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Scaling Renewables in the AI Era: How Emerging Economies Can Accelerate the Energy Transition

TONY BLAIR INSTITUTE FOR GLOBAL CHANGE

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Executive Summary

This is the renewable-energy decade.

In recent years, renewable energy has gone from being the expensive and less attractive option for powering economies to being cheaper and more viable than fossil fuels in many countries around the world.[1,2]

This is transforming the global energy landscape.

Renewables are now the largest source of electricity generation in 57 countries.[3] Investment in clean-energy sources has risen by 60 per cent since 2015, with more than $1 billion per day spent on deploying solar power alone. Where spending on fossil fuels and renewables was roughly equal in 2018, five years later $2 was being spent on clean energy for every $1 invested in fossil fuels.[4]

The positive impacts of this change are significant. The global power sector saved an estimated 465 megatonnes of carbon-dioxide emissions (Mt CO_2e)[5] and $520 billion in fuel costs in 2022 alone by using renewables instead of fossil fuels.[6] At the same time, countries are decoupling from volatile fossil-fuel markets and developing modern grids and decentralised energy sources to power economic growth and development. Their rewards for this move are energy independence, economic stability and more.

Despite the opportunities renewables present for every country around the world, the pace of their uptake is not equal. Recent increases in clean-energy spending come mostly from advanced economies and China, together accounting for some 85 per cent of global clean-energy spending between 2019 and 2024.[7] Other emerging markets and developing countries[8] (EMDCs), home to two-thirds of the global population, account for just 15 per cent.[9]

The world's ability to tackle climate change and enable sustainable global growth will rest on its ability to change this dynamic. At the moment, additional electricity demand continues to outstrip additional renewable capacity, a trend driven largely by EMDCs.[10] Unless there is a significant change, this trend will intensify as development accelerates, hurting global climate ambitions and preventing many EMDCs from benefitting from the opportunities of renewables-led development.

Accelerating the deployment of renewables in EMDCs is a clear priority for governments. The technology is mature, affordable and ready to be deployed. The private and public capital to fund these opportunities can be found. The end consumers, who will enjoy more affordable and cleaner energy, already exist. Missing is the political and regulatory environment to bring these factors together. What is needed, therefore, is the political courage to use reform and the smart application of new technologies to drive through the challenges that stand in the way of scaling renewables in these economies.

While these barriers cannot be resolved by EMDC governments alone, there are several steps that must be taken by in-country political leaders to help accelerate change. These include driving a transformation in how the energy system is managed – transitioning from a short-term, transactional approach to a long-term, strategic one, and from opaque, one-off projects to transparent markets into which private capital can flow. Any transition on this scale will upset vested interests, and therefore will require smart policy and the targeted use of political capital to implement reform in a way that balances the politically viable with the technically and economically optimal.

Artificial intelligence and other digital technologies present an unparalleled opportunity to enable these energy-system changes. By harnessing the potential of technology, political leaders in EMDCs can ease or eliminate barriers along the value chain, aiding everything from strategy and planning to market creation and project pipelines that unlock investment.

This paper is part of *Governing in the Age of AI*, a broader Tony Blair Institute for Global Change series exploring how AI-era technologies can help governments deliver radical-yet-practical solutions for this new era of invention and innovation.

To drive this transformation in their own countries, governments can take action in five key areas to accelerate the uptake of renewables. These include:

1. **Strengthening governments' strategic decision-making** by utilising advanced and dynamic energy-systems planning.
2. **Ensuring rigorous and accelerated project-feasibility processes** by using readily available data sources such as satellite data.
3. **Digitalising project contracting and procurement** to drive down costs, increase investor confidence and increase competition.
4. **Improving the transmission and integration of renewables** through advanced metering and demand-flexing technologies.
5. **De-risking financial transactions** for investors and end users through financial enablers that reduce project risk profiles and promote uptake.

This is an important moment for the world. The leaders who embrace change and the opportunities of the current technological revolution will deliver better outcomes for their citizens and help accelerate the global fight against climate change.

Editor's note: TBI is grateful to Octopus Energy Group for their support towards the research presented in this report. The analysis and conclusions of this report are solely the responsibility of TBI, in line with its intellectual independence policy.

02

Boosting Renewables in EMDCs Is Crucial for Climate Action

The accelerated uptake of renewables in recent years has been extraordinary. Global solar-photovoltaics (PV) capacity surged to 1,412 gigawatts (GW) in 2023, up from as little as 5 GW in 2005.[11] Annual solar installations grew by more than 80 per cent in 2023 compared with 2022. Other renewables are also growing rapidly: the capacity of onshore and offshore wind rose from 7.5 GW in 1997 to almost 1,000 GW in 2023.[12]

Despite this rapid growth in renewables around the world, the current rollout is not moving fast enough to meet climate goals. Power-sector emissions continue to rise, with 2023 seeing a 1.1 per cent increase in emissions on the previous year.[13] As a result, by some estimates, the uptake of renewables will need to triple from current levels by 2030 for new additions to outpace the growing energy demand globally. This would mean that the world would draw 60 per cent of its electricity supply from renewable sources by 2030, almost halving global power-sector emissions.[14]

