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THE ELECTRICITY ACCESS INDEX

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Progress toward universal electricity access is usually measured with one number: the share of the population that has electricity, or access rate. This number says little about whether a country is progressing fast enough to reach universal access by 2030, or about the financial, regulatory, and institutional conditions required to get there. This paper introduces the Electricity Access Index (EAI) to fill that gap, as a country-level diagnostic with two components. *Sufficiency* evaluates whether the current and planned electrification effort is enough to reach universal access, and whether the investment required to close the remaining gap can be financed, all of that in a reasonable time horizon. *Effectiveness* evaluates whether the rules, business models, and institutions in place are adequate to turn that effort into sustainable electricity service for all.

The proposed index methodology is applied to Rwanda, Malawi, Bangladesh, and Ecuador using the data available in 2022. In none of the four countries is the current effort sufficient to reach universal access by 2030. The access rate alone gives a misleading picture of the remaining challenge. Ecuador has the highest access rate, yet resolving its remaining gap still requires the development and adoption of regulatory and political decisions on how its cost will be recovered. Bangladesh has the strongest financing structure of the four—its own cash generation pays for most of the investment—but its planned effort still falls short of universal access by 2030. Rwanda and Malawi both start from much lower access levels, but only Rwanda has a plan that appears financially feasible, albeit with substantial subsidy support. On effectiveness, the country experts consulted in the four countries rate the political priority of universal access above the existing business models for mini-grids and stand-alone systems. The effectiveness scores do not follow the access rates: the score of Ecuador is below the scores of Rwanda and Bangladesh. These contrasts show that the challenge of reaching universal access depends on more than the number of people still unserved.

1 INTRODUCTION

Multiple factors shape the process of electrification in any country. The rate of electrification, the level of development of the existing power system, the credibility of sector institutions, and the revenue that can be expected from those still unserved are prominent in characterizing the electrification process and the necessary effort. Together they determine what can be built, who can finance it, how costs can be recovered, and which rules can sustain the service over time.

Access metrics are essential for describing outcomes. The SDG 7.1 indicator tracks the proportion of the population with access to electricity (IEA et al., 2026), and the Multi-Tier Framework (MTF) grades the quality of that access (Bhatia and Angelou, 2015). Both are indispensable for measuring a country's progress. However, both are outcome metrics. They describe the state of access at a given moment in time. They do not indicate whether the current effort and the existing policies and regulations can achieve and sustain universal access. Nor do they show whether a given electrification pathway fits within the fiscal, regulatory, institutional, and financial constraints of the country.

A least-cost electrification plan that is technically sound for two countries with similar electrification rates may therefore require radically different implementation strategies for each one. The main obstacle to achieving universal electricity access in a country could be the design of a suitable financing structure, or the political decision to close a residual gap, or the adoption of a suitable business model to provide the service.

Progress toward universal access differs widely across the regions of the world. Between 2010 and 2024, the number of people without access to electricity fell from 1.1 billion to 655 million. In Sub-Saharan Africa, the number of people without access barely changed: 565 million in 2010 and 563 million in 2024. The share of Sub-Saharan Africa in the world population without access therefore rose from 49% to 86%. Over the same period, the share of Central and Southern Asia fell from 36% to 3% (IEA et al., 2026).

A high access rate can be mistaken for an easy electrification case to be solved shortly. However, when a country is close to full access, the communities still without electricity are usually rural, poor, dispersed and isolated, and they consume very little. Reaching them often means one of two things. Either the grid is extended over long distances, at high cost and for little revenue, or mini-grids or stand-alone systems are installed. The latter are the least-cost solution, but they cost more per kWh supplied than the average cost of supply for those already electrified. The obstacle to completing electrification is often not technical. It is regulatory, fiscal, political and, above all, social. The extra cost must be accepted and allocated somehow, even when the country can afford it. And—this is usually the most difficult part—a direct interaction with the beneficiary communities is often needed to gain their trust and collaboration, so that the solutions meet their needs and are inclusive and sustainable.

This paper presents the Electricity Access Index (EAI), a country-level diagnostic that complements the access metrics. The index answers two questions. The first is whether the present electrification effort is large enough to reach universal access by 2030, the target year of SDG 7.1, and whether the plan that defines that effort can be financed. The second is whether the rules, business models, and institutions under which that effort is deployed can sustain the service once universal access is achieved.

Section 2 presents the index and its two components, sufficiency and effectiveness, which answer the first and the second question. Section 3 applies the index to four countries—Rwanda, Malawi, Bangladesh, and Ecuador—and Section 4 discusses the results. Section 5 concludes. The Annex

gives the detailed design of the two components and the full questionnaire sent to the country experts.

2 THE ELECTRICITY ACCESS INDEX[1]

This section describes the EAI, which was first presented in an earlier working paper (Pérez-Arriaga et al., 2022). The index assesses one country at a time and does not rank them. The index covers the distribution segment of the power sector, on the premise that distribution is the bottleneck of universal access. In many countries with low access rates, the distribution companies are in financial distress, and this hinders the investment needed to connect new customers. Here, distribution is understood broadly: it includes conventional on-grid distribution and retailing, but also mini-grids and stand-alone systems, with their generation and storage assets, when they are the way to supply communities that the grid does not reach.

2.1 CONCEPT AND SCOPE

The EAI has two components: sufficiency and effectiveness. Sufficiency asks whether the scale of current effort is close to the scale required for universal access, and whether the corresponding plan is financially viable. Effectiveness asks whether that effort is allocated, governed, and regulated in a way that can plausibly achieve sustainable electrification. Here, "sustainable" means a utility-like service: supply that is reliable, professionally operated, and financially and institutionally able to endure over the long term rather than to degrade once initial support is withdrawn.

A country may be underperforming because the volume of effort is too low. It may also be underperforming because, even if the volume of effort could suffice, the effort is poorly organized, weakly targeted, or not supported by credible business models, tariff rules, or subsidy rules. The first case is a sufficiency gap; the second is an effectiveness gap. The policy response is not the same. A sufficiency gap calls for more resources or a different mix of financing sources. An effectiveness gap calls for changes in how the effort is organized: regulation, business models, tariff and subsidy rules, and planning.

Read in this way, the EAI sits between the measurement of access and the full design of regulation and financing. It does not replace the SDG 7.1 indicator or the MTF. It complements them by asking a different question: whether the rules and institutions in place organize and finance electrification in a way that can plausibly sustain universal access.

[1] This paper builds on and extends the methodology introduced in:

- Pérez-Arriaga, I.J., Díaz-Pastor, S.J., Mastropietro, P., de Abajo, C. (2022). The electricity access index methodology and preliminary findings. MIT / Global Commission to End Energy Poverty working paper. Available at:

  https://www.iit.comillas.edu/publicacion/workingpaper/es/456/The_electricity_access_index_methodology_and_preliminary_findings

2.2 SUFFICIENCY

The first component of the EAI is sufficiency. It compares the current annual financial effort devoted to universal electrification in the distribution segment with the annual effort required by a financially sound electrification strategy consistent with SDG 7.1. The comparison is made in annual terms, and the relevant variable is total expenditure (TOTEX) rather than investment alone. TOTEX is defined here as capital expenditure (CAPEX) plus operating expenditure (OPEX), that is, the cost of building and running the system. Taxes, debt service, and dividends depend on the capital structure and are assessed through the business plan, in the viability dimension described below. This choice matters because electrification does not end at connection. Sustainable service also requires operation, maintenance, repair, and future asset replacement. A metric that tracks only new investment can therefore overstate progress by ignoring the cost of keeping systems in service over time. This TOTEX perspective is one of the main differences between the EAI and more conventional investment-based exercises.

The numerator of the sufficiency ratio captures the present annual financial effort. It is built from observed expenditure on grid extension, mini-grids, and stand-alone systems, using publicly available country-level information from utilities and other investment sources, including financial statements and international reporting databases such as the OECD/DAC Creditor Reporting System.

Computing the denominator is more demanding. It is not a simple engineering estimate. It is obtained from a country-specific techno-economic electrification plan and the associated financial plan required to achieve universal access by 2030. For each country, this denominator is based on a detailed business plan built over a 20-year horizon. The plan combines the annual TOTEX profile of the electrification pathway with expected revenues from regulated tariffs and the best feasible mix of public support, concessional instruments, and commercial finance. The EAI therefore does not stop at asking how much universal electrification would cost. It also asks whether those costs can be financed through a credible implementation plan under the tariff structure, subsidy mechanisms, institutions, and financing instruments available in the country.

