THE ENERGY SPRINT OF THE AI RACE

A GREEN WINDOW OF OPPORTUNITY FOR DEVELOPING COUNTRIES?

Knowledge Partners

TIDE CENTRE

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Table of Contents

Executive summary

The future of Artificial Intelligence (AI) will be shaped less by algorithms than by access to sustainable energy. AI may reshape economies, but it is ultimately founded on physical infrastructure, particularly energy systems. The long-term competitiveness of national AI ecosystems – and the opportunities that they can unlock – will therefore depend on access to abundant, reliable, cheap and clean electricity. This could fundamentally reshape the balance of power in global innovation, shifting the comparative advantage for this transformative technology towards countries with significant renewable energy potential, many of which are in the Global South.

The AI and climate agendas are not separate and require integrated policy approaches. They draw on the same foundations, including electricity, water, land, finance and governance. Yet too often they are pursued in isolation. This siloed approach is no longer viable and was never desirable. Countries need to drive strategic and coherent approaches to both – viewing the energy and AI transitions as two new, intertwined strands of industrial and economic policy. This coherence will be key in unlocking the potential of AI and keeping AI development within planetary boundaries.

Without sustainable energy systems, AI risks deepening global inequalities. Electricity consumption by data centres is projected to more than double by 2030, reaching 945 terawatt hours. AI is therefore becoming constrained not by algorithms or data but by access to abundant, affordable and low-carbon electricity. Countries without reliable and sustainable energy systems risk exclusion from the next digital revolution.

AI-energy tensions open a green window of opportunity

Beyond its direct energy needs, AI is also embedded in heavy physical systems with strategic implications. This includes semiconductor fabrication plants, high-performance compute clusters and hyperscale data centres that require stable power, water and rare minerals. Yet this materiality also creates strategic leverage. Countries that strengthen both their energy and digital infrastructures could become key actors in the global innovation economy. When designed as public interest infrastructure, integrated AI-energy systems can reduce system losses, stabilize tariffs and expand access for people, allowing households and small enterprises to benefit from lower costs and more reliable electricity. This can also open up new AI opportunities and pathways. For many developing economies, especially in Africa and Small Island Developing States, modular and distributed systems offer a more relevant entry point by aligning with current local demand, easing pressure on fragile grids and enabling gradual scaling.

AI stands at a decisive moment for global development and inequality. This report comes at an inflection point. AI is projected to add US$15.7 trillion to global output by 2030, yet less than 10 percent of this value is expected to accrue to developing economies. This is the foundation of what the report terms 'Green AI': the balanced development of AI, energy and nature. Green AI places people at the centre, framing AI-energy integration as a means to expand human capabilities, improve livelihoods and support a just transition, rather than an end in itself. This is a 'green window of opportunity' that AI could open.

Resource geopolitics of the AI race

AI is reshaping global power dynamics by turning energy into a core strategic asset. The rise of AI as an energy-dependent sector could reshape alliances and bargaining power. The rivalry between China and the United States of America now extends beyond semiconductor export controls to include competition for energy-secure AI clusters. This reconfiguration creates new and multipolar dynamics in which energy, minerals and data converge into a single strategic domain. These shifts have far-reaching implications for developing economies seeking to carve out development space in a rapidly shifting global technological order linked to energy-intensive digital infrastructure.

A renewables-based comparative advantage alone is not sufficient to secure a sustainable AI pathway. Solar and geothermal potential must be matched by stable grids, predictable policy, robust regulation and industrial capability-building. Without this, AI could deepen dependence on foreign cloud services, strain fragile energy systems and leave developing economies in extractive digital roles rather than as creators of value. The question is how developing countries can harness AI as a green window of opportunity rather than reinforce existing hierarchies.

A key gap in the AI-energy debate is that it has focused largely on supply-side constraints, while the conditions for adoption and demand creation have received less attention. AI does not diffuse automatically from global innovation hubs into local development systems. It requires trusted local use cases, affordable services, institutional buyers, skilled users, accessible data and financing models that allow firms, utilities and public agencies to experiment without taking on excessive risk. Users, entrepreneurs, utilities and public institutions are therefore central to AI diffusion, particularly in the energy sector, where adoption depends on real operational needs, procurement capacity and credible pathways to scale. Cross-country inequalities in AI readiness reinforce this divide. Within countries, uneven digital skills and widening gender and urban-rural gaps at higher skill levels shape who can build, use and benefit from AI.

AI-energy ecosystem development in the Global South

Green AI startups are emerging as key actors in translating the AI-energy transition into a green window of opportunity for developing economies. They sit at the operational intersection of power systems, digital infrastructure and climate sustainability. This report analyses nearly 90 of them from across the Global South—comprising innovators working on energy-climate technologies for AI (renewables, storage, grid optimization and efficient data-centre infrastructure) and AI for climate (forecasting, automation, decarbonization and resource optimization). These startups could offer strategic pathways where governments and development partners help create viable markets through procurement, regulatory sandboxes, utility partnerships, concessional finance, open energy data, testing facilities and support for early adopters.

Despite growing momentum, Green AI ecosystems face significant structural constraints. The mapping reveals that startups are clustered in nine Green AI activity areas, dominated by AI for energy, grid edge intelligence and AI-enabled infrastructure. Commercial traction is highly concentrated in a small subset of the startups, however, reflecting deep demand-side and institutional constraints. These constraints reflect weak demand, limited early adopters, thin venture capital ecosystems and misalignment between public institutions and private innovation.

A people-planet-prosperity roadmap

To meet these challenges, the report advances a holistic framework with three pillars: people, planet and prosperity. The people pillar focuses on building skills, inclusion and public benefit digital infrastructure so communities are empowered by AI and clean energy transitions. The planet pillar emphasizes safeguarding environmental boundaries by managing the AI resource footprint while deploying AI to strengthen climate resilience. The prosperity pillar looks at steering AI investment towards renewable energy, industrial upgrading and inclusive growth.

Five strategic policy actions can guide developing countries in shaping AI and energy transitions:

1. Strengthen economic resilience by building a local AI-energy innovation ecosystem that links domestic skills, institutions and infrastructure.
2. Adopt Green AI as the default approach to steer AI infrastructure, procurement and investment toward low-carbon development.
3. Move up the critical minerals-energy-compute value chain through strategic action to support domestic AI-energy innovation.
4. Align AI, energy and industrial strategies through integrated national development planning and partnerships.
5. Support Green AI startups through targeted entrepreneurship, finance and market-creation policy.

These actions link AI development to energy systems so that clean energy abundance supports inclusive growth, resilience and shared prosperity. For developing economies, the policy challenge is to shape the terms on which AI expands: whether countries remain suppliers of land, energy, minerals and data, or whether they use the AI-energy transition to build capabilities, improve services, strengthen power systems and capture higher-value economic activity.

This report critically examines these dynamics, aiming to contribute to global policy debates at the intersection of AI, energy and sustainable development.

Figure 1. Five policy actions for developing countries on AI and energy transitions

Source: Authors' elaboration.

01.

1. TWO CONVERGING REVOLUTIONS: THE AI RACE AND THE GLOBAL ENERGY TRANSITION

“Green is not a technological revolution. It is the direction in which the information revolution needs to be taken.”

— Carlota Perez

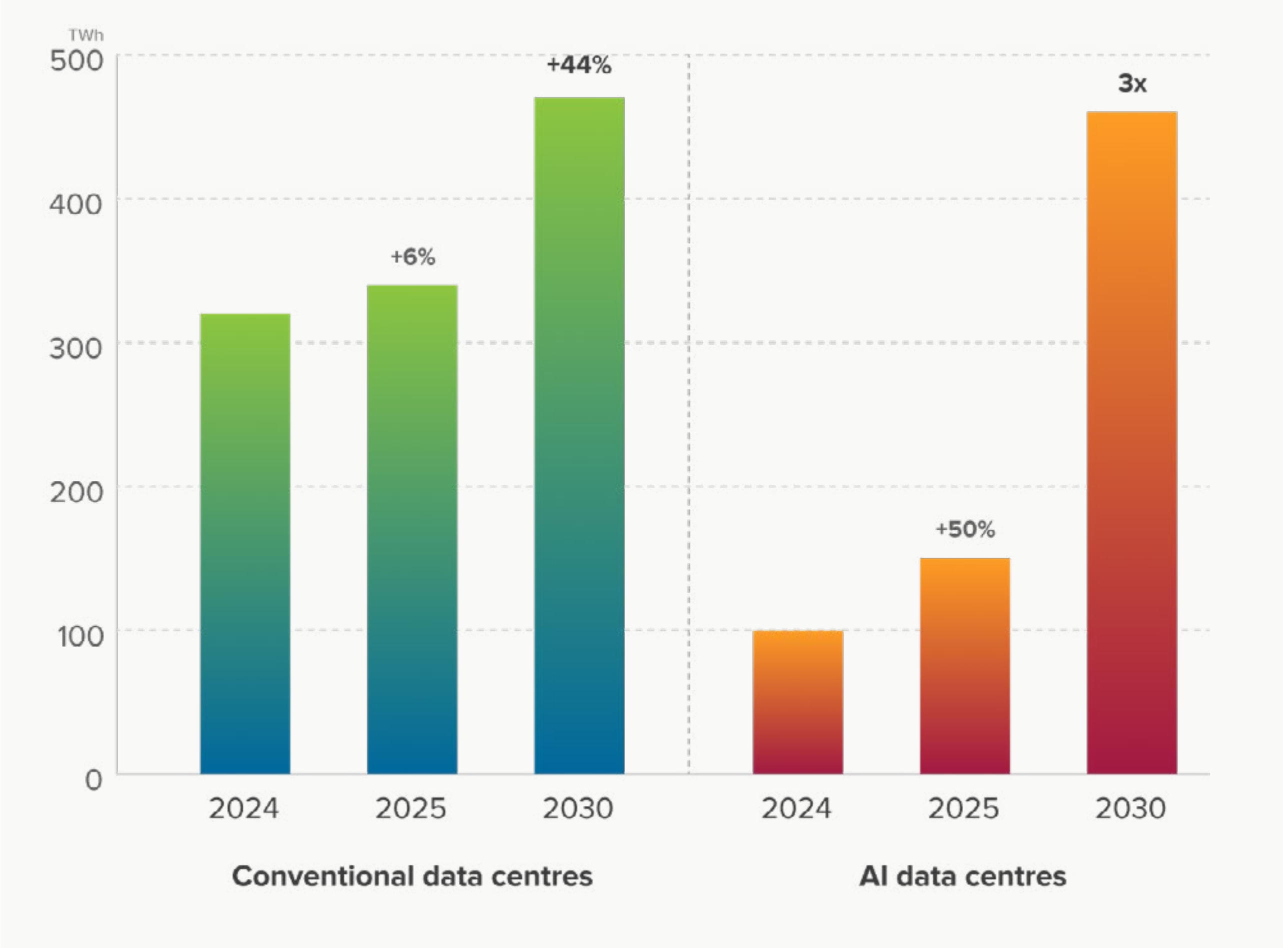
Introduction

The rapid development and deployment of AI is reshaping the global economy in ways comparable to the introduction of electricity or the Internet. AI is increasingly recognized as a similarly general-purpose technology shaping long-term economic and societal trajectories. Yet its progress is constrained not primarily by data availability or algorithmic sophistication but by access to abundant, affordable and low-carbon energy. AI models, particularly state-of-the-art systems, but also an expanding range of task-specific and decentralized applications, require exponentially growing computational power. This in turn depends on energy-intensive data centres, specialized chips and cooling infrastructure (Sevilla et al. 2022; Hernandez and Brown 2020; UNESCO 2024; Gmyrek et al. 2024). Fundamental questions emerge around whether the global AI race is ultimately an energy race, and what this means for developing economies.

Energy remains one of the sharpest dividing lines in development. Global electricity access reached 92 percent in 2023 (IEA 2025b), yet this headline masks deep structural inequalities. In sub-Saharan Africa, progress has stalled and, in some countries, reversed. Two thirds of South Sudan's population still lacks electricity, while in parts of rural Niger, clinics rely on fragile diesel generators. Nearly 730 million people are projected to remain without power by 2030 (ibid.). Energy keeps hospitals, schools, water systems, factories and digital networks running. When power is unreliable, development falters. Almost 1 billion people rely on health facilities with no or unstable electricity, and firms in parts of Asia report losing 5 to 7 percent of annual sales due to outages. These failures magnify poverty, disrupt education, constrain enterprises and weaken already fragile institutions.

AI training occurs in large data centres, which consume about 415 terawatt-hours annually (IEA 2025b), a figure projected to reach around 945 TWh in 2030, roughly equivalent to Japan's total energy consumption (Berreby 2024; IEA 2025b). Global electricity consumption from data centres surged in 2025, driven by AI, and is set to almost double by 2030, while electricity demand from AI-focused data centres could triple (see Figure 2).

Figure 2. Data Centre Electricity Demand Accelerates in 2025 and Continues to Rise



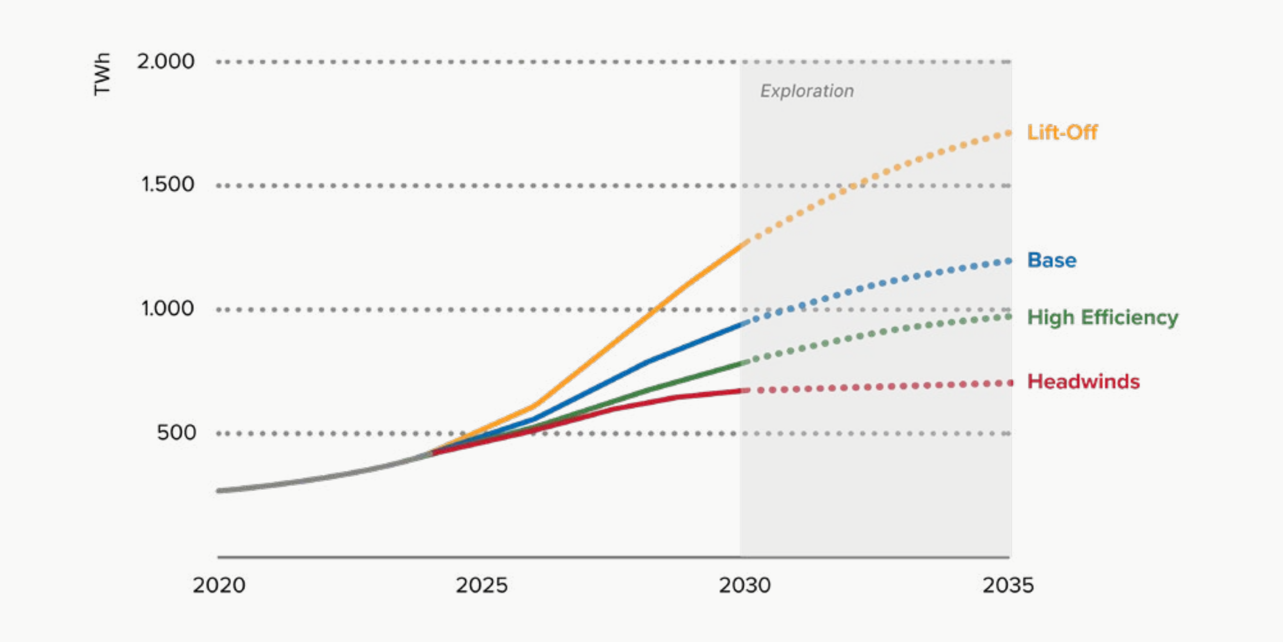
Source: IEA (2026)
Note: 2030 values are projections

This demand has grown by approximately 12 percent annually over the past five years; new global investments over the last two years have increased by 70 percent (IEA 2025b), driven by large-scale model training and data storage. The surge in generative AI (Gen AI) models following the release of ChatGPT in late 2022 has dramatically intensified computational demands on data centres, with demand projected to continue increasing. Several studies document exponential increases in the computational (and thus energy) requirements of frontier AI models, showing a 300,000-fold increase in compute usage since 2012 (Hernandez and Brown 2020; Sevilla et al. 2022). The International Energy Agency (IEA) projects that data centres may consume up to 8 percent of global electricity by 2030 compared to 2 percent today (Figure 3), raising concerns that AI growth could overwhelm national grids, particularly in emerging economies.

The energy divide is now colliding with the rapid expansion of AI. By 2030, almost US$7 trillion in capital investment may be required to expand global data centres and compute infrastructure, with more than US$5 trillion linked directly to AI workloads (Noffsinger et al. 2025). At the heart of this expansion lies compute, the processing power that trains and runs modern AI systems. Compute is delivered through a long, energy-intensive pipeline that begins with semiconductor fabrication, passes through high-performance computing systems and ends in hyperscale data centres designed for AI development and inference (many located in the Global North). Each step carries a heavy electricity, water and mineral footprint. A single advanced semiconductor fabrication plant can consume as much electricity as a mid-sized city such as Mombasa, a level of power that many countries still struggle to deliver reliably to clinics and schools. This is a microcosm of a potential era of global AI inequity. AI is expected to add US$15.7 trillion to global output by 2030, but only around 10 percent of this value is likely to accrue to developing countries (PwC 2018; UNDP 2024b).

Even so, the hyperscale AI model should not be treated as a universal blueprint. For many developing countries, particularly in Africa and Small Island Developing States, modular, distributed and edge-computing systems may be more appropriate as they can ease pressure on fragile grids, be designed for energy efficiency from the outset, and provide the compute needs for nearer-term AI exploration and implementation. Rather than competing to host large frontier-model clusters that are associated with significant financial and resource costs, they enable more gradual, context-sensitive scaling aligned with existing infrastructure. This approach could also open pathways for value creation through locally relevant applications and services rather than capital-intensive infrastructure alone. This could open new models and opportunities for approaches to AI energy infrastructure.

Figure 3. Global data centre electricity consumption by sensitivity case, 2020–2035



Source: IEA 2025b.
Note: TWh refers to terawatt-hour.

New opportunity—and new inequality?

Energy is becoming one of the decisive constraints shaping the geography of AI, alongside data, talent, capital, chips, institutions and market demand. Countries that can combine reliable low-carbon power with digital capability, regulatory credibility and domestic demand will be better positioned to capture value from AI. This geopolitical role intersects with other core development priorities, including (see Figure 4):

- **Mineral geopolitics:** with critical raw materials for chips and batteries.
- **Energy geopolitics:** with clean electricity a strategic asset, and energy intellectual property poised to become a new dividing line.
- **Digital geopolitics:** the control of our digital and innovation highways, platforms, and data and cloud infrastructure.
- **Economic geopolitics:** with research, development and technical human capital a fluid asset, one increasingly available to countries with the deepest pockets and most attractive packages.

There is an important nuance, however. Countries with strong renewable profiles could position themselves strategically if they avoid being relegated to extractive roles. China, for instance, has shown that technological hegemony has been anchored in public and regulatory control that aligns

Figure 4. Global geopolitical drivers of AI

Source: Authors' elaboration.

infrastructure with national industrial and development objectives. Its experience demonstrates how state coordination over core infrastructure (e.g., railways, electricity grids, semiconductor factories, data centres) can underpin technological upgrading and competitiveness.

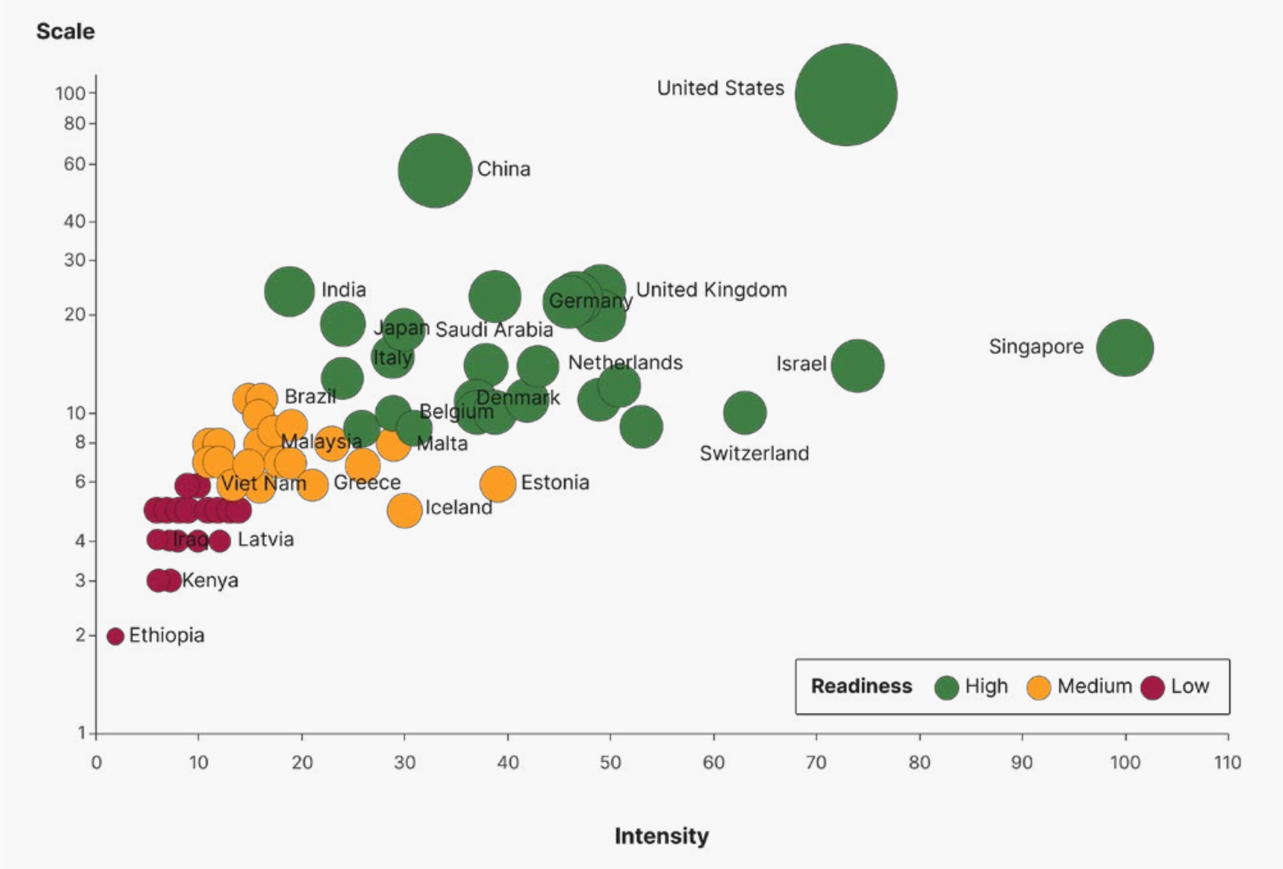
The emerging AI economy follows the same pattern. As AI models become larger and more compute-hungry, they require vast amounts of electricity, cooling water, refrigerants (depending on the technology used for cooling), and land for hyperscale data centres. These requirements bind AI to material and territorial constraints typically associated with heavy industry rather than digital services. The next wave of global competition will hinge on which countries can supply abundant, affordable and reliable electricity at scale. In the United States, the siting of data centres is increasingly shaped by a complex mix of power availability, grid interconnection timelines, land, tax incentives and access to low-cost electricity. While low-carbon power remains an important strategic consideration for many firms, new data-centre growth has also been concentrated in regions where grids remain significantly fossil-fuel dependent, underscoring the need to link AI infrastructure planning more directly with clean-power expansion and grid decarbonization.

The rise of AI as an energy-dependent sector is reshaping alliances and bargaining power. The China-United States rivalry now extends beyond semiconductor export controls to include competition for energy-secure AI clusters. Nations such as Brazil, India, Malaysia, Saudi Arabia and South Africa are positioning themselves as alternative hubs for AI infrastructure, creating new multipolar dynamics in which strategies on energy, minerals and data converge.