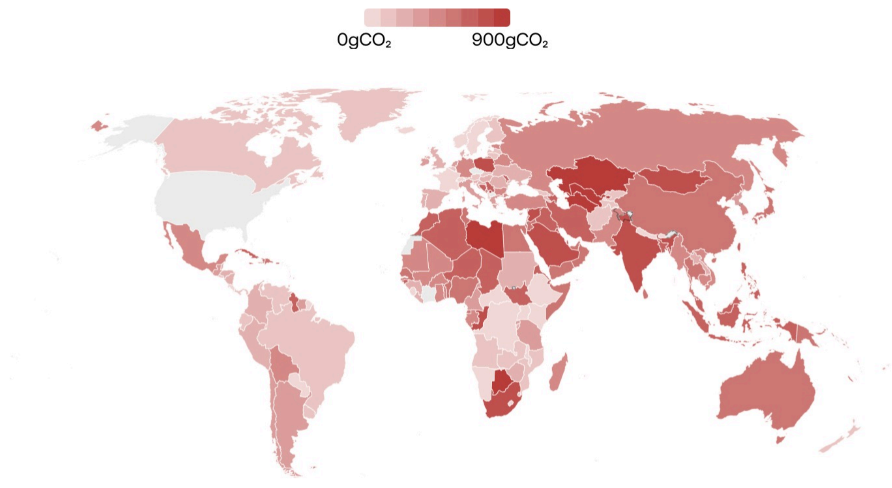
Developed countries continue to produce the majority of the world's emissions. The United States, Japan and Canada all rank among the world's ten highest-polluting countries, emitting almost 8,000 Mt CO_2e combined; the European Union, if treated as a single state, would be the world's fourth-biggest polluter.[15] However, power-sector emissions are rapidly reducing in these countries as they have been driving the rollout of renewable-energy solutions. Power-sector emissions in the Organisation for Economic Co-operation and Development (OECD) peaked in 2007 and have reduced by 28 per cent since then.[16] Not only is this helping mitigate climate change, but these countries are also benefitting from energy-independence and other gains, such as air-quality improvements, job creation and long-term cost savings.

This picture looks very different for EMDCs. Over the past decade, increased development has come with increased emissions. For example, emissions in EMDCs in Asia now contribute to around half of global emissions.[17] This trend could be exacerbated with further socioeconomic development. As Figure 1 shows, the carbon intensity of electricity generation is greatest in EMDCs.

Therefore, the key to combatting climate change now lies with accelerating the uptake of renewables in EMDCs, as TBI has argued in *Reframing the Debate: Reimagining the Path to Global Climate Action*.

FIGURE 1

In 2022, high-carbon-intensity electricity generation was concentrated in EMDCs in Asia and Africa



Source: Our World in Data, Ember, Energy Institute

This transformation has already begun, with some prominent countries leading the way. High emitters, such as India and China, are accelerating their uptake of renewables. In the first quarter of 2024, India added a record solar-power-capacity installation of 8.5 GW[18] and now has 63 GW in installed capacity, the fifth most in the world.[19] Moreover, China added 87 GW of solar in 2022 alone, equivalent to almost the entire solar capacity of Germany.[20] Brazil added 11.9 GW of new renewable capacity in 2023[21] and Vietnam increased its solar capacity from almost zero in 2017 to 18.5 GW in 2022.[22] This shows the potential of renewables-fuelled development.

However, this picture is not the same across all EMDCs, in particular due to different levels of development and political buy-in to the energy transition. Nor is the pace of change quick enough to match the pace of overall development.

While global investment in clean energy has increased by 60 per cent since 2015, most of this finance is flowing into developed economies. Of the $1 trillion in finance mobilised for climate in 2023, only 3 per cent, or $30 billion, went to least-developed countries and only 15 per cent went to EMDCs (excluding China).[23] This is mirrored when looking at investment data. Total international investment in renewables has tripled since 2015, but in EMDCs the growth rate has only narrowly exceeded GDP growth.

To illustrate, Africa, which has the world's greatest solar resources, only had slightly more than 56 GW of installed renewables in 2022.[24] Indeed, clean-energy investment in Africa equates to just 1.2 per cent of the continent's GDP.[25] Likewise, South-East Asia receives only 2 per cent of global clean-energy investment despite having 6 per cent of global GDP, containing 5 per cent of global energy demand and being home to 9 per cent of the world's population.[26]

To ensure future development is powered by clean sources, there is now an urgent need to close the widening gap between rapid economic growth and dwindling levels of investment in renewables in EMDCs. Currently, progress is happening at a far slower pace than what is needed. As argued in "Emerging Markets Need Projects That Attract Private Investors to Meet Climate Goals", climate-responsive projects funded by private investors have actually been decreasing by approximately 10 per cent per year since 2015.

This needs to change. To facilitate global development in a way that also delivers rapid emission reductions, installing renewables must be made easier and faster in every part of the world.

03

The Case for Renewables-Powered Development

Renewable energy can be an accelerant of economic growth and development for EMDCs. Some of the key benefits of renewables for these economies include:

- **Low-cost energy:** With the right infrastructure and market conditions, renewables such as solar and wind can be a lower-cost alternative for electricity generation compared to fossil fuels. The sharp drop in solar and wind costs has rapidly increased the share of renewables in EMDC power systems as the most affordable choice.
- **Accelerated energy-deployment times:** Utility-scale solar and wind projects can potentially be developed and deployed in half the time that it takes to build fossil-fuel infrastructure; coal or gas plants often take a decade or more to operationalise due to complex permitting, design and construction processes in most countries.
- **Wider energy access:** Decentralised renewable-energy solutions reduce the need for costly transmission and distribution networks. This approach is particularly effective in sparsely populated or island countries where extending the grid can be economically and logistically challenging.
- **Energy stability and independence:** Many EMDCs rely on fossil-fuel imports, making their economies vulnerable to price fluctuations and supply disruptions. For example, in 2022, a combination of post-pandemic gas demand and supply shortages related to Russia's invasion of Ukraine led to wholesale gas prices in Europe spiralling from $3.20 per million British thermal units (MBtu) in 2020 to $40.30 per MBtu in 2022.[27]
- **Economic resilience through green industrialisation:** Countries with abundant renewable resources can attract foreign investment, foster new industries, meet international demand for sustainable goods and promote long-term climate-mitigation efforts. For instance, policies such as the EU's Carbon Border Adjustment Mechanism place an incentive on companies to invest in green infrastructure to produce low-carbon

products, giving countries with renewable-powered industries a competitive advantage in the global markets of the future, which will be characterised by green industrialisation.

