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SPECIAL POLICY REPORT

Pathways to Advance Global Cooperation on Green Development



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China Council for International Cooperation on Environment and Development (CCICED)

Pathways to Advance Global Cooperation on Green Development

— Focusing on the green transformation of and from data centres

CCICED Special Policy Study Report

CCICED

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Special Policy Study Members

Co-chairs:*

LI Yonghong	Deputy Secretary General of CCICED; Director General of the Department of International Cooperation, MEE
Kevin Gallagher	Professor; Director, Global Development Policy Center, Boston University
ZHANG Jianyu	Chief Development Officer, BRIGC
Fabby Tumiwa	Executive Director, Institute for Essential Services Reform (IESR)

Special Policy Study Chinese Members:*

Wang Jinzhao	Executive Deputy Director, China Center for International Knowledge on Development
Ji Yongjun	Deputy Secretary-General, Chinese People's Association for Friendship with Foreign Countries
Li Zhong	Deputy Director, Energy Research Institute, National Development & Reform Commission
Luo Bixiong	Chief Scientist, China Energy Engineering Group; Party Secretary & Chairman, China Power Engineering Consulting Group; President, Electric Power Planning & Engineering Institute
Qu Kang	Director of Sustainability, Bank of China (Hong Kong)
Liang Xi	Guest Professor, Smart Energy College, Shanghai Jiao Tong University; Secretary-General, Guangdong Southern CCS Center
Li Xia	Deputy Director General, Foreign Environmental Cooperation Center, Ministry of Ecology & Environment

Special Policy Study International Members:*

Mengdi YUE	Non-Resident Fellow, Global Development Policy Center, Boston University

Cecilia Springer	Non-Resident Fellow, Global Development Policy Center, Boston University
Hamza Haroon	Regional Director, West and South Asia, the Climate Vulnerable Forum, and the Vulnerable Twenty Group of Finance Ministers (CVF-V20)
Renato de Gaspi	Senior Research Associate for Latin America, the Net Zero Industrial Policy Lab, Johns Hopkins University
Ardhitya Eduard Yeremia Lalisang	Senior Assistant Professor, FISIP Department of International Relations, Universitas Indonesia
Farid Wijaya	Manager of Sectoral Decarbonization Research, Institute for Essential Services Reform

Advisors:

Guo Jing	Standing Director, BRI International Green Development Coalition (BRIGC)
Zeng Jinsong	Vice President of Charoen Pokphand Group
Sara Jane Ahmed	Managing Director and Finance Advisor to the V20 Ministers of Finance
Erik Bergdorf	Inaugural Chief Economist, Asian Infrastructure Investment Bank
Minwen ZHANG	Beijing Office Director, the International Financial Reporting Standards Foundation (IFRS) and Special Adviser to the Chair of the International Sustainability Standards Board (ISSB)
Faizel Ismail	Director, Nelson Mandela School of Public Governance, University of Cape Town
Elizabeth Thurbon	Professor, University of New South Wales
Adrianna Abdenur	Co-founder and CEO, Plataforma CIPÓ
Pepukaye Bardouille	Director of the Bridgetown Initiative and Secial Adviser on Climate Resilience to the Barbados Prime Minister's Office
Eric Masanet	Professor, UC Santa Barbara Bren School of Environmental Science & Management

Fang Li	China Country Director, World Resource Institute
Shenyu G. Belsky	China Program Director/China Chief Representative, Rockefeller Brothers Fund
Sébastien Treyer	Executive Director of IDDRI (The Institute for Sustainable Development and International Relations)

Coordinators:

Guo Xiaolin	Director, Foreign Environmental Cooperation Centre (FECO), Ministry of Ecology & Environment
Lin ZHU	Program Manager, Global Development Policy Center, Boston University
Alexandra Miller	Project Coordinator, Global Development Policy Center, Boston University
Arief Rosadi	Program Manager, Diplomacy and Global Affairs, Institute for Essential Services Reform (IESR)

Research Support Team:

Yan Wei	Section Chief, Foreign Environmental Cooperation Centre (FECO), Ministry of Ecology & Environment
Duan Guangzheng	Senior Program Manager, Foreign Environmental Cooperation Centre (FECO), Ministry of Ecology & Environment
Xia Changyou	Project Director, Guangdong Southern CCUS Industry Centre
Hao Xiaoran	Deputy Director, BRI International Green Development Coalition (BRIGC)
Zhang Nan	Senior Program Manager, BRI International Green Development Coalition (BRIGC)
Shi Chuan	Senior Program Manager, Environmental Cooperation Centre (FECO), Ministry of Ecology & Environment

** The co-leaders and members of this SPS serve in their personal capacities. The views and opinions expressed in this SPS report are those of the individual experts participating in the SPS Team and do not represent those of their organizations and CCICED.*

Executive Summary

I. Research Background and Significance

At present, the world is undergoing rapid and profound changes unseen in a century, and international cooperation on green development is facing deep transformations. The rise of unilateralism and protectionism, together with policy shifts in major developed economies, has exacerbated the fragmentation and uncertainty of global climate governance. Persistent geopolitical conflicts are diverting international resources away from climate and other environmental agendas, while rising trade barriers are creating new obstacles to the cross-border flow of green technologies, products, and industrial chains. A few developed countries, leveraging their technological advantages, dominate the rule-making for low-carbon regimes, whereas the Global South countries continue to bear the dual pressures of development and emission reduction. Multilateral governance mechanisms are facing systemic challenges.

Against this backdrop, deepening international green cooperation has become a key "stabilizer" for global economic and political relations. As the world's largest developing country, China has been constructively participating in global ecological and environmental governance and has put forward the concepts of "building a community with a shared future for mankind" and "a community of life for man and nature," as well as the political proposition of "improving global ecological governance and building an eco-friendly world economy." These initiatives have played an important role in consolidating global consensus on ecological governance and promoting a fairer, more reasonable, and mutually beneficial global environmental governance system. At the same time, China's own achievements in ecological protection and green transformation have generated a wealth of innovations, and its continuous efforts to deepen South–South cooperation and the Green Belt and Road Initiative have steadily injected stability and positive energy into global environmental governance and the green and low-carbon transformation of the world economy.

As a key component of industrial green transformation, data centres—with their ability to integrate technology, capital, policy, and infrastructure—are emerging as core nodes that drive industrial green transformation. On the one hand, data centres underpin cutting-edge technologies such as artificial intelligence and cloud computing, and their energy demand and carbon emissions are growing exponentially, forcing innovation and large-scale deployment of green technologies. On the other hand, the construction and operation of data centres involve cross-sectoral coordination across power, cooling, construction, and IT hardware, which can effectively test and integrate various green solutions, thereby driving the green upgrading of upstream and downstream industrial chains including renewable energy, energy storage, smart grids, and liquid cooling technologies. In 2024, global data centre electricity consumption reached 415 terawatt-hours, accounting for 1.5% of total global electricity use; without intervention, this figure is projected to reach approximately 945 terawatt-hours by 2030. The tension between computing power demand and green transformation is a common global challenge that urgently requires international cooperation to explore development pathways that balance efficiency and sustainability. International cooperation should also ensure that this transformation delivers broad-based economic and social benefits, not only environmental outcomes.

For China, this research carries three strategic implications. First, as the world's second-largest digital economy, China has already established eight national hub nodes and 10 data centre clusters spanning 14 provinces, with total data centre supply exceeding 25 gigawatts in 2025. Promoting the green transformation of

data centres is both an inherent requirement for fulfilling the "dual-carbon" goals and a critical measure for consolidating its competitive edge in the digital economy. Second, China has developed systematic experience in the policy framework, technical standards, and operational practices for green data centres, including the "Eastern Data, Western Computing" spatial planning, mandatory power usage effectiveness (PUE) standards, and the green electricity direct connection mechanism, creating valuable knowledge that can be shared with developing countries. Third, the green transformation of data centres serves as a pivotal issue linking digital infrastructure with industrial green transformation. Through bilateral, regional, and multilateral cooperation, China can transform its domestic experience into international public goods and play a leading role in global green governance.

II. Core Research Content

This study addresses the following five key areas:

1. The role of data centre construction and operation in driving international cooperation on green development. From an industrial-system perspective, the study clarifies that the cooperation scenarios for green data centre transformation cover upstream green power development, investment, and application; midstream technology such as liquid cooling and waste-heat recovery; and downstream services such as carbon emissions accounting—all of which are suitable for participation by countries at different stages of development. Data centres can facilitate systemic carbon reduction in the energy sector, support the construction of new power systems, and promote joint renewable-energy projects, thereby building a green industrial cooperation network that extends beyond the boundaries of the data centre itself. The particular significance of this issue lies in the fact that previous international cooperation on green development has largely focused on energy, transport, and manufacturing sectors, leaving data centres—as an emerging industry—largely unexplored in academic and policy research. There is an urgent need to clarify, from a theoretical perspective, their hub status and driving mechanisms.

2. China's policy framework and implementation pathways for green data centre transformation. The study systematically reviews China's four-tier policy architecture: at the apex are the national climate commitments (the "dual-carbon" goals), the "1+N" governance architecture translates these commitments into sectoral mandates; the Five-Year Plans set quantitative targets; and the 2024 Special Action Plan consolidates binding requirements. At the implementation level, China drives policy delivery through four dimensions: spatial planning (the "Eastern Data, Western Computing" initiative), technology standards and innovation incentives, market-based enabling policies, and cross-border cooperation and capacity building. The particular significance of this issue is that the Chinese model offers a replicable reference pathway for developing countries, characterized by "government guidance, market enabling, and technological innovation."

3. Transferable best practices in resource-efficient data centre development accumulated in China. Through case studies—Alibaba Cloud Qiandaohu (deep-lake water cooling, design PUE below 1.3), Alibaba Zhangbei (wind-wall natural cooling with immersion liquid cooling, PUE of 1.13-1.25), Tencent Tianjin (waste-heat recovery avoiding 52,400 tonnes of CO_2 annually, PUE of 1.09), CPECC Qingyang (near-zero carbon industrial park, PUE $\leq$ 1.20, over 90% renewable energy), and CPECC Ulanqab (China's first green power direct connection demonstration, avoiding 567,000 tons of CO_2 annually)—the study verifies how policies are effectively translated into operational outcomes. The particular significance of this issue is that

practical validation provides quantifiable performance benchmarks and a foundation of technical trust for international cooperation.

4. Common challenges and opportunities for green data centre development in regions such as Southeast Asia, Africa, and Latin America. Studying data centre growth in these developing regions is important because it highlights how the rapid expansion of digital infrastructure intersects with climate vulnerability, resource and infrastructure constraints, and development priorities, raising the questions of whether data centres can support broad-based economic development rather than intensifying existing environmental and social challenges. In addition, China has been the largest bilateral development financier in these regions, indicating a strong foundation for cooperation. This study provides in-depth analyses of South Africa (facing a 9.5 GW "base supply cliff" in its power system and lacking mandatory green data centre standards), Brazil (with significant renewable power advantages but facing regulatory uncertainty and competition for transmission capacity), and the Climate Vulnerable Forum and V20 countries (home to nearly 2 billion people yet hosting less than 1% of global data centre capacity). The findings reveal that electricity supply constraints, resource competition, regulatory uncertainty, and skills gaps are common challenges across regions. The particular significance of this issue is that identifying regional differences and common bottlenecks provides a basis for differentiated cooperation strategies.

5. How to promote green data centre transformation through bilateral, regional, and multilateral cooperation. Taking Indonesia as an in-depth case study, the study diagnoses the country's green data centre industrial base (the strengths and gaps in its four pillars: industrial corridors, green industry components, clean energy ecosystem, and policy levers) and proposes three channels—"green chips and electronics," "clean-tech manufacturing," and "renewable energy and grid"—to direct data centre demand toward industrial transformation. On this basis, the study puts forward systematic policy recommendations across three cooperation levels (bilateral, regional, multilateral) and three time frames (short term, medium term, long term). The particular significance of this issue is that it translates theoretical research into actionable operational plans, providing decision-making references for policy-makers.

III. Policy Recommendations

International cooperation on data centres and green structural transformation should evolve from short-term dialogue and standard-setting to medium-term coordinated investment and institutional frameworks, and ultimately to long-term integrated industrial development and financing mechanisms. Different levels of cooperation play complementary roles in this process: bilateral cooperation can support tailored solutions aligned with national characteristics and priorities; regional cooperation can generate economies of scale and shared infrastructure benefits; and multilateral cooperation can provide common standards, financing, and governance frameworks.

A. Bilateral Cooperation

Short term: Launch structured policy dialogues between relevant ministries, developers, and utilities on green data centre planning, sharing China's experience in regulatory frameworks, market mechanisms, and green data centre development; initiate joint research on indicators such as PUE, water usage effectiveness (WUE), and other potential metrics to lay the foundation for future standards.

Medium term: Work with selected partner countries to establish dedicated bilateral frameworks for data centre cooperation that link data centres with green structural transformation; create bilateral working groups involving government agencies, utilities, financial institutions, and private-sector stakeholders; develop blended finance mechanisms that enable Chinese policy banks, commercial banks, and development institutions to work alongside partner-country financial institutions.

Long term: Integrate data centres into broader industrial development strategies and green investment ecosystems; institutionalize long-term cooperation mechanisms that strengthen local capacities and ensure that data centre development contributes to green industrial transformation by reinforcing domestic capabilities and generating broad-based economic and social benefits.

B. Regional Cooperation

Short term: Through regional platforms, such as the BRICS Digital Ecosystem Cooperation Network, the V20 coalition, China-ASEAN, and the Forum on China-Africa Cooperation, jointly develop green data centre standards and benchmarks; establish Memorandums of Understanding and regional cooperation frameworks on green data centres; and promote peer learning through technical exchanges, working groups, and knowledge-sharing initiatives.

Medium term: Bundle Chinese foreign direct investment with supporting infrastructure and supply chains for data centres; develop regional pilot corridors for integrated digital and clean energy infrastructure.

Long term: Leverage shared infrastructure and comparative advantages to build regional green data centre supply chains; support regional manufacturing hubs, technical training centres, and industrial cooperation platforms; promote downstream value creation in areas such as batteries, cooling systems, mineral processing, and low-carbon manufacturing.

C. Multilateral Cooperation

Short term: Elevate green data centres as a priority issue within the G20, UN Framework Convention on Climate Change (UNFCCC), and other global forums; collaborate with organizations such as the International Telecommunication Union (ITU) and the International Energy Agency (IEA) on analytical frameworks and data collection; position green data centres as a key component of global climate, energy, and development cooperation.

Medium term: Promote mutual recognition and alignment of green data centre standards globally; harmonize carbon accounting methods, Renewable Energy Certificates, and sustainability disclosure frameworks.

Long term: Mobilize climate finance and market-based mechanisms for green digital infrastructure, including using UNFCCC Article 6 to monetize emissions reductions from green data centres; engage with existing multilateral climate finance platform—the Green Climate Fund, the Global Environment Facility, and multilateral development banks—to crowd in concessional capital; establish dedicated financing windows or investment facilities for green data centres and associated infrastructure.

