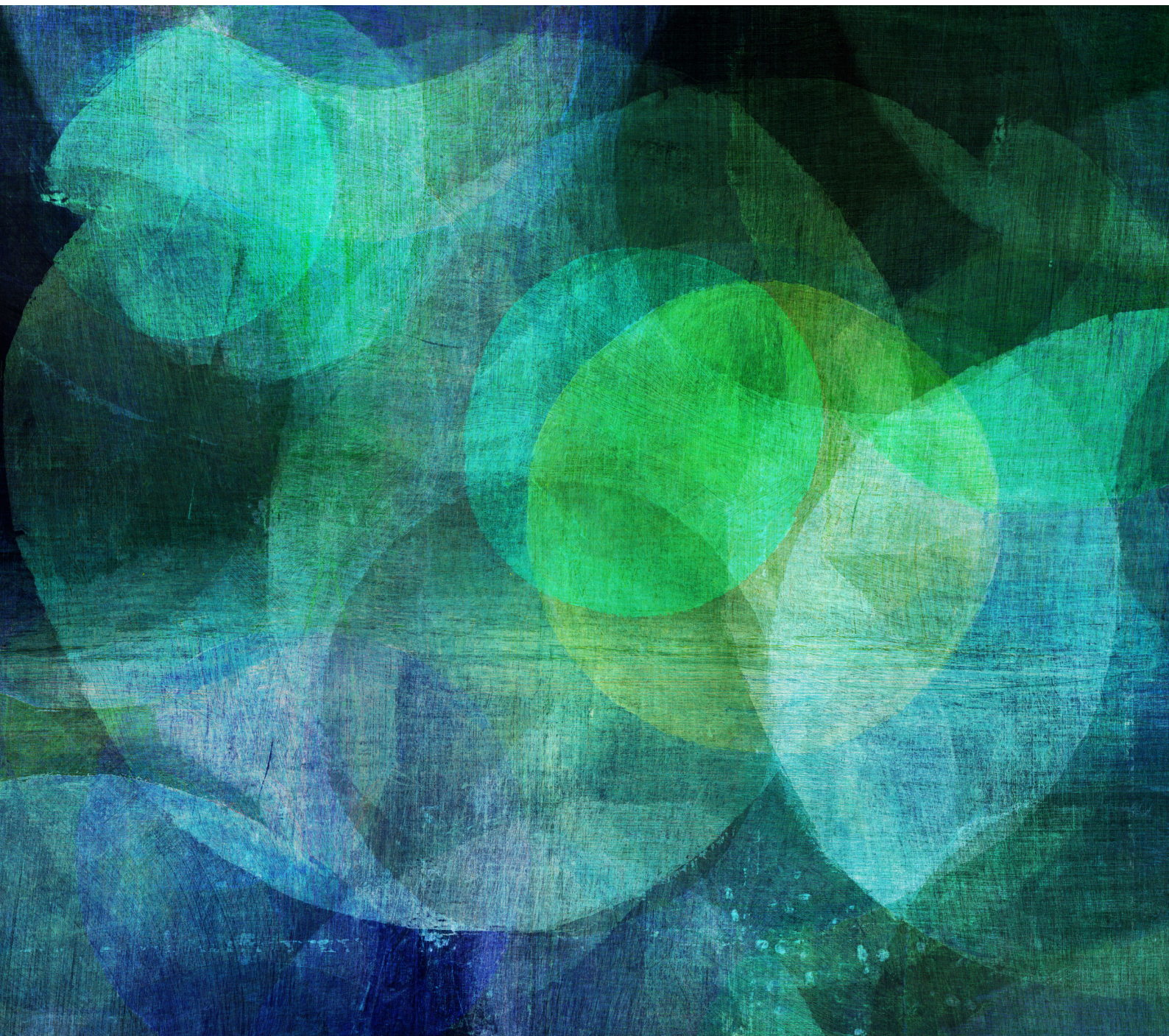




ORF GLOBAL
Quarterly

ENERGY AND TECH: POWERING THE FUTURE

© 2026 Observer Research Foundation. All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means without permission in writing from ORF.

Attribution: Sharon Stirling and Eszter Karacsony, Eds., *ORF Global Quarterly: Energy and Tech: Powering the Future*, ORF Global, July 2026.

All views expressed in this publication are solely those of the authors, and do not represent the institution, its affiliates, or partners.

All images used in this publication are from Getty Images: Cover page - Qweek; p8 - Westend61; p22 - timandtim; p31 - General_4530; p41 - adamkaz; p50 - zhen li; p60 - Tatiana Sviridova; p69 - J Studios; p79 - dem10;.

Editorial and Production Team: Vinia Mukherjee, *Editor and Producer*; Monika Ahlawat, *Assistant Editor*; Rahil Miya Shaikh, *Design and Layout*.

ENERGY *and* TECH: POWERING *the* FUTURE

Edited by
Sharon Stirling and Eszter Karacsony

EDITORS' NOTE

Welcome to the third issue of the *ORF Global Quarterly*. We asked ORF scholars across our three geographies of India, Middle East, and America, to revisit the prognoses that they made in the technology and climate and energy domains for the first issue of this journal published in January this year. They re-examined the nine megatrends that were identified, assessed the current landscape, and provided insights on how those trends are likely to progress in the last six months of this year and how Global South countries can navigate them.

World events whose scale and magnitude may have been unpredictable have greatly impacted the trajectory of several trends, most notably the US-Israel war on Iran, Iran's retaliatory strikes, and blockades of the Strait of Hormuz. The war has disrupted global supply chains and the advancement of AI by raising the costs of building and powering the infrastructure demanded by it. To understand further the impacts of these events, read the articles, *Building AI into the Energy Future* and *Choke Points: How Security and Politics Are Impacting Supply Chains*. Another surprise was when access to advanced AI models Mythos and Fable were removed for non-American nationals due to national security and cybersecurity concerns. This is one

example that highlights fragmentation in AI development, deployment, and access—a topic that is explored in this issue.

We are also living through one of the Earth's hottest years on record. In this complex environment, characterised by record-breaking climate extremes, our authors examine the growing energy demands placed by AI data centres on electrical grids and water resources, the impacts of extreme weather events, and who will pay for building a climate-resilient future. At a time when actors on the world stage should be coming together to solve these fundamental problems, our authors see deepening and troubling divergences in speed and priorities, and raise questions about who should bear the costs for the solutions. Increasingly, Global South leaders are asking how to finance, build, and benefit from technology advancements and the energy structures needed to power them.

This issue also examines specific trends that could have considerable impact in the next few years: 1) breakthroughs in quantum computing; 2) advancements in spintronic energy sources (and how the Global South could be missing out); and 3) digital currencies, which have moved beyond a “tech-bro” fad talked about on social media to 146 countries developing their own central bank digital currencies (CBDCs).

Throughout the publication, authors explore the potential developments that could alter, reverse, or accelerate the trends' trajectories in 2026 and how Global South countries could actively shape them in line with their own priorities, perspectives, and strengths. The authors draw on examples from Global South countries to illustrate their findings, highlighting common patterns and differences in priorities, strategies, and capabilities.

Indeed, many Global South countries have considerable advantages. On the supply side, they have many of the resources, including the critical minerals, needed to power the technology revolution; and on the demand side, they are demographic powerhouses with the highest concentration of AI users. These strengths should allow them to act with agency

rather than being mere bystanders to the impacts of these unfolding trends. By recognising the challenges that lie ahead, understanding their individual strengths, and exploring cooperation opportunities, Global South countries have a greater chance to leverage to their advantage the trajectories being taken by these trends.

Sharon Stirling
Chief Operating Officer, ORF America
and Director, ORF Global

Eszter Karacsony
Non-Resident Fellow, ORF Middle East

CONTENTS

8 Building AI into the Energy Future

Andreas Kuehn and
Cauvery Ganapathy



22 Ten Fault Lines That Will Define the Global Energy Transition

Piyush Verma



31 Choke Points: How Security and Politics are Impacting Supply Chains

Parul Bakshi and Lydia Powell



41 Who Will Pay for Climate Action Now?

Gopalika Arora



50 Global AI: A Story of Fragmentation

Siddharth Yadav



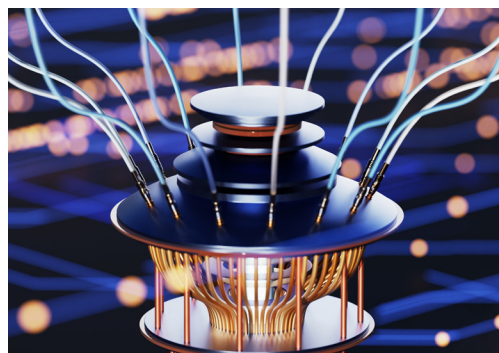
60 Power Up: How Spintronic Nanodevices Can Fuel the Future

Amoha Basrur and Pranoy Jainendran



69 Quantum Codebreaking Moves One Step Forward

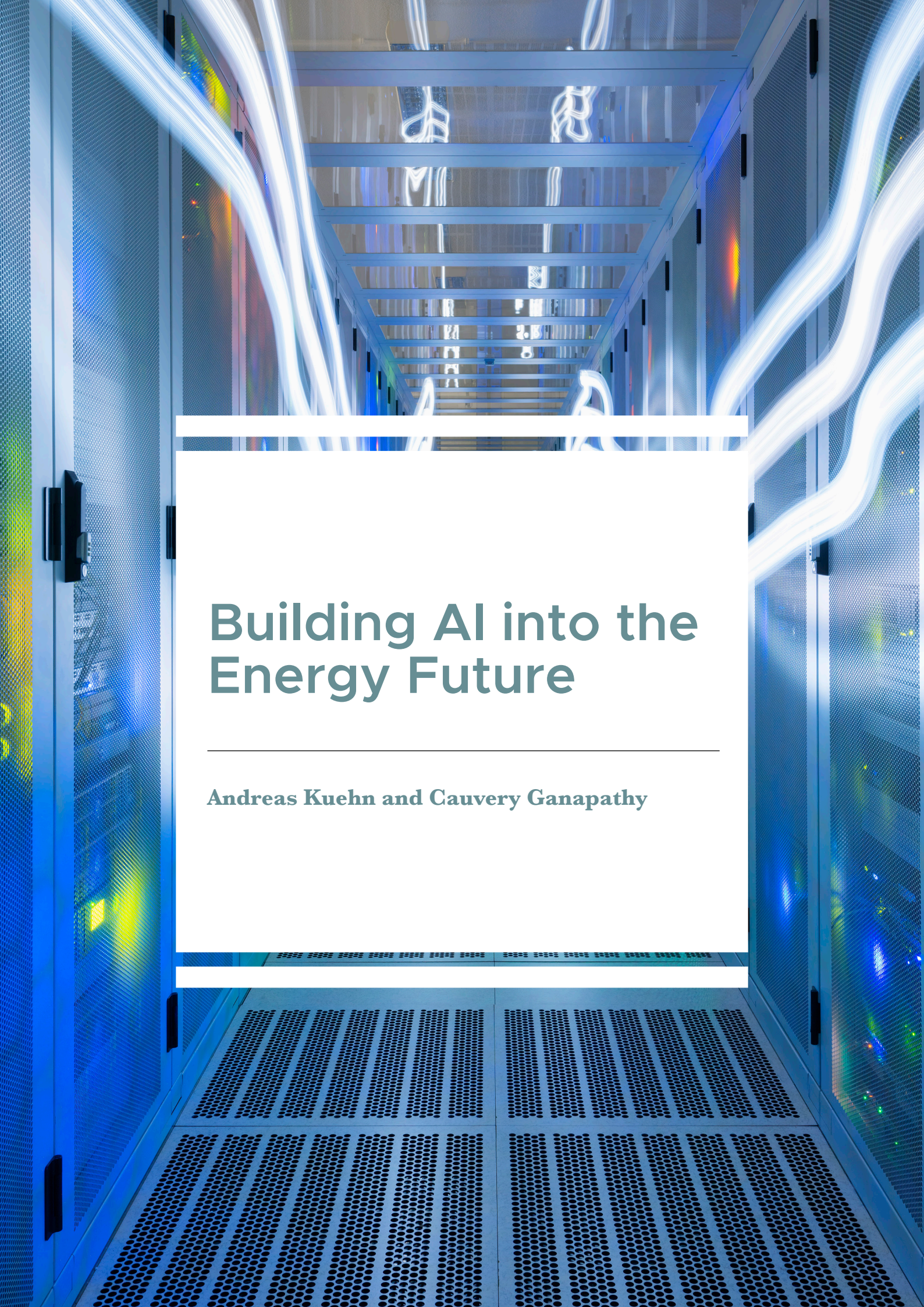
Prateek Tripathi



79 Digital Currencies: From Idea to Implementation

Sauradeep Bag





Building AI into the Energy Future

Andreas Kuehn and Cauvery Ganapathy

The appeal of artificial intelligence (AI) to the Global South lies in its potential to narrow persistent structural gaps that constrain human and economic development. Across these geographies, large sections of the population grapple with the interconnected challenges of lack of clean water, food insecurity, limited access to affordable and quality healthcare, financial exclusion, and inadequate economic opportunities. Structural barriers to energy access aggravate each of these pressures, while climate change further strains the fragile ecosystems within countries that are simultaneously pursuing industrial decarbonisation agendas while seeking to reduce inequities in energy access and development. By improving productivity across critical sectors, optimising energy access and distribution, and strengthening climate change mitigation techniques, an effective, equitable, and calibrated diffusion of AI could help alleviate these pressures across the Global South.

The widespread adoption of AI, alongside efforts to address developmental gaps, holds economic and business potential for countries of the Global South. This embrace will, however, also impart a significant footprint on global energy and climate ecosystems, as energy is a core enabler of the AI revolution. Simultaneously, AI itself could also serve as a system-level facilitator to address concerns of reliability and compromised efficiency in energy ecosystems.¹ Yet, while the integration of AI offers benefits for the optimisation of energy systems through grid management, renewable energy integration, predictive maintenance, and accurate forecasting of alternative forms of energy, its energy-intensive nature could also negatively impact the countries and ecosystems seeking to adopt it.

This article examines the most important trendlines that underpin the paradoxical relationship between the benefits of AI's deployment and the challenges it poses to energy and climate ecosystems in the Global South.

1 IEA, *Energy and AI*, April 2025, Paris, International Energy Agency, 2025, <https://www.iea.org/reports/energy-and-ai>.

Setting the Context

AI investments continue at scale globally, with data centre projects under construction, or moving through planning pipelines. Although experts' estimates of AI's future electricity demand vary widely, the direction is clear: AI is a driver of new energy demand.^{2,3} The effects will be felt most acutely in the Global South, where AI infrastructure and data centres could place substantial pressure on electricity grids, regional energy systems, power markets, and emissions trajectories. Ultimately, the value of AI for these countries will depend on whether it can be deployed without exacerbating existing constraints around energy access, grid reliability, climate vulnerability, and public investment.

Global South countries that are emerging as regional hubs for AI infrastructure, such as the Gulf states, India, Brazil, Malaysia, Kenya, South Africa, Indonesia, and Mexico, have to address these energy and climate implications from the rapidly growing demand

for AI deployments.⁴ Despite differences in their economic development and approaches to deploy AI,⁵ these countries are attracting substantial data centre investment to build sovereign AI capabilities and expand compute infrastructure as they seek to establish themselves as critical regional and global AI nodes.⁶

The AI Infrastructure Build-out

While overshadowed by the rapid expansion of AI infrastructure in the United States and China, AI infrastructure development across the Global South is well underway. The largest projects extend beyond conventional data centres and increasingly include gigawatt-scale AI infrastructure, particularly in the United Arab Emirates (UAE), Saudi Arabia, India, Brazil, and Kenya. Meanwhile, Malaysia, South Africa, Indonesia, and Mexico are developing AI infrastructure projects often at the scale of tens- to hundreds-of-megawatts.⁷ Table 1 provides an overview of installed and estimated IT load capacity for data centres.⁸

2 IEA, *Energy and AI*, April 2025, Paris, International Energy Agency, 2025, <https://www.iea.org/reports/energy-and-ai>. “Energy and AI”.

3 Unless otherwise indicated, the IEA figures cited in this article refer to the IEA's “base case” scenario: its central projection for global data centre electricity demand, against which the report compares its lift-off, headwinds, and high efficiency cases.

4 The analysis focuses on 2025–2030 to examine near- and medium-term developments in AI infrastructure buildout and their effects on energy demand and climate.

5 Although these countries have in common economic growth potential, vulnerability to impacts of climate change, and importantly, policy and business environments that prioritise AI adoption and deployment, the ‘Global South’ itself is a contested category and not homogenous. It includes the high-income, energy-abundant states, such as the UAE and Saudi Arabia that have robust technology partnerships with the United States, just as it counts less endowed countries of Asia, Africa, and Latin America.

6 This article refers to ‘sovereign AI’ as a country's ability to develop, deploy, and govern all relevant aspects of AI technology and systems, using domestic or foreign trusted infrastructure, data, talent, and institutions, in ways that align with national priorities, values, and regulatory requirements. See: McKinsey & Company, “What Is Sovereign AI?,” March 6, 2026, <https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-is-sovereign-ai>; John Letzing, “What is ‘Sovereign AI’? And Why is the Concept So Appealing?,” World Economic Forum, November 13, 2024, <https://www.weforum.org/stories/2024/11/what-is-sovereign-ai-and-why-is-the-concept-so-appealing-and-fraught>.

7 In some instances, capacity is undisclosed or data is not available.

8 Data centres are a broader category and may support workloads beyond AI, including cloud services, enterprise computing, storage, networking, and content delivery.

Table 1: Data Centre Capacity per Market: Current (2025/2026) vs. Estimated (2030/2031)⁹

Market	IT Load Capacity (2025)	IT Load Capacity (2030)
UAE	508 MW	676 MW
Saudi Arabia	410 MW	1.03 GW
India	4.48 GW	15.21 GW (2031)
Malaysia	1.53 GW (2026)	6.43 GW (2031)
Indonesia	1.44 GW	3.56 GW
South Africa	626 MW	972 MW
Brazil	950 MW	1.46 GW
Mexico	53 MW	1.27 GW

In the Middle East, the UAE and Saudi Arabia are building AI infrastructure at an extraordinary scale. Two factors enable this growth: sovereign wealth fund investments in AI infrastructure and ecosystem development, and US-linked agreements that provide access to advanced technologies. In the UAE, Stargate UAE is the flagship project—a planned 1 GW AI cluster in Abu Dhabi that forms part of the broader 5 GW UAE–US AI Campus, designed to host US hyperscalers and serve regional compute demand.¹⁰ Saudi Arabia’s HUMAIN, backed by the Kingdom’s Public Investment Fund, has announced plans to invest around US\$10 billion in deploying up to 500 MW of AI infrastructure over the next five years.

India, meanwhile, has the most extensive AI ecosystem in the Global South, supported by a large talent pool, a vibrant startup ecosystem, its Digital Public Infrastructure (DPI), and extensive datasets. Yotta Data Services has announced plans to deploy a US\$2-billion AI supercluster at its 60 MW Greater Noida D2 data centre,¹¹ while Google is building a US\$15-billion AI data centre hub in Visakhapatnam, expected to include a 1 GW facility.¹²

In Southeast Asia, Malaysia is emerging as a regional AI infrastructure hub, especially around Johor. Its YTL–NVIDIA AI data centre project received a US\$4.3-billion investment at

9 Numbers are based on Mordor Intelligence publicly available data sources, comparing current data centre IT load capacity in 2025 or 2026 with estimated capacity for 2030 or 2031, as indicated. IT load capacity refers to electrical power capacity (i.e., power demand) by installed computing, storage, and networking equipment, typically measured in megawatts (MW) or gigawatts (GW). It excludes additional facility power used for cooling, lighting, and other non-IT systems.

10 OpenAI, “Introducing Stargate UAE,” May 22, 2025, <https://openai.com/index/introducing-stargate-uae>.

11 Yotta Data Services, “Yotta to Deploy One of Asia’s Largest NVIDIA Blackwell HGX B300 Superclusters with Over 20,000 NVIDIA Blackwell Ultra GPUs,” February 18, 2026, <https://yotta.com/press-releases/yotta-to-deploy-20000-nvidia-blackwell-ultra-gpus>.

12 Thomas Kurian, “Our First AI Hub in India, Powered by a \$15 Billion Investment,” Google India Blog, October 14, 2025, <https://blog.google/intl/en-in/company-news/our-first-ai-hub-in-india-powered-by-a-15-billion-investment>.

the 600 MW YTL Green Data Center Park.¹³ In Indonesia, BDx's CGK4 campus is designed as the country's first renewable-powered AI data centre park and could scale to 500 MW.¹⁴

In Africa, South Africa's US\$1-billion JNB1 campus in Johannesburg will reach 120 MW capacity once fully developed.¹⁵ In Kenya, G42 and EcoCloud have announced a geothermal-powered data centre planned to open at an initial 100 MW capacity, with the potential to scale up to 1 GW.¹⁶ In South America, Brazil's Scala AI City is the region's most ambitious project, beginning with an initial capacity of 54 MW and projected to expand to 1.8 GW by 2033.¹⁷ In Mexico, CloudHQ's Querétaro campus is planned for a 360 MW of critical IT load.¹⁸

Energy Demand and Grid Constraints

Energy intensity of data centres: The International Energy Agency (IEA) estimates that data centres accounted for around 1.5 percent of global electricity consumption in 2024, or 415 TWh, and projects that this could more than double to 945 TWh by 2030.¹⁹ This is close to Japan's annual electricity consumption in 2025 terms. AI is the most important driver of growth in electricity consumption. Demonstrative of this interface between AI and energy is the US\$67-billion merger between two US companies, NextEra Energy and Dominion Energy,²⁰ creating the world's largest regulated electric utility with 110 GW of electricity generation capacity.²¹

-
- 13 Chester Tay, "YTL Power Completes First Nvidia-Powered AI Data Centre in Johor, YTL AI Cloud Now Operational," *The Edge Malaysia*, October 31, 2025, <https://theedgemalaysia.com/node/776142>.
 - 14 BDx Data Centers, "BDx Data Centers Launches the First Phase of 500MW Renewable-Powered AI Campus in Indonesia," July 31, 2024, <https://www.bdxworld.com/press-release/bdx-data-centers-launches-first-phase-of-500mw-renewable-powered-ai-campus-in-indonesia>.
 - 15 Vantage Data Centers, "Vantage Data Centers Expands to Africa with US\$1 Billion Flagship Johannesburg Campus in Continent's Largest Data Center Market," October 13, 2021, <https://vantage-dc.com/news/vantage-data-centers-expands-to-africa-with-us1-billion-flagship-johannesburg-campus-in-continents-largest-data-center-market>.
 - 16 G42, "G42 and Kenya's EcoCloud Unveil Green-Powered Mega Data Center Collaboration," March 6, 2024, <https://www.g42.ai/resources/news/g42-and-kenyas-ecocloud-unveil-green-powered-mega-data-center-collaboration>.
 - 17 "Google to Invest \$2 Billion in Malaysian Data Center and Cloud Hub," Associated Press, May 30, 2024, <https://apnews.com/article/malaysia-google-investment-94764341b721e1c1f3fb2d607604f011>; Ministério de Minas e Energia, "MME Abre Caminhos para Conexão de Complexo de Data Centers à Rede Básica no RS," May 13, 2025, <https://www.gov.br/mme/pt-br/assuntos/noticias/mme-abre-caminhos-para-conexao-de-complexo-de-data-centers-a-rede-basica-no-rs>.
 - 18 CloudHQ, "QRO Campus," <https://cloudhq.com/campus/qro-campus>.
 - 19 "Energy and AI".
 - 20 Nico Portuondo, Adam Aton, and Kelsey Tamborrino, "Super-Sized Utility Merger Runs through Virginia," *Politico*, May 19, 2026, <https://www.politico.com/news/2026/05/19/power-companies-merger-lower-bills-affordability-politics-00927494>.
 - 21 NextEra Energy, "NextEra Energy and Dominion Energy to Combine, Creating the World's Largest Regulated Electric Utility Business and North America's Premier Energy Infrastructure Platform Benefiting Customers," May 18, 2026, <https://newsroom.nexteraenergy.com/2026-05-18-NextEra-Energy-and-Dominion-Energy-to-Combine,-Creating-the-Worlds-Largest-Regulated-Electric-Utility-Business-and-North-Americas-Premier-Energy-Infrastructure-Platform-Benefiting-Customers>.

The planned 5 GW G42 AI Campus in the UAE, for instance, is estimated to consume 49.1 TWh annually, which is more than the entire nation's annual electricity consumption. The Barakah Nuclear Energy Plant, which produces 25 percent of the UAE's total electricity, would

be insufficient to power the new campus.²² To meet their growing energy demand, data centre operators have been considering captive or on-site power generation, raising concerns among some experts that this could further entrench fossil fuel consumption.²³

Table 2: Energy Types Powering Data Centres

Energy Type	Contribution to Powering Data Centres (2024)
Coal	30%
Renewables (wind, solar PV and hydro)	27%
Natural Gas	26%
Nuclear	15%

Source: IEA Energy and AI Special Report, 2024²⁴

Shifting energy mix amid rising energy consumption: While the IEA projects a larger role for nuclear energy in powering data centres towards the end of the decade, data centres currently rely on a predominantly fossil fuel-based energy mix.²⁵ Furthermore, many AI data centre projects are expected to come online within the next few years, whereas major energy infrastructure projects require longer planning, permitting, financing, and construction timelines. Therefore, new AI infrastructure is likely to draw power from each country's existing energy mix in the short term rather than from a decarbonised future grid.

The need for baseload round-the-clock (RTC) reliable power that is needed by AI data centres has also meant that legacy systems such as coal and natural gas have found greater advocacy by policymakers on the grounds that they are needed to ensure uninterrupted grid reliability. In the US, for instance, which is seeing the largest build-out of AI infrastructure globally, coal is reflected in several Department of Energy initiatives to be central to powering "America's reindustrialization and winning the AI race."²⁶ Indicative of this is the launch of a US\$625-million fund to retrofit and recommission old coal power stations in the country. This could

22 "UAE Data Center Capacity to Surge 165% by 2028," Emirates NBD Research, October 14, 2025, https://www.emiratesnbdresearch.com/-/media/emirates_nbd_research_-_macro_economics_10142025.pdf.

23 Mike Jacobs, "Power Hungry: Why Data Centers are Developing their own Energy Sources to Fuel AI," Union of Concerned Scientists, July 10, 2025, <https://blog.ucs.org/mike-jacobs/power-hungry-why-data-centers-are-developing-their-own-energy-sources-to-fuel-ai>.

24 "Energy and AI".

25 "Energy and AI".

26 U.S. Department of Energy, "Energy Department Announces \$625 Million Investment to Reinvigorate and Expand America's Coal Industry," September 29, 2025, <https://www.energy.gov/articles/energy-department-announces-625-million-investment-reinvigorate-and-expand-americas-coal>.

