in energy storage investments. The following sections address three policy-oriented applied research questions: (1) What are the main market barriers to large-scale energy storage applications in China? (2) What are the viable financing options to unlock energy storage investments? (3) How could China scale up its energy storage supply chains in lower-income countries through the Belt and Road Initiative (BRI)?

2. Domestic development of energy storage

2.1. Policy overview

China is committed to gradually developing a renewable-energy-based power system to support the integration of demand- and supply-side management [2]. An increased focus on energy storage development will significantly reduce the curtailment rate of renewable energy and add flexibility to peak shaving, contributing to coal phase-down in China.

During the 14th Five-Year Plan (FYP) period, China released mid- and long-term policy targets for new energy storage development. By 2025, the large-scale commercialization of new energy storage tech-

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nologies[1] with more than 30 GW of installed non-hydro energy storage capacity will be achieved; and by 2030, market-oriented development will be realized [3]. A cost-reduction target was introduced to lower the system cost per unit of electrochemical energy storage by at least 30% by 2025, as outlined in the 14th FYP on Energy Storage Development [4].

China's energy storage capacity accounted for 22% of global installed capacity, reaching 46.1 GW in 2021 [5]. Of these, 39.8 GW is used in pumped-storage hydropower (PSH), which is the most widely used storage technology. The share of novel energy storage technologies represents only 12.5% of the total installed capacity in China, where electrochemical storage is the most technically viable technology, followed by fast-growing compressed-air storage. Lithium-ion batteries, also known as battery energy storage systems (BESS), dominate most installed capacities of 4 GW for electrochemical storage.

The wider deployment and commercialization of lithium-ion BESS in China have led to rapid cost reductions and performance improvements. The full cost of an energy storage system includes the technology costs in relation to the battery, power conversion system, energy management system, power balancing system, and associated engineering, procurement, and construction (EPC) costs. The battery pack is the most expensive part, representing over 50% of the energy storage costs. Owing to the cost competitive advantage of BESS manufacturing capacity, China's lithium-ion battery storage production output reached 324 GWh in 2021, which increased by 106% from 2020 [6]. With an annual cost-reduction rate of 20%–30% in battery storage, China has absolute advantage in producing the world's lowest lithium-ion battery price at US$111 kilowatt-hour ($kWh^{-1}$), compared to the global average price at US$132 $\cdot kWh^{-1}$ in 2021 substantially fell by 89% from US$1,200$\cdot kWh^{-1}$ in 2010 [7].

With the rising demand for resilience and stability of the power grid, ancillary services for the energy storage market are projected to achieve exponential growth. China has annocunced a number of policy priorities, for example, exploring cost recovery mechanisms to support the development of stationary energy storage powered by wind and solar energy (i.e., "wind and solar power + energy storage"), by incorporating electrochemical and compressed-air energy storage into ancillary services in the power market [8,9]. Linking stationary energy storage projects to the power market will reduce the financial burden on power grid companies [10]. This supports utility-scale energy storage plants for power peak load management by offering cost reductions to power grid companies through T&D tariffs, renewable energy development funds (i.e., 0.019 yuan/kWh), and miscellaneous expenses. Having introduced the cost compensation mechanism, Zhejiang was the first province in China to improve its revenue models in the form of capacity payments on a per-unit basis, which will decrease over 3 years. A pricing mechanism for new energy storage in grid-side power stations will also be developed.

2.2. Investment overview

In 2021, global investments amounted to US$755 billion, of which China's domestic investments in the energy transition—mostly in renewable energy and electrified transport—increased by 60%, reaching a new height at US$266 billion [11]. While energy storage development is accelerating in China and other higher-income countries, the share of investment volume in storage technologies out of all forms of clean energy investments is very small. The International Energy Agency (IEA) finds that investments in battery energy storage are expected to reach US$20 billion by 2022, primarily owing to grid-scale development, accounting for 70% of the total investment flows [12].

