Electricity flexibility and smart system technologies in Africa and Asia's energy transition

Energy Insight

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Energy markets are in a state of flux as the use of electricity and other forms of energy is weakened by lockdowns and other COVID-19-related restrictions. Yet the long-term outlook remains one of global growth in energy and electricity demand, especially in developing countries. Meeting growing demand and limiting global temperature rises to well below 2°C, as envisaged under the Paris agreement, will require a major transition of the energy system towards renewable and other technologies consistent with net zero global carbon emissions. This will also necessitate significant investment in technologies to balance the intermittency of electricity generation both on the supply and demand side. Fossil fuel generation, pumped hydro and nuclear have traditionally provided balancing services, together with power trade, where interconnectors exist. Emerging technologies are providing new opportunities to meet the increasing need for flexibility.

Context

Electricity consumption is set to grow rapidly over the long term, with total demand in developing economies (excluding China) likely to be twice as high in 2040 than today.[1] This is driven by a rising population, urbanisation, industrialisation, and increased household wealth that affords possibilities for greater energy use. Future demand will also be shaped by progress towards the United Nation's Sustainable Development Goal 7 of universal access to electricity. Around 770 million people remained without access to electricity in 2019 globally, of which nearly 580 million were based in Africa alone.[2] In addition, existing electricity supplies in developing countries are frequently unreliable.

Most of the power generation technology to meet expected future demand in Africa and Asia has yet to be installed. It will consist of a combination of grid and off-grid connections. The International Energy Agency (IEA)[3] estimates that decentralised systems may be the least-cost solution for more than two-thirds of the additional household connections required to achieve universal access to electricity in Africa. Mini-grids will play a major role in urban areas that cannot be reached by the main grid before 2030. In rural areas, both mini-grids and standalone systems have a role to play, together accounting for three-quarters of Africa's new rural connections. Decentralised solutions play a key role in a low-carbon pathway for electrification as they are typically anchored around solar photovoltaic (PV).

Achieving global net zero carbon emissions will require significant change in the energy system. Across Africa, the share of fossil fuels will need to fall from the 80% today to 20% by 2040.[4] In developing countries more broadly, solar PV and wind may account for more than 40% of all electricity generation by 2040, with further growth thereafter (see Figure 1). This will be enabled by technological advances and rapid cost declines – wind and solar costs fell by 30% and 85%, respectively, between 2010 and 2018.[5] The cost of wind generation may fall further, by up to 35% by 2050, and the cost of solar may fall by as much as 70% by the same year.[6] In addition, a range of national and multilateral initiatives are seeking to incentivise and de-risk renewable investments. Combined with good underlying resource potential, some of Asia and Africa's emerging economies now rank amongst the most attractive in the world for renewable investments.[7]

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[1] IEA (2019a) 'World Energy Outlook 2019', IEA, www.iea.org/reports/world-energy-outlook-2019

[2] IEA (2020a) 'SDG 7: Data and Projections. Access to affordable, reliable, sustainable and modern energy for all', IEA, https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity

[3] IEA (2019b) 'Africa Energy Outlook 2019, World Energy Outlook Special Report', IEA, www.iea.org/reports/africa-energy-outlook-2019

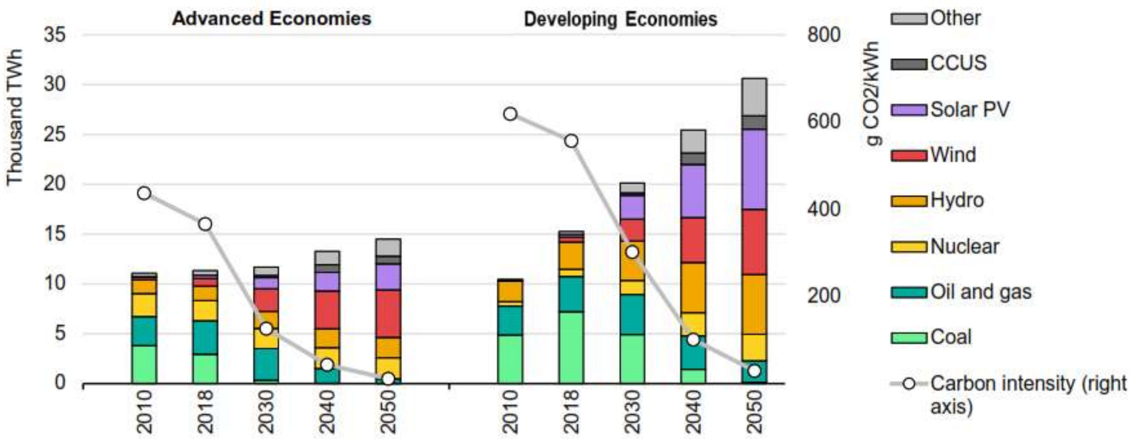
[4] *Ibid*.