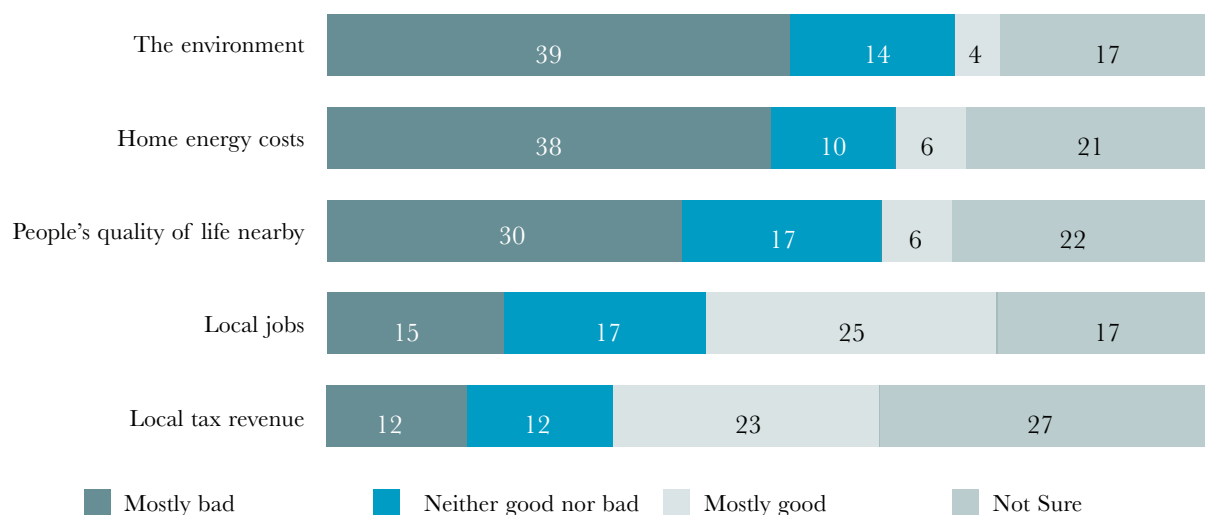
create a structural feedback loop that may lock hydrocarbons into the AI build-out, keeping them not just relevant but central.

AI's ancillary pressures on energy systems: Additionally, the high energy demand of data centres and integration of AI into energy systems can create additional pressures on local communities through increased energy utility bills.²⁷ Necessary grid expansions or modernisation could lead to some of the

costs of AI's expansion being one-sidedly and unfairly passed on to customers in geographies that house these data centres. The tensions and adverse public perceptions associated with the deployment of AI emerging in advanced economies such as the US, as shown in Figure 1, may be even more complicated in the Global South, where many countries already face financial and infrastructural constraints, while also grappling with competing development priorities.

Figure 1: US Public Perception on the Impact of Data Centres

How Americans view data centers' impact in various areas
% of U.S. adults who say data centers are __ for each of the following things



Note: Those who did not answer and those who have not heard about data centers are not shown.

Source: Survey of U.S. adults conducted Jan. 20-26, 2026.

Source: *Pew Research Centre*²⁸

27 Miguel Yanes Barnuevo, "Data Center Power Demands are Contributing to Higher Energy Bills," *Environmental and Energy Studies Institute*, February 24, 2026, <https://www.eesi.org/articles/view/data-center-power-demands-are-contributing-to-higher-energy-bills>.

28 John Gramlich et al., "How Americans View Data Centers' Impact in Key Areas, From the Environment to Jobs," *Pew Research Centre*, March 12, 2026, <https://www.pewresearch.org/short-reads/2026/03/12/how-americans-view-data-centers-impact-in-key-areas-from-the-environment-to-jobs>.

“The adverse public perceptions associated with the deployment of AI may be even more complicated in the Global South, where many countries already face financial and infrastructural constraints.

Structural concentrations strain local and regional energy systems: The IEA estimates that a typical next-generation data centre can consume as much electricity as nearly 2 million households.²⁹ Because this demand is often concentrated in single locations, such facilities can create local congestion points that place massive stress on electricity networks, increasing the risk of grid instability and failures.

This growing demand for energy and increasing stress on existing infrastructure is particularly consequential for many countries in the Global South, where electricity systems may already face severe challenges by way of shortages, unreliable grids, limited transmission and distribution capacity, and constrained public finance.

Insufficient grid capacity: Concentrated AI electricity demand can intensify grid capacity constraints and are closely related. South Africa’s data centre build-out, for instance, is constrained by electricity reliability and grid capacity. Similarly, current grid capacity limits have also stalled a proposed project in Kenya over concerns that the 1-GW data centre would strain the national grid, which presently supplies 3 GW.³⁰ Table 3 illustrates current and projected data centre electricity consumption.

29 “Energy and AI”; IEA, *World Energy Outlook Special Report, ‘Energy and AI’*, International Energy Agency, 2024, <https://iea.blob.core.windows.net/assets/de9dea13-b07d-42c5-a398-d1b3ae17d866/EnergyandAI.pdf>.

30 Georgia Butler, “Microsoft and G42 Data Center in Kenya Stalled Due to Lack of Power Capacity,” Data Center Dynamics, May 7, 2026, <https://www.datacenterdynamics.com/en/news/microsoft-and-g42-data-center-in-kenya-stalled-due-to-lack-of-power-capacity>.

Table 3: Data Centre Electricity Consumption per Market: Current (2024/2025) and Estimated (2029/2030)³¹

Market	Electricity Consumption (2025)	Electricity Consumption (2030)	Data Centre Electricity Demand (% of National Total)	Note
UAE	3 TWh	6 TWh	2 % (2025)	Data centre electricity demand in 2025 accounted for about 2% of the UAE's 173 TWh total electricity demand, which is projected to reach 225 TWh by 2040.
Saudi Arabia	2.8 TWh (2024)	Between 10.2 TWh and 42.2 TWh	0.85 % (2024); 2.8% to 11.6% (2030)	Data centre electricity demand in 2024 accounted for 0.85% of Saudi Arabia's total electricity demand, which is projected to rise by between 2.8% and 11.6% by 2030.
India	10–15 TWh (2024)	40-45 TWh	0.8% (2024); 2.5% to 3% (2030)	Data centre electricity demand in 2024 accounted for 0.8% of India's total electricity demand, which is projected to rise by between 2.5% and 3% by 2030.
Malaysia	9 TWh (2024)	68 TWh	30% (2030)	Malaysia's projected data centre electricity demand will reach 30% of national power consumption by 2030.
Brazil	11.3 TWh (2024)	27.3 TWh (2029)	1.7% (2024); 3.6% (2029)	Brazil's data centres used 1.7% of national electricity consumption of 650.4 TWh in 2024. By 2029, this share is projected to rise to about 3.6%, or 27.3 TWh out of 762.4 TWh.

³¹ Author's compilation from multiple sources, including industry reports, government statistics, and market estimates. Sources include Wood Mackenzie for the UAE; KAPSARC for Saudi Arabia; The Financial Express for India; Ember for Malaysia and Indonesia; and Brasscom for Brazil. No direct reported data were found for South Africa and Mexico.

The intent of more countries to host data centres must be considered against the backdrop of many among them contending with utilities and grids that were built in periods of lower industrial and public consumption.³² This build-out of data centres is occurring at a time when countries are also looking at increased electrification and electromobility, and can therefore be expected to exert additional stress on a grid that is already experiencing mounting pressure.

This new energy demand could lead to considerable strain on these grids and lead to system paralysis, heightened risks of grid instability, higher electricity costs, delayed interconnections, and political contestation over energy allocation.

Climate Implications, Emissions, and the Environment

While AI is expected to support climate change mitigation, at present, the carbon footprint of data centres and the e-waste that is being generated from these facilities remain important points of concern. Data centres are among the fastest-growing sources of emissions, which are projected to rise from 180 million tonnes (Mt) to between 300 Mt and 500 Mt by 2035, accounting for less than 1.5 percent of the total energy sector emissions in this period.³³ While the hydrocarbons-powered

data centres used to deploy this technology do contribute to greenhouse gas emissions, the integration of AI itself can have a positive impact on efforts to reduce emissions. AI-enabled methane-emissions tracking satellites, for instance, can support the timely detection of methane leaks in oil and gas operations and thereby contribute to meaningful reductions in methane emissions.³⁴

In addition to the emissions from the compute facilities themselves, the semiconductors and data centres that propel AI depend on extractive and environmentally damaging mining and processing of critical minerals and materials—much of which takes place in the Global South.

Further compounding the impact of AI deployment on environmental markers are concerns related to the stress it induces on water. Water is a highly salient constraint in local settings marked by water access and scarcity challenges, such as India and the UAE. Data centres require water directly for cooling, and indirectly for various forms of electricity generation to power them. In geographies where water scarcity is already being heightened by climate stress, urban growth, agricultural demand, and uneven provisioning, even efficient facilities may intensify concerns over freshwater allocation if they are perceived to compete with households, agriculture, or other industries.³⁵

32 World Economic Forum, “This is the State of Play in the Global Data Centre Gold Rush,” April 22, 2025, <https://www.weforum.org/stories/2025/04/data-centre-gold-rush-ai>.

33 “Energy and AI”.

34 Jade Sterling, “Methane Leak Detection Using Tracking Satellites,” Khalifa University, November 23, 2020, <https://www.ku.ac.ae/methane-leak-detection-using-satellite-imagery>.

35 UNCTAD, *Digital Economy Report 2024: Shaping an Environmentally Sustainable and Inclusive Digital Future*, July 2024, New York, United Nations Conference on Trade and Development, 2024, <https://unctad.org/publication/digital-economy-report-2024>.

The wealthiest 10 percent of the world's population are responsible for almost half of carbon released into the atmosphere, yet vulnerable populations in the Global South are most affected by climate-related loss and damage.³⁶ The challenge therefore is not simply whether Global South countries can attract AI investment, but whether they can build the clean, reliable, and resilient energy systems needed to power AI infrastructure without deepening existing climate inequities.

What Could Alter the Trajectory?

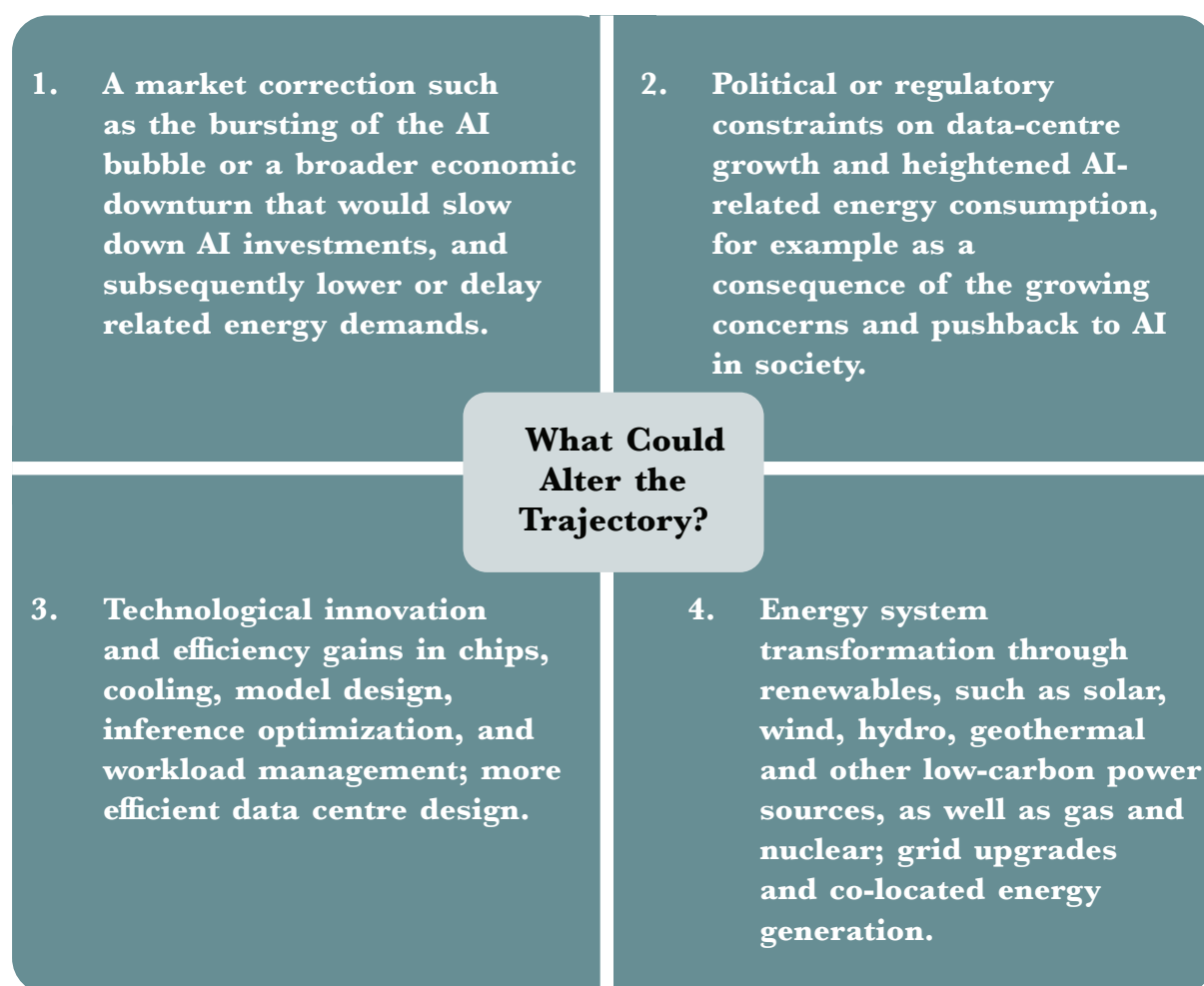
The implications for the Global South are uneven. Energy- and capital-rich states, particularly the UAE and Saudi Arabia, are better positioned to absorb rising electricity demand by mobilising sovereign capital, expanding generation capacity, and developing AI infrastructure hubs. Sustaining this approach, however, will require balancing growing energy consumption with climate commitments—including net-zero targets of 2050 for the UAE and 2060 for Saudi Arabia—as well as broader economic diversification objectives.

Large middle-income economies such as India, Indonesia, Malaysia, Brazil, South Africa, or Mexico face a more conditional opportunity. These countries must navigate trade-offs among grid reliability, electricity affordability, competing industrial demand, climate goals, decarbonisation commitments, and sovereign AI ambitions. Similar trade-offs over power, land, water, and public investment are emerging across much of the Global South. These challenges are particularly salient given that 666 million people worldwide still lack access to electricity, especially in rural areas in Central and Southern Asia and Sub-Saharan Africa.³⁷

For lower-income and more grid-constrained countries, deploying AI infrastructure becomes a more acute challenge, as new demand for power, land, water, and public investment could compete with basic energy access and development priorities. The increased energy demand could, by way of increased competition between AI deployment and other economic sectors, lead to more tensions in sub-national ecosystems, where electricity systems are already struggling to meet basic needs, and energy demands for AI may be politically and developmentally more difficult to justify.

36 Luiz Inácio Lula da Silva, “Speech by President Luiz Inácio Lula da Silva at the Opening of the 78th UN General Assembly,” Planalto, September 19, 2023, <https://www.gov.br/planalto/en/follow-the-government/speeches-statements/2023/speech-by-president-luiz-inacio-lula-da-silva-at-the-opening-of-the-78th-un-general-assembly>.

37 World Bank, *Tracking SDG 7 – The Energy Progress Report 2025* (Washington, DC: World Bank, June 2025), <https://www.worldbank.org/en/topic/energy/publication/tracking-sdg-7-the-energy-progress-report-2025>.

Figure 2: Forces Shaping AI, Energy, and Climate Megatrends

Source: Authors' own

Technological innovation and energy system transformation, the third and fourth forces described in Figure 2, are likely to have the biggest influence on future megatrends trajectories because they can change the underlying energy equation. Technological innovation can lower the energy required per unit of AI activity, while energy-system transformation can increase the supply of reliable

or low-carbon power available to data centres. For instance, an increase in the deployment of civilian nuclear energy,³⁸ including Small Modular Reactors (SMRs), and the larger-scale adoption and integration of Battery Energy Storage Systems (BESS) infrastructure could mitigate some of this concern but is unlikely to substantively reduce the pressure on existing grids in the immediate future.³⁹

38 IEA, *The Path to a New Era for Nuclear Energy*, January 2025, Paris, International Energy Agency, 2025, <https://www.iea.org/reports/the-path-to-a-new-era-for-nuclear-energy/executive-summary>.

39 World Economic Forum, "Large-Scale Battery Systems," <https://initiatives.weforum.org/future-power-system/case-study-details/large-scale-battery-systems/aJYTG00000013Ld4AI>.

Strong hardware and model-efficiency gains could materially reduce future data-centre electricity demand but not eliminate uncertainty. The IEA's projected range for 2035 spans from 700 to 1,700 TWh, with 20 percent less energy demand projected in the high-efficiency case when compared to the base case.⁴⁰ Under the circumstances, technical innovation and energy system transformation involve extended development and deployment cycles and, coupled with existing disparities, developing economies are finding themselves at a disadvantage. The short-term effect, therefore, is likely to be additional pressure on current power systems with larger shares of

fossil fuels, with efficiency and infrastructure gains shaping the medium-term trajectory rather than immediately bending the curve. Economic downturns or geopolitical crises, although unpredictable, could have a more immediate effect on the AI- and energy-related megatrends.

Paradoxical Trendlines

Based on the inherent tensions between AI deployment and its implications for energy and climate, the following paradoxes will shape future trajectories:

Table 4: Paradoxical Trendlines and Tensions Between AI and its Impact on Energy and Climate

- AI can improve energy-system management and strengthen climate mitigation and resilience efforts even as it increases energy demand, emissions, and resource pressures through the expansion of data centres.
- The Global South stands to benefit from AI's potential to address longstanding developmental deficits. Yet many countries may be unable to harness these benefits because of constraints related to energy availability, infrastructure, and access to capital.
- While AI presents a transformative economic opportunity for the Global South, the infrastructure that underpins it places additional pressure on already stressed water and energy ecosystems. Perceptions of inequitable allocation of these scarce resources could generate public discontent and opposition to future data centre development in energy- or water-stressed locations.
- Beyond data centres emissions, the AI ecosystems depends on industrial and critical-mineral supply chains that create further emissions and environmental degradation, much of which is concentrated in the Global South.

⁴⁰ "Energy and AI".

- AI can expand access to energy services and provide new tools for climate change mitigation while also potentially widening existing inequalities due to uneven access to technology, talent, and capital.
- Efficiency gains may reduce the energy required for individual AI tasks, while expanded energy supply can support larger data centre deployments. However, as AI becomes cheaper and more widely adopted, overall demand for compute—and therefore electricity—may continue to rise. This dynamic reflects the Jevons paradox, whereby greater efficiency can lead to higher aggregate consumption, potentially increasing pressure on power systems despite improvements in energy intensity.⁴¹

Conclusion

The critical issue discussed in this article is not only how much electricity AI consumes, but whether the terms under which that demand is met align with national development priorities and climate goals, especially in the Global South where systemic disparities shape energy access and climate vulnerability. Relatedly, societal acceptance of AI is becoming a growing governance concern in the Global South. AI infrastructure investment may intensify public anxieties over already constrained electricity and water resources.⁴² Globally, broader concerns about AI's disruptive economic and societal effects have been tilting public perception towards scepticism.⁴³

Given structural differences among Global South countries, there is no one-size-fits-all approach to address the rising impact of AI on energy and climate policies. Yet across contexts, national AI strategies, energy policy, climate commitments, and development priorities need to be aligned and treated as interconnected rather than separate domains. The ability to ingrain these considerations into its deployment in the Global South will ultimately determine whether AI emerges as a positive catalyst and enabler for development or an amplifier of existing inequities.

41 Jevons paradox challenges the common intuition that greater technological efficiency necessarily reduces total resource use. By lowering the per-unit cost of use, efficiency gains can stimulate wider adoption and more intensive deployment, causing aggregate resource consumption to rise. See: Blake Alcott, "Jevons' Paradox," *Ecological Economics* 54, no. 1 (2005): 9–21, <https://doi.org/10.1016/j.ecolecon.2005.03.020>.

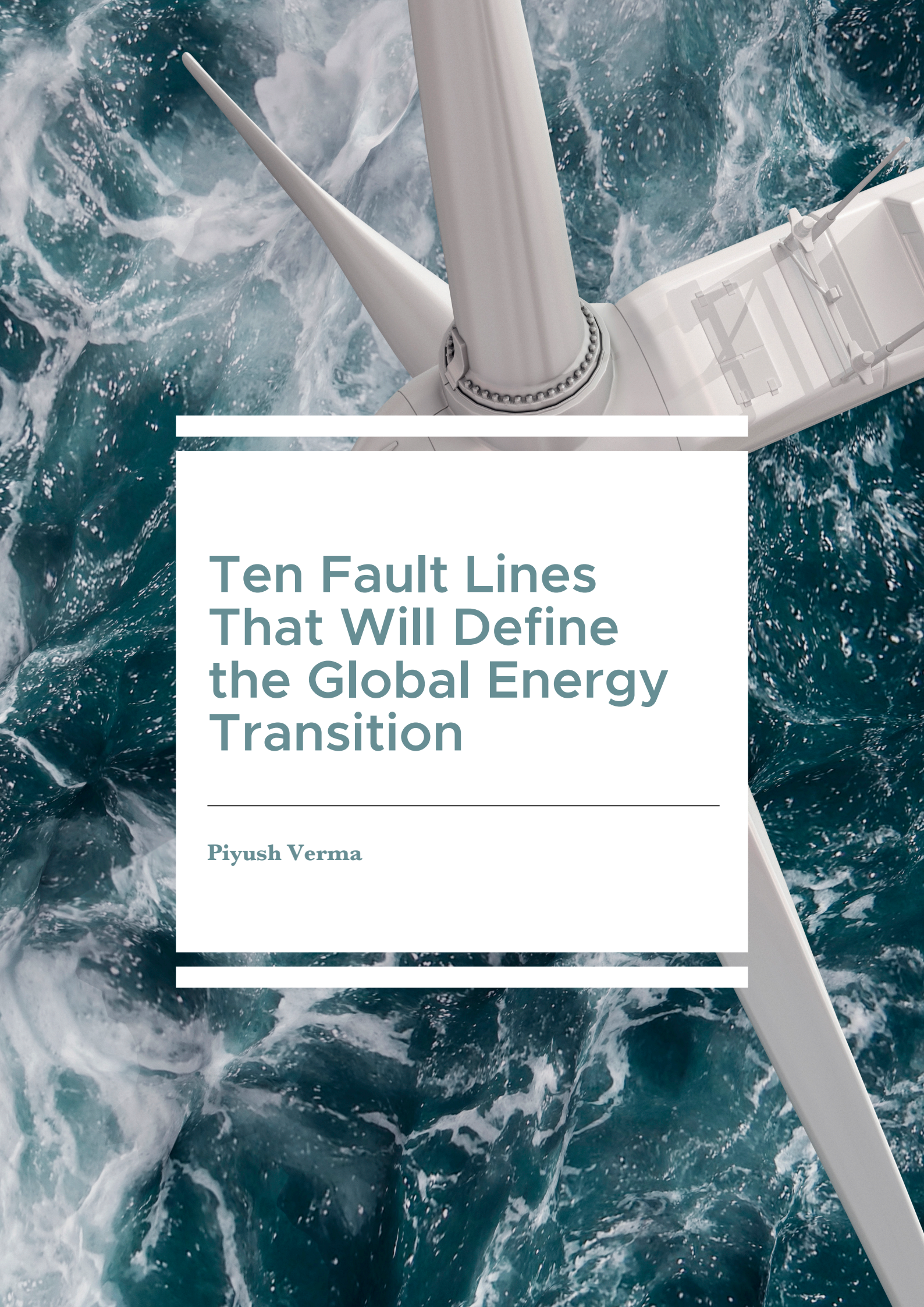
42 "Digital Economy Report 2024: Shaping an Environmentally Sustainable and Inclusive Digital Future".

43 Jacob Poushter, Moira Fagan, and Manolo Corichi, "Concern and Excitement About AI," in *How People Around the World View AI*, Pew Research Center, October 15, 2025, <https://www.pewresearch.org/global/2025/10/15/concern-and-excitement-about-ai/>.

Andreas Kuehn is Senior Fellow, Technology, ORF America.

Cauvery Ganapathy is Fellow, Climate and Energy, ORF Middle East.

The authors acknowledge the use of ChatGPT 5.5 to conduct a preliminary literature survey.



Ten Fault Lines That Will Define the Global Energy Transition

Piyush Verma

Global energy and climate policy is entering a period of deepening divergence. The world is not abandoning the energy transition, but countries increasingly disagree on what the transition should prioritise, how fast it should move, who should pay, and who should benefit from the new energy economy. What is emerging is not a singular global transition, but several of them, across various and overlapping domains: security, industry, finance, minerals, digitalisation, and resilience-building. These transitions are progressing at different speeds across regions and are creating new fault lines between advanced economies, emerging markets, fossil fuel exporters, mineral-rich countries, climate-vulnerable states, and technology powers.

These divergences can be understood through three analytical lenses: security and geopolitics; equity and development; and systems and technology (see Figure 1). How these divergences are managed will determine not whether the energy transition advances, but at what pace, on what terms, and for whose benefit. For the Global South, the stakes are particularly high: the transition could unlock industrialisation, resilience, and strategic bargaining power, but it could also reproduce older patterns of dependency through new technologies, standards, minerals, and financial asymmetries.

1 International Energy Agency, “Global Energy Review 2026,” April 20, 2026, <https://www.iea.org/reports/global-energy-review-2026/key-findings>.

Figure 1: Global Energy Transition Tensions and Implications for the Global South

Cluster	Divergence	What is deepening?	Global South implication	2026 watch point
 Security and geopolitics	1 Energy security vs climate ambition	Clean energy is expanding, but fossil fuels remain central to affordability and security	Import dependence, fuel-price shocks, and fiscal stress	 Oil/LNG volatility, conflict, and energy dominance politics
	2 Green industrial competition vs cooperation	Climate policy is increasingly becoming industrial policy	Manufacturing opportunity, but risk of exclusion from subsidy races	 Local-content rules and clean-tech trade disputes
	3 Old energy powers vs new energy powers	Power is shifting from oil and gas alone to minerals, manufacturing, grids, data, and finance	Chance to move up value chains	 Mineral deals, hydrogen corridors, and processing investments
	4 Mineral access security vs mineral value security	Consumer countries seek secure and diversified mineral supplies, while producer countries seek value addition and greater control over clean-energy supply chains	Opportunity to turn resource ownership into processing, jobs, and bargaining power, but risk of remaining trapped as raw-material suppliers	 Export restrictions, local processing mandates, and strategic mineral partnerships
 Equity and development	5 Rich-country rules vs developing-country capabilities	Climate rules are moving faster than compliance capacity	Higher reporting, verification, and technology costs	 CBAM implementation and climate-linked trade rules
	6 Investment growth vs finance inequality	Clean energy investment is rising but remains unevenly distributed	Higher cost of capital slows deployment	 MDB reform, guarantees, and local-currency finance
	7 Mitigation vs adaptation	Emissions reduction still dominates despite rising climate damages	Resilience, water, food, and disaster finance remain underfunded	 Adaptation finance, loss and damage, and disaster finance
	8 Carbon accounting vs development accounting	Climate metrics undercut jobs, access, affordability, and industrialisation	Domestic legitimacy depends on development outcomes	 Just transition design and social backlash
 Systems and technology	9 Technology optimism vs infrastructure reality	Technologies are available, but grids, storage, ports, skills, and utilities lag	Risk of stranded renewables and unreliable power	 Grid investment, storage, and permitting reform
	10 AI demand vs climate planning	AI and data centres are reshaping electricity demand	Opportunity for green digital infrastructure, but risk of power and water stress	 Efficiency rules, clean-power procurement, and grid planning

Source: Author's own analysis. Image generated through multiple prompts on ChatGPT 5.5.

Security and Geopolitics

The first divergence is between energy security and climate ambition. Since the COVID-19 pandemic, Russia's invasion of Ukraine, and disruptions across the Middle East and Red Sea region, energy security has moved from a policy concern to a strategic organising principle. Governments are no longer speaking only about decarbonisation, but are also focusing on energy sovereignty, strategic reserves, domestic production, supply chain resilience, and energy dominance. This has created a more complicated transition landscape: clean energy is expanding

rapidly, but fossil fuels remain deeply embedded in the global system. In 2025, low emissions sources supplied nearly 60 percent of global energy demand growth, with solar photovoltaic alone providing more than one fourth of that increase.¹ Yet the demand for oil, gas, and coal that year did not fall, and instead increased. For the Global South, this divergence is immediate and practical: energy security means affordable fuel, reliable electricity, fertiliser supply, industrial power, and protection from imported inflation.² A sudden increase in oil or gas prices can quickly become a balance-of-payments crisis, a food-price shock, or a fiscal burden.