In 2021, there were 146 approved energy storage projects, comprising 131 electrochemical and 5 pumped hydro storage projects. China's first salt cavern compressed-air energy storage project began operations in 2022 in Jiangsu Province and was co-developed by the China National Salt Industry Group Co., Ltd., China Huaneng Group, and Tsinghua University [13]. Building on the first phase of the concentrated solar power (CSP) project, the China General Nuclear Power Corporation (CGNPC) started the construction of a second solar thermal energy storage project in Delingha, Qinghai Province, including 160 MW of solar power and 40 MW of thermal storage. This project has the highest energy storage ratio of 25% with a 6-hour long duration of storage, which will reduce 1.1 million tons of standard coal and 2.6 million tons of CO_2 emissions [14]. In July 2022, the China Energy Construction Corporation began construction of the first solar thermal storage demonstration project in Xinjiang Province, with 10 MW of thermal storage and 90 MW of solar power.

In particular, China showcased its climate leadership in the 2022 Winter Olympics in Beijing. This was the first-ever Olympic Games powered by renewable energy, with the support of PSH plants in Fengning County, Hebei Province. This project started in 2013 and is the world's first PSH plant connected to direct current power grids, providing 600,000 KW capacity to Beijing and Zhangjiakou cities [15]. The project has replaced 480,000 tons of standard coal and reduced 1.2 million tons of carbon emissions per year while increasing the integration of solar and wind power into the regional power grid network.

2.3. Market barriers to the commercialization of large-scale grid-connected energy storage

Market-based mechanisms need to be the centrality of the early stage of technologies, however, there are several institutional and policy challenges that might hinder a large-scale investment in energy storage. For example, China's electricity dispatch system is determined by the annual power generation plan that is designed by provincial governments [16]. During a power shortage with limited electricity supplies, the government prioritizes rationing measures over market-based instruments, which hampers the flexibility of energy storage in the power system (ibid.). This indicates that fixed power generation prices may not reflect the market value of energy storage.

The recent renewable energy policy development may undermine investor confidence in energy storage. For example, 2021 feed-in tariff policy aims to phase out feed-in tariffs for new centralized solar and onshore wind power projects, and to introduce two measures that reflect the economic value of renewable energy development. This includes: (1) the on-grid tariff for new utility-scale solar and wind projects linked to the local coal-fired power generation benchmark price and (2) feed-in tariff rates that can be developed through voluntary market participation [17]. However, there are three possible reasons that might affect policy effectiveness. The National Development and Reform Commission (NDRC) stabilized market volatility against rapidly rising coal prices when China faced a power crunch in 2021, which resulted in lower coal prices that unable incentivize renewable energy investments. Furthermore, the lack of a feed-in-tariff mechanism implies that revenue streams are insufficient and unpredictable, which may not incentivize early-stage financing of energy storage technologies. Despite coal remaining the major power load in China, coal price is an inappropriate indicator linked to renewable electricity prices, in light of the global energy transition away from fossil fuels.

A lack of economic incentives may crowd out energy storage investments led by private investors. As of May 2022, 23 provinces in China introduced a new policy with mandatory requirements of at least 10% of the renewable-storage pairing ratio to scale up investments in energy storage [18]. This implies a major shift in energy storage investors to state-owned enterprises (SOEs) from power grid companies such as

[1] This refers to aqueous batteries in sodium-ion and lithium-sulfur, aqueous batteries (e.g., lead-acid), compressed air, hydrogen storage, thermal (cooling) storage, and flow batteries (e.g., vanadium rex flow, zinc bromide redox flow).

China Energy, Huaneng, Huadian, and State Power Investment Corporation (SPIC) [19]. The advantage of SOEs is that they are willing to accept unattractive risk-return profiles in the form of higher project risks and low economic returns, given that they can access low interest rates for project financing from commercial and development banks.