- **Socioeconomic improvements:** Deploying renewables can also lead to transformative socioeconomic impacts, including poverty reduction, gender equity and better health through reduced emissions. For example, a community-owned solar farm can generate local jobs and revenue for local public services.[28]

In the same way that populations in EMDCs leapfrogged landline infrastructure and moved straight to mobile phones, their governments are well-positioned to overcome the challenges faced by developed countries who are constrained by legacy infrastructure by harnessing the latest technologies to set out new paths to development.

04 The Context: Political and Financial Challenges Are Widespread

In EMDCs, an accelerated uptake of renewables is needed, and many of the conditions are there to make it happen. Solar panels, wind turbines and batteries are mass produced at record-low prices; mini-grids that supply electricity at a local level allow entire communities to be electrified without the need for updates to the main grid; and many EMDCs already have appropriate natural resources to harness renewable infrastructure.

However, political and financial challenges are holding back progress.

Delivering the changes needed to embed new technologies and transform grids is a significant political challenge. The energy transition is more complex than simply investing in renewables; it requires engaging dominant energy incumbents and those who have historically profited from fossil fuels. Addressing these challenges requires a large amount of political capital, and when set against a seemingly never-ending list of other priorities, such as education or health, it is easy to understand why leaders may sometimes deprioritise this issue. Many countries have complex domestic political landscapes or are characterised by instability that makes it difficult to achieve the structural changes required to de-risk foreign investment and attract private-sector capital into renewable-energy projects. While the specific problems will be nuanced and change based on countries' political landscapes, they include:

- **Pressure from incumbents** that leads to opaque contracts and regulatory frameworks that favour the status quo and prevent a transition to transparent energy-system planning.
- **Legacy contracts** that bind governments to fossil-fuel agreements, with the threat of legal challenge if those agreements are broken.

- **State-owned utilities** that are unable to charge cost-recovering tariffs, keeping prices too low to support even the most cost-effective renewable investments.
- **Unclear land rights or processes** for land acquisition that present near-insurmountable risks to private investors.
- **Lack of trust** in neighbouring countries and a lack of desire to create common regulatory standards, which together inhibit the opportunities of market integration via regional power pools.

This context also encompasses the significant financial hurdles that often inhibit the deployment of renewable-energy projects.

Renewables require high upfront capital investment, with lower operating and maintenance costs in comparison to fossil fuels. This means that access to affordable capital is essential for making projects viable. At the same time, energy costs from a project are defined for a 20-year period at the point of investment, making price changes difficult for utility firms to implement.

However, access to affordable capital is unavailable in many EMDCs, driven in part by a lack of "bankable" projects combined with a complex investment environment. Political instability and turbulent macroeconomic conditions significantly increase the cost of capital in many EMDCs, as do misaligned incentives and complicated regulatory frameworks stemming from local political nuances.

There are also wider structural financial risks that make capital markets and institutional investors wary of investing in renewable projects in EMDCs. These include:

- **Credit risk:** In many countries, the utility firm is the sole purchaser of power, and many are insolvent or highly subsidised. As a result, investors may demand government guarantees in the event of nonpayment. However, EMDC debt levels – as well as record levels of sovereign-debt defaults[29] – have resulted in a shortage of public finance available to fund and de-risk private capital, as we argued in *A New Debt Deal for Africa: Breaking the Vicious Cycle*.

- **Currency risk:** Utility firms generate revenue in their local currency, while most capital repayments or debt-servicing payments made to investors are typically in US dollars or euros. This currency mismatch represents a major risk for investors, for whom the utility represents their sole consumer. For example, many sub-Saharan African currencies have weakened against the US dollar, leading to inflationary pressure as import prices surge. This mismatch is usually bridged with government forex guarantees but, with many EMDCs facing balance-of-payments crises, they are becoming increasingly difficult to be sure of.
- **Delivery risk:** EMDC governments often need to lead on issues such as expropriating land, supporting clearances and ensuring timelines are kept, resulting in delivery and interface risks. These issues are further accentuated in markets where regulations are opaque and government institutions are weak.

Linked to these financial risks, and in part driven by them, is a further unaddressed challenge: insufficient investment in transmission grids has left outdated infrastructure unable to keep up with the rapid growth of renewables. This often results in higher energy costs for consumers, as they rely on expensive alternative forms of energy, and, in the long term, reduced economic productivity due to frequent power outages. Therefore, in areas where decentralised renewable-energy solutions are unfeasible, grid expansion is critical for overcoming financial challenges and supporting broader sustainable economic growth.

In many EMDCs, a significant amount of power generation is not creating revenue, either due to technical challenges in the network or because of power theft or corruption. Globally, more than 3,000 GW of renewable-energy projects are waiting in grid-connection queues.[30] In sub-Saharan Africa, power lines lose $5 billion worth of power per year due to theft and poor infrastructure, with line losses typically between 10 and 20 per cent of total electricity produced.[31] At present, the acceleration in renewable investment has not translated into the level of grid investment that would prevent the loss.

05 Recommendations to Address Barriers in Renewable-Energy Deployment

The current technological revolution brings new opportunities to help leaders reduce and overcome the barriers to deploying renewable energy faster and more effectively.

To understand how AI-era technologies can help overcome political and financial barriers, this paper now explores the different challenges across a standard renewable-energy project lifecycle and highlights some of the ways in which AI-era enablers can help overcome pressure from incumbents, ensure higher-quality and accelerated energy and project planning, and minimise financial risks related to revenue, currency and delivery.