Key words：

international cooperation on green development, green transformation, data centres, driving mechanisms

List of Abbreviations and Key Terms

Abbreviation	Full Term	Definition
AKTESP	Agreement, Knowledge, Technological, Economic, Social, Political	A theoretical framework for analyzing barriers to energy transition, structured around six categories of barriers.
BESS	Battery Energy Storage Systems	Systems that store electrical energy in batteries for later use, supporting grid stability and renewable energy integration.
BRIGC	Belt and Road Initiative International Green Development Coalition	A multilateral platform established in 2019 to promote green infrastructure cooperation among over 40 partner countries of the Belt and Road Initiative.
CCUE	Carbon Computing Usage Effectiveness	A metric measuring the carbon emissions per unit of computing output in data centres.
CEI	Carbon Emission Intensity	A metric measuring the amount of carbon emissions per unit of output or activity.
CERST	Carbon Emission Reduction Supporting Tool	A monetary policy instrument of the People's Bank of China providing low-cost funding (1.75% interest rate) for carbon reduction projects.
CPECC	China Power Engineering Consulting Group	A state-owned enterprise leading industrial-scale green data centre projects in China, including the Qingyang and Ulanqab developments.
CVF–V20	Climate Vulnerable Forum and V20 Group of Finance Ministers	The Climate Vulnerable Forum and Vulnerable Twenty Group of Finance Ministers (CVF–V20) represents 74 climate-vulnerable member countries and is home to nearly 1.7 billion people. The CVF-V20 aims to achieve prosperity for its member countries through its flagship initiative of the Climate Prosperity Plans (CPPs). CPPs are pioneering, medium-to-long-term national investment strategies that integrate development, climate, and nature. They are designed to provide a structured and strategic framework for building project pipelines, attracting capital, and accelerating access to and co-development of technology.
CUE	Carbon Usage Effectiveness	A metric measuring the total carbon footprint of a data centre relative to its IT energy consumption.
DC-CFA2	Data Centre Call for Application 2	Singapore's second round of data centre allocation under the BCA-IMDA Green Mark framework, with

Abbreviation	Full Term	Definition
		thresholds of PUE ≤1.25 at 100% information technology (IT) load and ≥50% green power.
EDWC	Eastern Data, Western Computing	A Chinese national spatial planning initiative launched in 2021 that established eight national computing hub nodes and 10 data centre clusters to route computing demand from eastern China to renewable-rich western regions.
EPR	Extended Producer Responsibility	A regulatory approach requiring producers to manage their products through to the post-consumer stage, including disposal and recycling.
ESO	Electronic System Operator	An entity registered under Indonesia's PP 71/2019 framework to operate digital infrastructure systems.
FOCAC	Forum on China-Africa Cooperation	A multilateral platform for cooperation between China and African countries, covering areas including digital infrastructure and green development.
GW	Gigawatt	A unit of power equal to 1 billion watts, commonly used to measure large-scale electricity generation or consumption capacity.
GJ	Gigajoule	A unit of energy equal to 1 billion joules, used to measure heat energy output.
GWh	Gigawatt-hour	A unit of energy equal to 1 billion watt-hours, used to measure large-scale electricity consumption or generation.
IEA	International Energy Agency	An intergovernmental organization providing analysis and policy recommendations on global energy issues.
IEC	International Electrotechnical Commission	An international standards organization that prepares and publishes international standards for electrical, electronic, and related technologies.
IPP	Independent Power Producer	A private entity that generates electricity for sale to the grid or to specific off-takers, distinct from utility-owned generation.
ISO	International Organization for Standardization	An independent, non-governmental international organization that develops voluntary international standards.
ITU	International Telecommunication Union	A UN specialized agency responsible for information and communication technologies, including green data centre standards (e.g., ITU-T L.1300, L.1320).

Abbreviation	Full Term	Definition
JDA	Joint Development Area	A designated zone for collaborative industrial development, such as the Galang Island JDA in Indonesia for semiconductor and photonics industries.
kWh	Kilowatt-hour	A unit of energy equal to 1,000 watt-hours, used as the standard billing unit for electricity consumption.
MEMR	Ministry of Energy and Mineral Resources (Indonesia)	The Indonesian government ministry responsible for energy policy, electricity regulation, and mineral resources management.
MIIT	Ministry of Industry and Information Technology (China)	The Chinese government ministry overseeing industrial policy, IT standards, and data centre regulation.
MW	Megawatt	A unit of power equal to 1 million watts, used to measure data centre capacity or electricity generation.
NDRC	National Development and Reform Commission (China)	China's top macroeconomic management agency, responsible for economic planning, pricing policy, and climate policy coordination.
NEA	National Energy Administration (China)	The Chinese government agency responsible for energy sector regulation and planning.
NIB	Nova Indústria Brasil (New Industry Brazil)	A Brazilian government industrial policy program, with Mission 4 focusing on digital infrastructure as a driver of productive transformation.
OECD	Organisation for Economic Co-operation and Development	An intergovernmental organization of developed economies that promotes policies to improve economic and social well-being.
OSS-RBA	Online Single Submission–Risk-Based Approach (Indonesia)	Indonesia's investment licensing framework operated by BKPM, using risk-based classification to streamline business permits.
PPA	Power Purchase Agreement	A long-term contract between an electricity generator and a buyer (offtaker) for the purchase of electricity, typically from renewable sources.
P3DN	Peningkatan Penggunaan Produk Dalam Negeri (Domestic Product Usage Enhancement)	An Indonesian policy framework promoting the use of domestically manufactured products in public procurement and infrastructure.
PFAS	Per- and Polyfluoroalkyl Substances	A group of synthetic chemicals known as "forever chemicals" for their extreme environmental persistence, used in some data centre immersion cooling fluids.

Abbreviation	Full Term	Definition
PLN	Perusahaan Listrik Negara	Indonesia's state-owned electricity utility, the primary power supplier and sole transmission grid operator.
PUE	Power Usage Effectiveness	The ratio of total energy consumed by a data centre to the energy delivered to IT equipment, calculated as total facility energy ÷ IT equipment energy. The industry-standard metric for data centre energy efficiency; a lower PUE indicates higher efficiency.
REC	Renewable Energy Certificate	A tradable certificate representing the environmental attributes of 1 megawatt-hour of electricity generated from renewable sources, distinct from carbon credits.
REDATA	Regime Especial de Data Centres (Special Data Centre Regime)	A Brazilian tax incentive framework (MP 1.318/2025) for data centre investments, which expired and is pending reinstatement.
REIPPPP	Renewable Energy Independent Power Producer Procurement Programme (South Africa)	South Africa's competitive bidding program for procuring renewable energy from private developers, administered under the Department of Energy.
RPJMN	Rencana Pembangunan Jangka Menengah Nasional (National Medium-Term Development Plan, Indonesia)	Indonesia's 5-year national development plan, currently in the 2025–2029 cycle, which sets sectoral priorities including digital infrastructure.
RUPTL	Rencana Usaha Penyediaan Tenaga Listrik (Electricity Supply Business Plan, Indonesia)	Indonesia's national electricity supply plan prepared by PLN, covering generation capacity expansion and fuel mix targets over a 10-year horizon.
SNI	Standar Nasional Indonesia (Indonesian National Standard)	Indonesia's national standards system, including SNI 8799 series for data centre design, operation, and energy management.
SS 564	Singapore Standard 564	Singapore's standard for resource efficiency in data centres, in effect since 2011, establishing baseline requirements for energy and water use.
TKDN	Tingkat Komponen Dalam Negeri (Local Content Requirement, Indonesia)	An Indonesian industrial policy instrument requiring a minimum percentage of domestically manufactured components in certain products and infrastructure.
TWh	Terawatt-hour	A unit of energy equal to 1 trillion watt-hours, used to measure national or global-scale electricity consumption.

Abbreviation	Full Term	Definition
UNFCCC	United Nations Framework Convention on Climate Change	The international treaty providing the framework for global climate action, including the Paris Agreement and Article 6 carbon market mechanisms.
UNEP	United Nations Environment Programme	The leading global environmental authority that sets the global environmental agenda and promotes sustainable development.
UNIDO	United Nations Industrial Development Organization	A UN specialized agency promoting industrial development for poverty reduction, inclusive globalization, and environmental sustainability.
WUE	Water Usage Effectiveness	The ratio of total water consumed by a data centre to the energy delivered to IT equipment, calculated as total annual water consumption (litres) ÷ IT equipment energy (kWh). A lower WUE indicates more efficient water use.

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1 Introduction Framing: Data Centres and the Need for Industrial Green Transformation

1.1 Opportunities for Industrial Green Transformation in the New Landscape of International Cooperation on Green Development

1.1.1 Current Global Developments and Their Impacts on International Cooperation on Green Development

At present, the world is undergoing rapid changes on a scale not seen in a century, and international cooperation on green development is facing new challenges. The rise of unilateralism and protectionism, coupled with policy shifts in major developed economies, has exacerbated the fragmentation and uncertainty of global climate governance. Geopolitical conflicts continue to divert international resources away from climate policy, while rising trade barriers are creating new obstacles to the cross-border flow of green technologies, products, and industrial chains.

Climate and other global ecological and environmental issues are deeply intertwined with politics and the economy, exerting an increasingly profound impact on global development. A few developed countries, leveraging their technological advantages, dominate the formulation of low-carbon rules, while Global South countries still face the dual pressures of development and emission reduction. Cooperation mechanisms are becoming fragmented, and multilateral governance mechanisms are facing systemic challenges.

Against this backdrop, global environmental governance urgently requires the establishment and strengthening of an international rules-based system that embodies the principle of equality among nations, adheres to multilateralism, and facilitates collaborative governance, in order to overcome the current challenges facing global environmental governance and promote the creation of a new framework for global environmental governance that is fair, reasonable, and efficient.

1.1.2 Opportunities for International Cooperation as a Stabilizing Force for Global Economic Development and Political Relations

Although the world is currently undergoing a period of upheaval and transformation, the challenges posed to human survival and development by climate change, biodiversity loss, and environmental pollution remain increasingly severe. The trend toward a green and low-carbon transition is irreversible, and therefore the opportunities presented by the global green transformation still outweigh the challenges. Deepening international green cooperation has become a key “stabilizing force” for the global economy and political relations, creating shared benefits through industrial and technological collaboration and providing a practical platform and a mutually beneficial narrative framework for reshaping the global governance system. In particular, China’s achievements in building an ecological civilization and its leading role in global

environmental governance are evident to all, and the international community's expectations of China are constantly rising.

As the world's largest developing country, China has always been constructively participating in global ecological and environmental governance, continuously contributing its wisdom and advancing global sustainable development. The concepts proposed by China, such as building "a community with a shared future for mankind" and "a community of life for man and nature," as well as its political proposition of "improving global ecological governance and building an eco-friendly world economy," have played an important driving role in consolidating global consensus on ecological governance and promoting the improvement of a fair, reasonable, and mutually beneficial global environmental governance system based on cooperation. Meanwhile, China has achieved numerous innovations in its own ecological and environmental protection and green transformation, while continuously deepening South–South cooperation and the Green Belt and Road Initiative, steadily injecting stability and positive energy into global ecological and environmental governance as well as the green and low-carbon transformation of the world economy.

1.1.3 Industrial Green Transformation as a Driving Force for Deepening International Cooperation

In the face of new developments and challenges in global environmental governance, countries are prioritizing green and low-carbon industries and technological innovation as key areas for consolidating their long-term competitive advantage. At the same time, the role of industrial green transformation in promoting international cooperation is becoming increasingly prominent. Data centres—with their ability to integrate technology, capital, policy, and infrastructure—are emerging as core hubs that can drive industrial green transformation. They can foster deeper, practical international cooperation on green initiatives and jointly generate multiple benefits, including economic growth and energy transition.

On the one hand, data centres underpin the development of cutting-edge technologies such as artificial intelligence, cloud computing, and the Internet of Things. Their energy demand and carbon emissions are growing rapidly, thereby driving innovation in green technologies and their large-scale adoption. On the other hand, data centres possess a strong capacity to integrate cross-sectoral resources—concentrating demand for green power, advanced cooling, low-carbon materials, and digital talent within a single facility. Their construction and operation require cross-sectoral coordination across power, cooling, construction, IT hardware, and waste management, which in turn makes each facility a testbed for bundled green solutions and a platform for scaling them across the wider industrial chain. Therefore, promoting the green and low-carbon transition of data centres can not only help to reduce the industry's own carbon footprint, but also drive the green upgrading of upstream and downstream industrial chains—including renewable energy, energy storage, smart grids and liquid cooling technologies, and sustainable e-waste management—through technological spillover and standard-setting, thereby creating a "point-to-area" transformation effect.

1.2 Definition of Industrial Green Transformation

1.2.1 International Understanding of Concepts Related to Industrial Green Transformation

Internationally, there is no universally accepted standard definition of "industrial green transformation," but the relevant concepts systematically articulated and promoted by organizations such as the United Nations are widely accepted. The United Nations Industrial Development Organization (UNIDO) defines "industrial

greening" as the green transformation of existing industries so that their development no longer relies on the increasing consumption of natural resources and the generation of pollution [1]. The United Nations Environment Programme (UNEP) defines a "green economy" as low carbon, resource efficient, and socially inclusive [2]. The Organization for Economic Co-operation and Development (OECD) defines "green growth" as economic growth and development that ensures the sustainable provision of resources and environmental services by natural assets [3]. Finally, "green and just transition" under the United Nations framework emphasizes comprehensive measures to address climate change and environmental degradation while ensuring social justice and equity.

1.2.2 China's Approach and Policy of Industrial Green Transformation

Industrial green transformation serves as a crucial lever for China to pursue high-quality development and achieve modernization characterized by harmony between humanity and nature. Its scope extends beyond the traditional notion of mere pollution control or end-of-pipe treatment; rather, it refers to a systematic and fundamental transformation of industrial structure, production methods, energy mix, and even development models, guided by green and low-carbon principles and driven by technological innovation. It involves deeply integrating the concept of green development into all areas and stages of economic and social development, and synergistically advancing carbon reduction, pollution control, ecological restoration, and economic growth, ultimately achieving a win-win outcome where economic and social development coexist harmoniously with ecological and environmental protection.

In practical terms, the Chinese government issued the *Guidance Catalog for Green and Low-Carbon Industrial Transformation* (2024 Edition), which provides a detailed classification of green and low-carbon industries, translating broad green concepts into actionable industrial policies. This policy document not only changed the terminology from "green industries" to "green and low-carbon transition industries," but also systematically restructured the sector's boundaries, scope, and requirements, clearly defining seven major categories of industries: energy conservation and carbon reduction, environmental protection, resource recycling, green energy transition, ecological conservation, restoration and utilization, infrastructure upgrading, and green services. Specifically, China's industrial green transformation encompasses both the in-depth transformation of traditional energy-intensive industries such as steel and petrochemicals, and the cultivation and expansion of emerging green industries such as new energy and new materials. It focuses not only on clean energy substitution at the supply end but also on the green upgrading of infrastructure at the consumption end. It extends the green transition from the production sector to a full-chain service system encompassing consultancy, finance, and technological research and development (R&D).

1.2.3 Comparison of Different Definitions and Interpretations, and Key Elements

An analysis of relevant concepts and policies reveals that the essence of industrial green transformation lies in systematic investment in or reform of technology, society, the economy, and institutions, with the aim of establishing a new, sustainable, and inclusive development model.

Overall, industrial green transformation can be defined as **a dynamic process aimed at promoting the comprehensive greening and decarbonization of economic and social development. It involves driving a systematic shift in energy structures, industrial structures, and production methods toward greater efficiency, cleaner practices, and lower carbon emissions through technological innovation, institutional innovation, and systemic optimization**. Its core elements include driving technological innovation,

comprehensive system coverage, continuous efficiency improvements, sustainable development, and social inclusivity.

Industrial green transformation must first strike a balance between economic development and carbon reduction, ensuring that the costs of transformation remain affordable and industrial competitiveness is maintained. For data centres specifically, this balance involves weighing their direct energy and carbon footprint against the system-wide efficiency gains they enable—such as optimizing grid load, accelerating renewable deployment, and substituting for more carbon-intensive compute elsewhere. The assessment is dynamic: as renewable penetration and cooling efficiency improve, the net balance shifts favourably over a facility's lifetime. At the same time, industrial green transformation should be a just transition. In the data centre sector, priority should be given to ensuring that the energy-related and economic benefits arising from its development are distributed equitably, and that the development rights of developing countries and vulnerable groups are safeguarded. Specifically, a socially inclusive transformation would consider who benefits from new investments and who may be disproportionately affected by transition policies. It also entails expanding participation, employment, skills development, and access to digital infrastructure across different population groups. Moreover, industrial green transformation in the data centre context extends beyond carbon to encompass water consumption, pollutant discharge, critical mineral stewardship, and e-waste dimensions addressed in Section 2.3.