2 Piyush Verma, "Smaller South Asian States Pay the Price for Hormuz Closure," ORF America, June 3, 2026, <https://orfamerica.org/orf-america-comments/smaller-south-asian-states-pay-the-price-for-hormuz-closure>.

Many developing countries, therefore, face a difficult balancing act: accelerating clean energy deployment without triggering a disorderly exit from fossil fuels before affordable and reliable alternatives become available at scale.

A second divergence is between green industrial competition and global cooperation. The 2010s were shaped by climate diplomacy and falling clean-technology costs, while the 2020s are increasingly being framed by green industrial strategy. The United States' (US) Inflation Reduction Act, the European Union's (EU) Green Deal Industrial Plan, China's clean-tech manufacturing scale, India's production-linked incentives, Japan's and South Korea's hydrogen and industrial decarbonisation strategies, and Gulf investments in hydrogen and low-carbon fuels all reflect this shift. Climate policy is no longer only environmental policy; it has become industrial policy.³

For the Global South, this creates both opportunity and risk. Supply-chain diversification could help certain economies attract investment in solar manufacturing, battery components, critical minerals processing, green hydrogen, low-carbon steel, and clean industrial clusters. However, green industrial policy could also

become a subsidy race that poorer countries cannot join. Advanced economies can mobilise large fiscal packages and cheap capital, while many developing countries face debt stress, higher borrowing costs, and limited fiscal space.⁴ Unless green industrial strategies are linked to technology partnerships, concessional finance, and market access, they may deepen global inequality even as they accelerate decarbonisation.

The third divergence is between old and new energy powers. The 20th-century energy order was built around oil and gas reserves, pipelines, shipping routes, refineries, and major consuming markets. The emerging energy order is more fragmented and multi-dimensional.⁵ Power is no longer determined only by who controls fuels, but also by who are on top of clean-technology manufacturing, grid equipment, battery supply chains, nuclear technologies, hydrogen corridors, electricity markets, finance, standards, and digital infrastructure. This shift is changing the geography of energy influence.⁶ Countries with large domestic markets, strong manufacturing ecosystems, abundant renewable resources, strategic capital, or control over key technologies are becoming more important in shaping the next phase of the transition.

3 Nikos Tsafos, "How the Energy Transition Will Rewire the World," Center for Strategic & International Studies, May 12, 2022, <https://www.csis.org/analysis/how-energy-transition-will-rewire-world>.

4 Medha Prasanna, Caroline Arkalji, and Hansika Nath, "IBSA+Indonesia Energy Transitions: Mapping Shared Ambitions and Challenges," ORF America, July 20, 2025, <https://orfamerica.org/newresearch/ibsa-indonesia-energy-transitions-shared-ambitions-and-challenges>.

5 Andreas Goldthau, Martin Keim, and Kirsten Westphal, "The Geopolitics of Energy Transformation: Governing the Shift: Transformation Dividends, Systemic Risks and New Uncertainties," SWP, 2018, <https://www.ssoar.info/ssoar/handle/document/60135>.

6 Jorge Arbache, "The Role of Trade in Global Energy Transition," CEBRI, November 6, 2025, <https://cebri.org/en/doc/400/the-role-of-trade-in-the-global-energy-transition>.

For the Global South, this creates a wider strategic opening than the fossil-fuel era allowed. Demand-rich economies can use their market size to attract manufacturing and investment; renewable-rich economies can become exporters of green molecules or clean industrial products; and technologically ambitious economies can build capabilities in grids, storage, digital energy, and clean manufacturing. This opportunity, however, will depend on whether countries can move from being passive adopters of technology to active shapers of standards, markets, infrastructure, and value chains.

The fourth divergence is between mineral access security and mineral value security. While mineral access security refers to the ability of consuming countries to secure reliable and diversified supplies of critical minerals, mineral value security refers to the ability of producer countries to capture more economic, industrial, and strategic value from those minerals at home. This is a narrower but increasingly consequential fault line within the new energy order. Advanced economies increasingly define mineral security as access to lithium, cobalt, nickel, graphite, copper, manganese, and rare earths for batteries, electric vehicles, grids, and clean manufacturing. Producer countries, however, are beginning to define their own security differently: not merely as exporting raw materials, but as securing domestic value addition, processing capacity, jobs, infrastructure,

environmental safeguards, and greater control over clean-energy supply chains.⁷

This contest is becoming more consequential as mineral demand accelerates: lithium demand rose by nearly 30 percent in 2024, while demand for nickel, cobalt, graphite, and rare earths rose by 6–8 percent, underscoring how quickly minerals are becoming strategic assets.⁸ For countries such as Indonesia, the Democratic Republic of Congo, Zambia, Chile, Argentina, Namibia, and South Africa, this could become a historic bargaining opportunity. However, this will require stronger institutions, financing, processing capacity, and negotiating power; otherwise, they risk remaining trapped in a cleaner version of the old extractive economy, where the resources are local but the value is captured elsewhere.

Equity and Development

The first divergence in this cluster is between rich-country climate rules and developing-country capabilities. The Paris Agreement created a universal climate framework, but implementation is increasingly being shaped by domestic and regional instruments such as carbon pricing, climate disclosure rules, green product standards, sustainable finance taxonomies, deforestation regulations, and carbon border measures. The EU's Carbon Border Adjustment Mechanism (CBAM), which entered its definitive regime in 2026 after a

7 International Energy Agency, “The Role of Critical Minerals in Clean Energy Transitions,” May 5, 2021, <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>; United Nations Trade & Development, “Critical Minerals, Critical Decisions: Industrial Policy for the Energy Transition,” United Nations Trade & Development, March 9, 2026, <https://unctad.org/publication/critical-minerals-critical-decisions-industrial-policy-energy-transition>.

8 International Energy Agency, “Global Critical Minerals Outlook 2025,” May 21, 2025, <https://www.iea.org/reports/global-critical-minerals-outlook-2025>.

transitional phase from 2023 to 2025, is the clearest example of this shift.⁹ For Europe, the CBAM is a climate-integrity tool designed to address carbon leakage.¹⁰ For many developing countries, however, it is also a test of capacity. Exporters now need product-level emissions data, verification systems, cleaner production technologies, administrative readiness, and access to low-carbon energy.¹¹ The divergence is therefore increasingly about the gap between the pace at which climate-linked market rules are being introduced and the capacity of developing-country firms and institutions to meet these regulations. Well-designed climate trade partnerships could help upgrade industries and create new export opportunities, but rules introduced unilaterally, without adequate consultation, transition periods, or support for compliance, could become market-access barriers for firms and countries that lack finance, technology, and standards infrastructure.

The second divergence is between rising clean-energy investment and unequal access to finance. Global energy investment is projected at around US\$3.3 trillion in 2025, with clean-energy technologies and infrastructure attracting roughly twice as much capital as fossil fuels.¹² Yet this investment boom remains unevenly distributed. Many developing countries have abundant renewable resources and fast-growing energy demand, but they face higher borrowing costs, currency risks, sovereign debt pressures, weak utilities, and limited fiscal space.¹³

Developing countries need around US\$1.7 trillion annually in renewable energy investment—including grids, storage, and efficiency—but attracted only US\$544 billion in 2022, and more recent International Energy Agency (IEA) data suggest that emerging markets and developing economies outside China are still receiving only a small fraction

9 European Commission, “Carbon Border Adjustment Mechanism,” https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en.

10 Antoine Dechezleprêtre, and Antton Haramboure, “EU Carbon Border Adjustment Mechanism: What Is It, How Does it Work and What Are the Effects?,” OECD, March 21, 2025, <https://www.oecd.org/en/blogs/2025/03/eu-carbon-border-adjustment-mechanism-what-is-it-how-does-it-work-and-what-are-the-effects.html>.

11 Simona Sagone and Maurizio Cellura, “The Carbon Border Adjustment Mechanism from Developing Countries’ Perspective: A Systematic Literature Review on Challenges and Opportunities for the Mediterranean Basin,” *Energy Strategy Reviews*, November 2025, <https://www.sciencedirect.com/science/article/pii/S2211467X25002470>; Bruce Byiers and Alfonso Medinilla, “The EU’s Carbon Border Adjustment Mechanism and Developing Countries: Threats, Opportunities and Strategic Responses,” European Centre for Development Policy Management, November 2024, <https://ecdpm.org/application/files/4817/3210/5775/EU-Carbon-Border-Adjustment-Mechanism-Developing-Countries-Threats-Opportunities-Strategic-Responses-ECDPM-Discussion-Paper-380-2024.pdf>.

12 International Energy Agency, “World Energy Investment 2025,” June 5, 2025, <https://www.iea.org/reports/world-energy-investment-2025>.

13 International Monetary Fund, “Debt Vulnerabilities and Financing Challenges in Emerging Markets and Developing Economies—An Overview of Key Data Strategy, Policy, & Review Department,” Strategy, Policy, & Review Department, February 20, 2025, <https://www.elibrary.imf.org/view/journals/007/2025/002/article-A001-en.xml>.

of global clean energy spending.¹⁴ This makes finance one of the deepest structural divides in the global transition. The technology may be increasingly affordable, but the delivered cost of clean energy is shaped by the price of capital. For the Global South, the question is not only how to attract more investment, but how to secure concessional finance, guarantees, local currency lending, and risk-sharing instruments that can turn renewable potential into bankable projects.

The third divergence is between priorities for mitigation and those for adaptation and resilience. Global climate policy has historically focused on emissions reduction because mitigation is measurable and directly linked to temperature goals. However, for climate-vulnerable countries, adaptation is not a secondary agenda; it is a pressing development necessity. Floods, heat stress, cyclones, drought, water insecurity, crop losses, and sea-level rise are already imposing costs on infrastructure, public budgets, food systems, and livelihoods.

The UN Environment Programme estimates that developing countries will need some US\$310 billion per year for adaptation by 2035 based on modelled costs, while international public adaptation finance flows were only US\$26 billion in 2023.¹⁵ This means adaptation

finance needs are roughly 12 to 14 times larger than current flows. The divergence is therefore between a global climate agenda still dominated by future emissions reductions and the immediate resilience needs of countries already facing climate impacts. For the Global South, climate policy cannot be limited to only renewables, electric vehicles, hydrogen, and carbon markets; it must also include resilient infrastructure, cooling, early-warning systems, water security, disaster finance, climate-resilient agriculture, and insurance.

The fourth divergence is between carbon accounting and development accounting. Global climate governance measures progress through emissions reductions, carbon intensity, carbon prices, net-zero dates, and Scope 1, 2, and 3 emissions.¹⁶ These tools are necessary, but they do not fully capture what matters politically in many developing countries: jobs, energy access, affordability, industrialisation, export competitiveness, and resilience. A coal phase-down may look efficient in a carbon model, but it may be difficult in a region dependent on coal jobs, railway revenues, local industry, and state finances. A carbon price may improve efficiency, but without redistribution it can raise costs for poor households and small firms.¹⁷ For developing countries, the central question is not simply how much carbon is reduced, but who

14 United Nations Trade & Development, “UNCTAD Calls for Urgent Support to Developing Countries to Attract Massive Investment in Clean Energy,” United Nations Trade & Development, July 5, 2023, <https://unctad.org/news/unctad-calls-urgent-support-developing-countries-attract-massive-investment-clean-energy>; International Energy Agency, “World Energy Investment 2025,” June 11, 2025, https://unfccc.int/sites/default/files/resource/Cecilia%20Tam_Updated.pdf.

15 United Nations Environment Programme, *Adaptation Gap Report 2025*, October 29, 2025, <https://www.unep.org/resources/adaptation-gap-report-2025>.

16 Scope 1 emissions are direct emissions from owned or controlled sources; Scope 2 emissions are indirect emissions from purchased electricity, steam, heating, or cooling; and Scope 3 emissions are other indirect emissions across a company’s value chain.

17 International Monetary Fund, “World Economic Outlook, October 2020 A Long and Difficult Ascent,” October 13, 2020, <https://www.elibrary.imf.org/display/book/9781513556055/ch03.xml>.

pays, who benefits, who gets jobs, who owns technology, and who becomes more resilient. Climate policy will gain legitimacy in the Global South only if it moves beyond carbon reduction alone and is visibly connected to development outcomes, industrial upgrading, affordability, and public investment.

Systems and Technology

The first divergence in this category is between technology optimism and infrastructure reality. The global energy transition is increasingly framed around the rapid scaling of solar, wind, batteries, green hydrogen, carbon capture, nuclear, digitalisation, and advanced grid technologies. Yet the bottlenecks are no longer only technological; they are increasingly infrastructural and institutional.¹⁸ Clean technologies may be available and increasingly cost-competitive, but their deployment depends on transmission lines, distribution networks, power transformers, storage, ports, land, permitting systems, skilled workers, financially viable utilities, and regulatory capacity. Electricity demand grew by nearly 3 percent in 2025, more than twice the rate of overall energy demand, reflecting the growing importance of electrification.¹⁹ Yet electricity systems are not expanding at the same pace everywhere. For many Global South countries, the challenge is especially complex because they are trying to expand access, improve reliability, reduce distribution losses, integrate renewables, and electrify transport and industry

simultaneously. The opportunity is significant: countries that invest early in grids, storage, digital system operations, and regional power trade can leapfrog to cleaner and more resilient electricity systems. But where infrastructure lags, renewable ambition can quickly turn into stranded capacity, curtailment, unreliable supply, and slower industrial growth.

The second divergence is between artificial intelligence (AI)-driven electricity demand and existing climate planning. For years, digitalisation was treated mainly as a climate and energy-efficiency tool through smart meters, digital twins, forecasting, demand management, and grid optimisation. That remains true, but the rapid growth of AI and data centres is changing the outlook for electricity demand. The IEA projects that global data-centre electricity consumption could more than double to around 945 TWh by 2030, slightly more than Japan's current electricity consumption, with AI as a major driver of this growth.²⁰ This creates a new planning challenge: digital infrastructure is essential for modern economies, but it also requires reliable power, cooling, water, land, and grid capacity.²¹

For the Global South, this divergence presents both a strategic opportunity and a resource-management risk. Countries with abundant renewables, available land, improving grids, and strong digital connectivity could attract green data infrastructure and build new economic capabilities. But if the growth of

18 International Energy Agency, "Electricity Grids and Secure Energy Transitions," October 17, 2023, <https://iea.blob.core.windows.net/assets/ea2ff609-8180-4312-8de9-494bcf21696d/ElectricityGridsandSecureEnergyTransitions.pdf>.

19 International Energy Agency, "Global Energy Review 2026."

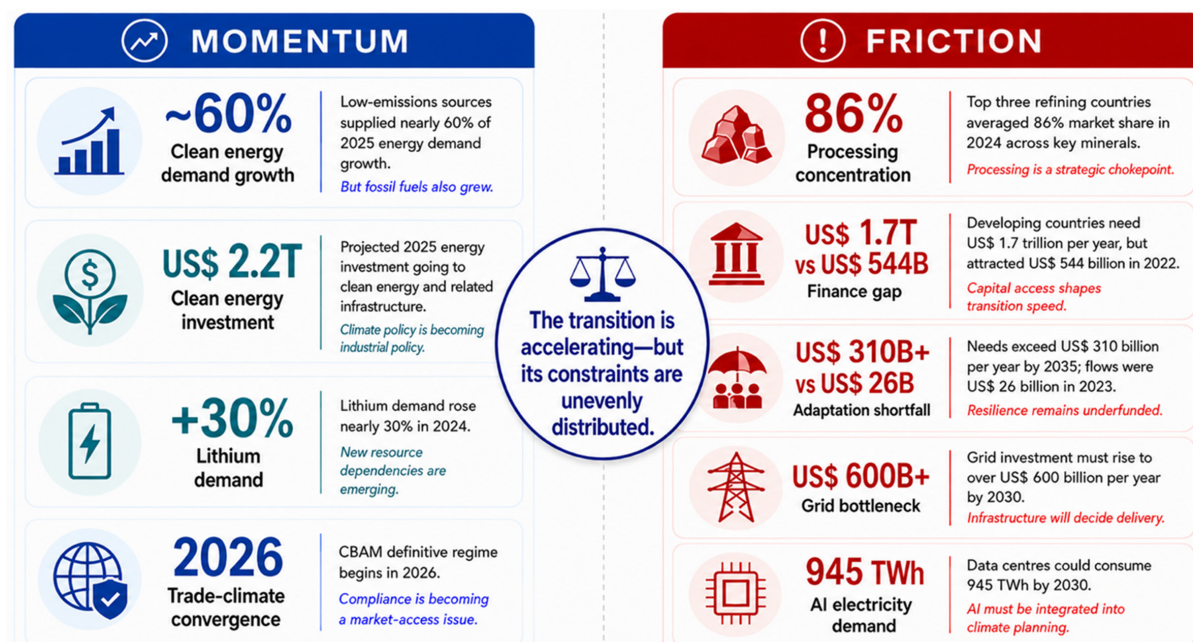
20 International Energy Agency, "Energy and AI," April 10, 2025, <https://www.iea.org/reports/energy-and-ai>.

21 Medha Prasanna, "Why the Hyperscale Data Center Boom Requires U.S.-India Collaboration," ORF America, October 6, 2025, <https://orfamerica.org/orf-america-comments/hyperscale-data-center-boom-us-india-cooperation>.

data centres is poorly planned, it could compete with households, public services, agriculture, and industry for scarce electricity and water. In 2026, the key question will be whether AI infrastructure is integrated into national energy

planning through efficiency standards, clean-power procurement, co-located renewables, grid investment, water-use safeguards, and demand-response requirements.

Figure 2: The Global Energy Transition in 2026: Momentum vs. Friction



Source: Author's own analysis. Image generated through multiple prompts on ChatGPT 5.5.

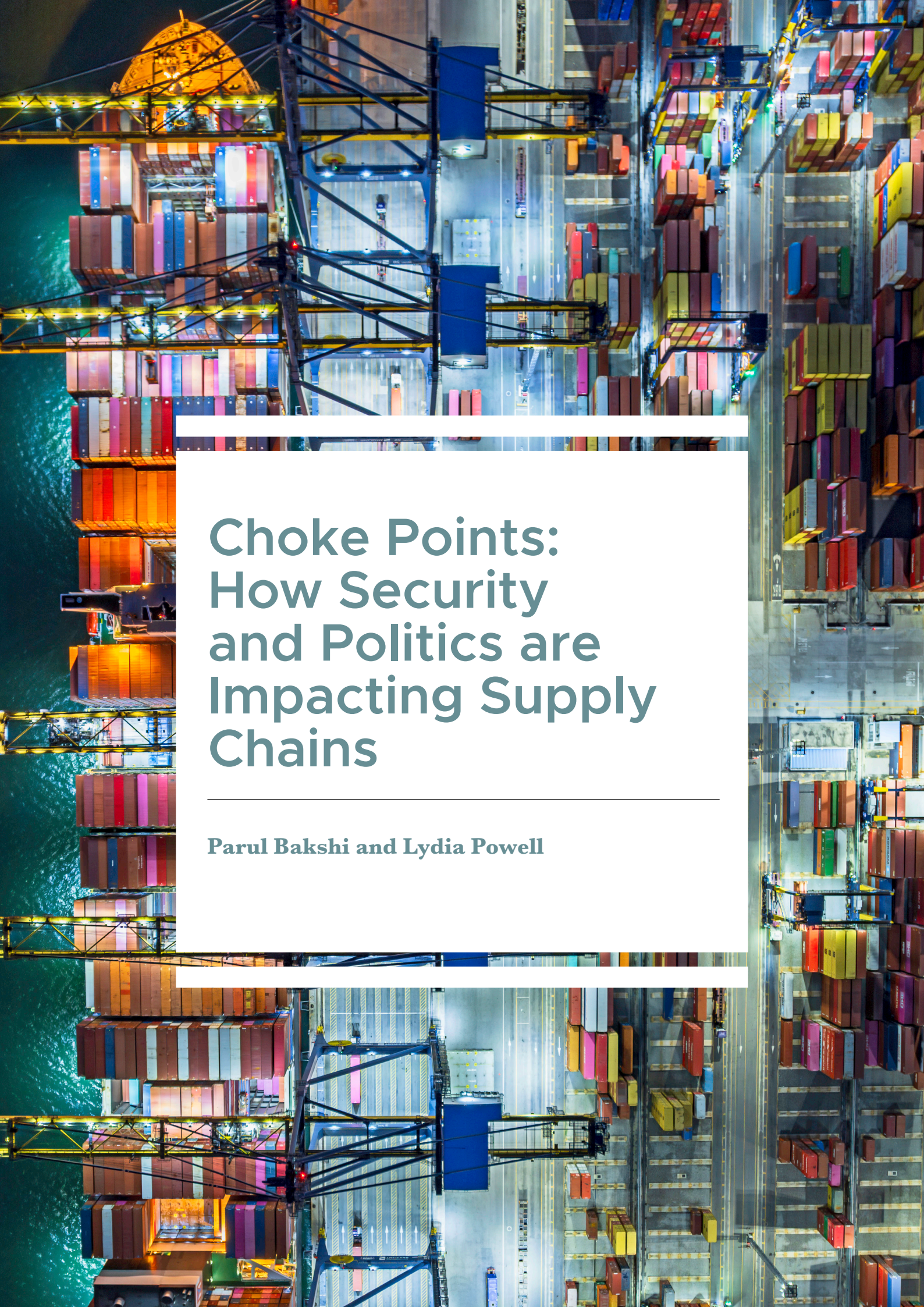
Conclusion

The divergences discussed in this article suggest that the primary challenge in 2026 will not be whether the energy transition continues. The deeper question is whether it becomes more cooperative, equitable, and systemically planned, or whether it fragments into competing national strategies, contested trade rules, unequal financing conditions, and new forms of resource dependency. For the Global South, the stakes are especially high. The transition could

unlock industrialisation, jobs, greater resilience, and new strategic bargaining power. It could also, if poorly designed, reproduce old patterns of dependency through new technologies, new minerals, new standards, and new financial asymmetries.

The task ahead is not to force a single global transition, but to build enough convergence across unequal transitions that security, climate ambition, industrial strategy, and development no longer pull in opposite directions.

Piyush Verma is Senior Fellow, Energy and Climate Programme, ORF America.

An aerial, high-angle photograph of a port at night. A large container ship is docked on the left, its deck filled with stacks of colorful shipping containers. A large gantry crane is positioned over the ship. The right side of the image shows a vast yard filled with numerous stacks of containers, organized in neat rows. The scene is illuminated by the port's lights, creating a vibrant contrast against the dark night sky and the dark water of the harbor.

Choke Points: How Security and Politics are Impacting Supply Chains

Parul Bakshi and Lydia Powell

On 4 March 2026, Iranian forces declared the Strait of Hormuz closed following the United States (US)-Israel attack on Iran on 28 February. The disruption has had serious ramifications for global energy security. In 2025, nearly 15 million barrels of crude oil per day—around 34 percent of global crude oil trade—passed through the Strait, with most exports destined for Asian markets.¹ China and India alone received 44 percent of these exports.² Yet the closure of Hormuz is not the only recent incident to bring energy security, diversification, and the energy-climate-trade nexus to the forefront.

Over the past decade, three structural shifts have been reordering global energy trade, encompassing not only traditional oil and gas flows but also the rapidly growing cross-border trade in electricity and clean energy goods.

First, supply chains in energy, clean technology, and critical raw materials have become increasingly securitised, with states treating dependencies as national security liabilities rather than economic efficiencies. Second, trade corridors have diversified, driven by geopolitical tensions and infrastructure competition. Third, the relationship between energy security, climate policy, and trade governance has evolved into an increasingly interconnected nexus, where a security shock in energy markets can immediately reprice climate commitments and reshape trade flows, while trade policy instruments such as carbon border tariffs feed back into both energy investment decisions and geopolitical posturing.

The Hormuz disruption has underscored the vulnerability of critical maritime chokepoints to geopolitical tensions and their potential to transmit shocks across supply chains and commodity

1 “Strait of Hormuz - Factsheet,” International Energy Agency, February 2026, <https://www.iea.org/about/oil-security-and-emergency-response/strait-of-hormuz>.

2 “Strait of Hormuz - Factsheet”.

markets, with repercussions similar to those observed during the three-year COVID-19 pandemic starting in 2020 and the Russia-Ukraine conflict that erupted in 2022.

This article examines how these structural shifts and trends are not coincidental but causally linked and what their entrenchment means, particularly for the Global South, which sits at the sharpest edge of all three.

The Uneven Costs of Geo-Economic Fragmentation

The logic of securitisation—treating supply disruptions as existential threats that warrant state intervention—is not new to energy markets. The 1973 Arab oil embargo and the 1979 Iranian Revolution produced lasting institutional responses—among them, strategic petroleum reserves, the International Energy Agency’s (IEA) emergency-sharing system, the institutionalisation of Organization of the Petroleum Exporting Countries (OPEC), the petrodollar architecture, and a generation of energy policies built around import diversification. What is new is the breadth of securitisation; its extension beyond fossil fuel supplies to clean technology supply chains, critical raw materials, and the industrial base of the energy transition itself.

The COVID-19 pandemic exposed the fragility of global supply chains and the concentration of essential goods production in a handful of countries. Russia’s invasion of Ukraine in

2022 demonstrated how energy dependencies could be weaponised within weeks, forcing policy reversals, particularly in Europe. At the same time, intensifying US-China strategic competition increasingly recast economic interdependence as strategic vulnerability, most visibly in semiconductors, electric vehicles, and battery technology. The 2026 Hormuz crisis, in this sequence, underscored rather than initiated this trend.

Trade barriers, which generally declined throughout the 20th century, have reversed course over the past decade.³ The International Monetary Fund (IMF) defines this phenomenon as “geo-economic fragmentation”: a policy-driven reversal of economic integration, of which international trade is a central component.⁴ The resulting domestic content mandates, friend-shoring policies, and technology export controls risk constraining the diffusion of clean technologies, especially across the Global South.

For energy systems specifically, this reversal is particularly consequential. Fragmentation in the trade of critical energy-transition minerals such as copper, nickel, cobalt, and lithium would increase the cost of the transition. Since these minerals are geographically concentrated and not easily substituted, disrupting their trade could lead to sharp swings in prices, suppressing investment in renewables and EV production.

Critical mineral markets have become more concentrated; for copper, lithium, nickel, cobalt, graphite, and rare-earth elements, the average

3 Marijn A. Bolhuis et al., “The Costs of Geoeconomic Fragmentation,” International Monetary Fund, June 2023, <https://www.imf.org/en/publications/fandd/issues/2023/06/the-costs-of-geoeconomic-fragmentation-bolhuis-chen-kett>.