However, SOEs alone may be unable to close financing gaps in large-scale energy storage projects, which are more capital-intensive at the early stage of development. The evidence suggests that each percentage point increase in the overall cost of capital is associated with an increase of US\$10·MWh^{-1} in the levelized cost of energy (LCOE) for a lithium-ion battery project, which is three times higher than the impact on the LCOEs of onshore wind and solar PV projects [20]. This indicates that policymakers need to design attractive financing structures, for example, by introducing the role of concessional finance in lowering the cost of capital of early stage technologies to reduce LCOEs and improve cost competitiveness and technological maturity.

3. Unlocking energy storage investment opportunities through blended concessional finance

Drawing on international knowledge sharing, blended finance mechanisms can contribute to addressing the challenge of financing clean energy transitions in lower-income countries [21,22]. There is no official definition of blended finance, which is varied by different institutions and stakeholders. For example, the OECD defines blended finance more broadly as "the strategic use of development finance for the mobilization of additional finance towards sustainable development in developing countries". Blended finance transactions occur when the public sector (e.g., governments or development finance institutions, DFIs) brings public or concessional capital that bear greater risks for lower returns, improving private investors' participation. Blended finance is also known as blended concessional finance, which aims at blending public and private finance to unlock climate investments by mobilizing private sector participation, with first-loss capital provided by DFIs and multilateral development banks (MDBs).

Concessional financing is the key to addressing the climate investment challenges. Concessional finance comprises a range of financial instruments in the form of grants and loans and, to a lesser extent, equity investments. This can be achieved through one or both measures: (1) below-market interest rates and (2) long-term maturity, long grace periods, and repayment profiles that may not be accepted by commercial financial institutions [23]. The degree of concessionality of a given financial instrument is measured using grant elements. Adopting environmental, social, and governance (ESG) standards in project development could maximize the use of grant financing in private investments.

However, blended finance mechanisms have two major issues: mobilization levels and ratios are low [24]. In particular, the ability of DFIs to mobilize private investment in lower-income countries is linked to the enabling environment in the country. In many cases, country risks and investment barriers are high in lower-income countries that are unattractive to private investors.

The next section draws on case studies from MDBs, demonstrating how policy instruments combined with blended financing structures could help to unlock energy storage investments.

3.1. Case studies in energy storage projects

3.1.2. Case study 1: southern Thailand wind power and battery energy storage project

In 2021, the DFIs Working Group Report first highlighted a case study on wind power with energy storage in Thailand, by using blended finance structures [25]. Thailand aims to increase its share of renewable energy in the energy mix from 11% to 25% by 2030 [26]. The Southern Thailand Wind Power and Battery Energy Storage Project, funded by the Asian Development Bank (ADB) in 2020, was the first private sector initiative to support the development of 10 MW utility-scale wind power generation with an integrated 1.88 MWh BESS in Thailand. Concessional funding is crucial for improving economic viability in project financing, which US\$4.75 million from a multilateral fund, the Clean Technology Fund (CTF) under the Climate Investment Fund was provided to Lomligor Company Limited.

A high-quality project design can improve revenue models, given the lack of development of ancillary services and wholesale markets is a major challenge in Thailand. For example, a long-term Power Purchase Agreement (PPA) was signed with a provincial power company, and a long-term tariff incentive for energy storage projects was secured over 10 years. A differentiated pricing approach was introduced for the peak, and off-peak power prices linked to the system average generation costs. The application of BESS will reduce the curtailment rate by storing energy when the wind turbine generating output exceeds the PPA capacity, and by consuming or exporting power when the generating output is below the PPA capacity.

3.1.3. Case study 2: concentrating solar power (CSP) with thermal energy storage

Fiscal incentives and credit enhancement mechanisms are important in supporting the deployment of CSP technologies. For instance, investment-based incentives, such as investment subsidies in the form of grants and soft loans, along with tax exemptions and tax credits, are mainly used to improve cash flows in the early stages of CSP project development [27]. Credit enhancement mechanisms are risk mitigation instruments, such as loan guarantees were used in this project to crowd in private investors, by improving their risk-adjusted return profiles.