[5] TERI (2020) 'Make Hydrogen in India: Driving India towards the clean energy technology frontier', TERI, www.teriin.org/sites/default/files/2020-06/Hydrogen-Policy-Brief.pdf

[6] BP (2020) 'Energy Outlook 2020', www.bp.com/energyoutlook, BP.

[7] Climatescope (2019) *Climatescope*, https://global-climatescope.org/results. *Note*: Climatescope is Bloomberg New Energy Finance's annual survey of investment opportunities in renewables in emerging markets.

Figure 1: Electricity generation by source and carbon intensity of electricity in IEA Sustainable Development Scenario consistent with below 2°C global warming



Source: IEA World Energy Outlook 2019. CCUS = carbon capture utilisation and storage. Other includes geothermal power, ocean energy, and hydrogen.

Traditional supply-side sources for balancing variable renewable energy

As renewables grow, their integration into the overall power system will become an increasing challenge. This is because of the intermittency of renewables, and because their output may not coincide with peak consumption times of the day or year. For example, solar PV plants only generate electricity when the sun shines, and hence will not meet peak evening demand. Flexible generating technologies that can be ramped up and down quickly have traditionally provided supply-side balancing services. This includes gas turbines, steam turbines, combined-cycle power plants, gas engines, reservoir hydropower plants, nuclear and, at a small-scale, diesel back-up generators. Dispatch can be managed across the grid or through direct bundling with renewables.

Natural gas offers significant climate benefits relative to other fossil fuels: gas-fired power generation has 50% lower CO_2 emissions than coal and 20% fewer emissions than oil.[8] Emissions savings relative to burning of traditional biomass are even larger.[9] On average, natural gas emits far fewer particulate air pollutants than coal, oil, or biomass.[10] Displacing back-up diesel generators within industry, commerce, and homes also offers economic benefits as they often have two to three times higher costs than grid power.[11] Flexible solutions exist on the generation side in the form of modular plants to scale up gas-fired power over time, when electricity needs are not yet fully known. Domestic resources of natural gas and existing import facilities in a number of African and Asian countries will permit growth of gas for baseload and flexible electricity generation. In addition, the increasing availability of floating storage and regasification units[12] (FSRUs) enables access to liquefied natural gas (LNG) for nascent gas markets at potentially lower cost than permanent regasification plants. They also enable access to

[8] IEA (2019b) 'The Role of Gas in Today's Energy Transitions, World Energy Outlook Special Report', IEA, www.iea.org/reports/the-role-of-gas-in-todays-energy-transitions
[9] PFPI (2011) 'Carbon Emissions from Burning Biomass for Energy', PFPI, www.pfpi.net/wp-content/uploads/2011/04/PFPI-biomass-carbon-accounting-overview_April.pdf
[10] IEA (2016) 'Energy and Air Pollution, World Energy Outlook Special Report', IEA, www.iea.org/reports/energy-and-air-pollution
[11] AGDI (2016) 'Filling the Power Supply Gap in Africa: Is Natural Gas the Answer?', AGDI, www.econstor.eu/handle/10419/149973
[12] Natural gas is transported by ship in liquified form at -162°C. Regasification is a process of converting LNG back to natural gas at atmospheric temperature, a necessary process before the gas can be used.

international gas in coastal countries when pipeline imports are either not possible or too expensive.

While there is a case for natural gas, it is a fossil fuel that generates CO_2 emissions. Carbon Capture, Utilisation and Storage (CCUS) may offer the possibility for making 'gas to power' climate-proof as the technology matures and costs decline. The majority of net zero emissions scenario models project an important role for CCUS in achieving a least-cost energy transition. So far, however, CCUS has not been cost-competitive for mainstream use. Absent major transformation of the underlying cost and remuneration structure, it is also inconceivable that gas CCUS power plants would be built purely for balancing generation or as reserve capacity – especially in emerging markets.