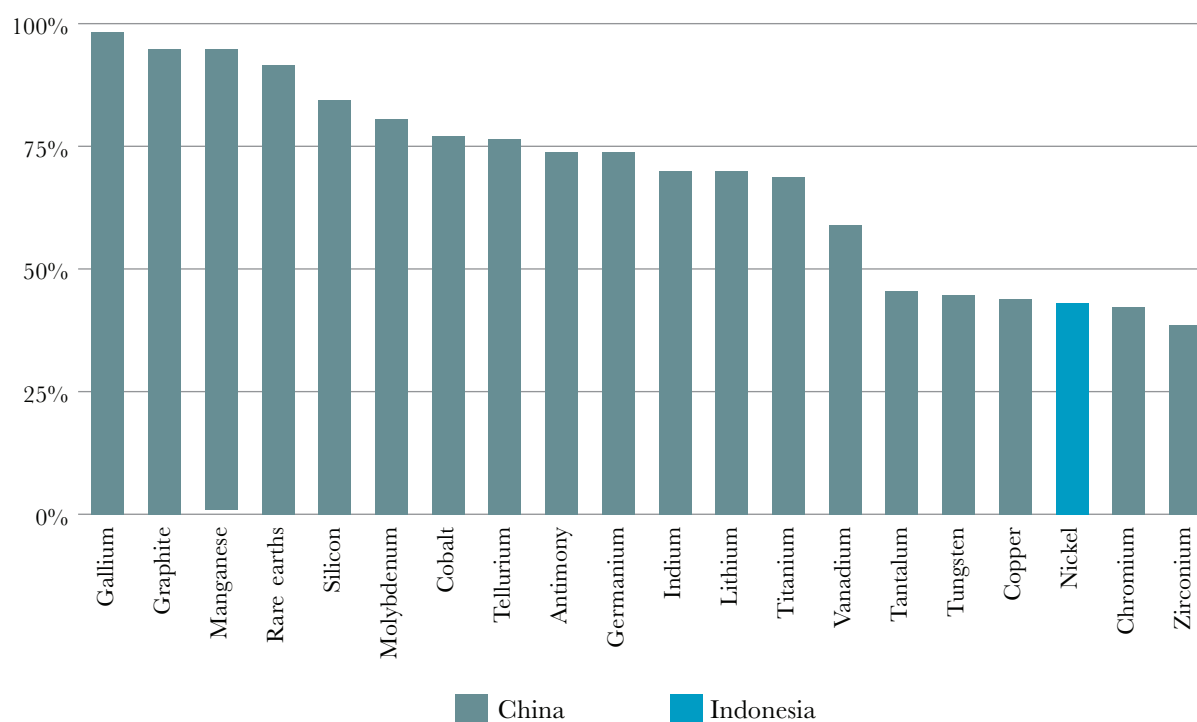
4 Shekhar Aiyar et al., “Geo-Economic Fragmentation and the Future of Multilateralism,” IMF Staff Discussion Notes 2023, no. 001 (2023): 1, <https://doi.org/10.5089/9798400229046.006>.

market share of the top three refining nations rose to 86 percent in 2024 from around 82 percent in 2020, with almost all supply growth coming from the single top supplier—Indonesia for nickel, and China for all others.⁵

percent of global solar panel production across the entire value chain—polysilicon, wafers, cells, and modules—meaning that the clean energy transition is structurally dependent on a geographically concentrated supply chain.⁶

The concentration extends beyond minerals into manufacturing. China controls over 80

Figure 1: Share of Top Producers of Refined Energy-Related Strategic Minerals



Source: IEA⁷

5 “Critical Minerals – A New Frontier for Global Energy Security,” International Energy Agency, <https://www.iea.org/topics/critical-minerals>.

6 “Executive Summary – Solar PV Global Supply Chains,” July 7, 2022, <https://www.iea.org/reports/solar-pv-global-supply-chains/executive-summary>.

7 “Executive Summary – Global Critical Minerals Outlook 2025 – Analysis,” International Energy Agency, June 2025, <https://www.iea.org/reports/global-critical-minerals-outlook-2025/executive-summary>.

In December 2024, China restricted exports of gallium, germanium, and antimony to the United States, followed in early 2025 by further restrictions covering tungsten, tellurium, bismuth, indium, molybdenum, and seven heavy rare-earth elements.⁸ Currently, more than half of a broader group of energy-related minerals are subject to some form of export controls. While some of these controls were partially suspended under the November 2025 US-China trade truce, licensing requirements remain and the broader export control architecture is intact.⁹ These are not merely commercial decisions; they are instruments of strategic statecraft, accelerating a race among consuming nations to secure alternative sources of supply.

States have responded to these concentration risks through an expanding body of industrial policy legislation. The US Inflation Reduction Act (IRA, 2022) operationalised supply-chain securitisation through domestic content requirements for clean energy tax credits, linking federal subsidy eligibility to sourcing from allied nations and explicitly excluding supply chains tied to designated foreign adversaries,

effectively restructuring solar, battery, and EV supply chains around geopolitical alignment rather than economic efficiency.¹⁰ The model is spreading, and post-Hormuz IRA-style domestic content logic is being actively discussed across countries as a template for energy transition resilience.

The EU Carbon Border Adjustment Mechanism (CBAM), which entered its definitive phase on 1 January 2026, is the most direct institutional expression of the energy-climate-trade nexus.¹¹ By imposing carbon costs on approximately €50 billion in annual imports across six sectors—cement, iron and steel, aluminium, fertilisers, electricity, and hydrogen—CBAM links trade access to climate performance.¹² It is simultaneously a climate instrument, a trade policy, and an industrial competitiveness measure. It is the first fully operational policy to begin charging costs based on the emissions intensity of imported goods, marking the first time that the price of carbon in a certain jurisdiction has been externalised beyond its borders.¹³ CBAM is the clearest example yet of the energy-climate-trade nexus hardening into regulatory architecture.

8 “Executive Summary – Global Critical Minerals Outlook 2025 – Analysis”.

9 “Fact Sheet: President Donald J. Trump Strikes Deal on Economic and Trade Relations with China,” The White House, November 1, 2025, <https://www.whitehouse.gov/fact-sheets/2025/11/fact-sheet-president-donald-j-trump-strikes-deal-on-economic-and-trade-relations-with-china/>.

10 U.S Department of Energy, “Inflation Reduction Act of 2022,” Energy.Gov, May 11, 2026, <https://www.energy.gov/edf/inflation-reduction-act-2022>.

11 “CBAM Successfully Entered into Force on 1 January 2026,” Taxation and Customs Union, January 14, 2026, https://taxation-customs.ec.europa.eu/news/cbam-successfully-entered-force-1-january-2026-2026-01-14_en.

12 Raj Deshmukh, “CBAM 2026: Complete Guide to EU Carbon Border Tax Reshaping Global Trade,” Informed Clearly, April 14, 2026, <https://informedclearly.com/en/environment/48223/cbam-carbon-border-tax-eu-guide-2026>.

13 “The Impact of the EU’s CBAM on Business and the Carbon-Pricing Landscape,” World Economic Forum, December 15, 2025, <https://www.weforum.org/stories/2025/12/eu-cbam-impact-business-carbon-pricing-landscape/>.

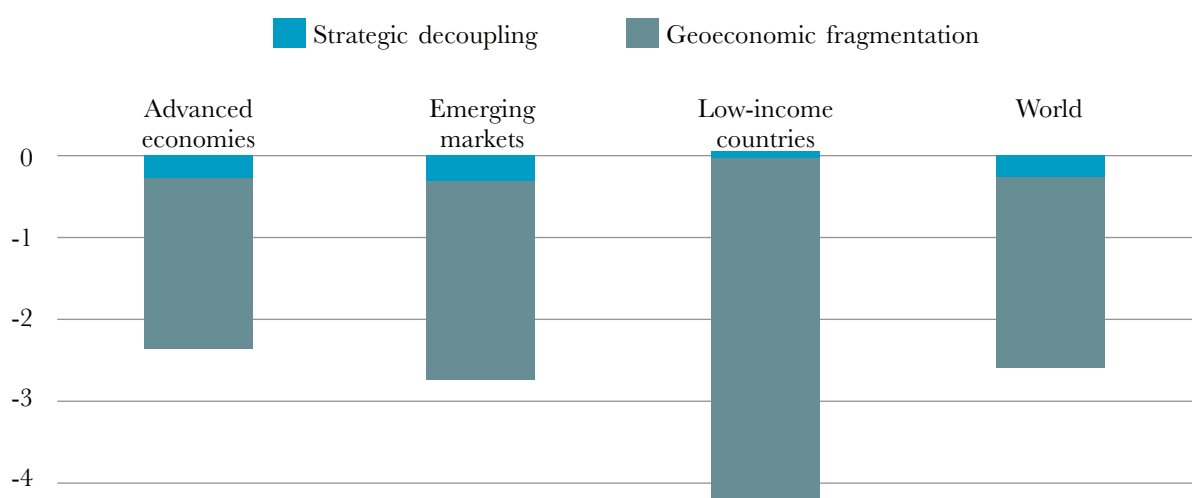
The Global South Asymmetry

The costs of securitisation are not distributed evenly. Financing costs in emerging economies remain up to seven times higher than in advanced markets, exacerbating a US\$2.2-trillion annual investment gap for clean energy.¹⁴

For the Global South, securitisation compounds this disadvantage in a specific way: legislative instruments of the North such as IRA, CBAM, and the EU Net-Zero Industry Act are designed to serve Northern industrial policy objectives, but their effects fall heavily on Southern export economies.

Figure 2: The Costs of Fragmentation

A world split into two exclusive trading blocs would result in permanent losses to global GDP, most severely in low-income countries. (permanent real GDP losses, percent)



Source: IEA¹⁵

For example, under CBAM, countries like India, Egypt, South Africa, and Morocco face a carbon tariff on their exports of steel, cement, and fertilisers—sectors where decarbonisation requires capital investment that those economies cannot readily mobilise. The instrument is already generating reactive policy responses. India introduced greenhouse gas emissions-intensity targets for an additional

208 industrial units in January 2026, bringing petroleum refineries, petrochemicals, textiles, and secondary aluminium into its carbon market as a CBAM resilience measure.¹⁶ Yet reactive carbon pricing under fiscal pressure is not the same as a genuine just transition.

Emerging markets and low-income countries tend to be most at risk from trade and

14 “Fostering Effective Energy Transition 2025,” World Economic Forum, June 18, 2025, <https://www.weforum.org/publications/fostering-effective-energy-transition-2025/in-full/introduction-c2a484c547/>.

15 Bolhuis et al., “The Costs of Geoeconomic Fragmentation”.

16 Ministry of Environment, Forest and Climate Change, Government of India, <https://www.pib.gov.in/www.pib.gov.in/Pressreleaseshare.aspx?PRID=2217239>.

technology fragmentation. Because they remain further from the technological frontier, they lose disproportionately when access to embodied technology, knowledge spillovers, and R&D is restricted. The clean energy transition, premised on global supply chains and comparative advantage, is thus being re-engineered as a theatre of strategic competition.

As the World Economic Forum's Global Risks Report 2026 notes, geoeconomic confrontation is now a key driver of economic and industrial policy, and the broader signal from recent disruptions is a shift towards resilience and diversification across global supply chains.¹⁷ Supply chain securitisation does not only reshape what is produced and where, it reshapes how goods move. As states treat energy and material dependencies as strategic liabilities, the corridors through which energy travels become as contested as the commodities themselves.

Diversification of Trade Corridors

A succession of multi-scalar supply-chain shocks over the last decade has structurally destabilised global trade corridors, precipitating significant contractionary pressures on aggregate economic growth. An estimated 15 percent of

global trade flows were disrupted by geopolitical tensions and climate-related events during this period.¹⁸ In 2024 alone, systemic supply-chain dislocations precipitated an estimated 7 percent contraction in global gross domestic product (GDP), representing an aggregate economic loss of approximately US\$7.77 trillion, equivalent to the GDP of Japan, assuming a global GDP of US\$110.98 trillion.¹⁹

Deliberately redistributing trade flows across alternative geopolitical, geographic, and modal routes, replacing or supplementing dominant chokepoint-dependent pathways, builds resilience and security but often comes with energy and emissions penalties.²⁰ The extent of the penalties depends on the transport mode, fuel type, and distance involved. In alternative corridors that involve shorter distances, efficient transportation modes and low-emissions fuels, energy and emissions penalties can be lower or even negative.²¹

International trade-related freight transport currently accounts for around 30 percent of all transport-related carbon emissions from fuel combustion and more than 7 percent of global emissions.²² Global trade remains fundamentally dependent on maritime transport, which has

17 "The Global Risks Report 2026," World Economic Forum, January 14, 2026, <https://www.weforum.org/publications/global-risks-report-2026/in-full/global-risks-report-2026-key-findings/>.

18 "Why Trade Corridors Are the Path to a More Resilient Future," World Economic Forum, January 16, 2025, <https://www.weforum.org/stories/2025/01/trade-corridors-resilient-future/>.

19 "World Economic Outlook, October 2024: Policy Pivot, Rising Threats," International Monetary Fund, October 2024, <https://www.imf.org/en/publications/weo>.

20 Qi Xu et al., "Eurasian Container Intermodal Transportation Network: A Robust Optimization with Uncertainty and Carbon Emission Constraints," *Frontiers in Marine Science* 12 (2025), <https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2025.1576006/full>.

21 Fabio Indeo, "Reshaping the India-Middle East-Europe Economic Corridor: New Challenges, Old Vulnerabilities," TRENDS Research & Advisory, February 15, 2026, <https://trendsgroup.org/insight/reshaping-the-india-middle-east-europe-economic-corridor-new-challenges-old-vulnerabilities/>.

22 Đurđica Stojanović et al., "Assessment of International Trade-Related Transport CO2 Emissions—A Logistics Responsibility Perspective," *Sustainability* 13, no. 3 (2021): 1138, <https://www.sciencegate.app/document/10.3390/su13031138>.

the lowest freight-mode carbon intensity. More than 80 percent of world merchandise trade by volume moves by sea, and maritime shipping alone contributes roughly 2.8–3 percent of global carbon emissions.²³ The emissions outcome of diversification is therefore not predetermined—it depends on route, mode, infrastructure, energy use and regional industrial geography; and the evidence is decidedly mixed.

The Suez Canal-Red Sea corridor normally handles 30 percent of global container traffic. Disruptions in October 2023 forced rerouting freight traffic to the Cape of Good Hope, which added about 4,000 nautical miles (nm) per voyage.²⁴ This increased GHG emissions by 70 percent per round trip for Asia–Europe routes. According to mandatory carbon-emissions reporting data, EU container-shipping CO₂ emissions increased to 52.7 Mt (million tons) in 2024 compared to 34.7 Mt when the Suez corridor was used, which is an 18 Mt carbon penalty.²⁵ The 2026 Hormuz closure is now replicating this dynamic as Asian refiners reroute tanker traffic around the Arabian Peninsula and towards the Cape of Good Hope.

Before 2022, the Northern Corridor, a remarkably direct, nearly straight, east-west rail line from Vladivostok to the Port city of Brest in France, accounted for 86 percent of China–Europe rail freight, while the Middle Corridor from Chengdu in China to Istanbul in Türkiye constituted less than 1 percent.²⁶ Following the conflict in Ukraine, freight volumes shifted to the Middle Corridor. The forced diversification from a high-capacity, relatively efficient Trans-Siberian rail corridor to the multi-model (rail–ferry–rail) Middle Corridor introduced inefficiencies that increased the energy overhead per tonne and consequently the carbon emissions per tonne of goods transported.²⁷

“Goeconomic confrontation is now a key driver of economic and industrial policy, and the signal from recent disruptions is a shift towards resilience and diversification.”

23 United Nations Conference on Trade and Development, *Review of Maritime Transport 2023* (2023), https://unctad.org/system/files/official-document/rmt2023_en.pdf.

24 Sadeque Hamdan et al., “Optimizing Asia–Europe Container Network: The Suez Canal and Cape of Good Hope Routes in a Changing World,” *European Journal of Operational Research* 325, no. 1 (2025): 167–88, <https://www.sciencedirect.com/science/article/pii/S037722172500205X>.

25 Stuart Todd, “45% Surge in EU Containership Emissions Due to Shipping Disruption in the Red Sea,” *American Journal of Transportation*, July 24, 2025, <https://www.ajot.com/insights/full/ai-45-surge-in-eu-containership-emissions-due-to-shipping-disruption-in-the-red-sea>.

26 Alberto Rizzi, “Risk and Reward: Why the EU Should Develop the Middle Corridor Trade Route,” European Council on Foreign Relations, April 11, 2024, <https://ecfr.eu/article/risk-and-reward-why-the-eu-should-develop-the-middle-corridor-trade-route/>.

27 Rizzi, “Risk and Reward: Why the EU Should Develop the Middle Corridor Trade Route”.

The China Railway Express (CRE), often described as a “Suez Canal on rails”, is not a direct corridor replacement but a strategic alternative to Suez-dependent sea routes, connecting 226 cities across 25 European countries and more than 100 cities in 11 Asian countries.²⁸ It is 65 percent faster than the Suez route, though more expensive.²⁹ Its climate credentials remain contested: despite an 11,000-kilometre distance reduction, studies indicate that a 90-percent cut in emissions intensity relative to current levels would be required for a net environmental benefit over sea freight, while a separate city-level analysis finds CRE services reduced CO₂ emissions by an average of 9 percent across 12 cities with regular operations.³⁰ CRE diversification is likely to carry climate benefits where it displaces air freight for export of electronics, automotive components, and other high-value items.³¹

When alternative corridors reduce per-unit transportation emissions, they simultaneously

induce systemic trade demand. This manifestation of the Jevons paradox³² implies that volume expansions within optimised corridors can partially or fully neutralise the projected net emissions reduction.³³ The Arctic Sea Route (ASR) illustrates this most sharply, reducing voyage distances between Europe and Northeast Asia by up to 40 percent; it is projected to increase global shipping emissions by 8.2 percent by 2100, with Arctic-specific emissions rising from 0.22 percent to 2.72 percent driven by induced demand, where lower costs stimulate additional shipping that cancels out per-voyage efficiency gains.³⁴

The emissions burden of corridor disruption and rerouting falls asymmetrically. When chokepoints close or become unsafe, it is import-dependent economies in South Asia and Southeast Asia, with thinner fiscal buffers and less diversified supplier bases, that face the sharpest freight cost spikes and the longest rerouting delays.

28 Sophia Shkuro, “Eurasian Railway Corridor: Overview of 2024 Trends in Rail Freight from China to Europe,” SeaRates, December 30, 2024, <https://www.searates.com/blog/post/eurasian-railway-corridor-overview-of-2024-trends-in-rail-freight-from-china-to-europe/>;

Nick Staunton, “China Built a New Route to Europe — Now It Will Reshape Global Trade,” Business, March 20, 2026, <https://europeanbusinessmagazine.com/china-built-a-new-route-to-europe-now-it-will-reshape-global-trade/>.

29 Staunton, “China Built a New Route to Europe — Now It Will Reshape Global Trade”.

30 Yilin Zhang et al., “Impact of CR Express and Intermodal Freight Transport Competition on China-Europe Route: Emission and Welfare Implications,” *Transportation Research Part A: Policy and Practice* 171 (2023): 103642, <https://www.sciencedirect.com/science/article/abs/pii/S0965856423000629>; Peiming He et al., “Unintended Environmental Gains: The Impact of China–Europe Railway Express on Carbon Dioxide Emissions in China,” *Transport Policy* 153 (July 2024): 127–40, <https://www.sciencedirect.com/science/article/abs/pii/S0967070X24001379>.

31 Staunton, “China Built a New Route to Europe — Now It Will Reshape Global Trade”.

32 Jevons Paradox, first observed by economist William Stanley Jevons in 1865 refers to the counterintuitive idea that improvements in resource efficiency often increase overall consumption rather than reduce it.

33 Pengjun Zhao et al., “Arctic Sea Route Access Reshapes Global Shipping Carbon Emissions,” *Nature Communications* 16 (September 2025): 8431, <https://www.nature.com/articles/s41467-025-64437-4>.

34 Zhao et al., “Arctic Sea Route Access Reshapes Global Shipping Carbon Emissions”.

The Energy-Climate-Trade Nexus

Global economic strategy is shifting from prioritising narrow cost efficiency to emphasising resilience through the diversification of trade corridors.³⁵ While diversified corridors reduce systemic vulnerability by spreading geopolitical and supply-chain risk, they can also increase energy intensity and lock-in higher emissions by duplicating production and transport infrastructure across less efficient, higher-cost locations.

Where corridor planning is integrated with scalable low-emissions fuels and advanced digital logistics (optimising routing, modal choice, and asset utilisation), much of the additional energy burden can be mitigated. Conditioning corridor financing on robust lifecycle-based GHG monitoring and reporting would align commercial incentives with climate objectives and create accountability for embodied emissions across routes and modes.

Yet the evidence suggests that such mitigation measures run counter to current policy momentum. Emergency rerouting locks in emissions-intensive pathways; induced demand erases efficiency gains; and the Global South absorbs the costs of both without meaningful

participation in the governance conversations that determine corridor terms.

The proposed India-Middle East-Europe Economic Corridor (IMEC), designed to transport low-emissions energy exports from India to European markets, illustrates how strategic corridor design can reconcile resilience with climate action.³⁶ Stalled since late 2023 by the Gaza conflict and regional instability, when combined with low-emissions supply sources, interoperable clean-energy infrastructure, and lifecycle emissions verification, IMEC represents the most concrete test yet of whether trade corridors can be designed to serve both security and climate objectives simultaneously, though sustained political commitment and predictable financing remain preconditions for that ambition to materialise.

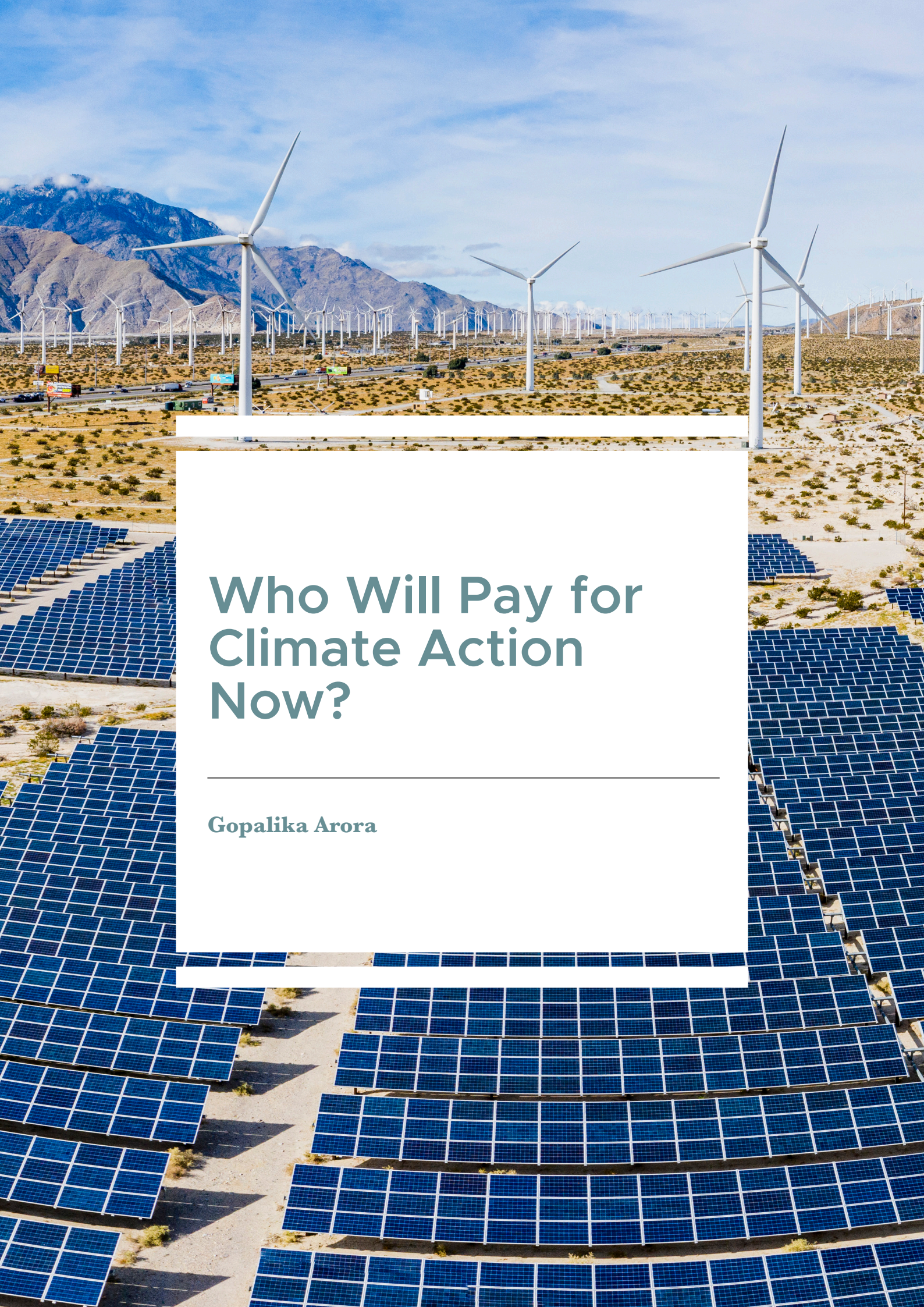
The nexus is entrenching not because states are governing energy, climate, and trade coherently—they are not—but because disruption in any one domain now automatically destabilises the other two. The Hormuz crisis did not create that interdependency. It revealed how deeply it had already taken hold, and how unevenly its costs are distributed: a reckoning that the current architecture of securitisation, corridor competition, and asymmetric climate governance is not yet equipped to address.

35 “The Belt and Road Initiative: Impacts on Global Maritime Trade Flows,” International Transport Forum Discussion Papers no. 2020/02, vol. 2020/02, https://www.itf-oecd.org/sites/default/files/docs/belt-road-initiative-maritime-trade-flows_1.pdf.

36 European Union Institute for Security Studies, *From Hype to Horizon: What the EU Needs to Know to Bring IMEC to Life* (2024), <https://www.iss.europa.eu/publications/briefs/hype-horizon-what-eu-needs-know-bring-imec-life>.

Parul Bakshi is Fellow, Energy and Climate, ORF Middle East.

Lydia Powell is Distinguished Fellow, ORF.



Who Will Pay for Climate Action Now?

Gopalika Arora

Despite strong and sustained multilateral efforts, global climate finance continues to fall short of the needs of Emerging Markets and Developing Economies (EMDEs), and the gap between financing needs and actual flows continue to widen. According to the Independent High-Level Expert Group on Climate Finance (IHLEG), annual global climate finance requirements will reach US\$6.7 trillion by 2030 and US\$8.1 trillion by 2035. Of this, EMDEs will require some US\$2.5 trillion annually by 2030 and US\$3.1 trillion by 2035.¹ However, the actual finance received by these economies has historically fallen short. In 2023, for example, EMDEs other than China mobilised only US\$385 billion, which is 15 percent of the total annual requirement.²

This retrenchment of finance is not merely a result of a temporary slowdown in climate finance commitments by the developed countries. It may also signal a deeper restructuring of the climate finance architecture driven by changing institutional priorities within the multilateral system that was expected to anchor the transition. Reversing this trend will require global policymakers to address three key challenges: where finance is flowing; on what terms it is being provided; and whether the institutions expected to support the transition to a renewable energy future remain available and fit for purpose.

To be sure, climate finance is just one part of a rapidly evolving global financial architecture. Traditional sources of public and private capital are becoming less predictable, while global multilateral finance institutions like the World Bank face growing political pressure to roll back climate policies and financing. At the same time, alternative sources of capital are emerging on

1 Amar Bhattacharya et al., *Raising Ambition and Accelerating Delivery of Climate Finance*, London: Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science, November 2024, https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2024/11/Raising-ambition-and-accelerating-delivery-of-climate-finance_Third-IHLEG-report.pdf.

2 Rajeev Gopal, “Miles to Go,” *Down To Earth*, April 16, 2026, <https://www.downtoearth.org.in/climate-change/miles-to-go>.

terms that may not align with the needs of EMDEs. For these countries, the challenge is not only to mobilise more financing but also to secure financing that is affordable, accessible, better distributed across climate priorities, and aligned with development needs.

Policymakers across the globe should adopt three priorities for the 2026 climate finance agenda: 1) reorienting private finance towards underserved sectors and geographies; 2) restoring concessional finance (finance at better than market rates) and working through MDBs to de-risk project pipelines and lower the cost of capital; and 3) reinforcing South-South cooperation as a growing channel for finance, technology transfer, and knowledge sharing.