With funding support from the World Bank, ADB and CTF, a 160 MW CSP project in Morocco was secured through 25 years of public and private partnerships. The Moroccan Agency for Solar Energy (Masen) issued Morocco's first green bond to attract a diverse pool of institutional investors in financing CSP projects. Likewise, a loan guarantee of US\$1.45 billion was issued by the US Department of Energy, which acted as a powerful catalyst for financing one of the world's largest CSP plants in the US, a 280 MW parabolic trough plant with molten-salt energy storage [28].

The following section presents China's emerging role in developing energy storage projects in lower-income countries through BRI, and highlights opportunities for lowering capital costs through blended finance.

4. Promoting energy storage investments in BRI countries

China is committed to accelerating a low-carbon energy transition in lower-income countries through BRI [29]. The BRI was launched in 2013 as a major platform for development cooperation aiming to enhance policy coordination, infrastructure connectivity, regional trade and financial integration, and people-to-people connectivity in 150 countries [30]. Between 2013 and 2021, the total investment flows in BRI countries reached over US\$ 900 billion, with approximately 40% of this going to the energy sector, mostly dominated by fossil fuels and hydropower projects. As shown in Fig. 1., BRI investments reached peak levels in 2015 at US\$125.59 billion and continued to decline from 2018 onwards [31]. The main drivers of investment slowdown are low project returns associated with investment uncertainties in BRI countries and a lack of due diligence at the project level by Chinese project developers (ibid.). To address the BRI project challenges, China has been committed to deepening the green development of BRI, including scale up renewable energy and energy storage investments [32].

Table 1 shows that BRI energy storage investments are concentrated in the Middle East, which is in line with China's growing role in deepening partnerships in the region [33,34]. The project size is by far the largest through BRI overseas investments in energy storage, such as the

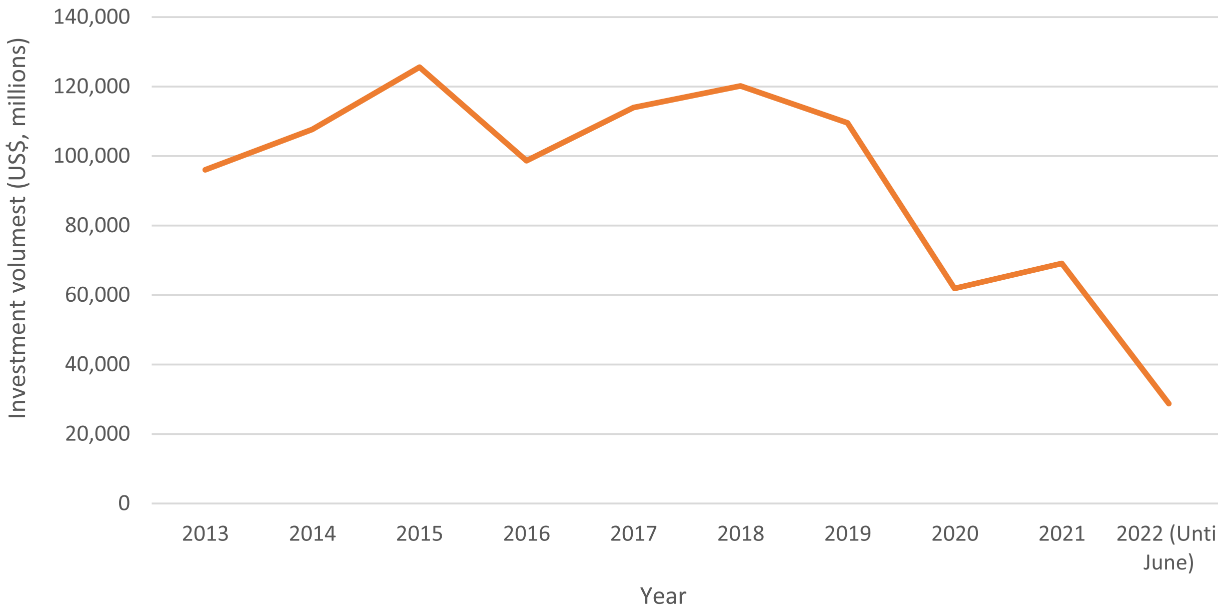

Fig. 1. Overall Chinese investment flows in Belt and Road countries (2013–2021). (Source: Green Finance & Development Center, 2022) [31].