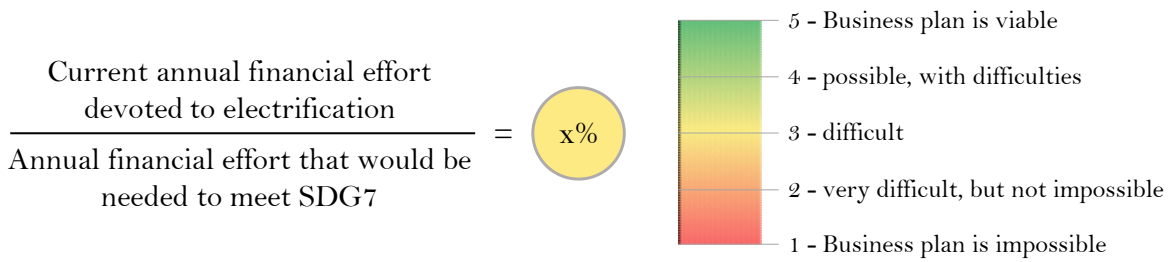

Figure 1. Graphical representation of the sufficiency component of the Electricity Access Index. Source: (Pérez-Arriaga et al., 2022).

For that reason, sufficiency in the EAI has two dimensions, as shown in Figure 1. The first is the ratio between present effort and required effort. The second is the financial viability of the business plan used to compute the denominator. This second dimension is essential. A country may still be making less effort than required, but the remaining gap may nevertheless be financeable under credible public support and blended finance. In other cases, the deeper problem is that no plausible

business plan can sustain the required rollout under prevailing regulatory, fiscal, and market conditions.

This viability dimension is assessed against practical infrastructure-finance criteria and is informed by consultation with experts in infrastructure finance, who review whether the country-specific business plan would be financeable under the prevailing institutional setting, risk profile, and available financial instruments. The result is then classified on a five-level scale, from impossible to viable, and translated into the color code shown in Figure 1. The index therefore captures not only whether the annual effort is large enough, but also whether the underlying universal-access plan is financially credible. Further methodological detail is provided in the Annex.

2.3 EFFECTIVENESS

The second component of the EAI is effectiveness. Its focus is not the volume of effort but the quality of the institutional and regulatory environment in which that effort is deployed. The question is whether the current electrification strategy is structured and governed in a way that can plausibly achieve and sustain universal access.

This component of the index is organized around four principles derived from the Integrated Distribution Framework (IDF)[2]. The first is universal access. Electrification should leave no one behind and should assign clear responsibility for service in a defined territory. The second is the integration of on- and off-grid solutions. Grid extension, mini-grids, and stand-alone systems should be planned and coordinated as parts of one strategy rather than as separate programs. The third is financial viability. Distribution must rest on a business model that can sustain service over time. This is often a concession or another long-term contract that provides legal security, supports external investment, and covers any remaining viability gap—the shortfall between the cost of service and the revenues that affordable tariffs can generate. The fourth is a focus on development. Electrification should support productive use, critical public services, and broader social and economic gains (Figure 2) (GCEEP, 2020).

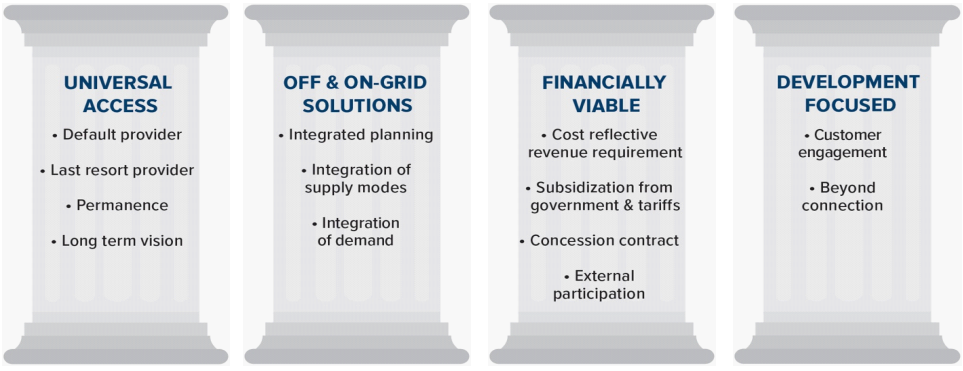

Figure 2. Graphical representation of IDF principles. Source: (GCEEP, 2020).

[2] The Integrated Distribution Framework (IDF), as introduced in the original EAI working paper, is the outcome of a collective research effort developed within the MIT / IIT-Comillas Universal Energy Access Laboratory over several years. The work was initially supported by the Shell Foundation and later developed in collaboration with the Global Commission to End Energy Poverty (GCEEP), with support from The Rockefeller Foundation. The approach has also been championed by the African School of Regulation (ASR) in the context of universal electrification in Africa.

This is also the point at which regulation becomes central in the analysis. The effectiveness component does not treat regulation as background context. It examines whether the regulatory and institutional environment is consistent with durable electrification. The assessment therefore asks whether adequate business models exist for grid extension, mini-grids, and stand-alone systems, and whether planning is integrated across the three electrification modes. It also asks whether transition rules are clear when the grid reaches an area already served by a mini-grid or a stand-alone system, and whether cost recovery or viability-gap support is available. Finally, it asks whether the sector provides enough legal and regulatory certainty to attract external capital. Regulation is therefore not outside the EAI. It is embedded most directly in the effectiveness assessment.

The effectiveness score is constructed through a 34-item questionnaire completed by country experts. Each item is scored from one to five. Items are grouped under the four principles, which allows the calculation of a score for each principle and an overall score for each country. A color code is then used to provide an intuitive graphical representation of the results. The specific questionnaire was designed to fill a gap left by existing instruments. The Regulatory Indicators for Sustainable Energy (RISE) and the Electricity Regulatory Index cover the regulatory environment, and Doing Business and the Global Competitiveness Report cover the broader business climate. They provide useful information on parts of the enabling environment, but none of them assesses electrification strategy from the perspective required by the EAI (AfDB, 2021; Schwab and Zahidi, 2020; World Bank, 2020a, 2020b).

Together, the two components separate two problems that are often mixed—a sufficiency gap and an effectiveness gap—and report them separately in the diagnosis. The country applications that follow are read with that distinction.

3 RESULTS: FOUR COUNTRIES, FOUR DIFFERENT FEASIBILITY PROBLEMS

The purpose of the four applications is to show that the same universal-access target can correspond to very different feasibility problems. The differences appear once the analysis moves beyond access outcomes and considers financeability, implementation rules, and the time profile of the rollout. The index is useful not because it produces one more score, but because it shows which parts of the electrification strategy need to improve in each country and how difficult compliance with SDG 7.1 may be at country level.

3.1 HOW THE RESULTS SHOULD BE READ

Before turning to the four country applications, three clarifications are needed. The first concerns what the scores mean. The original EAI working paper makes this point with three stylized country profiles, as represented in Figure 3.

In the first, a country is close to universal access, the financing need is small, but there is no political agreement to build and implement a credible financial plan. In the second, a country is investing, and may even have a viable business plan, but its electrification strategy is incomplete, typically

because grid and off-grid solutions are not properly integrated. In the third, a country has a very large access gap, severe fiscal constraints, and no viable business model under current conditions. In the figure, the four principles carry the labels of the original working paper: universality, integral plan, viability, and development.

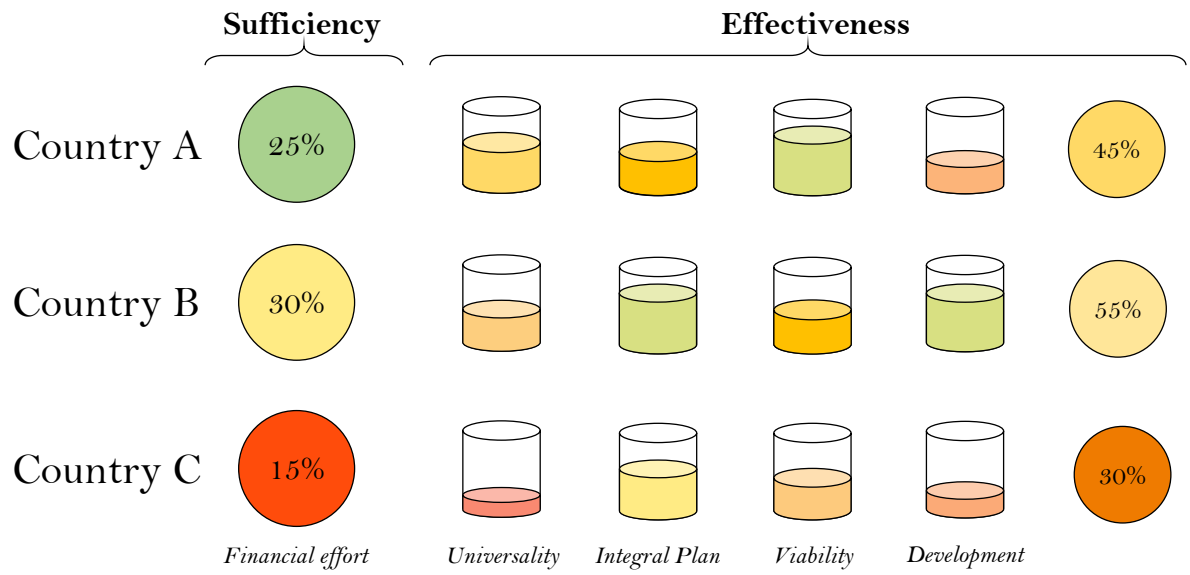

Figure 3. Possible presentation of the Electricity Access Index for three hypothetical countries. Source: (Pérez-Arriaga et al., 2022).

