LOW-CARBON PATHWAYS TO UNIVERSAL ELECTRICITY ACCESS IN DEVELOPING COUNTRIES: THE ROLE OF AN INTEGRATED DISTRIBUTION FRAMEWORK

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Global progress towards the achievement of universal electricity access by 2030 – as targeted under Sustainable Development Goal (SDG) 7 – remains insufficient. Significant improvements have been made, with an average of 136 million people gaining access each year between 2016 and 2018, substantially higher than the average annual population growth.[56] Off-grid technologies, such as stand-alone solar systems and mini-grids, are showing great promise. Over 170 million people obtained some form of access to off-grid renewables in 2018,[57] although the majority (136 million) only received basic services (under Tier 1 of the Multi-Tier Framework). Globally, at least 19,000 mini-grids are already installed, representing a total investment of US$28 billion, providing electricity to around 47 million people.[58]

Despite these positive developments, the world is still not on track to meet universal electricity access by 2030.[59] In 2018, an estimated 789 million people still lived without electricity access – 70 per cent of them in sub-Saharan Africa. Enormous challenges are faced in many parts of Africa – where population growth exceeds electrification rates – and in expanding last-mile access to remote pockets in Latin America, the thousands of islands in Indonesia, and the underserved rural communities with unreliable supply in India.

It is estimated that 620 million will remain without access in 2030 – not even accounting for the impact of COVID-19 on future investments.[60] Meanwhile, hundreds of millions of people and enterprises continue to face unreliable electricity access which comes at a significant social, economic, and environmental cost.

Diesel- and petrol-based generators are widely used to back up unreliable electricity supply. In developing countries, the total

[55] R. Moreno, *et al.*, "From Reliability to Resilience: Planning the Grid Against the Extremes", *IEEE Power and Energy Magazine*, vol. 18, no. 4, pp. 41-53, July-Aug. 2020.

[56] International Energy Agency, International Renewable Energy Agency, United Nations Statistics Division, World Bank, and World Health Organization, *Tracking SDG 7: The Energy Progress Report* (2020), https://trackingsdg7.esmap.org/data/files/download-documents/01-sdg7-executivesummary_0.pdf.

[57] International Energy Agency, International Renewable Energy Agency, United Nations Statistics Division, World Bank, and World Health Organization, *Tracking SDG 7: The Energy Progress Report* (2020), https://trackingsdg7.esmap.org/data/files/download-documents/01-sdg7-executivesummary_0.pdf.

[58] Energy Sector Management Assistance Program, *Mini-Grids for Half a Billion People* (2019), https://openknowledge.worldbank.org/bitstream/handle/10986/31926/Mini-Grids-for-Half-a-Billion-People-Market-Outlook-and-Handbook-for-Decision-Makers-Executive-Summary.pdf?sequence=1&isAllowed=y.

[59] International Energy Agency, International Renewable Energy Agency, United Nations Statistics Division, World Bank, and World Health Organization, *Tracking SDG 7: The Energy Progress Report* (2020), https://trackingsdg7.esmap.org/data/files/download-documents/01-sdg7-executivesummary_0.pdf.

[60] International Energy Agency, International Renewable Energy Agency, United Nations Statistics Division, World Bank, and World Health Organization, *Tracking SDG 7: The Energy Progress Report* (2020), https://trackingsdg7.esmap.org/data/files/download-documents/01-sdg7-executivesummary_0.pdf.

capacity of backup generators is estimated at 350–500 GW, spread across 20–30 million individual sites.[61] In certain countries, the installed capacity of backup generators is larger than that of the national grid. In Nigeria, for instance, the total installed generation capacity is estimated at 15–20 GW, while grid capacity is about 12.5 GW and only a third of it is in working condition. Across sub-Saharan Africa, one out of every five litres of diesel and petrol is burned in a backup generator, with total emissions equivalent to 20 percent of those from vehicles. Annually, such generators emit more than 100 Mt of CO_2 globally.[62]

Reaching SDG 7 requires significant investments in expanding new connections as well as ensuring reliability, affordability, and sufficiency of supply to existing consumers. However, in 2017 only about US$12.5 billion was invested in new connections, while at least US$40 billion was estimated to be needed annually to 2030.63 Mobilizing investments at scale is in large part hindered by financial challenges in the distribution sector in most low-access countries, as well as by the uncoordinated, siloed development of on- and off-grid electrification modes, resulting in a lack of permanence of supply and inclusivity.