From the perspective of driving factors, the industrial green transformation encompasses four dimensions—policy, technology, economy, and society—which are interlinked and work together to drive the achievement of transformation goals. From a full life-cycle perspective, the industrial green transformation involves green decarbonization across the entire industrial life cycle, meaning low-carbon practices throughout the entire chain—from production and manufacturing to construction, operation, and usage to recycling and disposal.

In this process, international cooperation can effectively promote the interaction and flow of policies, technologies, and capital; optimize resource allocation; and enhance resource utilization efficiency. It enables industrial green transformation to evolve from a single national action to transnational collaboration, establishing mechanisms for the provision of public goods such as technology, capital, and standards, thereby enhancing the effectiveness and sustainability of the green transformation. At the same time, the shared aspirations and concerns of various economies regarding policy, technology, finance, and social issues will further drive cooperation and exchange among them, leading to the deep integration and coordinated development of global industrial and supply chains.

1.3 Data Centres in the Context of Industrial Green Transformation: Mechanisms and Pathways for Driving International Cooperation on Green Development

1.3.1 The Rapid Development of Data Centres and the Urgency of Their Green Transformation

With the rapid growth of the digital economy, the contradiction between the exponential surge in computing power demand and the rigid constraints on energy supply has become increasingly apparent. According to the IEA's report *Energy and Artificial Intelligence*, global data centre electricity consumption

reached 415 terawatt-hours in 2024, accounting for 1.5% of total global electricity consumption—equivalent to the annual electricity consumption of the United Kingdom. Global data centre electricity consumption is projected to reach approximately 945 terawatt-hours by 2030. Data centres in the United States, the world's largest data centre market at present, represent 47 GW of power demand, with some projections estimating this will reach 95 GW by 2028. As a primary hub for global computing power demand, China has established eight major hub nodes and 10 data centre clusters spanning 14 provinces. In 2025, the total supply capacity of its data centres exceeded 25 gigawatts. Under the "East Data, West Computing" strategic framework, the mismatch in time and space between massive computing-power capacity and green electricity supply and demand is driving the accelerated advancement of "computing-power synergy" and green transformation. Furthermore, data centre construction in regions such as Africa and Southeast Asia is also experiencing explosive growth. Against this backdrop, the tension between computing power demand and green transformation represents a shared global challenge that urgently requires international cooperation to explore development pathways that balance efficiency and sustainability.

1.3.2 The Green Transformation of Data Centres: A Core Driver of International Cooperation on Green Development

As a key component of the modern industrial system, a vital infrastructure for the development of digital economy, and a strategic industry, data centres are major energy consumers with the potential to be hubs for the industrial green transformation. Data centres are significant consumers of electricity, water, land, and materials. At the same time, they play a crucial role in promoting industrial upgrading, attracting financial investment, and supporting the digital economy. Furthermore, they can stimulate the development of upstream and downstream green industries such as green power generation, long-duration energy storage, waste-heat utilization, and low-carbon materials. They also encompass development dimensions such as water and waste management, low-carbon energy systems, and benefit sharing and have the potential to become one of the key drivers of international cooperation on green development. From the perspective of industrial systems, the green transformation of data centres helps drive the transformation of upstream and downstream industrial chains. Cooperation scenarios span upstream green power development, investment, and application; midstream technology such as liquid cooling and waste-heat recovery; and downstream services like carbon emissions accounting. It suits the participation of countries at different development stages and plays a positive role in promoting systemic carbon reduction in the energy sector, potentially shifting economic activity away from carbon-intensive heavy industry, supporting the construction of new power systems, optimizing the power grid to facilitate the integration of green power, and promoting the joint development of renewable energy projects, thereby fostering the formation of a green industrial cooperation network that goes beyond the boundary of the data centre itself to provide broader benefits to the region hosting the data centre.

Currently, international cooperation on green development primarily focuses on sectors such as energy, transportation, and manufacturing. Although data centres, as an emerging industry, are increasingly recognized for their low-carbon, efficient, and sustainable operational models—which are becoming a key pathway to addressing their own energy consumption challenges and supporting the coordinated development of the digital economy and green transformation—there remain research gaps in areas such as relevant international green standards, cooperation mechanisms, and the provision of public goods. In addition, the exploration of green data centres to date has largely focused on decarbonizing onsite energy, resource, and material use, rather than

broader transformation in the area or country where the data centre is sited.

As a result, the green transformation potential of data centres remains largely untapped. Accordingly, this study focuses on the critical area of green transformation and data centres, exploring issues such as environmental pressures, carbon emission challenges, and host-country benefit sharing. Through specific case studies, it conducts an in-depth analysis of the mechanisms and pathways driving international cooperation for green development, with the aim of providing theoretical support and practical guidance for international cooperation on green transformation in the digital age.

2 China's Experience and Progress in Green Transformation of Data Centres

China's data centre electricity consumption reached 166 TWh in 2024 (1.68% of national total) and is projected to reach 400 TWh by 2030 (3.7%), with a compound annual growth rate of 13–16% [4, 5]. Nationally, average power usage effectiveness (PUE) stood at 1.46 by the end of 2024, with the eight national computing hub clusters achieving better performance at approximately 1.3 by March 2025 and the most advanced facilities reaching 1.04 [6]. As the world's second-largest digital economy, China has developed a green data centre transformation framework defined by "government guidance, market enabling, and technological innovation," balancing rapid computing capacity expansion with low-carbon transition.

This chapter outlines China's policy framework, implementation dimensions, resource efficiency practices, and operational cases for green data centre transformation, offering actionable reference pathways for developing countries.

2.1 China's Hierarchical Policy Framework for Green Data Centre Transformation

China's green data centre policy framework operates through a four-tier hierarchical architecture: (1) national climate commitments at the apex, (2) the "1+N" governance architecture translating commitments into sectoral mandates, (3) Five-Year Plans specifying quantitative targets, and (4) the 2024 Special Action Plan consolidating binding requirements (Figure 1). This hierarchical design ensures that high-level climate commitments cascade down into enforceable sectoral requirements, creating both directional clarity and compliance pressure.

At the apex, the dual-carbon goals—China's commitments to peak carbon emissions before 2030 and achieve carbon neutrality before 2060 [7]—and the "1+N" policy framework—the overarching climate governance architecture formalized in 2021, where "1" refers to the guiding document and "N" refers to sector-specific action plans—provide the overarching directional mandate [8].



Figure 1 China's policy framework architecture for green data centre transformation, showing the hierarchical structure from national climate commitments (Dual-Carbon Goals) through the "1+N" policy architecture and Five-Year Plans, to the binding 2024 Special Action Plan, and its four implementation pillars: spatial planning (Eastern Data, Western Computing), technology standards and innovation, market-based enabling policies, and cross-border cooperation under BRI, BRIGC, and FOCAC frameworks.

Note: BRI = Belt and Road Initiative, BRIGC = BRI International Green Development Coalition, FOCAC = Forum on China-Africa Cooperation.

The 14th Five-Year Plan for Digital Economy Development and the 14th Five-Year Plan for Information and Communications Industry translate the dual-carbon mandate into specific targets for digital infrastructure. These plans explicitly position data centres as both major energy consumers and key targets for decarbonization, setting requirements for PUE reduction, regional layout, and renewable energy utilization [9, 10]. These 14th Five-Year Plan targets are being carried forward and tightened under the 15th Five-Year Plan (2026–2030), which shifts the emphasis from efficiency improvement toward mandatory decarbonization of digital infrastructure (see Section 2.5.3).

Critically, the 2024 Special Action Plan for Green and Low-Carbon Development of Data Centres—issued by the National Development and Reform Commission (NDRC) together with the Ministry of Industry and Information Technology (MIIT), the National Energy Administration (NEA), and the National Data Bureau in July 2024—functions as the most authoritative sector-specific instrument to date, consolidating PUE thresholds, renewable energy targets, and retrofit obligations into a unified compliance framework [30]. Under the plan, newly built and expanded large and super-large data centres must achieve a PUE ≤1.25 by the end of 2025, while data centre projects at national computing hub nodes are required to meet a stricter PUE ≤ 1.2; existing non-compliant facilities are subject to mandatory retrofitting or decommissioning. By the end of 2025, new data centres at national computing hub nodes are mandated to source over 80% of their electricity from renewable sources. The plan also sets a 2025-year-end target of reducing the national average PUE of all data centres to below 1.5.

In April 2026, four ministries jointly issued the Action Plan on Promoting Bidirectional Empowerment of AI and Energy [12], extending the framework from data-centre-specific regulations to a comprehensive national regime linking AI infrastructure and energy systems, with 2027 and 2030 milestones and a "million-kilowatt-class" compute-energy synergy pilot program.

The policy framework outlined above establishes directional clarity and compliance pressure. Its practical realization, however, depends on four interlocking implementation dimensions—spatial planning, standards and innovation, market mechanisms, and international cooperation—each addressed in Section 3.2.

2.2 Policy Implementation: Four Supporting Dimensions

Building on the policy framework outlined in Section 3.1, China's implementation system operates through four mutually reinforcing dimensions: spatial planning creates the infrastructure foundation, standards define compliance pathways, market mechanisms reduce economic barriers, and international cooperation extends impact and facilitates learning.

2.2.1 Strategic Planning and Spatial Optimization

This dimension operationalizes the regional layout mandates. China's most distinctive contribution lies in its national-level spatial coordination of computing infrastructure and clean energy resources. Launched in 2021, with construction fully commencing in 2022, the Eastern Data, Western Computing (EDWC) Initiative established a national integrated computing power network anchored by eight national computing power hub nodes and 10 national data centre clusters [13], each assigned distinct functional roles:

Western hubs focus on non-latency-sensitive workloads-tasks that do not require real-time response, such as batch data processing, AI model training, and backup archiving, and can therefore be sited far from end users-and are explicitly prioritized for renewable electricity integration. As of the end of 2025, over 80% of electricity consumed by new data centres in these hubs is sourced from wind, solar, and hydro power [4].

Eastern hubs, located near China's economic cores—including the Beijing–Tianjin–Hebei region, the Yangtze River Delta, and the Guangdong–Hong Kong–Macao Greater Bay Area—support high-value, low-latency applications such as AI training, real-time finance, and e-commerce. Newly built large and super-large data centres must achieve a PUE of ≤1.25 (hub nodes ≤1.2) [30].

On water resources: The EDWC strategy prioritizes renewable energy over water abundance because water constraints can be addressed through liquid cooling, mandatory WUE metrics, and site-level planning. Western hubs are selected for wind, solar, and natural cooling advantages. Eastern hubs vary—coastal regions have better water availability.

International Transferability: The EDWC model offers a replicable blueprint for countries facing geographic mismatches between digital demand and renewable supply, such as India (Maharashtra demand vs. Himalayan hydro), Brazil (São Paulo clusters vs. Amazon hydro), and Indonesia (Java demand vs. Sulawesi solar), demonstrating that "green" and "digital" transitions can be mutually reinforced through coherent spatial strategy. However, the model relies on China's massive, unified market. Smaller countries may need to (1) pursue regional cooperation (e.g., ASEAN-wide planning) to aggregate demand; or (2) adapt the model to provincial or city-level scales.

2.2.2 Technology Standards and Innovation Incentives

This dimension provides the technical foundation for policy compliance, translating PUE and renewable energy targets into measurable benchmarks. China has built a life-cycle-spanning standards ecosystem and targeted innovation support, with over 30 national and industry standards governing data centre sustainability, including:

(1) GB 40879–2021: Maximum Allowable Values of Energy Efficiency and Energy Efficiency Grades for Data Centres" [14], a mandatory national standard setting binding PUE thresholds—data centres exceeding PUE 1.30 face compliance restrictions, with differentiated requirements for new vs. existing facilities [15];

(2) GB/T 44989–2024 "Evaluation for Green Data Centre" [16], integrating energy efficiency, water usage, carbon emissions, renewable energy utilization, and green procurement into a five-tier rating system; implemented in June 2025, it serves as the qualifying benchmark for National Green Data Centre designation (Level 2 or above), directly linking standards to policy incentives;

(3) A suite of five liquid cooling standards [17–21] (YD/T 3979–2021 to YD/T 3983–2021) covering immersion and cold-plate systems, cooling liquids [19], general technical requirements and testing methods, and energy efficiency, aligned with ITU-T L.1300 [22] and L.1320 [23].[1]

Complementing standards, China deploys practical demonstration and financial incentives:

(1) As of 2025, the Ministry of Industry and Information Technology (MIIT) and five other ministries have selected 246 National Green Data Centres across five batches [16,24]. Designated centres benefit from preferential policies, including eligibility for value-added tax (VAT) credit refunds under broader manufacturing policy [25], accelerated depreciation for qualifying equipment [26], and in some provinces, priority access to green electricity trading and subsidies for deploying liquid cooling and energy-efficient cooling technologies.

(2) China's liquid cooling market is growing rapidly: cold-plate systems account for 80–90% of deployed liquid-cooled capacity, while immersion cooling is gaining momentum, driven by AI workloads. The market was valued at approximately USD 498 million in 2024 and is projected to exceed USD 3.3 billion by 2032 (CAGR ~27%).

International Transferability: This "standards + showcase + incentive" triad can lower adoption risk and cost. The mechanism works as follows: (1) standards provide clear compliance pathways and reduce technology selection risk—policy-makers can adopt harmonized international standards (e.g., via ITU membership) rather than developing domestic standards from scratch; (2) demonstration programs verify technology performance under local conditions, building confidence among investors and operators; (3) fiscal incentives (tax credits, subsidized loans, grants) address the cost barrier and can be paired with concessional financing from development banks where domestic fiscal capacity is limited.

2.2.3 Market-Based Enabling Policies

This dimension addresses the economic viability gap between policy ambition and implementation cost. China's green data centre ecosystem operates through two interlocking market mechanisms:

(1) Green Electricity Procurement & Integration: In 2025, China's green electricity trading volume reached 328.5 billion kWh (+38.3% year-on-year) [27]. The NDRC established a "green electricity direct connection" mechanism allowing renewable supply via dedicated lines without passing through the public grid

[1] Note that L.1300 was initially approved in 2011; it is the 2014 revision that is referred to here.

[28], now available in over 20 provinces [29]. National targets require new data centres at hub nodes to achieve over 80% green electricity consumption by end-2025 [30], with the Inner Mongolia hub reaching 84.57% in Q1 2025 [31]. The April 2026 Action Plan on Promoting Bidirectional Empowerment of AI and Energy elevated this mechanism to a national priority [12].

(2) Targeted Financial Support: The People's Bank of China's Carbon Emission Reduction Supporting Tool (CERST) provides low-cost funding at a 1.75% interest rate [32]. By the end of 2025, China's total green loan balance reached ¥44.77 trillion [33], with green data centres increasingly eligible under expanding support categories [34]. The National Green Development Fund (first-phase capital of ¥88.5 billion) also invests in clean energy infrastructure underpinning green data centres [35], while local governments in hub regions offer additional incentives including subsidized land and discounted power tariffs [11].

International Transferability: These instruments address the two biggest barriers for developing countries—high upfront capital costs and lack of bankable project structures. Adaptation pathways include: (1) establishing "green data centre lending windows" at national development banks with PUE-tied subsidized rates; or (2) structuring bilateral green PPAs to reduce offtaker risk. Applicability varies by context: upper-middle-income countries with mature power markets (e.g., Brazil, South Africa) can adopt these more readily, while lower-income countries may need alternative pathways such as development bank concessional financing or multilateral co-financing facilities. Where national development banks are absent, alternatives include multilateral financing (ADB, AIIB, World Bank) and regional development funds; cross-ministerial coordination can be achieved through inter-agency task forces even without China's formal institutional architecture.