Low sufficiency can therefore mean very different things, and the same universal-access target can be missed for very different reasons. Sufficiency and effectiveness are reported separately because they reveal different weaknesses. One country may have a manageable financing need but weak implementation. Another may have a much larger financing problem but a more coherent institutional structure. A third may face both at once. The diagnostic value of the index lies in not collapsing these situations into one number. Sufficiency is computed against the country-specific business plan required to reach universal access by 2030, so the results are conditional on that target year. A later target would lower the required annual effort and raise the sufficiency score.

The second clarification concerns the evidence behind each application. The effectiveness scores are based on a 34-item questionnaire completed by country experts in 2021 and 2022. Rwanda has one response, Malawi three, and Bangladesh and Ecuador two each. The scores are therefore indicative assessments of the regulatory and institutional conditions reported by a small number of experts, rather than direct measures of implementation outcomes. Table 1 reports the overall score for each country, while Table 2 in the Annex provides the scores for each principle and the number of responses. The country assessments focus on the questionnaire results that help explain the financial findings or identify additional weaknesses in implementation. The detailed scores remain available in the Annex.

The five-level viability rating of the business plan is available on a fully comparable basis only for part of the sample. The viability of each business plan is therefore read here through the structure of the business plan itself. Four features matter: the balance between internal cash generation and external finance, the tariff design and the use of cross-subsidies, the length of the period of negative

operating cash flow, and the overall dependence on grants and subsidies. The experts in infrastructure finance who reviewed the approach stressed that the viability of a business plan also depends on its mix of electrification modes and on how predictable its cash flows are—the remuneration rules, and the treatment of losses and theft.

The third clarification concerns the dates of the country data. The four applications were prepared in 2022. Every country figure reported in this section—access rates, consumption levels, tariffs, macroeconomic indicators, and the status of programs and strategies—is taken from the most recent data that were publicly available at that time. The reference year of each figure therefore depends on its source and is not necessarily 2022, and several figures have since been revised or superseded by later releases. For Rwanda, Malawi, and Bangladesh, the access rates are those of the country scenario descriptions of the Global Electrification Platform (ESMAP, 2021), which cite the energy access database of the International Energy Agency. For Ecuador, the access rates and the consumption are those of the World Development Indicators of the World Bank (World Bank, 2022a). The results should be read as a diagnosis of each country's position as it could be observed in 2022, not as a description of current conditions.

Table 1. Summary of the four country applications [3]. Country figures reflect the data available at the time of the analysis (2022); reference years vary by indicator and source.

Country	***Access rate (national / rural)***	***Sufficiency***	***Effectiveness***	***CAPEX to 2030 (USD million)***	***Net operating cash flow to 2030 (USD million)***	***Main external financing (USD million)***	***Tariff design and cross-subsidy***
Rwanda	35% / 23%	62%	81%	1,462	1,427	Grants 300; commercial debt 240; equity 200	Indexation to inflation; 10% surcharge on commercial and industrial tariffs
Malawi	18% / 10%	11%	32%	4,059	788	Grants 1,600; commercial debt 1,620; equity 800	Indexation to inflation only; no cross-subsidy
Bangladesh	85% / 78%	72%	55%	4,409	10,789	Grants 200; commercial debt 210; equity 150	Indexation to inflation; 50% surcharge on commercial and industrial tariffs, declining to zero by 2030
Ecuador	99% / 97%	45%	43%	525	348	Concessional debt 220	Indexation to inflation; 5% surcharge on highest-consumption users

[3] For Rwanda and Malawi, net operating cash flow includes external subsidies to the distribution segment. Effectiveness scores come from the expert questionnaire; the Annex reports the scores by IDF principle.

3.2 RWANDA: LOW ACCESS ALONGSIDE A BROADLY FEASIBLE FINANCING PATH FOR 2030

Rwanda is the clearest example in the sample of a low-access country whose financing problem is demanding but solvable. According to the data available at the time of the analysis, national access was only 35% and rural access just 23%. The population is mostly rural, and average electricity consumption was very low, at 55 kWh per capita per year. On a simple access reading, Rwanda would appear very far from universal access. The EAI gives a more complete picture. Its sufficiency score reaches 62%, which is high relative to its access level and clearly above the weaker African case in the sample.

The business plan explains why. The electrification path requires about USD 1.46 billion of CAPEX up to 2030. This is still a major effort. The amount is equivalent to seven times the opening value of existing assets (property, plant, and equipment, PP&E) and ten times average operating cash flow during 2021–2030. Yet the plan is not built on grants alone. Net operating cash flow reaches USD 1.427 billion by 2030. Grants add USD 300 million, commercial debt adds USD 240 million, and equity adds USD 200 million. The transition is also relatively short: operating cash flow turns positive after only two years, and the cumulative funding gap to be bridged before that point is only USD 30 million. A short and shallow negative-cash-flow phase matters because it limits the working-capital and bridge-financing burden the sector must carry before revenues can cover ongoing costs. As the next paragraph makes clear, however, that early turn to positive cash flow rests in part on subsidies to the distribution segment. It should therefore be read as conditional support for feasibility rather than evidence of stand-alone bankability.

Rwanda also shows clearly that tariff design is part of the financing design, not a secondary detail. The plan assumes that the regulated tariffs are indexed to inflation: they rise each year with inflation, that is, they stay constant in real terms. Commercial and industrial consumers also pay a surcharge of 10% on their tariff. In other words, part of the rollout is supported through an explicit cross-subsidy inside the tariff system. At the same time, the plan still relies on external subsidies to the distribution segment, which are included in the operating cash flow. The important point is therefore not that Rwanda can electrify without public support. The important point is that support, internal cash generation, debt, and tariff design are combined in a way that makes the business plan look conditionally workable. The business plan of Rwanda shows that a low access rate does not by itself make universal access impossible to finance.

Rwanda has the highest reported effectiveness score in the sample (81%), although the assessment is based on a single expert response. The main finding is the contrast between the integration of on- and off-grid solutions (96%) and financial viability (69%). The respondent gives high scores to the least-cost electrification plan and the monitoring of its targets. However, the three questions on cost recovery, which assess financial viability after accounting for public support, each receive three out of five. The existing business models for mini-grids and stand-alone systems also receive relatively low scores under the universal access principle. These results suggest that integrated planning was more developed than the business models and cost-recovery provisions needed to sustain service across all three electrification modes.

This distinction matters when interpreting the business plan. The plan assumes subsidies to the distribution segment and USD 200 million in private equity, but these financing assumptions do not establish whether the necessary contractual and regulatory conditions were in place. The respondent gives one out of five to the combined question on unbundling and private participation in distribution, while assigning five out of five to the regulatory framework and the conditions for a distribution concession. These responses should not be interpreted as evidence of a general barrier to private investment. Rather, they raise a more specific question: whether the proposed financing structure could be implemented through financially viable business models for each electrification mode.

3.3 MALAWI: INSUFFICIENT EFFORT AND A PLAN THAT IS NOT FINANCEABLE FOR 2030

Malawi sits at the opposite end of the spectrum. Like Rwanda, Malawi starts from a low access rate, but here the sufficiency gap is much larger, and the effectiveness score is also low. The data available at the time of the analysis reported national access at 18% and rural access at only 10%, with GDP per capita of USD 395 and inflation of 9.5%. The country therefore enters the analysis not only with a large access gap, but also with much weaker public finances than Rwanda.

The sufficiency result captures that weakness immediately: the score is 11%. The effort observed was far below the level that would be required for a plan to reach universal access by 2030.

The financing structure confirms that conclusion. Up to 2030, the business plan requires about USD 4.06 billion of CAPEX, but internal net operating cash flow contributes only USD 788 million. The plan therefore relies heavily on external support: grants of USD 1.6 billion, commercial debt of USD 1.62 billion, and equity of USD 800 million. Cash flow only turns positive after five years, and cumulative negative operating cash flow reaches USD 564 million before that point. CAPEX is forty-six times the opening value of existing assets (PP&E) and fifty-one times average operating cash flow during 2021–2030. This is a much more stressed financing profile than Rwanda's.

What makes Malawi especially important is that the problem goes beyond the ratio itself. The business plan prepared for the index shows how large the task is. To reach universal access, Malawi would need 6.3 million new connections and about USD 5.9 billion of CAPEX between 2021 and 2040. Of that amount, USD 4.06 billion falls before 2030, which is the figure in Table 1. The national strategy of Malawi has a lower target: 60% access by 2030. To meet that target, the strategy planned 1.5 million connections and about USD 930 million up to 2030 (Government of Malawi, 2019). The CAPEX of the business plan before 2030 is more than four times the USD 930 million of the national strategy. Universal access by 2030 therefore requires much more investment than the national strategy planned.

