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Proposal to achieve universal electricity access in Colombian rural isolated communities

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Working Paper
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I. EXECUTIVE SUMMARY

Colombia has a high electrification coverage, above the Latin American and Caribbean average, with 97 of every 100 homes having access to electricity. However, there are still more than 400,000 residences without access, of which more than half are located in zones adjacent to the National Interconnected System (SIN) and the rest are in Non-Interconnected Zones (ZNI), which are mostly difficult to access and where providing electricity services is expensive.

Electrification in these areas requires new business models that can make an efficient use of new technologies. This project commissioned by the Government of Colombia is an opportunity to develop these models and the legislation that will make them possible. Increased coverage must be made possible by solutions that are sustainable over time and ensure permanence of supply, are compatible with a long-term energy model and adapted to the conditions of non-interconnected zones in Colombia. The proposed focus is in line with the "Integrated Distribution Framework" proposed by the Global Commission to End Energy Poverty in its Inception Report published in September 2019.

Relevant international experience

It defines the legal framework and business models that attract private and public capital to electrify non-interconnected and relatively isolated rural zones, as is the case in Colombia, and also of other pending electrification processes in Central and South America that have similar characteristics. It is based on international

experiences, with a few new elements and others that have been adapted specifically for Colombia.

International experiences display great diversity when it comes to key topics such as assigning the responsibility of electrification, the exclusivity conditions, the revenue criteria, conditions for determining the tariffs to be paid by end-consumers and the applicable subsidies, and the specific aspects of regulating the different modes of electrification – grid extension, minigrids and standalone systems – and their interconnectedness. We can learn from the successful experiences as well as the ones that have not been so successful.

The proposed focus

The regulatory focus proposed in this report gives the ultimate responsibility of supply in this zone – by any of the modes of electrification – to the concessionaire, applying a cost of service regulation to each one. It thus seeks to make the service universal, reducing the risk to the investor (and consequently, the capital cost) as well as guaranteeing continued supply over time (which additionally allows them to distribute annuities over greater time periods, thus reducing tariffs for the end consumers). This eliminates different problems created by other regulatory approaches, although without eliminating the need for a subsidy, which has always been necessary in one way or another in rural electrification. Additionally, it is not sufficient to provide subsidies for initial investments but they must continue over time in order to cover the costs of replacement and Management/O&M contracts when the revenue from tariffs is not sufficient.

The recommendations for increasing coverage under sustainable conditions have been grouped under three blocks: i) the need for an integrated benchmark planning, ii) a regulatory framework that permits scalability and mobilisation of all required efforts for universal service and long-term sustainability and iii) an institutional framework as well as a framework for governance that coordinates and promotes agents who can, by means of political and legislative tools, boost the actions required to expand coverage for universal access in Colombia.

Integrated planning for least-cost roadmap and benchmarking service costs

Planning the electrification of a territory, by any mode of supply, is required to determine the investment and project implementation roadmap, in order to meet electrification goals with the least possible cost. It also allows us to establish investment priorities for each of the different sections and phases of the implementation of the plan, based on the availability of funds and priority policies for energy and sustainable development. It also allows us to determine

benchmark service costs for different electrification modes to serve as the basis for calculating tariffs and subsidies required for the regulation and sustainability of long-term electricity supply.

A least-cost electrification plan must be able to compare, for the population still without electricity in each zone (both SIN and ZNI), electrification with grid, mini-grids and stand-alone systems to order to save on service costs while ensuring appropriate levels of service quality for each context. The growing availability of geo-referenced information should help to improve the level of detail in planning processes. It would be convenient if this labour was reinforced in the UPME by adopting an appropriate calculation model for these ends.

The overall planning seeks not only to overcome the increasingly unnecessary separation between the SIN and ZNIs, but it also seeks to include the different energy sources available to Colombians. In this regard, it also permits adding an analysis of clean and efficient energy for cooking – electricity versus fuel gas – when designing the least-cost plan. A future vision of an electric system where interconnected and distributed systems exist together in a flexible manner must foresee the currently isolated zones that may be connected in the future. The plan may be subject to environmental restrictions such as a cap on the use of fossil fuels.

Regulatory framework

In order to achieve complete and sustainable electricity coverage in ZNIs, it is necessary to attract investment, especially private investment. This requires a viable business model, with a sufficient revenue requirement and legal security that necessarily includes a reasonable stability of the regulatory regime over time. This business model must be compatible with a vision of the future that guarantees an adequate functioning and structure of the electricity sector in the medium and long-term.

The business model must include the different modes of electrification that have the least supply costs in proportion to the level of existing demand at all times, in accordance with a prior planning process of electrification in the territory under consideration. It must also ensure that no potential consumer is left without service. The grid operators must be authorised to make investments in isolated solutions under the same revenue considerations – i.e. cost-of-service remuneration –as are available to them today for grid extensions.

The aforementioned requirements lead to the proposal of a territorial concession model with the responsibility for universal service in the assigned zone, both as the default provider and as a last resort (should other providers in the zone

abandon it), but only for supply through the extension of the interconnected grid and not exclusively for isolated solutions, be they either mini-grids or stand-alone systems.

Whatever the mode of electrification, the provider is compensated to provide a service and not to sell a means of electricity production or a device even when dealing with stand-alone systems. The ownership and maintenance of the equipment is the responsibility of the service provider who has a utility-like relation with its clients regardless of the mode of supply.

The starting point is defining the electrification zones into which the ZNIs must be divided – by a mathematical planning model or one based on criteria defined by the Government – and the development of a least-cost plan for universal electricity access – subject to whatever limits of energy policy that are imposed – for each zone. Next, a public call for tenders will be made in each zone, open to all potential operators who fulfil the minimum qualification requirements, in order to determine the ones that offer the most attractive bid (least-cost) to execute the plan for each zone and separately, in accordance with a fixed timeline for the project development. The offers must have a social welfare component which includes; fostering demand creation of the zone on one hand through productive and consumptive activities, while implementing a culture of energy efficiency on the other.

The costs submitted by the winner will serve to determine their revenue requirement. The benchmark terms for the offers may include environmental restrictions such as, for example, an upper cap on the use of fossil fuels in mini-grids, so that the offers fulfil the established complementary goals of the electrification plan.

The revenue requirement of the electrical service of stand-alone solutions must be approached similarly to traditional regulated distribution: the established revenue requirement must repay the total costs of efficient service provision, including an appropriate revenue for the invested capital. This is applicable to grid extensions as well as to minigrids and stand-alone systems, taking into consideration for each case, the remunerable assets, their user life and necessary replacements, O&M costs as well as financial and management costs, following the usual revenue practices for distribution employed by the CREG, now including the necessary components for the functioning of mini-grids and stand-alone systems.

This unified approach simplifies the regulatory supervision of the distribution, as well as the tasks of the distributing company, so that all modes of distribution and all clients are treated equally – or delegated to subsidiary mini-grid companies

and/or stand-alone systems– as a service provision with established quality requirements, revenue requirement, consumers with regulated tariffs and reception of subsidies.

It must be stressed that the revenue requirement of the companies that provide electrical services must be cost reflective, that is to say, they must cover the efficient cost of supplying electricity (there are varying interpretations of efficient cost and varying methods for its calculation) as otherwise, the distribution would not be economically viable and negatively impacting permanence of supply. On the other hand, the tariffs established by the regulator do not necessarily need to be cost reflective, if they wish to subsidise certain groups of consumers, by means of solidarity allowances or with preferential rates, for example.

The regulations must acknowledge the need for subsidies and their inclusion within the planning schedule; likewise, they must foresee how to reduce them as far as possible – based on the evolution of the consumers' purchasing power – until the difference between the revenue from the application of electricity tariffs and the revenue requirement has completely disappeared. This does not include the amount dedicated to solidarity allowances for those consumers in the zone, as a preferential rate without a defined time limit.

The regulation must also establish how the mini-grids or standalone systems shall eventually link up or be completely connected in the SIN at some point, and what are the options for continued service and what conditions must be offered so that businesses that have invested in the generation as well as the assets or the building of the minigrid or a standalone system of electricity supply may receive an appropriate revenue or compensation.

The institutional framework and governance

It is necessary to overcome the institutional duplication and confusion of functions in the sector, especially as regards the separation between SIN and ZNIs. In this regard, the proposed institutional reform includes the centralisation, specialisation and strengthening of the bodies that execute public policy.

For an integral benchmark planning, we propose that the UPME be the exclusive planner for the sector, so that the functions distributed among other bodies are eliminated. In order to ensure consistency between what is planned and what is to be executed, it is recommended that the same agent who is responsible for the planning also spearhead the project.

II. INTRODUCTION

This document is a major part of a report for the Government of Colombia. It includes a plan to take electricity to 3% of the homes located in the most isolated areas of the country and to do so under conditions of financial, environmental and social sustainability. The complete report takes into consideration other goals apart from electricity coverage, such as the quality of the electricity service, natural gas coverage, replacement of firewood for cooking and heating, and subsidies plan. The full document describes and analyses each dimension in order to propose alternative solutions and dimensions, with the goal of building a more equitable sector in terms of providing energy services.

The present document limits itself to the first of these topics – increasing electricity coverage to reach the full population of the country. More than 400,000 homes in Colombia do not have electricity. This document outlines the steps to take electricity to 3% of the homes located in the most isolated areas of the country and to do so under conditions of financial, environmental and social sustainability. The proposed focus is in line with the "Integrated Distribution Framework" proposed by the Global Commission to End Energy Poverty in the Inception Report published in September 2019.

The authors of this document are Ignacio Pérez-Arriaga and Rutty Paola Ortiz Jara. Other aspects such as service quality and the implementation of a pilot project for electrification planning have been studied by Pablo Dueñas and Andrés González, with the support of Olga Ramírez. The team studying subsidies consisted of Marcela Eslava Mejía, Miguel Juan Révolo and Rutty Paola Ortiz Jara. For a complete overview of all the components of the study, consult the full document (in Spanish).

We are thankful for the collaboration by all organisations in the sector that provided us with information, comments and observations.