Leaders can embed AI-era technologies within domestic energy plans and along the project lifecycle to drive success. These technologies can ultimately accelerate timelines from the planning stage to the investment stage to align more closely with political timelines. This can help to de-politicise decision-making and to provide the transparency and confidence the private sector needs to invest.

By embracing AI-era technologies such as machine learning and digital twins, governments also gain access to the data they need to convince utility firms and fossil-fuel incumbents to allow greater access to renewables. In many EMDC governments, fossil-fuel companies are better-resourced than cash-strapped ministries and so are better positioned to leverage their insights to advocate for a business-as-usual approach. These new technological tools enable more informed and transparent decision-making, driving an evidence-based approach to rolling out renewables.

Beyond facilitating better decision-making, these technologies provide governments with a vital toolkit for addressing structural challenges in renewables-led development. They can help build a pipeline of projects that provide investment returns to assure private and public investors.

Governments need to develop a full understanding of the role modern technologies can play across the value chain – from planning and feasibility to financing and system operation. The following table outlines five critical barriers to scaling up renewables, paired with ways AI-era technologies can help address them. Each row serves as the foundation for a subsequent chapter, as this paper explores in depth the ways that AI-enabled digital tools can help EMDCs scale renewables.

FIGURE 2

Five actions to accelerate the uptake of renewables

Barrier	How technology can help
Incumbents hinder government planning Governments often lack access to independent planning data, while entrenched fossil-fuel interests manipulate or withhold critical information to maintain market dominance.	**Strengthening governments' decision-making** AI, machine learning and geographic information systems (GIS), aided by data collection and analysis, could support governments in system planning and setting out energy strategies.
Low-quality site studies Expensive, time-consuming feasibility studies delay projects and lead to poor decision-making, often forcing projects to proceed without adequate planning.	**Ensuring a rigorous project-feasibility process** Satellite data, digital twins, digital impact assessments and digitalised land-rights documents enable project feasibility to be done rigorously, reducing negative externalities.
Opaque contracts and market manipulation Lack of transparency in procurement and contract negotiations enables incumbents to manipulate markets and limit competition, hindering renewable-energy developers.	**Digitalising project contracting and procurement** Online renewable-energy auctions, digital-tendering platforms and bid-management technologies could help level the playing field between incumbents and new entrants.
Poor transmission and integration networks Ageing grid infrastructure and underinvestment in transmission make it difficult to integrate variable energy sources and match them with consumer demand, leading to inefficiencies.	**Improving renewables transmission and integration** Platforms such as demand-flexibility and power-balancing technologies, AI-enabled smart metering, battery-energy-storage systems, and mini-grids could help integrate utilities and incentivise customers to change their consumption during periods of high demand.
High risk to investors and developers Weak institutions, opaque regulations and market volatility make financing renewables riskier, discouraging private-sector participation and increasing project costs.	**De-risking financial transactions for investors and end users** Smart contracts, mobile-money platforms, distributed-ledger technologies and revenue-management tools could help reduce the risk profiles of projects and make them affordable for those who previously have not had energy access.

However, realising these benefits requires more than just technological adaption – it demands robust regulations and market structures that ultimately need to be underpinned by strong governance and political leadership. At the same time, governments should put in place the right policies, institutional and market structures, and regulations to harness the full potential of renewables.

Strengthening Government Decision-Making

A lack of cross-government commitment to a net-zero transition, aided by pressure from incumbents, inhibits the rollout of renewables in many EMDCs. While leaders can have models of how to develop a renewables-based energy system, those plans will struggle to come to fruition without a whole-of-government commitment to net zero. Securing this commitment is difficult, as governments may already be bound to existing infrastructure projects. They may also be under pressure from utility firms who choose to maintain the status quo and resist the transition to more transparent energy-systems planning. It is difficult for governments in this position to objectively weigh the advantages of pursuing renewable energy.

Developments in machine learning and geographic information systems (GIS), combined with open-access software and data, provide accurate and accessible outputs that assist governments in setting strategies – not only to identify optimal sets of investments but also to determine the need for mechanisms such as tariffs and subsidy reforms. In EMDCs, in instances where open-source data are of sufficient quality and reliability, using such models can prevent incumbents from data-hoarding while simultaneously allowing leaders to swap out data and assumptions to fit their use cases.

For example, by using asset-level financial, operational and environmental data on fossil-fuel and renewable-energy infrastructure, energy ministers can decide between using power imports, gas imports, or harnessing global renewables such as hydropower or solar.

CASE STUDY

Modelling Energy Investment in the Philippines

TBI recently partnered with TransitionZero, a startup that combines cloud computing and advanced data science to produce open-access data sets that support low-income countries in mapping out accurate scenarios and forecasts. TransitionZero's ultimate aim is to create tools that EMDCs can use for free and, eventually, without the need for coding knowledge. Together, TBI and the startup modelled the most cost-effective set of energy investments in the Philippines and provided evidence-based recommendations that could inform government policymaking.

Two models were developed. The first determined the most cost-effective set of investments, based on inputs such as demand, grid topology, the capital costs of different energy-generation sources and the country's renewable-energy potential. The second simulated energy-system operations at a granular level, ensuring different generation technologies work together to deliver a stable and uninterrupted supply.

This analysis contributed to the strategic direction of the energy sector in the Philippines and aligns with President Bongbong Marcos's goal of industrial development driven by low energy costs. In addition, the project has helped drive engagement in three areas: establishing market rules to position gas as a supporting player in the energy system, refining the tender process for renewable-energy projects to increase competition and securing flexible capital for transmission connections to support new renewables.

Ensuring a Rigorous and Accelerated Project-Feasibility Process

Projects require extensive feasibility studies before they can break ground. However, typical studies are costly and usually require on-site surveys and wide data collection. In addition, in many countries, tender processes are either substantially delayed while essential data are collected or proceed without them – shifting risk to the private sector and ultimately increasing costs for consumers.