2.2.4 Cross-Border Cooperation and Capacity Building

This dimension extends domestic policy impact beyond borders. Under the Belt and Road Initiative, China has integrated green data centre development into its digital infrastructure cooperation with developing countries. The BRI International Green Development Coalition (BRIGC), established in 2019, serves as a multilateral platform promoting green infrastructure cooperation among over 40 partner countries [36], with key cooperation areas including:

(1) Policy dialogue and standard alignment: China participates in ITU-T Study Group 5 [37], contributing to green data centre standards such as L.1300 [22] and L.1320 [23], and supports developing countries in adopting harmonized information and communication technology (ICT) sustainability frameworks [38].

(2) Technical assistance and training: Through the Forum on China-Africa Cooperation (FOCAC) and the "Digital Silk Road," China provides capacity building in: (1) green data centre design and operation—PUE optimization, liquid cooling deployment, and renewable energy integration; (2) policy and regulatory frameworks—standards adoption, monitoring systems, and compliance mechanisms; and (3) workforce development—training programs for facility managers and technicians [39]. China's "Digital Silk Road" initiatives have supported green data centre projects in Pakistan, Indonesia, and Malaysia [40].

(3) South–South climate cooperation: China's South–South Climate Cooperation Fund has provided climate-related technical assistance to over 40 developing countries [41], with green ICT infrastructure increasingly featured.

In 2025, the Cyberspace Administration of China released the *Digital and Green Co-Transformation*

Development Report, highlighting green data centre technology sharing with ASEAN and African nations [42], and co-hosted the Digital and Green Co-Transformation Forum at the 2024 World Internet Conference, convening participants from over 20 countries [43].

International Transferability: Engaging with multilateral platforms like BRIGC and ITU offers access to vetted standards, peer learning, and co-financing. The key lesson is that international cooperation works best when it strengthens local institutional capability rather than substituting for it. Capacity-building initiatives under these platforms should also encourage broad participation in technical education and workforce development, ensuring that women, youth, rural communities, and other underrepresented groups can benefit from opportunities in the digital infrastructure sector.

2.3 Best Practices in Resource-Efficient Data Centre Development

While Sections 3.1 and 3.2 address the policy and implementation architecture, sustainable data centre operation requires prudent management of water, minerals, and grid resources as well. As AI-driven computing density rises, data centres increasingly compete with local communities for scarce resources. This section examines China's experience in addressing these conflicts.

2.3.1 Managing the Water-Energy Nexus: Mitigating Resource Competition

Data centre expansion in China has intensified resource competition in water-scarce northern regions and grid-constrained eastern cities. Beijing exemplifies the water tension: in 2024, the city's data centres consumed an estimated 22–30 million cubic metres of water annually, with consumption rising rapidly during 2020–2024 [44]. Since 70% of Beijing's municipal supply comes from the South-to-North Water Diversion Project, data centres' reliance on tap water for cooling indirectly competes with residential water demand [44]. Meanwhile, saturated electricity distribution networks in eastern hubs create "connection difficulties" for new high-density facilities; for example, the Huailai, Hebei cluster required urgent construction of a new 220 kV transmission line (480 MW) to meet demand [45].

China addresses these constraints through a three-layer decoupling strategy:

(1) Spatial decoupling: the EDWC initiative relocates batch processing to western regions with abundant renewable energy while retaining real-time workloads in the east.

(2) Efficiency decoupling: government mandates enforce dual PUE and WUE metrics, driving operators toward liquid cooling and closed-loop systems.

(3) Temporal decoupling: coordinated storage systems charge during renewable surplus periods and discharge during peak demand, aligning load curves with variable generation.

Cooling innovation is central to closing the remaining gap. Liquid cooling is the most mature option: it reduces water consumption by 30–40% and electricity use by 30–50%, drives PUE below 1.1, and eliminates dependence on clean fresh water [46]. Natural cooling offers even higher efficiency but is geographically constrained. Leading operators are pushing further: Tencent has deployed undersea data centres using seawater for cooling and is piloting hydrogen fuel cells as backup power [47]. On thermal pollution, China's GB 3838-2002 limits temperature increase in receiving water bodies to ≤1 °C weekly average [48]. The shift toward liquid cooling (closed-loop systems) inherently avoids thermal discharge to water bodies. One environmental caveat warrants attention: certain immersion cooling technologies rely on fluorinated coolants-perfluorinated fluids valued for thermal conductivity and electrical insulation but flagged as PFAS ("forever chemicals") for their

extreme environmental persistence and high global-warming potential. As China (under its dual-carbon and chemical-control policies), the EU, and the U.S. tighten PFAS restrictions, the sector is pivoting toward fluorine-free alternatives such as synthetic oils and bio-based coolants-an area where Chinese firms are building capacity and where international cooperation on standards and alternatives can accelerate the transition.

International Transferability: The resource-competition model is not unique to China. The key transferable elements are: (1) spatial planning that matches computing load with resource availability; (2) mandatory efficiency metrics that create compliance pressure without prescribing specific technologies; and (3) integrated energy-storage systems that reduce grid dependency. The institutional prerequisite is coordination between digital infrastructure planners and water/energy regulators.

2.3.2 Experiences of Saving Critical Minerals and Resources

Data centre construction involves a "pyramid" structure of critical mineral consumption (Figure 2): at the base, copper for power transmission and cooling [49]; in the middle, lithium, cobalt, and nickel for backup power storage [50]; at the top, silicon, gallium, germanium, and rare earth elements for chip manufacturing [51].

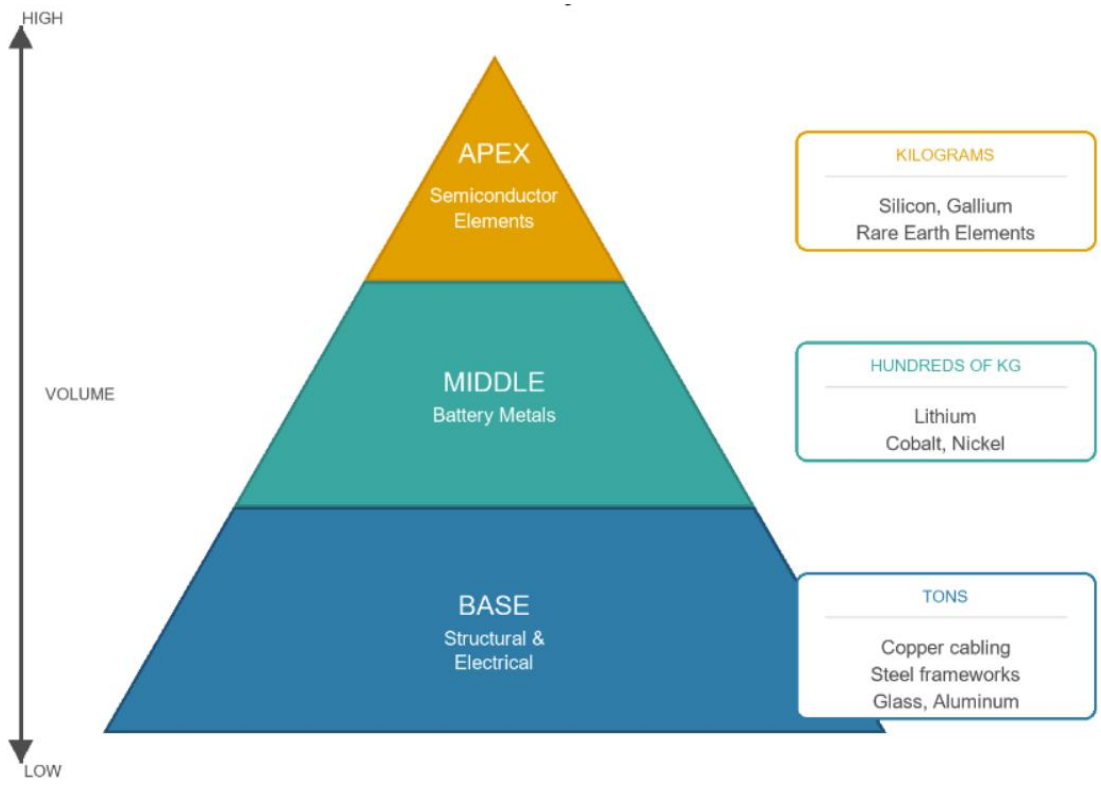


Figure 2 The " Pyramid" of Mineral Consumption in Data Centre Infrastructure

China is reducing critical mineral consumption through three pathways: in the short term, liquid cooling reduces cooling system scale and copper usage; in the medium to long term, computing energy efficiency improvements reduce the number of chips required for equivalent computing power, while emerging frontiers such as optical interconnect technologies are expected to reduce reliance on copper cables [52]. Additionally, the EDWC initiative promotes clustered deployment in western regions, reducing infrastructure investment per unit of computing power through scaled construction [53].

Beyond material consumption, the embodied carbon in data centre infrastructure—particularly in

semiconductors, servers, and construction materials—represents a significant share of life-cycle emissions that warrants attention. The carbon footprint of key materials varies substantially depending on the electricity mix used in their production: polysilicon refined with coal-heavy electricity carries a higher footprint than that refined with hydropower; aluminum produced with cleaner grids is markedly lower in embodied carbon. This opens cooperation possibilities with partner countries whose comparative advantages and cleaner electricity profiles make them potential co-production bases for lower-carbon inputs—for example, refining metallic silicon into low-carbon polysilicon using renewable hydropower (as explored in the Brazil case, Section 3) or manufacturing aluminum chassis and copper interconnects on cleaner grids. Such co-production extends coordinated planning beyond the data centre itself and links digital infrastructure demand to host-country industrial upgrading.

2.4 Low-Carbon Practices of Data Centres in China

This section presents four cases demonstrating how China's policy framework translates into operational practice: from enterprise-led natural-endowment design (Alibaba Cloud, Tencent) to industrial-park-scale source-grid-load-storage integration (CPECC's Qingyang and Ulanqab projects), illustrating how policy ambition, technological innovation, and organizational capability converge to deliver verifiable decarbonization outcomes.

2.4.1 Case 1: Alibaba Cloud – Qiandaohu & Zhangbei Data Centres

Alibaba Cloud's two flagship data centres demonstrate how natural resource endowments can drive energy efficiency at scale, unified by a common principle: design with nature, not against it.

Qiandaohu: Deep-Lake Water Cooling. Opened in 2015 in Zhejiang Province, this was China's first deep-lake water cooling facility. A closed-loop system draws water from depth, absorbs waste heat via heat exchangers, and returns warmed water through a 2.5 km canal for natural cooling [54], enabling over 90% of the year to operate without mechanical refrigeration, with a design PUE below 1.3 (minimum 1.17) [55].

Zhangbei: Wind-Powered Natural Cooling with Immersion Liquid Cooling (Figure 3). Located in Hebei Province at an ~1,400 m elevation, the campus exploits cold climate and wind energy. "Wind wall" technology channels fresh air into server rooms, reducing mechanical cooling to ~15 days per year [56]. Large-scale immersion liquid cooling enables power densities of 60 kW per rack [57], with campus PUE ranging from 1.13 to 1.25 [58].



Figure 3 Aerial view of Alibaba's Zhangbei Data Centre

In 2023, Alibaba Cloud launched a waste-heat-to-municipal-heating project at Zhangbei, delivering 14,670 GJ of heat in its first season and displacing 617.8 tons of standard coal [59]. With a planned Phase 1 capacity of 21 MW, the system transforms the data centre into a dual-purpose infrastructure node, providing both computing and winter heating [60].

Scaling Clean Energy Procurement. In FY 2024, clean electricity accounted for 56.0% of Alibaba Cloud's self-built data centre consumption [59], with a 20-year green power purchase providing 170 million kWh annually [59]. Average PUE across self-built data centres reached 1.20 [59].

Transferability: The Qiandaohu–Zhangbei model demonstrates that world-class efficiency begins with site selection and resource mapping—adapting deep-water cooling near large water bodies, natural air cooling in cold climates, and waste-heat recovery where district heating exists—rather than relying on technology alone.

2.4.2 Case 2: Tencent Tianjin Data Centre

The Tencent Tianjin Data Centre, located in the Binhai New Area, exemplifies a paradigm shift: recovering waste heat for municipal heating, turning the data centre from an "energy black hole" into a community heat source.

Waste-Heat Recovery. A magnetic-suspension heat pump captures low-grade waste heat (30–40°C) from the cooling loop and raises it to 55°C for residential heating [61]. Phase 1 (pilot) recovered ~1/10 of total waste heat for on-campus office heating, reducing CO_2 by 4,040 tonnes annually [62]. Phase 2 feeds into the Binhai New Area's district heating network, now avoiding 52,400 tonnes of CO_2 annually [61].

Distributed Renewable Energy Integration. The campus hosts a 10.54 MW distributed solar photovoltaic (PV) microgrid generating 12 million kWh of zero-carbon electricity annually [63].

Liquid Cooling and AI-Driven Optimization. Cold-plate liquid cooling combined with AI-driven temperature control achieves a PUE as low as 1.09 [64]—among the lowest for a large-scale operational data

centre in China. The campus also employs Tencent's T-block prefabricated modular architecture, which integrates IT, power, and cooling into factory-assembled blocks, enabling precise capacity scaling and saving approximately 150 million kWh of electricity annually across Tencent's portfolio [65].

LEED Platinum Certification. In 2021, the facility became China's first data centre to receive LEED V4 O+M Platinum certification—the highest level awarded by the U.S. Green Building Council [66], validating sustained operational performance across energy, water, waste, and indoor environmental quality metrics.

Transferability: The Tianjin model addresses an overlooked question: what happens to data centre waste heat? In regions with winter heating demand, waste-heat recovery transforms data centres from energy liabilities into community assets. The key barrier is institutional—connecting operators with heating utilities requires policy coordination—rather than technical. For tropical regions, waste heat can drive absorption chillers for cooling or industrial processes. The broader lesson is that sustainability design should extend beyond the facility boundary.

2.4.3 Case 3: Source-Grid-Load-Storage Integration – CPECC's Qingyang and Ulanqab Projects

While Alibaba Cloud and Tencent demonstrate enterprise-led natural-endowment design, China Power Engineering Consulting Group (CPECC) showcases a different paradigm: state-owned enterprise-led infrastructure at industrial-park scale, translating the "**source-grid-load-storage**" concept into operational reality through two complementary projects.

Qingyang: Near-Zero Carbon Industrial Park

Located in Qingyang, Gansu—a national computing hub node under the EDWC initiative—the CPECC Qingyang Smart Zero-Carbon Big Data Industrial Park is among China's most comprehensive data centre decarbonization projects. Designed for 24,000 standard racks (60 MW IT load), Phase A1 is operational at 85% rack utilization.

The project achieves PUE $\leq$ 1.20 with over 90% renewable energy, qualifying as a near-zero-carbon facility. Capitalizing on Qingyang's wind and solar resources, it includes 150 MW of wind power, 50 MW of solar PV, and a smart operations platform that dynamically matches demand with renewable generation.

Cooling employs immersion liquid cooling for high-density nodes and cold-plate with indirect evaporative cooling for medium-density nodes. The campus also meets China Green Building Two-Star standards, incorporating rainwater harvesting, waste-heat recovery, and prefabricated modular construction.