However, positioning as an infrastructure hub does not automatically translate into broad-based domestic gains. Abundant clean power does not by itself create a viable domestic AI economy. In many developing contexts, AI demand remains constrained by low firm digitalization, limited purchasing power, weak access to affordable compute and cloud services, shortages of technical and managerial skills, and limited diffusion of locally relevant applications. Without deliberate demand-shaping policies, countries may host data centres while capturing only a narrow share of the benefits, creating enclave-style growth built around imported technology, foreign platforms and limited local linkages. The development test is whether AI infrastructure strengthens the wider economy by improving grid reliability, expanding local supplier networks, creating technical jobs, supporting public-interest applications and enabling domestic firms to adopt AI.

These inequalities are also reflected in cross-country AI readiness (see Figure 5). The United States and China dominate in scale, while smaller economies such as Israel, Singapore and Switzerland perform strongly on intensity through concentrated investment and efficient ecosystems. Many developing economies, by contrast, remain at the lower end of the distribution. Countries such as Ethiopia and Kenya, for example, continue to face major constraints in broadband access, digital capabilities and innovation capacity, while middle-income countries such as Brazil and Malaysia occupy a more intermediate position, reflecting uneven but growing readiness. The figure therefore reinforces the broader point that AI opportunity remains highly uneven, with many developing economies still needing to build the basic foundations for adoption.

Figure 5. Global patterns of AI readiness by scale and intensity, 2024

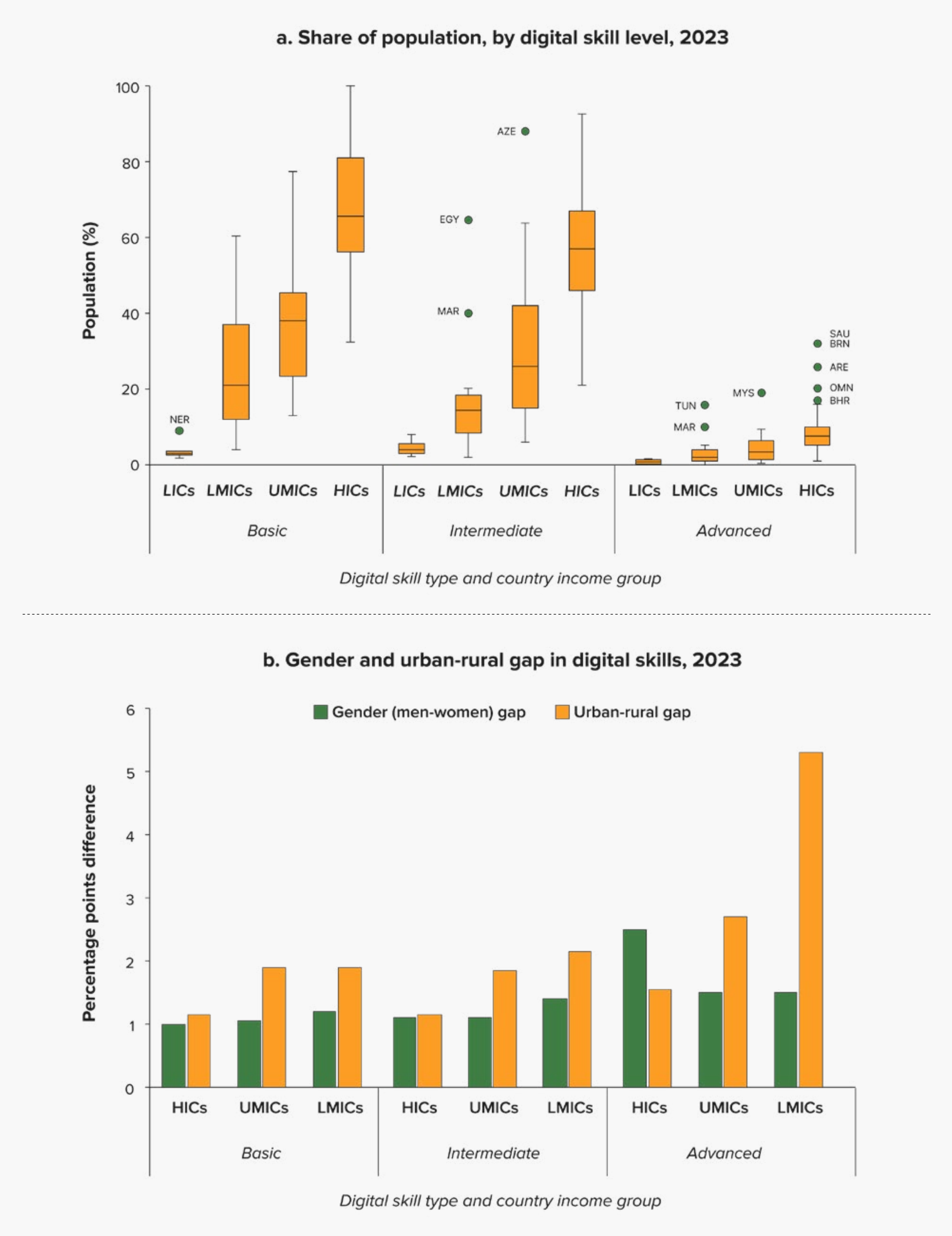


Source: World Bank calculations using data from Tortoise Media's Global AI Index.

These constraints reflect widening inequalities both between and within countries in access to the foundations of the AI economy. Digital skills remain highly uneven despite rising global demand (see Figure 6), with a stark cross-country divide. This AI readiness index combines indicators related to digital infrastructure, innovation capacity, human capital, governance, investment and ecosystem maturity. The distinction between scale and intensity helps separate countries with large absolute AI ecosystems from smaller economies that perform strongly relative to their size. According to a recent World Bank report, fewer than 5 percent of people in low-income countries have basic digital skills, compared to 21 percent in lower-middle-income, 38 percent in upper-middle-income, and 66 percent in high-income countries (see Panel a).

Moreover, in low-income countries, advanced digital skills are about five times more common in urban than rural areas. In lower-middle-income countries, the urban–rural gap reaches 5.30 for advanced skills, while the gender gap increases from 1.21 (basic) to 1.52 (advanced). Upper-middle-income countries show smaller but persistent disparities, with gender gaps rising from 1.05 to 1.47 and urban–rural gaps from 1.88 to 2.70 (see panel b). Even in high-income countries, both gender and urban–rural gaps persist and widen at higher skill levels.

Figure 6. Supply of digital skills, 2023



Source: World Bank (2025a)

Compute is even more concentrated. High-income countries host 86 percent of the world's top computing systems and almost all of their capacity, while middle-income countries excluding China and India host just 3 percent despite accounting for nearly half of the global population (World Bank 2025a). These asymmetries risk reinforcing a pattern in which some countries supply land, energy and minerals while others capture most of the value, innovation and decision-making power. Connectivity gaps further compound these inequalities. Around 2.6 billion people remain offline, including 1.8 billion in rural areas (ibid.). Although mobile coverage exceeds 98 percent globally, meaningful internet access remains a significant challenge. In low-income countries, penetration is just over one-quarter of the population, and basic access can cost nearly 30 percent of monthly income.

If these divides are left unaddressed, AI could deepen inequality both across and within countries, including by widening gender gaps in skills, employment, and access to digital public services. The key challenge, therefore, extends beyond securing clean electricity for AI systems to ensuring that access to AI capabilities, infrastructure, and opportunities is distributed more broadly and more fairly. This will require policies that expand affordable connectivity, support inclusive innovation ecosystems, and strengthen digital and managerial capabilities that better reflect the needs of underserved communities.

The AI race and the global energy transition

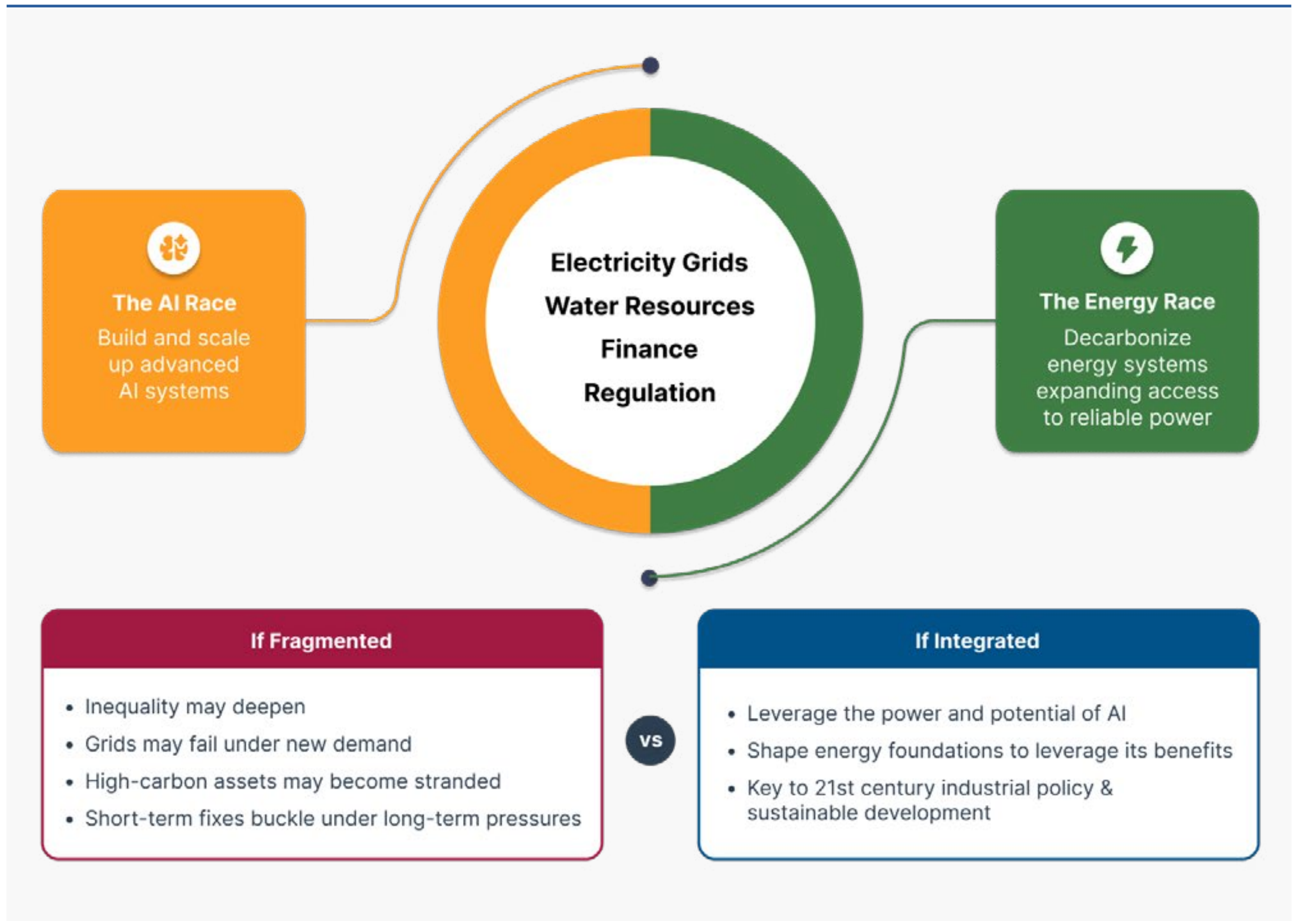
The world has two converging races (see Figure 7). One is to build and scale up advanced AI systems. The other is to decarbonize energy systems while expanding access to reliable power. These are intersecting and draw on the same foundations, including electricity grids, water resources, finance and regulation. Yet they are still treated as separate agendas. This fragmentation risks locking countries into short-term fixes that buckle under long-term pressures. If AI deployment races ahead of energy planning, inequality may deepen, grids may come under new pressure, and countries may increase reliance on fossil-based generation or temporary high-emission solutions, potentially locking AI growth into carbon-intensive energy pathways. This demands focus and attention from decision-makers. Leveraging the power and potential of AI, and shaping energy foundations and infrastructure to leverage its benefits, could be a key to 21st century industrial policy and sustainable development.

At the same time, this convergence creates a historic opportunity. Used strategically, AI can improve power-system management by strengthening demand forecasting, identifying flexibility opportunities, optimizing storage and distributed energy resources, reducing losses, and improving the dispatch of variable renewables. These gains can help defer or reduce some capital-intensive grid investments while improving reliability, especially in constrained systems.

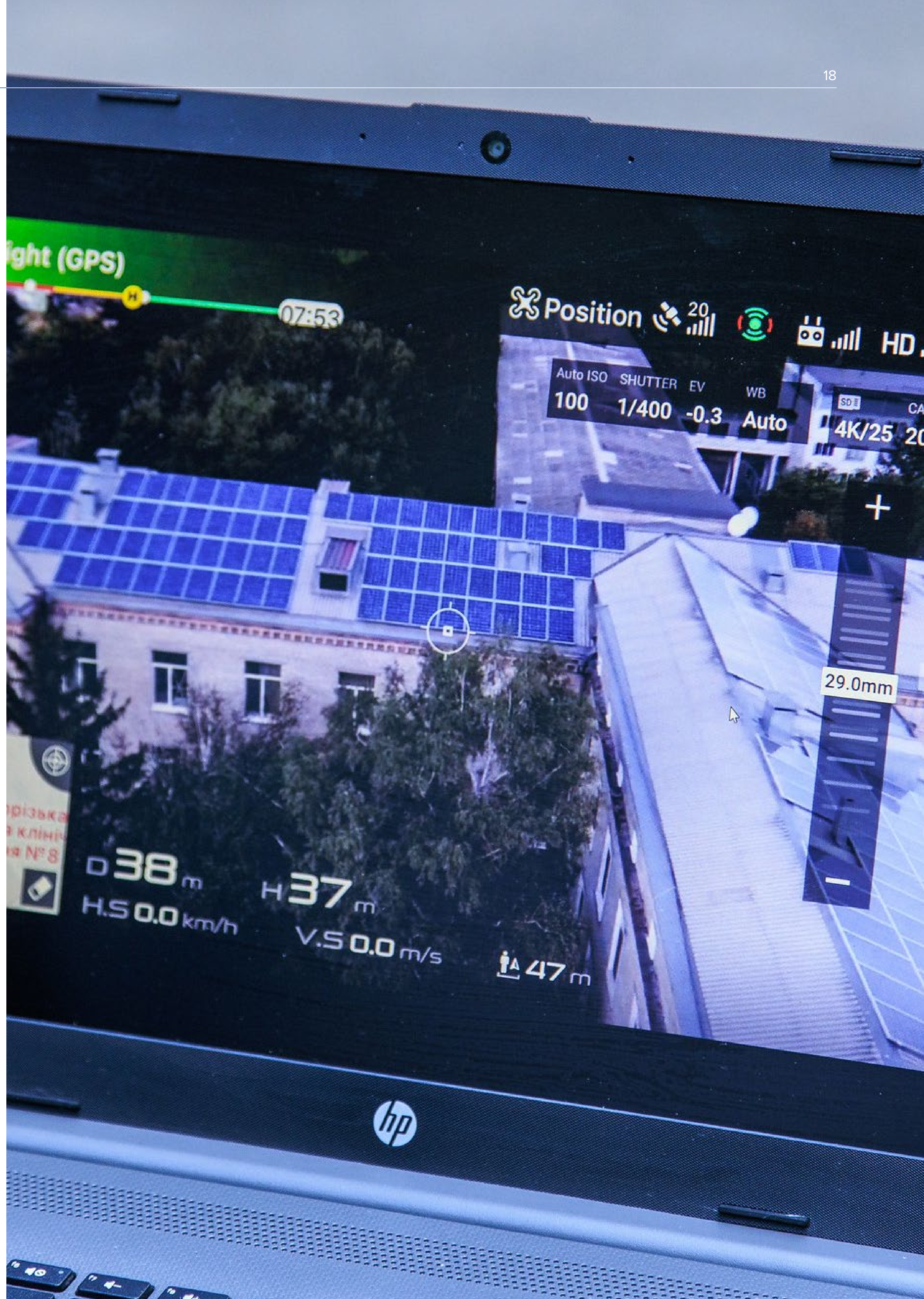
More fundamentally, the political and economic urgency surrounding AI is forcing countries to confront weaknesses in their energy systems that have persisted for decades. This convergence shows what the acceleration of AI implies for both existing energy systems and future policy choices (Figure 8). Energy policy is becoming digital policy. Together, these forces may shape a new era of industrial policy comparable to the great transformations of the twentieth century.

The energy hunger of AI also has implications for climate politics. If powered by fossil fuels, as is often the case in China and the United States, AI risks becoming a major contributor to global emissions. This could undermine global climate goals and intensify pressures on emerging economies to limit fossil-fuel powered AI adoption. Conversely, AI has the potential to accelerate decarbonization, particularly through grid optimization, predictive maintenance and the modelling of climate systems. Whether AI becomes a climate burden or climate protector depends, yet again, on its energy foundation. The fundamental question is whether developing countries can harness AI as a “green window of opportunity” or whether AI will simply reinforce existing hierarchies.

Figure 7. The Twin Transitions: AI Expansion and Clean Energy

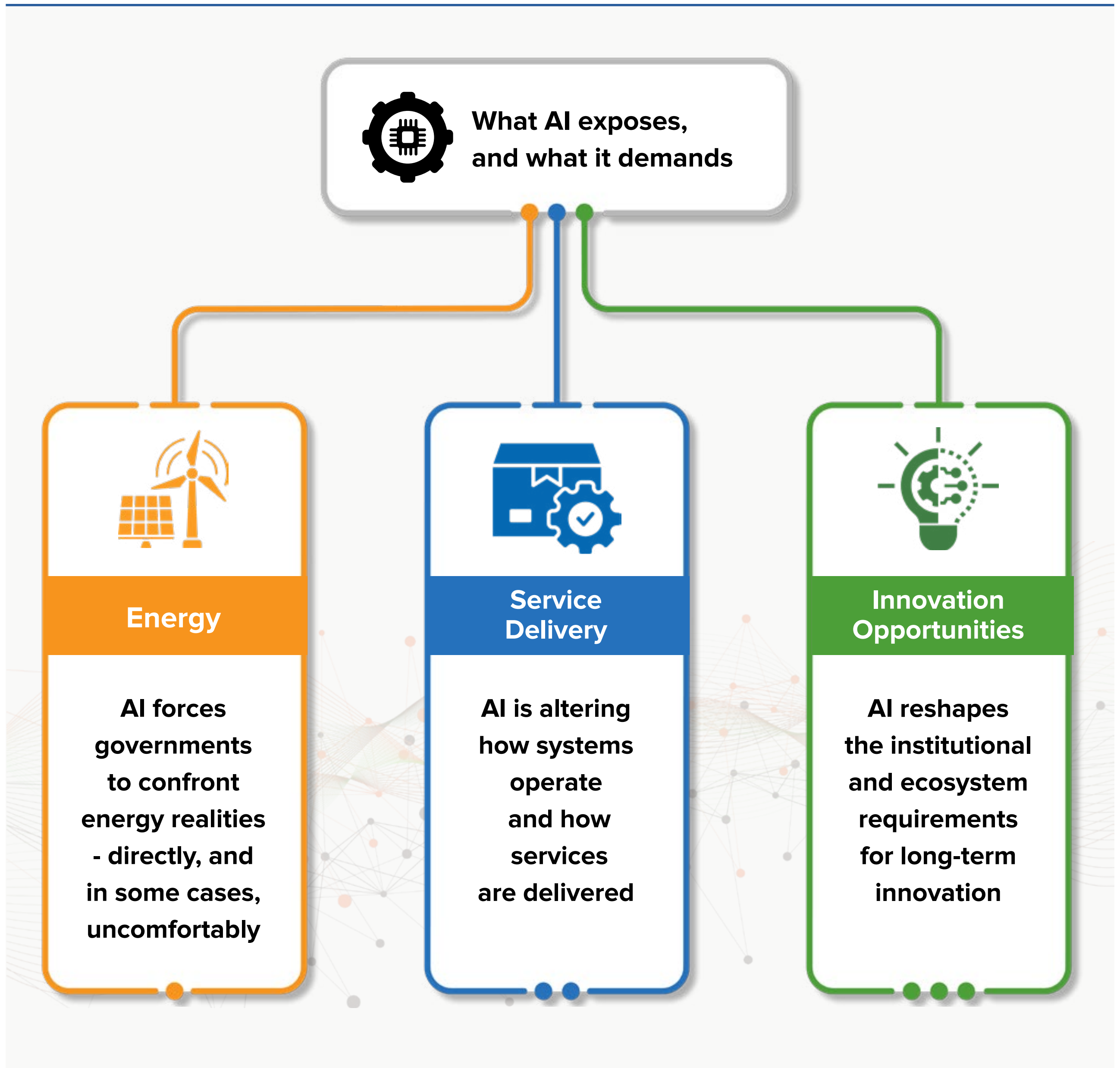


Source: Authors' elaboration.



As this report shows, the convergence between the rapid expansion of AI and the global shift toward clean energy may create a space for what the literature describes as a "green window of opportunity" (see Lema et al. 2020). The global energy transition may open new opportunities for emerging economies, as AI's growing reliance on abundant, low-carbon electricity creates potential entry points for countries with strong renewable energy resources. Yet as this report cautions, such opportunities are heavily dependent on reliable infrastructure, institutional capacity, human capital, and deliberate policy direction to translate energy advantages into technological upgrading and industrial development.

Figure 8. What AI exposes and what it demands



Source: Authors' elaboration.

For developing countries, much potential lies in coupling AI adoption with clean-energy expansion, grid modernization and firm low-carbon power solutions. Solar PV and wind can play a major role in lowering the emissions intensity of AI infrastructure, but data centres require high reliability and continuous power. Greening AI therefore depends on strengthening grids and combining them with storage, geothermal, hydropower, nuclear where appropriate, demand response and other solutions capable of providing reliable low-carbon electricity.

Countries that can pursue green policy initiatives and low-carbon electricity may attract green data-centre investment and position themselves as low-emissions compute hubs, while using AI to strengthen utility performance, climate resilience and productivity in sectors such as agriculture, manufacturing and public services. Unlocking this potential requires strong supply-side investment matched by deliberate efforts to build effective domestic demand. What matters is whether firms, farms, schools, clinics and governments can adopt and use AI in affordable, trusted and locally relevant ways.

This report sets forth analytical foundations for understanding the current moment. It frames the growing energy intensity of AI, alongside its expanding aggregate electricity demand, as a structural variable shaping development trajectories through the notion of the 'green window of opportunity'. This helps identify how sustainability transitions open policy-driven opportunities for economies to build new industries (Perez 2016; Lema et al. 2020; Lebdioui 2024). The report also proposes linking AI, energy and developing countries' industrialization through a people, planet and prosperity framework. It finds that:

AI will become increasingly energy-dependent, reinforcing the need for stable access to clean and cheap electricity, as the rapid expansion of total compute demand can outpace efficiency gains, increasing overall pressure on electricity systems.

Energy abundance (not data or talent alone) will become a decisive competitive factor for AI-based industrialization, offering pathways that avoid the carbon-intensive lock-ins experienced during earlier industrialization.

Developing countries can leverage their renewable energy potential, mineral resources and emerging digital ecosystems to position themselves in new technological niches through a strategic and coherent industrial policy.

02.

AI AS A GREEN WINDOW OF OPPORTUNITY?

Green Window of Opportunity

Green window of opportunity, as developed by Lema et al. (2020), refers to the openings created by sustainability transitions for developing economies to enter new industries, build capabilities and capture value. In the AI-energy transition, this window is shaped by rising demand for clean and reliable power, rapid advances in AI and shifting global investment patterns. It can emerge through different pathways: hosting low-carbon digital infrastructure, applying AI to improve energy systems and climate resilience, building local AI-energy services, or moving into higher-value segments of minerals, power, compute and data value chains. Capturing this opportunity depends on turning renewable potential, digital skills, infrastructure investment and institutional coordination into practical pathways for industrial upgrading, inclusive development and alignment with climate, nature and human development goals.