Table 1
China's overseas investment in energy storage in BRI countries.

Project name	Country	Project description	Project status
Noor Energy 1 project	United Arab Emirates (UAE)	The development of a 700 MW concentrated solar power (CSP) project with thermal energy storage + 250 MW solar photovoltaic (PV) project in Dubai's Mohammed bin Rashid Solar Park	Construction started since 2020
Red Sea project	Saudi Arabia	The development of a 1,300 MWh of BESS, including a 400 MW of solar PV	A project contract signed in 2021
Kokhav Hayarden pumped-storage hydropower (PSH) project	Israel	The development of a 344 MW Kokhav Hayarden pumped hydropower storage plant	A projectontract signed in 2022
Minety Battery Storage	The United Kingdom	The development of a 100 MW BESS in Wiltshire, Southern England	Construction completed in 2021

Source: Belt and Road Portal [34].

world's largest single-site CSP plant, BESS, and hydropower-pumped storage in Dubai, Saudi Arabia, and Israel.

China has a considerable potential to scale up energy storage supply chains in BRI countries, particularly given its dominant position in lithium-ion batteries, which represent nearly 80% of the global manufacturing capacity [35]. For example, the Dubai Noor Energy I project will be the world's biggest single-site solar PV with a CSP plant, including a 100 MW tower with 15 h of molten-salt thermal storage, as well as three 200 MW parabolic trough plants with 12.5 h of thermal storage. The Silk Road Fund, holds 24% of the project share through equity investment, combined with syndicated loans on commercial terms from 10 commercial banks, including major BRI financiers, that is, the Agricultural Bank of China, Bank of China, ICBC, China Everbright Bank, and China Minsheng Bank.

High-quality project design is critical for mobilising capital from private investors. A long-term power purchasing agreement (PPA) with an independent power producer was secured, which lowered the LCOEs. In this project, the PPA contract was extended to 35 years from 20–25 years on average, making the LCOEs for both CSP (US$0.073·kWh^{-1}) and solar PV (US$ 0.024·kWh^{-1}) among the world's lowest [36].

Beyond the Middle Eastern region, Chinese investors have constructed the largest grid-connected BESS project in the UK. This Minety Battery Storage project is to showcase China's international efforts to support a net-zero transition in the UK. The project was primarily funded by China Huaneng Group in 2019 and commercialized in 2021, with an installed capacity of 99.8 MW, located in Southeast England [37]. The Stonehill Project, which is the second phase of the Minety BESS project, began in December 2021, with a focus on peak shaving, frequency regulation, and auxiliary services.

In 2021, China hosted the BRI Energy Ministerial Conference in Qingdao, with the aim of supporting low-carbon energy development in lower-income countries [38]. China and BRI countries have endorsed a Qingdao initiative on green energy cooperation, to achieve the twin goals of energy security and economic growth. It highlights that China will be exploring blended finance structures with the support of MDBs, leveraging more private capital on the scale of renewable energy investments. This implies that China and MDBs will strengthen coordination and engagement to jointly address renewable energy financing challenges in BRI countries.

5. Policy recommendations

5.1. Advancing a carbon pricing agenda for promoting energy storage investments

Increased investments in large-scale energy storage technologies will help increase share of renewables in generation, which will gradually reduce the share of thermal power generation over time. As previously mentioned, current policy measures do not sufficiently reflect the economic value of energy storage development in China. Linking carbon prices with renewable energy prices could be a policy option for incentivizing energy storage investments; however, policy reform is required. Carbon pricing through an emissions trading scheme (ETS) is the main market-based instrument to support the transition to a carbon-neutral economy in China, with carbon allowance trading at an average 2021 price of CNY 42.85 per ton of carbon dioxide equivalent (tCO2e). However, this national ETS price was well below US$50–$100·$tCO2e^{-1}$ by 2030 recommended by the High-Level Commission on Carbon Prices to meet the objective of the Pars Agreement [39]. Some measures could be taken by policymakers to address ETS challenges, such as setting an emissions cap, using auctioning instead of free allowances, and improving carbon data quality [28]. In parallel, China could prioritize the development of a domestic carbon tax agenda within national development policies that will not only foster a just energy transition but also provide major health co-benefits of climate action, particularly from reduced air pollution, active travel and healthy eating [40].