III. ELECTRICAL ENERGY COVERAGE

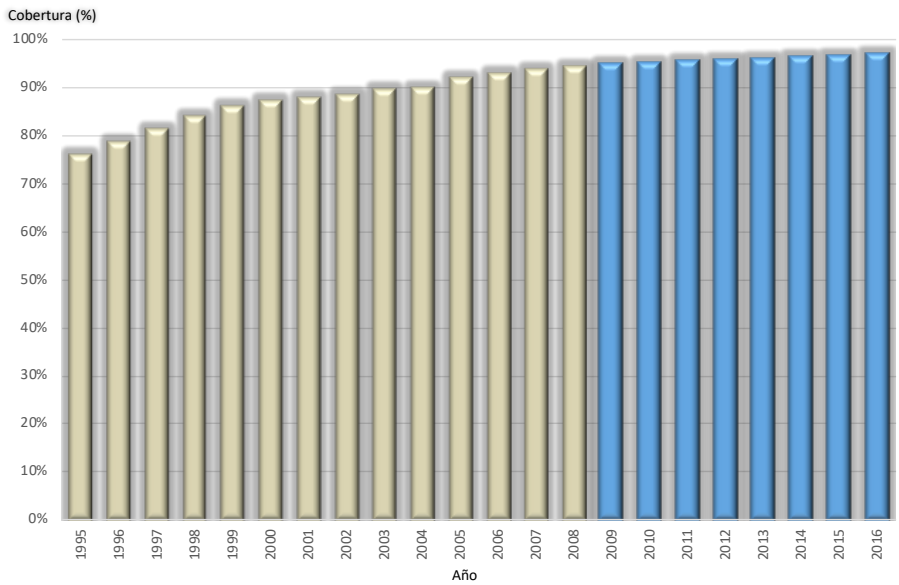
Increased coverage must be characterised by solutions that are sustainable over time, compatible with a long-term energy model and adapted to the conditions of non-interconnected zones in Colombia.

1. Description

Of every 100 homes in Colombia, 97 are supplied with electricity (PIEC 2017). According to World Bank data[1], Colombia is ranked above the Latin American and Caribbean average, with coverages of 99.72% in urban areas and 81.87% in the rural areas.

Nevertheless, there are still 431,137 homes without service, of which 223,688 are in zones adjacent to the National Interconnected System (SIN) and 207,449 in Non-Interconnected Zones (ZNI) (PND 2018-2022). The percentage of non-electrified homes is small, but it affects a significant number of persons who mostly live in areas that are difficult to access and where providing electricity services is expensive.

Graph 1. Rate of Electrical Energy Coverage 1995-2016.



Source: www.siel.gov.co

Graph 1 shows the advances made by Colombia in providing coverage since the last large-scale reform of the sector (Laws 142 and 143 of 1994). At the same time, it clearly shows how the mechanisms that boosted this coverage are

[1] https://data.worldbank.org/indicator/EG.ELC.ACCS.RU.ZS?end=2017&start=1990

reaching the limits of their capacity to reach Colombians who still do not have electricity, and will probably be unable to achieve universal access to modern energy for all in 2030 (SDG 7). Precisely given the technological development of the sector and the successful experiences of coverage in the world, this mission is an opportunity to review the adjustments required to rapidly reach and take advantage of the country's enormous potential for renewable energies in order to transform the lives of these families and communities that still remain in the dark.

It is estimated that 100% electrification will require investments to the tune of 5 trillion pesos (around 1,500 million dollars). As was highlighted in the latest Indicative Plan for Coverage Expansion (PIEC) 2016-2020, the cost of electrification per user increased during the period 2013-2015 from 7.4 to 11.4 million pesos in the SIN and from 11.4 to 17.1 million pesos in ZNIs. It may be expected that the costs per user will continue to rise as the level of electrification rises, as normally the last users to be connected are often the ones in the most remote locations and are therefore, more costly, given that that grid operators and investors begin by electrifying zones that have lower costs, in order to ensure their financial viability and sustainability.

The Government has set itself a goal of adding 100,000 new electricity users by 2022 (PND). While this goal seems modest, it depends on the possibilities of public funding for the four-year period. The zones that do not have electrical coverage are increasingly more remote, more expensive and display high levels of unfulfilled basic needs. Therefore, establishing sustainable systems of energy service requires an additional effort from the State in order to guarantee their proper functioning.

Fortunately, Colombia does possess a diverse wealth of renewable energy sources and agents with the necessary technical skills that, with the proper incentives, can assist in improving the levels of coverage with greater dynamism. Completing the electrification of the nation is therefore a significant challenge, but also one that is achievable. It has to do with finding the means for efficiently and sustainably performing this task over time.

Achieving greater dynamism in increasing electricity coverage requires regulatory signals that promote sustainable supply schemes in zones that owing to their low population density and distance from the SIN are not financially attractive for operators under current conditions. The challenges of bringing electricity to this sector involve taking an innovative look that complements traditional methods of electrification by grid and an in-depth revision of the experience of expansion by means of standalone solutions that present sustainability risks. Next we describe some international experiences that may be of interest when planning the

electrification to be carried out in Colombia. The following section presents the general principles of the approach that is sought to be adopted.

2. Relevant international experience

Numerous international experiences have demonstrated the difficulty of achieving 100% electrification in different countries. Generally the last 5%-10% of consumers without electrification are located in zones that are difficult to access or have other social or security issues, and the rapid progress made to achieve 90%-95% electrification slows down considerably. This is precisely the case in Central and South American countries that have reached high levels of electrification, but are yet to finish the task.

The electrification proposal presented in this document takes as its starting point the best international experiences, applied to the specific conditions of Colombia and with some new ingredients. The international experiences of interest here are those that refer to legal frameworks and business models that can attract private capital to electrify non-interconnected and relatively isolated rural zones, as is the case of pending electrification processes in Central and South America.

More specifically, it is worth examining how the most appropriate electrification mode (grid extension, mini-grids and stand-alone systems) is selected for each zone and for each demand; what are the legal instruments adopted to appoint operators, and the regulatory treatment for each of the three basic modes of electrification including how to fix the revenue from electrification activities, and how to set the tariffs and subsidies that may be required.

An additional topic which is critical in many developing countries is how to finance electrification processes. There are numerous experiences as basically, every country has its own story. The electrical sector in Colombia has very specific characteristics, which must be considered when deciding what experiences are applicable to it. A complete review of all these aspects would require a bundle of thick reports covering each and every one of them. These reports already exist, and we shall quote from some of them here, although this is a rapidly evolving area of knowledge.

2.1 Planning

Planning methods for rural electrification have experienced a dramatic transformation with the availability of geographic information systems (GIS), access to constantly-improving geo-referenced databases and advanced computational algorithms. The UPME currently uses these tools to perform calculations for electrification planning. It provides a solid starting point to identify

the mode of electrification to be used in each case, and to calculate the material and economic resources required.

A gold-standard in the field is the REM (Reference Electrification Model) calculation model, developed jointly by the Massachusetts Institute of Technology (MIT, Boston, USA) and the Institute for Research in Technology (IIT, Madrid, Spain) of Universidad Pontificia Comillas.[2] The REM model has been recently used, in collaboration with the World Bank, to develop and implement the National Electrification Plan of Rwanda and for the study Plan for Universal Access to Energy in Mozambique; and with the Asian Development Bank for the study Universal Electrification Plan for the Maluku Islands and Papua, Indonesia; in addition to studies in Peru, India, Uganda, Cambodia, Gambia, Nigeria and Kenya, among others.

The REM determines the least-cost electrification plan to satisfy a predetermined demand in every building in the territory under consideration, using the best combination of grid extension as well as mini-grids and stand-alone systems. A possible collaboration between MIT/Comillas Universal Energy Access Laboratory and the UPME is currently being planned in order to apply the REM model to ZNIs, a previous pilot study already having identified the potential and information needs and configuration of REM algorithms to suit planning requirements in Colombia. Other models such as ONSETT (Royal Institute of Technology, Sweden) and Network Planner (Columbia University) may also be used for this task, although they are less advanced than the REM model.

2.2 Assigning responsibilities in electrification processes.

In most countries, the territory is divided into administrative zones where historically an electricity company has received a license to be the exclusive distributor of electricity, under a system of regulated monopoly. In the early 1990's, these distribution companies were mostly state-owned with the notable exception of the US and some European countries. The process of liberalisation and privatisation of the power sector in many parts of the world transformed it into a privately-owned sector. Despite these changes, the regulatory model for network-related activities like distribution has continued to be that of a regulated

[2] For a more detailed description of the REM, consult Annex 1. For more information, visit http://universalaccess.mit.edu, the scientific article on the Proceedings of the IEEE *Optimal electrification planning incorporating on- and off-grid technologies: the Reference Electrification Model (REM)* available at https://ieeexplore.ieee.org/document/8760510, or the Working Paper *Computer-aided electrification planning in developing countries: the Reference Electrification Model (REM)* https://www.iit.comillas.edu/publicacion/mostrar_publicacion_working_paper.php.en?id=347

monopoly, under diverse revenue procedures. Some countries have liberalised commercialisation activities, unbundling them from distribution. (World Bank Group, 2019) has an updated review of the processes of reforms of the power sector in a large number of countries. [3]

The case of Colombia – as well as isolated zones in Peru and possibly other parts of Latin America – is unique because the distributors have not been assigned zones exclusively and especially the ZNIs currently have no supplying operators, except for some small independent operators who have established mini-grids in some populated areas or sell stand-alone systems for households. It is true that many countries permit the installation of mini-grids that are not connected to the national grid in territories for which they have granted an electrical supply license, as well as for grid consumers choosing to develop their own supply. But in general, there is a concessionaire for each territory, although in practice, they are not tasked with achieving universal electrification in many countries with an electrification deficit.

An interesting case is that of Nigeria, a country that has been unable to make progress in providing access to its numerous sections of population without electricity, in spite of having privatised all distribution companies 5 years ago. Trying to improve the situation of the distribution activity, Nigeria has allowed independent operators to develop their own distribution networks connected to the network of the incumbent licensed active operator in the zone. Nigeria also permits the installation of embedded generation in the distribution network of the incumbent operator to supply groups of demands that must amount to more than 2 MW, paying a charge per use of the network, or using their own ad-hoc network. This “liberalisation” of the distribution does not occur in industrialised countries with full electrification and solvent distribution companies.[4]

Nevertheless, some countries such as Nigeria that need to speed up electrification have resorted to drastic measures that may have immediate beneficial effects, but may lead to a future balkanised electrical system that is difficult to manage.

[3] See also Eberhard and Godinho, “A review and exploration of the status, context and political economy of power sector reforms in sub 2017. http://www.gsb.uct.ac.za/files/Eberhard_and_Godinho_2017.pdf

[4] In Spain, for example, the Law of the Electrical Sector of 1997 allowed local competition among distribution networks, but soon this provision was eliminated.

A more orthodox procedure that has given good results is that of concessions.[5] Normally, it has to do with a public distributor who delegates part of their activities to another company, under certain conditions that are specified in a contract. Some of the most interesting experiences are those of Senegal, Uganda, Cameroon and the "distribution franchises" in many Indian cities such as Delhi and Agra.

