sustainability of the energy supply. However, the development of a competitive and commercially secure gas-to-power supply chain is a complex task.

For Nigeria, the main concerns are the effectiveness of legal and institutional reforms in the power and gas sectors; the need for an independent regulator of the domestic gas supply; timely investment in and completion of essential infrastructures; efficient management of the costs and benefits of transitioning to a more liberalized and market-led gas to power system; the reliability and resilience of the power transmission network; and the liquidity of the power sector.

For Tanzania, achieving gas-to-power objectives requires timely investment in generation capacity and development of gas reserves upstream. There is also a need to leverage the technical and operational expertise of international oil companies for offshore reserves, both for export projects and to meet domestic requirements. Addressing TANESCO's liquidity crisis will require considerable economic and structural reforms.

The two countries now have a clear path towards maximizing gas utilization for power generation with an understanding of underlying pricing and governance challenges. Such understandings are increasingly leading to economic restructuring and new policy instruments intended to support the transition to a liberalized and competitive gas-to-power market. Renewables already play a significant role in Tanzania, and their use is growing in Nigeria. Looking-ahead it is expected that renewables fill the gaps created by inadequate gas-to-power infrastructure and provide energy access in remote and rural areas.

NEW ENABLERS FOR ACHIEVING SUSTAINABLE ENERGY FOR ALL IN AFRICA

Carlo Papa and
Giuseppe Montesano

At the beginning of the last century in the north-western United States, electricity salespeople were following the farmers who were turning the desert green, and new distribution lines were following the salespeople. At about the same time, in Italy, the economy was growing at double-digit rates year on year, powered by the 'white coal' of hydropower.

In both cases, our predecessors bet that electricity would play an essential role in economic development – considering electricity, at the very least in the access and development phases, a cause or a facilitator rather than assuming a unidirectional causal link from economic growth to electricity availability – and bet even more on humans' ability to become smarter masters of nature through lateral thinking.

In July 2018, United Nations Secretary General António Guterres will report to the High-Level Political Forum on Sustainable Development on progress towards the Sustainable Development Goals (SDGs), providing an overview of the current situation for each SDG. Commenting on progress on SDG 7 (ensure access to affordable, reliable, sustainable and modern energy for all), he will likely highlight that 'ensuring access to affordable, reliable and modern energy for all has come one step closer due to recent progress in increased access to electricity, particularly in Least Developed Countries (LDCs) and improvements in industrial energy efficiency'. Still, the report will draw our attention to the nearly 1 billion people who still lack access to electricity, a good portion of whom live in Africa. Surely, looking at this figure, we should avoid an overly pessimistic view and recognize the substantial progress that has been made. However, we must stress the need to find new and more effective ways to achieve sustainable energy for all (see here) in Africa, focusing on an integrated way to address the economic, social, and environmental dimensions of sustainable development.

In this context, we should be ready to bet once again, as our predecessors did, on electricity and on the capabilities of human beings by recognizing that humanity has the potential to develop in a sustainable way within the operating space of planetary boundaries (*The Human Quest: Prospering Within Planetary Boundaries.* Johan Rockström, Mattias Klum, 2012). This time, after a century of experience, it should be easier, given the evidence of the relationship between electricity and growth – to the extent the UN identifies access to sustainable energy as a prerequisite for poverty eradication and building the sustainability and resilience of communities – and the tremendous progress made on renewable generation and smart grids able to function as platforms for global and local sustainable development.

The human factor is indeed the indispensable element – and sometimes the most forgotten – to some extent, the real compass in the journey from poverty to sustainable prosperity in the realm of electricity.

We need to keep in mind our fellow human beings, their needs, and their competences in a given lifespan, when thinking about strategic and practical approaches to generation and supply of electricity in energy-deficit areas of the planet. We should consider what people need in order to thrive, with electricity as a key element – rather than setting a theoretical level of

demand based on the assumption that people in energy-deficit regions cannot expect a similar level of energy supply, and well-being, as people in energy-surplus regions. Undeniably, this requires us to design growth paths and set development milestones relying on and implementing, from the beginning, scalable solutions to accommodate growing energy needs in a sustainable and resilient setting.

Two megatrends have a direct impact on electricity access in Africa. Escalating birth rates and higher life expectancy are rapidly increasing the continent's population, exacerbating existing problems such as youth unemployment and unsustainable social services. Even if electrification efforts in sub-Saharan Africa are accelerating and the number of people without access to electricity decreased for the first time in 2014, these achievements will likely soon be overtaken by population growth.

Urbanization is the other social phenomenon that will significantly influence access to electricity: by 2030, more than 50 per cent of the population of Africa will be living in cities, and by 2050, over 60 per cent. Urbanization is creating significant opportunities for social and economic development and more sustainable living but is also putting pressure on infrastructure and resources, particularly energy.

For a smart, strategic, human-centred approach to electrification, and to achieving sustainable energy for all in Africa, we may want to consider new enablers in three fundamental areas: technical design, business model, and financing.

Technical design

Two possible technical solutions should be considered: utility-scale projects connected to the national grid to provide electrification for most of the population living in the towns or nearby, and decentralized solutions for remote rural areas. Analysis by the International Energy Agency (IEA) revealed that from 2000 to 2016 nearly all of the people who gained access to electricity worldwide did so through new grid connections, mostly with power generation from fossil fuels. Nevertheless, the technologies used to provide access have started to shift, with renewables providing 34 per cent of new connections since 2012, and with off-grid and mini-grid systems accounting for 6 per cent.

India's success story is a good example. Thanks to investment in grids and to new connections realized by the government over the last two decades, electrification grew at a significant rate, increasing the number of people with access to electricity from half a billion to one billion. The commitment of political institutions made it possible to massively improve the quality of life of the population and put India on track to reach universal electricity access in the early 2020s, with renewables providing energy to 60 per cent of the population that gains access.