The financing side is equally clear. Between 2021 and 2040, grants and government subsidies would provide more than 60% of the money the plan needs. Most of this support is the subsidy to the distribution segment, which is counted inside the net operating cash flow. The proposed financing structure cannot be considered bankable merely because the model allocates substantial amounts

to commercial debt and equity. Mobilizing that capital would require credible commitments to recover the system-wide revenue requirement through tariffs, cross-subsidies, and public support. Under the regulatory and financing conditions assessed in 2022, those commitments were not sufficiently established to support the proposed investment at scale. This is the clearest case in the sample where the first and second dimensions of sufficiency point in the same direction. Malawi was not only spending too little. Under the conditions observed at the time of the analysis, the implied plan to reach universal access by 2030 was also not financeable.

Malawi has the lowest effectiveness score in the sample (32%), based on three expert responses. Within the universal access and integration principles, the highest scores concern the national electrification strategy and the political priority given to universal access. However, these contrast with much weaker scores for the conditions needed to implement and sustain that strategy. The focus on development scores only 16%, with all three experts giving one out of five to incentives for reliable supply and demand growth. Financial viability also scores poorly (33%), particularly on the funding of the financial plan, cost recovery for stand-alone systems, and the allocation of power-sector funding to distribution. These results suggest that the weaknesses extend beyond insufficient investment to the business models and incentives needed to sustain electricity service.

The scores for universal access (40%) and the integration of on- and off-grid solutions (41%) reveal additional weaknesses in implementation. In particular, the experts give low ratings to the assignment of default- and last-resort-provider responsibilities and to the monitoring and enforcement of electrification targets. Contemporaneous sector evidence supports these concerns. In 2022, the World Bank reported that ESCOM's average tariff did not cover its cash-flow requirements and that the utility lacked borrowing capacity (World Bank, 2022b). Although the mini-grid framework adopted in 2020 allowed tariffs above the uniform national tariff to recover efficient costs (MERA, 2020), the experts still rated the existing business models for all three electrification modes below three out of five. Malawi therefore illustrates how insufficient investment can coexist with regulatory and institutional weaknesses that additional financing alone would not resolve.

3.4 BANGLADESH: A STRONG REVENUE BASE SUPPORTS FEASIBILITY

Bangladesh is the strongest case in the sample from the point of view of sufficiency. According to the data available at the time of the analysis, national access was already 85%, with rural access at 78%, but the country still faced a large absolute challenge because of its population size. The relevant point is therefore not that the remaining gap is small. It is that the financing structure supporting the path to universal access is much stronger than in the other cases. The sufficiency score reaches 72%, the highest in the group.

The main reason is the revenue base. CAPEX to 2030 reaches USD 4.409 billion, but operating cash flow reaches USD 10.789 billion. External support is comparatively small: USD 200 million of grants, USD 210 million of commercial debt, and USD 150 million of equity. The plan has no period of negative operating cash flow. CAPEX is only 0.4 times the opening value of the existing assets (PP&E) and four times average operating cash flow during 2021–2030. In practical terms,

Bangladesh is the case where internally generated cash flow, rather than external support, covers most of the financing requirement—the configuration that makes a financial plan self-sustaining and bankable.

The tariff assumptions reinforce that result. The plan includes tariff indexation for all users and a strong cross-subsidy from commercial and industrial consumers: a tariff surcharge of 50% at the start of the period, which then declines gradually to zero by 2030. This is the strongest tariff redistribution mechanism in the sample. It shows how a broader and stronger connected base can make a material difference to feasibility.

Bangladesh therefore shows that the level of electrification does not determine sufficiency mechanically. Bangladesh does not have the highest access rate in the sample. Ecuador does. But Bangladesh has the strongest sufficiency outcome because its business plan rests on much stronger internal cash generation and a tariff structure with greater capacity to cross-subsidize new customers from the existing ones.

Bangladesh has an effectiveness score of 55%, based on two expert responses. The highest ratings concern the political priority of universal access, the institution responsible for its implementation, and the regulatory framework. However, the six questions concerning mini-grids and stand-alone systems receive scores of three out of five or lower. These include the existing business models, cost recovery for mini-grids, and standards and national programs for stand-alone systems. Although the integration of on- and off-grid solutions is the highest-rated principle (63%), the results suggest that institutional responsibility for electrification was more clearly established than the regulatory provisions for decentralized service.

The focus on development receives the lowest score (48%), with both experts assigning two out of five to incentives for reliable supply. This raises a separate concern about the conditions needed to sustain electricity service after connection. The off-grid results also require caution, as the two experts differ by two points on four of the six questions. Nevertheless, the assessment identifies a distinction that the financial plan alone cannot establish. Bangladesh's strong projected cash generation supports the financing of the overall electrification program, but it does not demonstrate that financially viable business models and adequate regulatory provisions were in place for every electrification mode.

3.5 ECUADOR: NEAR-UNIVERSAL ACCESS, WHERE THE LAST MILE IS A POLITICAL AND REGULATORY RATHER THAN A FINANCIAL CONSTRAINT

Ecuador is the country in the sample that is closest to universal access. The electricity master plan of Ecuador reported a coverage of 97% in 2018 (MERNNR, 2019). The World Development Indicators of the World Bank, which are based on household surveys, report a national access rate of 99% in 2020, with 100% in urban areas and 97% in rural areas. The same source gives an average electricity consumption of 1,376 kWh per capita per year in 2014, much higher than in the other cases (World Bank, 2022a). On a conventional access reading, Ecuador looks almost complete. The

EAI shows why that reading is incomplete. Its sufficiency score is only 45%, which is well below Bangladesh and also below Rwanda, despite Ecuador's far higher access rate.

The reason is not that Ecuador faces the same type of challenge as Malawi or Rwanda. It does not. The remaining cost is modest in absolute terms and well within the sector's means. CAPEX to 2030 reaches only USD 525 million, and net operating cash flow already contributes USD 348 million. The rest of the cost, together with the other cash outflows of the business plan, is covered with USD 220 million of concessional debt. No grants, equity, or commercial debt are required in the baseline plan. Operating cash flow is positive from the outset. The high ratio of CAPEX to operating cash flow (about fifteen times the 2021–2030 average) reflects the low remuneration of the remaining users rather than any system-level financing shortfall. In other words, the last mile can be financed. What it requires is a decision on how its costs are recovered.

Tariff policy again forms part of the financing design. Ecuador's plan assumes tariff indexation for all users and a 5% surcharge on the tariffs of the highest-consumption categories. This is a smaller redistributive effort than in Rwanda or Bangladesh, but it is the key to the case. Ecuador's large, high-consumption connected base gives it ample room to recover the residual cost through cross-subsidies without a large increase for any consumer group. The financing instrument is therefore available; what remains open is whether the government and the regulator decide to use it. The revenue from the remaining users does not cover the cost of serving them, but in Ecuador the customers already connected can pay the difference.

Ecuador has an effectiveness score of 43%, based on two expert responses. The assessment reveals a contrast between the existence of an electrification strategy and the rules governing service provision for the remaining households. The national electrification strategy and the rules for grid extension each receive four out of five. However, the question on default- and last-resort-provider responsibilities averages only 1.5 out of five. Both experts also give one out of five to standards and national programs for stand-alone systems and to the rules governing transitions between electrification modes. As a result, the integration of on- and off-grid solutions scores only 38%. These findings suggest that the rules for assigning service responsibilities and coordinating electrification modes were less developed than those governing conventional grid extension.

Financial viability also receives a low score (36%), although its lowest-rated question combines unbundling and private participation in distribution and cannot, by itself, establish a lack of financing capacity. The financial plan indicates that the remaining electrification costs could be covered through the assumed tariff structure and concessional borrowing. The effectiveness assessment identifies a separate concern: whether the regulatory framework clearly assigns responsibility for serving the remaining households and provides adequate rules for stand-alone systems and transitions between electrification modes. Completing the last mile therefore requires both a decision on how this costs are recovered and clear obligations for the entities responsible for providing the service.

4 DISCUSSION

The four country applications show that neither the access rate nor the scale of the remaining investment requirement is sufficient to assess progress toward universal electrification. In all four countries, the observed effort falls short of what would be required to achieve universal access by 2030. Bangladesh has the highest sufficiency score (72%), followed by Rwanda (62%), Ecuador (45%), and Malawi (11%). These differences cannot be explained by access rates alone. Ecuador, with 99% access, has a lower sufficiency score than Rwanda, where access was only 35%. Rwanda and Malawi also face large access gaps, but their financing requirements and capacity to meet them differ substantially.