There is an interesting proposal made by the Nigerian Energy Regulation Commission (NERC) to introduce franchises (and attract private capital and management) in distribution companies that had been privatised before, in order to make the electrification process dynamic.[6]

A relevant Latin American example is the Project for Renewable Energies in Rural Markets (PERMER) in Argentina where, by means of public bids, territorial concessions are assigned for the provision and installation of photovoltaic equipment (solar kits and systems) for homes, schools and productive uses (including solar-powered electric fencing for cattle), as well as for electrification based on minigrids for communities. The government accompanies these territorial bids with bids for buying lamps and low-power home appliances. Another case of interest for Colombia is that of Peru with regard to systems outside the main grid, which we will discuss in more detail later.

The concessions model deserves a closer look, as given the right conditions of concession, it would attract investors in economically efficient ZNIs and ensure a long-term supply. The World Bank defines a concession as "any arrangement in which a firm obtains from the government the right to provide a particular service under conditions of significant market power" (Kerf 1998) which often means exclusivity, but not necessarily always. Concessions are regularly assigned to private companies; which in the most advanced concession models mean that the private concessionaire is responsible for performing, maintaining and expanding the activities in accordance with the agreed-upon terms, with the duty to return the assets to the public sector upon the end of the concession period. Many electrical concessions have been awarded (although the majority have not

[5] Here we will use this term to designate a group of different methods for assigning responsibilities to another entity in the management of a distribution company, which includes what has been deemed franchises. This World Bank report describes the different varieties that have been used and the experiences that have occurred in Africa in greater detail. World Bank Group. R. Hosier, M. Bazilian and T. Lemondzhava, "Increasing the potential of concessions to expand rural electrification in sub-Saharan Africa", Live Wire 2017/76.

https://openknowledge.worldbank.org/handle/10986/26570

[6] See https://nerc.gov.ng/index.php/component/remository/Consultation-Papers/?Itemid=591

been in distribution) in Sub-Saharan Africa, of which (Hosier et al. 2017) more than 200 have been identified in 15 countries, from mini-grid concessions to companies that service entire countries.

The concession may simply consist of taking charge of calculating, charging and collecting payments, or it may involve taking complete control of the company management for an extended period of time – usually 20 to 25 years – using currently available assets, investing in new ones and performing O&M tasks. However, this does not constitute privatisation of the sector. Once the concession period is over, if it is not renewed, all assets revert to the current distributor, who must pay the concessionaire the residual value of the assets that they have invested in. Concessions have worked well when the terms of the contract have been properly designed and balanced for both parties, and when the concessionaire company has the necessary experience and is of long standing in the power sector. The concession model forms the basis of the regulatory proposal made in this report, described in Section 4 of this document.[7]

It goes one step further by bringing the three modes of electrification (grid extension, minigrids and standalone systems) under one distribution company so that the combination of the grid with standalone systems under a single responsible entity can reach wider areas, provide universal service and optimise the mix of the three modes of electrification (and transition between them). The company in charge may in turn delegate or subcontract part of the electrification to third parties but they must always guarantee coordination and maintain the final responsibility for the service to the clients and the state.

Some examples are distribution franchises in India that, in order to bring the service to the communities they seek to benefit, have improved information access and client relations with the franchisee, improved service quality, reduced outstanding payments and attracted more clients to their business model, provided auxiliary services such as financing electrical equipment and apparatus, supported productive uses of electricity and even social and community projects (Banerjee and Pargal, 2014). Thus, approaches based on extending electrical service (both within and outside the grid) must simultaneously support productive and economic and social development activities, provide access to machinery and other electrical equipment that let us extend the uses of electricity to new

[7] A detailed description of this business model and a review of the most relevant international experiences may be found in the Working Paper: Grégoire Jacquot et al. “Assessing the potential of electrification concessions for universal energy access: Towards integrated distribution frameworks.” An MIT Energy Initiative Working Paper. September 2019.

electrified communities and in synergy with the provision of other community services such as access to drinking water.

2.3 Electrification Models

2.3.1 Electrification by grid extension

This is the traditional mode of electrification, but one experience of interest which took place officially and on a large scale in Brazil for the first time, was the use of official standards for low-cost grid extension for rural zones, linking the electrification strategy to socio-economic development from the beginning, lowering supply costs and promoting revenue generation and social services, which led to a sustainable acceleration of the grid extension to a larger part of the territory.[8] This practice has been adopted in other countries as may be seen in the electrification code of the state of Uttar Pradesh in India, published by the Electricity Regulatory Commission.

2.3.2 Electrification with minigrids

The main difficulty of electrification with minigrids is that it requires subsidies, as the CEO of PowerGen, the company that has installed the most minigrids in Africa and the founder-member of Africa Mini-grid Developers Association (AMDA) readily admits.[9] Supplying electricity with minigrids is expensive, with costs that are generally substantially higher than that of an inter-connected system. However, minigrids are competitive in areas where extending the main grid would be even more expensive, thus making them necessary in a least-cost plan, in addition to standalone systems.

Due to this necessary limitation, minigrid development requires donors – foundations, NGOs, programmes by multi or bilateral organisations for development – who generally do not have sufficient volume to launch massive electrification projects with this technology. Regulations on minigrids in different countries, where they exist, usually do not include the awarding of subsidies in their provisions for minigrids, generally leaving it up to independent operators to achieve economic viability by means of cross-subsidies among clients when some of them have the volume and payment capacity to accept it or with grants from different types of donors.

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[8]See the chapter dedicated to the electrification initiative in Brazil, by Fabio Rosa, in "How to change the world. Social entrepreneurs and the power of new ideas", David Bornstein.

[9] See https://www.powerforall.org/resources/audios/conversation-africa-mini-grid-developers-association-amda

An electrification model that frequently uses minigrids, has produced results in many cases, and has been abandoned in equally as many, is the cooperative model. The cooperative model of utilities has been successfully implemented in Bolivia for example, where minigrids have successfully supplied isolated communities with electricity (from tens to several thousands of users per system) with a business model that is sustainable over time. The early exclusive dependence on highly subsidised diesel generators has given way to solar hybridisation, reducing the energy supply cost (from 0.22 $/kWh to 0.14 $/kWh in the community of El Remanso) and increasing the power supplied by the minigrid to an increasing number of users, as well as the quality and level of service (which has increased from a few hours every day with the exclusive use of diesel, to 24x7 with the hybrid system).

These local electricity cooperatives receive public funding from the Government of Bolivia and are managed by the local community, with the availability of smart meters and prepaid electricity vouchers. This experience and others of interest in Latin America may be read about in the book “El acceso universal a la energía. La electrificación rural aislada”, published by ARIAE and the National Markets and Competition Commission (CNMC) in Spain, 2017. Cooperatives fail when their internal organisational structure and economic and technical resources are unable to meet the challenges of renewing obsolete equipment, growing demand or simply cannot cope with the challenges faced by all organisations that serve a large number of clients.

The regulatory approach proposed in this report, by incorporating minigrids into the zone's concessionaire with a revenue requirement based on the service cost, solves the main problems of earlier models although it does not eliminate the need for a subsidy. However it does reduce the investor risk (and therefore the capital cost) and guarantees continuity over time (which allows them to distribute annuities over greater time periods, thus reducing tariffs for the end consumers).

Consumers’ energy needs evolve over time and thus require the electrification modes to adapt, so that although it may have been more cost-effective initially to supply electricity by means of a minigrid, later on, when demand increases, it may be necessary to connect to the SIN grid. Service with grids, minigrids and standalone systems cannot be completely separated from one another. Regulations in many countries include schemes for compensation and integration of physical assets when the national grid reaches certain zones that were previously electrified with minigrids (the state of Uttar Pradesh in India, Cambodia, Nigeria, Rwanda, Tanzania, among others).

The experience of Cambodia deserves special attention, as it partially anticipates what we are going to discuss later in this report. Hundreds of existing minigrids, fed by diesel generators, have been connected to the grid, which has improved their reliability and ability to cope with growing demand. Private operators who previously applied unregulated tariffs to consumers, have become distributors in their zone and now receive a revenue requirement based on their service cost. Consumers now pay regulated tariffs below the cost, and the operator receives a subsidy that allows them to fulfil their revenue requirement.[10]

2.3.3. Electrification by standalone systems

Electrification by standalone systems shares many of the problems faced by electrification by minigrids. These are more expensive supply solutions that those provided by the interconnected grid, but are necessary when the demand surpasses the current grid capacity or it is not sufficiently reliable. Home systems are only affordable for a certain segment of the population, and therefore we cannot think of a universal electrification based on this technology without the aid of subsidies. However, current distribution companies have not displayed interest in promoting this mode of electrification.

In Peru, the regulation and design of subsidies for electrification by minigrids and standalone systems have allowed ambitious off-grid electrification programmes to be implemented with a focus analogous to that of distribution companies (utility-like), establishing its viability for non-interconnected zones, establishing regulated tariffs in addition to a subsidy that respects the principle that the established revenue requirement must reflect the service cost. This approach may be extended to the latest-generation solar systems (solar kits or individual solar systems) both with the fee-for-service scheme and with the pay-as-you-go scheme. This ensures the bankability of the projects and gives them access to credit and funding by companies that provide the service and also by users (micro-credit), ensuring the sustainability and continuation of the electricity service over time, as we will describe later.

The domestic electrification model developed in Peru is based on domestic direct current photovoltaic systems with batteries. The government regulates the applicable tariffs, by the average estimated energy consumption and the disconnection charges for different types of systems (“Rural Electric Tariffs for Photovoltaic Systems”, established by OSINERGMIN and revised every four

[10] See World Bank Group & ESMAP (2017). Mini-grids and arrival of the main grid. Lessons from Cambodia, Sri Lanka and Indonesia.

years), and for investments made both by companies and the state for different regions (the Coast, the Mountain Areas and the Amazon Rainforest). The regulation also takes into consideration the business, operating and maintenance costs of service companies with photovoltaic systems according to the zone of service. The difference (viability gap) between the service cost and the tariff is reimbursed by means of the Social Electrical Compensation Fund (FOSE; Law 27510). This approach was a proposal made by the social enterprise Acciona Microenergía to the Government of Peru, and it now supplies power to tens of thousands of users in Cajamarca and Loreto, through micro-franchises of customer service centres (Centros Luz en Casa), with a fee-for-service payment model that includes equipment warranty and maintenance along with the sale of electrical home appliances (TVs, radios, lamps, phone chargers, tablets, DVD players, blenders and battery chargers). It is important to not underestimate the value of community labour in this business model, in order to explain mutual commitment and why people should pay, as they are dealing with persons who have never made periodic payments for a service before.