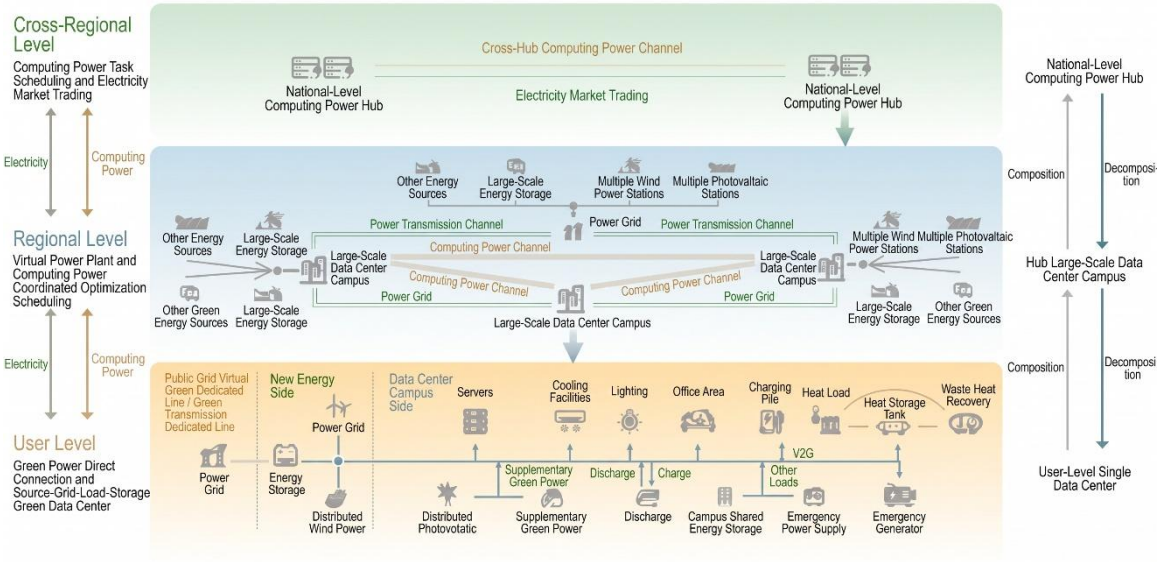


Figure 4 Cross-Provincial → Regional → User-Level Compute-Energy Integration Architecture. Qingyang exemplifies regional integration (self-contained industrial park), while Ulanqab demonstrates user-level green power direct connection.

Ulanqab: China's First Green Power Direct Connection Demonstration

The Centrin Data Ulanqab 380 MW project operationalizes the "green electricity direct connection" mechanism described in Section 3.2.3. Located in Inner Mongolia, it integrates wind power generation, smart transmission, direct supply, and energy storage to achieve traceable clean energy supply to the data centre cluster (Figure 5).

The project's defining innovation is its "load-determined source" approach: renewable energy capacity is sized to actual data centre load, with generation and demand operated as a unified system that eliminates curtailment.

Phase I (operational) includes 200 MW of wind and 100 MW of solar PV, producing 848 million kWh of green electricity annually, achieving a 38.74% renewable substitution rate and reducing CO_2 emissions by 567,000 tonnes per year.



Figure 5 Aerial rendering of the Centrin Data Ulanqab campus, showing integrated deployment of data centre infrastructure with co-located wind turbines and solar PV arrays.

Building on these projects, CPECC has proposed a three-tier integration architecture—"cross-provincial → regional → user-level"—forming a replicable template for aligning digital infrastructure with clean energy availability.

Implications: The CPECC model demonstrates that aligning computing and energy infrastructure as a single coordinated program yields higher renewable utilization and lower costs. Three elements are replicable: (1) the "load-determined source" principle—sizing renewable capacity to committed demand eliminates curtailment; (2) the integrated delivery model—a single entity responsible for generation, grid, and operations reduces coordination friction; and (3) the tiered architecture—countries can begin with user-level direct connection at a single facility and expand to regional integration as demand grows. The core insight is that computing and energy transitions are most effective when planned as one system.

2.4.4 Global Access to China's Green Compute Resources

As leading Chinese facilities achieve PUE below 1.15 and renewable shares above 80% in western hub regions, international users can access this infrastructure as a complement to—not a replacement for—local capacity.

Building an equivalent AI training cluster locally typically runs 2–3× higher than connecting to China's western regions. For organizations under net-zero commitments (e.g. EU Fit for 55, Singapore Green Plan 2030), green computing from renewable-abundant zones offers a Scope 3 reduction pathway, adding a low-carbon node to a multi-cloud strategy rather than replacing domestic infrastructure.

Two concerns arise. On data sovereignty, workload partitioning allows sensitive data to remain on-premises while computation-intensive tasks (inference scaling, batch processing, fine-tuning) run on green infrastructure abroad. On standards, the path forward is mutual recognition of green data centre certification (PUE, WUE, carbon footprint metrics).

The underlying logic is simple: the world needs more computing capacity, and it needs it clean. Countries

can partner with China to route non-sensitive, compute-intensive workloads-such as AI inference, batch processing, and model fine-tuning to China's green computing infrastructure, reducing their carbon footprint while accessing cost-effective compute resources.

2.5 Chapter Synthesis: China's Model, Challenges, and Future Outlook

This section synthesizes the defining characteristics of China's green data centre transformation, acknowledges remaining hurdles, and outlines the trajectory toward the 15th Five-Year Plan and international cooperation priorities.

2.5.1 The China Model: Synthesis of Policy, Resource Efficiency, and Practice

China's approach integrates six interdependent dimensions—three from the policy-architecture layer and three from the practice-validation layer.

Policy-Architecture Dimensions:

(1) Top-Down Strategic Coordination. The dual-carbon goals and "1+N" framework cascade through Five-Year Plans into sector-specific instruments such as the 2024 Special Action Plan, ensuring data centre decarbonization is integral to national climate governance.

(2) Spatial-Energy Coupling. The EDWC initiative matches computing demand with renewable energy supply across geographic space, with dedicated fibre networks making this reallocation commercially viable for most workloads.

(3) Standard-Driven Innovation with Market Hybridization. Mandatory PUE thresholds (GB 40879–2021) and green rating systems (GB/T 44989–2024) create compliance pressure, while parallel market mechanisms—green electricity trading, carbon reduction financial tools, and fiscal incentives—enable operators to exceed regulatory floors at the lowest cost.

Practice-Validation Dimensions:

(4) Resource-Efficiency Innovation through Three-Layer Decoupling. China's response to resource competition follows a systematic logic: spatial decoupling (relocating batch processing to resource-abundant western regions), efficiency decoupling (dual PUE/WUE metrics driving liquid cooling), and temporal decoupling (energy-storage systems aligning loads with renewable generation).

(5) Natural-Endowment-Driven Design. Achieving high efficiency begins with site selection. Alibaba Cloud's Qiandaohu Data Centre exploits deep-lake water, while its Zhangbei campus leverages cold climate and wind energy. These examples show how location selection can reduce energy needs, with technology amplifying rather than substituting for geographic advantage.

(6) Practice-Led Validation. China's framework is anchored by verifiable results: Tencent Tianjin avoids 52,400 tonnes of CO_2 annually (PUE 1.09); Alibaba Zhangbei delivered 14,670 GJ of waste heat for municipal heating; CPECC Qingyang achieves PUE $\leq$ 1.20 with over 90% clean energy; and CPECC Ulanqab avoids 567,000 tonnes of CO_2 annually as China's first green power direct connection demonstration. These examples verify that policy has been effectively translated into operational outcomes.

These six dimensions correspond to the policy framework (Section 2.1), implementation dimensions (Section 2.2), resource efficiency practices (Section 2.3), and implementation cases (Section 2.4) documented above.

2.5.2 Remaining Challenges

Despite significant progress, structural hurdles persist:

(1) AI-Driven Energy Surges. The rapid expansion of large-model training clusters is accelerating energy demand beyond current efficiency gains. China's data centre electricity consumption is projected to reach 3.7% of national use by 2030, up from approximately 1.6 in 2024 [4,5,67], driven primarily by AI workloads. This growth trajectory challenges the assumption that efficiency improvements alone can offset rising consumption.

(2) High Retrofitting Costs for Small and Medium Data Centres. While new large facilities readily achieve PUE ≤1.25, thousands of older, smaller data centres still operate at PUE above 1.5–2.0, where retrofitting with liquid cooling or efficient power systems lacks economic return at current energy prices—creating a "long tail" of inefficiency.

(3) Incomplete Green Power Market Mechanisms. Green electricity trading volumes have grown rapidly, but cross-provincial barriers, limited green certificate liquidity (green certificates here attest to the renewable origin of electricity and are distinct from carbon credits, which monetize verified emission reductions) and the absence of unified carbon pricing for the digital sector mean operators in some regions cannot access green electricity at competitive rates. The "green electricity direct connection" mechanism, while available in select provinces, is not yet universal—though the Ulanqab project (Section 3.4.3) provides a replicable template, its scaling requires policy coordination not yet in place nationwide.

Resource Competition Intensification. As computing density rises, competition between data centres and local communities for water and grid capacity intensifies. Current policy frameworks address this through PUE/WUE metrics but do not yet fully integrate data centre planning with water resource allocation and grid capacity planning at the local level.

2.5.3 15th Five-Year (2026–2030) Plan Outlook: Toward Mandatory Decarbonization

The 15th Five-Year Plan will mark a strategic shift from "efficiency improvement" to "mandatory decarbonization" for digital infrastructure:

(1) Carbon Metrics and Monitoring. In April 2026, China designated digital infrastructure as one of five key energy-saving sectors. During the 15th Five-Year Plan, data centres will face more stringent carbon regulations—metrics such as carbon usage effectiveness (CUE) and carbon emission intensity (CEI) are expected to be integrated into evaluation frameworks, aligning with international practices such as the EU Energy Efficiency Directive.

(2) Strict Entry Barriers and Hard Constraints. This designation enables enforcement of strict PUE entry barriers (≥80% green power for hub nodes), mandatory liquid cooling for high-density facilities, and accelerated decommissioning of non-compliant facilities.

(3) Computing-Power Synergy. Data centres will increasingly evolve into flexible grid nodes absorbing variable renewable energy, supported by improved green electricity trading, expanded energy storage, and retrofitting subsidies. The concept of "computing-power synergy"—co-optimizing computing schedules with renewable generation—has transitioned from pilots to systematic deployment, as confirmed by the April 2026 Action Plan on Promoting Bidirectional Empowerment of AI and Energy. CPECC's "cross-provincial → regional → user-level" integration architecture provides an early framework for this transition.

2.5.4 International Cooperation: Future Needs and Recommendations

China's green data centre transformation offers several entry points for international cooperation—not as a one-way model, but as contributions to a shared decarbonization agenda.

(1) Green Standards and Certification Alignment. National green data centre standards—China's GB/T 44989, the EU's Codes of Conduct, ASEAN's green ICT frameworks, ISO/IEC standards—currently operate without formal equivalence. Priority should be given to mutual recognition of PUE/WUE measurement methodologies and renewable energy attribution rules, with ITU-T Study Group 5 providing an existing venue.

(2) Technology and Operational Experience Exchange. China's practices—liquid cooling at scale, waste-heat recovery, closed-loop water systems, AI-driven cooling optimization, and integrated renewable energy-storage systems—are commercially proven but not yet widely adopted. These practices primarily address cooling and infrastructure efficiency; for direct computing-related emissions, opportunities include energy-efficient server hardware, AI workload scheduling optimization, and renewable-powered computing operations. Structured exchange programs and joint pilots can accelerate adoption while allowing recipients to validate performance under local conditions. These are context-adaptive methodologies, not fixed blueprints.

(3) Green Computing Resource Cooperation. China's western hubs, with renewable shares exceeding 80% and PUE below 1.2, offer low-carbon computing capacity for international users. CPECC's Qingyang project demonstrates the operational viability of this model. Realizing it requires bilateral data governance frameworks for workload partitioning, cross-border network infrastructure, and mutual recognition of green electricity attribution, with pilot corridors between China's western hubs and ASEAN centres as potential testbeds.

(4) Capacity Building for Developing Countries. China's experience underscores the importance of inter-ministerial coordination—integrating digital infrastructure planning with energy, water, and climate policy—a governance capacity many countries are still building. Programs should transfer adaptive capability, not just equipment. This means (1) building local capacity to operate and maintain green data centres; (2) supporting policy and regulatory development so partner countries can design their own green data centre frameworks; and (3) ensuring that access to Chinese green computing resources serves as a stepping stone toward domestic capacity, not a permanent substitute. Multilateral platforms such as BRIGC, the South–South Climate Cooperation Fund, and FOCAC can serve as delivery channels. Bilateral cooperation agreements between China and partner countries offer additional pathways, particularly for project-specific technology transfer and coordinated infrastructure investment.

(5) Joint International Projects and Standards Harmonization. The April 2026 Action Plan on Promoting Bidirectional Empowerment of AI and Energy calls for coordinated international expansion of AI and energy infrastructure, along with cross-border alignment of "AI + energy" technical standards, creating opportunities for technology transfer, joint pilots, and participation in globally harmonized standards development.

(6) Enabling Infrastructure Cooperation. Beyond data centres themselves, cooperation on enabling infrastructure—renewable energy generation, energy storage, and transmission networks—is equally critical, as these auxiliary sectors often become the binding constraints on data centre growth. China's experience with the "green electricity direct connection" mechanism and integrated planning of computing-power hubs with renewable energy zones offers a replicable model.

These five directions are interconnected: standards alignment (i) builds trust for resource cooperation (iii) and project collaboration (v); technology exchange (ii) and capacity building (iv) ensure locally owned outcomes. The overarching principle is that cooperation should expand choices, not prescribe a single path.

3 International Experience and Best Practices in Green Data Centre Development

Data centres have emerged as one of the most energy-intensive industrial workloads globally, driven by surging AI and cloud computing demand [68]. Global electricity demand from data centres is projected to increase from approximately 415 TWh in 2024 to 945 TWh by 2030 [69]. Data centres are growing rapidly in key regions such as Southeast Asia, sub-Saharan Africa, and Latin America. At the same time, developing regions are facing increasing energy demand, pressing infrastructure needs, and policy mandates to upgrade and transform their industrialization processes. This chapter assesses the green data centre landscape in South Africa, Brazil, and climate-vulnerable countries in order to identify current practices, challenges, and opportunities for data centre-driven green industrial transformation.

3.1 Case Studies: South Africa, Brazil, and Climate-Vulnerable Countries

3.1.1 South Africa: Regulatory Reform and Innovative Water and Waste Management

South Africa hosts Africa's largest data centre market, accounting for over 40% of the continent's capacity in 2025, with more than 60 facilities concentrated in Johannesburg, Cape Town, and Durban [70]. Hyperscalers (Microsoft Azure, AWS, Google) and co-location providers (Teraco, Africa Data Centres) are expanding rapidly, yet the power system they depend on remains carbon-intensive: only 17% of South Africa's electricity came from low-carbon sources in 2024, compared to a global average of 41% [71]. Data centres draw mainly from Eskom's coal-based system and rely on diesel backup generators during load shedding events.

Recent big-tech investment in South African data centres has given rise to concerns over transparency on their impact on water, the environment, and whether data centres translate into shared benefits for local communities [72]. One positive environmental trend is the growing use of renewable energy to power these facilities (Box 1). These deals illustrate that by acting as major off-takers, data centres can drive new renewable capacity onto the grid rather than reallocating existing generation.

Box 1: Electricity licensing reform and the wave of renewable PPAs

South Africa's Electricity Regulation Act was amended in August 2021 to raise the licensing threshold for embedded generation from 1 MW to 100 MW, and in December 2022 the threshold was removed entirely. This reform triggered a wave of corporate renewable power purchase agreements (PPAs) across industries, including data centres.

Africa Data Centres signed a 12 MW wheeled solar PPA with Distributed Power Africa [73]; Vodacom concluded a virtual PPA with SOLA; and Teraco, the country's largest co-location

provider, commissioned a 120 MW solar PV facility in the Free State, delivering over 338,000 MWh annually [74], and added a wind PPA with NOA in 2025 to diversify supply [75].

While progress is being made, several barriers still need to be addressed in order to fully convert data centre growth into community-wide benefit-sharing and broader green industrial transformation.

First, South Africa's power system faces the triple challenges of supply shortfall, energy access, and grid connection in the power system. A projected base-supply cliff of 9.5 GW between 2029 and 2030 is driven by the retirement of 8.4 GW of Eskom coal capacity and the expiry of the 1.15 GW Cahora Bassa import from Mozambique [76]. With 12% of South Africans still lacking any electricity connection, data centre expansion risks crowding out residential needs and deepening existing equity gaps [77]. Furthermore, in both the 2022 and 2024 Renewable Energy Independent Power Producer Procurement Program (REIPPPP) rounds, no wind projects were awarded due to insufficient transmission infrastructure in the Cape provinces where wind resources are strongest [78].