Weakening Commitments and Architecture

The United States' (US) withdrawal from the Paris Agreement in 2026 and its reduced engagement with multilateral climate initiatives—including the Green Climate Fund—have created uncertainty around future climate finance flows. It has also pressured the World Bank to scale back its climate finance commitments and increase financing for natural gas projects. This marks a notable shift for an institution that had committed to allocating 45 percent of its financing to projects with climate co-benefits by 2025 and exceeded that target by directing US\$39.2 billion (48 percent

“Policymakers must address three key challenges: where finance is flowing; on what terms it is being provided; and whether the institutions expected to support the transition to a renewable energy future remain fit for purpose.”

of its financing) to such projects in 2025.³ As multilateral development banks (MDBs) remain the largest source of international public climate finance,⁴ any dilution of the World Bank's climate commitments could have wider implications for climate finance flows to developing countries.

A similar trend is evident across the broader climate finance landscape. Bilateral and multilateral Official Development Assistance (ODA) is also shrinking, with Germany, the United States, the United Kingdom, Japan, and France accounting for more than 95 percent of the projected decline in ODA in 2025.⁵ This is significant because ODA remains a critical source of financing for climate-sensitive sectors such as healthcare, nutrition, food security, and resilience.⁶ Declining ODA may intensify competition between climate and broader development priorities in countries already facing fiscal stress.

3 Matteo Civillini, “US Pressure Puts World Bank's Climate Plan at Risk,” Green Central Banking, April 23, 2026, <https://greencentralbanking.com/2026/04/23/us-pressure-puts-world-banks-climate-plan-at-risk/>.

4 *Global Landscape of Climate Finance 2025: Summary Handout*, Climate Policy Initiative, November 2025, <https://www.climatepolicyinitiative.org/wp-content/uploads/2025/06/Global-Landscape-of-Climate-Finance-2025-Summary-Handout.pdf>.

5 “A Historic Decline in Foreign Aid: Preliminary 2025 ODA Data,” OECD, April 9, 2026, <https://www.oecd.org/en/data/insights/data-explainers/2026/04/a-historic-decline-in-foreign-aid-preliminary-2025-oda-data.html>.

6 Nilanjan Ghosh and Swati Prabhu, eds., *No Country for Aid Alone: Strategic Partnerships for Development Finance*, Observer Research Foundation, May 11, 2026, <https://www.orfonline.org/research/no-country-for-aid-alone-strategic-partnerships-for-development-finance>.

As traditional sources of finance become less predictable, alternative pools of capital are gaining prominence. Gulf sovereign wealth funds (SWFs) have emerged as an important source of green finance, investing in projects ranging from established renewable energy assets to emerging green hydrogen ventures. However, this capital cannot substitute for concessional and multilateral finance, as investment decisions are driven by commercial returns and geopolitical considerations. The West Asia crisis of 2026 has also raised questions over the investment priorities of Gulf SWFs, as major regional economies reassess investments worth an estimated US\$5 trillion. A greater share of these resources may be redirected towards domestic priorities and fiscal stabilisation.⁷

The Persistent Misalignment Challenge

While the overall climate finance gap remains substantial, financing is also distributed unevenly across climate priorities. Mitigation continues to receive the large share, while adaptation initiatives struggle to mobilise long-term finance despite being an immediate priority for climate-vulnerable countries in the Global South. In 2023, approximately 94 percent of the global climate finance (US\$1.8

trillion) went towards mitigation, driven mainly by private-sector investments in energy systems, transport electrification, and energy-efficient infrastructure.⁸ Mitigation finance also remains highly concentrated in certain geographies. Of the US\$980 billion of mitigation finance received by EMDEs in 2023, US\$670 billion went to China alone.⁹ This finance is also largely driven by domestic private-sector investments in sectors considered commercially viable, such as energy and transport.

The adaptation finance gap, meanwhile, continues to widen. According to the United Nations Environment Programme's (UNEP) *Adaptation Gap Report* of 2025, developing regions will require adaptation finance equivalent to 12 times current flows by 2035. The cost of adaptation by 2035 is estimated to be around US\$310 billion to US\$365 billion per year.¹⁰ However, in 2023, of the total climate finance mobilised (US\$1.9 trillion), adaptation finance accounted for only US\$65 billion, of which US\$48 billion went to EMDEs.¹¹ The majority (~93 percent) of the adaptation finance flowing into these markets came from public sources.¹² Private sector investment remains limited because adaptation projects often lack clear revenue models and have long investment horizons before benefits are realised.

7 Andrew Mills, Rachna Uppal and Federico Maccioni, "Gulf Trio Review Sovereign Investments to Offset Iran War Impact, Official Says," *Reuters*, March 11, 2026, <https://www.reuters.com/world/middle-east/some-gulf-states-reviewing-sovereign-investments-offset-economic-shock-iran-war-2026-03-11/>.

8 "Global Landscape of Climate Finance 2025: Summary Handout".

9 Baysa Naran et al., *Global Landscape of Climate Finance 2025*, Climate Policy Initiative, October 2025, <https://www.climatepolicyinitiative.org/wp-content/uploads/2000/10/Global-Landscape-of-Climate-Finance-2025-EMDE-Spotlight.pdf>.

10 United Nations Environment Programme, *Adaptation Gap Report 2025: Running on Empty - The World is Gearing up for Climate Resilience - Without the Money to Get There*, UNEP, October 2025, <https://wedocs.unep.org/items/b547996e-14ee-4f1c-a6d4-b811dd373ae9>.

11 "Global Landscape of Climate Finance 2025: Summary Handout".

12 "Global Landscape of Climate Finance 2025".

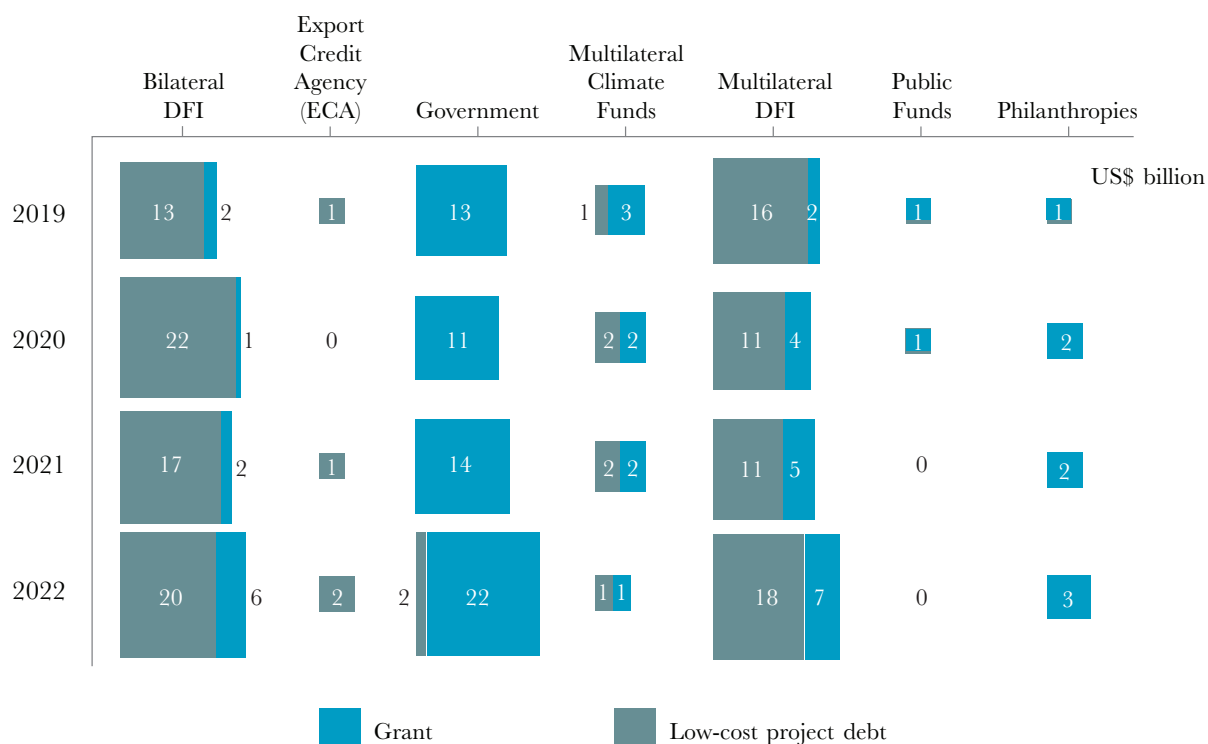
Developing economies do not have well-developed capital markets that can provide long-term finance for climate projects.¹³ This makes the mobilisation of private finance essential, not as a substitute for public capital but as a necessary means to bridge the climate finance gap. The dearth of private sector finance, specifically for adaptation projects, can be attributed to various factors.

There is a clear mismatch between investor expectations of immediate returns and short gestation periods and the nature of adaptation investments. Unlike sectors such as clean energy, which often have clear and well-defined revenue streams, some adaptation interventions, like the nature-based solutions, may not generate traditional income but can provide long-term benefits and protection against floods and landslides. Quantifying these outcomes may require complex methodologies and resources, which further adds to the cost and perceived high risks of adaptation investments.¹⁴ Additionally, many development banks also struggle to create a comprehensive project pipeline of good-quality and scalable projects for adaptation. The lack of skills in the project development community adds to the challenge.¹⁵

The Concessionality Gap

Although international concessional finance—defined as “finance offered at more favourable terms than the market”¹⁶—has increased by 50 percent over the last decade, reaching US\$81 billion in 2022, it remains insufficient to meet global climate finance needs. Global concessional finance will need to increase at least five-fold by 2030 to achieve the global climate goals.¹⁷ Additionally, most concessional finance is provided as low-cost project debt instead of grants (See Figure 1). Bilateral and multilateral development finance institutions (DFIs) usually rely on concessional loans, while the grant component of concessional finance remains limited. Multilateral climate funds, which are better placed to provide grant-based concessional support—especially for adaptation—remain small. The withdrawal of US\$4 billion in US funding from the Green Climate Fund further weakens this important source of grant-based concessional finance for developing economies.¹⁸

-
- 13 Zeineb Ben Yahmed et al., “Managing Currency Risk to Catalyze Climate Finance,” Climate Policy Initiative, August 2024, <https://www.climatepolicyinitiative.org/wp-content/uploads/2024/08/Currency-Risk-Report.pdf>.
 - 14 Gopalika Arora, *Mobilising Private Finance for Ecosystem-Based Adaptation Through Nature-Based Solutions*, Observer Research Foundation, November 2024, <https://www.orfonline.org/public/uploads/posts/pdf/20241121122709.pdf>.
 - 15 Guillermo Martinez, Ken Schell-Smith and Abha Nirula, *Partnering for Finance Adaptation*, Climate Policy Initiative, September 2024, https://www.climatepolicyinitiative.org/wp-content/uploads/2024/09/CPI_Partnering-for-Finance-Adaptation.pdf.
 - 16 Baysa Naran, Tinglu Zhang, and Ishrita Gupta, *Understanding Global Concessional Climate Finance 2024: Enhancing Its Scale and Efficiency for Climate Action*, Climate Policy Initiative, October 2024, <https://www.climatepolicyinitiative.org/wp-content/uploads/2024/10/Understanding-Global-Concessional-Climate-Finance-2024.pdf>.
 - 17 “Global Landscape of Climate Finance 2025”.
 - 18 Matteo Civillini, “After US Retreat, Countries Clash Over Who Should Make Up Green Climate Fund Shortfall,” *Climate Home News*, February 21, 2025, <https://www.climatechangenews.com/2025/02/21/after-us-retreat-countries-clash-over-who-should-make-up-green-climate-fund-shortfall/>.

Figure 1: Global Concessional Finance, by Actors and Instruments

Source: Climate Policy Initiative¹⁹

This gap cannot be ignored as the terms and quality of finance directly impact the viability of climate investments. Emerging market economies already face a higher cost of capital than most developed countries. For instance, even mature segments like renewables have a cost of capital that is at least twice as high as that in developed economies. The average cost of capital for a 100 MW solar project in India is estimated at 10.5 - 11 percent, compared with 2.8 percent in Germany and 5.3 percent in the

United States.²⁰ According to the International Monetary Fund's (IMF) estimates, even a one-percentage-point decline in the cost of capital could lower annual transition finance costs by approximately US\$150 billion.²¹

In addition to the high cost of capital, climate projects also face currency risks. Developing countries rely on hard currency for their climate finance, but climate projects, especially those related to clean energy, usually generate

19 "Global Landscape of Climate Finance 2025".

20 Franco Bruni et al., *Beyond Global Polarization: New Cooperation Wanted*, ISPI, ORF, and PCNS, December 2025, <https://www.orfonline.org/public/uploads/posts/pdf/20251217144432.pdf>.

21 "Beyond Global Polarization: New Cooperation Wanted".

revenue in local currency.²² These projects also have a long tenor, which further exposes them to these currency risks. For example, the average life span of solar panels is usually 20-30 years.²³ Institutional and regulatory risks further exacerbate the problem. In many emerging economies like India, renewable energy projects face delays in signing PPAs due to uncertainty and disputes over tariffs.²⁴

These risks combined trigger a vicious cycle of macroeconomic pressures, debt sustainability challenges, and shrinking fiscal space for climate investments which eventually weakens the creditworthiness of the developing economies.²⁵ The concessionality gap therefore goes to the core of climate finance effectiveness. For EMDEs, the issue is not only whether capital is available but also whether it is available on terms that make climate projects viable without worsening debt pressures or crowding out other development priorities.

The 2026 Climate Finance Agenda

These trends expose structural gaps in the way global climate finance is organised and disbursed. The year 2026 is likely to be another year of competing signals in climate finance, especially for emerging economies, where the need for capital is higher. Climate leaders should focus on the following three priorities.

First, private-sector finance will remain central to scaling climate investment, but it must be reoriented towards geographies, sectors, and technologies where investment needs are high, emissions abatement potential is high, and commercial risks remain difficult to price. This includes institutional investors, commercial banks, private equity, infrastructure funds, and corporate capital.²⁶ Reorienting private finance will require building the information architecture around climate investments. This means stronger climate-related disclosures, better project-level data on climate risks, and more credible transition planning frameworks that allow investors to assess risks and opportunities more objectively.

For adaptation finance, the information gap is even more pronounced, as investors often struggle to assess how adaptation projects generate value or fit within their return expectations. This is partly because adaptation still lacks clear and widely accepted taxonomies, making it difficult to define what qualifies as an adaptation activity. Stronger disclosure, governance, and climate-risk data frameworks are therefore essential to ensure that finance flows to credible projects.

22 Yahmed et al., “Managing Currency Risk to Catalyze Climate Finance”.

23 Yahmed et al., “Managing Currency Risk to Catalyze Climate Finance”.

24 Yahmed et al., “Beyond Global Polarization: New Cooperation Wanted”.

25 Yahmed et al., “Beyond Global Polarization: New Cooperation Wanted”.

26 Morgan Richmond, Pallavi Sherikar and Jake Connolly, “Tracking Private Investment for Adaptation: The Need, Our Progress, and Next Steps,” Climate Policy Initiative, July 23, 2025, <https://www.climatepolicyinitiative.org/tracking-private-investment-for-adaptation-the-need-our-progress-and-next-steps/>.

“There are structural gaps in the way global climate finance is organised and disbursed. The year 2026 is likely to be another year of competing signals in climate finance, especially for emerging economies, where the need for capital is higher.”

Second, restore concessional finance. MDBs and DFIs must improve both the scale and quality of finance by de-risking project pipelines, structuring and advancing blended finance mechanisms, and further reducing the cost of capital. Since traditional concessional finance structures are under pressure, 2026 will also test whether new mechanisms can generate affordable capital for climate action. The Brazil-led blended-finance mechanism launched at COP30, called the Tropical Forests Forever Facility (TFFF), aims to mobilise US\$125 billion (US\$25 billion from donor countries and US\$100 billion from private investors) for tropical countries.²⁷ However, its success will depend on the ability to source the initial US\$25 billion from donor countries and build on the existing US\$6.6 billion mobilised last year at COP30.

Third, reinforce South-South cooperation. Climate finance flows among developing-country institutions have grown steadily, rising from US\$16 billion in 2018 to US\$26 billion in 2023.²⁸ This points to the growing role of South-South climate finance, including through regional development banks and finance from larger EMDEs to other developing economies. Existing initiatives, from the India-backed renewable energy projects in Cameroon to small hydropower and renewable energy research partnerships in Asia, demonstrate the range of cooperation. South-South cooperation also extends beyond finance to knowledge sharing and local implementation. Platforms and city-level initiatives led by ICLEI, have enabled municipalities in India, Indonesia, and South Africa to exchange experiences on renewable energy deployment and energy-efficiency practices.²⁹

India has also helped shape South-South climate cooperation through platforms such as the International Solar Alliance and the Coalition for Disaster Resilient Infrastructure (CDRI). While the ISA supports wider access to affordable solar energy across solar-rich countries, particularly in the Global South, the CDRI focuses on strengthening infrastructure resilience by bringing together governments, institutions, and experts working on climate and disaster risks.³⁰

27 Edward Davey et al., “The Tropical Forests Forever Facility Could Finally Finance Nature Conservation. Will Funders Back It?” World Resources Institute, November 26, 2025, <https://www.wri.org/insights/financing-nature-conservation-tropical-forest-forever-facility>.

28 “Global Landscape of Climate Finance 2025”.

29 REEEP, “Local Renewables: South–South Cooperation Between Cities in India, Indonesia and South Africa,” https://reep.org/projects_programmes/local-renewables-south-south-cooperation-between-cities-in-india-indonesia-south-africa-done/.

30 Ananya Shukla, “Climate Shifts, Power Plays: India’s Climate Diplomacy in a Changing Global Order,” *The Geostrata*, October 26, 2025, <https://www.thegeostrata.com/post/climate-shifts-power-plays-india-s-climate-diplomacy-in-a-changing-global-order>.

Institutions like the BRICS New Development Bank are also emerging as channels for mobilising more finance for EMDEs. The NDB's 2024 annual report shows that, by the end of 2024, the Bank had approved around US\$6.5 billion for mitigation-related projects and US\$1.6 billion for adaptation finance.³¹ South-South cooperation needs to be more systematically tracked and strengthened as an emerging avenue for climate action. Beyond expanding finance for EMDEs, it can support technology transfer, knowledge sharing, and

wider economic cooperation across the Global South.

The retrenchment of climate finance is not only about declining volumes but also about changing priorities and a weaker system for financing climate action in EMDEs. In 2026, the credibility of climate finance will depend less on headline commitments than on whether finance becomes more accessible, affordable, and better aligned with development priorities.

31 "Global Landscape of Climate Finance 2025".



Global AI: A Story of Fragmentation

Siddharth Yadav

The inaugural issue of this series identified the rapid, fragmented growth of artificial intelligence (AI) as a megatrend for 2026.¹ This article revisits that trend at the year's midpoint to examine how it has unfolded across the AI stack, and the challenge it poses for the Global South. The layers that require significant amounts of capital and expertise—frontier research, compute, and the investment that sustains them—have become increasingly concentrated in a handful of jurisdictions. Meanwhile, the user-facing layer has dispersed widely across the Global South. Global corporate AI investment reached US\$581.7 billion in 2025, more than double the previous year's total, with most of it flowing to the economies that already dominate research and hardware. This creates a structural vulnerability for countries outside the core. Economies with nascent domestic digital infrastructure, investment vehicles, research ecosystems, and governance frameworks risk being marginalised by the AI-driven future.

That concentration has a distinct geography. Frontier model development, chip design, and cutting-edge research remain concentrated in the United States (US); sovereign capital, energy, and connectivity corridors in the Gulf; and talent and advanced manufacturing in Asia, particularly China. Beneath these are a series of niche chokepoints—from leading-edge fabrication to specialist materials—controlled by a small number of actors elsewhere. In response, countries across the Global South have sought to build domestic capacity in selected layers of the stack. However, these efforts remain sub-frontier in scope, and no single country has pursued the entire value chain.

Yet concentration characterises only the supply side. Demand is moving in the opposite direction, reflecting the shift towards diffusion and use cases identified in the inaugural issue of this publication. The largest and fastest-growing user bases for frontier systems are now found in India, Indonesia, Brazil, Nigeria, and neighbouring markets. It is here that the region's leverage—substantial but largely unrealised—is accumulating.

¹ Sharon Stirling and Eszter Karacsony, Eds., *ORF Global Quarterly: Navigating Megatrends for 2026*, ORF Global, January 2026, <https://www.orfonline.org/english/research/orf-global-quarterly-navigating-megatrends-for-2026>.

The rest of this article examines how growth has remained fragmented across research, infrastructure, investment, commercialisation, and governance; assesses the developments that, since the trend was first identified, have begun to reshape this landscape; and considers whether these emerging opportunities can be institutionalised before concentration becomes entrenched.

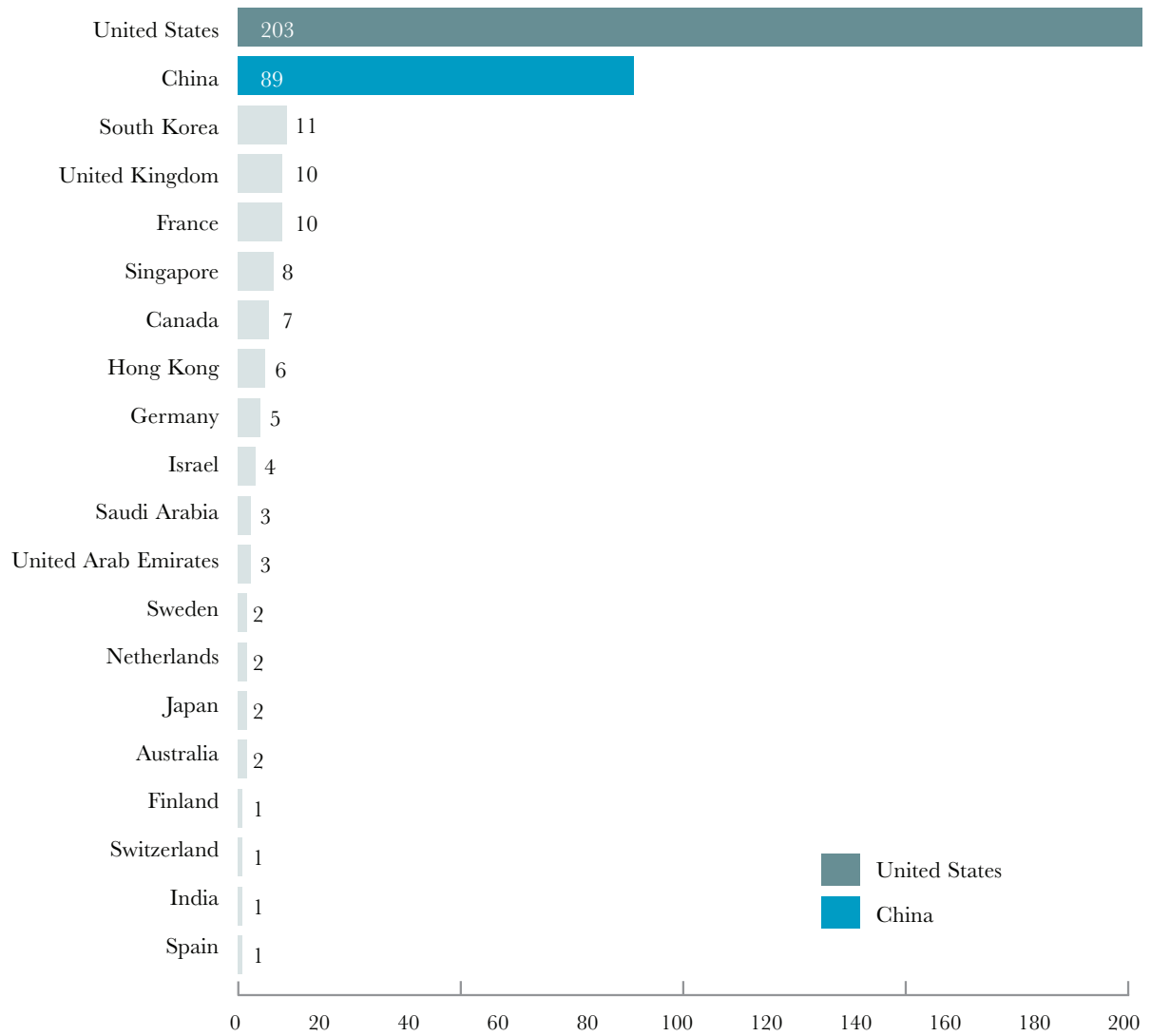
The Story of Fragmented Growth

Research in AI has historically been led by the US, but the frontier and the broader research base have increasingly diverged. In terms of notable model releases, the landscape remains highly concentrated: the US and China together account for the large majority

each year,² while every other country named in the Stanford AI Index contributes only low single-digit shares. New entrants have emerged at the margins, from Saudi Arabia and the United Arab Emirates to scattered launches across Latin America and Southeast Asia. Publications are far more geographically distributed. China now produces 17.8 percent of all papers on AI globally; India accounts for 7.6 percent, and the steadily declining share of the US is at 7.3 percent.³ This divergence between a broadening publication base and a concentrated frontier defines the conditions under which the Global South enters the next phase of AI development. It demonstrates that wider participation in research does not, by itself, convert into frontier capability.

2 Nestor Maslej et al., *Artificial Intelligence Index Report 2025*, Chapter 1: Research and Development, Stanford, CA, Stanford Institute for Human-Centered Artificial Intelligence, 2025, https://hai.stanford.edu/assets/files/hai_ai-index-report-2025_chapter1_final.pdf.

3 Nestor Maslej et al., *Artificial Intelligence Index Report 2026*, Research and Development, Stanford Institute for Human-Centered Artificial Intelligence, April 2026, <https://hai.stanford.edu/ai-index/2026-ai-index-report/research-and-development>.

Figure 1: AI Model Releases, by Country (2023-2025)

Source: Author's own, using data from Epoch AI⁴

4 Epoch AI, "AI Models," June 25, 2026, <https://epoch.ai/data/ai-models?view=graph&tab=notable>

Infrastructure Development

Research participation has broadened, but infrastructure remains concentrated. The United States retains the largest share of global data-centre capacity by far,⁵ and the electricity consumed by its data centres—around 31 GW in 2025—is expected to roughly double by 2027.⁶ Spending by the largest cloud companies has risen in step, from about US\$256 billion in 2024 to a projected US\$600–750 billion in 2026.⁷ The Gulf joined this expansion at scale in 2025. The UAE’s MGX helped finance OpenAI’s Stargate project, while Saudi Arabia’s HUMAIN, backed by its sovereign wealth fund, committed to data centres on a similar scale.⁸ Both, however, remain dependent on American chips and the firms that operate these facilities.

India’s IndiaAI Mission was launched in 2024 with roughly 34,000 GPUs against a US\$1.25-billion budget.⁹ Although comparatively small, the mission sets a precedent on which the region’s leverage may later depend, that of an early case of a country building AI capacity of its own, short of the frontier but tailored to its strengths and challenges. Through all of this, close to 90 percent of TSMC’s chip-manufacturing capacity, and effectively all production of the most advanced AI chips, has stayed in Taiwan. Computing power, therefore, remains with US cloud giants and a small group of Gulf and East Asian state-backed players, leaving most of the Global South reliant on outside providers.