In order to introduce renewable energy resources into the energy grid, Peru held the first international call for tenders for off-grid renewables (OSINERGMIN 2014), awarding the license for the distribution and maintenance of up to 500,000 domestic photovoltaic systems with a supply guarantee for a duration of 15 years to the company ERGON, a subsidiary of the Tozzi Green Group, who have taken up the commitment to provide electricity to 200,000 registered users after the initial concession. It appears that this rapid expansion in scale has caused delays in the execution process. Additionally, the exclusion of the default risk to the service provider has removed a significant performance incentive, which has given rise to elevated levels of defaulters.

An additional disruptive innovation has been the Pay-As-You-Go (PAYG) system, which has led to a significantly large number of customers, although without reaching the “lower strata of the pyramid”. The PAYG business model also offers a service in exchange for a payment, of a high quality, without technical or financial complications, and with added advantages. The consumer pays an initial low amount of money – affordable for a section of the population – and from this moment, uses their mobile phones to pay a monthly sum which allows them to enjoy the apparatus – solar panel and battery – and often also a series of additional devices – LED lights, phone charger, radio, fan, TV, etc. depending on their budget. If the consumer does not make the payment within a week, the apparatus ceases to function but it does not have to be returned. Once the payment is made, it begins functioning again. Some providers increase the monthly amount to be paid, and after two or three years, the system becomes the

property of the consumer. Where there is no mobile network coverage, the payments are made to a local business that provides this service, and an employee is sent periodically by the company to collect the accumulated sum of money. The lack of digital payment technology adds to the transaction cost associated with physical collection and monitoring which has limited the adoption of PAYG models in countries such as India.

Some providers include the transfer of the ownership of the apparatus after a period of time – usually two or three years – if payments have been made on a regular basis. If there is phone network coverage, the apparatus may be continuously monitored by the provider, who can detect anomalies in its functioning and arrange for its repair or replacement, as it is part of the service that is provided. Or the user can take it (it weighs 3 or 4 kg) to the store where it was bought in order to be repaired or replaced. The PAYG model lets families with irregular incomes enjoy electrical service (without having to pay fines or return the apparatus). As the payments are registered, the users have a credit history. If it is positive, it lets them acquire a more advanced model or even obtain funding to buy electrical appliances or other products. The organisation Gogla[11] provides updated information on standalone systems that use solar photovoltaic technology.

Currently, the most frequent users of the PAYG model have been urban or suburban consumers with low quality of service who use this apparatus as back-up. Although “solar kits” do provide a greatly useful electrical service, they cannot power energy-intensive electrical appliances, nor can they be used in most production processes.

Some companies that offer PAYG services are in financial stress or have declared bankruptcy. The reason behind this is an excessively rapid growth, offering services to the highest number of clients possible which in turn requires large investments in physical assets which can only be recouped later, thus creating financial instability. In some cases, the consumers’ ability to pay was not thoroughly verified. This is a very capital-intensive business that may fail if it does not obtain the payments it requires to cover its financial commitments on time.

The business models that we have just described have created, to a certain extent, a “no-strings-attached” electrical company, another form of utility. In most companies with the PAYG model, there is no service commitment over time beyond the physical or contractual duration of the apparatus. On the contrary, the

[11] https://www.gogla.org

business model of the company Acciona Microenergía in Peru, with the support of the regulator and the state government, is a true utility-like commitment to the consumer.

An interesting and recent additional development of the PAYG model is its separation (unbundling) into various independent business models (R&D with or without manufacturing; financing; transport and installation logistics; and consumer relations) in order to segment activities and risks, thus facilitating investments.[12]

2.4 Determining revenue requirement, tariffs and subsidies

There is a universal "good practice" in distribution revenue that, with many variations, consists of a "revenue requirement of the total effective service cost". That is to say, a revenue requirement that every year covers all the costs of an efficient company management, to achieve at least a reliability and quality of service established by the regulations. These costs must include capital costs plus O&M costs. Revenue requirement may include incentives (penalties and bonuses) linked to improved performance goals.

Additionally, every year the regulator must establish the tariffs based on the type of consumer and applied to the consumption of all consumers of each type, in order to recoup the total revenue requirement for the year of distribution. Tedious, but relatively simple.

Unfortunately, in many countries with significant electrification deficits, either the revenue requirement set by the regulator is insufficient or the tariffs to be paid by end consumers are lower than the costs. This creates a revenue deficit for distributing companies, with devastating effects on the quality of the service and new investments, especially those meant to provide access to more consumers. As reaching consumers who are increasingly at greater distances, scattered and poor, with low levels of demand, becomes progressively more expensive, distributors refrain from doing so, as connecting new consumers involves more losses for them.

In many cases, the low quality of the service also discourages consumers, who refuse to pay the bills or set up illegal connections. Periodically, the governments have to bail out distribution companies so that they are not completely insolvent and can continue to function, a costly rescue without medium and long-term

[12] These developments have been discussed at the Off-Grid Energy Access Forum, in October 2019 in London. https://www.pv-magazine.com/2019/11/23/the-weekend-read-offgrid-goes-global/?utm_source=dlvr.it&utm_medium=linkedin

solutions. Both distributors and governments have proposed different solutions in order to break this vicious circle, with alternative or complementary business solutions, such as concessions, franchisees or privatisation. It must be pointed out that this is not the case of Colombia, where the active operators in the SIN are viable and there are no active operators – either solvent or insolvent – in ZNIs. Nevertheless, we may extract certain useful insights from some of these experiences.

The first is that business models must be designed to be feasible in the short, medium and long term. The electricity sector has demonstrated how to build viable business models for the distribution segment in multiple countries. If private capital is required in order to electrify ZNIs, the business model must be financially attractive. Electrifying ZNIs has a sufficiently large volume (in terms of consumers) so that it need not be done only by NGOs, foundations or even with donations from banks for development. It requires private investment that must be paid for adequately. The Government must find the means to subsidise the difference between the supply costs and the revenue generated from regulated tariffs adapted to the consumers' purchasing power.

Therefore, the electrification of ZNIs by grid extension must be paid following the same principles as for SIN operators. The service cost procedure, or more advanced versions such as the RPI-X method developed in the United Kingdom, have been described in numerous documents and are known and used by the CREG.[13] A detailed description of the service cost method as well as the MYTO (Multi-Year-Tariff-Order) may be found on the website of the Nigerian Energy Regulatory Commission (NERC).

If least-cost planning determines that some points of demand are supplied more cheaply with minigrids or if, as is the case of Colombia, the regulatory framework allows the installation of minigrids by independent producers, these minigrids must receive a revenue that ensures their sustainability, understood here as economic feasibility over time, and in the future dependent on minigrids being installed in the zones as specified by the planner. The same criterion must apply to services delivered through stand-alone systems. What are the relevant international experiences in this regard?

Among the numerous reports that describe the experiences or make proposals on regulating off-grid systems and especially minigrids, we may point to the following: i) the by-now classic report of the World Bank (Tenenbaum et al., 2014)

[13] Ignacio Pérez-Arriaga. "Regulation of the power sector". 2013. Springer Verlag.

that discusses in detail all regulatory aspects that affect minigrids; ii) the IRENA report (IRENA, 2018) which carries out a comparative study of the most representative regulations on minigrids in a group of nations; iii) the recent report of the World Bank (World Bank Group, 2019) which reviews the current situation of minigrids in the developing world; iv) the regulatory proposal of the Africa Mini-grid Developers Association (AMDA), which appears to have been favourably received by regulators and governments (although it has not yet materialised as official regulations) and which advocates for Results-Based Financing (RBF) i.e., that a sum of money (subsidy) be paid to independent minigrid operators every time they provide service to a new consumer[14]; and v) the recent report on the situation in Indian states where 300 million people have been provided with electrical connections by means of grid extension during the last three years (CSIS, 2019). Next we discuss the lessons that may be extracted from these references with regard to financing minigrids and applied to the electrification of ZNIs in Colombia.

As was mentioned before, the immense majority of existing minigrids have been financed with donations or subsidies, through NGOs, foundations or government programmes financed with the help of banks for development, as generally the consumers are unable to meet the real cost of minigrid supply.

Some minigrids may be self-funded without the need for subsidies, when there is a special demand – a typical example is that of a telecommunications tower, but also a mine or other industrial facility – that can compensate for the reduced tariffs for domestic consumers by means of cross-subsidies in tariffs. In some cases, the organisation that provides the aid selects the community for whom the minigrid will be installed, while the state government decides which communities will participate in the programme. In the latter case, the operators are selected by means of bids for the lowest subsidy for the installation and operation of minigrids.

In most cases, the subsidy consists of assistance for the initial investment, which makes it possible to cover the remaining costs of operating the minigrid with the tariffs paid by the consumers. These tariffs are negotiated between the operator and consumers where there is no official assistance, while in government programmes they are usually set by the regulator. The current problem with a funding model based entirely on an initial assistance is the financial sustainability of the business model which, in the case of minigrids, requires substantial periodic investments in replacing batteries (every 4 or 5 years) as well as other

[14] See the online interview outlining the AMDA's vision at https://www.powerforall.org/resources/audios/conversation-africa-mini-grid-developers-association-amda

elements, apart from additional investments for including new consumers or to respond to increased demand. In Colombia it has been identified that the revenue for ZNIs is insufficient to guarantee adequate levels of maintenance, make replacements and update equipment as well as replacing diesel-based generation (EY, 2018). Since June 2014, the revenue from services for providing electricity in ZNIs has been in the suggestions phase (CREG Resolution 004 of 2014).

In its regulations on minigrids, Nigeria has introduced a method for calculating required revenue that follows the same principles (MYTO) of service costs that are applied to the calculation of distribution revenue.[15] This is a very pertinent proposal for Colombia, as it is meant to achieve sustainability in the service and to include conditions for service quality, all in one – note that the reliability goals must be adjusted to the conditions of accessibility for each zone, among others. An adequate revenue allows us to establish the corresponding performance level for providers of standalone solutions. More recently, Nigeria has announced a programme for standalone technologies – minigrids and standalone systems – with subsidies for each (a novelty in the sector of standalone systems) and a total sum of $350 million.

3. Principles for proposing an increase in sustainable coverage

The regulatory framework must guarantee conditions for the viability, sustainability and universality of service in isolated zones. At the same time, it must be adapted to the conditions of the zones to be electrified to maximise the use of available public resources and to promote the required private participation. Based on the analysis of the experiences and best regulatory practices that have been reviewed in the earlier section and the examination of the specific characteristics of the Colombian electricity sector and especially the ZNIs, we now list some general considerations and propose the principles on which we will subsequently make recommendations for increasing coverage in isolated zones under sustainable conditions.