Hydroelectricity will play an important role in balancing and baseload generation, particularly in Africa.[13] However, recent droughts have exposed the vulnerability of such systems. This vulnerability may increase as planned hydro plants are bunched into single basins. More than 80% of east Africa's planned new large hydro capacity to 2030 is to be built on the Nile, while almost 90% of southern Africa's large hydro plants are to be sited along the Zambezi river.[14] Yet the Intergovernmental Panel on Climate Change noted that, out of Africa's 11 basins, the Zambezi is the most likely to be negatively affected by climate change.[15]

Nuclear will be an integral part of Asia's clean energy transition, with China alone accounting for c. 40% of global nuclear generation growth to 2050 under energy transition scenarios.[16] India is seeking to triple its nuclear generation capacity over the coming decade. Growth will also be strong in other parts of Asia and, to a lesser extent, in Africa. Most of this will rely on existing nuclear reactor designs that offer some flexibility in ramping production up or down to meet demand. Small modular reactors (SMRs) are currently at the prototype development stage, including floating units, of which the first was installed in Russia in 2019.[17] The potential of SMRs for shorter lead times and lower investment requirements means that they are likely to become part of the long-term transition to support the rising share of variable renewables.[18]

New and emerging technology options

Technological progress means that options abound to provide flexible energy system solutions. The following sections provide a snapshot of investment-ready opportunities in Africa and Asia.

Storage is undoubtedly the most frequently cited technology solution for balancing intermittency. Where conditions are favourable, solar thermal plants can provide effective storage solutions and be cost-competitive, especially if also linked to hot water generation.[19] Other electricity storage options include, but are not limited to, compressed air and liquid air, sodium sulphur, and flow batteries. Lithium-ion is emerging as the main commercial solution for short-term storage, with costs expected to fall by between 50%[20] and 70%[21] from current levels. The average battery energy density is also rising by 4–5% per year and new chemistries are entering the market.[22] Stationary

13 See, for example, IEA (2020b) 'Secure, Sustainable and Affordable Power Systems in Emerging Economies', IEA, www.iea.org/reports/secure-sustainable-and-affordable-power-systems-in-emerging-economies
14 Climatescope (2019).
15 *Ibid.*
16 BP (2020).
17 World Nuclear News (2019) 'Russia connects floating plant to grid', World Nuclear News, www.world-nuclear-news.org/Articles/Russia-connects-floating-plant-to-grid.
18 IEA (2020c) 'Energy Technology Perspectives 2020', IEA, www.iea.org/reports/energy-technology-perspectives-2020
19 *Ibid.*
20 Bloomberg New Energy Finance (2019) 'New Energy Outlook 2019', Bloomberg New Energy Finance, https://about.bnef.com/new-energy-outlook/
21 Energyworld.com (2019) 'Solar power cost will fall to Rs 1.9 per unit in India by 2030: TERI study', *Energyworld.com*, https://energy.economictimes.indiatimes.com/news/renewable/solar-power-cost-will-fall-to-rs-1-9-per-unit-in-india-by-2030-teri-study/67972162
22 Bloomberg New Energy Finance (2020) 'Electric Vehicle Outlook 2020', Bloomberg New Energy Finance, https://about.bnef.com/electric-vehicle-outlook/

batteries are already being deployed effectively for behind-the-meter standalone solar PV, mini-grid systems, utility-scale battery storage plants, and overall grid storage. As electric vehicle penetration increases (in particular with battery swap solutions), such vehicles can also become part of grid balancing. Yet questions remain over battery performance within hot and humid conditions, decommissioning needs to be considered, and requirements for skills, maintenance, and spare parts have to be evaluated. In addition, the value chain of cobalt and other battery components needs to be assessed for both its environmental and social impact in producing countries.

Hydrogen is one of the few options beyond hydroelectricity for balancing power systems over days, weeks, or even seasons (see Figure 2). Hydrogen can act as a form of electricity storage either directly, or via ammonia, methane, or other synthetic fuels. Yet hydrogen remains expensive and significant research and development will continue to be required to reduce costs. However, hydrogen offers additional promises that may incentivise production.

Once created, hydrogen can be used in applications such as heating, cooking, and transport. Most importantly, hydrogen can decarbonise otherwise hard-to-abate industrial sectors, such as steel, refining, fertiliser production, and methanol. Moreover, 'green hydrogen' from electrolysis of water and renewable electricity allows countries to export their renewable energy, in the form of hydrogen-derived fuels, to other geographies that lack similar resource. Countries such as Germany and Japan are recognising the case for hydrogen imports, while Australia (for example) is seeking exports.[23] Some African countries may find opportunities for exports as well, given their high solar and wind potential. In addition, there is the possibility to create hydrogen via natural gas combined with CCUS ('blue hydrogen'). Saudi Arabia sent the world's first shipment of blue hydrogen, in the form of ammonia, to Japan in late September 2020.[24] Opportunities for blue hydrogen production are also anticipated in other countries in the Middle East and North Africa region, and in Russia and the United States, where there is low natural gas cost and CO_2 storage potential.[25]

Figure 2: Selected technologies to help balance power systems at different durations

Source: BP Energy Outlook 2020

[23] *Ibid*.
[24] Bloomberg (2020) 'Saudi Arabia Sends Blue Ammonia to Japan in World-First Shipment', *Bloomberg*, www.bloomberg.com/news/articles/2020-09-27/saudi-arabia-sends-blue-ammonia-to-japan-in-world-first-shipment.
[25] IEA (2020c).