The business plans explain these differences. In Bangladesh, projected net operating cash flow to 2030 is 2.4 times the required CAPEX, and the plan relies comparatively little on external financing. Rwanda's projected net operating cash flow is equivalent to 98% of CAPEX, but it includes external subsidies to distribution. In Ecuador, the remaining investment requirement is comparatively small and could be covered under the assumed tariff structure and concessional financing. Malawi presents the most difficult financing conditions: projected net operating cash flow represents only 19% of CAPEX, even after accounting for external subsidies, and the plan requires substantial grants, debt, and equity. The cross-subsidies also differ. The surcharge on commercial and industrial tariffs is 50% in Bangladesh, declining to zero by 2030, and 10% in Rwanda. Ecuador applies a 5% surcharge to its highest-consumption users, and the business plan of Malawi has no cross-subsidy. These results show why financing feasibility depends not only on investment needs but also on the revenue available to support the plan, the tariff structure, and the credibility of external financing and public support.

The timing of operating cash flows adds another important distinction. Bangladesh and Ecuador have positive operating cash flow from the beginning. Rwanda reaches positive operating cash flow after two years, while Malawi requires five. Longer periods of negative operating cash flow increase the need for bridge financing and expose implementation to delays in public transfers and additional financing requirements. The time profile therefore matters alongside the total amount of funding required. A business plan can appear financially viable over its full horizon while facing substantial liquidity needs during the initial network rollout.

The effectiveness assessment adds a separate institutional and regulatory perspective. Across the four countries, political commitment and the existence of national electrification strategies generally receive more favorable scores than the existing business models for mini-grids and stand-alone systems. The questions concerning cost recovery for these two electrification modes receive no more than three out of five in any country. This is particularly relevant in Rwanda and Bangladesh, where the business plans offer comparatively favorable financing paths but the scores on these questions are no higher. Malawi combines insufficient effort with low scores for financial viability, reliable supply, and demand-growth incentives. Ecuador presents a different problem: the financing plan indicates that the remaining investment could be supported, while the experts identify weaknesses in service obligations and the rules governing off-grid electrification.

The effectiveness results identify potential weaknesses rather than establish their effects on actual electrification outcomes. Nevertheless, they demonstrate the value of assessing financing requirements and implementation conditions separately. A financially plausible plan does not establish that the regulatory and institutional conditions required to implement it are in place.

The four applications therefore support a country-specific diagnosis. The EAI identifies whether the present effort is sufficient and which aspects of the financial plan, regulation, and business models require further examination. It does not determine which regulatory or financing instruments a country should adopt. That requires a detailed assessment of the implementing entities, their obligations, and the financial commitments that can be made under the country's conditions.

5 CONCLUSION

This paper has applied the Electricity Access Index to answer two questions about universal electrification: whether the current financial effort is sufficient to achieve universal access by 2030, and whether the regulatory and institutional conditions are adequate to sustain electricity service. The four country applications show that neither answer can be inferred from the access rate alone.

The first finding is that the observed electrification effort was insufficient in all four countries under the conditions assessed in 2022. The sufficiency scores range from 11% in Malawi to 72% in Bangladesh. However, the financial implications differ substantially. Bangladesh has a comparatively strong revenue base, while Rwanda's financing path depends in part on external subsidies. Malawi faces a much larger financing requirement relative to its available resources and, under the conditions assessed, does not have a financeable plan to achieve universal access by 2030. Ecuador illustrates a different situation: the remaining investment could be financed under the modeled assumptions, but its implementation requires decisions on how the costs of providing the service to the remaining households are recovered and allocated.

The second finding concerns the conditions under which electrification is implemented. The effectiveness assessment identifies weaknesses that are not apparent from the financial plans alone. In particular, the questions concerning cost recovery for mini-grids and stand-alone systems receive scores of three out of five or lower in all four countries. The overall effectiveness scores range from 32% in Malawi to 81% in Rwanda, although the small number of expert responses limits their interpretation. These results suggest that progress in planning and financing does not necessarily extend to the business models and regulatory design required for sustainable service across all electrification modes.

The analysis also highlights the difficulty of measuring electrification effort consistently at country level. Public data remain fragmented, particularly for distribution investment, off-grid provision, and operating expenditure. This limits the ability to compare actual expenditure with the requirements of a complete electrification plan and to monitor progress over time.

The contribution of the EAI is therefore diagnostic. By assessing sufficiency and effectiveness separately, it helps identify the problem that each country faces, which the access rate does not show. Rwanda and Malawi, both in Sub-Saharan Africa and both with low access rates, show that

a regional aggregate cannot replace that diagnosis. The results provide a starting point for country-specific regulatory and financial analysis, rather than a substitute for the detailed design of an implementable electrification program.

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ANNEX

DETAILED DESIGN OF THE ELECTRICITY ACCESS INDEX

A.1 SUFFICIENCY COMPONENT

The elaboration of the index requires the development of a business plan to finance the electrification plan that can achieve universal access in the country by 2030. In some countries the electrification plan is the existing national electrification strategy. In other cases, it has been obtained from publicly available studies performed by development organizations—such as the World Bank's Global Electrification Platform using the OnSSET model—or from the authors' own analysis with the Reference Electrification Model (REM).[4]

The business plan is critical for one reason. An electrification process that aims at universal access in less than a decade, starting from a large access gap, requires very large investments in assets with long economic lives within a short period. Regulated tariffs recover those costs slowly, even when they are designed on a cost-reflective revenue requirement, and more slowly when the access rate is low and the customer base is small. This lack of synchronism or time offset between costs and revenues creates financial needs. When tariffs remain below cost recovery, or revenue collection has significant gaps, the business model is stressed and becomes non-viable in some countries. This is a key indicator that the business plan can detect. In other countries, the business plan absorbs this time offset without much difficulty. It returns to balance a few years after 2030, with a cost-reflective revenue requirement and a capital structure that stabilizes at sustainable leverage ratios.

For the sake of homogeneity, so that the results could be comparable, some common criteria have been adopted for all the techno-economic plans and business plans:

- Adopt the viewpoint of the government, as the ultimate responsible entity in the electrification process.
- Consider the entire distribution system, both on- and off-grid, existing and new. The techno-economic electrification plan should correspond as much as possible to the least cost mix of the three electrification modes.
- All residential customers receive at least Tier 2 service of the Multi-Tier Framework, and all commercial and industrial customers receive reliable power.

[4] See the MIT / IIT-Comillas Universal Energy Access Laboratory: https://universalaccess.mit.edu

- The business plan considers all costs (including the costs of maintenance and replacement of assets) and all revenues of the distribution activity.
- When the latest financial statements of the distribution utilities are available, this becomes a primary information source of the business plan.
- As the business plan extends over a 20-year horizon, all assets must be replaced at the end of their economic lives.
- The current regulated tariff structure (i.e., breakdown into consumer types) of grid-connected customers is assumed to continue over the entire horizon of the business plan, although the numerical values can evolve over time. Mini-grid customers are charged the same tariff as grid consumers. Stand-alone system users are charged the average Rural Household Energy Consumption equivalent.
- Grants from DFIs to governments are linked to the deployment of CAPEX and recognized in the profit and loss account as revenues, whereas subsidies from the Government can be used without restrictions.
- The time horizon of the business plan has been divided into two periods. The first one covers the interval from the present time to 2030, when universal access is assumed to be achieved. This is a period of heavy investment and with the revenues from the tariffs gradually growing, as more people are supplied with electricity. During the second period, the decade following the universal-access target year, investments are only needed to cope with the increment in demand due to population and demand growth, as well as to replace assets that reach the end of their economic lives.
- The design of the financial plan must balance several factors: the distribution of the investments during the first period (until 2030), which customers to supply first, the evolution of the tariffs over the whole horizon of the business plan, the limits that the sovereign debt of the country may impose, the mix of financial resources, and the parameters of each financial instrument. The business plan must maintain acceptable values of the key financial ratios so that it is possible to raise the capital necessary for the electrification plan until 2030. Finally, the business plan must attain a stable financial condition by the end of the second period or earlier, whereby the annual expenditures, the regulated revenue requirement from all the distribution activities and the revenues from the regulated tariffs tend to converge.
- The total amount to be financed must be calculated over the financial projections period. It includes three items: the operating cash flow until the business plan becomes cash-flow positive and starts to fund the electrification CAPEX, the investment plan up to 2030, and the cash outflows for interest and taxes under the proposed capital structure. The three items are computed as shown in Figure 4.