5.2. Tapping the potential of the domestic capital market for energy storage technologies

According to the 14th FYP energy storage implementation plan, China's green financial system will leverage public funding to attract private capital in carbon-neutral technologies, including energy storage. China will roll out infrastructure REIT pilots for renewable energy projects [41], which will increase the liquidity of infrastructure assets by turning them into tradable financial instruments. Currently, REITs accounted for only 3% of asset-backed securities (ABS) in China's capital market [42]. This is in part because DFIs rely on traditional approaches such as loan syndication structures to mobilize capital from institutional investors, however, securitizations of loans were not often used [24]. This presents an enormous investment opportunity for institutional investors to tap the potential of domestic capital markets through the securitization of green loans, or green ABS, given that 90% of green financing in China is provided in the form of bank loans [43].

As policy-based development financing has been identified as a priority for new types of infrastructure development [44], relevant policymakers and government agencies could facilitate the China Development Bank (CDB) and National Green Development Fund (NGDF) to establish strategic partnerships for carbon nuetrality financing challenges. To meet investor demand, all types of new energy storage technologies need to be included as the emerging infrastructure asset classes, which have not yet been introduced by the NDRC [41]. CDB and NGDF could jointly prepare for a pipeline of energy storage projects that can be securitized with the support of the public sector for regulatory enforcement and inspections. For example, CDB could take a leading role in green bond issuances, while the public finance provided by NGDF could act as a de-risking mechanism to crowd in institutional investors for energy storage investments.

5.3. Multilateral cooperation in scaling up energy storage supply chains

China's new development cooperation mechanism, third-party market cooperation, encourages BRI investors (i.e., Chinese companies and financial institutions) to develop new partnerships with Western companies for high-quality climate-related infrastructure investments in BRI countries. The IEA estimates that emerging markets and developing economies will require an annual investment of US$26 billion in battery storage between 2026 and 2030 [12]. This coincides with China's recent green BRI commitments to scale up green energy supply chains and green financing through international cooperation. [31]. In this sense, China could enhance international research cooperation with higher-income countries to establish research and development (R&D) centers abroad through a third-party market cooperation mechanism. The joint development of energy storage supply chains in BRI countries is a win-win solution, which could improve technological innovation capacities of Chinese companies, and host countries may benefit from value-added green manufacturing growth. For example, the enhanced China-Indonesia relationship presents a enourmous investment opportunity for Chinese investors to support Indonesia in developing a regional export hub of electric vehicles in Southeast Asia [45].

The Asian Infrastructure Investment Bank (AIIB) could play a crucial role in supporting BRI invetors to meet international standards for developing energy storage projects in lower-income countries. For example, the Energy Sector Strategy of AIIB could emphasise the importance of financing energy storage technologies for increased deployment of renewable energy, by incorporating novel energy storage technologies more explicitly into its lending priorities [46]. This means that AIIB would scale up concessional financing to de-risking energy storage projects in its member countries. Through multilateral cooperation, BRI investors could jointly work with AIIB and other MDBs in developing high-quality energy storage supply chains in lower-income countries. For example, ADB's 2021 Energy Policy highlights that increased support will be given to deploy various types of energy storage that enhances system flexibility in support of low-carbon energy transitions [47]. The European Investment Bank plays a key role in addressing energy storage financing challenges in Europe [48], by incorporating all types of energy storage technologies into its corporate energy lending policy with mobilising private capital through blended finance [49].

Declaration of competing interest

The authors declare that there are no conflicts of interest.

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