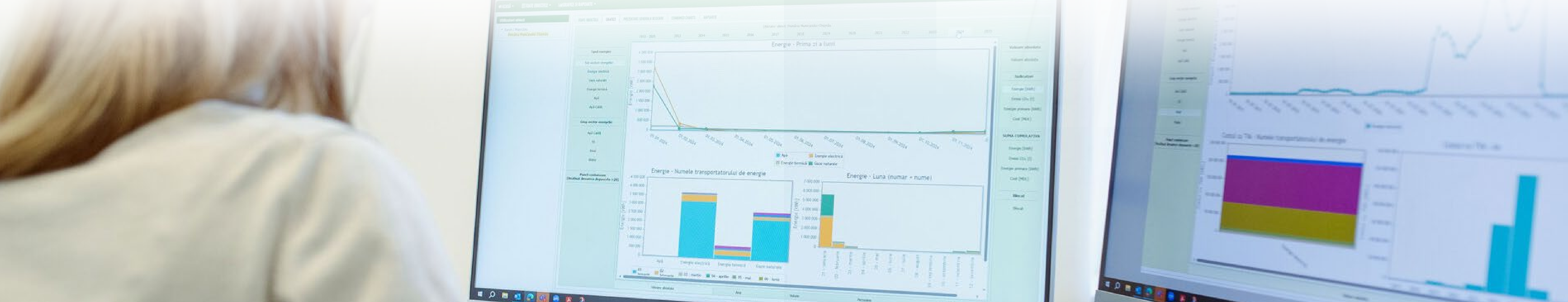
The literature on AI, energy systems and industrialization has expanded rapidly in recent years, yet remains fragmented across disciplines. To understand what the AI-energy transition means for developing economies, three strands need to be brought together: the economics of general-purpose technologies; evidence on the energy, infrastructure and resource requirements of AI; and scholarship on green windows of opportunity and sustainability-oriented industrial development.

This integration is important because AI is increasingly embedded in physical systems: semiconductor supply chains, data centres, cloud infrastructure, electricity grids, cooling systems, water resources and critical minerals. AI should therefore be understood as a political, social and technical regime, whose evolution is shaped by material infrastructures, policy directionality, geopolitical competition and national development priorities. For developing economies, the central issue is whether AI reinforces dependence on externally controlled compute, platforms and value chains, or becomes a basis for building domestic capabilities, improving services and upgrading productive sectors.

This section therefore examines the conditions under which developing economies can shape, adopt and benefit from AI in ways that support sustainable development. The green window of opportunity framework (see Lema et al. 2020) is particularly suited to this task because it links technological change to development strategy. It emphasizes three core dimensions (Figure 9): the opportunity space created by global technological and market shifts; the structural conditions that shape developing countries' entry; and the policy directionality needed to build capabilities, guide investment and translate AI-energy integration into inclusive development outcomes.

Figure 9. Framework for capturing the green window of opportunity

Source: Authors' elaboration.



AI as a general-purpose technology with a high environmental footprint

AI is conceptualized as a general-purpose technology with pervasive applications, high potential for spillovers and complementarities with other technologies (Brynjolfsson and McAfee 2017; Agrawal et al. 2018). General-purpose technologies historically have reconfigured industrial paradigms, enabling productivity surges but also producing uneven global distributions of benefits. AI clearly fits this pattern. It evolves rapidly, diffuses across sectors, and can induce process and product innovations. However, its deployment is also shaped by structural and social constraints, including access to electricity, critical minerals, skilled labour, and institutional capacity (Crawford 2021). In other words, focusing on data and algorithms has overshadowed the materiality of AI. This observation challenges the notion that developing countries can 'leapfrog' into AI through skill-building alone. Instead, its deployment requires tackling deep structural constraints linked to reliable electricity and water, access to affordable capital, skilled labour, institutional capacity and geopolitical control over key supply chains. Access to minerals is not necessarily a binding constraint for every country seeking to develop AI infrastructure, since resource-poor economies can secure inputs through trade and supply-chain partnerships; however, concentrated supply chains and protectionist pressures can shape costs, risks and bargaining power.

The relevance of the materiality of AI, and its energy footprint, cannot be overstated. AI's voracious resource appetite threatens local ecosystems, with mounting scientific concern over accelerating environmental footprints (UNESCO 2024; Gmyrek et al. 2024). Deforestation, unsound mining, competition for minerals and water, and, critically, data centre pressures in drought-prone regions such as Chile, Mexico and Uruguay pose difficult dilemmas. The lack of transparency around the resource intensity of data centres compounds these risks (Lebdioui et al. 2025). Policy innovation is possible. Chile's recently launched Plan Nacional de Datacenters (2024–2030) offers a regional model. It aims to mobilize US$4 billion, expand sector training and integrate environmental accountability. Yet overall, AI's accelerating energy and resource consumption, with corporate environmental footprints rising annually in the double digits, presents a dilemma. The policy challenge is not a binary choice between rapid AI expansion and environmental protection. The more strategic question is how developing regions can sequence AI adoption, infrastructure investment and environmental safeguards so that digital growth strengthens energy systems, protects ecosystems and builds domestic capabilities over time.

The compute backbone of modern AI has become one of the fastest-growing sources of electricity demand (World Economic Forum 2025). Moreover, AI systems follow a multi-stage lifecycle including planning and data collection, model development, training, deployment, and monitoring, each with distinct computational and energy demands (Figure 10). Energy consumption in data centres depends on algorithmic complexity, hardware efficiency and scale (World Economic Forum, 2025), reflecting the need for efficiency across the AI lifecycle, consistent with the 'Green AI' approach discussed in this report.

Green AI

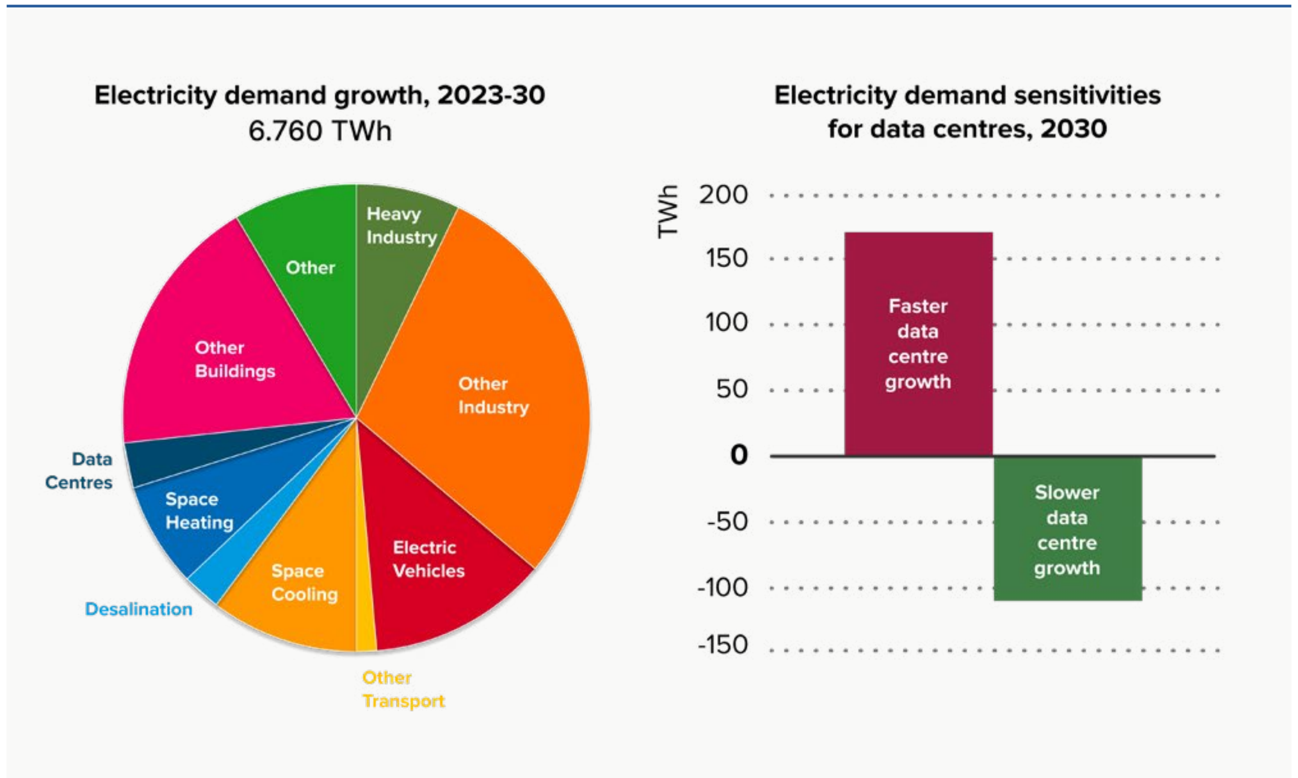
Green AI refers to a policy approach for the balanced development of AI, energy systems and environmental sustainability, with human development at the centre (Lebdioui et al. 2025). In the context of this discussion, it refers to powering AI with increasingly clean and reliable electricity, minimizing water, land and mineral pressures, using AI to improve energy and climate outcomes, and ensuring that AI infrastructure and applications create local value rather than new forms of dependency. This report advances Green AI as a development strategy for aligning digital transformation with people, planet and prosperity. The approach is relevant across the AI life cycle, as shown in Figure 10 below.

Figure 10. Energy consumption across the AI life cycle

** Insufficient data available for estimation*
Source: Adapted from World Economic Forum (2025)

The concern is not only how much energy these systems use, but how and where that demand lands and what environmental footprint it leaves. Globally, data centres consume an estimated 1.5 to 2 percent of all electricity, yet this average masks the pressure they can place on specific grids and the climate (IEA 2025a). By 2030, electricity use across all sectors is expected to grow by around 6,760 terawatt-hours under the Stated Policies Scenario (STEPS) as presented in the World Energy Outlook scenario framework, surpassing the 2023 electricity consumption of the United States and European Union combined (Figure 11). In several emerging data-centre hubs, AI infrastructure already accounts for roughly 5 to 20 percent of total electricity demand, effectively creating a new industrial-scale load on the system. Where capacity is tight or heavily reliant on fossil fuels, an extra surge in AI demand can lock in new thermal generation, push up emissions and increase local air pollution.

Figure 11. Electricity demand growth by end use in STEPS, 2023–2030, and data centre sensitivity cases



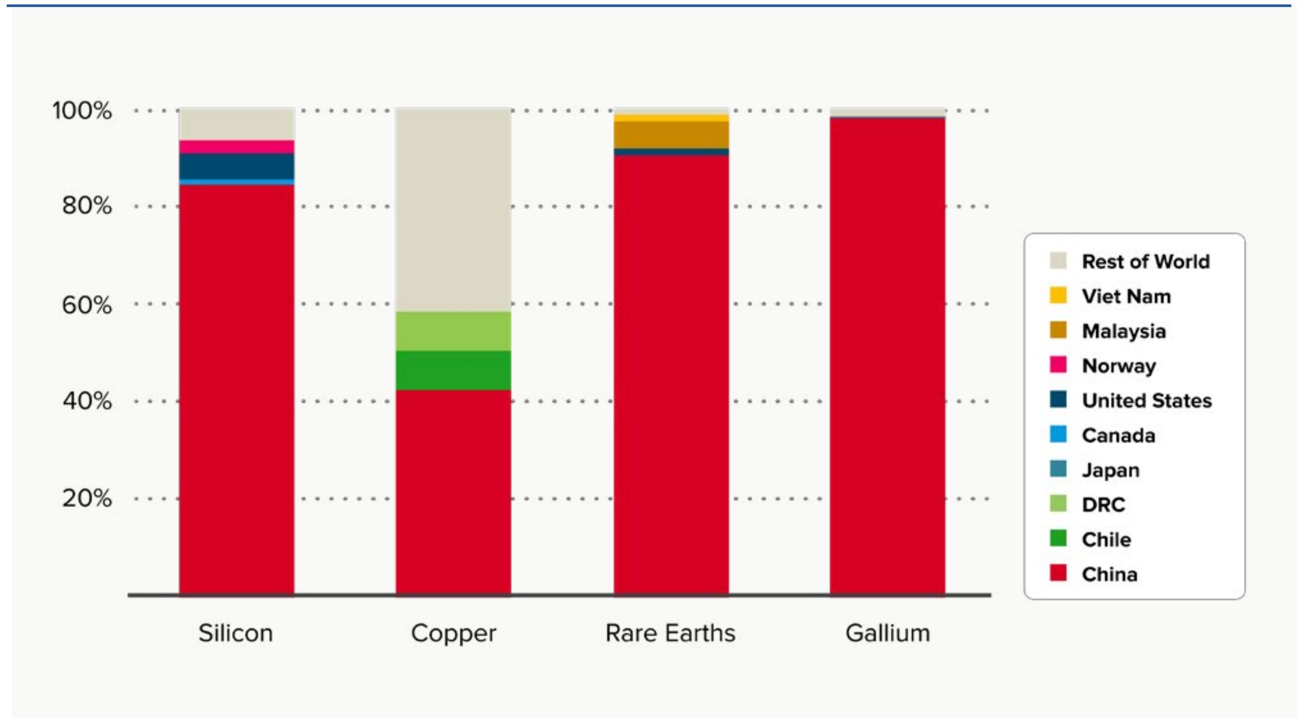
Source: IEA 2024.

The availability, use and sustainability of raw materials pose further risks as AI servers, power backup systems and cooling infrastructure rely on materials such as rare earth elements, lithium and nickel. Demand for these minerals is projected to quadruple by 2040 under global net-zero scenarios, driven by the expansion of clean energy and digital technologies (IEA 2025c).

The problem is twofold. First, supply chains are highly concentrated in a few countries—for example, a large share of rare earth processing occurs in China (Figure 12). Second, many developing economies supply the raw materials and data streams that power AI but capture only a small share of the resulting economic benefits.

For instance, the Democratic Republic of the Congo's link to the global AI ecosystem is not through data centres or model development but through minerals. It supplies more than 70 percent of the world's cobalt—critical for AI hardware, data-centre batteries and electric mobility—yet almost all higher-value stages of the chain, from refining to component manufacturing, happen abroad (Kalu 2025). As a result, the country absorbs the social and environmental impacts of extraction while capturing little of the economic or technological benefits generated by the AI systems it helps to power. This disconnect underscores a wider structural risk: AI could reproduce long-standing extractive and dependency patterns in new digital forms, deepening pressures on land, water and mineral resources rather than supporting a just, planet-compatible transition.

Figure 12. Geographical concentration of the supply of selected refined critical minerals needed for data centre expansion, 2024



Source: IEA 2025b.

Crucially, computing costs seem increasingly driven by energy availability and electricity prices, not just chip capacity. This raises questions about the factors that will drive competitive advantage in AI over the long term. Beyond energy costs, skills and physical and digital infrastructure will also shape competitive Green AI ecosystems.

The green window of opportunity and the missing conversation on AI

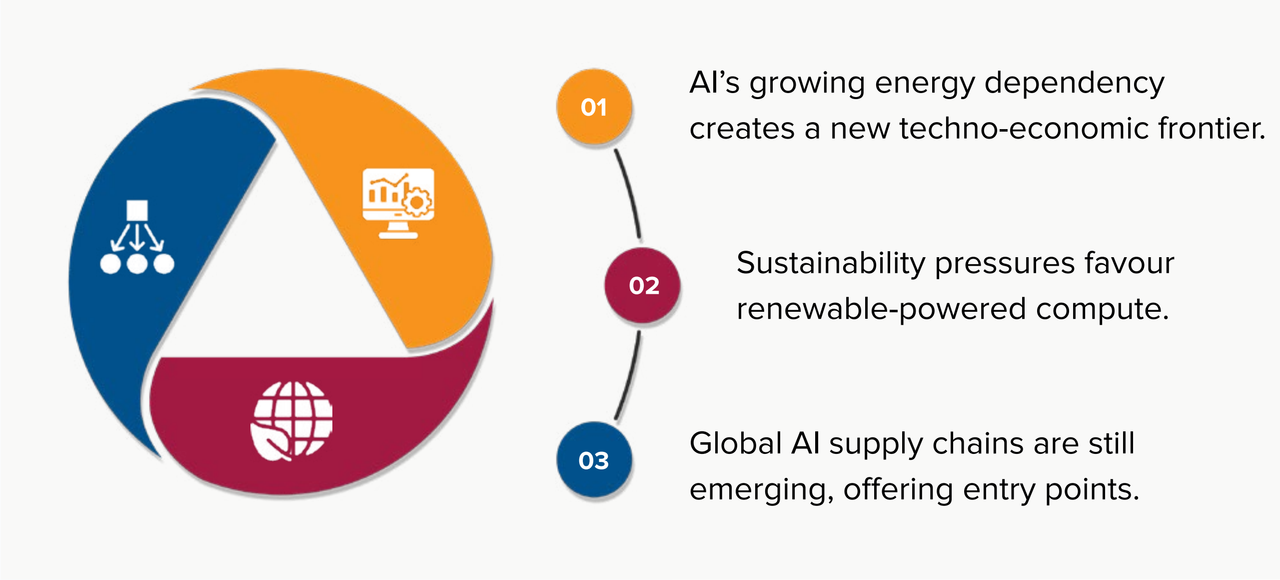
A small but growing body of work suggests that AI's energy intensity could reshape global production geographies. Nordic countries have emerged as data centre hubs due to cold climates and cheap renewable electricity (Östling 2025). The Gulf States leverage surplus natural gas and solar power for AI clusters (Yildiz 2025). Ethiopia and Kenya market geothermal resources as low-carbon power sources for digital infrastructure (Payton 2025). This echoes earlier findings in literature on sustainability-oriented industrialization. Natural endowments matter but only translate into competitive advantage when embedded within deliberate industrial policy frameworks (Chang, 2002; Lebdioui, 2024). An abundance of renewables alone does not create a data centre industry, nor does talent alone enable AI leadership. The key is the combination of industrial and energy policies and institutional coordination to align these two components, as emphasized in comparative political economy literature on industrial catching-up (Amsden 2001; Lee 2019).

A large body of work on green industrial policy has highlighted the ways in which sustainability opens opportunity for late industrialization (e.g., Altenburg and Rodrik 2017; Anzolin and Lebdioui 2021; Lebdioui 2024; Lema et al. 2020). The concept of the green window of opportunity is particularly relevant (Perez 2010, 2016; Lema et al. 2020). This highlights how sustainability transitions create temporal openings for economies to enter new industries during periods of technological upheaval. The idea is that green transition opens many doors for technological and industrial development (Lema et al. 2020) in ways that amount to the advent of a new 'techno-economic paradigm', as posited by Christopher Freeman (1992, 1996) and Carlota Perez (2016). From that perspective, the greening of AI is highly relevant, because it represents both risks and a significant green window of opportunity.

According to this framework, opportunities emerge when technological trajectories are not yet locked-in, allowing new entrants; when climate and sustainability imperatives reshape incentives, favouring low-carbon solutions; and when policy directionality creates demand for new green industries. Success also hinges on coherent industrial strategies that align domestic capabilities with emerging green value chains. Indeed, applications of green window of opportunity analysis include solar photovoltaic systems (Avenyo 2024; Quitzow 2015), offshore wind (Steen and Hansen 2014) and electric mobility and green hydrogen (Lebdioui 2024; UNDP 2025). These studies suggest that windows close quickly. Success depends on using policy strategically to build domestic productive capabilities while technological and market opportunities remain open.

To date, no substantial literature connects AI energy dynamics with the green window of opportunity framework. Few existing studies examine AI as part of broader material and environmental systems (see Crawford 2021; Lebdioui et al. 2025; Melguizo et al. 2025). Yet the synergies are evident: AI is both a consumer of massive energy resources and a potential enabler of greener, more efficient systems, especially in energy grids, mobility, agriculture and industrial processes. The structural conditions are aligned:

Figure 13. Structural Conditions for an AI Green Window of Opportunity



AI may represent a *green window of opportunity* where developing countries can specialize in various energy segments of AI value chains or where energy and AI intersect in their applications, including, for instance, green data centre hosting, AI-enabled clean energy optimization, AI applications for climate and development, and energy-intensive AI model training. These are significant opportunities with the potential to generate jobs, upgrade skills and deliver productivity gains. But they are conditioned by political economy constraints, global power asymmetries, infrastructure gaps and industrial path dependency.

The green window of opportunity framework is particularly suited to understanding the future of AI-based industrialization because it emphasizes three core dimensions: the opportunity space created by global technological and market shifts, the structural conditions shaping developing countries' entry and the policy directionality needed to unlock capability-building.

- The first dimension, **opportunity space**, is shaped by AI's energy dependency. Regions with abundant renewable resources, such as North Africa (solar), East Africa (geothermal), Latin America (hydro) and Southern Africa (wind), can offer clean and cheap electricity, which increasingly determines the marginal cost of AI. This creates an unusual alignment: Countries that have not historically been leaders in digital technologies may nonetheless become competitive hosts for energy-intensive compute clusters. However, this advantage can only be leveraged where those resources can be converted into reliable, competitively priced and contractable electricity. For AI infrastructure, the relevant advantage is the ability to provide firm low-carbon power, grid connection, predictable permitting, credible regulation and long-term investment certainty. For many developing economies, other promising entry points include modular, edge-based and sector-specific AI systems which extend beyond infrastructure. AI also enables application-driven windows in agriculture (precision farming), natural resource management (geospatial models), industrial efficiency (predictive maintenance) and climate adaptation (risk forecasting). These are areas where local knowledge, data and institutional alignment matter greatly, giving developing countries strategic agency.

- The second dimension, **structural conditions**, encompasses the economic, institutional and infrastructural foundations needed for developing countries' entry. These include a stable electricity supply, competitive renewable energy prices, robust regulatory frameworks, talent formation systems, digital infrastructure and institutional capabilities for coordinating industrial strategy. Historically, late industrializers have succeeded when they built synergistic ecosystems rather than isolated projects. For AI, this means ensuring reliable grids capable of supporting energy-intensive data centres; governing land, water and mineral resources sustainably; attracting investment in cloud and semiconductor-related activities; and cultivating human capital through vocational programmes and university-industry linkages. At the same time, structural barriers such as dependency on foreign cloud platforms, intellectual property constraints and capital scarcity cannot be ignored. These shape the feasibility and durability of any green window of opportunity.

- The third dimension, **policy directionality**, refers to the strategic orientation of the State in shaping markets and technological pathways. AI diffuses through policy-led mechanisms: the procurement of digital public goods, regulation of data flows, energy investment frameworks, incentives for renewable industrial parks, tax regimes for compute infrastructure and support for applied research. Directionality is essential because markets alone will not internalize the environmental costs of AI nor ensure equitable capability-building. Governments must deliberately steer AI in ways that align with sustainability and industrialization goals. Examples include policies that mandate renewable-powered data centres or incentives for low-carbon digital infrastructure.

Finally, critical scholarship stresses the risks AI poses for developing countries. These include dependency on foreign cloud providers (Plantin et al. 2018; El Kadi 2025; Rikap et al. 2024), extractive data relations, the concentration of value capture in a few firms and regions and environmental burdens from data-centre infrastructure in fragile electricity systems (see Section 5). Without deliberate governance, AI may reproduce the same structural inequalities observed in past technological revolutions. Yet the literature also notes that emerging economies sometimes benefit from being unencumbered by legacy infrastructure, allowing them to adopt greener and more efficient systems from the outset (Geels et al. 2016). This resonates strongly with the green window of opportunity perspective, whereby sustainability transitions destabilize incumbent systems, potentially creating openings for late industrializers if they act strategically.

Going in not too early, not too late: first-mover disadvantage and first-follower advantage

Investing in the green window of opportunity around AI requires recognizing that the technology is undergoing rapid and contested evolution. On the one hand, this creates temporary windows before technological trajectories harden. Countries that can strategically align their energy systems, digital capabilities and industrial strategies may find leverage points to enter emerging segments, whether in AI model training, green data-centre services, or applied AI for energy, agriculture and health. However, the strategic question is how to sequence entry beyond the choices of moving early or waiting. For many developing countries, especially fiscally constrained ones, the most credible pathway may be to move early in applications, skills and institutions, while moving more cautiously in physical compute infrastructure.