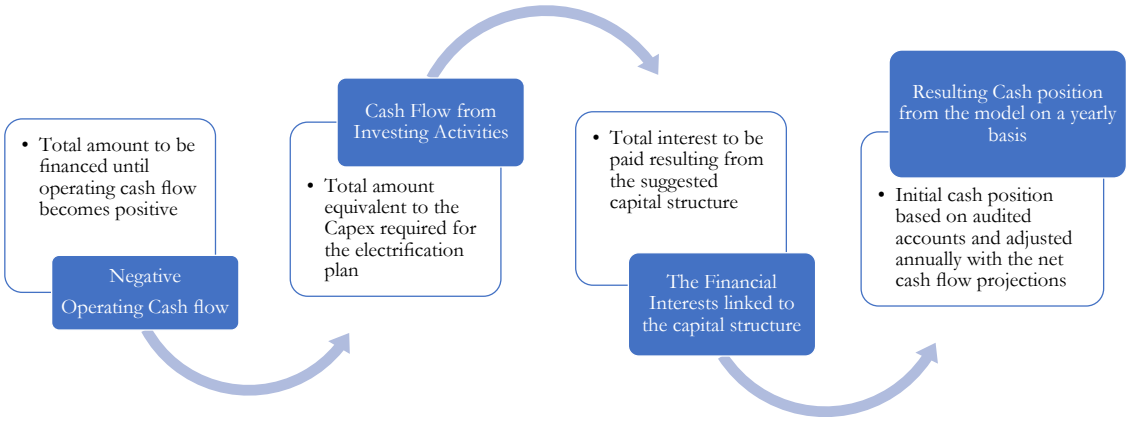

Figure 4. Term-by-term determination of the total amount to be financed. Source: (Pérez-Arriaga et al., 2022).

Other more technical aspects in the elaboration of the financial plan are:

- The iterative adjustment of parameters in the financial plan must be carried out noticing that the different components (Debt/Equity/Grants) are interrelated and conditioned to each other. In each iteration, some key financial ratios are analyzed to make a first assessment of the optimal capital structure and maximum amount of debt (corporate/commercial) that the business plan can tolerate.
- Government support is critical for several reasons: respect for the regulatory framework, subsidies where they exist, grants, and the channeling of DFI financing for both equity and debt. The overall impact on the Government, and the support expected from it, is therefore also analyzed.
- The most challenging component of the capital structure, both to structure and potentially to raise, is the equity (rate/governance/return and exit, if any). Additionally, both the dividend (as per market practice) and the overall return on equity are modeled and computed.

Once the business plan has been developed, it can provide two key pieces of information. In the first place, the business plan shows how much annual expenditure is presently needed to be on the right path to meet the SDG 7.1 target. This is the amount that goes into the denominator in Figure 1.

In the second place, the business plan can be presented to experts in the evaluation of large infrastructure projects in developing countries, who assess its overall viability. After examining the business plan and the additional information provided, each expert classifies the financial viability of the business plan into one of five categories: (1) impossible; (2) very difficult, but not impossible; (3) difficult; (4) possible, with some difficulties; (5) viable.

The information that must be provided to the experts for the evaluation is listed below.

Information that is provided to the expert evaluators

For each considered country, the following information is provided in a separate file:

- Relevant general information on the country:
    - Total population, broken down into urban and rural. National electrification rate, and the individual rates for rural and urban populations.
    - Average electric consumption per household and per capita.
    - GDP present value and rate of growth, inflation rate, and sovereign credit ratings, as well as the World Bank's Ease of Doing Business index.
    - Total value of the assets of the power distribution segment.
- The ratio (in percentage) of the present electrification effort to the effort that would be needed.[5]
- Summary Table of Financing Sources and Uses
    - Internal sources of financing:
        - Collected revenue from the regulated tariffs, which may include cross-subsidization among categories of consumers.
    - External sources of financing:
        - Grants based on DFIs funds to Government, typically linked to the deployment of the CAPEX of the electrification plan.
        - Concessional Debt from DFIs.
        - Subsidies from the Government (bailouts to the distribution segment).
        - Commercial debt.
        - Equity.

The information provided must differentiate two periods: i) the first one covers the initial years, until the operating cash flow becomes positive; ii) the second one covers the subsequent period until 2030, when the heavy investments necessary to achieve the universal access goal stop and are followed by a period where the need for financing new investments is significantly reduced.

[5] This is the first element that is needed to compute the sufficiency component of the index. For each country, the numerator is computed from actual data in the annual reports of the utilities, complemented with other databases with information on off-grid solutions. The denominator is obtained from national electrification strategies (when they exist and are SDG 7 compatible) or standard electrification plans in the World Bank databases.

- Key financial ratios of the business plan

From a financial perspective, the evolution of the ratios is of most interest until 2030, when the heavy investments associated with the electrification plan stop. However, the second period, after the heavy investment phase, is also of interest to understand how the financial situation evolves towards a state of equilibrium between the annual revenues from regulated tariffs and the annual incurred costs. The provided ratios are:

  - EBITDA / (Interest + repayment)
  - (EBITDA + CAPEX) / (Interest + repayment)
  - Subsidized & concessional debt / EBITDA
  - Commercial & corporate debt / EBITDA
  - Total debt / EBITDA
  - Net debt / EBITDA
  - EBIT / Financial interest
  - EBIT / (Equity + Net debt)
  - Net Operating Profit After Tax / (Equity + Net debt)
  - Net income / Equity
  - Total debt / Property, Plant, and Equipment (in %)

- **Other information from the business plan**

  - Total CAPEX of the electrification plan over Property, Plant and Equipment (PP&E) at the beginning of the considered period (2021). Same over Average Cash Flow during the 2021–2030 period.
  - Period until EBITDAs become positive (both timing and quantum). Same for the cash flow.

A.2 EFFECTIVENESS COMPONENT

The effectiveness component is computed via the results of a questionnaire, based on 34 items, which are divided among the four principles of the Integrated Distribution Framework: universal access, integration of on- and off-grid solutions, financial viability, and focus on development. For each country, the questionnaire is sent to several country experts, looking for a balance of the different perspectives that may be present in the country by engaging experts from public

institutions, utilities and the private sector. Experts are asked to evaluate the institutional and regulatory framework in the country, assigning a score from one to five to each item.

The scores from different experts are averaged to define a final score for each item. Items are all given the same weight, thus the score for each principle is obtained by simply averaging the scores of the items corresponding to that principle. Finally, the overall compliance with sound electrification principles is obtained by averaging the scores of the four principles and translating the score from one to five into a percentage, as shown in Figure 5. In this figure, the four principles carry the labels of the original working paper: universality, integral plan, viability, and development. The percentage is the average score minus one, divided by four: a score of one corresponds to 0% and a score of five to 100%.

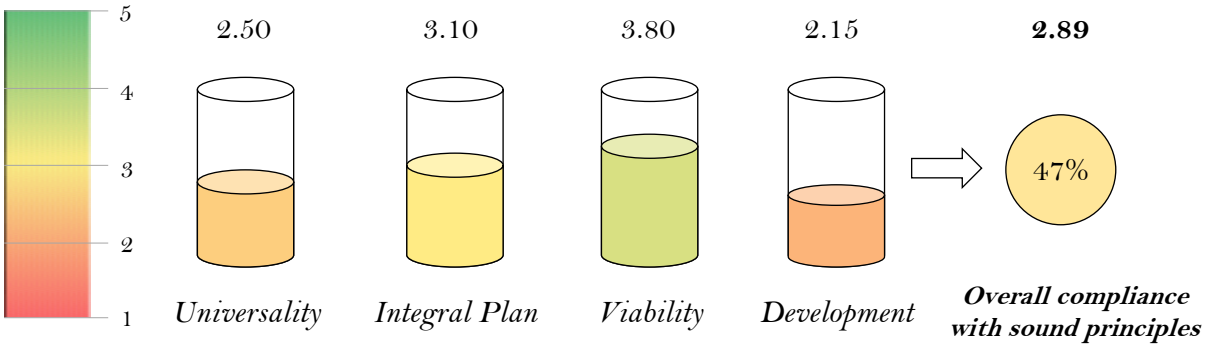

Figure 5. Example of the results of the effectiveness component of the Electricity Access Index. Source: (Pérez-Arriaga et al., 2022).

Table 2 reports the effectiveness scores of the four country applications, by principle. Country experts answered the questionnaire in 2021 and 2022: one expert in Rwanda, three in Malawi, two in Bangladesh, and two in Ecuador. With this number of responses, each score depends on the judgment of those experts and is indicative. The overall score is the average of the four principle scores before rounding.

Table 2. Effectiveness scores of the four country applications, by principle. Source: authors, from the expert questionnaires answered in 2021 and 2022.

Country	***Universal access***	***Integration of on- and off-grid solutions***	***Financial viability***	***Focus on development***	***Overall score***
Rwanda	78%	96%	69%	79%	81%
Malawi	40%	41%	33%	16%	32%
Bangladesh	60%	63%	51%	48%	55%
Ecuador	49%	38%	36%	48%	43%

The remainder of this annex presents and justifies the principles of the Integrated Distribution Framework (IDF). Then it presents the 34-item questionnaire that country experts must fill in. Each item of the questionnaire has an introductory statement defining the topic, and a set of sub-questions. The experts can also provide comments for any of the topics.

A.2.1 UNIVERSAL ACCESS

The principle of universal access requires that some entity, or combination of entities, makes sure that all customers in a territory receive at least a minimum level of service[6] and reliability. The service can combine on- and off-grid solutions. Some entity must accept the role of default supplier, responsible for ensuring that nobody is left without service. The same or another entity must accept the role of last-resort supplier, responsible for providing the service if a previous supplier fails to do so. If these roles and responsibilities are not clearly defined, as often happens, the electrification initiative may stop after a few years. The usual causes are the absence of maintenance, funding, or management, or the lack of anyone to repair, replace, or upgrade the equipment when demand grows.