The principles and business model proposed in this report are based on the approach that the Universal Energy Access Lab jointly operated by MIT and IIT Comillas propose as an “integrated distribution framework or IDF” This integrated distribution framework may have multiple legal components, from public-private

[15] Seehttps://nerc.gov.ng

partnerships, individual businesses, unions and even distribution cooperatives that are responsible for supply in the territory under consideration.[16]

The isolated rural zones present an additional funding difficulty for the high cost of supply – investment and operation and maintenance – to scattered and low consumption clients, especially if they are far from the SIN.[17] As applying local tariffs that allow the total recovery of the incurred costs is not politically acceptable nor can the affected population pay the real cost of service delivery, it is necessary to use subsidies. Subsidies have been implemented in different ways. In any case, it is essential that the estimated revenue earned by applying regulated tariffs (with a pre-established trajectory in time of the revenue percentage) along with the subsidies should completely cover the total service cost, ergo, the revenue requirement. And it is not sufficient to provide subsidies for initial investments but they must continue, in order to cover the costs of replacement and Management/O&M contracts when the revenue from local client tariffs is not sufficient.

The use of complex electrification models (Ciller et al. 2019) may assist determination when the different modes of electrification are considered, that is to say, SIN extension and off-grid solutions (mini-grids and stand-alone systems) under a single provider in a specific territory. In any case, the possible mix of electrification modes should not create differences in principle when calculating revenue. Every asset with its user life must be remunerated, the O&M costs exist for all modes, as do the rest of the identifiable and acknowledged costs.

New technologies and distributed generation have done away with the need for regulatory separation between the SIN and ZNIs. Adopting an approach that includes mixed electrification schemes between the SIN and off-grid solutions contributes to achieving all the goals of the electrification policy: universalisation of the service, increased coverage with clean energy within a high-quality and sustainable model.

Knowledge of the unique characteristics of the community with regard to their usage habits and potential for development will help us to develop sustainable

[16] See Universal Energy Access Laboratory, http://universalaccess.mit.edu. The justification and the dissemination plan and the application of the concept of the "integrated distribution framework" is found in the report "Global Commission to End Energy Poverty. Inception Report", September 2019. https://www.endenergypoverty.org/reports (project funded by the Rockefeller Foundation) and (Pérez-Arriaga et al. 2019).

[17] The cost of connection per user according to PIEC data is 50% higher for ZNIs with regard to SIN extension.

schemes for provision based on the use of energy to increase local income generation.

Designing a process of electrification must take into consideration its proper inclusion in the projected vision for the long-term planning of the sector. A key aspect is obviously, ensuring continuous electrical supply over time for all consumers, regardless of the type of service.

A sustainable, continuous electrical supply requires the electricity sector to have a stable business structure. The companies that are in charge of providing the service must be of long standing, that is to say, they must be "utility-like". The more guarantees they can provide, the better. In this regard, when it comes to Colombia, an additional difficulty is that previously the electrical supply within the national territory was not fully assigned to a certain number of "active" distributors who were given the responsibility of supplying the assigned territory. Currently, ZNIs make up 51% of the territory and most do not have an "active operator" assigned to them. An added complexity is the presence of small "spontaneous" providers in ZNIs who supply electricity for themselves or for population groups or businesses with their own resources, often without complying with the current legislation[18]. In general, these providers are highly dependent on subsidies[19] and have great difficulty in maintaining a continuous service. When implementing more efficient models which include providers with greater technical and financial capacity such as grid operators, mechanisms for collaboration or exiting must be placed for these small providers, for example, by purchasing or reimbursing them for equipment and markets.

To avoid an excessive fragmentation[20] of the electricity sector in Colombia, and also to take advantage of the experience and stability provided by the current grid operators established in the country, it is preferable that they be given priority when supplying ZNIs, although always keeping open the chance for competition with new players. Offering reasonable conditions for the business model will naturally attract the current operators who have clear competitive advantages.

[18]For example, in 2018, only 11 of 65 providers registered with the Single Registry of Utilities Providers fulfilled their obligation to declare financial information to the Single Information Service of the Superintendent's Office for Domestic Utilities.

[19] 82% of the revenue of ZNI providers come from subsidies (SSPD 2018).

[20]Of the 65 ZNI providers registered in the Single Information System of the Superintendent's Office for Public Utilities in 2018, 2 were public utility companies, 25 were authorised organisations (administrative bodies, service cooperatives, associations of users and associative labour enterprises), 8 direct municipal providers, 25 public limited companies, 4 industrial and commercial State companies and a provider of the Governor's Office of Vaupés. 42 providers have been removed from the register for not disclosing information or more than 3 consecutive years, which may be a sign of the instability of the current system.

The current grid operators have the capital, access to disruptive technologies (such as distributed generation or smart grids) and experience in management (for example, with consumers or communities at the point of sale or payment systems) that would allow them to provide a reliable, low cost, higher quality supply with reduced energy losses and greater consumer involvement, confidence and commitment. However, they initially lack experience in supplying clients through minigrids or domestic standalone systems, and therefore mixed solutions in the form of consortiums created by the concessionaire may be advisable, as we shall discuss later.

The business model may have multiple supply modes. Optimising the cost of the electrification plan to supply rural demand usually requires a combination of supply modes (SIN extension, minigrids and individual systems) that the assigned provider must implement in an efficient manner, balancing the costs, reliability, consumer preferences and the distributed and centralised energy resources, among other factors. Additionally, these modes of supply must be considered integrally and flexibly, taking into account the fact that ZNIs may eventually be connected to the SIN, thus requiring the use of minigrids compatible with the national grid. The regulatory framework must be transparent and objective about the rules of transition between the models of standalone and connected supply.

3.1 List of adopted principles

Therefore, the principles for proposing an increase in sustainable coverage in isolated zones are the following:

- Attracting private investment, especially in the most isolated zones, requires a viable business model, with a sufficient revenue requirement and legal security with regard to the continuation of the regulatory system over time.
- The adopted business model must be compatible with a reasonable vision of the future that guarantees its sustainability. The electricity service must be continued over time, it must be flexible enough to accommodate new investments, adapt to new situations as they emerge (changes in levels of demand, new uses of electricity, new disruptive technologies, etc.).
- The business model must include the different modes of electrification that have the least supply costs in proportion to the level of existing demand at all times, in accordance with a previous process of electrification process in the territory under consideration. It is important to establish that, whatever be the mode of electrification – connection to the SIN grid,

minigrid or standalone systems – the provider is paid to provide a service and not to sell a means of electricity production or a device, even when dealing with individual systems. The ownership and maintenance of the equipment is the responsibility of the provider of the service, who has a "utility-like" relation to their clients, regardless of the mode of supply.[21]

- The aforementioned requirements lead to the proposal of a territorial concession model with the responsibility for universal service in the assigned zone, both as the default provider and as a last resource (should other providers in the zone abandon it), but only for supply through the extension of the interconnected grid and not exclusively for isolated solutions, be they either minigrids or standalone systems.
- The regulation must also establish how the minigrids or standalone systems shall eventually link up or be completely connected in the SIN at some point, and what are the revenue conditions offered so that the businesses that have invested in the generation as well as in the assets and building of the minigrid or a standalone system of electricity supply may receive an appropriate compensation. The regulations must also specify the conditions based on which the concessionaire of a zone (A) leased according to the suggested procedure and adjacent to the zone (B) supplied by a SIN operator may connect to the SIN operator's grids in zone (B) to provide access by means of grid extension in zone (A).
- The regulations must facilitate, and as far as possible promote, the active participation of the concessionaire of a zone in the integration of electricity supply with services, especially those related to productive uses that positively impact local socio-economic development outcomes.
- Regulations must acknowledge the need for subsidies and their inclusion within the planning schedule, likewise, they must foresee how to reduce them as far as possible – based on the evolution of the consumers' purchasing power – until the difference between the revenue from the application of electricity tariffs and the revenue requirement (or viability gap for the service provider) has completely disappeared. The amount dedicated to solidarity allowances for those consumers in the zone as a preferential rate without a defined time limit, is excluded from this goal.

[21] This is an aspect to be reflected upon before proceeding to set down these principles in legal texts. Most consumers in countries in Sub-Saharan Africa who opt for a PAYG supply system prefer to pay a higher weekly quota to become the owner of the apparatus after two or three years, at least until the battery needs to be replaced another two or three years later. The apparatus may also need to be subsidised, which would require a careful design of the incentives to the provider and the consumer.

4. Recommendations for increasing coverage under sustainable conditions

In Section 2 of this document, some relevant international experiences have been described. Section 3 presents the fundamental lines of approach for the proposed electrification. Next we propose the concrete mechanisms for the implementation of the afore-mentioned lines of approach. The proposal has been divided into three blocks:

- The need for an integrated benchmark planning for attaining short-term (2022) and medium-term (2030) goals, both for electrification by SIN extension and ZNI electrification by means of mini-grids and solar kits or more powerful standalone systems for other isolated larger loads.
- A solid regulatory framework, without which it is impossible to scale the service or mobilise the efforts required to ensure universal coverage and make it sustainable in the long term. Regulations will allow risk mitigation in the electrification process, especially taking into account the difficulties of extending the service universally to low or very low income sections of the population, especially in remote or isolated zones, thus helping to attract private capital and the "bankability" of electrification projects, among other benefits.
- An institutional and electrical governance framework that articulates and promotes agents who can, by means of political and legislative frameworks, promote the actions required to expand coverage for universal access in Colombia. This block will be developed in Section 4.

4.1 Integrated benchmark planning

Planning is necessary not only to determine the roadmap for investment and project implementation in order to meet electrification goals with the least possible expense, but also because a rigorous calculation of the design of electrical supply systems, whether connected to the SIN, or with minigrids or standalone systems[22], lets us establish investment priorities for each phase and section of the plan implementation, in accordance with the availability of funds and the priority energy and sustainable development policies. They help to determine the benchmark service costs that may serve as a basis for calculating

[22]The distinction between the SIN and ZNIs must be reevaluated and instead, differences must be established based on the modes of electrification, whenever applicable.

the tariffs and subsidies required for the regulation and sustainability of the electrical supply in the long term.

The following aspects and key proposals from the analysis of the planning context of electrification in Colombia may be highlighted.