Challenges facing electrification: a focus on the distribution sector

The poor performance of the incumbent distribution segment in low-access countries is a bottleneck that impedes progress in electrification. Only two countries in sub-Saharan Africa are known to have financially viable power sectors – Seychelles and Uganda (the distribution concession involving Umeme) – with the majority relying on periodic government subsidies.[64] The ensuing viability challenges hinder the mobilization of the substantial investment in networks needed to improve reliability of supply and to expand new connections.

As a result, underserved areas have seen growth in the adoption of distributed generation, traditionally based on fossil fuels. Recently low-cost, reliable distributed renewable energy solutions have flourished, backed by tailored business and financing models; these directly compete with the distribution companies for grid-connected commercial, industrial, and well-off private customers faced with unreliable and poor service. This trend further erodes the distribution companies' customer base, exacerbating their financial deficit.

In areas not covered by the national grid, siloed investible frameworks are being created through dedicated regulations and tailored financing programs to deploy mini-grids and solar home systems largely without the involvement of the distribution companies. The rapid deployment of distributed solutions is a welcome development to rapidly expand access in unconnected regions and augment supply in already electrified areas. However, at the national or regional level, there is usually no common framework that ensures that the combination of on-grid and off-grid electrification initiatives will lead to universal access, leave no one behind, use the least-cost mix of technologies, and ensure permanence of supply.

To reach universal electricity access, while ensuring permanence of supply and viability of the distribution sector, will require the integration of the three modes of electrification (the grid, mini-grids, and stand-alone systems) under a single responsible utility-like entity. This entity – public, private, or a partnership – will have exclusivity on grid extension and can engage other stakeholders to deploy off-grid solutions where feasible and preferred. However, the entity will always be the default provider and the last-resort provider for all consumers in the assigned territory (typically as a concession), thereby ensuring permanence. This approach forms an integral component of the Integrated Distribution Framework (IDF), which is further elaborated below.

The Integrated Distribution Framework

The convergence of technological advancements, political commitment to the SDGs, and innovative financing and business models make it an opportune moment to think differently and at scale about electrification, in particular the distribution segment. There is also growing consensus that investments in low-carbon infrastructure and modern energy access must be a central pillar of COVID-19 recovery efforts, given large long-term socio-economic and environmental dividends.[65]

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[61] International Finance Corporation, *The Dirty Footprint of the Broken Grid: The Impacts of Fossil Fuel Back-up Generators in Developing Countries* (2020), https://www.ifc.org/wps/wcm/connect/dfab4f4c-9247-46ed-8f35-b25fa527b636/20190919-Summary-The-Dirty-Footprint-of-the-Broken-Grid.pdf?MOD=AJPERES&CVID=mR9UXpH.

[62] International Finance Corporation, *The Dirty Footprint of the Broken Grid: The Impacts of Fossil Fuel Back-up Generators in Developing Countries* (2020), https://www.ifc.org/wps/wcm/connect/dfab4f4c-9247-46ed-8f35-b25fa527b636/20190919-Summary-The-Dirty-Footprint-of-the-Broken-Grid.pdf?MOD=AJPERES&CVID=mR9UXpH.

[63] Sustainable Energy for All, *Energizing Finance: Understanding the Landscape* (2019), https://www.seforall.org/publications/energizing-finance-understanding-the-landscape-2019; International Energy Agency, *SDG7: Data and Projections* (2020), https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity.

[64] M. Kojima and C. Trimble, *Making Power Affordable for Africa and Viable for Its Utilities* (Washington, DC: World Bank, 2016), https://openknowledge.worldbank.org/handle/10986/25091.

[65] See International Renewable Energy Agency, *The Post-COVID Recovery: An Agenda for Resilience, Development and Equality* (2020),

A new business model for distribution is needed that leaves no one behind, ensures permanence of supply, integrates the various electrification modes, and is aligned with the long-term development of the power sector. Advancing these principles, the IDF is built around the idea of an entity – public, private, or a partnership – that is responsible for distribution in a given territory. The entity would operate as a concession – thus, privatization is not necessary – with a mandate to reach universal access within its service area by using an appropriate mix of electrification modes with a viable business plan supported by cost-of-service regulation, viability gap funding, and adequate risk mitigation. (Cost-of-service regulation ensures that utilities receive revenues that reflect their costs and earn a reasonable return on investment. Viability gap funding covers any deficit between the annually determined revenue requirement and revenues from tariffs.)