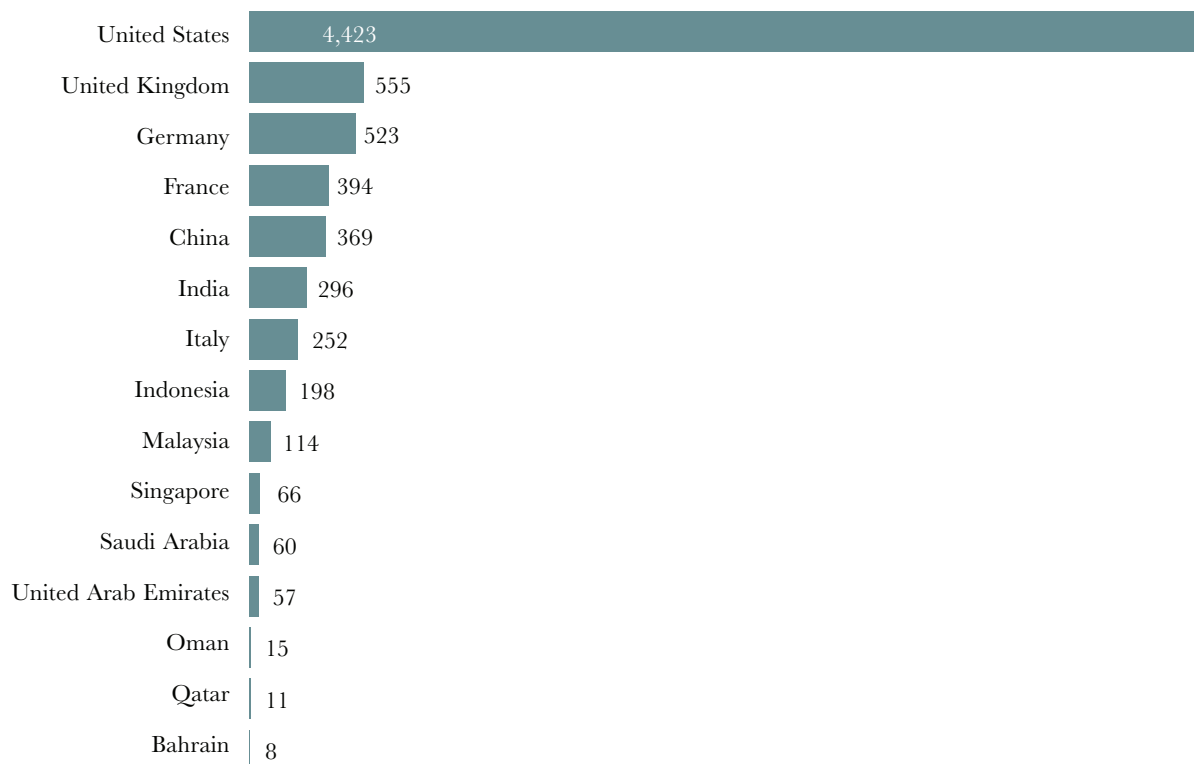
5 United States International Trade Commission, *Recent Trends in U.S. Services Trade: 2022 Annual Report*, Publication No. 5325, Washington DC, United States International Trade Commission, May 2022, 54, <https://www.usitc.gov/publications/services/pub5325.pdf>; “Artificial Intelligence Index Report 2026”.

6 “US Data Center Power Demand Projected to Double by 2027,” Goldman Sachs, May 20, 2026, <https://www.goldmansachs.com/insights/articles/us-data-center-power-demand-projected-to-double-by-2027>.

7 Sharon Goldman, “Big Tech is About to Spend \$700 Billion on AI this Year. No One Knows Where the Buildout Ends,” *Fortune*, April 30, 2026, <https://fortune.com/2026/04/30/big-tech-hyperscalers-will-spend-700-billion-on-ai-infrastructure-this-year-with-no-clear-end-in-sight-eye-on-ai/>.

8 “Announcing The Stargate Project,” OpenAI, January 21, 2025, <https://openai.com/index/announcing-the-stargate-project/>; “G42 to Lead Consortium of US Partners to Build 5GW UAE-US AI Campus,” G42, May 2025, <https://www.g42.ai/resources/news/g42-lead-consortium-us-partners-build-5gw-uae-us-ai-campus>; Donovan Vanderbilt, “HUMAIN’s AI Infrastructure Machine: 600,000 GPUs, \$77 Billion, and the Race to Build Saudi Arabia’s Compute Future,” Vision2030, April 18, 2026, <https://vision2030.ai/analysis/humain-ai-infrastructure/>.

9 Ministry of Electronics and Information Technology, Government of India, “IndiaAI Compute Capacity,” IndiaAI Mission, 2024, <https://www.indiaai.gov.in/hub/indiaai-compute-capacity>; “Artificial Intelligence Index Report 2026”.

Figure 2: Data Centre Concentration, by Country

Source: Author's own, using Statista¹⁰

Investment Flows

AI investment has consolidated into three pools over recent years. Global corporate AI investment hit US\$581.7 billion in 2025, more than double the US\$253 billion recorded in 2024 and well above the previous peak of US\$360 billion in 2021.¹¹ Of this total, US\$344.7 billion came from private investment, with the United States capturing US\$285.9 billion—roughly 83 percent of the global private pool. Foundation-model labs alone accounted for an estimated US\$80 billion.¹² China represents a second pool,

supported by state guidance funds that have deployed an estimated US\$184 billion into AI firms since 2000.¹³ The third is emerging in the Gulf. Mubadala, with US\$326.7 billion in assets under management (AUM), became the world's most active sovereign wealth fund in 2024, while MGX was launched that year as its dedicated AI investment vehicle.¹⁴ Saudi Arabia's Public Investment Fund (PIF) has similarly channelled investment through HUMAIN, launched in May 2025. Efforts to mobilise capital elsewhere are also underway. India's IndiaAI Mission, approved in 2024 with US\$1.25 billion over

10 Statista, "Number of Data Centers Worldwide as of June 2026, by Country or Territory," June 2026, <https://www.statista.com/statistics/1228433/data-centers-worldwide-by-country/>.

11 "Artificial Intelligence Index Report 2026".

12 Partech Partners, *2025 Africa Tech VC Report*, Partech, 2025, [https://partechpartners.com/africa-reports/2025-africa-tech-venture-capital-report/topline-deals-and-volumes-\(equity-&-debt\)](https://partechpartners.com/africa-reports/2025-africa-tech-venture-capital-report/topline-deals-and-volumes-(equity-&-debt))

13 "Artificial Intelligence Index Report 2026".

five years, and Africa's cumulative AI startup funding of US\$803 million since 2019 reflects growing interests in building AI ecosystems across the Global South.¹⁵ However, the gap in the availability of capital remains structural, not transitional.

Commercialisation

Deployment is the least concentrated layer of the AI stack and the one where the weight of the Global South is apparent. The fastest and most intensive adopters are often small, advanced economies like the UAE and Singapore, which have led global AI adoption through 2025 and into 2026.¹⁶ The scale, however, sits elsewhere. India is now OpenAI's second-largest market, with around 100 million of the platform's users,¹⁷ while Indonesia, Brazil, Egypt, Mexico, and Vietnam rank among its fastest-growing markets.¹⁸ Enterprise adoption is following a similar pattern: 87 percent of Indian firms report active AI use, and many have already deployed generative-AI applications in production.¹⁹

This weight, however, should not be mistaken for market power. Revenue per user and enterprise spending remain higher in North America and Europe and are likely to do so for some time. A large user base, therefore, does not automatically translate into commercial leverage. What it creates is potential: sustained growth in these markets and incentives for developers to adapt products to local languages, costs, and conditions. This gives the region a hold on the demand side that the supply side does not offer. That hold is not without cost, however. Rapid adoption can also displace existing work, as it threatens to do in India's IT and business-process sectors, so the same demand that confers leverage carries disruption alongside it.

Policy and Governance

Governance has fragmented as the supply layers concentrated, splitting along bloc lines that reflect distinct regulatory philosophies.

-
- 14 Shweta Jain, "Mubadala Asset Base Grows to \$326bn on AI and Future-focused Investments," *The National*, May 8, 2025, <https://www.thenationalnews.com/business/2025/05/08/mubadala-asset-base-grows-on-back-of-ai-and-future-focused-investments/>; "Mubadala is 2024's Most Active Sovereign Wealth Fund," *Gulf News*, January 1, 2025, <https://gulfnews.com/business/markets/mubadala-is-2024s-most-active-sovereign-wealth-fund-1.500009652>.
 - 15 Ministry of Electronics and Information Technology, "IndiaAI Compute Capacity"; StartupList Africa, "The AI Revolution in Africa 2025," June 2025, <https://blog.startuplist.africa/articles/ai-revolution-in-africa-2025>.
 - 16 "Artificial Intelligence Index Report 2026".
 - 17 Jagmeet Singh, "India has 100M Weekly Active ChatGPT Users, Sam Altman Says," *TechCrunch*, February 15, 2026, <https://techcrunch.com/2026/02/15/india-has-100m-weekly-active-chatgpt-users-sam-altman-says/>.
 - 18 "ChatGPT Usage by Country Statistics: February 2026," Siana Marketing, March 2026, <https://www.sianamarketing.com/resources/chatgpt-usage-by-country-2026>.
 - 19 "Indian Companies are Investing in AI for the Long Term," *IBM Newsroom India*, February 12, 2025, <https://in.newsroom.ibm.com/2025-02-12-Indian-Companies-Are-Investing-In-AI-For-The-Long-Term-IBM-Study>; "India's AI Shift from Pilots to Performance: 47% of Enterprises Have Multiple AI Use Cases Live in Production," *EY Newsroom India*, November 16, 2025, https://www.ey.com/en_in/newsroom/2025/11/india-s-ai-shift-from-pilots-to-performance-47-percent-of-enterprises-have-multiple-ai-use-cases-live-in-production-ey-cii-report.

The European Union has gone furthest in establishing binding rules. Its AI Act, which entered into force in 2024, adopts a risk-based approach that scales obligations according to the risks posed by a system. Yet even the EU has moderated its approach, deferring core obligations for high-risk systems to 2027 and 2028 through a 2026 simplification package amidst growing competitiveness concerns.²⁰

The US has moved in the opposite direction. The Biden administration's 2023 executive order was rescinded in January 2025 in favour of an openly deregulatory stance in its July 2025 AI Action Plan.²¹ China, meanwhile, combines targeted rules on generative-AI and data with a state-directed industrial push, its 2026 Five-Year Plan elevating AI to a national priority built around economy-wide diffusion and home-grown compute. Global South frameworks are taking shape in the gaps these three leave, and tend to converge on data sovereignty and localisation, with India's data protection law and the African Union's 2024 continental strategy among the early markers.²²

Above these national and bloc-level frameworks sit voluntary initiatives such as UNESCO's 2021 Recommendation on the

Ethics of Artificial Intelligence²³ and the G7's Hiroshima process.²⁴ These provide a shared language but lack enforcement mechanisms. The summit process that began at the United Kingdom in 2023 and continued through South Korea, France, and India has become the main forum through which this voluntary layer develops. Its southward drift, with India co-hosting in 2025 and hosting the 2026 Impact Summit, demonstrates the growing footprint of the Global South in AI development and governance agendas.

This is where the region's governance leverage lies, and where its priorities diverge from the North. While the United States and Europe foreground frontier safety, security, and risk, Global South governments press for access to models and compute, for data sovereignty, and for rules that serve development goals as much as control. The largest concentrations of AI users already sit in the Global South, and the authority to convene around governance, set against that demand-side weight, gives middle powers a hand they have yet to fully play. Building a common position across these priorities is the leverage the summit series makes possible.

20 "Artificial Intelligence: Council and Parliament Agree to Simplify and Streamline Rules," *Council of the European Union*, May 7, 2026, <https://www.consilium.europa.eu/en/press/press-releases/2026/05/07/artificial-intelligence-council-and-parliament-agree-to-simplify-and-streamline-rules/>.

21 White House, "Executive Order on Initial Rescissions of Harmful Executive Orders and Actions," Executive Order 14148, January 20, 2025, <https://www.federalregister.gov/documents/2025/01/28/2025-01901/initial-rescissions-of-harmful-executive-orders-and-actions>.

22 Parliament of India, *The Digital Personal Data Protection Act*, 2023, Act No. 22 of 2023, Gazette of India, August 11, 2023, <https://www.indiacode.nic.in/bitstream/123456789/22037/1/a2023-22.pdf>; African Union, Continental Artificial Intelligence Strategy, African Union, July 2024, https://au.int/sites/default/files/documents/44004-doc-EN-Continental_AI_Strategy_July_2024.pdf.

23 UNESCO, *Recommendation on the Ethics of Artificial Intelligence*, Paris, UNESCO, 2022, <https://unesdoc.unesco.org/ark:/48223/pf0000381137>.

24 G7, *Hiroshima Process International Code of Conduct for Organizations Developing Advanced AI Systems*, 2023, https://www.soumu.go.jp/hiroshimaaiprocess/pdf/document04_en.pdf.

Shifting Trajectories

Shift from Multilateral to Bilateral Frameworks:

The frontier advances of 2026 are further widening existing divides. The India AI Impact Summit briefly suggested that multilateral deliberations were expanding to include the Global South, but two developments since then have narrowed that opening. The first is the arrival of gated frontier models. Anthropic's Claude Mythos, released through Project Glasswing, and OpenAI's GPT-5.5 alarmed regulators with their cybersecurity capabilities.²⁵ Access has been extended selectively but without any predictability. India is among the small group of countries granted entry to Glasswing in late May. However, on 12 June, the White House ordered Anthropic to restrict access to Mythos and Fable—the commercial version of Mythos—only to Americans due to national security reasons,²⁶ making the question for most of the Global South one of the terms of access to the frontier.

The second development is a shift in US posture. Washington's containment strategy had isolated China from advanced hardware while promoting bilateral deals with the UAE, Qatar, and India and underwriting frameworks such as Pax Silica. The May 2026 Beijing visit, in permitting Nvidia H200 exports to China and opening talks on AI guardrails, marked a

notable departure from that line,²⁷ though the wider architecture remains in place. The move also carries a security dimension since exporting advanced compute and loosening guardrails widens access to capabilities with clear dual-use and military potential. Consequently, Gulf players are likely to scrutinise the security conditions attached to US hardware more closely, and a formalised US-China channel that excludes them could push the multilateral platforms they host towards the narrower work of managing dependencies.

Regional Tensions and Second-Order Effects

The US-Israel-Iran conflict is repricing the cost of building compute. The roughly US\$300 billion in investment pledges, along with the Pax Silica framework aligning the UAE and Qatar with US chip controls, have so far remained intact. However, the strain is now showing on the supply side. Strikes on Qatar's Ras Laffan have disrupted the global supply of helium, a gas the chip industry depends on for cooling critical equipment. The shortfall fed through to Samsung and SK Hynix in Korea, the two firms that make most of the high-bandwidth memory used to train AI models, with the resulting shortages projected to run into 2027.²⁸ The costs compound through 2026 as war-risk insurance for Gulf shipping has already

25 "Project Glasswing: Securing Critical Software for the AI Era," Anthropic, April 7, 2026, <https://www.anthropic.com/glasswing>; "Introducing GPT-5.5," OpenAI, April 23, 2026, <https://openai.com/index/introducing-gpt-5-5/>.

26 Maxwell Zeff, "Anthropic Says It's Taking Claude Fable 5 Offline to Comply With US Government Order," *Wired*, June 12, 2026, <https://www.wired.com/story/anthropic-says-us-government-ordered-it-to-shut-down-mythos-models/>.

27 Trisha Ray, "Three Elements Trump's 'Pax Silica' Needs to Succeed," *Atlantic Council*, April 15, 2026, <https://www.atlanticcouncil.org/dispatches/three-elements-trumps-pax-silica-needs-to-succeed/>.

28 Prateek Tripathi, "Has the Iran War Triggered Another Semiconductor Crisis?," *Observer Research Foundation*, April 13, 2026, <https://www.orfonline.org/expert-speak/has-the-iran-war-triggered-another-semiconductor-crisis>.

risen several times over.²⁹ The next phase of construction will divert significant spending into physical and cyber defence, making resilience a built-in feature of AI infrastructure in the region.

The effects extend beyond the Gulf. For much of the Global South, where growth in AI users is concentrated, higher infrastructure costs may translate into more expensive compute and AI services. At the same time, politically stable countries with sufficient scale become more attractive as alternative locations for investments. This strengthens the case for building sovereign AI capacity short of the frontier and reducing dependence on any single regional axis. One knock-on effect may be faster adoption of open-weight models, a market that Chinese developers currently lead,³⁰ and which offers the region a way to deploy capability it does not have to build itself.

Conclusion

The fragmentation in the global AI landscape that began to emerge in the past few months has hardened in some areas and loosened in others.

The layers that lend towards concentration—research, infrastructure, and investment—have become more tightly clustered around the United States and a small number of allied partners, while deployment has continued to shift towards the Global South. Events in 2026 have further reshaped this landscape. The Pax Silica framework, the repricing of compute by the US-Israel-Iran conflict, and the energy and cybersecurity pressures that followed have together reset what AI infrastructure costs and what it takes to keep it safe.

The leverage of countries of the Global South runs along the demand side, in the scale of its user base, its strength in application and use cases, and the pull towards open-weight models, together with the room for sovereign capacity short of the frontier in stable geographies and the convening authority earned by hosting the summits. None of it is yet converted into outcomes. Whether these countries can institutionalise the opening before the configuration hardens again is the open question of the year ahead.

29 “Strait of Hormuz Reopening Won’t Mean Cheaper Shipping as Insurance Premiums Surge,” *Khaleej Times*, May 12, 2026, <https://www.khaleejtimes.com/world/strait-hormuz-reopening-shipping-costs-insurance-premiums>.

30 Siddharth Yadav, “After Project Glasswing: Frontier AI and Sovereign Recovery,” *ORF Middle East*, May 11, 2026, <https://orfine.org/expert-speak/after-project-glasswing-frontier-ai-and-sovereign-recovery/>.



Power Up: How Spintronic Nanodevices Can Fuel the Future

Amoha Basrur and Pranoy Jainendran

The exponential growth of Artificial Intelligence (AI) computing is pushing conventional charge-based electronics towards their fundamental limits in power consumption and scalability. As transistors shrink and processing demands increase, the heat generated by leakage currents and switching energy is exceeding what chip architectures can safely dissipate. This has drawn attention to spintronics,¹ a branch of nanotechnology that exploits both the magnetic and electrical properties of electrons. Spintronic nanodevices offer superior energy efficiency for brain-inspired computing architectures, with magnetic tunnel junctions emerging as especially promising building blocks that are compatible with existing chip manufacturing processes.²

The technology is now considered not only a key enabler of next-generation, low-power AI hardware but also a foundation for next-generation memory, logic, and quantum computing. With applications already spanning the automotive, aerospace, and data-centre sectors, spintronics has become a strategic priority for countries with the manufacturing capacity to compete for it, driving targeted R&D funding, national roadmaps, and industry partnerships aimed at securing technological leadership and supply chain resilience. This strategic importance is already reshaping geopolitics and driving indigenisation. For the Global South, which sits almost entirely on the consumer side of this value chain, the stakes are high. The technology's concentration among a handful of advanced economies risks blocking the entry points for the Global South to be a part of the next wave of technological change.

1 Nanotechnology is the understanding and control of matter at the nanoscale, at dimensions between approximately 1 and 100 nanometres, where unique phenomena enable novel applications.

2 Julie Grollier et al., "Neuromorphic Spintronics," *Nature Electronics* 3 (2020):360, <https://doi.org/10.1038/s41928-019-0360-9>.

The Historical Arc

The origins of spintronics can be traced to the Stern–Gerlach experiment of 1922 in Germany, which provided the first experimental evidence that electrons possess an intrinsic quantum property known as ‘spin’.³ This concept was formally theorised in 1925 by Dutch-American physicists George Uhlenbeck and Samuel Goudsmit, whose work laid the foundation for decades of scientific enquiry.⁴ The technological significance of electron spin, however, was not realised until 1988, when the physicists Albert Fert of France and Peter Grünberg of Germany discovered that the spin orientation of electrons could dramatically influence the

flow of electrical current through ultra-thin metallic layers. This phenomenon, known as Giant Magnetoresistance (GMR),⁵ enabled the development of sensors and memory devices capable of storing and retrieving information by detecting electron spin states rather than relying solely on electrical charge.

Commercialisation followed in 1997, when IBM first deployed spintronic technology in hard disk drives (HDDs).⁶ Subsequent advances during the 2000s increased HDD storage capacity by roughly two orders of magnitude within a decade. The second wave of commercial adoption emerged with the transition to Magnetoresistive Random-Access Memory (MRAM) in the latter half of the 2010s. Milestones such as GlobalFoundries’ introduction of STT-MRAM in 2016 and TSMC’s 22nm Ultra-Low Power process in 2017 significantly expanded the technology’s applications across the automotive and Internet of Things (IoT) sectors.⁷

“For the Global South, which sits almost entirely on the consumer side of the nanotech value chain, the stakes are high.”

-
- 3 Horst Schmidt-Böcking et al., “The Stern-Gerlach Experiment Revisited,” *The European Physical Journal H* 41 (2016): 327, <https://doi.org/10.1140/epjh/e2016-70053-2>.
 - 4 George E. Uhlenbeck and Samuel A. Goudsmit, “Spinning Electrons and the Structure of Spectra,” *Nature* 117 (1926): 264, <https://doi.org/10.1038/117264a0>.
 - 5 Vincent Cross et al., “The 2007 Nobel Prize in Physics: Albert Fert and Peter Grünberg,” in: *The Spin. Poincaré Seminar 2007 (Progress in Mathematical Physics, Vol. 55)* ed. Bertrand Duplantier, Jean-Michel Raimond, and Vincent Rivasseau (Birkhäuser, 2009), 147-6, https://doi.org/10.1007/978-3-7643-8799-0_5.
 - 6 “1990: Magnetoresistive Read-head HDD Introduced MR, GMR & TMR Heads Deliver Successive Increases in Storage Density,” Computer History Museum, <https://www.computerhistory.org/storageengine/magnetoresistive-read-head-hdd-introduced/>.
 - 7 “GLOBALFOUNDRIES Launches Embedded MRAM on 22FDX® Platform,” Everspin Technologies, September 15, 2016, <https://www.everspin.com/news/globalfoundries-launches-embedded-mram-22fdx%C2%AE-platform>; TSMC, *2017 Annual Report*, April 19, 2018, investor.tsmc.com/sites/ir/annual-report/2017/e_11_3.pdf.

Figure 1: The Evolution of Spintronics

Source: Authors' own, generated using Sonnet 4.6⁸

The Technology and its Applications Today

Spintronics is gaining cross-sectoral significance because its advantages are most evident where conventional electronics encounter fundamental physical limits. In AI hardware, the technology addresses two principal constraints on continued scaling: energy consumption and memory bandwidth. Global data-centre electricity consumption reached approximately 415 TWh in 2024, representing roughly 1.5 percent of worldwide electricity use, and is projected to more than double to 945 TWh by 2030.⁹ Spintronic chips enable compute-in-memory architectures that eliminate the energy cost associated with moving data between processors

and memory. They are already deployed in edge AI applications, powering devices such as industrial sensors and smart cameras.¹⁰

In the automotive sector, magnetoresistive random-access memory (MRAM) is now in volume production for microcontrollers used in electric vehicles. These chips capture real-time engine control data, facilitating functions including advanced driver assistance systems, reliable over-the-air firmware updates, and infotainment systems. In aerospace and defence, radiation-hardened MRAM is being deployed in satellites, spacecraft, and military electronic platforms, where conventional flash memory is susceptible to degradation from cosmic radiation.¹¹

8 Otto Stern and Walther Gerlach, "Der experimentelle Nachweis der Richtungsquantelung im Magnetfeld," *Zeitschrift für Physik* 9(1922): 1, https://link.springer.com/chapter/10.1007/978-3-540-70626-7_214; Priti Rajput et al., "A Review on—Spintronics an Emerging Technology," *Silicon* 14 (2022), <https://link.springer.com/article/10.1007/s12633-021-01643-x>; "Spintronics Market to Witness 36.48% CAGR Amid Surge in AI, IoT, and Electric Vehicles," Precedence Research, January 28, 2026, <https://www.globenewswire.com/news-release/2026/01/28/3227739/0/en/Spintronics-Market-to-Witness-36-48-CAGR-Amid-Surge-in-AI-IoT-and-Electric-Vehicles.html>.

9 "Energy and AI," International Energy Agency, April 10, 2025, <https://www.iea.org/reports/energy-and-ai>.

10 Ibrahim A. Tasiu et al., "Spintronics Technology: A Comprehensive Review of Materials, Applications, and Future Trends," *Journal of Science: Advanced Materials and Devices* 11 (2026): 101086, <https://doi.org/10.1016/j.jsamd.2025.101087>; "Exploring Spintronic Devices in Nanotechnology Applications," Eureka by patsnap, October 21, 2025, <https://eureka.patsnap.com/report-exploring-spintronic-devices-in-nanotechnology-applications>.

11 "Introducing Enhanced MRAM Product Family for Space and Defense," *Avalanche Technology*, July 29, 2024, <https://www.avalanche-technology.com/avalanche-technology-introduces-enhanced-mram-product-family-for-space-and-defense/>.

Spintronic magnetic sensors are also demonstrating utility in biomedical applications, including disease diagnosis, medical imaging, and detection of biomagnetic fields, owing to their high sensitivity and robustness.¹² In industrial automation and the IoT, spintronic sensors and embedded MRAM are increasingly employed in programmable logic controllers, robotic systems, and connected manufacturing devices. The non-volatility of MRAM allows factory systems to recover instantaneously after power interruptions without data loss, offering a reliability advantage over flash-based alternatives in continuous production environments.¹³

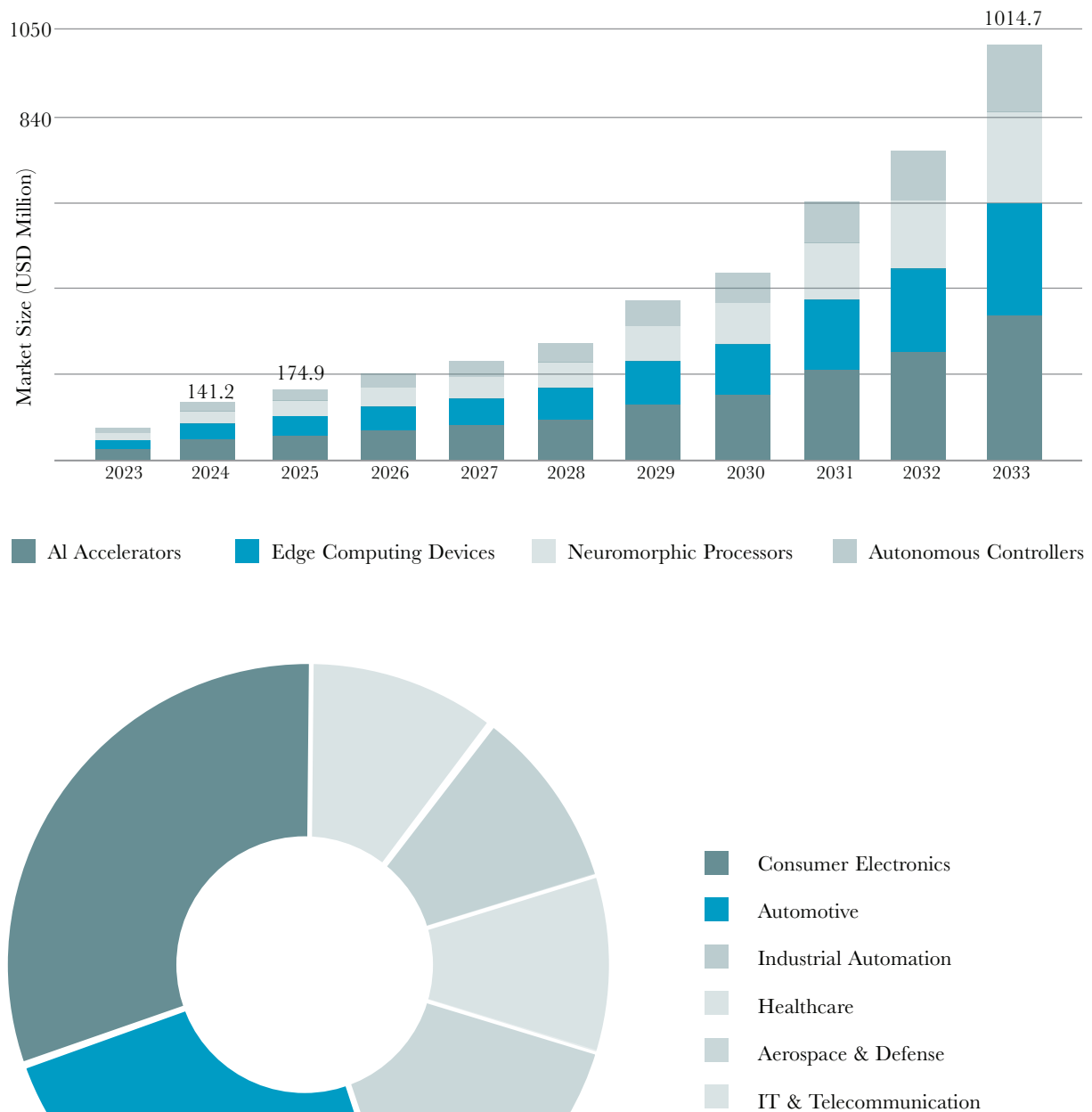
Beyond these established applications, spintronics is expected to play key roles in quantum computing, navigation, and advanced communication systems. Its relevance to defence and security has elevated the technology to a matter of strategic state interest. More broadly, the semiconductor industry has become a central arena of global technological competition, with its importance extending beyond economic value to encompass national

security and technological sovereignty. This has prompted a worldwide shift from market-led to security-driven policy approaches. Countries across the world have taken diverse approaches to spintronics, choosing various applications that drive their economies and future strategies. The United States, which led the spintronics market in North America in 2024, made advancements in aerospace and defence applications.¹⁴

Among countries of the European Union, France has taken a leading role in the domain, having invested about €38 million over eight years in the PEPR SPIN national research programme targeting applications in AI, cloud storage, and the communication networks of the future.¹⁵ Meanwhile, Chinese initiatives funding domestic research and development in spin, as well as its broader focus on quantum technology and semiconductors, has driven breakthroughs in spintronics.¹⁶ Mastery of spin-based memory is expected to soon become inseparable from broader objectives of digital sovereignty, AI leadership, and defence preparedness in an era of intensifying technological competition.