- It is necessary to delve into the strategy for coordinating and centralising responsibilities and boosting planning capacities, concentrating the functions in the UPME as the central unit for the development of the planning instruments that shall subsequently be adopted by the Energy Ministry.
- An integrated plan for electrification must avoid the fragmentation of efforts and the static consideration of the different modes of electrification (grid, minigrids and standalone systems) and of the different zones (SIN or ZNI). It is necessary to review existing plans that project the average cost of connections to the SIN in the future to be between 17 and 20 million pesos per client until 2030, whereas in 2015 this average cost was 11.4 million, thus on average, the remaining electrification would be 50% to 70% more expensive. In this situation, even within SIN zones, electrification with minigrids compatible with the national grid, installing the capacity for local generation (largely renewable energy) may represent a significant saving with regard to these projected levels of future expenditure for grid extension. A minimal cost electrification plan must be able to compare, for the population still without electricity in each zone (both SIN and ZNI) the possibility of electrification with grid, minigrids and individual systems to order to save on service costs while ensuring appropriate levels of quality for each situation.
- Likewise, for a correct technical and economic analysis of the cost-effective option for electrification, it is worthwhile to increase the level of detail of the analysis if the required data can be obtained, going from the consideration of communities as a whole and limited to domestic consumption (to determine if it is necessary to connect rural areas to the central grid), to the detailed calculation of generation and grid systems (according to the catalogue of available and regulated technologies for different voltage levels). It delves into each individual connections of different types of users (domestic, community and productive) according to their specific demand profiles. Both the calculation of the required isolated generation, and the lines and transformers required for grid connection must be in line with the criteria for designing electrical systems that fulfil the technical codes and quality standards of service. The development plans with a territorial focus – PDET and the PERS

sustainable rural electrification plans have methodologies that make it possible to reach the aforementioned level of detail.

- This integral planning allows us to incorporate the analysis of the most efficient cooking energy – including electric cooking – within the minimum costs plan, as well as the substitution of wood as a fuel.
- A future vision of an electric system where interconnected and distributed systems exist together in a flexible manner, must foresee the currently isolated zones in the grid that may be connected in the future. Prior generation or previously installed minigrids may later be integrated into the SIN. This transition should also accommodate new realities such as the significant penetration of distributed generation, storage, smart grids and demand management. This flexibility requires the planning effort to be made in an integrated manner, taking into consideration all possible modes of electrification and the interaction between them.
- The electrification plan will be adjusted to the specifications established by the regulatory bodies and the distribution companies based on the demand to be supplied, the minimum service reliability and quality that must be achieved overall and on an individual basis for each client, the types of components to be used and the electrification code to be followed. For example, the minimum supply conditions to be provided by mini-grids and stand-alone systems must be specified.
- The electrification plan of a zone may be subject to environmental restrictions, such as an upper cap on the use of fossil fuels. Similarly, minigrids may be designed in such a way that the use of diesel generation as a backup to maintain a minimum level of reliability does not exceed 10% of the total minigrid energy consumed throughout the year.

4.1.1 Potential application of an advanced geo-referenced planning model

Within the framework of the collaboration between MIT/Comillas Universal Energy Access Laboratory and the UPME to apply the REM model to ZNIs, a previous pilot study has already identified the potential and information needs and configuration of REM algorithms to suit planning requirements in Colombia. The pilot study is analysing the suitability of the model for the case of ZNIs, as well as information availability and needs in order to determine the zones of least electrification cost with grid extension, minigrids or standalone systems (solar kits with direct current or systems for productive and community uses with alternating current, in this particular example).

Although geo-referenced information on the distribution networks of currently active operators is already available (medium-voltage lines and medium/high-

voltage transformers), in the case of smaller operators for whom this information is not yet available, it may be worthwhile to estimate the location and characteristics of thee lines based on the estimates of the electrified population, using both REM and RNM (Reference Network Model) models.

With regard to consumers, based on the existing information on electrified consumers, the High-Resolution-Settlement Layer for Colombia, which provides a population density map with an approximate resolution of 30x30 metres, would allow us to calculate the non-electrified population in both ZNIs and the SIN.

On this basis, the REM would help to perform quick estimates of the total investments to be made by each supply system (both grid and off-grid) so that interventions where the impact of electrification is more urgent and immediate are prioritised in the short term; by extending the existing grid or by densifying connections in the zones where the grid is already present (and does not therefore require a new territorial assignment which would increase execution times). In other zones without a provider, the best mode of electrification (grid, standalone systems and minigrids) will be determined before they are prioritised and assigned.

This will help to establish a scheme for universal coverage in the medium and long term, and to fulfil the extension commitments made by the Government for 2022.

Finally, REM and RNM models let us determine the individual efficient service cost for each portion of the grid, minigrid or standalone system, thus facilitating the calculation of regulated tariffs and the subsidies required for the sustainability of the service.

4.2 Proposed regulatory framework

Based on the regulatory principles we have discussed before in Section 3.1, we now define the proposed regulatory framework.

4.2.1 Defining areas of responsibility

It falls to the Energy Ministry, with the support of the UPME, to carry out this task, starting from the following considerations: i) previously created clusters; ii) available information from a planning model using geographic information systems (GIS), so that the resulting zones are independent of each other with regard to grid extension; iii) first defining the zones adjacent to the SIN that may be easily supplied at least partially by extending the grid of current operator and later defining more remote areas; iv) zone homogeneity with regard to the

electrification mode and the presence of commercial and industrial demand that may contribute to reducing the subsidy required to cover electrification costs in each zone.

In this regard, the structure of the national electrical system as well as policy elements provide input in the establishment of proper zoning to assign those ultimately responsible for the universalisation of all homes and providing the service within established levels in each zone.

The definition of areas must be oriented towards fulfilling the long-term goal of having a sector where the levels of optimal reliability and sustainability converge, in addition to the short-term objective of achieving the 2022 coverage goal. With this vision in mind, it may be practical to focus on the regionalisation generated from the presence of grid operators and different areas may be determined only where there are no operators, or when the financial, administrative or technical conditions of the active operator make it preferable to establish another operator.

Finally, in cases where the need to overcome market weaknesses make it necessary to outsource the service as in the case of Cauca and Chocó, the regulatory and contractual conditions must be revised so that operators, whenever appropriate, can attend to the defined areas.

4.2.2 Assigning each area of responsibility to a concessionaire.

Once the universal access plan for electrification has been drawn up for each of the zones defined in the previous stage, a call for tenders will be made for each zone, open to all potential operators who fulfil the minimum requirements, in order to determine which of them submit the lowest price for executing the aforementioned plan for each zone, on a separate basis.

The parameters of the plan shall be established by the Energy Ministry, with the support of business in the sector. For example, the goal of the electrification plan may be to provide universal access for 2025 in a specific zone, in accordance with a fixed schedule for the development of the project. The plan will specify the mode of electrification of each point of demand (not strictly points, rather small zones that are similar to the real geographic distribution of the buildings). It must follow the electrification code specified in the CREG resolutions and the technical regulations of the Energy Ministry. It will also establish minimum levels of reliability, supply quality and losses.

The pre-qualified providers will have to offer the present value of the cost of the plan, using a given discount rate. The offered cost must be the total cost and unit cost by electrification mode, including investment costs (interests on capital and

debt, plus depreciation), operation and maintenance, management, in addition to social welfare which is described later. The total cost elements must be listed in the offer. The costs offered by the winner will serve to determine their revenue requirement. Details on the implementation of the operator's required revenue shall be discussed between the regulator and the winner of the call for tenders, once the results have been declared.

Prior to the call for tenders, the regulator shall make public the method for calculating required revenue from the basic cost elements, according to the usual procedures. The parameters of the algorithm shall be adapted for each zone, in accordance with the results of the corresponding call and negotiating with the concessionaire.

Structuring the contract is essential to achieve the coverage and quality goals in accordance with the vision of the future. Apart from the technical structure resulting from the mathematical modelling to establish the most efficient combination among the modes of electrification and the cost and revenue conditions, the contract should be clear about the following aspects:

a) Identifying the assets to be provided: as there is no exclusivity in non-interconnected provision, which active assets should be linked to the concession, their ownership, the operating condition and if they are received as part of State support (when public) or if their acquisition should be included within the financial structure of the contract (and therefore remunerated).
b) Time period: the scheme must guarantee that both the revenue and the time period permits the recouping of the investment and incentivises a proper AOM to respond to the quality conditions of the offer.
c) Compensation: given the vision of long-term coverage and quality, it may be assumed that during the concession, users who are initially served by means of isolated solutions will be interconnected. It will then become necessary to establish a mechanism for compensating investments that do not have sufficient time to be recouped (e.g., defining depreciation schedules to arrive at residual values of assets). The technical conditions must be in line with the long-term planning so that the costs of this compensation are minimised.
d) Reversion clause: the concession must clearly establish the conditions for the reversion of the assets acquired to provide the service.

The Government always has the option of assuming, through the IPSE, the responsibility for the AOM and investment in energy infrastructure in any of the defined zones where the business schemes have not yet been

implemented.[23]The IPSE must boost its technical and financial capacity, if it is to fulfil this function. Another alternative is that in areas without a willing active operator or where it is not possible in the short or medium term, this service is taken up by the State via a company that has the necessary experience and capacity, as is the case of Gensa. This of course, taking into consideration the relevant conditions and controls.

4.2.3 Facilitate the incorporation of active operators

With the goal of achieving a more compact structure of the Colombian electricity sector, enabling continued supply over time and to achieve economies of scale, it is preferable that the current operator adjoining a zone to be electrified be the concessionaire of that zone. This may be done in the following two ways which are not wholly exclusive of each other:

a) The Ministry may offer the concession of a zone to the closest active operator, with a required revenue obtained according to the public procedure and standard costs. If the active operator does not accept the offer and there is no other SIN operator sufficiently close by (to whom the same offer may be made), any potential pre-qualified concessionaire may be invited.
b) In the case of an open call for tenders for a zone to all potential pre-qualified concessionaires, once the submitted offers have been studied, the closest active operator will be given the chance to match the best offer. If they do not take up the offer, it will then be offered to other operators who are sufficiently nearby. If none of them wishes to match the offer, the concession will be awarded to the lowest bidder. This option has the disadvantage of discouraging potential new players. An alternative would be to give some extra points in the auction to those operators that are participating in the tender and are in close proximity. This ensures transparency and will not discourage potential new players too much. The extra points can be given during the pre-qualification stage or during the actual bidding stage.
c) The bids should include, in an explicit section and with a included budget, an action plan to promote the services that access to electricity may promote, for residential as well as commercial and industrial consumers

[23]According to Decree 257 of 2004, Article 15, Section 6, the IPSE is responsible for supporting the energy service provision with AOM and energy infrastructure investment in ZNIs where business schemes have not been implemented.

(see following section). The method for evaluating offers must include a procedure for assigning a weight to this component of the offers.

However, universalisation is not achieved exclusively with connections to the grid, and therefore the grid operator must have the incentive and be legally able to commit to investing in standalone solutions that provide efficient coverage in their area. Another possibility is to include another or other new operators specialising in mini-grids or stand-alone systems in the bidding consortium of the closest active operator, and enable an agreement between them and the assigned concessionaire.