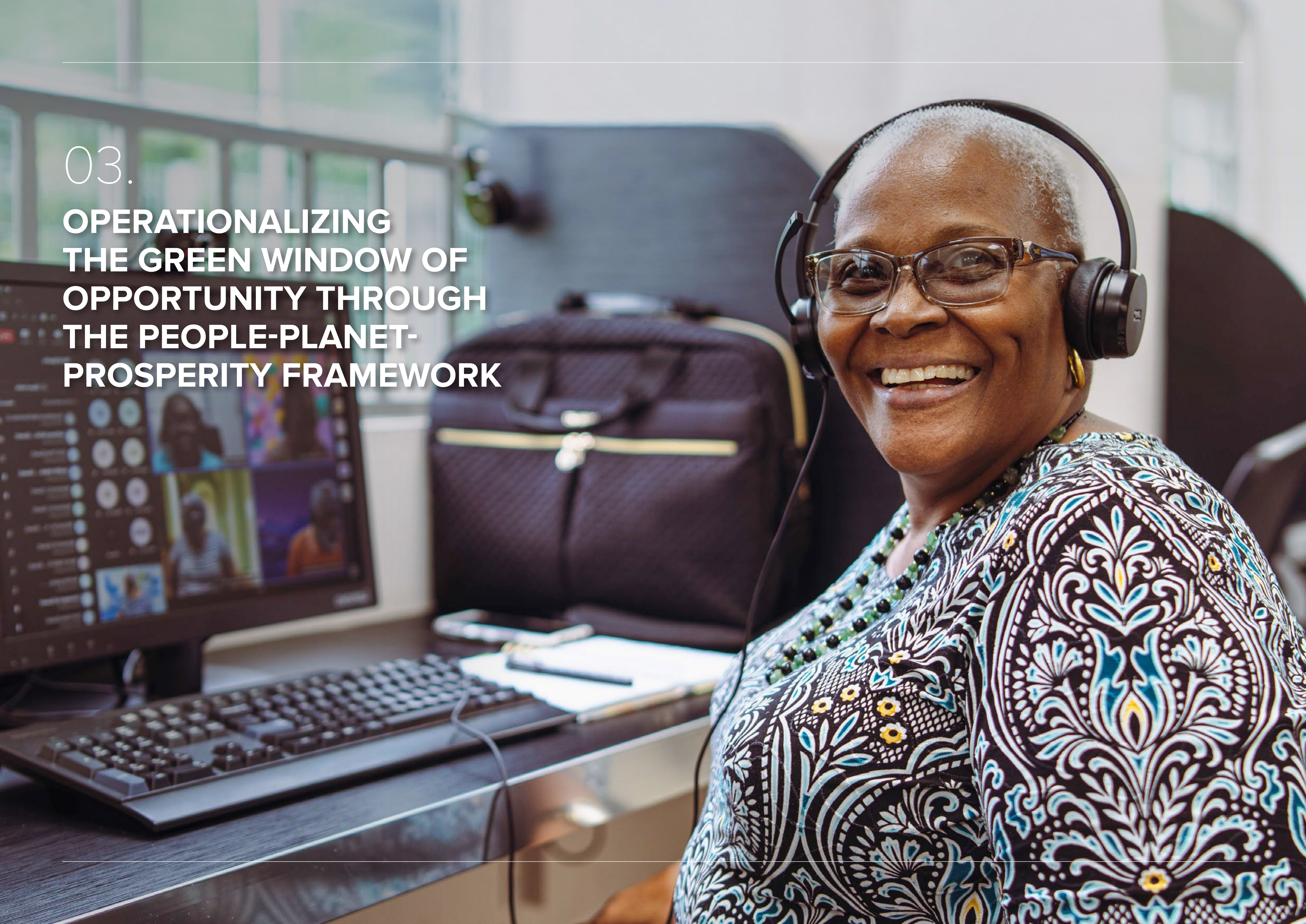
On the other hand, there may be a first-mover disadvantage, given market uncertainty and the rapid pace of technological disruptions. A cautious experimental approach as a first-follower may be more appropriate for many fiscally constrained developing countries, where lessons from early entrants can inform more cost-effective and scalable AI development strategies at more mature stages of the learning curve. As companies and industries produce more of a given technology, they gain experience, improve efficiencies and adopt innovations, all of which help to reduce production costs over time. The learning curve for AI is still in its early stages, where costs are high and technological and market uncertainties are considerable.

This suggests that developing countries' advantage lies less in competing for frontier and hyperscale compute and more in building capabilities around cloud-based AI applications, local data ecosystems, and addressing domestic needs. In the initial phase, countries can leverage existing cloud infrastructure to develop public-interest tools such as climate forecasting and agricultural prediction without large upfront investment in physical infrastructure. Over time, as skills, demand, regulation, and energy systems grow, they can transition to computing systems and infrastructure investments. A first-follower strategy may, therefore, focus on phased entry, starting with applications and scaling infrastructure as conditions mature.

Although many countries are eager to position themselves as first-movers, the benefits are not always clear—or automatic. They require navigating complex interactions between energy, technology and industrial policy, an endeavour this report seeks to advance through the integrated people-planet-prosperity framework.

03.

OPERATIONALIZING THE GREEN WINDOW OF OPPORTUNITY THROUGH THE PEOPLE-PLANET-PROSPERITY FRAMEWORK

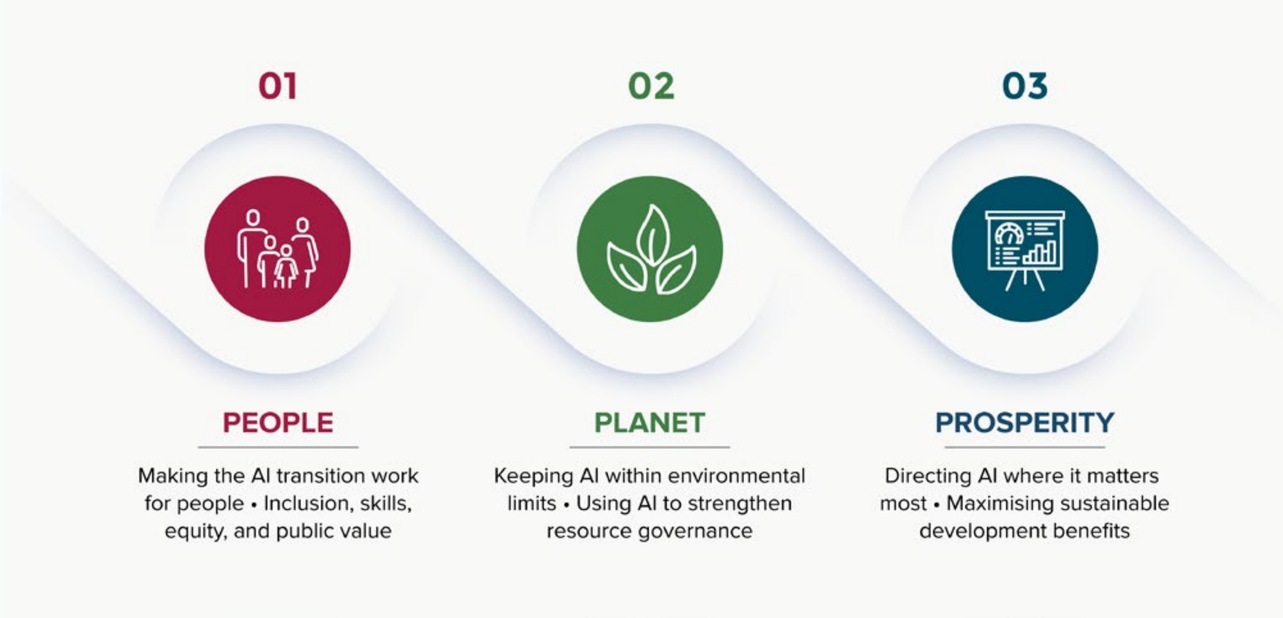


The core insight of the green window of opportunity framework is that opportunity is not automatic. It is shaped by institutions, policy choices and the ability to coordinate energy, digital and industrial strategies so that AI strengthens inclusion, accelerates decarbonization and builds domestic productive capacity, rather than creating enclaves or new dependencies. Aligning AI with clean energy goals is, first and foremost, an institutional challenge. Success is not solely about technology but about governance, leadership, policy innovation, service delivery reforms and behaviour change across public and private actors. Without ecosystems that support long-term innovation, environmental sustainability and social inclusion, even technically sound strategies will underperform.

In that sense, the people-planet-prosperity framework provides a practical structure for operationalizing the green window of opportunity in policy and investment decisions (Figure 14). It places human development, environmental sustainability and economic transformation at the centre of the twin transitions in energy and AI:

- The people dimension focuses on human development and distributional effects. AI can enhance service delivery in education, health and social protection, but also threatens labour markets and risks exacerbating inequality if talent development remains confined to elites.
- The planet dimension captures environmental impacts: AI can accelerate the integration of renewables, early climate prediction and energy efficiency, but also imposes heavy energy and water demands. Without clean energy, AI risks becoming a highly carbon-intensive sector.
- The prosperity dimension concerns productive transformation: AI can boost competitiveness, enable upgrading into greener value chains and open new export niches, but only when coupled with deliberate industrial policy. Otherwise, profits accrue disproportionately to foreign firms.

Figure 14. The people-planet-prosperity framework for inclusive twin transitions



Source: Authors' elaboration.

This framework, developed for policymakers, regulators and industry leaders in developing and emerging economies, presents a structured roadmap for aligning AI and energy transitions with sustainable development goals. It defines key concepts, identifies priority challenges, and offers concrete, actionable recommendations to guide more inclusive, integrated and forward-looking decisions. It positions AI within a broader political economy of energy and industrialization, and provides a robust foundation for assessing how developing economies might leverage the green window of opportunity while avoiding new traps of dependency or environmental harm. Table 1 explains the benefits and risks, and related policy tools.

Table 1.

The people-planet-prosperity framework applied to AI to map a green window of opportunity for developing countries

	PEOPLE	PLANET	PROSPERITY
BENEFITS	• Public health system improvement through AI-enabled diagnostics and service delivery. • Education access and quality via adaptive learning and digital public services. • Social protection targeting through data-driven welfare systems. • Climate early warning and disaster risk adaptation for vulnerable populations.	• AI can accelerate decarbonization through grid optimization, predictive maintenance for renewables, AI-enabled forecasting of variable generation, and precision agriculture reducing water, fertilizer and chemical use.	• Productive transformation through upgrading into greener global value chains. • New export niches such as green data-centre hosting and AI-enabled energy services. • Productivity gains across manufacturing, agriculture, logistics and public services.
RISKS	• Job disruption without adequate reskilling pathways. • Algorithmic bias reinforcing social exclusion. • Digital dependency on foreign platforms, eroding sovereignty.	• Massive electricity consumption from compute expansion. • High water use for cooling data centres. • Escalating pressures on critical mineral extraction and fragile ecosystems.	• Prosperity concentrated in a few hubs without deliberate policy. • Exposure to speculative AI bubbles that crowd out real investment. • First-mover disadvantage: high costs and stranded assets from premature AI infrastructure.
POLICY ACTIONS	• National AI-energy skills strategies integrating power engineering, data science and digital governance • Large-scale vocational retraining programmes linked to clean energy and digital infrastructure projects. • Requirement for AI strategies to include local language data sets and use cases that directly address community needs. • Public procurement of digital infrastructure to ensure AI supports health, education and social protection systems.	• Mandatory renewable power requirements for new data centres and AI compute clusters. • Grid modernization programmes using AI for loss reduction, forecasting and resilience. • Environmental impact standards for AI infrastructure covering water, land and mineral use. • Support for 'biomimicry', broadly understood as design approaches that emulate natural systems and processes alongside other nature-inspired innovations to reduce resource use intensity.	• Targeted industrial policy linking renewables deployment, green data centres and local AI ecosystems. • Public finance instruments to support AI-energy startups, including grants, concessional funding and risk-sharing tools to enable early-stage growth and innovation. • Demand-side tools such as targeted public procurement, regulatory sandboxes and incentives for early adopters to create markets for AI-energy solutions. • Regional coordination for sovereign compute, shared high-performance computing facilities and collective bargaining power in minerals and cloud markets.

People: Inclusion, capability, skills and social outcomes

The choices governments make about how to build, power and govern AI and digital infrastructure will shape livelihoods, rights, skills and well-being for workers, communities and the public at large. This will determine whether the green window of opportunity translates into broad-based capability-building or deepens existing divides. Kenya's Silicon Savannah, Chile's Chilecon Valley and other Global South ecosystems are exploring and defining new AI and innovation pathways driven by local needs, realities and aspirations. These learnings in community participation, rights and inclusion, and public-private collaboration can drive important progress in the AI era.

Recognizing this potential, countries need to expand equitable access to both AI and energy, and make greater and more coordinated efforts to engage with strategic opportunities. AI-related infrastructure should be planned around national goals for universal electrification, resilient power systems and the fair distribution of energy services, not just around the needs of large firms. Inclusion is not only a question of digital skills. It is also about whose energy needs are prioritized, whose land and water are affected by infrastructure, who can access affordable AI-enabled services, who participates in data governance, and who captures jobs and business opportunities created by the AI-energy transition.

When governments integrate AI into power generation, transmission and end-use systems, they lay foundations for smart grids and smart cities that can improve the affordability, reliability and quality of electricity services for households and enterprises alike. At the same time, this requires investing in people's skills and actively linking capabilities to AI and clean-energy strategies, so that new technologies create decent jobs and opportunities rather than deepening divides.

Energy is a foundational human need and a human right. Advancing AI is not just about efforts to support and enable the supply side, however. Shaping demand through digital skills, inclusion and technology that is real, relevant and tangible to people's lives and livelihoods helps to translate the green window of opportunity into broad-based gains rather than enclave-style growth. AI-enabled energy management, including smart metering, demand-side response and building-level optimization, can deliver energy efficiency gains of around 10 to 20 percent, and in some contexts up to 30 percent, while creating new jobs and skills in digital energy services, data analytics and power-system management (IEA 2025b). This reduces operating costs for families, schools, hospitals and small businesses, while improving service reliability over time.

In this context, strengthening public sector institutions and governance is essential. Robust rules, accountability and public participation through meaningful feedback loops can steer the twin transitions towards shared prosperity instead of reinforcing old inequalities and locking in

exclusionary pathways. For instance, local data on climate, agriculture, linguistics and Indigenous knowledge are largely absent from global models. Most AI systems are trained on English-language data. English is spoken by only 19 percent of the global population, yet it dominates over 98 percent of scientific papers and more than half of open-source data sets (Toledo 2024). That skews the usefulness of generative models in many developing countries. Expanding AI access means investing not just in general human skills but in local data, languages and applied research that reflects real needs, so that countries build the domestic knowledge base needed to capture value from the green window of opportunity.

AI infrastructure is often led by business strategies and investments, however. Governments do not always have the capacity to align this new, rapid and significant infrastructure roll-out with national priorities. Universal access, grid resilience and fair energy distribution could be achieved through greater coordination. In South Africa, for example, data centres are being fast-tracked even as many communities endure daily blackouts (Colmer 2025). It is not uncommon for private data centres to invest in diesel-fuelled backup systems while ordinary residents endure rotating load-shedding. When AI runs on fossil-heavy or fragile grids, it pushes emissions higher, strains already weak electricity systems, and leaves households and small businesses absorbing the worst impacts, undermining an inclusive, low-carbon path (Claasen 2025).

Infrastructure imbalances are amplified by gaps in capabilities, one of the main channels through which countries may lose the green window of opportunity. In many developing countries, the digital skills needed to capture the benefits of the twin transitions remain thin, limiting the ability to move from AI adoption to domestic value creation (IEA 2025b). The skills gap extends beyond AI and information and communications technology into the energy sector. Shortages of technicians, engineers and data specialists to design, operate and maintain modern energy systems persist. At the same time, the expansion of AI-enabled energy systems creates new demands for hybrid skills at the intersection of power systems, data analytics and digital services, opening pathways for job creation if training systems are aligned accordingly.

Gender gaps also remain stark. Women make up just 32 percent of the global renewable energy workforce, and only 24 percent in science, engineering, technology and math (STEM) roles (IRENA 2024). In AI and digital systems, they account for only 30 percent of generative AI learners and about one-third of ChatGPT users, a gap that is wider than the overall internet gender gap (World Bank 2025a). This gap persists in advanced economies. In the United States, 32 percent of men use generative AI at work compared to 23 percent of women (Bick et al. 2024), while in Denmark, women are 18 percent less likely to use ChatGPT than men (Humlum and Vestergaard 2024). In developing countries, the gender gap is often wider due to constraints in affordability, access to devices, and digital skills. As a result, unequal participation in AI risks reinforcing existing inequalities in labour markets, services, and access to opportunity.

Regional disparities add other challenges. While Asia leads in renewable energy jobs, Africa and Latin America capture only a small share, limiting their capacity to adopt and scale up digital

energy solutions and narrowing room to compete. At the same time, highly skilled workers in digital and energy fields are increasingly leaving developing countries in search of better opportunities, draining local talent and weakening systems to support AI and clean-energy transitions (World Bank 2025a). China, India and the United States account for over half the world's information and communications technology specialists (World Bank 2025a). In contrast, developing countries such as Bangladesh, Lebanon, Nigeria and Ukraine are seeing digital talent leave at rates three to four times higher than they can attract it (Figure 15).

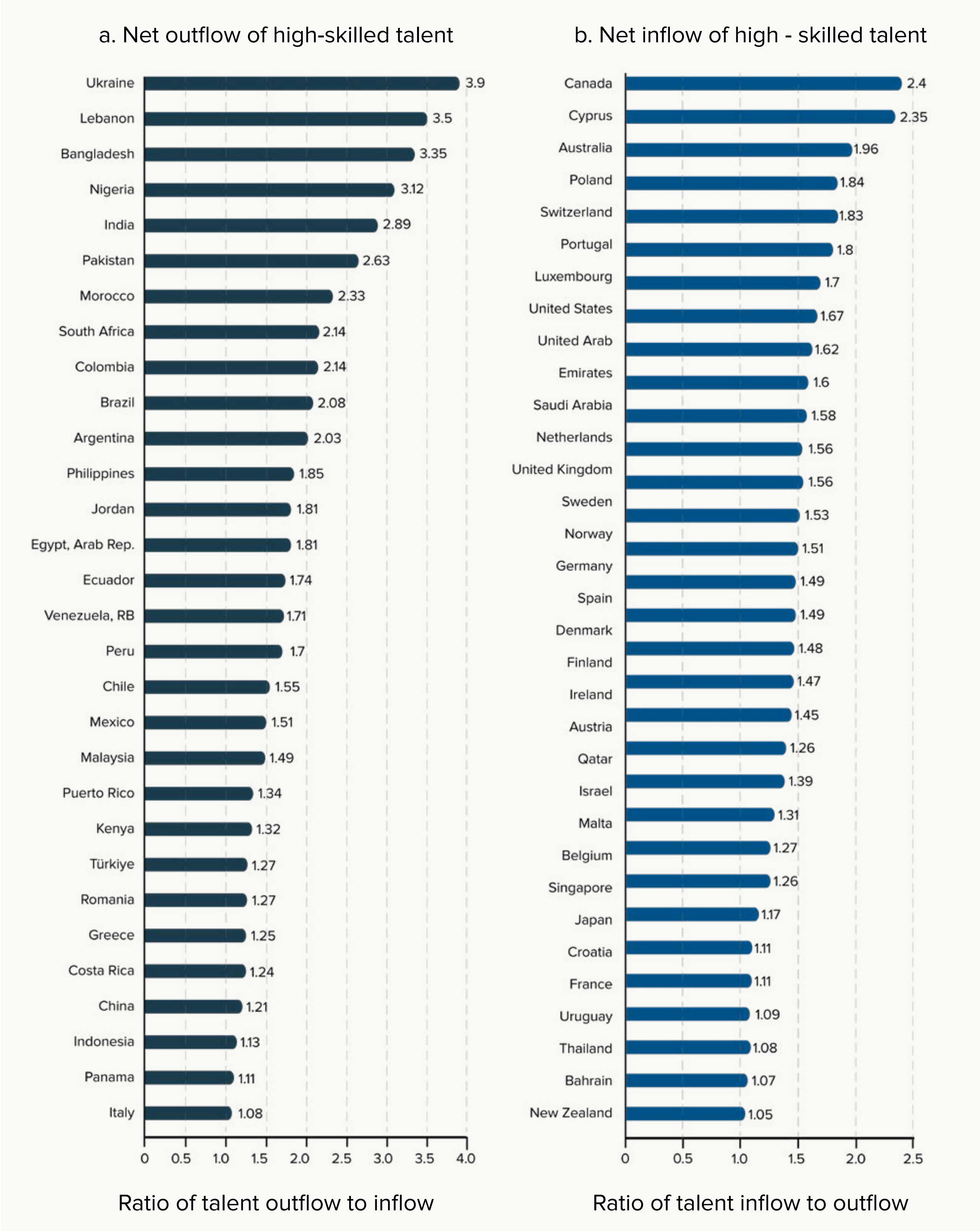
A country's ability to develop, adapt and govern AI depends on its human capital, yet many developing economies face a widening digital skills gap. As highlighted earlier, fewer than 5 percent of people have basic digital skills in low income economies, compared with around 66 percent in high-income economies (World Bank 2025a). ICT specialist capacity is also highly concentrated, with China and the United States (21 percent each) and India (15 percent) dominating, while low-income countries account for less than 1 percent. The sector is also gender-skewed, with men dominating in many countries such as Germany and Italy, while countries like the Philippines (1.9), China (2.3), and India (2.8) are relatively more balanced.

Across much of Africa, limited Internet access, high data costs and a shortage of computers, AI labs and specialized facilities compound this divide. Fewer than 30 percent of universities have labs for AI, data science or computer-aided design (World Bank 2025a; World Bank forthcoming). Many computer science students cannot afford personal computers, which significantly limits their ability to practice programming and build technical expertise, further weakening the human capital base (World Bank 2025a).

Even where infrastructure and skills begin to catch up, a third barrier lies in who sets the rules. This ultimately determines whether the green window of opportunity yields shared benefit or reinforces dependency. Too often, decisions about data infrastructure, AI systems and their local impact are made far from the communities they affect. Around the world, there is growing recognition that governance cannot be an afterthought or top-down exercise. Models such as Maori data sovereignty in New Zealand, community co-design frameworks and 'good neighbour' approaches in data-centre planning show how digital development can be grounded in consent, shared benefit and long-term stewardship (Lilley et al. 2025; Isabel and Griffen 2024). These examples point towards a broader lesson: Governance has to move beyond one-off consultations. It must become a structured process where communities, local institutions and national authorities jointly shape AI and data infrastructure building, governance and accountability.

Effective governance frameworks promote inclusion and transparency, and guard against risks such as bias or misuse. Many developing countries will need to modernize data protection laws and turn high-level AI principles into enforceable ethics guidelines, rather than leaving them as aspirational statements (Harvard Law Review 2024). Regional collaboration can help. Grouping resources, talent and data across countries can improve bargaining power and reduce duplication.

Figure 15. Cross-border migration of high-skill talent, 2022



Source: World Bank 2025a.

The African Union's Continental AI Strategy, the Guide on AI Governance and Ethics of the Association of Southeast Asian Nations (ASEAN) and the Santiago Declaration for Latin America and the Caribbean all emphasize local ownership, regional cooperation and public interest digital and data infrastructure (African Union 2024; ASEAN 2024; Chile 2023). Building regional institutional capabilities may require resources and concerted efforts, but it offers a foundation for AI and energy transitions to spur long-term development, not just short-term gains. It may support developing economies in capturing the green window of opportunity through inclusive rules, stronger sovereignty and technology spillovers.

Planet: Environmental boundaries, resource use and system sustainability

AI comprises a global network of physical supply chains, from lithium mines providing critical minerals to power AI-enabled digital services to the water supplies that keep data centres functioning. It needs to be developed and deployed in a sustainable manner, respecting safe boundaries for humanity and the planet. This includes the land, water, energy and infrastructure required for compute, chips, data centres, networks, devices and cooling as well as the emissions and waste generated (IEA 2025a).