AI-era technologies, such as satellite data, digital twins, virtual cadastres or registers and digital impact assessments, can ensure a rigorous project-feasibility process. These accelerate the procedure by providing years of historical data instantaneously, helping build stronger cases for developers and giving investors confidence in the viability of projects.

It is worth noting that this is the stage – upon receiving adequate feasibility data to inform whether the required return can be made – when funding is typically provided. Financiers, including development-finance institutions (DFIs), must become comfortable relying on inputs from innovative technologies. For example, satellite-based data could replace solar-irradiation data that is specific to the project site.[32]

EMBEDDING SATELLITE IMAGERY AND MACHINE LEARNING

One key enabler of effective feasibility assessments is the combination of satellite imagery and machine learning, which can help link wind and solar data, grid data and data on land values, allowing the optimal renewable-energy project locations to be identified.

This software helps both governments and project developers assess the viability of potential project locations at a much faster rate than they could by conducting individual site visits. This accelerates the site-identification process and shortens the timeline for governments to move from strategy to investment using more accurate data. Such technologies can also be combined with ground-based sensors to estimate when maintenance is required and equipment may fail. One solar farm in Spain used GIS and AI to orientate their solar panels from the south to the west. While the modules produced less energy overall, they produced more in the evening – when energy was more valuable from a systems perspective – increasing project revenue.[33]

CASE STUDY

Expediting Procurement

Odyssey is a technology firm that offers procurement and project-tracking software, allowing companies to submit tenders for energy projects and governments to verify, evaluate and accept bids. Odyssey's software also helps governments monitor how grid connections are tracking predetermined targets so subsidy disbursements can be provided to developers who electrify the hardest-to-reach areas. The advantage of Odyssey's approach is that its technology can be integrated across the entire procurement phase, enabling governments to achieve their desired decarbonisation strategy without bringing in additional partners.

For example, Odyssey worked with a mini-grid developer in Nigeria to shortlist the 150 best sites from more than 1,200 proposed for an electrification project funded by an American development agency to deliver health centres. The aim of their collaboration was to ensure the mini-grid would have sufficient demand so the investment could help drive economic development in the area and secure sufficient revenue rather than continue to depend on subsidies.

CASE STUDY

Mapping Future Infrastructure

VIDA is a leading geospatial data platform that is used by the World Bank, the International Finance Corporation (IFC), the African Development Bank and other regional development banks in more than 70 countries. The platform provides data sets on climate and environmental risk as well as biodiversity. To date, VIDA has mapped 1.8 billion buildings and identified 1.5 million settlements around the world, helping international financial institutions and governments plan infrastructure more efficiently. Its data are granular enough to help plot street lighting, education and health facilities, and agricultural production. VIDA has worked with TBI at the political level to help further mini-grid investments and advance the regulatory framework for mini-grids.

For example, in Sierra Leone, TBI and VIDA are helping the government achieve its ambitious policy target of increasing electricity access from 25 per cent of its population in 2021 to 92 per cent by 2030.[34] Using satellite imagery and geospatial analysis, VIDA has set up a national electrification platform that enables the Ministry of Energy to access information on more than 21,000 settlements and plan the most appropriate energy infrastructure for each one. This is crucial information for government policy that ensures limited public funding is allocated as effectively as possible and channels and de-risks private-sector investment.

VIDA and TBI are also working with the Democratic Republic of Congo (DRC) government and the IFC to identify, using satellite imagery and ground-based surveys, a ranked list of potential mini-grid sites across the country.[35] This has helped the government analyse a number of potential connections, the distance to the national grid and contextual information on nearby conflict, agricultural activity and access to local trade centres. Based on this, 184 towns were shortlisted where electrification was identified as a priority. In a separate case, VIDA supported the DRC's national rural-electrification agency in identifying and prioritising large-scale sites for ministry-led development, overcoming the need for individual site studies and visits.

USING DIGITAL TWINS

Digital twins offer a significant step forward in modelling the impact of different environmental and logistical factors on possible project sites in a virtual environment. They are different to other types of modelling, such as simulation modelling, as they allow for the introduction of real-time data, meaning that they can be iterated and developed to provide a more active simulation. The input of actual data into digital twins, such as from internet-of-things devices, means that they can simulate real-world feedback for a specific location or process.

In Hubei province, China, a digital twin was created to help build an 80 megawatt (MW) solar plant.[36] It was needed because of the complexity of the project site, which encompassed a rugged landscape with steep slopes and several lakes. Each of the site's 14,080 panels required a different angle and spatial positioning, which would have otherwise resulted in a significant number of individual adjustments.[37] By building a digital twin, the site developer automated the placement and angle of each panel and was able to keep total shading on the site below 2 per cent, guaranteeing maximum sunlight exposure. The digital twin also prevented 40 instances of re-work, resulting in significant financial and time savings.

Digital twins could be deployed to help governments model the potential trade impacts of different global decarbonisation policies, fossil-fuel price shocks, carbon-tax costs and so on. One operator in Scotland is developing a digital twin of the United Kingdom's electricity network in order to model and test digital solutions that could manage increased demand.[38] The system would use AI to identify ways to optimise capacity and develop green-energy solutions within the network.

CASE STUDY

Modelling Energy Systems

Enline, a technology startup specialising in energy transmission, generation and storage modelling, has developed a cloud-based digital twin that leverages AI and deep-learning algorithms alongside sensorless technology for real-time and predictive monitoring. In combining these existing, publicly available data with its sensorless technology, the company is able to build digital twins of assets, power lines or entire synchronised energy systems.