The PND eliminated the prohibition on agents performing different activities within the energy supply chain. Currently, an operator is able to perform energy generation activities. Likewise, the PND has expanded the definition of electrical energy service provision which was linked to grid supply by Law 142, extending it to the new forms of supply. Having overcome these limitations the following step is to invest in standalone solutions, whether it be minigrids or standalone systems, are recognised within the tariff remuneration. To do so properly, the highlighted investments must be included in the operator's Regulatory Asset Base (RAB) by acknowledging the new constructive units of these technologies.

In this regard, it must be mentioned that the separation of the SIN and ZNIs is a limiting factor in developing coverage in isolated areas. This is a clearly illustrative case of this situation but it has a possible short-term solution.

Within public policy lines with regard to expanding electricity coverage[24], different chapters discuss the rules that govern the expansion of coverage in the SIN and ZNIs. In the first case, the decree highlights that the expansion of SIN coverage relies on the OR and are paid according to the distribution charges established by the CREG. In the case of ZNIs, while it is established that OR may make investments in standalone solutions, the decree clearly states that payment shall be established on the basis of tariffs (that have a separate calculation method in the case of ZNIs).

For the former, it is concluded that on the basis of technological advances that have overcome the causes for the distinctions between agents, institutions, resources and procedures for the SIN and ZNIs, this segregation must be eliminated in order to promote investments in standalone solutions and boost the convergence of both sectors. One solution in this route would be to update the single decree of the sector to enable the recognition of minigrids and standalone

[24]Decrees 1623 of 2015 and 1513 of 2016.

solutions units through the remuneration of distributor activity. On the other hand, in cases where the projected remuneration for the SIN does not constitute a sufficient incentive for increasing coverage with standalone solutions, as mentioned in Section 4.2.7, a remuneration which in any case acknowledges the service costs is required.

4.2.4 Evaluating the social component of an electrification plan

Both the electrification plans and the evaluation of the bids for a concession, must include a social welfare component. There are two important points.

Firstly, owing to its design, the electrification plan for each zone drafted by the UPME must include the social cost of the unavailability of a basic electrical supply, as well as the cost incurred by a lack of reliable supply. A planning model must therefore include the unsupplied energy cost (UEC) as another element of the total cost, as if it is not included, the obvious least cost solution is to not incur any costs: that is to say, no investments, no power plant operation, etc. At the very least, two UEC values must be considered: one is the cost of the absolute lack of electrical service. If a very high value is assigned to this cost, the plan will deem it "economical" to provide basic electrification, at the very least, to all potential clients even the most remote ones, therefore giving an economic justification to universal electrification. The other value is the UEC for those clients who already have a connection, but it malfunctions, causing a loss for them. Advanced models for optimising electrification plans such as the REM model discussed in this document can include both types of costs.

Secondly, it must be demanded within the conditions to be fulfilled when submitting bids, that potential operators should offer, in addition to the strictly electrical supply, a consumer interaction plan, that must include two principal aspects: i) social work with the communities, for agreements on the electrical service to be provided, the functioning of the system and its possibilities, and the payments to be made; ii) initiatives to boost the social benefit of having electricity, for domestic, community, commercial and industrial purposes;[25] for example, providing microcredit for acquiring electrical appliances and other energy efficient devices, arranging the acquisition and use of devices for productive uses of electricity, whether commercial or industrial; imparting courses of how to install, operate and maintain electrical installations. The distributing company, given their direct contact with the client, can initiate these tasks more easily, as they are in

[25]The recent document on smart technology in Colombia, "Microrredes sostenibles en ZNI. Lineamientos estratégicos", September 2019, has some very interesting ideas in this regard.

favour of the clients and the company itself, as supporting the productive and entrepreneurial development of the region increases the purchasing power of the clients, thus increasing demand and reducing the kWh cost.

Different types of special considerations may lead to prioritising a certain electrification project or a zone, and thus adopting a mode of electrification that may not strictly be a least cost plan: for example, budget limitations that necessitates the adoption of the plans with higher social cost, different political priorities (PDET programmes, ZOMAC areas or zones affected by armed conflict, borders) limitations of human or technical resources, etc.

The benchmark terms for the offers may include environmental restrictions such as, for example, an upper cap on the use of fossil fuels in minigrids, so that the offers fulfil the established goals of the electrification plan.

4.2.5 Supply by default and last resort, but not exclusive.

The concessionaire of a zone shall be the sole provider by grid extension for said zone. Under current legislation, there is no obstacle to a concessionaire from a zone adjacent to the SIN seeking an authorisation to connect to the national transmission system (STN) or even a regional transmission system (or STR) located in said adjacent zone, operated by the other operator, as long as they comply with the rules for connection.[26]

Once the electrification plan for a zone has been defined and assigned to a concessionaire, private initiatives – including those of the concessionaire themselves – for setting up minigrids in the areas or for the populations designated in the plan, may be set up, as well as for the sale and/or installation of standalone systems. In any case and as specified below, the concessionaire is also the default and last resort provider, for the entire zone.

The concessionaire of a zone shall be the default provider – using the mode of electrification which is compatible with the least cost plan – for all clients in the zone. Provided the electrification plan stipulates the need to set up minigrids and/or standalone systems in a zone and no operator other than the concessionaire has expressed their intention to do so within the stipulated period of time, the concessionaire of the zone must take up the responsibility for this supply.

[26]Resolution 070 of 1998, and subsequent developments. http://apolo.creg.gov.co/Publicac.nsf/Indice01/Resolución-1998-CREG070-98.

The concessionaire of a zone shall be the last resort provider, replacing a provider that may have gone bankrupt or abandoned the service for any reason whatsoever, taking over the assets of the defaulting provider and the electricity supply to the latter's erstwhile clients. The terms under which the physical assets and existing information systems become the property of the zone concessionaire must be regulated, as well as the economic compensation derived from taking over and continuing the service for affected clients.

If the electrification plan of a zone contains significant percentages of each of the three modes of electrification, it is possible that a potential concessionaire submits their offer on behalf of a consortium formed by: the main operator – with experience in traditional distribution –, a company specialising in minigrids and another in standalone home systems. If they are awarded the concession, they must establish the rules of mutual co-existence and cooperation, including the transfer of consumers and their data as demand increases and the grids expand, as well as incentives for better performance by the firms subcontracted for off-grid services, for example, to reduce the rate of outstanding payments.

4.2.6 The service conditions and incentives for better performance of the distribution activity.[27]

The regulatory bodies must establish the minimum conditions to be satisfied by the electric supply for each mode of electrification. At the same time, it is preferable that the revenue conditions for distribution incorporate incentive-based regulation, that is to say, increased or decreased revenue based on the completion of certain goals: reliability, service quality, technical and commercial losses, progress in the number of consumers supplied until universal access is achieved in the zone under consideration, but not only for grid-based distribution (as is mentioned in Resolution CREG 015 of 2018) but also for off-grid distribution.

Minimum levels of reliability must be set, properly expressed for each mode of electrification and the accessibility conditions of the zone, among other factors. The remuneration for distribution must include incentives and penalties for exceeding or failing to meet the established minimum values. For questions relating to reliability we refer to that which has already been discussed in Chapter 2 of this report.

[27]Distribution activity is understood here in a wide sense to include the three modes of electrical supply to end-consumers.

Standalone home systems must be able to provide a minimum power and the battery must also have a minimum charging capacity, which should be enough to ensure, making a reasonable use of the systems, a minimum number of working hours – including a pre-fixed number of hours during the normal peak hours of electricity usage – for a certain number of days every year at least.

The concessionaire has a natural incentive to reduce both commercial and technical losses, therefore it may not be necessary to establish additional incentives in this regard, unless metering, billing and charging costs are higher than what is expected to be earned by applying the tariffs. This is applicable only if the concessionaire receives a required remuneration based on the recognised investment and operations costs, where the latter includes the wholesale cost of energy acquired from the SIN, as recommended later.

With regard to the progress made on providing access to electricity for more consumers, the deviations from the electrification plan agreed upon with the concessionaire must be penalised, if the goals are not met and rewarded (slightly) if they exceed their targets.

4.2.7 Required revenue, tariffs and subsidies.

The revenue requirement of the electrical service of standalone solutions must be approached similarly to traditional regulated distribution: the established revenue requirement must repay the total costs of efficient service provision, including an appropriate revenue for the invested capital – where a clear line must be drawn between the investments made by the concessionaire and any public investments made previously or additionally. This is applicable to grid extensions as well as to minigrids and standalone systems, taking into consideration for each case, the paid assets, their user life and necessary replacements, O&M costs as well as financial and management costs, following the usual revenue practices for distribution employed by the CREG, now including the necessary components for the functioning of minigrids and standalone systems.

It must be remembered that for all modes of electrification –grid extensions, minigrids and standalone systems – both the active distributor and the possible concessionaire are providers of the electricity service – also in the case of standalone systems and minigrids – and therefore they must invest in certain physical assets, operate and maintain them, thus incurring the corresponding costs, which must be properly repaid according to normal practice.[28] This unified

[28]For grid extensions and minigrids, the MYTO procedure of the Nigerian Electricity Regulatory Commission (NERC) can be consulted. The use of a regulated revenue for service costs for standalone system is less frequent; the Peruvian

approach simplifies the regulatory supervision of the distribution, as well as the tasks of the distributing company, so that all modes of distribution and all clients are treated equally, as a service provision with established quality requirements, revenue requirement, consumers with regulated tariffs and reception of subsidies.

The revenue mechanism must include incentives so that the concessionaire does not deviate from the established goals and conditions of the electrification plan, with regard to the mode of electrification and the demand to be supplied for each type of consumer.

The revenue requirement of the companies that provide electrical services must be cost reflective, that is to say, they must cover the efficient costs of supplying electricity (there are varying interpretations of efficient cost and varying methods for its calculation) as otherwise, the distribution would not be economically viable. On the other hand, the tariffs established by the regulator do not necessarily need to be cost reflective, if they wish to subsidise certain groups of consumers, with preferential rates, for example.

This is the case for ZNI consumers in Colombia, where they enjoy a state subsidy to guarantee service in the zone. In this proposal, the difference between the amount recouped with subsidised tariffs and the required revenue (cost reflective) is the subsidy granted to the distribution concessionaire, whose payment must be guaranteed in order to attract private capital for this activity. In conservative regulations, tariffs for end-users must be cost reflective, except for preferential rates (which in ZNI may be applicable to a large percentage of the population) where the deficit is covered with public funds (preferential) or in part with a supplement (uplift) in the rest of the tariffs, as in the mixed approach used in Colombia and Peru.

It must be noted that practically all countries have cross-subsidies in tariffs, for reasons of social cohesion or industrial policy. For example, it is common practice to apply the same tariff to domestic consumers (for each level of consumption or contracted power) irrespective of whether the client is in an urban or rural zone, when the supply costs are very different. What is important is that tariffs – overall – should recoup the total required revenue for the electrical supply. Section 3 goes into more detail on the scheme of cross-subsidies.

