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Exploring the effect of subsidies on small-scale renewable energy solutions in the Brazilian Amazon

M.F. Gómez [a, b, *], A. Téllez [c], S. Silveira [a]

[a] KTH Royal Institute of Technology, Division of Energy and Climate Studies, Sweden
[b] Energy, Materials, and Environment Laboratory, Department of Chemical Engineering, Universidad de la Sabana, Campus Universitario Puente del Común, Km. 7 Autopista Norte, Bogotá, Colombia
[c] Producción más Limpia – PML. Consultant, Colombia

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ABSTRACT

The Brazilian government aims at universal electricity access. The national rural electrification initiative has provided electricity services to more than 14 million people since 2003, mainly through grid extension. However, the initiative has not been able to reach remote areas in the Amazon, thus requiring a review of conditions for small scale off-grid power generation projects. As a result, new rules established under the national rural electrification program address the design and implementation of off-grid power generation projects with an installed capacity up to 100 kW. The objective of this paper is to explore the effects of the new set of rules on the levelized cost of electricity for different power generation solutions in the Amazon. Our study shows that the new rules may be beneficial to isolated communities, as they reduce the levelized cost of electricity, favor renewable energy technologies and may contribute to reduce CO_2 emissions. In addition, the new rules may help engage new actors to provide rural electrification of the Amazon region. To fully take advantage of the current scheme, action at local level is required to define the most appropriate model for small-scale power generation projects and establish synergies between concessionaires and local energy providers.

1. Introduction

The Brazilian government has made significant efforts to increase electricity access and promote social inclusion in the country. The last national rural electrification initiative launched in 2003, called Light for All – *Luz Para Todos (LPT)*, was designed with the aim of achieving universal electricity access in the national territory. LPT has already provided electricity services to more than 14 million people, mainly through the extension of the grid. During the first eight years of the program implementation, the federal government contracted electrification at a total value of R$ 13.7 billion, equivalent to approximately 5.7 USD billion [1]. In terms of cost per connection, the Brazilian program has been the most costly in the whole of Latin America [2]. A subsidy scheme was put in place which combines connection and consumption subsidies.

Off-grid power generation systems have now become an integral part of the rural electrification program in Brazil. Still, significant challenges arise in relation to the implementation of decentralized electrification in low-density and remote areas [3]. This includes assessment of locally available resources, choice of technologies, and implementation and management plans. Estimating the costs of providing off-grid electricity to isolated communities in the Amazon is no simple task as there are many uncertainties to be addressed related to local conditions and key factors such as fuel price and system design options.

Recently, the Brazilian government created a new set of rules that directly affect the development of LPT in isolated communities. The new rules address the design and implementation of off-grid power generation projects with an installed capacity up to 100 kW in remote areas. Concessionaires are now allowed to conduct bidding processes, under the surveillance of the government, in order to select a third party to provide electricity in specific areas of their concession areas. This shall open opportunities for new agents to formally become electricity providers. This means also that these new agents now have access to financial resources in the form of capital and operation subsidies which were previously reserved for concessionaires only [4–8].

* Corresponding author. Universidad de la Sabana, Campus Universitario Puente del Común, Km. 7 Autopista Norte, Bogotá, Colombia.
E-mail address: mfgg@kth.se (M.F. Gómez).

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The objective of this paper is to explore the effects of the new set of rules on the Levelized Cost of Electricity (LCOE) for different small-scale off-grid power generation solutions in isolated communities of the Amazon. Does the new scheme improve the attractiveness of renewable energy technologies as an alternative to provide electricity access in remote areas of the Amazon? Based on local resources and available technologies, we propose the best possible technology configuration for a micropower system[1] designed to supply electricity services in a typical and hypothetical non-electrified rural village located in Moju municipality. The best possible configuration is based on the lowest Net Present Cost (NPC) and it is determined using HOMER®, an optimization-based tool to capture technical and economic dimensions of decentralized power generation at village level. We study the effect of fuel prices on the LCOE for the best system configuration under different power generation scenarios. Scenarios were built according to local realities and with the main purpose of providing electricity services to households and local productive activities (e.g. manioc flour production). A household comprises 4 inhabitants on average.

In Section 2, we present the subsidy schemes put in place through LPT which are now available to multiple electricity providers, and help improve the competitiveness of renewable energy sources for off-grid electrification. In Section 3, we describe the methodology used to perform the LCOE analysis. Section 4 provides an analysis of local resources and electricity demand in an isolated village of the municipality of Moju. Section 5 presents the assessment of technologies and the design of a power generation system for the village. For that, we defined our baseline as a diesel-based system, and established four different scenarios. Section 6 presents the results of the economic evaluation and discusses the effect of capital and operation subsidies on the LCOE in the four scenarios. Also in Section 6, we estimate the CO_2 net emissions resulting from the different systems evaluated. Finally, we present our findings and conclusions in Section 7.