Second, there is an absence of dedicated green data centre standards. The National Data and Cloud Policy acknowledge "low-carbon sustainable development requirements," but no enforceable benchmarks for PUE, WUE, renewable energy share, or embodied carbon in construction materials are in place. Therefore, operator transparency relies on voluntary corporate commitment, weakening the baseline for green finance, certification, and bilateral cooperation.

Third, water use and hardware waste are creating local pressure. South Africa is increasingly water-stressed [79], with data centre water consumption estimated to rise from 18 billion litres in 2025 to 30 billion litres by 2030 [80]. However, this is not to say that data centres in water-stressed areas are necessarily unsustainable—best-practice data centres can achieve very efficient WUE using advanced cooling technologies. On the waste management front, the short hardware lifespan of data centres is another concern. South Africa's Extended Producer Responsibility Regulations of 2021 obligate producers to manage their products through to the post-consumer stage, with a supplemented scheme covering electrical and electronic equipment that applies to data centres.

Box 2: Operator practice on water use and hardware end-of-life

Leading operators are moving ahead on water and waste management. Teraco's newer data centres, including JB4 and JB5 in Johannesburg and the CT2 expansion in Cape Town, use closed-loop chilled-water systems with free-air cooling, targeting zero water for ongoing cooling and less water usage per IT kWh. A 2025 Carnegie Mellon Africa study found South African data centres use less water than the U.S. average when performing the same task [81]. Regarding hardware, certified IT asset disposal firms such as Desco and ITAD Africa assess retired servers for refurbishment, reuse, or resale before dismantling the remainder to recover precious metals under South Africa's EPR and e-waste compliance frameworks [82].

3.1.2 Brazil: Powershoring and Green Industrial Chain Integration

Brazil currently stands as the undisputed leader of the data centre market in Latin America, holding around 41% of the region's market investments [83]. A key driver of this position is powershoring [84], which refers to the strategic relocation of energy- and resource-intensive industrial activities to regions that combine access to abundant, low-cost clean energy with proximity to key natural inputs. Powershoring green data centres represents a "renewables-pull effect," where clean energy availability increasingly dictates the location of global value chains [85].

Brazil's key competitive advantage, in the government's own framing, lies in the type of electricity itself: according to a senior advisor at the Finance Ministry, the country's renewable matrix could reduce the carbon footprint of AI processing by up to 75% compared to other regions [86]. This has shaped official discourse around positioning Brazil as a "sustainable hub" for low-carbon digital infrastructure. The government is also concerned with data sovereignty, as 60% of Brazilian data are processed abroad [87], raising broader questions that data centre localization alone cannot resolve, including who controls digital infrastructure and whether Brazil can retain strategic control over its data and AI ecosystems even when facilities are located domestically.

International technology firms are establishing a significant presence in Brazil's data centre sector, ByteDance's R$50 billion complex at Ceará's Pecém Port Complex being the most prominent example. However, the Brazilian government's objective, articulated through Mission 4 of the New Industry Brazil (NIB) program, goes beyond this—it seeks to use data centre investment as a lever for productive transformation, stimulating domestic component manufacturing, fostering local supply chains, and anchoring R&D in national institutions [88].

Brazil's legislative landscape for data centre investment has been in regulatory limbo since the REDATA tax incentive (MP 1.318/2025) expired (Braun 2026). This failure created significant fiscal uncertainty for international investors, prompting Congress discussions around Bills No. 3018/2024 and 278/2026 to regulate and incentivize data centres respectively, the latter with the permanent reinstatement of REDATA [89,90].

Beyond regulatory uncertainty, the sector's rapid expansion has intensified a structural competition for clean infrastructure. Data centres now account for 7.04 GW of load across 34 of 39 recent access requests to the National Interconnected System, placing digital infrastructure in direct competition with industrial and green hydrogen projects for limited transmission capacity [91]. Once constructed, they also generate few permanent local jobs relative to other sectors [92], a point that has been raised prominently in congressional debates [93]. The political difficulty is that costs are immediate and tangible while benefits remain largely prospective. Closing this gap requires moving beyond passive hosting toward a deliberate integration of data centre investment with green industrial transformation and domestic value chain development. In this sense, Brazil-China complementarities offer concrete possibilities of cooperation and shared development.

As the world's fourth-largest exporter of metallic silicon, Brazil has significant potential for pairing data centre development with green industrial transformation. Metallic silicon is the foundational input for polysilicon, central to both solar panels and semiconductor manufacturing. Brazil has an expanding industrial base of large-scale processing plants [94]. China, meanwhile, dominates downstream polysilicon refining and is already Brazil's primary data centre hardware supplier [95]. There is thus potential structural complementarity for international green data centre cooperation, with Brazilian metallic silicon processed using Chinese refining expertise and powered by Brazil's predominantly renewable electricity grid, yielding some of the lowest-carbon polysilicon in the world. Low-carbon polysilicon can enable both low-carbon construction and operation of data centres.

Given the strong potential for green industrial transformation driven by Brazilian data centres and an associated manufacturing base, the primary challenge is ensuring that future data centre investments translate into genuine industrial integration rather than mere hosting. Debates around data sovereignty and control over digital infrastructure have intensified, as Brazil seeks to ensure that the economic value and strategic benefits associated with data generation, storage, and processing are retained domestically rather than concentrated in foreign-owned platforms and infrastructure. Data centre development in Brazil also raises concerns about the uneven distribution of benefits, particularly if investments primarily serve global technology firms while

vulnerable populations continue to face inadequate energy access—a challenge in some parts of Brazil—or limited participation in the digital economy. Addressing these challenges will require approaches that support a just and inclusive transition by strengthening local capacity, expanding access to digital opportunities, and ensuring that the economic and social benefits of investment are more broadly shared.

3.1.3 Climate Vulnerable Countries: Cooperation and Diversification

Climate-vulnerable economies, such as the 74 country members of the Climate Vulnerable Forum and its V20 Group of Finance Ministers (CVF–V20), remain largely excluded from global data centre-driven transformation. Despite representing nearly 2 billion people, climate-vulnerable countries host less than 1% of global data centre capacity. This reflects both a structural gap and a strategic opportunity for international cooperation.

Recent developments show momentum. The Philippines has operationalized an AI-ready hyperscale data centre and is targeting 1.5 GW of capacity by 2028 [96]. Kenya is developing geothermal-powered data centres alongside new cloud infrastructure [97]. Pakistan has initiated partnerships for AI-ready data centres and allocated up to 2,000 MW for future demand, while importing 17–22 GW of solar power, mostly from China [98].

Despite these advances, global hyperscale providers such as Amazon Web Services, Google Cloud, and Microsoft Azure have minimal presence across climate-vulnerable country markets, while Chinese firms, particularly Huawei, maintain a stronger footprint. This positions China as a key partner in these markets and the rapidly developing global green data industry. China's position as a strategic energy partner in many climate-vulnerable countries reinforces this opportunity.

Data centre development in climate-vulnerable countries faces several unique challenges. First, climate-vulnerable countries face an elevated climate risk premium, which increases borrowing costs (V20 countries face a 1.2% higher cost of debt, producing USD 62 billion in excess interest) [99]. Climate investment needs are estimated at USD 490 billion per year, far exceeding current financing flows of roughly USD 90 billion. Risk mispricing and limited access to climate finance further constrain infrastructure development.

Second, data centres require stable, high-capacity electricity systems. However, many climate-vulnerable countries face grid inefficiencies and limited transmission capacity. In addition, operational efficiency for data centres is, to some extent, climate-constrained. PUE in tropical climates averages around 1.7, compared to best-in-class facilities that can achieve PUE as low as 1.3 in China—or even 1.1 under optimal conditions such as liquid cooling in cold climates [100]. In addition, water constraints also add a layer of complexity in countries that face climate-related risks for water resources. Data centres can place additional pressure on already scarce water resources, especially where cooling systems depend on significant water use, making water efficiency, climate-resilient design, and sustainable water management essential to green data centre development that is just and sustainable.

At the same time, many V20 countries rely heavily on imported energy to power data centres, adding pressure on import bills and fiscal space. There also remains a looming threat of stranded assets and sunk costs if efficiency parameters do not pan out economically. This creates a clear opportunity for China to support V20 economies through investments in renewable energy capacity, storage, and grid infrastructure so that future data centres are powered by clean, affordable, and sustainable energy.

Given these challenges, the strategic case for cooperation is strong. Climate-vulnerable economies are among the fastest growing economies. Thus, integrating green digital infrastructure while leveraging green BRI

inroads can establish long-term technology partnerships in these economies. Doing so also reaffirms China's position as an enabling global technology leader with the Global South.

Data centre growth in climate-vulnerable countries can also reduce the risks of concentrating digital infrastructure in a few large markets. Distributing green data centres across climate-vulnerable countries creates a more resilient, diverse, shock-absorbing network.

Finally, at a moment of shifting global climate leadership, cooperation with CVF-20 countries by aligning with their Climate Prosperity Plans and Country Platforms offers China and other countries an opportunity to advance investment programs and multilateral solutions. Green data centre partnerships create linkages across energy, finance, and technology. As climate-vulnerable countries grow over the next decades, today's cooperation can translate into lasting trade relationships and investments and, most importantly, a reliable and more resilient supply chain across different industries capable of harnessing the full potential of the digital economy. While the climate resilience of digital infrastructure is beyond the scope of this study, it will increasingly matter for investment planning and budget allocation and could be cross-linked with follow-up work on climate change adaptation.

3.2 Priority Areas and Emerging Trends for Green Data Centre Development in Key Regions

The above case studies have highlighted several shared priority areas across countries and regions that will shape the potential for data centres to contribute to green industrial transformation. First, electric power supply constraints are a top shared challenge across developing regions with rapid data centre growth. Despite differing electricity profiles in terms of sources of electricity, grid infrastructure, and power market structure, additional load from data centres contributes to reliability and cost pressures for electricity grids across all regions. A lack of sufficient generation resources can lead to load shedding and associated negative economic effects. Transmission constraints can also be a bottleneck to data centre development, highlighting the importance of a balanced, coordinated buildout of generation and transmission and distribution (T&D) capacity to meet growing electricity demand. In lower-income countries, the lack of firm grid capacity limits the ability to host large data centre loads at all. For green data centres, the carbon intensity of the local electricity grid can be a constraint on decarbonized power supply. In addition, the ability to directly procure renewable electricity, such as through PPAs, varies significantly from country to country depending on renewable supply and regulatory context.

Second, beyond electricity supply, data centres are intensifying competition for other local resources, including land and water. Data centres require large parcels of land for server facilities and supporting infrastructure, often with specific siting needs, such as being near transmission access and fibre networks. Data centres use significant volumes of water when using evaporative cooling technologies—and cooling is essential to the efficiency and overall functioning of computing equipment. The competition for resources and access has led to a growing backlash against data centres in some regions that threatens their ability to meet their potential. The needs of local communities with regard to shared resources are thus a priority area for green and responsible data centre development.

Energy and resource access are common and well-understood priorities for data centres across regions. It is also important to highlight emerging trends for green data centre development. International experience shows

that data sovereignty is increasingly shaping the deployment of data centres in developing regions. Countries where a large share of data is processed abroad (for example, Brazil, discussed above) potentially face both economic leakage and reduced control over sensitive data flows, while also incurring higher latency from long-distance transmission to overseas data centres. Low-latency applications (e.g., real-time services, AI inference, financial transactions, e-government platforms) benefit from geographically proximate data centres, highlighting the need to consider how data sovereignty goals could be aligned with certain types of computing applications.

In addition, an emerging concern for green industrial transformation from data centres is misalignment between population centres and data centre capacity. For example, climate-vulnerable countries host under 1% of global data centre capacity despite being home to 1.8 billion people. While some regions of the Global South are projected to experience rapid growth in digital infrastructure investment, many countries are increasingly concerned that insufficient domestic or regional data centre capacity could deepen existing technological and digital divides. This concern is particularly acute for climate-vulnerable countries, which stand to benefit significantly from the use of green data centre technologies, in particular, to support climate adaptation, energy system optimization, and broader economic development. Limited access to domestic digital infrastructure may also constrain countries' ability to retain economic value from growing digital demand, strengthen digital sovereignty, and participate more fully in emerging AI- and data-driven industries.

3.3 Further Needs for Green Data Centre Development in Key Regions

A range of emerging mechanisms could support the development of green data centres in ways that contribute more directly to green industrial transformation in Global South countries, while promoting a just and inclusive transition. One potential approach involves the co-development of green data centre standards and benchmarking frameworks through existing multilateral, regional, or bilateral cooperation platforms, such as the BRICS Digital Ecosystem Cooperation Network, V20 member countries coalition mechanisms, and bilateral standards dialogues. Such frameworks could establish common metrics for PUE, WUE, renewable energy sourcing, and embodied carbon disclosure, helping create clearer baselines for green finance, certification, and international cooperation. For regional-level frameworks, regional integration should be a key consideration.

In parallel, countries could reframe data centre demand as an asset rather than a burden on the power system. In countries where renewable energy projects struggle to secure financing because future buyers are uncertain, a large, predictable, creditworthy data centre customer can act as the anchor that makes new solar, wind, storage, or transmission projects bankable, as in the case of South Africa.

Where data centres are supported by public finance (such as policy banks, multilateral lenders, or blended-finance vehicles), the role of renewable energy can be made a financing condition. Funds are only available when new or expanded data centres come with new renewable capacity and grid or storage upgrades that add to host-country supply, rather than displacing it. It would also shift the proposition from "China finances a green data centre" to "China uses digital demand to anchor the next wave of clean power and grid investment" in partner countries.

Another area of focus involves linking data centre development to broader domestic industrial and socio-economic objectives. Rather than limiting benefits to hosting digital infrastructure, emerging models seek to connect data centre investment with local supply chain development, industrial processing, workforce training, and circular economy activities. Examples from the countries analyzed above include polysilicon processing in

Brazil, localized green data centre supply chains (cooling systems, batteries, solar components) in South Africa, and industrial growth, skills development, and storage/cooling efficiency in climate-vulnerable countries. Data centre investment could also be linked to other critical minerals processing and e-waste circular economy, using anchor-demand contracts and joint industrial parks to bring smelting, refining, and server-refurbishment capacity onshore.

Collectively, these approaches can contribute to a just and inclusive green transition by strengthening local industrial capacity, creating quality employment opportunities, fostering technology transfer, and generating broader economic and social benefits. These approaches also reflect broader concerns among many Global South countries about retaining more economic value from digital infrastructure expansion and reducing dependence on foreign technology providers. Related discussions around data sovereignty have also become increasingly prominent, as governments seek to ensure that growing digital demand translates into domestic infrastructure investment, local data storage, stronger national or regional digital ecosystems, and greater local participation in the digital economy. For example, South Africa has introduced national regulations mandating that data generated in-country should stay in South Africa.

Climate finance and carbon market instruments may also provide pathways for scaling renewable-powered and energy-efficient data centre infrastructure. Mechanisms under UNFCCC Article 6, alongside multilateral climate finance institutions and country platform approaches, could potentially be used to monetize emissions reductions associated with renewable-powered data centres and related grid investments. This may help improve project bankability and attract concessional or blended finance for integrated digital and energy infrastructure projects. More broadly, proposals for cross-border “green digital corridors” and coordinated investment platforms have emerged as possible models for combining fibre infrastructure, cloud services, renewable energy deployment, storage, and logistics systems into larger regional development strategies that encourage participation along the value chain. Across these discussions, a central concern remains ensuring that data centre growth in energy-constrained countries supports broader improvements in energy access, grid reliability, industrial development, and local capacity rather than creating isolated infrastructure systems that primarily serve foreign commercial demand. Such an approach can help ensure that digital infrastructure contributes to a just and inclusive green transition by generating broad-based economic and social benefits.

4 Indonesia–China Case Study

4.1 Indonesia–China Strategic Relations

Indonesia and China have reached 76 years of a diplomatic relationship, which was established on April 13, 1950. Since then, both countries have continued cooperation in various strategic sectors, from trade, infrastructure, automotives, energy and mining to cultural cooperation. The strong ties between the countries can be measured by their achievements in economic and political aspects. China has been the largest trading partner for Indonesia for over 10 years, with total trade value reaching USD 167 billion in 2025 [101].