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model may be taken as a benchmark. The Photovoltaic Tariff for the Peruvian Electric Rural Expansion. Miguel Juan Revolo.

Each consumer supplied by the concessionaire – either connected to the SIN grid, a mini-grid or that has a standalone system – is subject to the regulated tariff, subsidised or not. The concessionaire receives the income from charging the tariffs paid by the consumers, plus the amount of the difference between the required revenue established by the regulator for supply by grid extension, minigrids and standalone systems and the estimated amount to be recouped by tariffs.

This focus regularises the treatment of the three modes of electrification, integrating supply by minigrids and standalone systems into the traditional regulatory approach to electricity distribution. This approach also guarantees technical and economic sustainability with standalone solutions for an indefinite period of time, which is not the case when the support for minigrids consists of a subsidy for the initial investment, or when a discount is given for the purchase of the first standalone system.

4.2.8 Treatment of independent operators

As mentioned before, once the electrification plan for a zone has been defined and assigned to a concessionaire, private initiatives – including those of the concessionaire themselves – for setting up minigrids in the areas or for the populations designated in the plan, may be set up, as well as for the sale and/or installation of standalone systems. It proposes to look at how the existence of subsidised regulated tariffs in a zone can affect the activities of independent operators in the area.

It must be clear that the regulatory approach proposed here for standalone systems – i.e., minigrids not connected to the SIN grid and standalone systems – is different from the promotion mechanisms based on discounts for the purchase of domestic solar systems or subsidies for the initial investment for installing minigrids, which is the most widespread promotion method currently used. It is possible to add these discounts or subsidies to the focus proposed here (conveniently modifying the amount of subsidies, but maintaining the same approach proposed here), conveniently adapting the required revenue.

With regard to independent minigrid operators, it is proposed that a regulation similar to that which is currently implemented in Nigeria and inspired by the system previously established in the Indian state of Uttar Pradesh. Independent operators with an installed power generation capacity lower than a certain capacity (for example 100 kW) have two options.

According to the first option, an independent operator can freely negotiate with their clients certain tariffs and operate their minigrid, subject only to the

electrification code, which guarantees the potential future connection to the SIN network and a economic compensatory scheme. The possibility of supporting independent operators by providing them with a one-time remuneration for each consumer that connects to their minigrids (remuneration based on performance) is left open to debate. This is not a consequence of the selected regulatory planning, but it may accelerate the electrification process and contribute to the fulfilling of short-term goals proposed by the PND.

In the second option, the operator must register their minigrid project with the regulator and comply with the same conditions as the concessionaire: required revenue, regulated tariffs and a compensation for tariff deficit, to make up the amount of the required revenue.

With regard to standalone systems, their sale in isolated zones is perfectly legitimate, but there is no available subsidy for the upfront cost of the systems, it being incompatible with the regulation proposed here. Independent providers of this equipment would have to compete with the subsidised regulated tariff that would be available to certain domestic consumers. For standalone systems a regulatory regime similar to the second option for minigrids may be established, when the provider of these systems has a “utility-like” function, selling service and no apparatus, and establishing their annual required revenue on the basis of their total costs for the year under consideration. These costs could be recouped by means of the tariff and a compensation that would cover the “viability gap”.

4.2.9 Co-existence of off-grid solutions with the SIN.

All minigrids that are installed in a zone – either developed by the concessionaire or by an independent operator – must comply with the electrification code in force and especially the safety criteria for the users of the installations. Unless otherwise authorised – understood as connection to the SIN not being technically or economically feasible – the minigrid installations must be compatible with the SIN and be able to connect to it.

The providers of domestic electric service with standalone systems must be registered and their products duly authorised in order to be eligible for the subsidies that are established. These procedures must be simplified as much as possible in order to avoid creating unnecessary administrative obstacles.

In accordance with the initial electrification plan and its subsequent modifications, the SIN grid shall be progressively extended, reaching the location of some of the current minigrids. Technically, the inter-connection must be made without problems, as the minigrid is compatible with the SIN grid. No additional regulation is required when the connected minigrid is operated by the concessionaire of the

zone, but adjustments must be made to the remunerated base of the physical assets, depending on the use made of the batteries/diesel generators, that may either be of great use or not useful at all. If the minigrid is operated by an independent operator, an agreement must be made between the three parties: the independent operator, the affected community and the concessionaire. This agreement must be approved by the CREG regulatory body and there are various options.

In the first option, the minigrid continues to be managed by the independent operator, but now with the possibility of exchanging energy at the point of interconnection. The electricity tariffs for the minigrid clients are established by the regulatory body. The price of the energy derived taken by the minigrid from the SIN grid at the point of connection and the price paid by the concessionaire for the delivery of the surplus energy produced by the minigrid shall be determined by the regulatory body. The minigrid is remunerated according to the service cost, as minigrids developed by the concessionaire or their subsidiary firm.

A second option for an existing mini-grid is to maintain regulatory independence, although it is connected to the grid and exchanges energy with it at regulated prices. The tariffs for end-consumers would continue to be established freely between the parties. It is a self-managed system, like a cooperative. The situation of minigrid consumers who prefer to not subscribe to this scheme must be resolved, as they are now connected to the main grid.

In the third option, the independent operator transfers the ownership of the grid assets to the concessionaire and becomes an independent energy producer with the production and storage facilities of the minigrid. The energy inserted into the grid shall be purchased by the concessionaire at a price established by the regulatory authority. The concessionaire must reimburse the independent operator for the grid assets according to their residual value plus, for example, a year's worth of the revenue from those assets.[29]

Finally, a last option is that the minigrid operator is not interested in any of the previously mentioned options and decides to liquidate the business, sell the physical assets and turn over the operation of the minigrid to the concessionaire as a last-resort operator.

[29]This is, for example, the regulation on minigrids in Nigeria, 2017.

4.2.10 Improving the quality of the electrical energy

The levels of quality in Colombia are far below the acceptable levels for providing the service. In 2018, there were on average 48 interruptions per user in the service, with an average total duration of 37.7 hours that is today, more than a day and a half without electricity. In comparison, the CREG has set out long-term goals equal to a maximum average of 9 interruptions and 2 hours per year. Additionally, there is an enormous regional disparity. Depending on their location, a user may suffer on average, from a low-quality service with 21.8 interruptions totalling 17.3 hours per year, to an unacceptable service, with 600 interruptions per year that may reach 1000 hours in duration. The quality conditions in ZNIs are even more precarious and the regulations make only basic demands. An illustrative example is that continued supply is only required of ZNIs that have 24 hours of service, which are required to meet the minimum required standards of the SIN.

There is a direct relation between the investments and the O&M costs, and the frequency and duration of the interruptions. The regulations on service quality must take into consideration this cost-quality ratio in a balanced fashion for the different modes of electrification, either grid extension or minigrids or standalone systems, according to their respective characteristics.

5. Institutional reform

It is necessary to overcome the institutional duplication and confusion of functions arising especially from the separation between SIN and ZNI. In this regard, the proposed institutional reform includes the centralisation, specialisation and strengthening of the bodies that execute public policy. By constitutional mandate, relocating functions or reforming the legal nature of an entity is the sole responsibility of the legislature. Nevertheless, the President of the Republic has the power to create and eliminate functions as well as distribute them from Ministries to public bodies.

For a benchmark integral planning, we propose that the UPME be the exclusive planner for the sector, so that the functions distributed among other bodies be eliminated. In order to ensure consistency between what is planned and what is to be executed, it is recommended that the same agent who is responsible for the planning also spearhead the project.

Additionally, the institutional strengths must be boosted in order to develop projects and bring forward the hiring processes and performance monitoring. In line with the proposal for specialisation and separation of functions, it is proposed

that the project developer also be responsible for its execution, with the support of the appropriate information systems and an efficient intervention mechanism. A strengthened and restructured IPSE would be in charge of execution for this sector, in order to face the challenges inherent in this task.

Given the diversity of available sources of funding[30] it is essential to establish a single window to receive and manage initiatives for expanding coverage and improving quality, standardising the feasibility criteria of the projects and centralising information in a project database, from the presentation onwards until the operation. The strengthened IPSE will be in charge of the single window and the project database.

In order to attract private investment and to properly manage the resources and the operations of projects in this sector, information must be centralised and made available to the public with complete transparency through an energy information manager.

6. Implementation

This section classifies measures as short, medium and long-term, based on the time taken to implement the proposals, which is estimated based on the implementing authority.

Short-term measures

Most of the proposed adjustments correspond to administrative measures, that is to say, they depend on the decision of the National Government and are implemented by means of decrees, resolutions and even technical documents. These are deemed to be short-term measures, for their relative ease of application.

Updating the lines of coverage expansion, eliminating the differences between the SIN and ZNIs, and enabling the grid operators to invest in isolated solutions charged to distribution revenue, requires a National Government Decree.

Overall, the entire application of the scheme for defining the responsibilities as well as assigning the responsible entity, are the Government's functions, that range from the overall planning to the awarding and monitoring of the assigned provider. While the activities in the scheme may be carried out through

[30] It is necessary to standardise criteria and coordinate funding sources. Even if energy funds, general public resources and resources for cooperation are unified, they will be destined for sector-based goals.

resolutions of the Energy Ministry, it is desirable that a policy with a long-term vision such as the one we have proposed be a CONPES policy document, in order to make it continuous and to facilitate resource management by a declaration of strategic importance.[31]

With regard to quality improvement, we propose measures that fall under the purview of the Regulator but are not as complex as a regulatory initiative or modification, but are executed by means of the CREG's power to apply its regulation and are therefore classified as short-term.

Another administrative element is the enforceability of including telemetry systems in standalone projects so that the regulator and the Supervisor may perform their functions with the relevant and timely information.

Medium-term measures

Proposals that require regulatory adjustments are deemed to be medium-term measures. Among them is the regulation that incentivises expansion through standalone solutions and regulatory modifications for improved quality of service.

Long-term measures

Long-term proposals are those that require legal modification, as they do not depend on the exclusive decision of the national Government and are subject to procedures that normally take time to be accomplished.

The scheme proposed for achieving universal coverage may be applied without legal modifications, nevertheless, it is worthwhile that the separation between the SIN and ZNIs be eliminated by law, and the sector unified with a vision of quality and sustainability, although the electrification modifications would require laying down technical and revenue conditions. Likewise, the expansion of coverage would acquire a dynamic nature with an entity specialising in project planning and execution with the technical and financial capacities required to face this challenge. A reorganisation of this scale requires a law.

[31]The declaration of strategic importance allows the allocation of resources from future general State budgets even when the current Government is not in power, as these are State policies that are not dependent on each Administration.

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