Operating mainly in South America, Europe and Africa, Enline's technology allows transmission-system operators to simulate and optimise operations without making changes to physical assets. This eliminates the need for fieldwork, sensors or drones at a project site.

For example, Enline created a digital twin to carry out technical due diligence on a solar park in Brazil, assessing whether the existing transmission line could meet an intended power-generation expansion. Using static data, grid topologies, and generation and consumption data, the startup ran various climate scenarios on a digital twin of the site, identifying the scenarios under which the transmission line could not produce the generated power required.[39]

FORMALISING LAND MANAGEMENT

Understanding land-ownership structures in EMDCs is a key part of feasibility assessments that is often overlooked. Up to 70 per cent of land in emerging economies is unregistered,[40] impacting the ability of governments to transparently plan renewable-energy projects and preventing communities from adapting land use to promote food security.

Land management is an area in which satellite imagery and analytical modelling can provide significant value, enabling governments to assess a large number of viable potential project sites and ultimately decide where there would be the highest yield and lowest impact on local communities. This helps eliminate a significant source of financial risk, cost and time delays for private investors.

Numerous EMDC governments have attempted to digitise their land records, including in Bangladesh,[41] India,[42] Kenya[43] and Pakistan.[44] Digitising land records is an onerous but rewarding practice and can tackle various issues linked to the renewables-project lifecycle, such as complex paperwork, ownership disputes and fraudulent transactions. The practice can also benefit marginalised communities by improving their access to land-rights documents.

CASE STUDY

Digitising Cadastres

IGN FI, a geographic-information consultancy, recently completed a two-year project in Côte d'Ivoire to modernise and digitise the country's land-registry cadastres. In collaboration with the minister of land planning, IGN FI undertook a land-administration project to digitise archival maps and property-rights documents. This allows citizens to view virtual land-ownership records and log disputes without visiting municipal or government buildings. The cadastres are particularly valuable for siting mini-grids and other renewables infrastructure, as land must be nationalised and impacted communities compensated for these projects to be viable.

IGN FI has also produced a "solar cadastre", a geospatial database of rooftop types and angles to help the government better identify properties best suited for solar energy. Using remote sensing to analyse the configuration of rooftops eliminates the need for in-person site studies and streamlines government funding into green-energy initiatives.

Digitalising Project Contracting and Procurement

During project contracting and procurement, the absence of standardised processes and frameworks significantly lowers the chances of project success. This stage also gives well-resourced incumbents an advantage, allowing them to use monopolistic power to block, stall or derail attempts to attract renewables developers to the market.

Therefore, project contracting and procurement must be as transparent and open to new developers and investors as possible. Online renewable-energy auctions, digital tendering platforms and other bid-management technologies help level the playing field between energy incumbents and renewables developers.

STANDARDISING POWER PURCHASE AGREEMENTS USING ADVANCED PROCUREMENT TOOLS

In many EMDCs, common electricity contracts, such as power purchase agreements (PPAs), are negotiated behind closed doors. This could have broader socioeconomic consequences beyond inhibiting renewables adoption, including higher energy costs and risks to supply security. A transparent, advanced procurement tool coupled with best-practice standardised project documentation (project agreements, construction and operation contracts, permits and financing documents) will enhance competition, increase investment, lower project costs and shorten timelines.

ONLINE TENDERING AND BID-MANAGEMENT PLATFORMS

Some of the most significant barriers for renewable-energy projects in EMDCs are poor tendering processes that are highly susceptible to political influence.

Digital solutions such as e-procurement platforms offer an opportunity to improve the clarity and transparency of the tendering process. By streamlining bid management, these platforms help ensure a fair and consistent process. Since bid documents can be complex and must be managed transparently, software can assist with bidder registration, responding to information requests, and distributing or amending bid documents.

There are also instances when governments have taken the lead in developing innovative tendering solutions.

CASE STUDY

Fostering Independent Power Producers

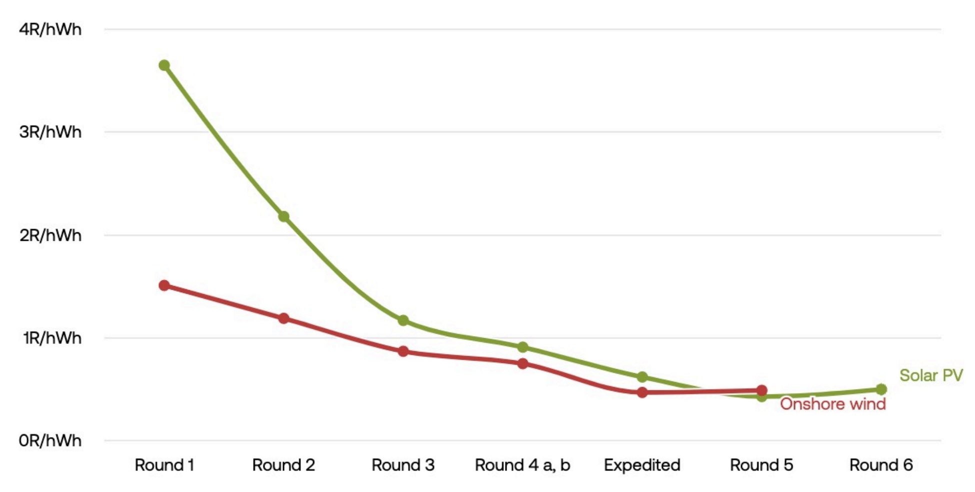
South Africa's renewable-energy auction programme has been hailed as a regional success. In 2011, the government launched the Renewable Energy Independent Power Producer Procurement Program (REI4P), a public-private technology-procurement platform designed to transparently procure low-cost energy while empowering independent power producers. This partnership involved leveraging private-sector investment and operation of renewable-energy projects under long-term power purchase agreements with South Africa's state-owned utility, Eskom. Since then, South Africa has been one of the first countries in Africa to procure renewable electricity through auctions. By 2023, it had awarded 123 projects to the private sector, with a total investment of more than $17 billion.