This economic integration underpins both countries’ move to elevate their relationship to a more strategic level by launching the Comprehensive Strategic Dialogue (CSD). The CSD is a new bilateral platform designed to steer strategic cooperation across five key pillars: politics, economics, maritime affairs, people-to-people relations, and security [102]. The CSD also covers broader topics like energy, trade, minerals, industrial

cooperation, and China's commitments in ASEAN [103]. This high-level diplomatic agreement indicates that both countries are committed to deep, wide-ranging cooperation from politics to economics, with the two partners as strategic allies.

The role of China's investment is already well known to Indonesia's public and business stakeholders, from its role in engineering, procurement, and construction (EPC) in Indonesia's renewable energy projects [104] to developing the CATL battery factory in Karawang [105], the BYD EV factory in Subang [106], and the joint venture between PT PLN, Trina Solar, and PT Agra Surya Energy in building solar PV manufacturing [107]. Those investments are evidence of China's contributions to Indonesia's green development ecosystem. Given this, cooperation between China and Indonesia can expand to the new trend and emerging issue of green data centres.

4.2 Envisioning Indonesia's Digital Economy, Data Centres, and Sustainability

The concept of data centres and green industrial transformation is strongly related to Indonesia's digital economy vision and need to improve its digital infrastructure [108]. The vision had two aspects: first, leveraging AI capabilities to drive efficiency and productivity gains across public administration, services, and the creative-entertainment economy; and second, developing data centres and their surrounding ecosystems as a new growth sector in their own right, aligning with this study's emphasis on data centres driving green industrial transformation [109]. The government treats data centres as national strategic infrastructure, emphasizing decentralization schemes through collaborative ecosystems and welcoming foreign investment.

One effort to develop this data centre ecosystem and infrastructure is the establishment of the Special Economic Zone in Nongsa Digital Park Batam, with a focus on data centres [110]. This location has a strategic value due to its position near Singapore and Johor, potentially supporting Southeast Asia's digital economy ecosystem [111]. The idea is backed by existing regional policy, namely the ASEAN Digital Masterplan 2030, the ASEAN Digital Integration Framework, and the Digital Economy Framework Agreement (DEFA) [112].

Currently, there are around 204 data centres in Indonesia, mostly located in Jakarta (107) and Batam (20), and other cities in Indonesia [113]. Data centre development is expected to grow, with a projected average 13.71% CAGR between 2026 and 2031 [114]. Data centre growth also will affect power sector demand: the government estimates that the electric power demand from data centres will reach 5.2 GW by 2033, up from 1 GW at the end of 2025.

Various companies are developing data centres in Indonesia. Most foreign companies are from the U.S. (hyperscalers like AWS, Microsoft Azure, Princeton Digital, Digital Realty, and Google), with only several being Indonesian companies. The presence of Chinese data centre companies in Indonesia data centres is very limited despite several flagship projects, such as Tencent Group's USD 500 million investment to develop infrastructure [115] and Huawei's USD 300 million investment from 2022 to 2027, with a focus on Indonesia's cloud infrastructure to support various businesses in ICT, transportation services, banking services, conglomerates, and retail services [116]. By H1 2026, the total investment in data centres in Indonesia reached IDR 144 trillion (USD 8.1 billion) [117]. However, there is a call to incorporate data centres into a green development and broader economic growth agenda. Data centres are not only computational operations; they also require environmental management and resource considerations, including a large, stable electricity load, efficiency and cooling targets, renewable energy procurement, and water, backup, and resilience needs.

4.3 Barriers to Sustainability and Scaling

4.3.1 Green Data Centre Readiness in Indonesia

In this study, readiness is not defined by technical parameters, but rather focuses on policy alignment that makes green data centre development more attractive and investment-ready. Indonesia's green data centre readiness is best understood not as a single position along a single trajectory but as a different configuration of policy instruments shaped by different binding constraints.

Table 1 below compares Indonesia with Singapore, Malaysia, and the European Union on policy configuration. It shows that Indonesia's green data centre readiness is at an earlier stage of development—the key issues of PUE and WUE are not yet regulated, nor are connections with carbon credits. In terms of environmental impact compliance, compared to the other three countries/region, Indonesia's data centre standards are still voluntary, with no statutory data centre-specific disclosure regime in force. In terms of integration with national goals, the Mid-Term Development Plan (RPJMN 2025–2029) has integrated AI and digital infrastructure and developed public–private partnerships schemes for green data centres; however, implementation is still challenging. For the last indicator on carbon credits, this system is still developing in Indonesia, and Indonesia's carbon price is relatively low, at USD 4–5 per tonne.

Table 1: Green data centre policy configuration: Indonesia in a comparative perspective[2]

Indicator	Indonesia	Singapore	Malaysia	European Union
Environmental impact compliance	Voluntary Greenship Data Centre standard (GBC Indonesia / IPUSTAH-ID); no statutory DC-specific disclosure regime in force.	Mandatory: SS 564 in force since 2011; 2024 BCA-IMDA Green Mark for Data Centres refresh; DC-CFA2 applicants required to meet Platinum certification and PUE ≤1.25 at 100 percent IT load.	MCMC MTSFB TC G004:2024 Technical Code for Green Data Centres; National Sustainable Data Centre Framework (NSDCF) launched October 2025.	EED Article 12 and Delegated Regulation (EU) 2024/1364 require annual reporting from data centres with installed IT load ≥500 kW; first report 15 September 2024.
Sustainability compliance	KemKominfo Green Data Centre Policy; PLN Green-as-a-Service / Renewable Energy Certificate scheme (10.99 TWh in 2024, up 117 per cent year-on-year); compliance light.	DC-CFA2 requires at least 50% green-pathway power for new capacity; carbon tax SGD 25 / tCO_2e in 2024–25, rising to SGD 50–80 by 2030.	NSDCF six-tier classification; Corporate Renewable Energy Supply Scheme (CRESS) enables third-party clean-power procurement.	EU Code of Conduct for Data Centres (voluntary); EU-wide sustainability rating scheme adopted March 2024; alignment with EU Taxonomy data-processing criteria.

[2] This matrix adopted from [118].

Integration with national goals	RPJMN 2025–2029 integrates AI and digital infrastructure under Bappenas leadership; PPP scheme for green data centres named; implementing regulations pending.	Sequenced with the Singapore Green Plan 2030 and the IMDA Green Data Centre Roadmap; DC-CFA2 thresholds aligned to national digital economy targets.	NETR target of 70% renewable capacity by 2050; NSDCF positioned as the sectoral implementation layer.	EED implements Fit-for-55; CSRD ties data centre disclosure into value chain corporate climate reporting.
Carbon credits	IDXCarbon launched September 2023; compliance with ETS expanded to 99 coal-fired units in 2023 and 146 in H1 2024; data centre coverage remains light.	Carbon tax applies to direct emissions of large emitters; voluntary international credits permitted as a partial complement under defined eligibility.	Bursa Carbon Exchange (voluntary, since 2022); compliance ETS at pilot stage.	EU ETS in full operation; covers electricity generation and therefore implicitly prices data centre grid consumption.

In terms of electricity supply, most of Indonesia's data centres source electricity from PLN, the state-owned utility. However, most of PLN's electricity generation portfolio comes from coal, at around 57%–67%, due to lack of renewable energy deployment (only 18)% [119]. By regulation, data centre companies are also allowed to prepare diesel generation as emergency or backup power [120, 121]. There is also growing awareness in Indonesia that foreign companies demand green energy as a requirement [122]. As an alternative, PLN offers Renewable Energy Certificates (RECs) [123], but the quality of this instrument tends to be questioned due to electricity generation still being dominated by fossil fuels.

Similar patterns also appear in power and water management. Indonesia's data centres still rely on PAM Jaya (a state-owned water provider) and groundwater and haven't established regulation for WUE data centre standards. The other challenge is a clean water crisis, with groundwater not fitting standard criteria for data centres. As a recommendation, data centres in Jakarta should use recycled water rather than increase PAM Jaya's water burden and decreasing ground water availability. In addition, PUE is also not regulated by the government. However, separately from the government, Green Building Council Indonesia (GBCI) developed Greenship certification as a green building rating system, which is setting PUE (<1.3) and WUE (<2L/Kwh) standards as a requirement [124].

In Indonesia, several foundational elements are in place for a green data centre ecosystem, including green building certification, PLN REC Schemes, and a nascent carbon market, but integration with a green data centre framework has not evolved yet.

4.3.2 Ease of Investment

High ease of investment not only requires tax or fiscal incentives, but also a stable and transparent environment that reduces project risk and timelines [125]. Currently, there is no specialized tax incentive for green data centres in Indonesia. For non-tax incentives, the government provides generalized accelerated permits and customs exemptions for "energy-efficient" equipment and other equipment related to data centres

(e.g., cooling systems) [118].

4.3.3 Policy Uncertainty

Demand is high for data centres and digital infrastructure, but policy alignment still faces challenges. For example, the urgent need for renewable energy sources to power data centres is not aligned with current energy policy that still favours fossil fuel generation. Uncertainty stems from the evolving regulatory framework for digital infrastructure, e.g., Law No. 27/2022, which regulates Personal Data Protection, and its derivative law that treats data as a consignment, not an asset. At the same time, Indonesia has introduced the SNI 8799 series [126] of data centre standards covering facility design, operations, and energy management, but adoption and enforcement remain uneven, and a comprehensive mandatory framework for green data centre performance has yet to be established.

4.4 The Data Centre as a Node in an Industrial Ecosystem

The current expansion of data centre capacity is usually framed in terms of outcomes: megawatts commissioned, dollars invested, and services exported. Yet a modern data centre at scale is more accurately understood as an industrial node, a major purchaser of electricity at demanding load profiles, using equipment certified to standards few other industrial buyers ever set, and requiring connectivity, water, human resources, and increasingly, granular emissions accounting. For Indonesia, the significance of this framing is that the flows a data centre participates in are largely the same flows on which green industrial development depends. The policy task is not to use data centres to build a separate green data center sector, but rather to use data centre anchor demand to integrate the demand pull across the green industrial value chains Indonesia is already pursuing (see Figure 6 below).

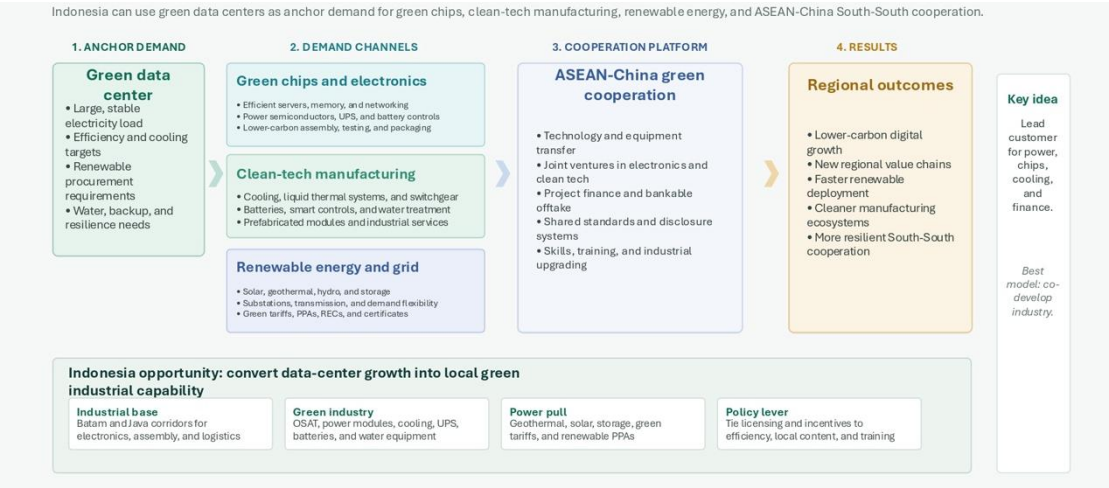


Figure 6. Green Data Centre Value Chain and Cooperation Pathway in Indonesia

4.5 Industrial Bases in Indonesia

This section presents the industrial bases in Indonesia and their installed assets, key actors, regulatory instruments, and reported figures. The types of industrial bases we focus on are industrial corridors, green

industry components, the clean-power ecosystem, and policy levers.

4.5.1 Industrial corridors: Java and Batam

Indonesia's data centre activity is concentrated in two corridors with distinct industrial and grid characteristics. The Java corridor, comprising Jakarta, Bekasi, Cibitung, Cikarang, and Karawang, is the established hub, anchored by financial sector demand and a long-developed co-location market. The Batam corridor is a more recent development, supported by special economic zone status and the latency advantages of proximity to Singapore's submarine cable infrastructure [127]. Batam sits on a smaller, separately balanced grid system administered by PT PLN Batam, with a different fuel mix and different scaling constraints. Their strategic position and advantage could convert data centre growth into local green industrial capability, including for electronics, assembly, and logistics.

4.5.2 Green Industry Components

Indonesia's manufacturing capacity across green industry components relevant to data centres is uneven. Indonesia has a well-developed battery raw materials industry [128], with increasing value-added. The Batam corridor also has semiconductor and photonics industries. However, other typical data centre equipment, such as power modules, cooling systems, uninterruptible power supplies (UPS), and water equipment, are still categories where domestic capability is largely absent.

4.5.3 Clean-Power Ecosystem: Geothermal, Solar, Storage, RECs, and PPAs

Indonesia's clean-power ecosystem is structurally distinct in terms of resource endowment but faces challenges in delivery and bankability. Given the tendency of foreign investors to seek green energy for data centres, demand for green electricity could increase renewable energy penetration through geothermal or solar, as well as combine generation with energy storage and various schemes like RECs and PPAs. Increasing demand from green data centres could contribute to the development of a clean-power ecosystem.

4.5.4 Policy Levers: Licensing, Fiscal Incentives, Efficiency, Local Content, and Training

Indonesia's data centre policy landscape is layered, but its depth is conditioned on investment scale rather than green outcomes. Several government regulations, fiscal incentives and initiatives exist, e.g. Online Single Submission–Risk-Based Approach (OSS-RBA), regulation on electronic transactions [129], and regulation on special taxes for specific business [130]. However, none of these instruments is conditioned on PUE, WUE, or carbon-intensity outcomes, and Greenship certification remains voluntary, so a hyperscaler operating an inefficient coal-grid-powered facility qualifies for the same envelope.

Local content under TKDN / P3DN, simplified for foreign direct investment operators by Permenperin No. 35 of 2025, applies to smartphones, medical devices, and telecoms infrastructure but not yet to data centre servers or GPUs. Training is another major gap. The Komdigi–NVIDIA–Cisco–Indosat Indonesia AI Centre of Excellence[3] and the Danantara–ARM agreement of February 2026 are recent additions, yet no Indonesia National Work Competency Standard (SKKNI) module covers data centre commissioning or critical-environment maintenance, no dedicated data centre degree programmes exist at Indonesian universities, and the 200% training super-deduction remains underused. Across these five categories, a gap exists, but the data centre boom is an opportunity to increase leverage.

[3] Launched July 2025, targeting one million digitally skilled Indonesians by 2027 [131].

4.6 Forging Green Industrial Transformation Potential: Channelling Demand

Below, we present the three channels through which data centre-related demand can be harnessed to drive green industrial transformation in Indonesia.

Channel 1: Green chips and electronics

The first channel concerns the upstream silicon, optical, and packaging layer of the data centre value chain, the layer whose efficiency improvements most directly translate into reduced power-and-cooling load per unit of compute. Indonesia's base on this layer is the thinnest of the three channels; the pull-through opportunity is correspondingly the most ambitious, the longest-term, and the most dependent on technology-transfer-conditioned joint ventures. The Galang Island JDA and the Danantara–ARM agreement together mark an entry point [132].