-
- 12 Shahriar Mostufa et al., “Spintronic Devices for Biomedical Applications,” *npj Spintronics* 2 (2024): 26, <https://doi.org/10.1038/s44306-024-00031-6>.
 - 13 “Case Study: Koyo Electronics Industries Programmable Logic Controller (PLC),” *Everspin*, 2015, <https://www.everspin.com/factory-automation>.
 - 14 Grand View Research, *Neuromorphic Spintronics Market (2025 - 2033)*, 2025, <https://www.grandviewresearch.com/industry-analysis/neuromorphic-spintronics-market-report>.
 - 15 “France 2030: The CEA and CNRS are Leading a National Spintronics Programme for Frugal, Agile, and Sustainable Digital Technology,” *CNRS*, January 29, 2024, <https://www.cnrs.fr/en/press/france-2030-cea-and-cnrs-are-leading-national-spintronics-programme-frugal-agile-and>.
 - 16 “China to Include Quantum Technology in its 14th Five-Year Plan,” *The State Council, The People’s Republic of China*, October 22, 2022, https://english.www.gov.cn/news/videos/202010/22/content_WS5f90e700c6d0f7257693e3fe.html; “Chinese Scientists Make Breakthrough in the Field-Free Full Switching of Chiral Antiferromagnetic Order,” *National Natural Science Foundation of China*, https://www.nsf.gov.cn/english/site_1/news/A2/2026/04-13/522.html; Ke Meng et al., “Room-Temperature Organic Spintronic Devices with Wide Range Magnetocurrent Tuning and Multifunctionality via Electro-Optical Compensation Strategy,” *Advanced Materials* 37 (2025):11, <https://doi.org/10.1002/adma.20241799Fig15>.

Figure 2: Neuromorphic Spintronics Market Projections by Application (2023–2033) and Application Share by End Use (2024)



Source: Grand View Research¹⁷

17 “Neuromorphic Spintronics Market (2025 - 2033)”.

The Concentration Problem

As advanced industrial economies compete to dominate this technological frontier, spintronics also carries important implications for countries that remain outside the manufacturing race. The global spintronics market is highly concentrated. In 2025, the Asia-Pacific accounted for 48.4 percent or US\$0.7 billion of the US\$1.44 billion global market, driven almost entirely by the semiconductor manufacturing hubs of South Korea, Japan, Taiwan, and China.¹⁸ North America, led by the US, represents US\$0.31 billion, attributable to its strong technological infrastructure, investment in scientific research, and existing industrial base.¹⁹ Meanwhile, South America's share is just US\$0.06 billion, and the Middle East and Africa, taken together, account for US\$0.09 billion;²⁰ these figures are marginal relative to the technology's strategic importance.

The barriers to entry are substantial. Fabricating advanced semiconductor nodes requires multi-billion-dollar investments and highly specialised technical expertise. As a result, most Global South nations remain confined to the consumer end of the value chain,

purchasing chips, controllers, and IoT devices designed and manufactured elsewhere. High production costs and integration challenges already constrain 27 percent of potential market applications globally.²¹ These obstacles are compounded by energy and infrastructure deficits, limited research ecosystems, and the persistent outflow of skilled talent.²² Without deliberate intervention, the spintronics transition risks deepening the digital divide by reinforcing existing patterns of technological dependence and exclusion.

The Opportunity Window

MRAM holds particular potential for the Global South due to its reduced power usage combined with high speed and endurance.²³ This is highly advantageous for energy-constrained environments like sub-Saharan Africa and South Asia, where edge computing is most needed for research and applications but power supply is least reliable. Similar to mobile banking's bypass of standard banking infrastructure to enable financial inclusion,²⁴ MRAM-powered edge devices could allow

18 "Spintronics Market, May 2026," *Fortune Business Insights*, 2026, <https://www.fortunebusinessinsights.com/spintronics-market-110877>.

19 Spintronics Market, May 2026, <https://www.fortunebusinessinsights.com/spintronics-market-110877>.

20 Spintronics Market, May 2026, <https://www.fortunebusinessinsights.com/spintronics-market-110877>.

21 "Spintronics Market, May 2026," *Business Research Insights*, 2026, <https://www.businessresearchinsights.com/market-reports/spintronics-market-111846>.

22 World Bank, *Forging Viet Nam's Semiconductor Future: Talent and Innovation Leading the Way*, September 2025, Washington DC, World Bank Group, 2025, <https://openknowledge.worldbank.org/server/api/core/bitstreams/fdbcbbf-84e9-4ed8-b1ff-b7caa4c86bcb/content>.

23 Shanon Davis, "The 2025 MRAM Global Innovation Forum to Showcase MRAM Technology Innovations, Advances, & Research from Industry Experts," *Semiconductor Digest*, December 8, 2025, <https://www.semiconductor-digest.com/the-2025-mram-global-innovation-forum-to-showcase-mram-technology-innovations-advances-research-from-industry-experts>.

24 ITU Telecommunication Standardization Sector, *The Mobile Money Revolution Part 2: Financial Inclusion Enabler*, May 2013, Geneva, International Telecommunication Union, https://www.itu.int/dms_pub/itu-t/oth/23/01/t23010000200002pdf.pdf.

these economies to participate in this revolution without the infrastructure assumptions of more developed environments like continuous power.

Despite the barriers to entry, China's experience demonstrates that participation in the spintronics market is achievable. The country's Ministry of Science and Technology has made the expansion of the memory industry a pillar of its semiconductor indigenisation strategy.²⁵ In late 2025, Shanghai Siproin Microelectronics began commercial shipments of China's first STT-MRAM chips, marking the country's first commercially available emerging memory technology.²⁶ This demonstrates that sustained state support, long-term investment, and a willingness to absorb extended development timelines can help narrow technological gaps.

India's semiconductor push and Brazil's deep-tech clusters in São Paulo and the broader Latin American materials-science ecosystem similarly represent potential entry points at the research and design layer, even if advanced fab-level participation remains distant. For smaller economies, the more immediate path is through procurement policy for MRAM, which over time could lead to design and integration capability.

The Geopolitics of Spin

State-level strategic interest has made spintronics part of the broader contest for technological sovereignty. This is especially

evident in the US-China semiconductor rivalry, where escalating and retaliatory export controls have shaken the sector and begun to reshape which countries can access, and which must indigenise, the next generation of memory technology. Under the current US regulations, MRAM is not included in the controlled categories. As the calculus shifts, this cannot be taken for granted.

For China, export controls have functioned as an accelerant for domestic ambition. Siproin's achievement, combined with other Chinese manufacturers such as ChangXin Memory Technologies' DDR5 DRAM—the current-generation standard for the volatile, high-speed memory used in computers and smartphones—and Yangtze Memory Technologies Corporation's NAND—the flash storage technology underlying solid-state drives and mobile devices—forms an increasingly complete domestic memory ecosystem.²⁷

Meanwhile, the European Union's Chips Act has aligned with the US chokepoint strategy, and the industry is actively advancing next-generation MRAM.²⁸ The net effect is a technology landscape in which the memory supply chain is dividing along geopolitical lines.

Future Trajectories

The future spintronics landscape will be shaped by several factors. The expansion of AI computing is likely to be the strongest driver

25 Yole Group, "China's Next Move: the Five-Year Plan that Could Reshape Semiconductors," Yole Group, December 1, 2025, <https://www.yolegroup.com/strategy-insights/chinas-next-move-the-five-year-plan-that-could-reshape-semiconductors>.

26 "TechInsights Confirms China's First Commercial STT-MRAM Chips," TechInsights, December 8, 2025, <https://www.techinsights.com/blog/techinsights-confirms-chinas-first-commercial-stt-mram-chips>.

27 "TechInsights Confirms China's First Commercial STT-MRAM Chips".

28 "Bringing SOT-MRAM Technology Closer to Last-level Cache Memory Specifications," imec, December 16, 2024, <https://www.imec-int.com/en/articles/bringing-sot-mram-technology-closer-last-level-cache-memory-specifications>.

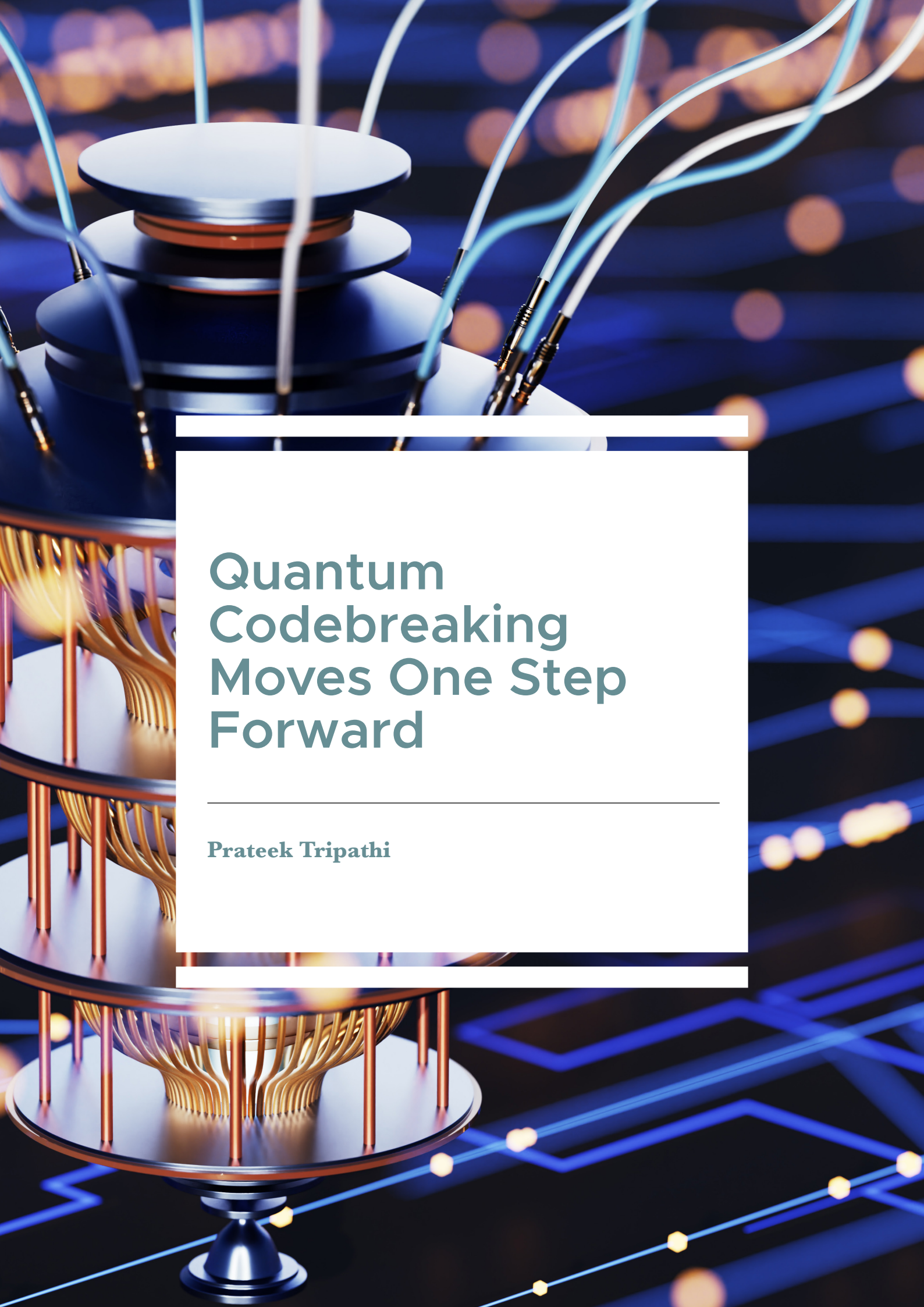
of growth, with edge AI emerging as a major market for MRAM. Tighter US export controls could provide a further boost, particularly for China's domestic ecosystem. As the Siproin breakthrough illustrates, restricting access to foundry services creates the industrial policy rationale for domestic capability development. The primary risk of slowdown is process economics. If silicon CMOS scaling proves more durable than expected, the speed of the MRAM transition could decrease. A recalibration in US-China technology relations could similarly reduce the pressure driving Chinese indigenisation.

What is clear is that the decisions made in 2026—including which architectures to fund and regulate and which countries to include in the emerging memory ecosystem—will shape the spintronics landscape to come. For the Global South, the window to participate in those decisions is open but narrowing. Spintronics may not define the next few years, but these years will do much to define who benefits from spin.

Amoha Basrur is Junior Fellow, Centre for Security, Strategy and Technology (CSST), ORF.

Pranoy Jainendran is Research Assistant, CSST, ORF.

The authors acknowledge that Sonnet 4.6 was used to generate Figure 1 and for refining language for clarity.



Quantum Codebreaking Moves One Step Forward

Prateek Tripathi

In terms of potential, quantum computing (QC) may be the holy grail of modern technology. The ability to control individual particles at the microscopic scale unlocks the enormous possibilities of exploiting purely quantum mechanical phenomena, fundamentally altering the collection, processing, and communication of information. At the same time, QC poses a significant cybersecurity threat in the form of Cryptographically Relevant Quantum Computers (CRQCs), which could break most current asymmetric encryption protocols¹ and threaten the foundations of the global digital landscape.

Threats aside, the growth of QC technology has been impeded by quantum error correction (QEC) since its inception. Though superconducting qubits emerged as the most viable candidate for QC,² overall progress remained relatively stagnant in the ensuing decades, largely due to a lack of scalability. In recent years, enhanced global interest and investment have opened new avenues for QEC while advancing existing frameworks.³ Though the field of QC is not mature enough to provide remarkable practical applications at the moment, recent developments serve to exemplify the asymmetric nature of quantum technology (QT) development and how multiple incremental advancements can potentially lead to overall progress.

As a result, it is becoming more likely that the next breakthrough will occur in the short run, especially given the rapid advancements in QEC and QC modalities such as neutral atoms and trapped ions.⁴ While this is a positive trend towards achieving practical and commercially relevant

1 Public-key cryptography is largely reliant on asymmetric encryption protocols which hinge on the inability of classical computers to solve a certain class of mathematical problems, namely, that of prime number factorisation. However, CRQCs are capable of doing so via Shor's algorithm.

2 A qubit is the quantum analogue of the bit used in classical computers. Superconducting qubits utilise the unique properties of superconductors to encode information in the form of qubits.

3 Earl Campbell, "A Series of Fast-paced Advances in Quantum Error Correction," *Nature Reviews Physics*, February 16, 2024, <https://www.nature.com/articles/s42254-024-00706-3>.

4 Neutral atom qubits utilise arrays of uncharged atoms controlled through lasers. Trapped ions qubits use charged particles (ions) which are trapped using electric fields and manipulated by lasers.

applications across a broad range of fields, progress towards fault tolerance also brings QC one step closer towards CRQCs. As such, the progressive trends in QEC are being accompanied by a universal push towards quantum-resistant cryptographic algorithms through Post-Quantum Cryptography (PQC) migration.

Given its relatively limited investment capabilities and the dilemma posed by escalating export controls, the Global South must capitalise on these trends while identifying nationally relevant and optimal areas for capacity building. This would enable it to gradually carve out individual niches within the broader field of QC, while enabling simultaneous preparation for the threat posed by CRQCs through PQC migration strategies and implementation. Moreover, pursuing multilateral collaborations and initiatives would also be a prudent step towards addressing gaps in investment, infrastructure, and standardisation.

Unpacking Error Correction and Fault Tolerance

Quantum Error Correction: Similar to the role of bits in classical computing, QC

relies on qubits, which are individual particles like electrons, photons, or atoms. The main impediment to QC comes in the form of decoherence or “noise”, which essentially refers to the decay of information⁵ carried by a qubit as a result of its interaction with the external environment.⁶ Another source of error is gate error, which can cause a quantum logic gate⁷ to give erroneous outputs due to noise, miscalibration, or other sources.

These errors are addressed by a set of algorithmic techniques known as Quantum Error Correction (QEC), which essentially combines multiple physical qubits⁸ into “logical” qubits, which are capable of performing meaningful operations and tasks.⁹ In order to do so, QEC entails running quantum algorithms repeatedly while extracting “error syndromes” (see Figure 1).¹⁰ These are subsequently fed into a classical computer, which suggests remediation and recovery steps. However, this process itself introduces a significant computational overhead, which necessitates the requirement for time-efficient QEC algorithms.

5 Technically, decoherence can lead to bit-flip and phase-flip errors in a qubit’s state.

6 Emily Grumbling and Mark Horowitz, “Quantum Computing: Progress and Prospects,” *National Academies of Sciences, Engineering, and Medicine*, 2019, <https://doi.org/10.17226/25196>.

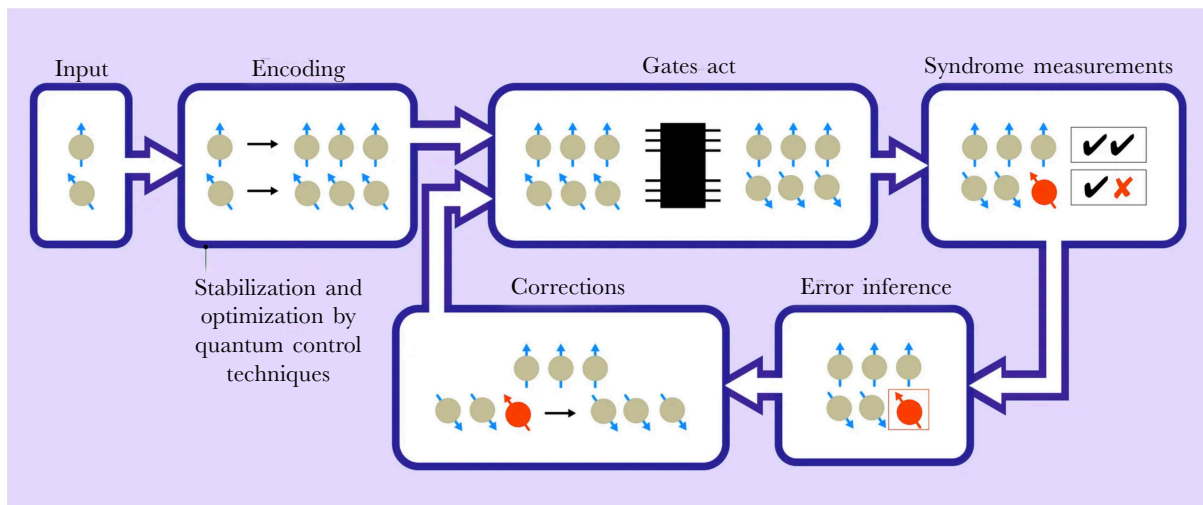
7 A quantum logic gate is the quantum counterpart to classical logic gates used in typical computers. Though they are functionally similar, there are significant differences at an operational level.

8 A physical qubit refers to the actual hardware implementation of the qubit in a quantum computer whereas a logical qubit combines several error-corrected physical qubits and can perform fault-tolerant applications.

9 Joschka Roffe, “Quantum Error Correction: An Introductory Guide,” *arXiv*, July 25, 2019, <https://arxiv.org/abs/1907.11157>.

10 Jens Eisert and John Preskill, “Mind the Gaps: The Fraught Road to Quantum Advantage,” *arXiv*, October 22, 2025, <https://arxiv.org/abs/2510.19928>.

Figure 1: Basic Steps of Quantum Error Correction

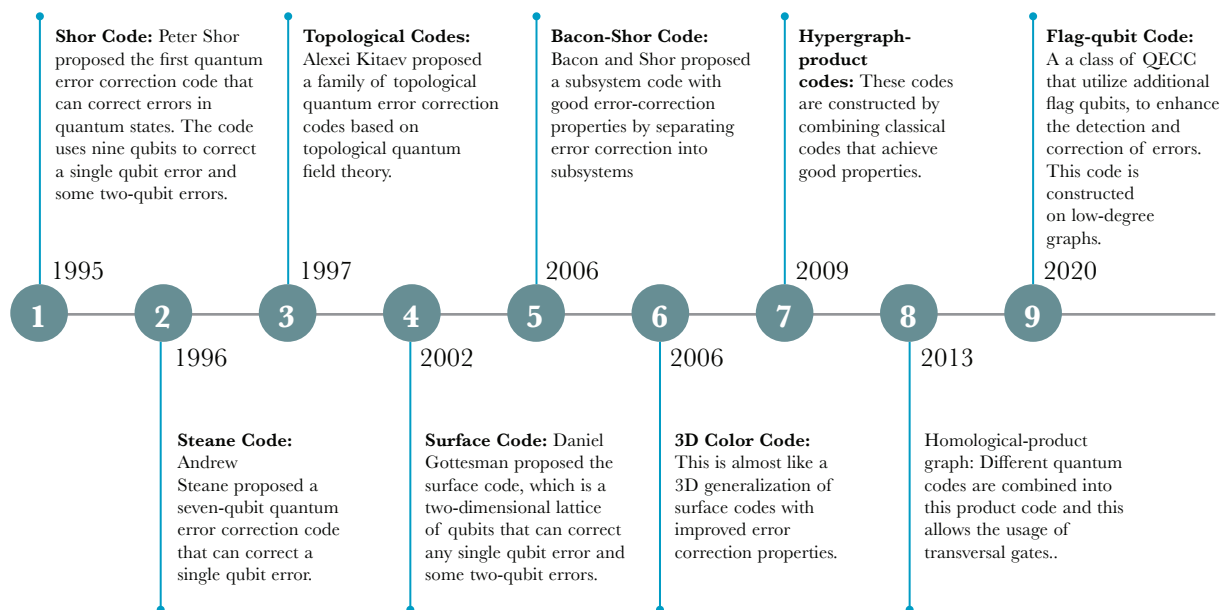


Source: Biercuk and Stace (2022)¹¹

In terms of its history, QEC began with the Shor Code proposed in 1995.¹² Subsequently, the field has witnessed multiple advancements,

particularly with the inception of topological codes¹³ such as surface and colour codes.

Figure 2: Evolution of Quantum Error Correction



Source: Chatterjee et al¹⁴

11 Michael Biercuk and Thomas Stace, “Quantum Error Correction: Time to Make it Work,” *IEEE Spectrum*, June 26, 2022, <https://spectrum.ieee.org/quantum-error-correction>.

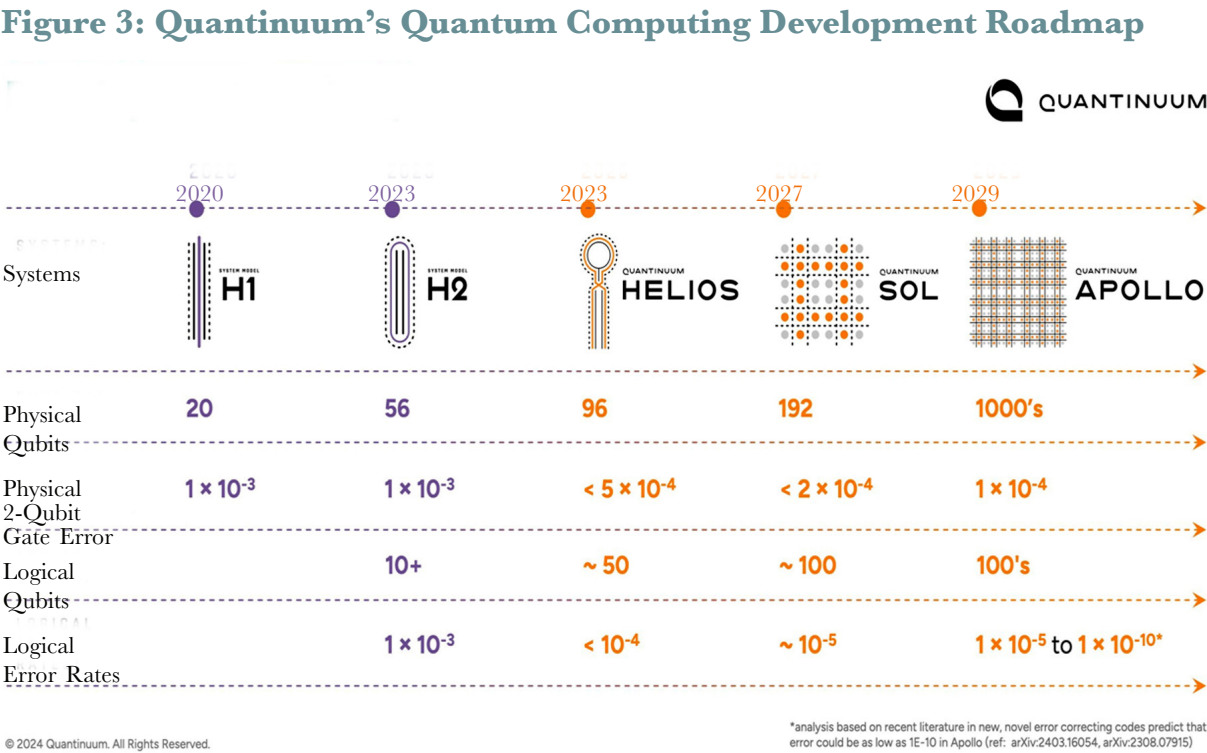
12 Roffe, “Quantum Error Correction: An Introductory Guide”.

13 While QEC began with relatively simpler repetition codes and the Shor Code, it got a significant boost with the development of topological codes which entail organising qubits in a 2D or 3D lattice. Topological codes are particularly suitable for achieving fault tolerance.

14 Avimta Chatterjee, Koustubh Phalak, and Swaroop Ghosh, “Quantum Error Correction for Dummies,” *arXiv*, April 18, 2023, <https://arxiv.org/abs/2304.08678>.