High-voltage AC or DC interconnectors are another supply-side solution. They allow the dispatch of least-cost electricity generation units within interconnected areas, which can help to balance the system over larger geographies. Yet interconnections require the construction of physical infrastructure across jurisdictions, and hence are contingent on permitting, technical feasibility, high levels of regulatory convergence between actors, clear legal frameworks for dispute resolution, as well as well-functioning internal markets. These requirements are often the source of delays in securing financing and in constructing interconnectors and power pools in Africa and elsewhere.

Options for balancing intermittency are not limited to large-scale assets. In particular, digital and ‘smart’ technologies offer a myriad of solutions. Digital energy investment is growing at 20% per annum and already in 2016 was 40% larger than global gas-fired power generation investments.[26] Digital innovation can have a major impact on optimising the utilisation and performance of assets, including high- and low-voltage networks, substations, electric vehicle charge points, buildings with embedded solar or storage, and front-of-the-meter storage.

Smart grids can help optimise the operational efficiency and utilisation of transmission and grid infrastructure. Investment currently remains focused on hardware, including digital substations, power engineering equipment, and smart metering.[27] Smart metering options can be integrated with connected devices (‘internet of things’ (IoT)) within buildings or transport to smooth consumption to match power generation profiles better, and thereby to help overcome intermittency issues. Globally, IoT-related hardware and software investment may grow from US$ 742 billion in 2020 to US$ 1.1 trillion in 2024.[28] Opportunities for demand-side response are set to increase further with the growing use of electric vehicles, heat pumps for water, and space heating.[29]

Data and data management are becoming increasingly important for integrating renewables within power systems. This will require digitising power networks, which will allow dispatch to be automated, rather than relying on manual operations, as remains the case in many African countries. Real-time data analytics makes it possible to manage distributed energy resources within seconds to balance the system. Beyond smart grid hardware investments, this implies software and local data gathering needs. Utilities are increasingly employing sophisticated software tools and artificial intelligence for data processing, predictive analytics, and machine learning.[30]

At the grid edge, computing technologies optimise energy use and cost, while ensuring energy availability and power quality. Edge computing processes data at the source of data collection, using the in-device computing capability of smart objects, mobile phones, or network gateways. This removes dependency on transmitting data over a network (which may not be reliable) – making it possible, for example, to forecast energy demand in near real-time to drive automated decisions at electricity substations to ensure grid stability and safety. Edge computing can also optimise energy use within industry and buildings. This offers a potentially cost-effective, safe, and energy-efficient solution that can mitigate/optimise the need for investment in traditional electricity infrastructure. It will require secure connectivity service providers and architecture to integrate devices, as well as clear data regulation. The market for grid edge computing could be worth US$ 6.5 billion by 2027.[31] While the application within Africa’s energy sector has yet to emerge fully, a scalable solution is being developed in Uganda. More broadly, a number of businesses are positioning themselves to develop and apply edge computing solutions.

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[26] IEA (2017) ‘Digitalisation and Energy’, IEA, www.iea.org/digital/
[27] IEA (2020d) ‘Smart Grids’, IEA, www.iea.org/reports/smart-grids
[28] IDC (2020) ‘Worldwide Spending on the Internet of Things Will Slow in 2020 Then Return to Double-Digit Growth, According to a New IDC Spending Guide’, IDC, www.idc.com/getdoc.jsp?containerId= prUS46609320
[29] IEA (2020c).
[30] IEA (2020d).
[31] Navigant (2018) ‘Global Market for Grid Edge Computing and Distributed Intelligence is Expected to Reach $6.5 Billion by 2027’, https://guidehouseinsights.com/news-and-views/global-market-for-grid-edge-computing-and-distributed-intelligence-is-expected-to-reach-65-billion-b

Concluding remarks

All of the solutions summarised above have sufficiently high technical readiness levels for investments now. A multitude of additional technologies are on the horizon and venture capital investments in apps and other digital technologies abound. Together, these technologies avoid or defer investment in traditional transmission and other network infrastructure.[32] They are key to the least-cost integration of variable renewables.

About the author

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[32] IEA (2020d).