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Energy access: Lessons learned in Brazil and perspectives for replication in other developing countries

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HIGHLIGHTS

- Energy access is one important problem for 1.3 billion people not having access to electricity and 2.7 billion using primitive fuels for cooking-heating.
- We discuss the approach introduced in Brazil through the introduction of LPG as a cooking fuel that replaced significantly the use of fuel wood in rural areas.
- We describe the program introduced to supply electricity, reducing the number of people without access to electricity in rural areas.
- Lessons learned could be replicated in other DCs, contributing to poverty alleviation.

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ABSTRACT

Energy access has been singled out by the AGECC in 2010 as one of the important problems to be tackled in the next few decades in a world where 1.3 billion people do not have access to electricity and 2.7 use primitive fuels – mainly fuel wood – for cooking and heating.

To solve such problems, innumerous small scale projects have been implemented around the world either on the improvement of cooking stoves, biogas and others, as well as in generating electricity in decentralized systems.

We discuss here the "large scale approach" to solve these problems in Brazil through the introduction of LPG (liquid petroleum gas) in Brazil 70 years ago, all over the country, as a cooking fuel that replaced significantly the use of fuel wood in rural areas. In addition to that, we describe the governmental program (*Luz para Todos* – LPT – Light for all) introduced more recently to extend the electricity grid to around 10 million people, reducing considerably the number of people without access to electricity in the rural areas of the country.

Such experiences and the corresponding lessons learned could be replicated in other developing countries, contributing significantly to poverty alleviation.

1. Introduction

There are presently 1.3 billion people with no access to electricity worldwide and 2.7 billion people using traditional biomass for heating and cooking.

To address these problems, the UN Secretary General established in 2008 the Advisory Group on Energy and Climate Change (AGECC). One of the two main ambitious goals recommended by AGECC was to ensure universal access to modern forms of energy by 2030 in poor countries (AGECC, 2010).

According to the World Energy Outlook 2011 (OECD/IEA, 2011), energy access is defined "as a household having reliable and affordable access to clean cooking facilities, a first connection to electricity and then an increasing level of electricity consumption over time to reach the national average".

The definition of energy access usually includes both electricity access and access to modern fuels for cooking and heating to replace traditional biomass[1] . However, only electricity access to allow basic needs is not enough for poverty alleviation and economic development. The concept of energy for productive use (or energy services) is being considered an important and fundamental factor (UN-Energy, 2007; AGECC, 2010; OECD/IEA, 2011; GEA, 2012), among others. In this context the Brazilian experience can be significant for other DCs, since it addresses not only the electricity access for basic needs but also for the economic development of the region.

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[1] Further discussion on "traditional biomass" is presented in Karekesi et al. (2006).

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In his foreword of AGECC publication (AGECC, 2010), the chairman of the group[2] stresses that it is fundamental "an appropriate target for access to minimum energy services, (but) this need not detain action. The lowest threshold is proposed by IEA (International Energy Agency), namely 100 kW h of electricity and 100 kgoe[3] of modern fuels (equivalent to roughly 1200 kW h) per person per year. This can be used as a starting target". This means that besides the implementation of energy access for basic needs, also a higher electricity supply is needed.

According to GEA (2012), it is important the "access to affordable modern energy carriers and end-use conversion devices to improve living conditions and enhancing opportunities for economic development". Also here it is mentioned the idea of energy carriers for economic development instead of only "electricity access", reinforcing the idea of energy for productive uses.

Aiming to achieve that ambitious target, "a multi-track approach is needed, combining grid extension with micro-grids and household systems" (GEA, 2012).

Following this idea, GEA (2012) concludes that "for many remote populations grid extension by 2030 will be highly unlikely and micro grids offer an alternative, based on local renewable energies or imported fossil fuels".

Also, as discussed by UN-Energy (2007), energy services are an essential input to economic development and social progress, notably to achieving the Millennium Development Goals. "Energy services are necessary for successful implementation of almost all sectorial development programs, notably revenue generating activities, health, education, water, food security, agricultural development, etc.". Increased access to energy allows economic growth and poverty alleviation.