In practical terms, ensuring the universality conditions laid out above requires a long-term contract, such as a concession, that secures the permanence of supply. These long-term contracts can be established through a tender or via direct negotiation between the government and the potential project developers. The selected company (or companies) would commit to supply some prescribed level of electricity access to all customers and should also accept the role of last-resort provider in the assigned area, being paid the corresponding cost for this service.

These agreements should encompass all areas where the population without electricity access lives. This requires a strong commitment from the government, which should also pursue the engagement of local communities to define the service level and its characteristics. This commitment must be further backed by key development partners and embedded in a lead ministry or public agency that can guide the efforts of the many entities that will be involved.

A.2.2 INTEGRATION OF ON- AND OFF-GRID SOLUTIONS

Within the population lacking electricity access in a certain country, very different conditions can be found, in terms of distance from the network, geography of the territory, or economic development. Therefore, a sound electrification plan must consider different electrification modes (grid extension, mini-grids, and stand-alone systems) that could best fit each one of these conditions. The most efficient combination of these electrification modes should be determined with a GIS-based optimization tool. The tool should be able to internalize preferences or constraints that go beyond economic aspects, such as those that could be raised by local communities or public institutions.

The outcome of this exercise should be a techno-economic plan that provides two things. The first is a roadmap for investments and project implementation that meets the electrification targets at least cost. The second is an estimate of the cost of supply, including both capital and operating expenditure, with a yearly granularity. The financial plan needs this estimate as an input to calculate regulated tariffs and to assess the need for subsidies.

[6] There are different methodologies to define service level in electrification programs (Bhatia and Angelou, 2015). In any case, the level of electricity demand should reflect a basket of basic services (which are context-dependent), but it should also consider affordability issues.

An efficient integration of different electrification modes also requires a certain degree of coordination among them, especially at the regulatory level. Decisions should be taken on the boundaries of each electrification mode and what happens when two modes meet, as when the main grid eventually reaches an area covered by a mini-grid (Tenenbaum et al., 2018). A lack of clarity on these aspects may increase the risk perceived by the entities involved and hamper investments.

Turning a geospatial plan into reality raises further challenges. They concern the design of remuneration rules for each electrification mode, the management of interfaces between modes, provisions for default and last-resort service, and the integration of the electrification modes as demand changes over time.

A.2.3 FINANCIAL VIABILITY

A sound electrification plan should be able to attract private partners who can mobilize investment capital, take advantage of advanced technologies, and bring technical and managerial expertise. These entities will show interest only if the financial viability is ensured for all the electrification modes considered by the electrification plan. This requires the signature of long-term agreements based on a regulated revenue requirement that encompasses all the costs faced by these companies. The revenue requirement should be computed through the cost-of-service method commonly used in monopoly regulation, with the application of some performance incentives[7]. Deviating from this basic regulatory approach increases the cost of capital, deters investment, and compromises the quality of service.

While the regulated revenue requirement should include all costs, the same is not true for end-user tariffs, which could internalize any sort of consumption subsidy. For instance, in some contexts, the regulation imposes the application of uniform tariffs in the entire national territory, and this would apply also to the new connections resulting from the electrification plan, regardless of the costs actually incurred. Consumption subsidies are legitimate and, in many cases, essential to overcome affordability problems. What matters is that any difference between the revenue requirement and the amount to be collected through tariffs is covered through a specific subsidy budget and paid to the company in charge of electrification. This budget may come from the government or international institutions, or it can be raised through cross-subsidies.

A.2.4 FOCUS ON DEVELOPMENT

The ultimate goal of universal access is not to connect consumers, but rather to provide electricity as a facilitator of social and economic development. For the electrification plan to bring socio-economic benefits, a top-down approach has to be complemented by the bottom-up participation of electricity end-users. Entities such as non-governmental organizations (NGOs), foundations, and cross-sector agencies have important roles to play in the definition of the electrification plan (Batidzirai et al., 2021), which should reflect the priorities of local communities. Public institutions

[7] These performance incentives may focus on service quality, customer services, or billing efficiency.

should promote these customer-engagement activities through specific participation processes or by including dedicated clauses in the long-term agreements.

There are several aspects that could help align the electrification plan with the social development of the newly connected territory. Access to electricity does not by itself lead to productive uses of electricity in rural communities (Johnstone, 2019). The electrification strategy should include specific initiatives to facilitate the purchase of efficient appliances, foster the creation of small enterprises, or promote capacity building. The electrification plan should also include community services, such as the supply of electricity to schools, hospitals, or water treatment facilities. Finally, the electrification strategy must consider a gender perspective. Women are disproportionately affected by the lack of access to electricity. There is also growing awareness that women can play an essential role in the effectiveness of the electrification plan and in its social impact (Dutta et al., 2017; Winther et al., 2020). This could be reflected in the electrification strategy through specific assessments or initiatives targeting, for instance, female-led households.

A.3 FULL QUESTIONNAIRE SENT TO COUNTRY EXPERTS

The questionnaire is displayed in the following pages. Each item of the questionnaire has an introductory statement defining the topic, and a set of sub-questions. Experts can also provide further comments beyond raw scores.

A.3.1 UNIVERSAL ACCESS

Do the existing policy, regulation, institutions, and business models make sure that everyone will have an adequate electricity supply on a sustainable basis?

nº	Question	Score (1 to 5)
1	*Priority from a political perspective.* Is universal electricity access a **political priority**, as compared with other important needs of the power sector and other economic sectors? Other needs of the power sector may include electricity supply for industrialization, improvement of the quality of service in urban centers, transmission interconnections, and the development of large generation plants for exports."	
2	*A sufficient level of access, which may be context dependent, will be guaranteed for all.* Is there a **national electrification strategy** with a **minimum access target** that at least: meets some reliability and quality requirements, is being followed or at least somehow enforced, used as a guide, and updated as needed? These targets may be context-adapted (e.g., tailored for urban, rural, and isolated communities, etc.).	
3	*Attention paid to specific categories of consumers.* Does the national electrification strategy include special provisions for informal settlements, vulnerable households, and female-headed families?	

4	*Existence of a competent local entity in charge of achieving universal access, i.e., nobody is left behind.* Is there a **national champion** institution that has been given the responsibility to **achieve universal access**, with executive power and the technical competency to accomplish this mission, and the technological, human, and financial resources to do it?	
5	*The business model for grid extension is adequate for discos to do their part of the electrification plan.* Is the existing regulatory and **business model *for grid extension* adequate to supply demand for everyone** according to an electrification strategy as defined previously, on a permanent basis (i.e., in a financially sustainable regime)?	
6	*The business model for mini-grids is adequate for mini-grids to do their part of the electrification plan.* Is the existing regulatory and **business model *for mini-grids*** adequate to supply demand for everyone according to an electrification strategy as defined previously, on a permanent basis (i.e., in an economically sustainable regime)?	
7	*The business model for stand-alone systems is adequate to do their part of the electrification plan.* Is the existing regulatory and **business model *for stand-alone systems*** adequate to supply demand for everyone according to an electrification strategy as defined previously, on a permanent basis (i.e., in an economically sustainable regime)?	
8	*Full electrification needs a default provider: one that must supply where others would not – and a last resort provider: one that will take over supply where others have failed or quit.* Does the regulation explicitly include the roles of **default provider** and **last resort provider**?	

9	*The adopted regulation and business models must avoid resulting in a disorganized multiplicity of suppliers, technical standards, and contractual arrangements that will be difficult to coordinate in the future.* Are the present power sector structure and regulation and the national electrification strategy consistent with a **sound long-term vision** of the power sector in the considered country? Is electricity supply in the hands of "utility-like" entities?	
Comments:		

A.3.2 INTEGRATION OF ON- AND OFF-GRID SOLUTIONS

Is there a national electrification strategy to be followed by an actionable plan that integrates all electrification models in an efficient manner, is supported by adequate regulation and business models, and is accepted by decision-makers?

nº	Question	Score (1 to 5)
1	*Existence of a competent local entity in charge of taking responsibility for the development and implementation of the national electrification plan.* Is there one or more institutions responsible for the **development and the implementation of a national electrification plan**? Is this institution technically able to manage the implementation of the plan, with executive power to accomplish this mission, and with the technical, human, and financial resources to do it? It is permissible that this institution consults third parties when developing the national electrification plan.	
2	*The plan must be based on least-cost principles and therefore must integrate the three modes of electrification.* Has the electrification plan been established following a **least-cost criterion**, employing GIS-based approaches, **considering all electrification modes** and the future transitions among them, subject to clearly specified objectives and constraints?	
3	*The development of the distribution segment must be consistent with other actions in the other segments of the power sector to achieve an efficient and reliable electrification target.* Is the electrification plan aligned with a **comprehensive power system development strategy** including generation, transmission, distribution, and off-grid development?	