This preference for auctions, rather than feed-in tariffs, offered a more competitive price formation, lower support costs and more flexibility in selection criteria.[45] As financiers have grown increasingly confident, subsequent auctions have resulted in lower prices.

The REI4P initiative succeeded in fostering independent power producers, even though the state-owned, vertically integrated utility controls more than 90 per cent of energy-generation assets in South Africa.

FIGURE 3

REI4P has lowered the tariff of solar PV and onshore wind



Source: GreenCape

Note: In the sixth round, no onshore wind projects were awarded due to insufficient grid capacity in the regions where wind resources are strongest. R/hWh is equal to rand per half watt-hour (half watt-hours are used for breaking down energy consumption into smaller units and they can also help with pricing models).

Improving Renewables Transmission and Integration

The intermittent nature of renewable-energy sources such as wind and solar poses significant integration challenges for EMDCs, many of which struggle to balance energy supply with demand. Introducing AI-enabled electricity metering and demand-flexing technologies to help match demand with supply can help integrate renewables into the transmission grid. This in turn helps develop a sustainable energy sector that can more accurately balance supply with demand, thus improving a utility's finances and possibly spurring further investment.

To resolve these integration issues, solutions like combining solar with battery-energy-storage systems (BESS) and mini-grids play a crucial role. BESS can store excess renewable energy to use when generation is low, ensuring a consistent energy supply. Mini-grids, which operate independently or alongside central grids, enable localised energy distribution and enhance resilience by providing tailored, scalable power solutions for remote or underserved areas. The versatility of mini-grids also allows them to be adapted to local geographic conditions and be powered by a range of sources including solar, wind or, where necessary, diesel.

Demand-flexing technologies can help governments provide incentives and flex electricity load in line with availability. This also helps utilities and providers incentivise consumers to voluntarily shift their electricity consumption away from periods when there is high demand and therefore more pressure on the electricity grid. Similarly, AI-powered grid-optimisation systems can be used to analyse real-time data to ensure stability and reliability when integrating renewables into the grid.

As planning procedures become automated, AI and machine-learning platforms can provide political leaders with evidence-based information on energy-demand forecasts, renewables integration, grid improvements and more. By using large data sets, such as those related to weather patterns and consumption, governments can accurately balance supply with demand and more transparently track energy generation. With countries shifting away from centralised, fossil-fuel based energy sources towards renewables, there will be a greater need for demand-side flexibility to balance consumer demand with generation supply. In addition, as entire sectors begin to electrify and energy increasingly comes from a wider range of sources, electricity grids will need to embrace new technologies to match increased demand for energy. For example, AI and energy-consumption data could be used to manage system stability and optimise demand-side assets such as batteries, electric-vehicle (EV) chargers and other renewables infrastructure. For this to be most effective, governments should also promote the deployment of smart-metering technology and adapt market structures to incentivise flexibility through price signals that better reflect the true cost of energy at a specific time, in a specific place. This technology relies on smart metering and communications infrastructure, which should form the starting point for countries that have less liberalised power markets and lower smart-metering penetration.

In turn, the benefits of adopting demand-flexing technology are wide-ranging. Network operators can defer network-reinforcement costs, as existing generation can be better matched to reduce peaks in demand. Due to a more balanced, stable and efficient grid, consumers are incentivised to use energy at times when it is cheapest. Governments can meet their net-zero targets in a more cost-effective manner.

CASE STUDY

Using AI-Driven Flexibility to Integrate Renewables and Reduce Grid Constraints

The Kraken platform has an AI-enabled energy-flexibility system that connects, monitors and optimises distributed energy assets, helping to balance supply and demand in real time. By integrating batteries, EVs and flexible industrial loads, Kraken enables grids to absorb more renewable energy, reducing curtailment and reliance on fossil-fuel backup generation.

Kraken has been deployed across energy markets in multiple countries, helping grid operators, utilities and energy suppliers manage increasing volumes of renewables. In the UK, Kraken aggregates flexible assets into a virtual power plant that can respond dynamically to grid constraints. The platform is integrated into demand-response programmes, dynamically adjusting consumer and business energy use during peak periods. This happens with their explicit permission and according to the parameters they set – such as ensuring their EV is charged when they need to drive – helping to stabilise the grid while reducing costs.

The platform helps maximise grid-scale battery-storage value while supporting reliability and stability by intelligently charging and discharging batteries based on real-time market and grid conditions. This capability means Kraken can ensure stored renewable energy is used when demand is highest, reducing network strain.

Kraken can also shift EV-charging times to periods of high renewable generation or low demand. This reduces peak demand pressure and helps grids operate more efficiently, lowering the cost of integrating renewables.

By automating demand-side flexibility, Kraken demonstrates how AI-driven platforms can help emerging markets scale renewables faster, reducing grid constraints and improving energy security while minimising the need for costly infrastructure upgrades.

De-risking Financial Transactions for Investors and End Users

For the deployment of renewables to succeed, they need appropriate financing. Novel financial enablers, such as smart contracts, mobile-money infrastructure, distributed-ledger technologies and revenue-management tools, now reduce project risk profiles while making energy access more affordable for first-time users.

INNOVATIVE CAPITAL-ALLOCATION SOLUTIONS

A number of AI-powered analytics platforms now exist to help provide capital to the most climate-vulnerable populations by lending to local power distributors who provide energy access to last-mile customers. These platforms may combine investment management, using blended finance, and analytical services to help banks, investors and microfinance institutions develop sustainable, climate-focused financial products.