2. Subsidy schemes for electrification

Initially, in order to promote electricity access, LPT provided financial support to the concessionaires in the form of grants and soft loans. Concessionaires were expected to pass the resources to the end users in the form of free-of-charge connections. All rural households were provided with electricity services, including light bulbs, electrical outlets and all internal wiring [5]. In addition to federal sources, state governments and concessionaires were expected to provide approximately 10% and 15% of the required funds respectively [9]. The subsidy scheme was mainly used to provide electricity access in areas close to the grid.

Concerning operation costs, the Fuel Consumption Account (CCC) subsidized fossil fuel used for large-scale thermoelectric power generation in areas not covered by the interconnected system. The CCC reimbursed expenditures related to fuels for power generation covering the cost difference to the equivalent for hydraulic power, by large the most common electricity source in Brazil [10]. The cost for hydraulic energy equivalent was set by the Brazilian Regulatory Energy Agency (ANNEL), and the difference between the cost of fuel for thermal generation and the cost of hydropower was allocated to each concessionaire according to its specific power generation. The reimbursement was calculated based on the description provided by ANNEL in the corresponding resolution [10]. For that, we used Equation (1).

$$Rcc = CF_{ISOL} - (GT_{ISOL} * EH_{equiv}) \quad (1)$$

where,

Rcc = Reimbursement from CCC (R$)
CF_{ISOL} = Annual fuel cost for thermal power generation in non-interconnected systems (R$)
GT_{ISOL} = Annual power generation in non-interconnected systems (MWh)
EH_{equiv} = Cost of hydropower generation in the regulated, interconnected system, as indicated by ANNEL (R$/MWh)

Only concessionaires and authorized power generation agents had access to fuel subsidies. Community organizations, NGOs or private actors have long been the main operators of off-grid systems, but they have worked autonomously and without any linkages to the benefits provided by LPT [11,2]. Currently, concessionaires supply electricity services to just 62% of the rural households of the Amazon, or about 2.4 million people. About 14% of the rural population in the region, or approximately 500 thousand people, are supplied by organizations other than concessionaires, and 24%, or about 900 thousand people, are not served at all [12]. The Brazilian government recognizes the need for off-grid solutions to supply these citizens who are mainly located in remote areas. As a result, a differentiated treatment was established for off-grid solutions in a review of the Ministry of Mines and Energy (MME) handbook[2] [13]. New requirements and procedures, including a bidding model, to put in place small-scale off-grid power generation projects were formalized [7,8,14].

Despite the fact that off-grid diesel generators have been commonly used in the Brazilian Amazon, off-grid technologies considered in the new scheme include also small wind, mini and micro hydropower generation, hydrokinetic and photovoltaic systems, biofuel-based power generation systems and hybrid systems of wind, solar, biomass, hydro and/or diesel power generators [14]. ANEEL defines requirements and procedures for off-grid power generation projects with an installed capacity up to 100 kW. Projects must ensure a minimum autonomy of 48 h according to the monthly guaranteed electricity availability. A reduced supply is allowed on daily basis when, for technical or economic reasons, electricity supply on a 24-h basis is not possible. In any case, electricity supply must be guaranteed for at least 8 h per day either consecutively or in two periods [8].

The new scheme allocates grants covering 100% of the initial investment for off-grid power generation projects. The subsidy is covered with funds from the Energy Development Account (CDE) which in turn relies on electricity consumers who all contribute via tariff [5,14]. In addition, the CCC has recently been reformed to reimburse concessionaires and authorized power generation agents an amount equal to the difference between the total cost of generating electricity in isolated systems, and the average cost of generating the corresponding amount of electricity in the regulated, interconnected system. This is a remarkable reform in the Brazilian subsidy scheme. While the fund was previously used to exclusively subsidize fossil fuel costs, and reimbursements were calculated in relation to hydropower only, the monthly reimbursement for power generation is now calculated in relation to the more diversified interconnected system as well as power

[1] We follow the definition of the Brazilian Electricity Regulatory Agency (ANEEL), according to which a micropower system has an installed capacity lower than 100 kW. The systems are referred to as MIGDI (Microssistema isolado de geração e distribuição de energia elétrica) in official documentation [8].

[2] The MME handbook establishes formal procedures, and technical and financial criteria to develop LPT. It has been periodically reviewed since its inception.