4	*The electrification strategy and/or plan must be followed to be effective.* Is there a formal procedure of **monitoring and enforcing** targets concerning the **mix of electrification modes** that results from the electrification plan or strategy? Are these targets legally binding? Are electrification development partners' endeavours coordinated under the guidance of the national electrification strategy and/or plan?	
5	*The regulatory and financial environment should be able to attract mini-grid developers.* Are private developers of mini-grids **allowed to install, charge for, and operate** their facilities? Are there national programs which aim to develop mini-grids or support the development of mini-grids? Are there **licensing or authorization procedures for mini-grid operators**? Is there any regulation establishing the tariffs – or limits to the tariffs – for customers of mini-grids? Does the regulation consider any capacity thresholds or simplified procedures (e.g., depending on the technology or size of the mini-grid, etc.)? Are the procedures streamlined to facilitate the deployment of off-grid solutions, reduce administrative waiting times, and facilitate the procurement process?	
6	*The regulatory and financial environment should be able to attract stand-alone system developers.* Is there regulation requiring minimum quality standards for stand-alone systems? Are there national programs which aim to deploy stand-alone systems or **support the development of stand-alone systems**?	
7	*Regulation should exist that facilitates transfers between electrification modes.* Is there regulation ensuring that **future transitions among electrification modes happen smoothly** for customers and for the electricity suppliers? Specifically: Are there technical standards (i.e., a section of the distribution grid code) detailing the requirements for installing and operating mini-grids? Does regulation exist establishing when and what will occur if the main grid reaches a mini-grid or an area with a concession to deploy solar kits? Is the interaction between interconnected mini-grids and the main grid regulated? Is there any requirement to facilitate common access (or transfer of access) of consumer data?	

Comments:	

A.3.3 FINANCIAL VIABILITY

Are the present institutional, political, social, policy, legal, and regulatory conditions adequate to do business in the country, attracting substantial private investment in the distribution segment of the power sector?

nº	Question	Score (1 to 5)
1	*Substantial private investment in a country will only happen if some fundamental conditions exist.* How **easy is it to do business** in the country? Categories that can be considered are: starting a business, getting credit, protecting minority investors, paying taxes, and enforcing contracts.	
2	*One of the critical conditions to attract private investment into the power sector of a country is legal security, which must be based on a solid record of sound regulation, both the content of the regulation itself as well as the quality of the regulatory institutions.* How sound is the **regulatory framework** in the country? Categories that can be considered are: existence of a legal mandate, clarity of roles and objectives, independency of the regulator, transparency of decisions, and predictability of the regulatory framework.	
3	*The appetite for private investment in the distribution segment should be comparable with that for other power sector investment opportunities in the country.* Is the distribution segment obtaining a **share of the total amount of funding** that the power sector presently receives that can be considered adequate, given the typical distribution of investment expenditures into generation, transmission, and distribution, as well as the lack of access to electricity in the country?	

4	*Not only the volume of investment matters; how the funds are utilized is also important.* Are current expenditures on electrification within the distribution segment of the power sector **well-employed?** The answer to this question must consider whether funds have been employed in some electrification mode when they could had been used better in a different mode, the efficiency of procurement and operation activities, the choice of minimum levels of access, the adopted minimum reliability requirements, and the incurred level of public indebtedness, among other criteria.	
5	*Private investment in the distribution segment of the power sector can only happen if it is facilitated by the country's energy policy and regulation.* Is the distribution segment **unbundled** (at least on an accounting basis) from other segments of the power supply chain? **Is some form of PSP** (private sector participation, in property, management, or outsourcing of activities) **allowed in the distribution segment**?	
6	*A distribution concession model can be a plausible approach to attracting private investment and improving overall distribution performance in a country. Are conditions in the country suitable for the implementation of a distribution concession model?*. Can the adoption of a **distribution concession model** come in the form of a PPP (public private partnership) in the considered country? Do laws governing PPP exist? Are there clear processes and institutional responsibilities for selecting PPPs? Are defined PPP models available for distribution? Are unsolicited proposals, solicited proposals, or competitive tenders for power sector infrastructure investments possible?	
7	*A SDG7.1 compliant techno-economic business plan may be wishful thinking and fail to attract investment in the absence of a business plan specifying how the electrification process can be financed in a credible way.* **Does a business plan (financial plan) exist** that makes sure that the techno-economic electrification plan of any national electrification strategy can be viable? Are the present or envisioned funding mechanisms sufficient to cover the activities specified in the electrification plan?	

8	*Many developing countries are seriously indebted, and this may pose serious limitations to procuring loans necessary for executing electrification plans.* Could issues related to **sovereign debt** constrain the amount of financing that the country can get for its electrification plan? Are financial instruments available to distribution companies that could mitigate these financial constraints, such as DFI guarantees, escrow agreements for private distribution investors, or concessional lending not limited to government-owned companies?	
9	*Private investor confidence is possible only if cost recovery is expected, either through cost-reflective tariffs or through grants and subsidies.* Is the present business model for the **grid-connected distribution** segment financially viable? Is the annual revenue collected from end customer tariffs (reduced by the amount of theft and non-paid bills) able to recover the annual total cost of supply as determined by the cost-reflective regulatory revenue requirement? Are there publicly funded mechanisms to secure viability gap funding for grid extension in rural areas (i.e., the difference between the cost reflective annual revenue requirement and the estimated actual revenue collection from end customer tariffs)?	
10	*Private investor confidence in the mini-grid activity is possible only if cost recovery is expected, either through cost-reflective tariffs or through grants and subsidies.* Is the present business model for mini-grids financially viable? Is there an established revenue requirement calculation method for mini-grids? Are mini-grid tariffs regulated under a national uniform tariff approach? In case a viability gap exists, are there publicly funded mechanisms to secure viability gap funding for operators of mini-grids everywhere they are needed?	
11	*Private investor confidence in stand-alone systems is possible only if cost recovery is expected, either through cost-reflective tariffs or through grants and subsidies.* Is the present business model for stand-alone systems financially viable? Is there an established procedure to determine the revenue requirement for electricity supply with stand-alone systems? In case a viability gap exists, are there publicly funded mechanisms to secure viability gap funding for operators of stand-alone systems everywhere they are needed? Are there regulated tariffs under a national uniform tariff approach for subsidized customers supplied by stand-alone systems?	

12	*Is there sound regulation for expanding distribution through grid extension?* Do rules exist that mandate providing connection by the DSO (distribution system operator) where it has a concession or a license to operate? Are there rules imposing penalties or the removal of distribution licenses in case of noncompliance? Is there a grid code defining system operation rules for distribution? Regarding transparency and availability of data: are the balance sheets of public utilities publicly available? Is data regarding distribution grid operations and quality publicly available? Is there a clear and publicly available procedure to get the distribution authorization/license?	
Comments:		

A.3.4 FOCUS ON DEVELOPMENT

Do the electrification plans contemplate "beyond electric supply" dimensions that facilitate human development?

nº	Question	Score (1 to 5)
1	*The economic and human development of non-electrified communities can only be achieved with electrification strategies that go beyond the supply of residential demand.* Does the plan include **productive uses** (e.g., agricultural, commercial, industrial activities, etc.)? Are the resources devoted to productive uses included in the national electrification plan sufficient in volume and tailored to the economic activity in the country/area?	
2	*The economic and human development of non-electrified communities can only be achieved with electrification strategies that go beyond the supply of residential demand.* Does the plan include **community facilities** (e.g., health centers, schools, administrative buildings, etc.)? Are the resources devoted to community uses included in the national electrification plan sufficient in volume and are they properly addressing the needs of the communities?	
3	*Most economic and community activities that are enabled by electricity access are only possible if the electricity supply meets acceptable standards of reliability and quality of service.* Does the business model for each electrification mode include incentives to provide an adequate level of reliability so that productive and community uses can happen?	
4	*Residential, commercial, and industrial customers may need some commercial and financial support and capacity building to make use of the opportunities that electricity access can provide.* Does the business model for each electrification mode include incentives to promote	

	demand growth or to support the acquisition of appliances for residential, commercial, and industrial utilization (e.g., through microfinancing schemes, etc.)?	
5	*Careful regulatory design is needed for companies in charge of each electrification mode to experience the right incentives to perform well in terms of the elimination of "commercial" losses and other aspects related to customer engagement, even if these aspects are not directly related to electricity supply (e.g., participation of women in revenue collection activities, literacy or handicraft schools, financing social activities, etc.).* Does the business model for each electrification mode include incentives to promote best practices in billing, revenue collection, and customer engagement regarding complaints and any other issues?	
6	*Universal access should promote the development of the entire society and it should pursue gender equality and the empowerment of women*. Does the electrification plan or strategy include a gender perspective? Does it consider specific instruments to provide access to female-headed households?	
Comments:		