This report adopts a Healthy Planet lens, in line with UNDP's Strategic Plan 2026–2029, recognizing that AI's environmental implications extend beyond climate to biodiversity, ecosystems, freshwater, land use and material extraction. Aligning AI and energy transitions therefore requires integrated solutions that reduce planetary pressures and support sustainable, inclusive development. This integrated approach is also consistent with broader international commitments, including the Paris Agreement and the Kunming-Montreal Global Biodiversity Framework. From a green window of opportunity perspective, staying within planetary boundaries is not a constraint on growth but a condition for capturing green industrial opportunities through low-carbon, resource-efficient pathways, rather than repeating high-impact industrialization.

Globally, energy consumption of data centers is expected to grow sharply across all regions by 2030, driven by rapid digitalization and the expanding deployment of AI systems (IEA, 2025). In the base case, global consumption could reach nearly 950 TWh, with North America and the Asia-Pacific region accounting for more than two-thirds of the total (see Table 2). Within this, IT-related operations alone may consume about 730 TWh, reflecting the intensifying computational demands of AI workloads and cloud services. China's share is projected to triple, underscoring its accelerating investment in hyperscale and AI-optimized infrastructure.

A recent study compares these projections across regions through 2030 and beyond under varying scenarios, illustrating how global data centre electricity use could rise steeply (Figure 16). Under a high projection, total electricity consumption from data centres could grow by over 150 percent globally, with China and the United States leading the increase due to rapid AI deployment and cloud expansion. The United Kingdom and European Union exhibit more moderate growth patterns, reflecting efficiency gains and renewable integration. The current trajectory suggests that by 2050, global data centre demand could surge by up to 872 percent, underscoring the urgency of low-carbon infrastructure investments (Oxford Institute for Energy Studies 2025).

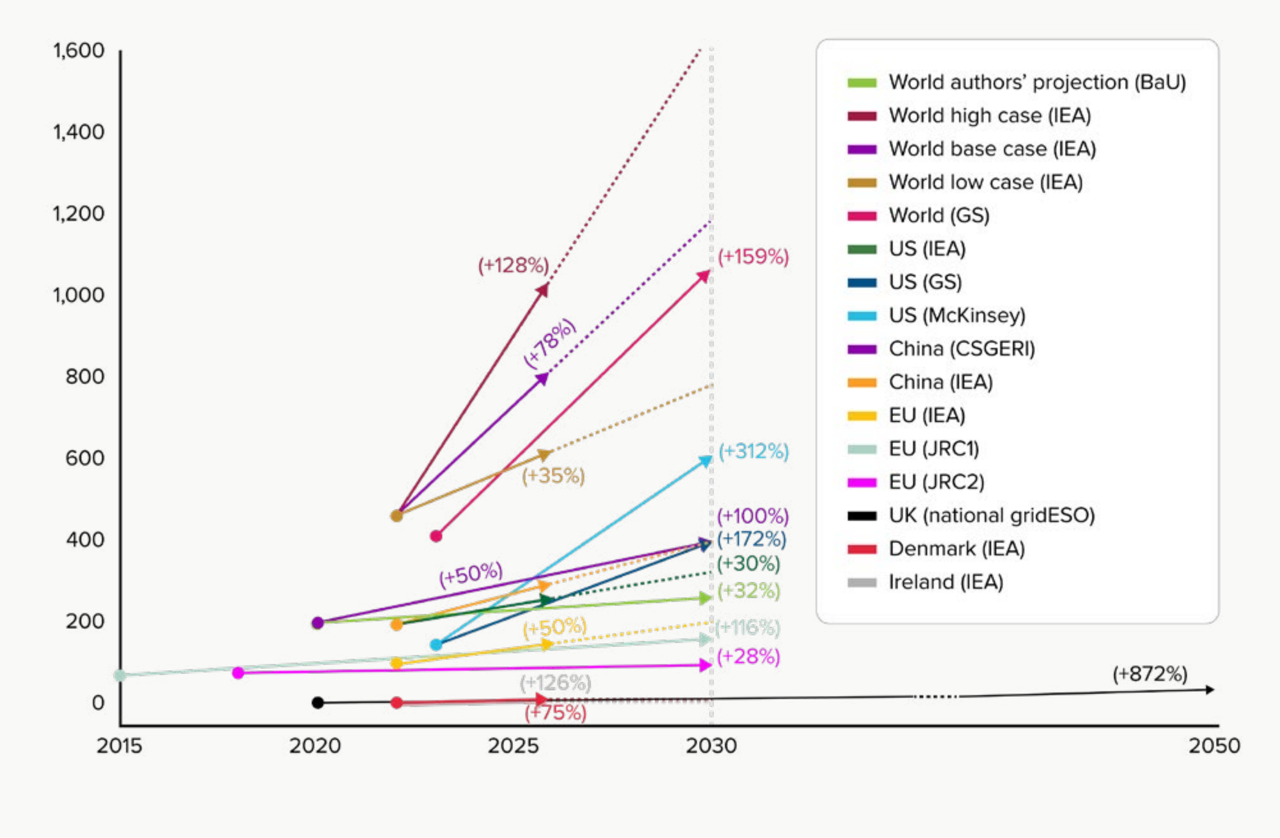
Global discussions are beginning to recognize these pressures, but practice has not yet caught up. More than 190 countries have endorsed the Recommendation on the Ethics of Artificial Intelligence of the United Nations Educational, Scientific and Cultural Organization. It includes

Table 2. Data centers electricity consumption by region

Sector	2020	2023	2024	2030
Total electricity consumption (TWh)				
World	269	361	416	946
North America	112	158	187	434
United States	108	154	183	426
Central and South America	1.5	1.5	1.7	3.3
Europe	57	66	68	113
Africa	1.1	1.3	1.4	2.9
Middle East	1.1	1.3	1.5	3.0
Asia Pacific	93	128	150	378
China	62	84	102	277
IT electricity consumption (TWh)				
World	176	252	295	733
North America	80	120	142	351
United States	78	117	139	345
Central and South America	0.8	0.8	1.0	2.2
Europe	36	45	47	88
Africa	0.6	0.7	0.8	1.8
Middle East	0.5	0.7	0.8	1.7
Asia Pacific	55	82	100	281
China	37	54	68	205

Source: Energy and AI (IEA 2025).

Figure 16. Projected increase in data centre electricity consumption in different regions



Source: Oxford Institute for Energy Studies 2025.

guidance on environmental responsibility, yet concrete implementation remains limited (UNEP 2025). Without careful regulation, the expansion of AI risks intensifying pressure on electricity grids, forests, water systems and critical minerals, reproducing environmental inequalities and social harms. These risks are particularly acute in hot and water-stressed regions, where cooling requirements can account for a substantial share of total data centre energy use and where freshwater scarcity increases the environmental costs of AI deployment. When AI systems are designed to be centred on communities, local knowledge and public priorities, however, they can enhance climate resilience, strengthen essential services and support ecosystem restoration. AI also presents opportunities to reduce energy emissions (Box 1).

Many countries are still struggling with the clean energy transition even as they expand their AI ambitions. In Saudi Arabia, for instance, investment in digital infrastructure is accelerating while the power mix remains dominated by fossil fuels, raising concerns that AI demand could deepen carbon lock-in rather than support a shift to cleaner energy (Conte 2025).

The supply of freshwater is also a challenge. AI data centres convert approximately all the electricity they use into heat, requiring substantial year-round cooling systems. Cooling alone can

BOX 1: THE ROLE OF AI IN REDUCING ENERGY EMISSIONS

Despite its growing energy footprint, AI is emerging as a powerful tool to reduce greenhouse gas emissions across the energy value chain—from fuel extraction and generation to industrial processes, transport and use in buildings. By enabling real-time optimization and smarter resource allocation, AI can directly reduce energy use or indirectly enable more efficient system-level performance across sectors.

AI applications contributing to emissions reductions across sectors

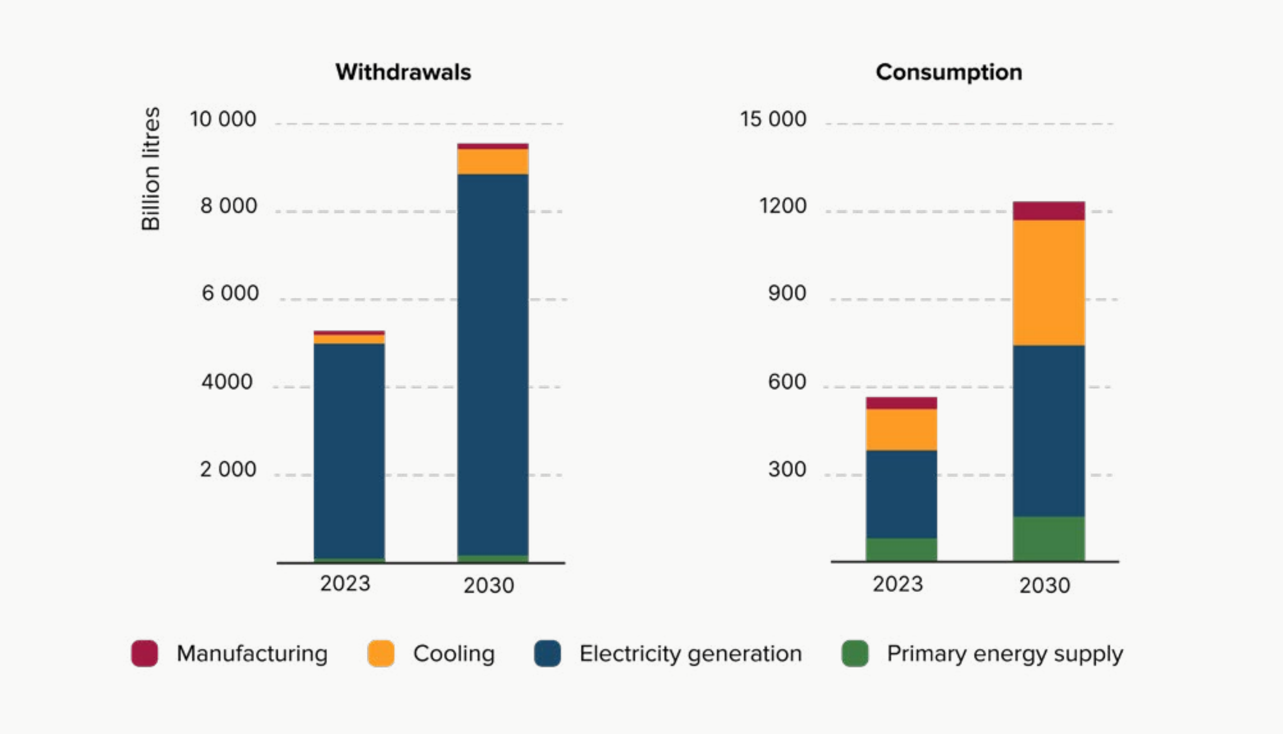
Sector	AI application / mechanism	Example of impact	Estimated efficiency or emissions reduction
Oil and gas	AI-enabled leak detection and predictive maintenance using satellite and sensor data	Methane leak identification allows faster repair and reduced flaring (e.g., MethaneSAT, Shell Leak Detection AI)	Significant reductions in methane leaks; up to 70–90 percent faster detection
Power generation	Process optimization and plant efficiency improvement	AI keeps natural gas plant operations near optimal performance conditions	Improvement in efficiency, lower fuel use and carbon dioxide emissions
Industry (manufacturing and cement)	AI-driven process control and fuel mix optimization	Improved fuel mix and kiln management in cement production	2–3 percent energy efficiency gains, reduced carbon dioxide emissions per tonne produced
Transport	Smart routing, driving behaviour analytics and fleet optimization	AI-assisted route planning and traffic control (e.g., UPS ORION, DHL Smart Fleet)	5–10 percent efficiency gains, substantial fuel and emissions savings
Buildings	AI-based energy management and heating and cooling system optimization	Predictive control of heating, cooling and lighting systems (e.g., BrainBox AI)	About 10 percent energy savings on average, improved occupant comfort and reduced carbon dioxide emissions

According to the IEA's Widespread Adoption Case, existing AI applications in end-use sectors could reduce carbon dioxide emissions by 1.4 gigatonnes by 2035, three times greater than the projected total emissions from data centres in a Lift-Off Scenario. Achieving this, however, depends on overcoming significant barriers, including limited data access, inadequate digital infrastructure, skills gaps and weak regulatory support.

Source: IEA 2025b.

account for a significant proportion of total data centre electricity consumption, particularly in high-temperature environments, creating a direct nexus between energy demand, water use and land-intensive infrastructure. Add the water used for electricity generation and chip manufacturing and the pressure intensifies. Global water consumption by data centres is estimated at approximately 560 billion litres per year, projected to increase to around 1,200 billion litres annually by 2030 under a base case scenario (IEA 2025b; see Figure 17). A large share of this growth is driven by water-based cooling systems, many of which can consume millions of litres per day in large AI-optimized facilities. Global water withdrawals for data centres are projected to rise sharply through 2030.[1]

Figure 17. Water withdrawals and consumption by data centres in a base case scenario, 2023 and 2030



Source: IEA 2025b.

Many countries are not starting from a strong position, with incidences of drought increasing around the world (Kuzma et al. 2023). Malaysia, South-East Asia's most water-stressed country, has over 100 proposed data centres that could consume more than 808 million liters a day. Regulators now require all new facilities to use only recycled, reclaimed or rainwater as part of the approval process.

1 Water withdrawals refer to the total volume taken from surface and groundwater sources. Consumption denotes the portion of that water not returned to its original source after use. Typically, it is lost through processes such as evaporation.

By 2030, about half of the global water consumption by data centres will occur in Asia and the Pacific, where warm, humid conditions make cooling more water-intensive. For example, in Asia and the Pacific, the regional water-use effectiveness rate is 1.65 litres per kilowatt-hour, over three times the global average of 0.5 litres per kilowatt-hour (IEA 2025a). This highlights a fundamental trade-off faced by many countries with high solar potential and ample land availability. While renewable energy can reduce carbon and water intensities relative to fossil fuels, high ambient temperatures and water scarcity significantly increase cooling demand, complicating siting decisions for AI infrastructure.

The environmental challenge goes beyond electricity and water. For instance, waste heat brings its own challenges. Data centres lose energy twice, first through the inefficiency of converting electricity into compute and then again when cooling systems expel the heat they generate. In some data centres in developed countries, waste heat reuse efforts focus on district heating, such as Stockholm Data Parks (Sweden), Facebook's Odense (Denmark) and Equinix's TR5 data center facility (Canada) (European Commission 2023; Sustainability n.d.; Mondesir and Nkonge 2025).

But that model rarely fits the many countries, particularly in tropical regions, where the priority is cooling, not heating. In these contexts, unmanaged waste heat can exacerbate local heat stress and increase surrounding land and water pressures, reinforcing the need for integrated planning across energy, water and land systems. The more relevant opportunities lie in heat-intensive sectors such as desalination, food processing, aquaculture and low-temperature hydrogen production, where low-grade heat can ease pressures on water and energy systems. These circular-economy links represent a concrete opportunity for developing economies to take advantage of emerging technologies and tools. By developing lower-impact AI infrastructure, including modular and edge-based systems suited to local demand and resource constraints, they can generate local spillovers, strengthen resource security and avoid replicating high-footprint hyperscale models imported from developed countries.

Prosperity: Economic transformation, infrastructure and industrial policy

The success of the twin transitions depends on whether they can deliver shared, sustained and inclusive prosperity. The United Nations, through the 2030 Agenda for Sustainable Development, frames prosperity as ensuring that "all human beings can enjoy prosperous and fulfilling lives and that economic, social, and technological progress occurs in harmony with nature".[2] In this report, prosperity refers not only to economic growth but also to the ability of individuals and communities to build better lives, fulfil their potential, participate meaningfully in economic activities and rely on stable and forward-looking institutions. This broader view underscores that prosperity requires innovation, clean power and modern digital infrastructure that create widespread opportunity, rather than growth concentrated in a few sectors. Prosperity, therefore, is not only about higher income or output. It is also about human well-being, innovation capacity and society's ability to sustain progress over time, particularly as economies undergo the transformation driven by AI adoption and the clean energy transition.

Despite recent progress, many developing countries remain constrained by persistent structural barriers due to low productivity, limited economic diversification and dependence on a narrow set of economic activities. These restrict the transition to higher-value and competitive economies (Delechat et al. 2024). Nearly 60 percent of Africa's economic rebound in 2024, for example, came from the service sector, while agriculture and industry remained comparatively subdued (World Bank 2025b). Concentrated growth in lower-productivity segments limits the potential for inclusive, long-term prosperity. Infrastructure gaps deepen these challenges. Weak and unreliable electricity systems, slow digital connectivity and limited data infrastructure continue to raise production costs, deter investment and restrict firms' ability to modernize. Without reliable power or digital foundations, firms cannot incorporate AI, integrate into global value chains or shift towards higher-value production. The misalignment between fast-growing AI and digital demand and slow-paced renewable energy deployment and grid upgrades further exacerbates these constraints.

Data centres illustrate both the promise and the system-level implications of this transition. A typical 100-megawatt facility generates around 500 full-time equivalent jobs during its two- to three-year construction period and maintains a specialized operational workforce of roughly 50 (Lee et al. 2025).[3] Contractors from abroad may fill some construction roles, however, and the operational workforce remains small. This means data centres alone do not constitute a national AI strategy or a broad pathway for domestic job creation.

At the same time, these facilities also create indirect employment through renewable energy development, telecommunications, cooling systems and local contracting. More importantly, data centres often act as anchor institutions that expand fiber networks, strengthen grid infrastructure and attract investments in cloud services and AI-driven enterprises. Their broader impact emerges from the ecosystems they catalyse, particularly when paired with clean energy expansion. The scale of prosperity gains ultimately depends on whether countries use these investments to build domestic capabilities and move into higher value segments, such as AI-enabled services, local platform development, specialized engineering and maintenance, and regionally competitive digital offerings, rather than remaining solely hosts of energy-intensive infrastructure.

These challenges make clear that achieving broad-based prosperity will require deliberate actions to align energy systems, digital infrastructure and AI deployment. As the AI economy expands, countries that coordinate clean electricity expansion, grid resilience, investment frameworks and industrial capability-building will be better positioned to capture value, diffuse productivity gains and sustain competitiveness over time. The next section reviews the panorama for Green AI ecosystem development in the developing world and its existing barriers, before outlining the strategic pathways needed to guide this transition so the AI-energy shift strengthens economic transformation rather than reinforcing existing divides.

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2 See the United Nations 2030 Agenda for Sustainable Development for more details.
3 These figures are from an analysis by the Boston Consulting Group based on expert interviews and press releases from data centre operators.

04.

A GREEN AI ECOSYSTEM IN THE GLOBAL SOUTH: OPPORTUNITIES AND BARRIERS

Startups play a key role in the digital-energy nexus and can help translate the energy transition into new markets, services and capabilities.[4] They also act as early indicators of where capabilities are emerging, where market demand exists, and where public policy can reduce barriers to experimentation and scale. Their contribution depends on the wider system around them: utilities willing to procure innovation, regulators able to test new models, financiers prepared to support growth, and public institutions that can create demand for locally relevant solutions. This section presents a startup mapping linked to the people-planet-prosperity framework. Startups provide an early signal of whether the green window of opportunity is translating into more affordable and reliable energy services, lower-resource digital growth, and new pathways for local value creation, jobs and productive upgrading.

To better understand opportunities and constraints in developing countries, this section analyses startups and Green AI ecosystems in seven key developing economies: Brazil, Chile, India, Malaysia, Mexico, Nigeria and South Africa. These firms operate at the intersection of AI, energy systems and climate sustainability. Green AI, as used in this report, refers to the balanced development of AI, energy and nature. It includes both energy-climate technologies for AI, such as renewable generation, storage, grid optimization and efficient data-centre infrastructure, and AI-for-energy and AI-for-climate applications, such as forecasting, automation, decarbonization and resource optimization. As AI acceleration, especially generative AI, increases pressure on electricity systems, Green AI ecosystems can help align digital transformation with environmental sustainability, energy-system resilience and long-term development value.

Current status of the Global South Green AI ecosystem

The mapping identified 88 startups across the seven economies, along nine principal Green AI activities: AI for energy, AI for climate, energy generation, energy storage and flexibility, grid infrastructure, climate finance, sectoral applications, deeptech and materials, and AI/compute infrastructure. Across all countries, activity is heavily concentrated in the AI–energy overlap, especially in AI for energy, grid-edge intelligence and AI-enabled infrastructure. This suggests that founders are prioritizing the operational performance of power systems and digital infrastructure over upstream climate analytics.