Four guiding principles

The IDF has four guiding principles that can inform electrification programme design and help evaluate ongoing efforts: universal access, multiple modes of electrification, financial viability, and a development-centred approach.

Universal access entails leaving no one behind, ensuring permanence of supply, and establishing a utility-like entity that takes responsibility for a territory and commits to supply its customers with a minimum level of access and reliability. It further accepts the role of default and last-resort supplier (taking over in the event a current supplier fails). Universal access must be accompanied by a commitment to permanence, which is needed to perform the roles of default and last-resort provider.

Integrating the three modes of electrification (on-grid, mini-grids and stand-alone systems) requires electrification planning at distribution level while taking a comprehensive view of all types of consumers in a cluster, district, or entire country. In an integrated approach, the electrification modes engage in an efficient, complementary, and dynamic manner over time to provide reliable, affordable, and sufficient access.

Ensuring financial viability of the business model for electrification at the right scale will typically require some form of distribution concession to provide legal security, the participation of external and mostly private investors, and the inevitable presence of public subsidies as viability gap. Cost-of-service remuneration, complemented in some cases with performance-based incentives, must be the general approach to follow for each electrification mode.

While there is substantial experience in the application of this method to a traditional distribution company, the presence of distributed energy resources may bring some complexities.66 There is less regulatory experience in estimating the cost of supply with mini-grids. These can be estimated using existing models, or through competitive auctions in specified areas. There is also limited experience with electricity supply from stand-alone solar home systems under regulated conditions, although some instances exist using auctions (e.g. in Morocco, Argentina or Peru) with mixed results.

A cost-of-service remuneration that guarantees reasonable returns under acceptable legal conditions can attract investors with the right blend of equity and debt for each electrification mode to meet the prescribed target. A central element of cost-of-service remuneration is a regulated revenue requirement which is accompanied by regulated tariffs. The revenue requirement must correspond to incurred costs. But the tariffs to be applied to the end customers do not necessarily have to be cost-reflective, either for each category of customer (thus allowing cross-subsidization), or at a system level, or both. In such cases, a subsidy will be needed if the aggregated revenue collection with the existing tariffs is insufficient to cover the total costs, which is typically the case for rural electrification.

A development-centred approach looks beyond a connection and links electricity services to social and economic outcomes. A top-down approach has to be complemented by the bottom-up participation of end users, as well as other entities such as NGOs, foundations, and cross-sector agencies, which can support demand growth through the development of productive and community energy uses. A viable electrification scheme requires end customers to be offered a high-quality supply that is properly metered and billed, and access to training, financing, and support for productive use development.

An adaptable approach

The IDF comprises diverse elements of regulatory approaches and business models that have worked well in several countries

https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Post-COVID_Recovery_2020.pdf; International Energy Agency, *Sustainable Recovery* (2020), https://www.iea.org/reports/sustainable-recovery.

[66] See MIT Energy Initiative, *The Utility of the Future* (Massachusetts Institute of Technology, 2016), https://energy.mit.edu/wp-content/uploads/2016/12/Utility-of-the-Future-Full-Report.pdf.

under different conditions, but had not been put together before with the explicit purpose of achieving universal electrification effectively and efficiently.

As a set of guiding principles, the IDF approach can be adapted to diverse local conditions within countries to scale electricity access. Early versions of the IDF were applied in Morocco and Argentina and parts of it are being implemented across the developing world, including in Nigeria, Rwanda, Uganda, and parts of India. In Nigeria, for instance, a sub-concession agreement between Konexa (a private entity) and Kaduna Electricity Distribution Company (a distribution company) was approved by the regulator in March 2020. Under the arrangement, Konexa will be responsible for distribution activities within the sub-concession area and for ensuring reliable supply and universal access using an optimum mix of on- and off-grid solutions guided by an electrification model. In the arrangement's current stage, Konexa adheres to the principles of the IDF, with cross-subsidizing tariffs fully covering the cost-reflective revenue requirement. As the model expands to cover a larger share of rural populations, explicit subsidies will be required to meet the revenue requirement.