Even though the Indian contexts differ in some ways from the African ones, including population density, Africa's strong urbanization trend makes access through power plants connected to the grid the main solution. The role of decentralized systems, on the other hand, will be fundamental where scattered populations and remote locations make construction and maintenance of grids difficult, or as a temporary solution prior to grid connection.

This approach can help resolve the debate between advocates of mini-grids and those who argue that, although they may be cost-effective for small and isolated communities, they cannot provide the economies of scale and the resilience of utility-scale smart grids. In powering energy-deficit areas of the planet, we should approach mini-grids as building blocks. Practical implementation of this approach is currently rare, if not nonexistent, so it would require a change in perspective, but it could be successful because of its scalability. Gradually connecting mini-grids could help to systematically expand energy access, progressively offering growth opportunities and local benefits with the eventual goal of connecting areas to large grids wherever possible.

Developing and implementing standardized mini-grid solutions throughout areas using IEA-compatible equipment – from analytical site-selection tools that help ensure consistency and impact, to software and hardware – could help drive down costs and ensure consistent quality standards in the short term, and help to intensify and expand large smart grids in the medium term. Clearly, a positive policy and regulatory environment that recognizes and promotes this electrification solution will create momentum and stimulate new entrants, such as traditional distribution companies, to the micro- and mini-grid space. This is happening in Colombia, where Codensa, part of the Enel Group, has just installed a standardized off-grid system and is planning to reach thousands of households in the near future.

Business model

Conventionally, power generation is seen as a technical component totally integrated into the mini-grid. We could instead consider decoupling it from the mini-grid system, restricting the latter to distribution and supply to end-users, while sourcing power from bigger renewable power plants built nearby serving more than one mini-grid. This approach could benefit from the presence of renewable plants, mostly in semirural areas, often relatively large installations connected to larger grids,

which now represent a significant portion of annual capacity additions. It would allow mini-grid customers, who would otherwise be excluded from connection to the larger grid, to enjoy lower electricity costs, mini-grid operators to provide a higher level of service, and the entire community to experience greater resiliency. Last but not least, it would result in a more flexible consumption profile with room to grow over time. Such growth opportunities can serve several productive and social uses, increasing the ability of new customers to pay tariffs and therefore supporting the recovery of investments in grids and increasing their profitability over time.

Financing

International agencies frequently refer to the tremendous amount of investment needed to power rural Africa and the difficulty of raising capital for this purpose. As the electricity sector has evolved over time, transmission and distribution have probably been among the most stable and lucrative segments of the value chain over the medium and long term – to the point that they have become an important element of infrastructure investment, an alternative asset class able to reduce portfolio volatility and gather interest for pension funds, insurance companies, and sovereign wealth funds.

In this context, in a scenario where committed and forward-thinking actors will be able to create clusters of projects, from mini-grid to industrial-scale renewables and grid lines, which can be increasingly integrated with one another, and systematically scale up the electricity system in Africa, we believe there will be ample room for both venture capital and private equity, through which pension funds can invest in powering Africa, receiving the benefit of diversification in the short run while establishing a path to traditional infrastructure deals in the long run. Clearly, this scenario is more likely to materialize where there is a clear institutional framework and a robust regulatory environment.

Conclusion

To ensure that smart grids and renewables become increasingly important elements in the effort to provide energy for all, adopting the operational approaches described above, human-centred and conscious of planetary boundaries, the name of the game is indeed convergence. Reaching consensus among communities on the type of future they want is paramount, as well as tight cooperation between government, local, and international institutions, to ensure that a clear policy framework and robust regulatory environment are in place that encourage all stakeholders to make mutually beneficial choices in enlightened self-interest.

OPPORTUNITIES AND CHALLENGES IN ACHIEVING UNIVERSAL ELECTRICITY ACCESS IN SUB-SAHARAN AFRICA

Anteneh G. Dagnachew, Paul L. Lucas, Andries F. Hof and Detlef P. van Vuuren

Access to electricity is an important prerequisite for human development. This was acknowledged by the global community through the adoption of the Sustainable Development Goals (SDGs), which call for universal access to electricity by 2030. Currently, more than 600 million people in sub-Saharan Africa (SSA) have no access to electricity, and the total installed generation capacity in the region is less than that of the United Kingdom. Thus, universal access in SSA is unlikely to be met under business-as-usual scenario, especially since the expansion of access to electrification has lagged behind population growth.

Based on relationships between electricity access on the one hand and GDP per capita, population density, and urbanization rate on the other, model projections show that following historical trends about 515 million people will still lack access to electricity in 2030. Eastern Africa is projected to have the highest proportion of people without access to electricity by that date (48 per cent), followed by southern Africa without the Republic of South Africa (44 per cent), western and central Africa (31 per cent), and the Republic of South Africa (12 per cent). Access to electricity is especially lagging in rural areas, which are projected to account for 85 per cent of the population without access by 2030.

Providing universal electricity access requires major investments in generation capacity and transmission and distribution. However, strategies to achieve this goal should also consider possible trade-offs and synergies with other SDGs, including how they affect greenhouse gas emissions.

This article reports on a study that explored ways to achieve universal electricity access in SSA, technology options, investment needs, and synergies and trade-offs with global climate policy, using the integrated assessment model IMAGE-TIMER. The study sought to identify the roles of individual and institutional actors and the role of regulations in the transition to universal electricity access in SSA. It involved workshops conducted in the Netherlands and Ethiopia with actors involved in the region's electricity system; case studies of centralized and decentralized electrification programs and projects in Nigeria, Ghana, Tanzania, and Ethiopia; and a desk study.