AI for energy dominates as a field, with 30 startups, covering grid optimization, virtual power plants, smart metering, forecasting and the Internet of Things. Sectoral applications account for 12 startups, focused on energy embedded in agrotech, mobility, aquaculture and mining. Nine startups fall in the categories of AI for climate and finance, reflecting strong climate/carbon and

4 This section relies on Melguizo and Wald 2026.

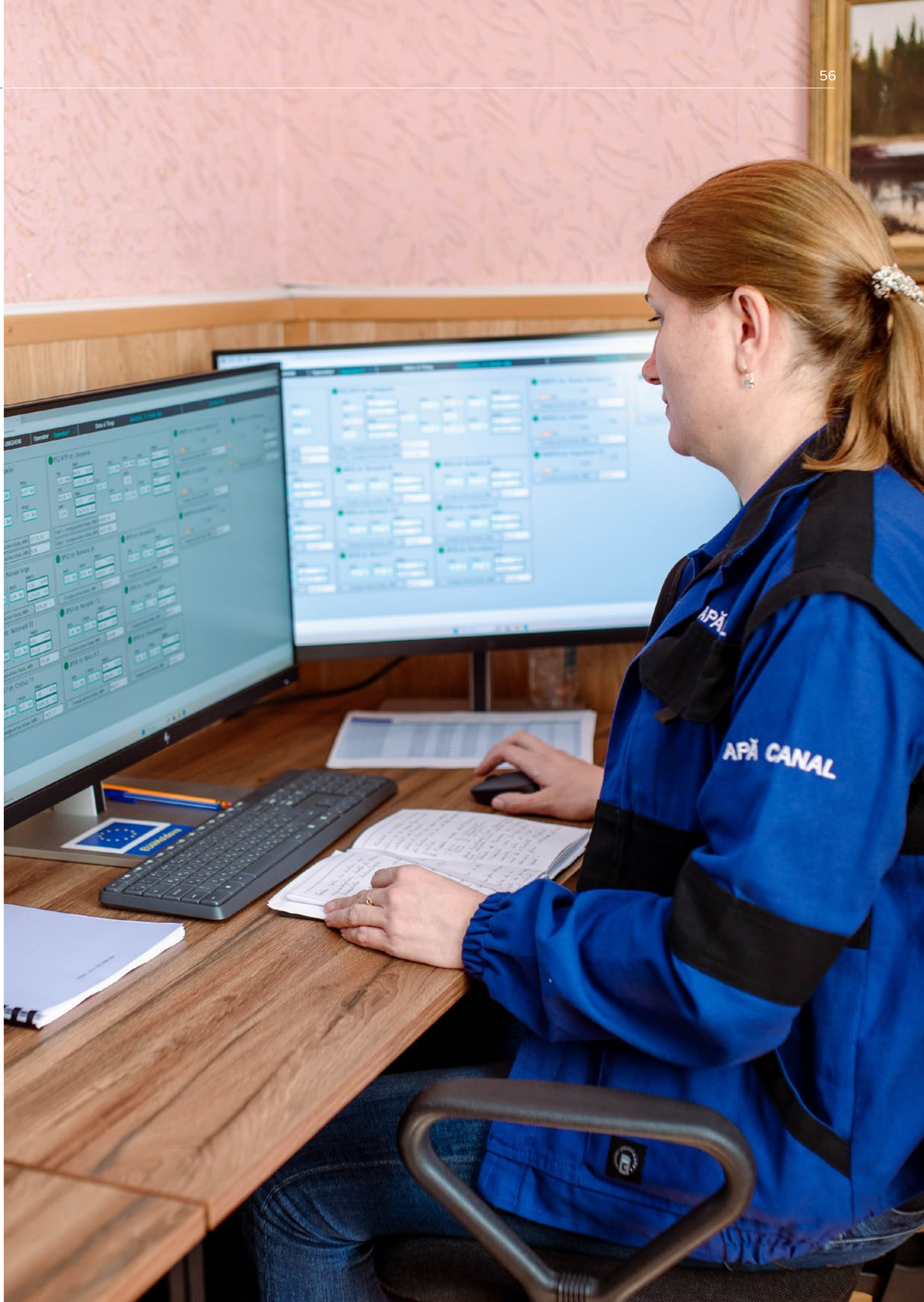
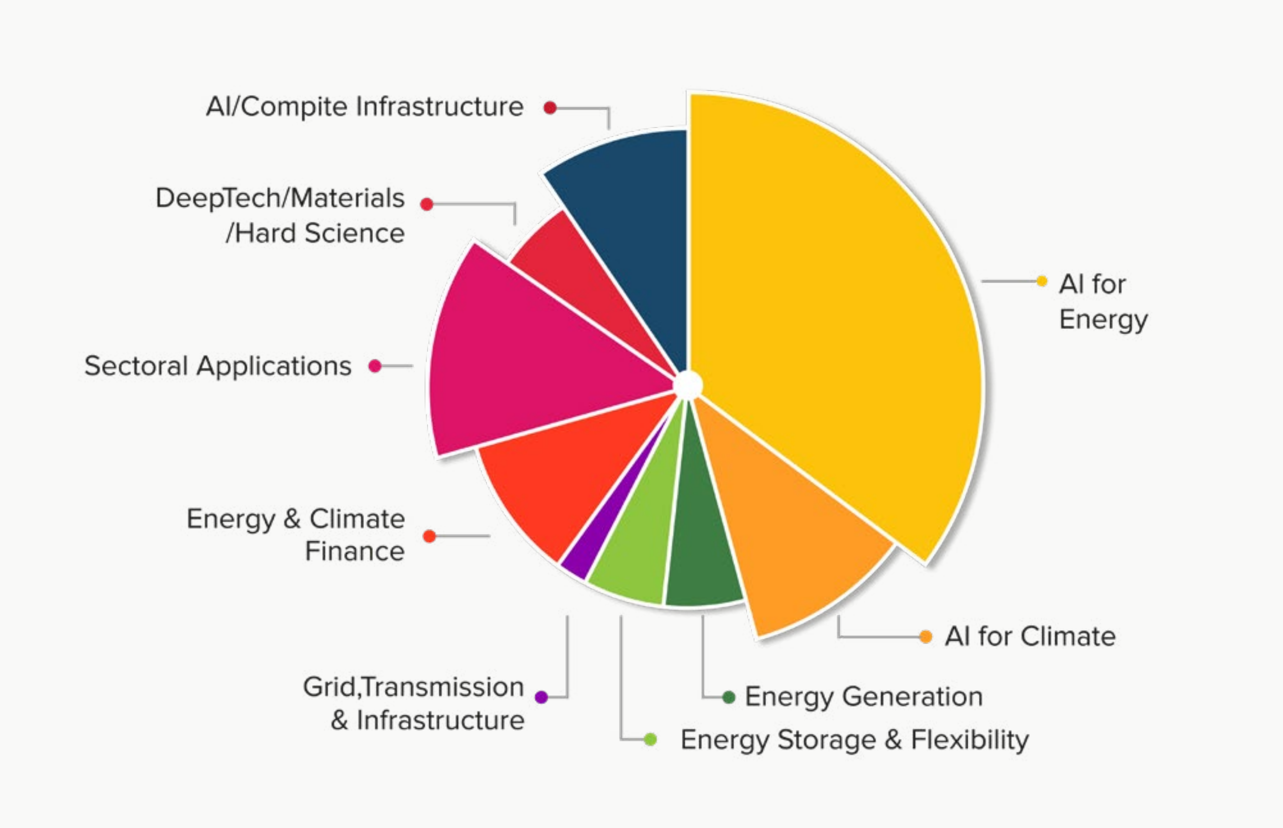


Figure 18. Green AI startups in seven selected developing economies, by activity



Source: Authors' elaboration.

fintech activity. AI/compute infrastructure accounts for eight startups, confirming a major trend towards renewable-powered AI data centres (Figure 18).

Interviews with firms across the sample revealed that founders repeatedly cite electricity reliability, energy pricing volatility and regulatory uncertainty as shaping both business models and location decisions. This directly affects their ability to benefit from the green window of opportunity. For many firms, proximity to renewable resources and grid modernization programmes are primary determinants of investment, indicating the emergence of a geography of compute that is driven less by talent clusters than energy endowments.

Despite this breadth of entrepreneurial activity, commercial traction remains highly concentrated. A small subset of ventures accounts for a disproportionate share of observable customer relationships. Many others display strong ecosystem engagement—accelerator participation, competition awards and grant funding—without corresponding evidence of product-market fit. This asymmetry suggests that supply-side dynamism alone is insufficient to catalyse commercial momentum without complementary demand-side interventions such as public procurement reform, regulatory sandboxes and early adopter programmes.

The mapping reveals both promise and fragility. While the Global South has clean energy advantages and growing digital talent pools, the Green AI ecosystem remains nascent, with most ventures operating at the pilot or demonstration stage rather than at scale. Without coordinated policy, finance and market-shaping interventions, these conditions risk leaving the green window of opportunity only partially realized, reinforcing market concentration rather than enabling broad-based ecosystem growth.

Barriers to ecosystem development: What holds back Global South startups?

Understanding why ecosystem development remains challenging in developing countries is critical for designing effective interventions to seize the green window of opportunity. A thriving innovation ecosystem requires experienced founders, access to appropriate technologies, customers willing to adopt early-stage solutions, financing from seed to late-stage rounds, and credible exit options (Saxenian 1994). These dimensions operate as a virtuous cycle; success in one reinforces the others. Developing economies typically face gaps across all these dimensions simultaneously, producing a vicious cycle that suppresses scaling up.

The challenge lies in addressing gaps across these dimensions simultaneously, as a weakness in any single element can prevent a virtuous cycle from beginning or sustaining itself. Gaps fall in two broad categories: visible and invisible, as summarized in Table 3.

Table 3. Visible and invisible barriers to AI-energy startup development in developing countries

Visible ecosystem gaps		Invisible ecosystem gaps	
Talent constraints	• Shortage of experienced founders who understand customers, markets and organizational scaling. • Absence of serial entrepreneurs who can mentor new generations of founders. • Lack of functional leaders in product development, engineering, data science and sales. • Weak labour mobility and limited knowledge spillovers from established firms. • Preference of local talent for stable employment over startup risk and equity compensation.	**Cultural barriers to entrepreneurship**	• High uncertainty avoidance producing strong fear of failure. • High power distance reducing engagement between senior decision makers and junior founders. • Collectivist norms discouraging standing out and bold value propositions. • 'Tall poppy' dynamics such as Chile's chaquetear that penalize visible success. • Sales strategies constrained by social sanctions against differentiation. • Limited peer communities providing social proof and psychological insulation for risk-taking.
Customer access limitations	• Lack of early adopters willing to evaluate and adopt risky early-stage technologies. • Limited influence of innovators and champions inside incumbent organizations. • Oligopolistic market structures that suppress innovation and reduce incentives for incumbents to work with startups. • Cultural resistance to failure and experimentation in buyer organizations. • Absence of external forcing mechanisms or "wave functions" that drive market timing and adoption. • Weak pattern recognition capabilities among founders regarding when to enter markets.	**Low social trust**	• Low generalized trust reducing transaction efficiency between unfamiliar actors. • Strong in-group preferences channelling resources to insiders rather than the best ideas. • Structural disadvantage for founders without elite social networks.
Capital availability constraints	• Shortage of venture investors with first-hand entrepreneurial experience. • Investors applying traditional business risk frameworks to high uncertainty startup contexts. • Unrealistic expectations on timelines, governance and control from local investors. • Limited merger and acquisition activity and weak initial public offering (IPO) markets constraining exit options. • Persistent global exit backlog, particularly in developing markets, delaying liquidity. • High concentration of global exit value in high income economies. • Thin information networks that prevent capital from flowing to high potential ventures.	**Incentive misalignment and the Series B cliff**	• Oligopolistic market structures reducing incentives for technology adoption. • Government programmes focused on seed funding without parallel customer development. • The Series B cliff, where startups fail to progress beyond early rounds due to weak traction. • Long time lags between Series A and Series B rounds. • The valley of death between early funding and commercial revenue. • Impact-driven founders underestimating the importance of economic incentives for customers.
Regulatory and administrative barriers	• Excessive administrative complexity in licensing and permitting processes. • Long timeframes to formally start a business in lower ranked economies. • Opaque compliance requirements and manual government processes. • High transaction costs associated with in-person signatures, notarization and approvals. • Public grant programmes imposing administrative burdens that offset intended benefits. • Misaligned public sector incentives focused narrowly on local job creation and brain drain prevention.		

Source: Authors based on interviews with start-up founders.

As explained in Table 3, visible gaps include severe talent constraints that directly limit whether developing economies can seize the green window of opportunity. High-growth startups require founders with experience in customer discovery, organizational scaling and market expansion, as well as functional leaders in engineering, data science and sales. In many developing markets, these skill profiles remain unevenly distributed, reflecting differences in education systems, research ecosystems, firm capabilities and access to advanced digital infrastructure. However, countries such as China and India demonstrate that public policy, sustained investment and institutional coordination can build these capabilities over time. The problem extends to the broader labour market, where local talent pools may prefer employment at stable, established companies over the uncertainty of startup employment with equity compensation. Research on entrepreneurial ecosystems demonstrates that labour mobility and knowledge spillovers from established firms represent critical inputs to new venture formation (Saxenian 1994). This further suggests that the ability to capture the green window of opportunity depends on ecosystem dynamics that allow skills, ideas and people to circulate into new enterprise growth.

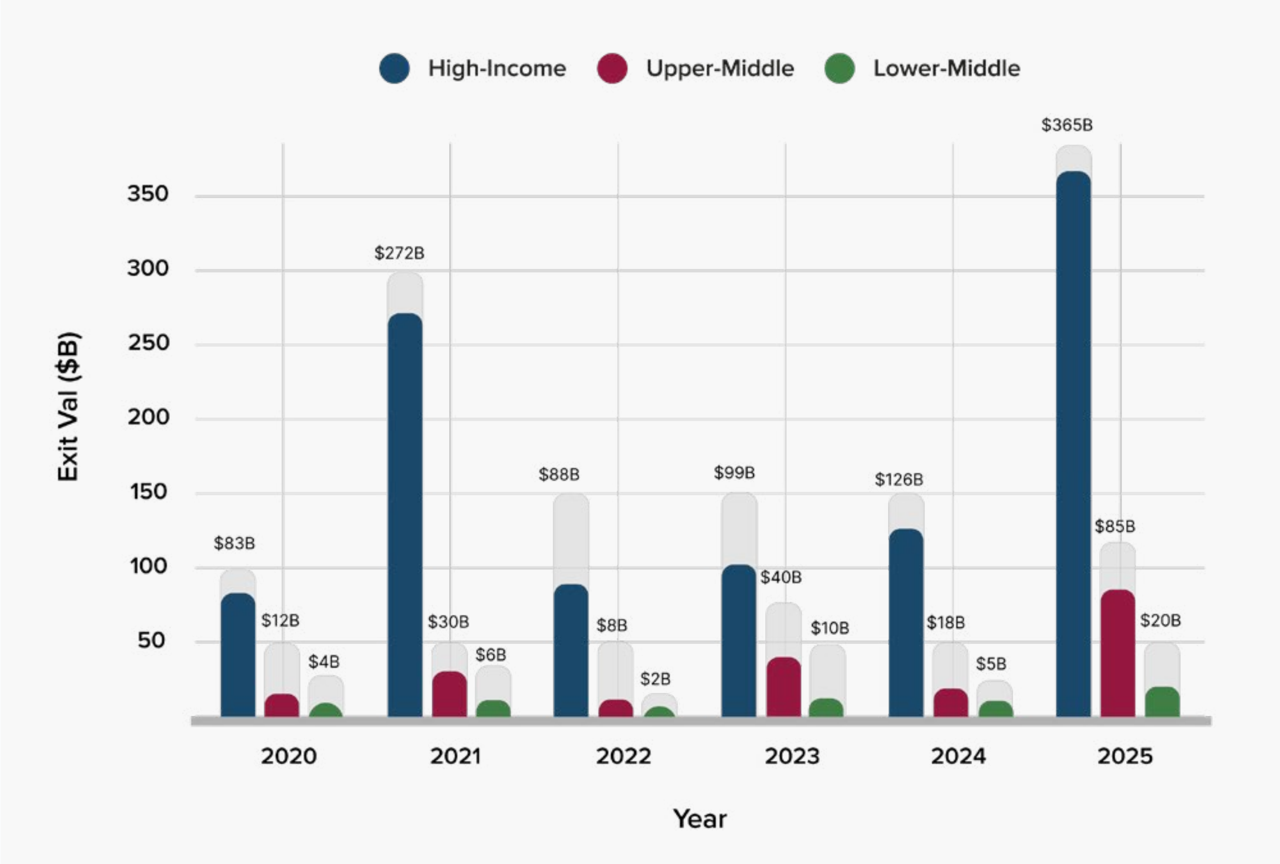
Customer-access limitations are another major barrier, limiting the ability of the green window of opportunity to become real markets for local AI-energy solutions. Startups need early adopters willing to absorb technological risk, but oligopolistic market structures in many developing economies can reduce competitive pressure on incumbents and weaken incentives to experiment (World Bank and OECD 2017). When dominant firms face limited threats to their market position, they often underinvest in new technologies and avoid unproven vendors, creating a structural barrier for startups regardless of the technical merit of their offerings.

Financial constraints compound these challenges, delaying scale-up and shifting value capture toward better-capitalized hubs. Venture capital ecosystems remain thin, especially for deep-tech ventures with long development horizons. Limited merger and acquisition activity, few IPO pathways and weak exit options reduce investor willingness to deploy patient capital. Although secondary-market activity has increased in some regions globally, its relevance for developing-country AI-energy startups remains uncertain where exit constraints reflect deeper structural market limitations.

Annual exit values by income tier show high-income economies (above US$13,935 in per capita gross national income, GNI) account for 78 to 90 percent of global exits, ranging from US$83 billion to $365 billion. Upper-middle-income (US$4,496 to US$13,935 in per capita GNI) and lower-middle-income (US$1,136 to US$4,495 GNI in per capita) countries contribute 10 to 27 percent and 2 to 7 percent, respectively (Figure 19). This is problematic as successful investment ecosystems depend on dense information networks that guide capital towards promising opportunities.

Invisible barriers are equally important, combining with invisible gaps to suppress the virtuous cycle required for Green AI ecosystems to mature. They include cultural risk aversion, weak trust

Figure 19. Global venture capital/startup exits by income classification



Source: Authors' elaboration using data from Cambridge Associates, KPMG, the National Venture Capital Association and Preqin.
Note: Income definitions are based on those of the World Bank.

in early-stage technology providers, fragmented public sector governance, and misalignment between innovation agencies, energy regulators and digital ministries.

Cultural norms inhibit adoption where organizations are risk-averse and reluctant to work with unproven vendors. This reduces early-adopter demand precisely when the green window of opportunity hinges on experimentation and rapid learning. Hofstede's cultural dimensions framework, developed through research spanning four decades and encompassing data from more than 50 countries, provides analytical tools for understanding cross-national variation in entrepreneurship rates (Hofstede 2001). Meta-analytic reviews confirm that cultural values explain significant variance in organizational and individual outcomes across countries (Taras et al. 2010). Research examining 33 countries in 1975 and 1980 found that higher innovation rates are most closely associated with acceptance of uncertainty, less hierarchical social relations, and individualism (Shane 1993). Uncertainty avoidance demonstrates a consistent relationship with stigma around failure.

In the sample countries, Brazil (76), Mexico (82) and Chile (86) score high on uncertainty avoidance, showing significant fear of failure. This compares to levels under 50 in India, Nigeria and South Africa. High uncertainty avoidance channels talent towards intrapreneurship rather than independent ventures (Liebregts et al. 2024) while making founders reluctant to pursue aggressive enterprise strategies carrying visible risks of rejection. Research across 1,048 firms found that uncertainty avoidance and power differences negatively influence risk-taking in small and medium-sized enterprises (Kreiser et al. 2010). Significant power differences create communication barriers mediated by fear of authority.

A factor to consider in addressing cultural issues is social proof. This entails creating peer-based communities that offer a self-reinforcing culture of support for those who wish to take risks and stand apart from the crowd, even where that might involve failure. These communities can be a force multiplier and offer insulation from local cultural pressures, helping to sustain experimentation and confidence to convert the green window of opportunity into scalable ventures.

Panel data analysis across 43 countries from 1995 to 2015 demonstrated that firms in high-trust environments produced greater innovation output, measured through patents and new product introductions (El Ghoul et al. 2023). Low social trust creates friction in transactions between unfamiliar parties, which is disadvantageous to new founders without established reputations. In-group preferences compound trust-related barriers by channelling resources and opportunities towards individuals with existing social connections to decision makers. Founders with promising technologies but without access to relevant social networks face systematic disadvantages in raising capital, accessing customers and recruiting talent.

Lastly, government programmes frequently address early-stage ecosystem gaps through grants for startup formation and seed funding, without corresponding attention to customer development and exit mechanisms. This creates the Series B cliff: a funding drop-off in which companies that successfully raise seed and Series A capital cannot advance to later stages because they lack the customer traction and growth metrics to justify larger investments. Analysis of progression rates from Series A to Series B indicates that companies require approximately 24 months between rounds, and that fewer than half of Series A companies successfully raise Series B funding within four years (Lemkin 2024). The valley of death phenomenon, extensively documented in technology commercialization research, describes the gap between early-stage funding and sustainable commercial revenue (Auerswald and Branscomb 2003).

Founders in ecosystems that restrict traction and the adoption of technologies will likely struggle even if they look outside local ecosystems for funding. Cleantech ventures face particularly acute challenges. The first investment boom in this arena demonstrated how capital availability without corresponding customer demand produces poor outcomes for investors and entrepreneurs alike. Capturing the green window of opportunity requires not only finance but also market creation, early adopters and pathways to scale up.

05.

POLICY RECOMMENDATIONS FOR DEVELOPING COUNTRIES: BUILDING A PEOPLE-CENTRED AI-ENERGY ECOSYSTEM

Recognizing the strategic openings associated with seizing the green window of opportunity, this section sets out five strategic actions to help policymakers and partners translate that potential into practical interventions. The recommendations reflect the report's core finding that success in the AI-energy transition depends not only on infrastructure and resources, but also on demand, local capabilities, coordination and inclusive markets. The aim is to ensure that the twin transitions of AI and clean energy reinforce and catalyze one another, rather than creating new technological divides, new forms of extractivism and deeper inequalities.

These actions are not linear but have a significant cumulative impact. As shown earlier in the report, economies differ significantly in AI readiness, digital capabilities, energy-system reliability and institutional capacity (see Figure 5). For many developing countries, particularly in parts of Africa where energy access remains limited, the most credible entry point may be an application-first, infrastructure-light pathway based on existing cloud services, while delaying large physical AI investments until demand, skills and grid conditions improve. For early adopters, such as Kenya, Nigeria and Chile, the priority shifts to selective build-out: adapting AI to domestic sectors and investing where demand is visible and justified. For strategic innovators, such as Malaysia, Brazil and South Africa, the task is to move beyond adoption towards innovation, ecosystem leadership and more advanced infrastructure.

Against this differentiated landscape, the following actions provide a policy agenda for countries to build inclusive and context-specific AI-energy ecosystems, while considering that each country will sequence implementation according to its infrastructure, capabilities and demand conditions.

1. Innovation and skills policy: Building domestic AI-energy ecosystems

Recognise the opportunity to strengthen domestic economic resilience through the development of a local AI-energy innovation ecosystem driven by local energy and AI skills

Building domestic AI-energy ecosystems is essential if countries are to capture value from the twin transitions rather than depend on imported systems that may not fit local realities. connecting AI and energy innovation ecosystems across firms, universities, applied research groups, utilities and public agencies, while also ensuring that these institutions have access to the reliable electricity, connectivity and compute resources needed to test and scale solutions for grids, water, agriculture, mobility and resource governance. For most emerging economies, the focus should be on digital literacy, core public-sector capability and inclusive access with basic safeguards. For early adopters and adapters, the emphasis should shift to stronger technical, managerial and regulatory capacity, closer university–industry collaboration, and AI deployment that supports gender inclusion and local development. For more advanced ecosystem builders, the priority is to deepen research and regulatory strength, retain talent, and align AI innovation

CASE STUDY

CHINA'S THOUSAND TALENTS PLAN – REVERSING BRAIN DRAIN AND BUILDING STRATEGIC INNOVATION CAPACITY

Launched in 2008, China's Thousand Talents Plan was designed to attract top Chinese scientists, scholars, and entrepreneurs living abroad. In 2011, the programme expanded to include younger researchers and foreign scientists, helping to remove administrative barriers and integrate them more easily into China's research ecosystem. Over the past decade, the initiative has recruited more than 7,000 high-skilled individuals, becoming one of the world's largest talent-return schemes. Participants receive competitive salaries, substantial research funding, laboratory start-up packages, and leadership opportunities in strategic fields such as AI, semiconductors, biotechnology, and advanced manufacturing. These incentives have significantly increased China's ability to reverse high-skill outmigration and strengthen domestic innovation capacity. For returning Chinese scientists, the programme offers strong professional and financial motivation to establish their careers at home, while for foreign researchers it provides streamlined entry into China's rapidly expanding innovation system. Overall, the Thousand Talents Plan has played a central role in positioning China as a major global hub for science, technology, and frontier AI research.

Source: World Bank (2025); Jia (2018).

with resilience, sustainability and longer-term industrial upgrading. Malaysia's Saya Digital initiative, which delivers digital-skills training in local languages and responds to local challenges, shows how skills programmes can be strengthened when linked to employer demand, applied training pathways, public-sector adoption and opportunities for local firms to deploy AI-enabled solutions (MDEC 2022).

In the short term, the priority is to make it easier for firms, startups and public institutions to test and adopt AI-energy solutions. In many lower-income contexts, the main barriers are expensive compute and cloud services, unreliable and costly electricity, weak connectivity, scarce early-stage finance, gaps in technical and business know-how, and regulatory uncertainty that raises the cost of experimentation. This points to a practical set of near-term instruments for ministries of industry, energy, education and digital affairs, working with regulators, universities and development partners: public challenge funds and early-stage grants for AI-energy startups; shared digital and compute infrastructure; regulatory sandboxes for supervised testing; and procurement mechanisms that create first markets for relevant local solutions. Rwanda's Kigali Innovation City shows how co-locating higher education, technology activity and supporting infrastructure can help generate innovation spillovers, while the United Arab Emirates' AI Sandbox initiative demonstrates how governments can encourage experimentation without sacrificing oversight and public trust (Africa50 2025; Dubai Future Foundation 2025).

Over the medium term, countries should move from isolated pilots to stronger ecosystems by investing in skills pipelines, institutional coordination and scale-up support. Developing countries in particular should cultivate and retain a full-spectrum AI-energy talent base of technicians, engineers, data specialists and regulators, while broadening AI literacy across business, government and communities. This requires embedding AI, digital and energy competencies into national education and workforce plans, scaling STEM and technical and vocational education and training, and funding specialized skills in power systems, data engineering, cybersecurity, AI safety and semiconductor-adjacent fields through curriculum reform, accreditation and training funds. Weak innovation systems and gaps in productive capability can otherwise slow diversification and productivity growth, reinforcing the case for targeted public action that expands the space for locally grounded problem-solving (UNCTAD 2025).