Fault Tolerance: QC is currently in the era of Noisy Intermediate-Scale Quantum (NISQs) computers, which seek to use a relatively limited number of “noisy”, or non-error-corrected, qubits to perform useful tasks that provide a measurable computational advantage over classical computers.¹⁵ As QEC techniques, hardware, and control systems evolve, it is estimated that QC will eventually enter the era of Fault Tolerant Quantum Computers (FTQCs), which are large-scale quantum computers comprising millions of logical qubits, which provide a computational

advantage over classical computers for a wide variety of applications, particularly with respect to performing accurate quantum simulations, which could have groundbreaking implications for fields like biology, chemistry, material discovery, optimisation problems, and machine learning, not to mention enhancing humanity’s fundamental understanding of natural laws and the universe. Multiple R&D and corporate institutions have published various roadmaps towards achieving fault tolerance. One example by Quantinuum is given in Figure 3.



Source: Quantinuum¹⁶

15 John Preskill, “Beyond NISQ: The Megaquop Machine,” *arXiv*, February 24, 2025, <https://arxiv.org/abs/2502.17368>.

16 “Quantinuum Unveils Accelerated Roadmap to Achieve Universal, Fully Fault-Tolerant Quantum Computing by 2030,” *Quantinuum*, September 10, 2024, <https://www.quantinuum.com/press-releases/quantinuum-unveils-accelerated-roadmap-to-achieve-universal-fault-tolerant-quantum-computing-by-2030>.

Historically, superconducting qubits constituted the most actively researched and well-developed modality of QC, largely due to hardware breakthroughs such as the development of transmon and fluxonium qubits,¹⁷ on the one hand, accompanied by the advancements in QEC via surface codes on the other.¹⁸ However, the prospect of fault tolerance remained elusive due to multiple reasons, primarily the lack of scalability.

Emerging Prospects in Error Correction

A notable development in the NISQ era has been the emergence of Quantum Error Mitigation (QEM), a set of passive alternative techniques designed to reduce error impact as opposed to the active feedback correction provided by QEC.¹⁹ Though the sampling costs involved with QEM can make them less relevant for FTQCs, techniques such as Zero Noise Exploitation (ZNE), Probabilistic Error Cancellation (PEC), and dynamical decoupling are proving to be quite effective when it comes to NISQs.²⁰

For instance, in 2024, Google's Willow processor achieved a major milestone by

demonstrating "below threshold" performance, implying that increasing the number of physical qubits exponentially reduces the error rate of logical qubits, a critical requirement for achieving fault tolerance.²¹ It utilised transmon qubits with surface code-based QEC alongside multiple QEM techniques, including dynamical decoupling.

Another recent advancement has been the emergence of new QEC paradigms such as the quantum low-density parity-check (qLDPC) codes, which have been particularly useful for other QC modalities like trapped ions and neutral atoms.²² This has even prompted corporations like IBM towards officially transitioning to qLDPC codes. A particularly important development was a paper by a research team from the California Institute of Technology, published in March 2026, which proposed a QC architecture based on neutral atoms and qLDPC-based error correction, which could potentially break ECC-256 encryption with 10,000 physical qubits and RSA-2048 encryption with 100,000 qubits, thereby accelerating the development of CRQCs.^{23,24} Similarly, in February 2026, Australian startup Iceberg Quantum announced its Pinnacle architecture, which uses a similar approach to

17 A transmon qubit is the most well-established hardware implementation of superconducting qubits. It uses a shunting capacitor which suppresses charge noise aiding significantly in error correction. A fluxonium qubit is a more recent implementation which uses a superinductor in addition to a capacitor, significantly enhancing coherence time.

18 Julian Jang-Jaccard, Philippe Caroff, Evan Blezinger, Valentin Mulder, Alain Mermoud, and Vincent Lenders, "Quantum Technologies: Trends and Implications for Cyber Defense," *Springer Nature*, 2026, <https://library.oapen.org/handle/20.500.12657/109316>.

19 Eisert and Preskill, "Mind the Gaps: The Fraught Road to Quantum Advantage".

20 Jang-Jaccard et al, "Quantum Technologies: Trends and Implications for Cyber Defense".

21 Hartmut Neven, "Meet Willow, Our State-of-the-art Quantum Chip," Google, December 9, 2024, <https://blog.google/innovation-and-ai/technology/research/google-willow-quantum-chip/>.

22 Marin Ivezic, "Quantum Low-Density Parity-Check (qLDPC) Codes," *PostQuantum*, March 4, 2026, <https://postquantum.com/quantum-computing/quantum-low-density-parity-check-qldpc-codes/#4-industry-adoption-who-is-pursuing-qldpc-codes->.

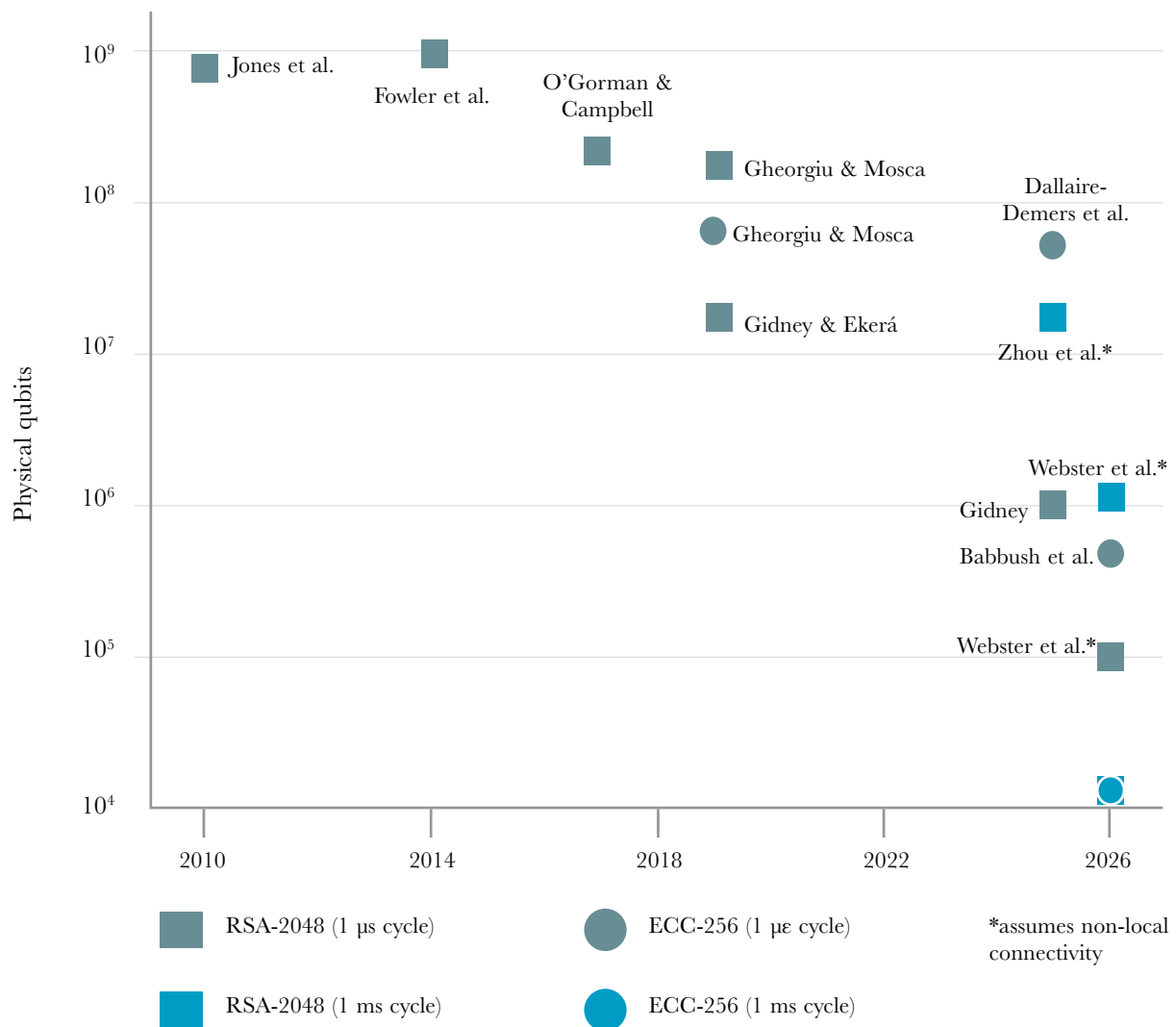
23 CRQCs are large-scale quantum computers capable of running Shor's algorithm efficiently. They are capable of breaking most current encryption protocols and hence, constitute one of the most critical applications of QC.

24 Whitney Calvin, "Caltech Team Finds Useful Quantum Computers Could Be Built with as Few as 10,000 Qubits," *Caltech*, March 31, 2026, <https://www.caltech.edu/about/news/caltech-team-finds-useful-quantum-computers-could-be-built-with-as-few-as-10000-qubits>.

bring down the physical qubit requirement for breaking RSA-2028.²⁵ These advancements are particularly relevant since the RSA-2048 and ECC-256 encryption algorithms are utilised universally for various applications such as web browsing, email security, digital signatures, cryptocurrencies, and messaging apps.

These developments are in line with the gradually declining physical qubit requirement for CRQCs over the past 15 years, as shown in Figure 4.

Figure 4: The Declining Physical Qubit Requirement for CRQCs (2010-2026)



Source: Cain et al (2026)²⁶

25 “Pinnacle and Series Seed,” *Iceberg Quantum*, February 13, 2026, <https://www.iceberg-quantum.com/blog/pinnacle-and-series-seed>.

26 Madelyn Cain, Qian Xu, Robbie King, Lewis R.B. Picard, Harry Levine, Manuel Endres, John Preskill, Hsin-Yuan Huang, and Dolev Bluvstein, “Shor’s Algorithm is Possible with as Few as 10,000 Reconfigurable Atomic Qubits,” *arXiv*, March 30, 2026, <https://arxiv.org/abs/2603.28627>.

Other QC modalities such as electron spin and photonic qubits are also being actively explored, along with their respective QEC implementations, though these are relatively less developed at the time of writing.

The Future of Quantum Computing

The field of QC currently lies at a crossroad. On one hand, recent years have witnessed the emergence of positive trends in QEC and technical strides across multiple hardware platforms. Moreover, the increasingly important contribution of Artificial Intelligence (AI) towards QEC algorithms through tools such as Google's AlphaQubit, coupled with the possibility of hybrid error correction architectures such as combined QEM-QEC frameworks, present promising possibilities for the future.²⁷ Additionally, hybrid hardware architectures involving multiple QC modalities are also likely to provide emergent capabilities imminently. If these trends were to continue, the field could witness the emergence of FTQCs sooner than expected.

On the other hand, the path towards fault tolerance is still obstructed by hurdles. A

primary issue stems from a lack of consensus on QC benchmarking. Currently, there are multiple benchmarks, including randomised benchmarking, random circuit sampling, quantum volume, and algorithmic qubits.²⁸ Different companies, institutions, and countries utilise varying benchmarks rendering performance and progress assessment a particularly difficult task. Novel programmes such as DARPA's Quantum Benchmark Initiative can help in this regard.²⁹

Furthermore, different QC modalities suffer from individual issues pertaining to QEC which must be overcome. For superconducting qubits, real-time decoding³⁰ impedes scalability.³¹ At the same time, though neutral atoms and trapped ions are inherently more scalable, they suffer from slower operation times as compared to other modalities.³²

Another hurdle for QC stems not from QEC, but from the lack of hardware infrastructure and commercial scaling owing to the largely fragmented nature of quantum hardware supply chains coupled with unfocused national strategies.³³ The situation is further exacerbated by multiple export controls on both QC hardware and the critical minerals required for

27 "AlphaQubit Tackles One of Quantum Computing's Biggest Challenges," Google, November 20, 2024, <https://blog.google/innovation-and-ai/models-and-research/google-deepmind/alphaqubit-quantum-error-correction/>.

28 Marin Ivezić, "Quantum Computing Benchmarks: RCS, QV, AQ, and More," *PostQuantum*, November 28, 2024, <https://postquantum.com/quantum-computing/quantum-computing-benchmarks/>.

29 Prateek Tripathi, "DARPA's Quantum Benchmarking Initiative: A Make-or-Break for Quantum Computing," Observer Research Foundation, May 6, 2025, <https://www.orfonline.org/expert-speak/darpa-s-quantum-benchmarking-initiative-a-make-or-break-for-quantum-computing>.

30 Real-time decoding refers to the extraction of error syndromes by classical computers which must have low latency and be achieved in real-time in order for the quantum computation to be performed optimally. For superconducting qubits, the latency requirements are particularly stringent (about 10 µs).

31 Preskill, "Beyond NISQ: The Megaquop Machine".

32 Eisert and Preskill, "Mind the Gaps: The Fraught Road to Quantum Advantage".

33 Constanza M. Vidal Bustamante and John Burke, "Quantum's Industrial Moment," *Center for a New American Security*, March 12, 2026, <https://www.cnas.org/publications/reports/quantums-industrial-moment>.

a number of other nations across the European Union.³⁴ This necessitates the development of sovereign supply chains in addition to enhanced international negotiation and cooperation.

Implications for the Global South: Building National Strengths

The importance of obtaining novel computational capabilities through FTQCs for the Global South cannot be overstated. FTQCs can provide novel capabilities in agriculture, material design, medicine, manufacturing, and unprecedented optimisation and simulation capabilities. Moreover, the prospect of CRQCs in the hands of any state renders most global databases and digital repositories highly vulnerable to mass-scale breaching. However, the dual-use nature of the technology has had the unfortunate consequence of rendering it open to arms and export control regulations by global powers. As such, in the absence of sovereign initiatives, the Global South risks getting potentially locked out of a technology that can offer it strategic advantages in the near future while essentially exposing its digital landscape to quantum-enabled cyberattacks.

While it may not be economically feasible for Global South nations to explore all emerging QC platforms, they can focus on avenues that identify with national strengths in addition to analysing and following emerging trends. For instance, given the formidable IT and software development workforce possessed by India, it can focus on QEM and QEC via open-source platforms such as IBM's Qiskit which provide cloud access to quantum hardware. Given the

criticality of error correction for QC, as well as QT in general, this would be an invaluable contribution to the field and may help the country carve out its niche. Other Global South countries can adopt similar approaches based on their relevant strengths within the overall QC stack, ensuring that they establish and retain their relevance as the technology continues to evolve.

At the same time, the rapidly emerging trends in QEC are being accompanied by a global push towards PQC implementation, with the majority of nations setting a target of 2035 for complete migration. Given the threat posed by CRQCs to the global digital architecture, the Global South must follow suit or face the future risk of coercion by more developed states possessing the technology. Global South nations must hasten their PQC migration strategies and pursue them aggressively if they wish to avoid catastrophic consequences in the future.

Conclusion: Instituting Multilateral Frameworks and Alliances

Owing to all the issues and caveats discussed in this article, pursuing QT in isolation is an arduous task for any nation, regardless of economic capabilities or geographical location. Consequently, in addition to building national strengths, the Global South should also consider developing multilateral frameworks for QT with like-minded nations. This would aid in addressing and bypassing the hurdles posed by export controls, economic constraints, and PQC standardisation and implementation. Similar

34 Prateek Tripathi, "Impediments in Global Quantum Technology Collaboration," Observer Research Foundation, December 6, 2024, <https://www.orfonline.org/expert-speak/impediments-in-global-quantum-technology-collaboration>.

arrangements are already being pursued by Global North countries via multiple NATO and EU initiatives on QT such as the Transatlantic Quantum Community and the Quantum Flagship programme, respectively.³⁵

In this context, pursuing partnerships with both, nations not intricately tied to any particular framework, and Global South states that are relatively underdeveloped in the field, could provide important collaborative opportunities. For instance, countries such as Finland, Spain, and Canada have well-established QC ecosystems and could potentially develop multilateral frameworks with Global South nations like India, Indonesia, Brazil, and South Africa, who are in the process of pursuing novel capabilities in QC.

Furthermore, against the backdrop of a nascent and fragmented global quantum hardware and

critical mineral supply chain landscape, China has emerged as one of the few nations with a relatively well-established QT supply chain ecosystem.³⁶ Consequently, regardless of existing geopolitical realities and tensions, it is in the interest of the Global South to invoke Chinese cooperation in aiding individual efforts. Given China's active role in furthering Global South QT cooperation via the establishment of two inter-continental Quantum Key Distribution (QKD) links with BRICS nations such as Russia and South Africa, BRICS could serve as a viable platform for enhancing QT collaboration amongst Global South nations and can aid in keeping up with emerging trends in the field.³⁷ Establishing a formal framework under BRICS would be a good starting point in this regard. Additionally, other established platforms such as Quantum Leap Africa and the Africa Quantum Consortium could also serve as valuable forums for enhancing Global South cooperation.

35 Michal Krelina, "Military and Security Dimensions of Quantum Technologies: A Primer," SIPRI, July 2025, <https://www.sipri.org/publications/2025/other-publications/military-and-security-dimensions-quantum-technologies-primer>.

36 Constanza M. Vidal Bustamante and John Burke, "Quantum's Industrial Moment," Center for a New American Security, March 12, 2026, <https://www.cnas.org/publications/reports/quantums-industrial-moment>.

37 Matt Swayne, "China Establishes Quantum-Secure Communication Links with South Africa," *The Quantum Insider*, March 14, 2025, <https://thequantuminsider.com/2025/03/14/china-established-quantum-secure-communication-links-with-south-africa/>.



Digital Currencies: From Idea to Implementation

Sauradeep Bag

For much of the past decade, scholarly and policy discourse on digital currencies has remained largely prospective. Central banks commissioned feasibility studies, launched pilot programmes, and often deferred implementation, while proponents and sceptics alike debated futures untested at scale. Today, with 146 countries, representing 98 percent of global Gross Domestic Product (GDP), exploring or developing central bank digital currencies (CBDCs), and 11 BRICS nations pursuing similar initiatives, the central question is no longer whether sovereign digital money will emerge but what institutional form it will take, who will govern it, and whose economic interests it will serve.¹

Concurrently, a parallel transformation has advanced with less institutional fanfare. The emergence of privately issued stablecoins, now subject to comprehensive regulation by a major economy for the first time,² is restructuring the architecture of global payments in ways that central bank frameworks neither fully anticipated nor have adequately addressed.

Two distinct but intersecting trends define the current landscape. The first is the uneven progress of CBDCs, technically ambitious yet politically complex. The second is the rapid institutionalisation of dollar-pegged stablecoins, accelerated by the passage of the United States GENIUS Act in July 2025, which has transformed these instruments from reputational risks into regulated financial infrastructure.³ In 2024, stablecoin transfer volume surged to US\$27.6 trillion, more than Visa and Mastercard combined. That figure alone signals that the centre of gravity in digital currency has shifted from government-led experiments to market-driven reality.⁴

1 Atlantic Council, *CBDC Tracker*, 2026, <https://www.atlanticcouncil.org/cbdctracker/>.

2 United States Congress, S.1582 — *GENIUS Act of 2025*, Congress.gov, 119th Congress, 2025, <https://www.congress.gov/bill/119th-congress/senate-bill/1582>.

3 United States Congress, S.1582 — *GENIUS Act of 2025*, Congress.gov, 119th Congress, 2025, <https://www.congress.gov/bill/119th-congress/senate-bill/1582>.

4 World Economic Forum, *Stablecoins and Cryptocurrency Are on the Rise: What This Means for Financial Systems*, March 2025, <https://www.weforum.org/stories/2025/03/stablecoins-cryptocurrency-on-rise-financial-systems/>.

The CBDC Problem

China's digital yuan remains the most advanced CBDC deployment among major economies, with programmable payment functionality already in operation. Brazil's Drex initiative has stepped back from a blockchain-based architecture because of privacy and scalability concerns, narrowing its focus to collateral management and reconciliation while targeting a public launch in mid-2026.⁵ The Riksbank recommends establishing an enquiry to examine the legislative changes required for introducing an e-krona within a reasonable timeframe, should the Swedish Parliament decide to authorise the Riksbank to issue one.⁶ The enquiry is proposed to begin after the European Union's digital euro legislation is finalised and the European Central Bank makes a formal decision on issuing a digital euro. The process could be initiated either by the Government directly or through a parliamentary request instructing the Government to establish the enquiry. In Europe, policymakers have framed the digital euro partly as a measure to reinforce monetary and payment-system sovereignty in the face of increasing reliance on non-

European digital platforms, though differences of opinion between the ECB, the European Commission, and the European Parliament over the appropriate approach remain unresolved.⁷

India's experience is instructive precisely because it is the most honest available data point on what happens when a CBDC meets a mature digital payment ecosystem. Daily retail e-rupee transactions have fallen from a peak of one million to approximately 100,000, a stark indication of limited public enthusiasm. By March 2025, the retail pilot included 17 banks and over six million users, with circulation reaching ₹10.16 billion, a notable increase from the previous year. The Indian case reveals a fundamental design challenge that applies globally.⁸ Where real-time payment infrastructure already exists and functions well, a CBDC must offer something meaningfully different to justify adoption. Convenience alone is insufficient. The answer may lie in programmability—specifically, conditional payments, targeted welfare disbursements, and offline capability in low-connectivity areas, but most current pilots have yet to deliver these features at scale.

5 Aaron Stanley, "Brazil Abandons Blockchain For Its Drex CBDC Project," *Forbes*, August 13, 2025, <https://www.forbes.com/sites/digital-assets/2025/08/13/brazil-abandons-blockchain-for-its-drex-cbdc-project/>.

6 Sveriges Riksbank, *Recommendation for Riksdag and Government to Set Up an Inquiry On An e-Krona*, March 12, 2026, <https://www.riksbank.se/en-gb/payments--cash/payments-in-sweden/payments-report-2026/the-riksbanks-policy-recommendations/recommendation-for-riksdag-and-government-to-set-up-an-inquiry-on-an-e-krona/>.

7 Piero Cipollone, "The Digital Euro: Enhancing Payments in the Euro Area," European Central Bank (ECB), February 19, 2026, <https://www.ecb.europa.eu/press/key/date/2026/html/ecb.sp260219~e9f59ca8c0.en.html>.

8 "E-rupee in Circulation Grows to Over Rs 1,000 Crore; RBI Exploring Cross-Border CBDC Pilots," *The Economic Times*, May 29, 2025, <https://economictimes.indiatimes.com/tech/technology/e-rupee-in-circulation-grows-to-over-rs-1000-crore-rbi-exploring-cross-border-cbdc-pilots/articleshow/121485395.cms?from=mdr>.

The Stablecoin Acceleration

While CBDCs have struggled for traction, stablecoins have found it. Stablecoin transaction volume rose 83 percent between July 2024 and July 2025, reaching over US\$4 trillion in the first half of 2025 alone and accounting for 30 percent of all on-chain crypto transactions.⁹ The regulatory development most responsible for accelerating this growth was the GENIUS Act, signed into law in the United States in July 2025. Hailed by President Donald Trump as a step towards cementing American dominance, the legislation established the first comprehensive federal framework for stablecoins, embedding structural demand for US Treasuries and reinforcing the dollar's network effects in digital commerce.¹⁰

The geopolitical implications of this development deserve more attention than they typically receive in financial commentary. Under the GENIUS Act, a merchant in Lagos accepting dollar stablecoins, a remittance recipient in Manila holding them rather than converting them to pesos, and a Venezuelan family preserving savings in them, all become indirect purchasers of US Treasury securities, channelling demand through end users worldwide and bypassing foreign central banks entirely. This is dollar hegemony extended into the crypto era not through coercion but through the structural logic of regulatory legitimacy and network effects.

The Global South Calculus

For the Global South, the digital currency transition presents a genuine strategic dilemma. The immediate benefits are tangible. Average global remittance costs remain near 6 percent, and settlement is not truly real-time even when customer-facing interfaces suggest otherwise.¹¹ Stablecoins are introducing a parallel settlement layer that is beginning to structurally transform these corridors. For households in high-inflation economies, dollar stablecoins have become de-facto savings instruments.

The long-run risks, however, are equally real. Widespread adoption of dollar stablecoins is, in economic terms, a form of dollarisation, carrying all the monetary sovereignty implications that entails. Countries that have spent decades building independent monetary infrastructure now face the prospect of their citizens voluntarily migrating to dollar-denominated digital instruments that sit outside the reach of domestic monetary policy.

Nigeria's experience captures the tension. The eNaira has seen modest retail adoption as a CBDC, but the launch of eNGN, a central bank-backed naira stablecoin interoperable with the eNaira, in 2025 marked an important course correction, contributing alongside structural reforms to increased remittance inflows.¹² This hybrid approach—a sovereign stablecoin that competes on usability while preserving monetary control—may represent the most viable path for large developing economies.

9 “2025 Crypto Adoption and Stablecoin Usage Report,” TRM Labs, October 21, 2025, <https://www.trmlabs.com/reports-and-whitepapers/2025-crypto-adoption-and-stablecoin-usage-report>.

10 The White House, *Fact Sheet: President Donald J. Trump Signs GENIUS Act into Law*, July 18, 2025, <https://www.whitehouse.gov/fact-sheets/2025/07/fact-sheet-president-donald-j-trump-signs-genius-act-into-law/>.

11 “Remittance Prices Worldwide Database,” World Bank, 2026, <https://remittanceprices.worldbank.org/>.

12 Central Banking, *Nigeria to Reposition its Struggling CBDC*, 2025, <https://www.centralbanking.com/central-banks/payments/7976086/nigeria-to-reposition-its-struggling-cbdc>.

India's strategic position is more complex than most. Unified Payments Interface's (UPI) dominance in domestic payments means that dollar stablecoins face a genuinely competitive alternative in the retail segment.¹³ The Reserve Bank of India's (RBI) initiation of a retail sandbox for CBDC innovation in October 2025 suggests an awareness that the current approach requires recalibration.¹⁴

What Could Alter the Trajectory in 2026

Three developments could materially change the course of this story. The first is implementation of the GENIUS Act's full requirements, scheduled to take effect no later than January 2027. Full reserve and audit requirements for stablecoin issuers could consolidate the market significantly around a small number of well-capitalised players, potentially reducing competition and raising the cost of access for smaller economies and users.

The second is the trajectory of China's digital yuan in international trade settlement. In July 2025, the People's Bank of China Governor proposed a multipolar global monetary system

that reduces US dollar dominance in favour of coexistence and competition among multiple sovereign currencies.¹⁵ If China succeeds in embedding the digital yuan into Belt and Road trade corridors, it would offer the Global South an alternative digital currency infrastructure that does not route through dollar-denominated rails, with different—but not necessarily smaller—geopolitical dependencies.

The third is whether CBDCs can find a compelling use case that justifies their complexity. The most plausible candidate is programmable welfare delivery: targeted, traceable, conditional transfers for social protection that existing payment systems cannot efficiently implement. If a major economy demonstrates this at scale in 2026, it could reframe the CBDC debate from payments competition to development infrastructure, a framing that is both more accurate and more politically durable.

The digital currency transition is no longer a question of whether it will happen. It is one of whose infrastructure it runs on, whose monetary interests it serves, and whether the countries that stand to gain the most from cheaper, faster, and more inclusive payments can shape the architecture before it is set.

13 BIS, *Speech/Remarks on Digital Currencies and the Future of Payments*, Bank for International Settlements, December 2025, <https://www.bis.org/review/r251216i.htm>.

14 "RBI Launches Digital Currency Retail Sandbox," *The Economic Times*, October 2025, <https://economictimes.indiatimes.com/news/economy/policy/rbi-launches-digital-currency-retail-sandbox/articleshow/124388034.cms?from=mdr>.

15 "China's Central Bank Says Promote Digital Yuan in Multi-polar Currency System," *Reuters*, June 18, 2025, <https://www.reuters.com/markets/currencies/chinas-central-bank-says-promote-digital-yuan-multi-polar-currency-system-2025-06-18/>.



ORF Global is a virtual centre. It serves as a collaboration hub for ORF's three India locations—Delhi, Mumbai, and Kolkata— and two overseas affiliates, ORF America and ORF Middle East.

<https://www.orfonline.org/>