For example, Nithio is a data-driven finance platform dedicated to expanding clean-energy access and building climate resilience across Africa. It does this by combining capital provision (for example, debt financing to off-grid energy companies) with advanced analytics (such as data-driven credit scoring) to help solar distributors, mini-grid operators and other energy generators scale sustainably.

SMART CONTRACTS

Smart contracts are self-executing agreements with terms and conditions embedded directly in the code. They can automatically settle funds once pre-agreed conditions are met, and their immutable nature means that all stakeholders have access to the same data, enhancing trust and accountability. They also require fewer intermediaries, which lowers transaction costs and streamlines the contracting process.

For example, a smart contract could be set up to purchase international renewable-energy certificates, allowing companies to credibly track and report renewable-energy use across EMDCs. If this energy is not delivered, the smart contract will not execute and therefore the payment will not be released. Once deployed, smart contracts cannot be altered, censored or shut down. As such, they provide investors with an added layer of assurance by addressing counterparty risk. To make sure payments are honoured on time, smart contracts could be paired with standard governance arrangements, such as collection accounts, to ensure sufficient funds are available in the paying account.

Companies such as Attributes, a startup spun out from French utility firm Engie, use smart contracts to generate tamper-proof origin certificates, allowing utilities firms to track a specific renewable-energy asset from generation to consumption.

DISTRIBUTED-LEDGER TECHNOLOGY

Distributed-ledger technology (DLT) can help establish tamper-proof smart contracts. DLT is a digital system used to securely record transactions across multiple locations without requiring a central authority. In the energy sector, it can improve grid stability, enable peer-to-peer energy trading and support the integration of renewable-energy sources. This allows stakeholders to track funds with pinpoint accuracy, making sure they are being directed to legitimate renewables initiatives. By leveraging DLT's features, investors gain insight into the deployment of funds, which streamlines auditing and enhances their confidence. DLT could also be used for renewable-energy certificates, for environmental, social and governance compliance purposes and in carbon taxes such as the Carbon Border Adjustment Mechanism to demonstrate who has purchased the rights to the renewable-energy credit.

For example, the cryptocurrency SolarCoin was established as a global rewards programme for solar-electricity generation. For every megawatt hour of solar electricity produced by a generator, they receive a SolarCoin in a digital wallet. DLT then helps verify the authenticity and origin of the energy generated.

REVENUE-COLLECTION TOOLS

Revenue-collection tools can help automate the collection of data on market pricing and provide actionable insights into daily energy operations, enabling timely, strategic decisions.

Companies such as Odyssey offer planning and finance platforms that can guide project developers through the financing process. They offer end-to-end planning, from data collection using on-site surveys to employing a financial model that provides clear metrics about project payback time, operating margins and more. This helps governments streamline procurement processes. In results-based financing projects, it also centralises programme advancement, increasing transparency and improving subsidy-programme management.

Revenue-collection tools also include services such as mobile-money payments, which are often a household's first foray into the financial-services sector – for example, through monthly payments to offset the cost of a solar home system. Such data can be used in establishing a credit history and that, in turn, facilitates access to further finance. Therefore, governments also need to establish policies on accessing and governing these data, as currently the data are owned by the solar provider and are priced accordingly.

CASE STUDY

Leveraging Revenue-Collection Tools to Improve Grid Flexibility and Monetise Excess Energy

MARA Holdings provides digital-asset-compute technology that utilises blockchain ledgers to support renewable-energy projects. Spanning 11 digital-asset sites, three continents and a data-centre portfolio of 1,100 MW, the company works to improve grid flexibility and absorb excess energy from new renewables projects by providing steady baseload demand for intermittent renewables, which in turn smooths out revenue streams and makes renewables projects more bankable.

In one example, MARA Holdings helped launch a joint venture to monetise excess hydropower in Paraguay. The country derives 99.7 per cent of its electricity from two hydroelectric dams and has one of the lowest electricity-consumption rates in South America. Prior to MARA Holdings' intervention, the government of Paraguay exported 60 per cent of its electricity to Brazil and Argentina, each of which has a 50 per cent stake in one of the two hydroelectric plants. This was inequitable for Paraguay, as Brazil and Argentina received a larger share of the energy generated. By launching a joint venture, MARA Holdings and the joint venture partner were able to monetise excess hydroelectric energy via digital compute infrastructure, allowing the government to instead charge a per-megawatt-hour fee for each unit of energy used.

06

Conclusion

The net-zero transition offers the opportunity to pursue economic growth in a more equitable and sustainable manner. With significant cost reductions now making renewables cost-competitive with fossil fuels – and prices continuing to fall – countries have a once-in-a-decade chance to pursue long-term, sustainable socioeconomic growth.

With their accelerating energy demands, growing populations and expanding economies, EMDCs will be key drivers in the global energy landscape; AI-era technologies can help them make up for lost ground. Many of these countries also have abundant renewable-energy resources and the opportunity to leapfrog directly to renewable technologies that are now technically and commercially mature.

Governments must actively leverage technology to de-risk investments in renewable energy and accelerate its uptake. Those that embrace AI-driven renewables strategies today – combined with strong, transparent market design – will be best positioned to manage transition costs and position themselves at the forefront of global decarbonisation efforts. By doing so, they can capitalise on the economic growth, energy security and climate resilience that renewables bring.

Spotlight on TBI's global work in the energy sector

TBI supports more than 20 governments worldwide in advancing their energy sectors. By providing in-country advisory support alongside central expertise, we help them develop strategies to identify optimal investments and sector reforms, design politically viable yet technically and economically sound policies, and – through harnessing the authority of political leaders – drive the often complex and contested delivery of reforms and investments. Our work spans across the power sector, from facilitating power trading and large hydropower projects in Africa to enabling market reforms in Asia that prevent fossil fuels from crowding out lower-cost renewables.

Endnotes

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