Over the longer term, countries should work to keep talent, firms and knowledge at home so that AI-energy innovation supports domestic transformation rather than outward migration and dependency. Skills strategies must therefore go beyond training to include talent-retention measures such as competitive remuneration for critical public roles, return-of-talent schemes, innovation fellowships and startup-friendly regulation that lowers the cost of experimentation and scaling. China's Thousand Talents Plan offers a high-profile example of how incentives, research funding and career pathways can help reverse brain drain and consolidate innovation capacity at scale (World Bank 2025a; Jia 2018) (see Case Study). Complementary instruments, including applied research and development grants, seed funding for deep-tech ventures and procurement frameworks that create early markets for local solutions, can help trained professionals build careers at home. Together, these measures support decent jobs, stronger problem-solving capacity and long-term resilience in the AI-energy system.

2. Regulatory and infrastructure policy: Making 'Green AI' the default

Align policy, regulation and institutions with climate, nature and energy-system goals to make Green AI pathways financially viable and politically feasible.

The global community is at an AI inflection point. One pathway leads to AI expansion powered by fossil fuels, rising water stress and extractive infrastructure models that deepen inequality and undermine climate goals. The other establishes 'Green AI' as the baseline for how AI is deployed, financed and governed. For governments, this means positioning AI within energy, industrial, and environmental policy frameworks, aligned with broader sustainable development goals (Lebdioui et al. 2025). The practical implications of Green AI, however, will differ across countries. For early starters, such as Ethiopia and many Small Island Developing States, Green AI would most likely begin with application-first, infrastructure-light models. For more advanced adopters, such as Malaysia, Brazil or South Africa, it should guide the selective scaling of efficient, low-carbon compute linked to domestic value creation.

In the short term, governments, regulators and utilities should put in place the basic rules and incentives that shape AI infrastructure from the outset. New data centres and major AI deployments should be required to meet minimum standards on renewable power, energy efficiency and water use, with licensing linked to renewable procurement and, where relevant, grid- or transmission-upgrade plans. Public procurement can also be used to favour efficient hardware, lower-water cooling systems and AI services that improve energy and public-service outcomes. In lower-readiness contexts, these measures should be paired with support for cloud-based services, open-source tools and practical applications in health, agriculture, education and energy management, so that countries build real demand and local capability before committing capital to infrastructure that may quickly become obsolete. Morocco's Digital 2030 approach shows how this can be packaged: a renewable-powered data-centre strategy, efficient design (outdoor air cooling, heat recovery, water recycling), and wider enablers such as skills, connectivity and investment incentives (Green Times 2025) (see Case Study).

A parallel priority is to ensure that energy-efficiency knowledge on AI infrastructure reaches developing countries before major infrastructure choices are locked in. For many emerging countries, especially those taking an application-first pathway, the period before large-scale compute investment should be used to learn from frontier experience on efficient chips, cooling systems, siting and water use. UNDP, the IEA, regional development banks and bilateral partners could help transfer this knowledge through practical guidance and technical assistance for ministries, regulators, utilities and investment agencies. In essence, this waiting period becomes a strategic advantage, allowing countries to embed efficiency early rather than retrofit it later.

In the medium to long term, governments will need to engage more proactively with the AI value chain to avoid overloading grids and water systems as AI scales up, while also guiding investment toward activities with stronger potential for domestic value addition. This requires attention to market demand, value-chain opportunities and the sequencing of public support, so that incentives and infrastructure investment are directed toward sectors where countries can realistically build capabilities over time. This also means prioritizing energy efficiency through the use of high-efficiency chips, modern cooling systems and more efficient AI models, supported by practical policy tools such as performance-per-watt requirements for compute hardware, public procurement incentives for efficient accelerators and cooling, and routine reporting of power and water usage effectiveness alongside renewable energy shares. Where cooling is unavoidable, standards can prioritize lower-water approaches such as dry cooling or immersion, while heat reuse can be encouraged where it fits local demand (IEA 2025a). Framed this way, Green AI becomes more than an environmental and biodiversity safeguard: it becomes a develpoment strategy that lowers resource pressures, builds markets and capabilities over time, and ensures that AI growth contributes to inclusive and sustainable development.

3. Industrial and minerals policy: Moving up the critical minerals-energy-compute value chain

Capture greater value from the critical minerals–energy–compute chain to strengthen domestic AI, energy and innovation capacity

The strategic opportunity for mineral-rich developing countries is to use the low-carbon transition to move beyond extraction and capture more value at home. Many developing countries hold major deposits of critical minerals such as cobalt, lithium, nickel, copper, graphite and rare earths, yet remain locked in low-value extraction models generating limited jobs, weak industrial linkages and high exposure to commodity volatility. Demand for minerals used in batteries, electric vehicles, grid infrastructure and data-centre and semiconductor-adjacent hardware is accelerating. Lithium demand, for example, has risen sharply in recent years and remains a central growth driver across clean energy applications (IEA 2025b). The low-carbon transition creates major opportunities for mineral-rich countries, but only if they can shape, adopt and embed deliberate strategies and investment to capture value in addition to exporting raw materials (World Bank 2017). Industrial policy can guide investment where countries have realistic potential to capture value, which requires phased upgrading strategies that identify where public spending, infrastructure investment and incentives can unlock the highest domestic benefits.

CASE STUDY

MOROCCO'S PATH TO GREEN, CARBON-NEUTRAL DATA INFRASTRUCTURE

Morocco is positioning itself as a continental leader in sustainable digital infrastructure through its Morocco Digital 2030 strategy, which prioritises data centers powered by solar and wind energy from major renewable hubs such as Ouarzazate and Dakhla. New facilities are being designed with energy-efficient architecture, including outdoor air-cooling, heat-recovery systems, and water-recycling processes, supporting the national goal of achieving carbon-neutral data centers by 2035. Global technology firms are reinforcing this transition: Oracle is developing a cloud and AI platform in Casablanca-Settat; AWS and Orange Morocco are launching Africa's first Wavelength Zone; and Google Cloud is establishing an energy-efficient region in Rabat. Large green-compute investments – such as Naver and Nvidia's 500-MW centre in Tangier and Iozera. ai's 386-MW hub in Tetouan – are expanding AI capacity while integrating low-carbon design. To sustain this ecosystem, Morocco is scaling digital-skills programmes, expanding fibre and 5G, strengthening data protection, and promoting favourable regulatory and fiscal incentives that attract green, energy-efficient cloud infrastructure.

Source: Green Times (2025).

In the short term, governments should identify realistic upgrading pathways and put in place the basic conditions needed to make them investable. Upgrading will require concerted effort and strategic policy choices, including exploring nascent opportunities that shift countries from extraction towards refining, chemical processing, precursor production, component manufacturing and energy storage systems. Broader interventions, including strengthening foundational infrastructure, shaping funding and financing environments, and improving environmental governance, also need to be considered. Key measures include (i) establishing public-private partnerships to de-risk investment in downstream processing and manufacturing, (ii) directing research and development and innovation funding towards local refining and component technologies, and (iii) building coordination across ministries responsible for mining, industry, energy and finance. Regional cooperation will also be important from the outset, particularly through cross-border value chains and joint industrial zones that can help countries achieve scale and shared benefits where national markets are too small to support upgrading on their own.

Over the medium term, the priority should be to turn mineral endowments into stronger industrial ecosystems linked to energy, logistics, skills and domestic supplier networks. Countries are already making progress. Indonesia's nickel downstreaming offers a concrete example: export restrictions and coordinated industrial investment helped drive a shift towards domestic smelting and refining, leading to a major rise in nickel export value (CSIS 2025; see case study). Morocco has made recent investments in cathode materials and precursors for electric vehicle supply chains, while Chile's State-led push for strategic participation across the lithium value chain has been supported by public-private co-investment and joint venture models that provide the necessary long-term capital. These examples suggest that successful upgrading depends not only on mineral endowments, but also on industrial coordination, patient finance and institutions that can crowd in investment over time.

Over the longer term, regional scale and deeper downstream capacity will be critical if countries are to convert mineral wealth into broader structural transformation. The joint battery and electric vehicle initiative of the Democratic Republic of the Congo and Zambia, which includes plans for cross-border value-chain development and special economic zones, signals how neighbouring producers can collaborate to build precursor and manufacturing capacity rather than competing only as exporters of raw materials. In this context, moving up the critical minerals–energy–compute value chain becomes more than a resource strategy. It also serves as an industrial policy tool that can generate jobs, deepen domestic capabilities, and ensure that the benefits of the clean energy and digital transitions are captured more broadly at home.

CASE STUDY

INDONESIA'S MINERAL AND BATTERY MANUFACTURING POLICY TO CAPTURE DOMESTIC VALUE

Indonesia provides an example of a developing country using mineral policy, energy planning, and public–private investment to move up the critical-minerals value chain. The government's prohibition on raw nickel ore exports - first introduced in 2014 and tightened in 2020 – forced a shift toward domestic smelting, refining, and battery-material production. Indonesia's downstreaming policy has achieved several of its intended objectives by sharply increasing domestic value captured from the nickel sector. As the CSIS analysis notes, the government reports that nickel export value rose from 17 trillion Rupiah to 510 trillion Rupiah following the introduction of the export ban and downstreaming requirements. This period also saw a 44.2 percent increase in foreign direct investment, reaching USD 45.6 billion in 2022 as global firms invested in refining, processing, and manufacturing facilities. By 2024, Indonesia had become the world's leading producer of nickel, accounting for 58 percent of global output, strengthening its position in battery-material supply chains. While downstreaming has not eliminated structural challenges – particularly dependence on Chinese inputs and markets - it demonstrates how coordinated mineral regulation, industrial policy, and investment incentives can significantly expand domestic value addition in resource-rich economies.

Sources: Center for Strategic & International Studies (CSIS, 2025) with additional insights from Guberman et al. (2024)

4. Governance and coordination policy: Aligning AI and energy for greater investment and impact

Strengthen whole-of-government coordination and cross-sector partnerships to connect AI and energy planning, investment and implementation

The central governance task is to ensure that AI and energy policy are designed together, not in isolation. Treating AI as a narrow digital issue owned by a single ministry or regulator systematically underestimates its energy, industrial and distributional implications. AI systems are embedded in physical infrastructure that draws power and requires water, land, minerals and skilled labour, while energy systems are increasingly shaped by digital tools for planning, forecasting and optimization. When AI policy is decoupled from energy planning, the result is predictable: grid stress, rising electricity costs, ad hoc exemptions for data centres and missed opportunities to align AI growth with renewable expansion, grid modernization and demand-side management. Conversely, energy strategies that ignore AI risk underplanning for future demand, misjudging load profiles and failing to capture the productivity and system-efficiency gains that AI can unlock.

Effective coordination must be grounded in real domestic demand. For many developing countries, coordination should distinguish between two types of demand. The first is near-term commercial adoption, which is likely to move fastest in professional services, financial and business services, telecommunications, logistics, and other higher-capacity service sectors. The second is public-interest adoption in health, agriculture, education and energy services, where the development impact may be high but spending capacity, data readiness and workforce skills are often more limited. Public R&D, procurement and donor support should therefore help bridge this gap by targeting high-impact sectors where market demand alone may be too weak to drive adoption. For early adopters, this means using demonstrations, early-adopter programmes and procurement by utilities, regulators and public agencies to build initial demand. More advanced ecosystems should then deepen adoption across industry, logistics and public services, creating stronger home markets for innovation and export growth. Without this sequencing, countries risk planning AI infrastructure around hyperscale assumptions rather than domestic digital demand and energy realities.

Institutionally, this means placing AI-energy coordination above the level of a single line ministry and giving it authority to shape investment, regulation and market formation across government. AI-energy policy needs to be treated as a whole-of-government challenge that links fiscal policy, industrial policy, education and skills policy, competition policy and trade policy. Public procurement, for example, should not be treated as a narrow administrative tool, but as a strategic instrument for creating first markets for local AI-energy solutions. Several countries have deliberately placed AI coordination at the centre of government to drive cross-ministerial alignment. In Colombia, the presidency leads the national AI strategy. In China, the State Council

CASE STUDY

KENYA – LEVERAGING DATA-CENTER INVESTMENT TO SHAPE A COHERENT DIRECTION FOR JOBS, SKILLS, AND COMMUNITY INFRASTRUCTURE

Kenya offers a leading example of how developing countries can tie data-center expansion to inclusive development outcomes – and a shared national economic direction. As Nairobi grows into a regional digital hub, the government has increasingly incentivized major investors such as Africa Data Centers (ADC) and IXAfrica to embed commitments to job creation, skills development, and community infrastructure in their project agreements. ADC's hyperscale Nairobi campus has committed to creating local jobs and engaging local contractors for construction and is part of broader regional initiatives to develop data-centre skills and workforce capacity in East Africa, including training programs supported by industry-wide partnerships with universities and technical colleges. IXAfrica's multi-phase Nairobi campus has taken a similar approach, partnering with Kenya Power and county authorities to co-finance grid reinforcement, improving electricity reliability for surrounding communities—not just the facility itself. Kenya's model shows how strategic AI development through public–private partnerships can align AI-enabling infrastructure with inclusive economic development and community well-being.

Source: Africa DataCentres (2025). Ma (2025).

and Communist Party leadership coordinate the national AI strategy. In France and the United Kingdom, the Prime Minister's office plays a coordinating role, while in Singapore national AI governance is also anchored at the centre. The key design principle is not institutional form per se, but authority and a cross-cutting mandate.

A joined-up approach must also extend beyond government if AI-energy strategies are to become credible instruments for development rather than aspirational plans. Utilities, regulators, universities, firms, startups, financiers and civil society all shape whether AI and energy transitions generate resilience, inclusion and local value creation. Structured consultation and co-design processes can help ensure that strategies reflect real system constraints, local demand conditions and social priorities. Without such coordination, policy can become fragmented, demand can remain weak, and promising innovation can fail to scale.

Beyond national coordination, regional integration should also be part of this agenda, especially where fragmented markets constrain clean-power and compute investment. Stronger regional integration can turn fragmented markets into investable power and compute corridors, making it cheaper and more reliable to run AI on clean electricity while improving grid performance. Practical measures include regional power pools, cross-border power purchase agreements and shared transmission planning, backed by instruments such as multi-country guarantees, regional green bonds and blended finance. ASEAN illustrates this direction through the ASEAN Power Grid, the ASEAN Digital Masterplan 2025, and the ASEAN Guide on AI Governance and Ethics. Evidence from West Africa shows that regional energy projects improve reliability and reduce costs, reinforcing cross-border infrastructure as a platform for electrification and AI-era competitiveness (ASEAN 2024; ASEAN Digital Masterplan 2025; World Bank 2025b).

5. Entrepreneurship, finance and market-creation policy: Supporting 'Green AI' startups to survive and scale

'Fund', 'build and 'govern' Green AI ecosystems so that startups can reach customers, attract capital and grow beyond the valley of death.

The priority is to move beyond startup formation and build the market conditions that allow Green AI ventures to survive and scale. As Section 4 shows, barriers are interconnected: limited early adopters, weak investor networks, the Series B gap, concentrated markets, and risk aversion reinforce one another. Addressing them in isolation has limited impact. Capital without demand sustains grant dependence, while training and coordination alone do not create investors, customers or viable ecosystems. The policy challenge is therefore to fund, build and govern startup ecosystems in ways that align incentives across startups, investors, customers, utilities and governments (van den Heuvel and Popp 2022; Meddeb 2024a).

CASE STUDY

START-UP CHILE: HOW GOVERNMENTS SUPPORT CLEAN ENERGY START-UPS

Start-Up Chile provides an example of how public policy can do more than fund startups: it can help build the wider entrepreneurial ecosystem needed for innovation to scale. Launched by the Chilean government in 2010, the programme is a government-run incubator and accelerator that provides non-dilutive finance. It has an international outlook and supports overseas founders, including assistance with relocating to Chile to participate in the programme. While not energy-specific, it has also run dedicated calls for solar and energy efficiency and management start-ups. According to its application materials, Start-Up Chile has supported more than 3,000 startups and 6,000 founders from over 85 countries. This suggests that its value lies not only in financial support, but also in shaping entrepreneurial culture, attracting global talent, and connecting founders to networks of mentors, peers, and investors. In this sense, it illustrates how governments can use accelerators as ecosystem-building instruments that densify founder networks and lower barriers to entry, rather than relying on grants alone. While this model does not by itself resolve later-stage challenges such as scale-up finance or market access, it demonstrates how deliberate public action can help create the social and institutional foundations for more dynamic startup ecosystems.

Source: Start-Up Chile (n.d); IEA (2022)

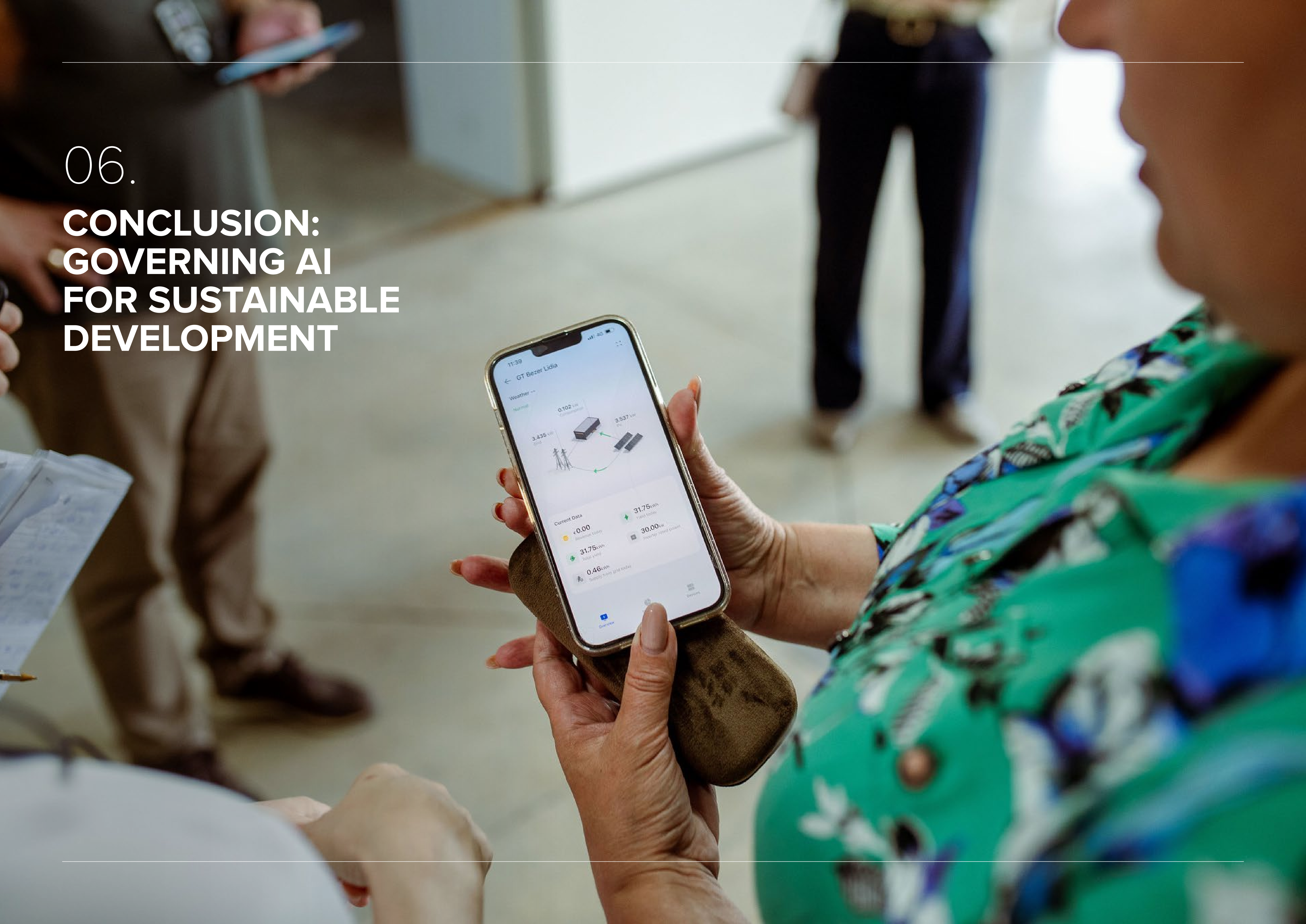
In the short term, the priority is to reduce pilot risk, create first markets and widen access to early-stage finance. Governments and development finance institutions can support this through challenge funds, milestone-based grants, matched pilot financing and public procurement programmes that help startups secure first contracts. Where firms are reluctant to work with unproven vendors, intermediaries such as development banks or innovation agencies can de-risk pilots and share lessons. Additional instruments could include an International AI Data Center Financing Fund providing concessional debt and guarantees for qualifying low-carbon data infrastructure in the Global South, alongside fund-of-funds support for local angel and venture investors. Digital Development Bonds could similarly help channel long-term capital into sustainable data centres, fibre, cybersecurity and AI-enabled energy systems, especially where traditional development finance is poorly suited to digital projects (Meddeb 2024b).

Over the medium term, the objective should be to 'build' stronger startup pipelines, investor capability and scale-up support. Venture studios are especially relevant in this context because they are designed to address several of the market failures identified in Section 4: Evidence suggests that venture studios can accelerate the startup journey and improve outcomes relative to traditional pathways, while accelerators can improve funding success and survival when they provide structured support and real market access (Bundl 2024; Bergen 2023). In contexts where uncertainty avoidance is high and failure carries strong stigma, venture studios and stronger accelerators can provide a more structured and credible pathway into entrepreneurship. Investor-development programmes linking local investors with experienced global venture mentors can also help build capacity across seed, Series A and Series B stages. these measures help prevent startups from stalling before scale due to weak finance, demand and ecosystem support.

Over the longer term, the task is to 'govern' Green AI ecosystems to align with national development goals while generating durable entrepreneurial dynamism. This does not mean over-regulating them, but ensuring that decentralized innovation, entrepreneurship and infrastructure choices support wider public goals, exploit synergies and do not deepen inequality. National AI strategies should therefore be adapted to technological maturity and fiscal space. In earlier-stage contexts, the focus may be on basic AI governance, low-emissions regulatory pilots and support for local energy-AI startups. In more advanced phases, governments can embed Green AI standards into procurement, foster sectoral innovation hubs, deepen exit and acquisition markets, and position domestic ecosystems to export sustainable AI and energy solutions (Meddeb 2024a; Lebdioui et al. 2025). Across all stages, policy should also normalize experimentation and failure, recognize acqui-hires and modest exits as valuable ecosystem outcomes, and create pathways for founders, talent and capital to circulate productively through the economy.

06.

CONCLUSION: GOVERNING AI FOR SUSTAINABLE DEVELOPMENT



The next phase of development will not be shaped by AI alone but by how countries respond to the deep interdependencies that AI exposes. Energy, infrastructure, water, minerals, institutions and talent are no longer separate policy agendas. They interact with social dimensions such as inequalities, access to social services, and uneven distribution of opportunities, which will influence how societies benefit from or are marginalized by technological change. Together, they now form part of the core infrastructure of national development strategies.

AI has brought urgency and political visibility to long-standing gaps in power systems, planning capacity and institutional readiness. This attention creates space for action, but it also raises the stakes. Countries that treat AI growth as a standalone digital initiative will confront rising system strain, stranded investments and widening inequality. Those that approach the twin transitions of AI and energy as a single integrated challenge will gain greater leverage, resilience and long-term stability.

Looking ahead, three principles should guide government action.

First, **energy planning is now digital planning**. Without clean and reliable power, AI infrastructure cannot scale up. And when it does, it can overwhelm fragile grids unless deployment is carefully sequenced and co-located with renewable capacity.