The Universal Energy Access Laboratory (https://universalaccess.mit.edu/) comprising researchers from the Massachusetts Institute of Technology and IIT-Comillas, including as part of its activities supporting the Global Commission to End Energy Poverty,[67] is engaged in high-level dialogues with governments, investors, regulators, and Development Finance Institutions (DFIs) to implement and expand the IDF in selected first-action countries such as Colombia, India, Rwanda, Nigeria, and Uganda.

The IDF and expansion of low-carbon electricity access

The IDF approach offers a pathway to ensure that reliable, affordable, and sufficient electricity is available to all through an appropriate mix of on- and off-grid solutions deployed using principles that support long-term viability of the distribution sector. Improvements in reliability of electricity supply through investments in networks and reduction of technical and commercial losses can result in immediate emissions reduction from less generation loss and lower use of fuel-based backup generators. With the IDF emphasizing integrated electrification planning and cost-of-service regulations, the full potential of renewable-energy-based mini-grids and stand-alone systems can be harnessed by ensuring all those suitably serviced through such solutions are reached in a given time frame and that renewable technologies permanently remain in operation.

The viability of the power sector also hinges on the financial health of distribution. Efforts that improve the financial viability of distribution reduce off-taker risks for utility-scale power generation projects, including those based on low-carbon solutions, avoiding small inefficient fossil-fired generation plants. Improving the capacity of the distribution sector to attract private capital is also likely to raise investments in networks and technologies, including smart metering and remote monitoring, that enable integration of rising low-carbon and variable generation on the grid.

Conclusion

Achieving universal electricity access by 2030 under a business-as-usual approach – uncoordinated development of on-grid and off-grid solutions, unviable distribution sectors, lack of focus on permanence and inclusivity, and limited public and private investments – will not be possible. Unreliable electricity supply encourages the adoption of fossil-fuel-based backup generators to power households and businesses, while the distribution sector struggles to serve as a reliable off-taker for much-needed investments in low-carbon generation and networks.

The impact of COVID-19 is likely to result in a significant public funding crunch and competing priorities during the recovery phase. The power sector in emerging economies has seen decades of underinvestment and may now see new investments further curtailed – global investment in the sector is likely to fall to its lowest level in over a decade in 2020[68]. This trend will directly hurt global ambitions to reach universal access by 2030. Investing now in the distribution sector to deliver affordable, reliable, and sufficient electricity supply for all will underpin the creation of new jobs in rural and urban areas, improve the competitiveness of domestic firms, and enhance access to public services such as healthcare, education and water. However, short-term and long-term investments must not reinforce traditional, unviable distribution business models but ensure that the sector is placed on a trajectory towards long-term viability to mobilize sufficient capital to meet electrification and decarbonization objectives. The IDF approach outlined in this article is aligned to these objectives.

[67] I. Pérez-Arriaga, R. Stoner, D. Nagpal, and G. Jacquot, *Global Commission to End Energy Poverty: Inception Report* (September 2019), https://www.endenergypoverty.org/reports.

[68] See International Energy Agency, *World Energy Investment 2020: Power Sector,* https://www.iea.org/reports/world-energy-investment-2020/power-sector#abstract.

At the core of the IDF is an investment-worthy concession agreement that makes an entity (the concessionaire) responsible for undertaking distribution activities in a given area and ensuring universal access through coordinated development of on-grid and off-grid solutions, while providing the legal basis for ensuring cost recovery. The IDF frees up public funding from governments that would otherwise have to be used for capital expenditures or pay subsidies (for distribution and for fuels such as diesel). The concession approach proposed by the IDF shifts most of the economic burden for maintaining, improving, and expanding a country's power sector off the shoulders of the government for the duration of the concession (typically 20 or 25 years). This leaves the government in a better position to focus its efforts on other sectors of the economy.

Over the long term, electrification approaches should be aligned with the well-tested fundamentals of the distribution business – long-term remuneration schemes based on a cost-reflective revenue requirement that is computed each year. Implementing the IDF requires applying these principles to all three electrification modes, while recognizing that the initial optimum mix of grid- and off-grid solutions will vary from country to country and will evolve with time. This should be done within an integrated framework that makes sure that supply is inclusive, sustainable – over time, environmentally, and financially – and aligned with socio-economic and environmental objectives.