Channel 2: Cleantech manufacturing

The second channel concerns the equipment and infrastructure layer that distinguishes a generic data centre from a green data centre. Indonesia's base on this channel is materially deeper than on chips. The pull-through opportunity is correspondingly more tractable than on chips, with shorter horizons and smaller capital requirements. Yet the same maturity that makes these layers promising also makes them face greater regional competition [133]: Vietnam, Thailand, Malaysia, and the Philippines all host varying amounts of cleantech manufacturing capacity. Indonesia is not the natural winner of any single layer but a credible mid-tier candidate that must convert demand-side advantage into supply-side capture.

Channel 3: Renewable energy and grid

The renewable-energy-and-grid channel concerns the demand-side instrument that data centre procurement creates in Indonesia's power system. Yet the pull-through logic is the same: data centre demand is an investment anchor, and the challenge is whether Indonesia's procurement architecture can convert that demand into new-build renewable capacity, transmission delivery, and bankable certificate signals.

4.7 Channelling and Uplifting Cooperation: ASEAN–China

Indonesia is the largest single discrete market for green data centre industrialization in Southeast Asia, but it is not the only one, and the strategic value of cooperation with China should be read by the rest of ASEAN as a regional public good. The pull-through from chips, cleantech, and renewable energy is regional in its component flows even where it is national in its tax base. Similarly, the demand it organizes is regional in its hyperscaler clientele even where it is national in terms of the grid offtaker. In that regard, cooperation with China can enhance several areas that can contribute to green industrial transformation: lower-carbon digital growth, new regional value chains, faster renewable energy deployment, a cleaner manufacturing ecosystem, and more resilient South–South cooperation.

5 Policy Recommendations for International Cooperation on Data Centres and Green Structural Transformation

Data centres are a growing priority for international cooperation due to their effects on global climate change, water resources, and energy systems. At the same time, international cooperation faces challenges from weakening multilateral governance, financing gaps, and geopolitical disruptions. This study has made the case that the opportunities outweigh the challenges for international cooperation on green development through data centres and green structural transformation. This section puts forward concrete policy recommendations for international cooperation on data centres and green structural transformation across three main themes highlighted by the study that are essential for data centres to contribute to green industrial transformation: water and waste management; low-carbon operation; and domestic linkages.

These three themes represent complementary dimensions of data centres' potential role in green structural transformation. Water and waste management focuses on reducing pressures on local natural resources by improving water efficiency, promoting circular economy approaches for electronic waste and critical materials, and minimizing other environmental externalities associated with rapid data centre expansion. Climate-vulnerable countries face particular concerns with regard to water stress and water resource availability. Other countries, like South Africa, have emerging circular economy regulations meant to address the short hardware lifespan of data centres and manage potential waste from a growing sector. Water use, cooling technologies, and waste management practices can be improved relatively quickly through operational standards, reporting requirements, and environmental safeguards, making them near-term priorities for international cooperation.

Low-carbon operation refers to minimizing life-cycle greenhouse gas emissions associated with data centre construction and operation while promoting the integration of the necessary low-carbon technologies and practices into broader green transformation. The technologies and practices discussed in this study include renewable electricity procurement, energy efficiency improvements, smart energy, and computing management that leverages flexibility, and low-carbon supporting infrastructure. As highlighted in Sections 3 and 4, renewable electricity procurement and PUE face challenges in many Global South countries. At the same time, case studies in China discussed in Section 2 present compelling advancements in these areas, for example high-efficiency cooling technology at the Qiandaohu and Zhangbei data centres, distributed renewable energy at the Tencent Tianjin Data Centre, and other cases. Achieving low-carbon operation requires coordinated investments in renewable energy generation, transmission, storage, and supporting regulatory frameworks, making it a medium-term cooperation objective as clean energy infrastructure expands alongside data centre growth.

Finally, domestic linkages refer to the extent to which data centre investment generates broader economic and industrial benefits within host countries, underpinning the concept of green industrial transformation. This is a gradual process that depends on sustained investment, institutional capacity, and the maturation of domestic industries, making it a long-term pillar for international cooperation. At the same time, the ultimate goal of ensuring access and benefits from data centre development should also guide the short- and medium-term goals.

Our policy recommendations focus on these three themes, and we organize these recommendations by cooperation level (bilateral, regional, and multilateral) and by time frame (short term, medium term, and long term). The bilateral level of cooperation refers to cooperation between China and individual countries, such as through direct coordination between relevant ministries or public–private partnerships. The regional level of cooperation refers to China's cooperation within regional frameworks such as ASEAN or multi-country issue

groups such as BRICS or the V20 coalition. The multilateral level of cooperation refers to China working within global platforms such as the G20, UNFCCC, and other frameworks that include countries from multiple regions.

In terms of time frames, for the purposes of this study, the short-term time frame refers to the next 1–3 years. The medium-term time frame refers to the next 3–5 years. The long-term time frame refers to actions taken 5 years from now and beyond. Given the long time frames of infrastructure and development planning, our long-term recommendations should also be seen as guiding principles for short- and medium-term actions.

5.1 Policy Recommendations for Bilateral Cooperation

In the short-term, bilateral cooperation should focus on leveraging China's experience in building a green data centre ecosystem domestically. China's policy framework for green data centre transformation can be adapted to other countries' contexts based on other countries' national commitments and policy architecture, sectoral and geographical characteristics, and the status of market-based enabling environments. A practical starting point could be structured policy dialogues between relevant ministries, developers, and utilities to exchange experiences on green data centre planning.

Outcomes of dialogues could include calls for joint research on indicators such as WUE, PUE, Carbon Computing Usage Effectiveness (CCUE), and other potential metrics—including local workforce participation, skills development, technology transfer, and community benefits—that could form the basis of future standards. Focusing on water and waste management can generate relatively near-term transformation.

Where partner countries are CVF-V20 members, these dialogues could be convened as pilots through the Country Platform and Climate Prosperity Plan structures, allowing several climate-vulnerable economies to share a single dialogue track with China rather than engaging in isolation, reducing the transaction costs of participation for smaller economies.

In the medium term, China can work with a selected partner country to build a dedicated bilateral framework for data centre cooperation that is anchored on low-carbon operation and its supporting infrastructure. This study has highlighted the potential for China–Indonesia cooperation on developing data centres in a way that promotes Indonesia's industrial upgrading, potentially focusing on green chips and electronics, cleantech manufacturing, and renewable energy and grid infrastructure, although a formal framework has yet to be proposed or developed. Such frameworks could move beyond individual investment projects and focus on coordinated investment, for example in green industrial parks that integrate data centre low-carbon operation with shared clean energy infrastructure or waste-heat utilization systems. Going beyond short-term policy dialogues, medium-term cooperation could include bilateral working groups that bring together government agencies, utilities, financial institutions, and private sector stakeholders to jointly identify priority actions, address regulatory barriers, and align standards with China's domestic green data centre policy framework. In addition, promoting data centre load flexibility through technology, policy, and regulation can have broad-based benefits for the local grid.

Medium-term bilateral cooperation will also need to include consideration of green finance, given the financing gaps that many developing countries will continue to face in the medium term and the need for high-quality infrastructure to enable green data centres. As China continues to provide digital and physical infrastructure financing overseas, regulators should ensure that overseas data centre projects meet the same standards that apply to new data centres in China, including the PUE targets in China's 2024 Special Action Plan on green data centres and the stipulation in China's 2026 Carbon Peaking Action Plan that new data centres

primarily use green electricity. We propose also adding WUE targets for overseas projects, given the pressing water resource issues in many partner countries.

Finally, in terms of longer-term bilateral cooperation, the focus should be on domestic linkages and maximizing the broader developmental benefits associated with digital infrastructure investment. For example, in the case of Indonesia, China could work with Indonesia to build on an existing bilateral framework and embed green data centres into the unique features of Indonesia's green investment landscape, including upgrading critical mineral processing and domestic manufacturing of cooling systems, solar PV, and energy storage technologies. Similar approaches could be adapted to other partner countries based on their comparative advantages and industrial priorities.

5.2 Policy Recommendations for Regional Cooperation

In the short term, China can work with regional platforms to co-develop green data centre standards and benchmarks. Examples of regional platforms that could host such standards and benchmarks include the BRICS Digital Ecosystem Cooperation Network, the V20 coalition, China-ASEAN, and the FOCAC. These platforms could facilitate the development of Memorandums of Understanding for green data centres, which can serve as a starting point for later investments and other actions. Regional platforms could also support peer learning among regulators, utilities, and industry stakeholders across diverse country contexts by creating working groups, technical exchanges, and knowledge-sharing initiatives focused on data centres, water and waste management, and green industrial transformation. Existing coordination, such as China-ASEAN energy cooperation frameworks, can be strengthened and expanded to include green data centres.

In the medium term, regional cooperation should emphasize coordinated investment in low-carbon infrastructure, which often transcends national borders. China's outward foreign direct investment can bundle data centre investment with underlying clean energy and transmission infrastructure. Another medium-term opportunity for regional cooperation is the development of interoperable green digital infrastructure, including mechanisms such as green tokens and flexible computing, to facilitate the exchange of low-carbon computing resources at the regional and digital levels, in parallel with strengthening regional physical integration. Combined, this coordinated investment can become a "green digital corridor" that integrates and optimizes physical and digital infrastructure in a partner region.

For long-term cooperation at the regional level, China should work with regional platforms to promote downstream value creation. In the longer term, China should help partners build regional green data centre supply chains that draw on regional shared infrastructure. For multi-country issue groups that are not located in the same regions (e.g., V20 countries), China can align its engagement on data centres to focus on industrial growth, skills development, and platform-specific issues such as cooling efficiency in V20 countries. In ASEAN, regional cooperation could leverage existing manufacturing capabilities to develop integrated supply chains for solar modules, batteries, cooling systems, and power management equipment used in green data centres. In Africa, cooperation through FOCAC could support regional manufacturing hubs and technical training centres linked to digital infrastructure deployment. Within BRICS, cooperation could focus on industrial complementarities among member countries, including mineral processing, battery manufacturing, and low-carbon industrial production.

5.3 Policy Recommendations for Multilateral Cooperation

In the short term, China should position green data centre cooperation as a deliverable from key existing multilateral venues such as the G20 and the UNFCCC. A key objective in the short term should be elevating green data centres from a niche infrastructure issue to a fundamental component of global climate and development cooperation. China could also work with international organizations such as the International Telecommunication Union (ITU) and the IEA to develop shared analytical frameworks, technical guidance, approaches to data sovereignty, and data collection efforts related to data centres. In particular, China should support multilateral initiatives like the UN Secretary-General's proposed AI Environmental Transparency Initiative for reporting the multifaceted carbon, water, air quality, land, equity, and cost impacts of data centres. Understanding the cost responsibilities for data centres is necessary for ensuring they contribute to access and benefit sharing outside of the digital sector. Within these multilateral venues, China should promote the near-term development of a metric that assesses the system-wide green transformation potential of data centres. Relatedly, strategic environmental assessment (SEA), an area where China has well-established expertise, could provide a frame for institutionalizing the thematic scope, time horizons, and metrics needed for ex-ante evaluation and periodic re-evaluation of data centre initiatives.

In the medium term, China should prioritize mutual recognition and alignment of green data centre standards and related standards, such as for carbon accounting, RECs, etc. As countries develop their own standards for data centre efficiency, renewable energy sourcing, and emissions accounting, there is a risk that fragmented regulatory systems could create barriers to low-carbon investment and international cooperation. China can work through multilateral institutions and standard-setting bodies to encourage greater interoperability among these emerging green data centre-related certification and accounting systems. Cooperation could involve international organizations such as the ITU, the International Organization for Standardization (ISO), and the International Electrotechnical Commission (IEC), which could provide platforms for technical coordination. Greater standardization would reduce uncertainty for investors, improve global comparability, and facilitate the development of international green finance mechanisms linked to digital infrastructure.

In the long term, China's cooperation with multilateral platforms should shift to unlocking climate finance and market-based instruments to ensure available financing for green data centre-driven transformation. Examples include using UNFCCC Article 6 to monetize emissions reductions for green data centres and engaging with existing multilateral climate finance platforms at the Green Climate Fund, the Global Environment Facility, and multilateral development banks to crowd in concessional capital. Over time, multilateral cooperation could support the creation of dedicated financing windows or investment facilities for green digital infrastructure, similar to existing mechanisms for renewable energy and climate resilience. Such initiatives would help ensure that developing countries are able to participate in the growth of the global digital economy while advancing climate goals, strengthening energy systems, promoting green structural transformation, and supporting a just and inclusive transition through local capacity building, technology transfer, and broad-based economic and social benefits.

These policy recommendations are summarized in Figure , which presents a matrix of recommendations by level and time frame, noting the key themes to focus on within each time frame and the key recommendations from the study.

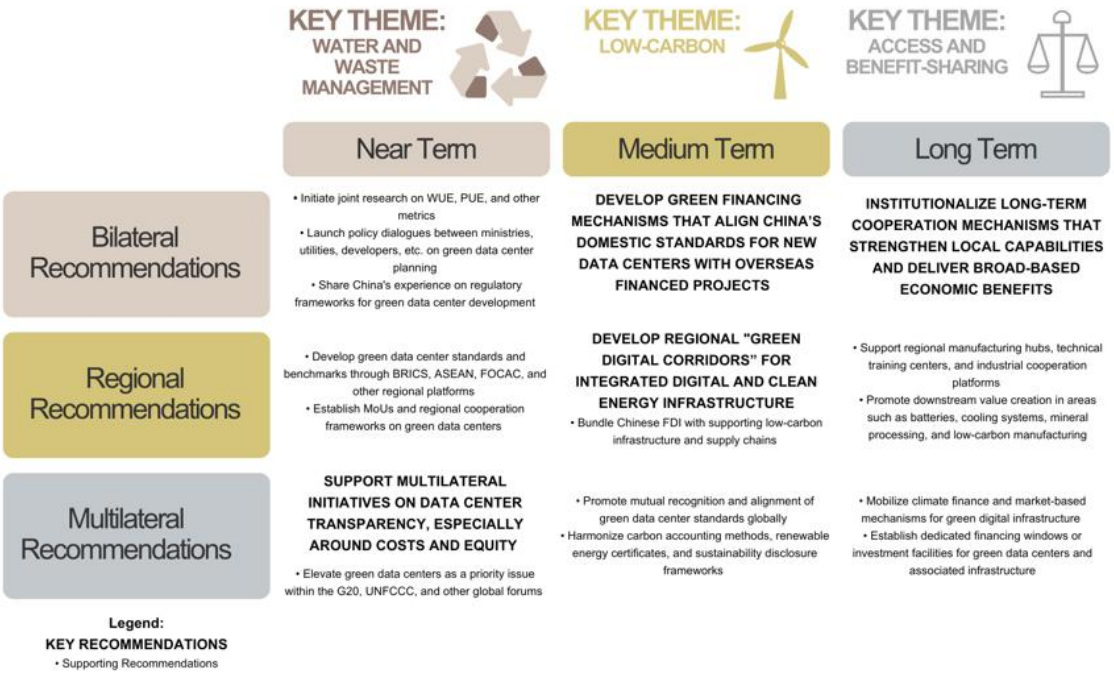


Figure 7. Policy Recommendations by Cooperation Level, Timeframe, and Key Theme

Taken together, these recommendations suggest that international cooperation on data centres and green structural transformation should evolve from dialogue and standard-setting in the short term to coordinated investment and institutional frameworks in the medium term, and ultimately to integrated industrial development and financing mechanisms in the long term. In addition, the focus themes within each time frame reflect the differing pace at which these objectives can be achieved: operational improvements to water and waste management can be implemented relatively quickly, low-carbon operation depends on medium-term energy system investments and policy reforms, and strong domestic industrial linkages require sustained, long-term economic and institutional development. By pursuing these recommendations at different levels and over different time frames, China and partner countries can establish a new direction for data centres and digital infrastructure, ensuring that they contribute to broader green structural transformation across the Global South in ways that are environmentally sustainable, economically resilient, and socially inclusive.

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