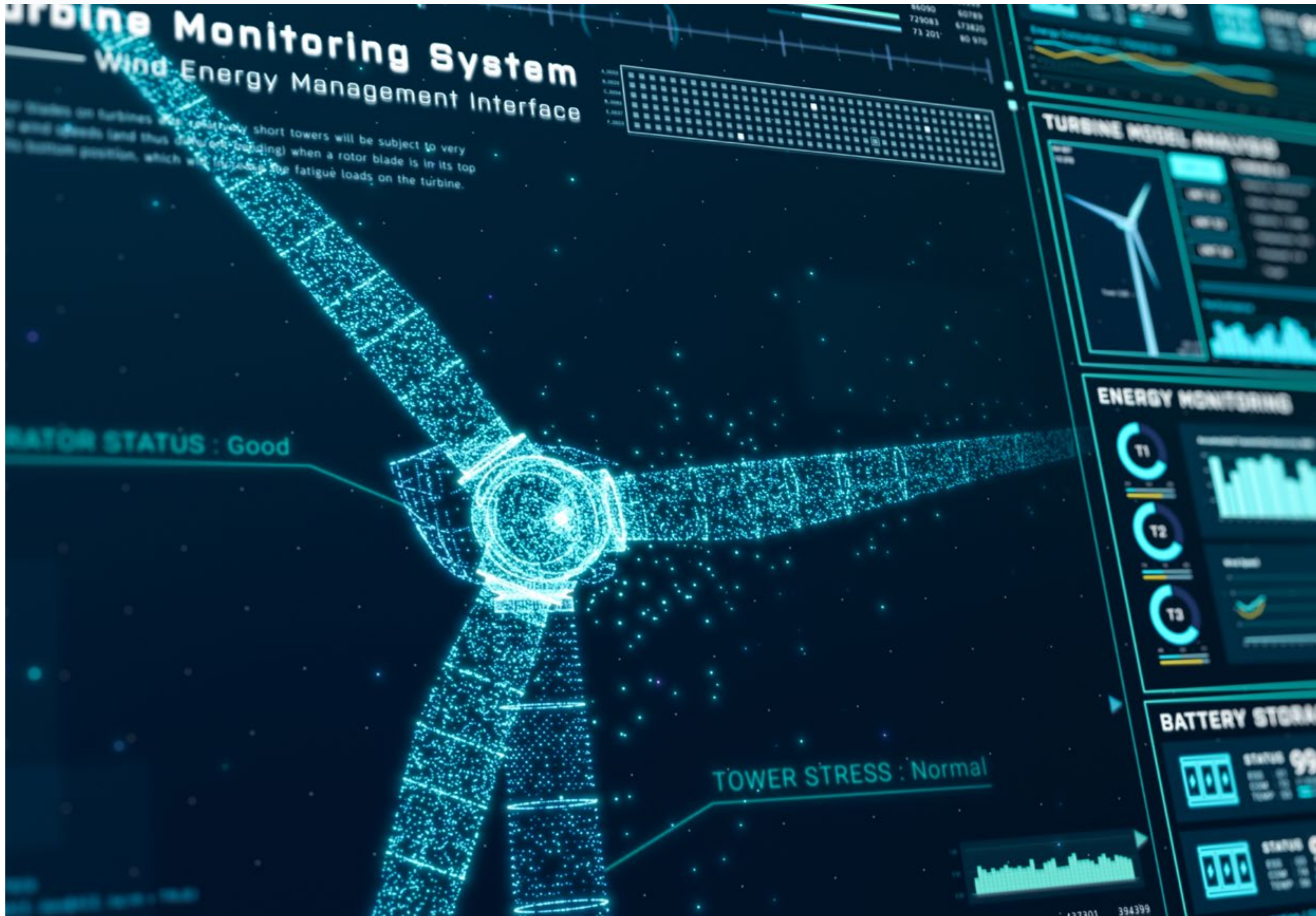
Second, **AI is fundamentally a governance issue, not just a technical one.** From land use and data standards to compute regulation and grid permitting, decision-making will need to become faster, more coherent and more integrated across ministries and sectors.

Third, **sustainable value creation depends on building local capability.** Talent, institutions, startups and civil society must all be embedded in this transition. Otherwise, countries risk becoming sites of digital extraction rather than centres of innovation.

Developing economies face growing pressure to respond quickly to AI infrastructure demand. Firms seeking data-centre capacity can move toward markets that offer low-cost power, fast approvals and available land, creating incentives for countries to compete on price and speed rather than sustainability or long-term value creation. This can favour short-term expansion over cleaner, better-planned energy pathways. Yet the same dynamics also create strategic openings. Renewable energy potential, favourable geography, biodiversity assets and vibrant digital and entrepreneurial ecosystems can position developing regions as providers of climate-aligned AI solutions and energy services, rather than only suppliers of land, minerals, power, or data.

The mapping of 88 Green AI startups across Brazil, Chile, India, Malaysia, Mexico, Nigeria and South Africa reveals growing activity in the Global South, but not yet the momentum needed for scale. The visible and invisible barriers documented in this report produce ecosystems where most firms struggle to progress beyond early-stage funding. The virtuous cycle that characterizes successful innovation ecosystems requires simultaneous progress across multiple dimensions at once, especially as the green window of opportunity for developing economies may narrow as technologies, markets and value chains become more established.

The five recommendations outlined in this report are designed to support this shift: from treating AI as a standalone digital agenda to governing it as part of a wider energy, industrial and development strategy. For developing countries, the task is to shape AI expansion so it builds domestic capabilities, improves public services, advances clean energy systems and creates pathways for local value capture. Aligned with clean power, public-interest needs and accountable institutions, AI infrastructure and applications can expand productive opportunities, enable more inclusive development and reduce the risks of dependency, resource pressure and unequal value capture. The green window of opportunity will therefore be shaped less by the technology itself than by the policies, institutions and coalitions that give it direction.



Bibliography

Africa50. 2025. Kigali Innovation City project.

Africa DataCentres. 2025. Website.

African Union. 2024. Continental Artificial Intelligence Strategy.

Agrawal, A., J. Gan and A. Goldfarb. 2018. Prediction Machines: The Simple Economics of Artificial Intelligence. Harvard Business Review Press.

ASEAN (Association of Southeast Asian Nations). 2024. ASEAN Guide on AI Governance and Ethics.

Auerswald, P. E., and L. M. Branscomb. 2003. "Valleys of Death and Darwinian Seas: Financing the Invention to Innovation Transition in the United States." The Journal of Technology Transfer 28: 227–239.

Bergen, M. 2023. "Venture Studios Are Redefining the Startup Landscape." Medium, 27 October.

Bick, A., A. Blandin, and D. J. Deming. 2024. "The Rapid Adoption of Generative AI." Working Paper 32966, National Bureau of Economic Research, Cambridge, MA.

Brynjolfsson, E., and A. McAfee. 2017. Machine, Platform, Crowd: Harnessing Our Digital Future. W. W. Norton & Company.

Bundl. 2024. "Venture Studio Success: Why These Startups Outperform the Rest."

Cambridge Associates. 2025. "US PE/VC Benchmark Commentary: Calendar Year 2024."

Center for Strategic and International Studies. 2025. From Divide to Delivery: How AI Can Serve the Global South.

Chang, H.-J. 2002. Kicking Away the Ladder: Development Strategy in Historical Perspective. London: Anthem Press.

Chile. n.d. Start-Up Chile.

Chile. 2023. National Lithium Strategy: For Chile and Its People.

Chile, Ministry of Science, Technology, Knowledge and Innovation. 2023. Declaración de Santiago sobre la Integridad en la Investigación.

Claasen, L. 2024. "South Africa's Data Centers Have Adapted Well to the Energy Crisis." Cape Business News.

Colmer, C. 2025. South Africa's AI Data Center Boom Risks Overloading a Fragile Grid. Techcentral.

Conte, C. 2025. "Understanding Saudi Arabia's Resistance to Environmental Policy Change."

Crawford, K. 2021. Atlas of AI: Power, Politics, and the Planetary Costs of Artificial Intelligence. Yale University Press.

CSIS (Center for Strategic & International Studies). 2025. "Indonesian Industrialization: Downstreaming Up the Value Chain."

Delechat, C. C., G. Melina, M. Newiak et al. 2024. "Economic Diversification in Developing Countries – Lessons from Country Experiences with Broad-Based and Industrial Policies." International Monetary Fund.

Dubai Future Foundation. 2025. "Sandbox Dubai Strikes First Global Partnership in Mou with AI Center Hamburg."

El Ghoul, S., Z. Gong, O. Guedhami et al. 2023. "Social Trust and Firm Innovation." Journal of International Financial Markets, Institutions and Money 84: 101745.

Euchner, J., and J. Euchner. 2022. "Timing." Research-Technology Management 65(4): 9–10.

European Commission. 2023. "Stockholm, Sweden: Heat Recovery from Data Centers."

Geels, F. W., F. Berkhout and D. P. Van Vuuren. 2016. "Bridging Analytical Approaches for Low-Carbon Transitions." Nature Climate Change 6(6): 576–583.

Green Times. 2025. "Green Data Centers: Morocco Paves the Way for Carbon-Neutral Digital Infrastructure."

Guberman, D., S. Schreiber and A. Perry. 2024. "Export Restrictions on Minerals and Metals: Indonesia's Export Ban of Nickel." Working Paper ICA-104. Office of Industry and Competitiveness Analysis.

Hallen, B. L., S. L. Cohen and C. B. Bingham. 2020. "Do Accelerators Work? If So, How?" Organization Science 31(2): 245-534.

Harvard Law Review. 2024. "Co-Governance and the Future of AI Regulation."

Hernandez, D., and T. B. Brown. 2020. "Measuring the Algorithmic Efficiency of Neural Networks." OpenAI.

Hofstede, G. 2001. Culture's Consequences: Comparing Values, Behaviors, Institutions and Organizations Across Nations. Second edition. Sage Publications.

Humlum, A., and E. Vestergaard. 2024. "The Adoption of ChatGPT." Becker Friedman Institute for Economics Working Paper 2024–50, University of Chicago, Chicago.

IEA. 2022. "How Governments Support Clean Energy Start-ups Insights from selected approaches around the world."

———. 2023a. Access to Electricity Stagnates, Leaving Globally 730 Million in the Dark.

———. 2023b. Data Centers and Data Transmission Networks.

———. 2024. Energy and AI Observatory: Energy for AI.

———. 2025a. Energy and AI: World Energy Outlook Special Report.

———. 2025b. Global Critical Minerals Outlook 2025. Paris.

———. 2025c. World Energy Investment 2025.

———. 2026. Key Questions on Energy and AI.

India, Department of Science and Technology. 2025. National Super Computing Mission.

India, Ministry of Electronics and Information Technology. 2025. India AI Governance Guidelines: Enabling Safe and Trusted AI Innovation.

IRENA (International Renewable Energy Agency). 2024. Renewable Energy and Jobs: Annual Review 2024.

Isabel, S., and S. Griffen. 2024. "The Good Neighbour Theory: How Data Centers Can Strike a Better Balance Between Technology, Community and Nature."

Jia, H. 2018. "China's Plan to Recruit Talented Researchers." Nature 553(7688): S8-S8.

Kalu, M. 2025. "Driving on Destruction: How EVs Are Exploiting Congo's Mines." UCL Bartlett Faculty of the Built Environment.

Kreiser, P. M., L. D. Marino, P. Dickson et al. 2010. "Cultural Influences on Entrepreneurial Orientation: The Impact of National Culture on Risk Taking and Proactiveness in SMEs." Entrepreneurship Theory and Practice 34(5): 959–984.

Kuzma, S., L. Saccoccia and M. Chertock. 2023. “25 Countries, Housing One-Quarter of the Population, Face Extremely High Water Stress.” World Resources Institute.

Lebdioui, A. 2022. “Nature-Inspired Innovation Policy: Biomimicry as a Pathway to Leverage Biodiversity for Economic Development.” Ecological Economics 202.

———. 2024. Survival of the Greenest: Economic Transformation in a Climate-Conscious World. Elements in Development Economics. Cambridge University Press.

Lebdioui, A., A. Melguizo and V. Muñoz. 2025. “Artificial Intelligence, Biodiversity & Energy: From a Resource-Intensive to a Symbiotic Tech.” Working paper 90. Oxford University, TIDE Centre.

Lee, K. 2013. Schumpeterian Analysis of Economic Catch-Up, Knowledge, Path-Creation and the Middle-Income Trap. Cambridge: Cambridge University Press.

Lee, K., and F. Malerba. 2017. “Catch-up Cycles and Changes in Industrial Leadership: Windows of Opportunity and Responses of Firms and Countries in the Evolution of Sectoral Systems.” Research Policy 46(2): 338–351.

Lee, V., P. Seshadri, C. O’Niell et al. 2025. Breaking Barriers to Data Center Growth. Boston Consulting Group.

Lema, R., X. Fu and R. Rabellotti. 2020. “Green Windows of Opportunity: Latecomer Development in the Age of Transformation Toward Sustainability.” Industrial and Corporate Change 29(5): 1193–1209.

Lemkin, J. 2024. “Navigating the Funding Gap: Insights from 10,755 US Startups.”

Liebregts, W. J., J.P.C. Rigtering and N. S. Bosma. 2024. “Uncertainty Avoidance and the Allocation of Entrepreneurial Activity across Entrepreneurship and Intrapreneurship.” Entrepreneurship Theory and Practice 49(3): 883–915.

Lilley, S., G. Oliver, J. Cranefield et al. 2024. “Māori Data Sovereignty: Contributions to Data Cultures in the Government Sector in New Zealand.” Information, Communication & Society 27(16): 2801–2816.

Ma, J. 2025. “Kenya’s Ixafrica Secures Financing for 20MW Expansion to Data Center.”

Malaysia Digital Economy Corporation. 2022. “Saya Digital.”

Meddeb, R. 2024a. “Building Smarter, Cleaner Storage with AI.” UNDP Sustainable Energy Hub.

———. 2024b. “Digital, Data and AI for the Future of Sustainable Energy.” UNDP Sustainable Energy Hub.

Meddeb, R., A. Lebdioui and P. Bilek. 2025. “Navigating the Currents of Green Hydrogen: Towards a Human Development-Centered Framework.” New York: UNDP

Melguizo, A., J. Jung and R. Katz. 2026. “Can AI Grow Green? Evidence of a Kuznets Curve Among AI, Renewable Energies and Emissions.” Energy Policy 208: 114883.

Melguizo, A., and H. Wald. 2026. “Towards Stronger Green AI Ecosystems in the Global South: Fund, Build and Govern.”

Mondesir, M., and N. Nkonge. 2025. “The Hidden Benefit of Data Centers: Warming Communities, Not Just Servers.” Equinix.

National Venture Capital Association. 2025. 2025 Yearbook: Showcasing 2024 VC Trends.

Noffsinger, J., M. Patel and P. Sachdeva. 2025. “The Cost of Compute: A $7 Trillion Race to Scale Data Centers.” McKinsey Quarterly.

OECD (Organisation for Economic Co-operation and Development). 2016. OECD Due Diligence Guidance for Responsible Supply Chains of Minerals for Conflict-Affected and High-Risk Areas. Third edition. Paris.

———. 2025. Innovation Procurement in Croatia: Boosting Innovation in the Public Sector. OECD Public Governance Reviews. Paris.

Östling, B. 2025. “Finland Attracts Data Centers with Cheap Electricity and a Cool Climate.” Nordic Labour Journal, 27 November.

Oxford Institute for Energy Studies. 2025. “AI and Its Implications for Energy Systems.”

Payton, B. 2025. “Inside the Race to Fire up Africa’s Power-Hungry Data Centers.” African Business, 23 December.

Perez, C. 2010. “Technological Revolutions and Techno-economic Paradigms.” Cambridge Journal of Economics 34(1): 185–202.

———. 2016. “Capitalism, Technology and a Green Global Golden Age: The Role of History in Helping to Shape the Future.” In M. Jacobs and M. Mazzucato, eds., Rethinking Capitalism: Economics and Policy for Sustainable and Inclusive Growth. London: Wiley Blackwell, vol. 1, pp. 191–217.

Preqin. 2024. 2025 Global Report: Venture Capital.

PwC. 2018. The Macroeconomic Impact of Artificial Intelligence.

Rwanda, Ministry of Public Service and Labour. 2012. Rwanda Public Sector Pay and Retention Policy and Implementation Strategy.

Rikap, C., C. Durand, E. Paraná et al. 2024. “Reclaiming Digital Sovereignty: A Roadmap to Build a Digital Stack for People and the Planet.”

Saxenian, A. 1994. Regional Advantage: Culture and Competition in Silicon Valley and Route 128. Harvard University Press.

Sevilla, J., et al. 2022. “Compute Trends Across Three Eras of Machine Learning.”

Shane, S. 1993. “Cultural Influences on National Rates of Innovation.” Journal of Business Venturing 8(1): 59–73.

Singapore, Infocomm Media Development Authority. 2024. “Green Data Center Standard.”

———. 2025. “Driving a Greener Digital Future: Singapore’s Green Data Center Roadmap.”

South Africa, Department of Forestry, Fisheries and the Environment. 2025. South Africa’s National Waste Management Strategy.

Steen, M., and G. H. Hansen. 2014. “Same Sea, Different Ponds: Cross-Sectorial Knowledge Spillovers in the North Sea.” European Planning Studies 22(10): 2030–2049.

Sustainability. n.d. “Denmark Data Center to Warm Local Community.”

Taras, V., B. L. Kirkman and P. Steel. 2010. “Examining the Impact of Culture’s Consequences: A Three-Decade, Multilevel, Meta-Analytic Review of Hofstede’s Cultural Value Dimensions.” Journal of Applied Psychology 95(3): 405–439.

Toledo, E. G. 2024. “English Dominates Scientific Research—Here’s How We Can Fix It, and Why It Matters." 27 March.

Tony Blair Institute for Global Change. 2024. “Powering AI in the Global South.”

Tran, B. 2025. Semiconductor Manufacturing Energy Consumption: How Green Is the Chip Industry? (Latest Stats). PatentPC.

UNCTAD (United Nations Conference on Trade and Development). 2023. Technology and Innovation Report

2023. Geneva.

———. 2024. “Chile Launches National Data Centers Plan.”

———. 2025. Technology and Innovation Report: Inclusive Artificial Intelligence for Development.

UNDP (United Nations Development Programme). 2024a. “Beyond Access: 1.18 Billion in Energy Poverty Despite Rising Electricity Access.”

———. 2024b. “Equitable AI for Africa: Unlocking New Engines of Growth and Creativity.”

UNEP (United Nations Environment Programme). 2025. “AI Has an Environmental Problem. Here’s What the World Can Do About That.”

UNESCO (United Nations Educational, Scientific and Cultural Organization). 2021. “Recommendation on the Ethics of Artificial Intelligence.”

United Nations. 2024. “SDG 7: Affordable and Clean Energy.”

United Nations Technology Executive Committee. 2025. Artificial Intelligence for Climate Action: Advancing Mitigation and Adaptation in Developing Countries.

United States of America, Department of Commerce, International Trade Administration. 2024a. Uruguay: Data Centers Market Intelligence.

———. 2024b. Egypt: Data Centers Market Intelligence.

United States of America, Department of Energy, Office of Electricity. 2024. Benefits of Demand Response in Electricity Markets and Recommendations for Achieving Them.

Van den Heuvel, M., and D. Popp. 2022. “The Role of Venture Capital and Governments in Clean Energy: Lessons from the First Cleantech Bubble.” NBER Working Paper 29919.

WHO (World Health Organization). 2023. “Electricity in Health-Care Facilities: Fact Sheet.”

World Bank. 2017. “The Growing Role of Minerals and Metals for a Low Carbon Future.” Washington, DC.

———. 2020. Doing Business 2020: Comparing Business Regulation in 190 Economies. Washington, DC.

———. 2025a. Digital Progress and Trends Report 2025: Strengthening AI Foundations. Washington, DC.

———. 2025b. “Pathways to Job Creation in Africa.” Africa’s Pulse, 32.

———. Forthcoming. Digital Skills for Africa Report. Washington, DC.

World Bank and OECD (Organisation for Economic Co-operation and Development). 2017. A Step Ahead: Competition Policy for Shared Prosperity and Inclusive Growth.

World Economic Forum. 2025. Artificial Intelligence’s Energy Paradox: Balancing Challenges and Opportunities.

———. 2024. “The Water Challenge for Semiconductor Manufacturing and Big Tech: What Needs to Be Done.”

———. 2025. “Data Centers Use Vast Amounts of Water—Here’s How We Advance Water Circularity.”

Yildiz, G. 2025. “UAE 2026: What Powers Microsoft’s $15 Billion Abu Dhabi Data Centers?” Forbes, 9 December.

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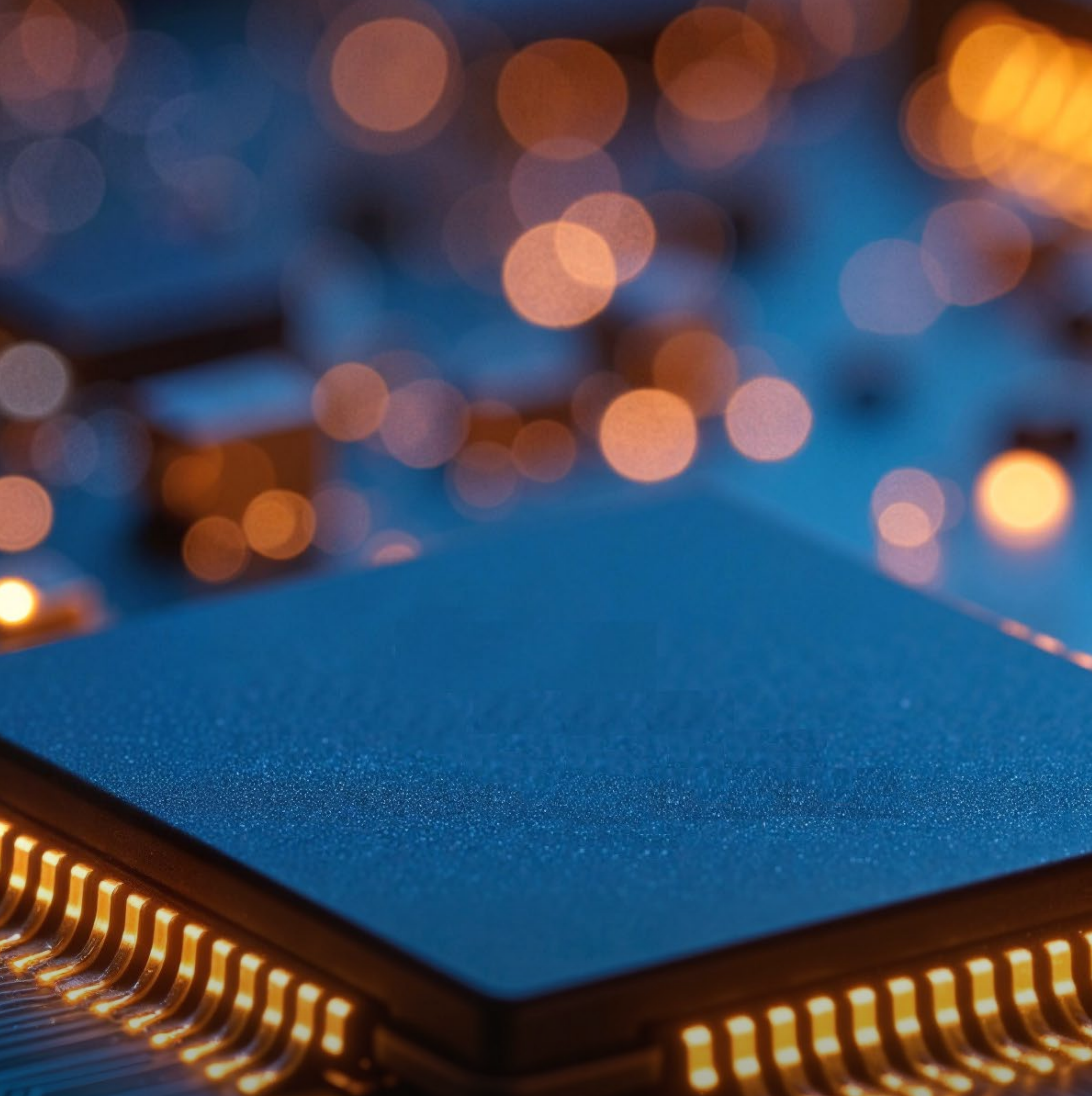

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