This definition envisages clearly two steps: a first connection that solves the basic problems of lighting and the use of radio and TV; and a more ambitious step of using electricity for productive uses (OECD/IEA, 2011[4]).

Recently, Birol and Bew-Hammond (2012) have presented the results of the Task Force One – "Sustainable Energy for All" – aiming to achieve the objectives of AGECC (2010) – universal access to modern energy services by 2030 – in the context of the Secretary General's High-level Group on Sustainable Energy for All. Also in this document, the concept of energy for productive use is pointed as an important and fundamental support for economic development.

According to some recent studies (Palit and Chaurey, 2011; Sanoh et al., 2012; Lemaire, 2011), the contribution of electricity access mainly in rural areas for poverty alleviation and economic development in developing countries (DCs) may be substantial but many existing initiatives have not been successful to increase electricity access, particularly in the case of off-grid initiatives. The need for adequate capacity building and more adequate policies in all sectors involved in energy access issues (including energy access plans and financial policies) seems to be fundamental.

Palit and Chaurey (2011) analyze the off-grid rural in South Asia and conclude that, despite several initiatives and policies to support electrification, in the region there are still 42% of global population without electricity and consequently economic development for poverty alleviation. The main challenges include technical, financial, institutional and governance barriers. Electricity supply need to be enhanced using locally available renewable energy sources, through the development of a regulatory mechanism, as well as access to micro credit and institutional arrangements.

Sanoh et al. (2012) discuss electricity planning in SSA (Sub Saharan Africa) and show that local electricity utilities focus the expansion mainly already covered by the existing grid; rural households do not receive electrification because of the very low demand.

Lemaire (2011) evaluates the off-grid electrification in South Africa and concludes that electrification with PV systems was quickly abandoned after strong financial support from international donors. To support rural solar companies that remain fragile, an institutional framework must be created together with adequate capacity building in all areas including business models.

Another issue is raised by Welle-Strand et al. (2011), stressing that, in fact, "electricity contribution to poverty alleviation and economic development may be substantial". But, together with it, "other infrastructural needs must be tied in with electricity production".

Welle-Strand et al. (2011) concluded also that "without an appropriate set of evaluation metrics is nearly impossible to discern the actual effect of improved electricity provision on growth".

In Brazil, existing programs on energy access in the country allowed the country to reach more than 99% of the urban population with electricity access. In the past, the LPG program commercialized all over the country with high subsidies to make it affordable to poor people contributed to reduce significantly the use of firewood in households (12% less in 2010 compared with 2006). Several programs have been introduced since the 60s with limited resources (Goldemberg et al., 2004; Winkler et al., 2011; Obermaier et al., 2012). More recently, the LPT program, launched by the Federal Government in November 2003, aiming to eliminate the electric exclusion in the country mainly in rural areas, has reached over 10 million people by 2008 (2 million households).

What we will discuss here are the policies and programs adopted by the Brazilian government to tackle these problems.

We will discuss the introduction of LPG to replace fuel wood and charcoal in cooking, some 60 years ago and, more recently, the extension of electricity grids to remote villages in the Northern/Northeastern regions of Brazil, discussing how Brazil is working to solve difficulties related to energy access in the country, including the case of remote villages in Amazon rainforest.

2. Energy access in developing countries

According to OECD/IEA (2011), in 2009 it is estimated that more than 9 billion US$ were invested globally to supply 20 million more people with electricity access and 7 million people with advanced biomass cook stoves. A scenario from OECD/IEA (2011) shows that between 2010 and 2030, 296 billion US$ will be invested but it still leaves 1.0 billion people without electricity and 2.7 billion people without clean cooking facilities in 2030.

Table 1 ahead shows recent results (OECD/IEA, 2011) for the lack of access to electricity and use of traditional biomass for cooking in developing countries (DCs) compared to the world.

The high consumption of traditional biomass for cooking and heating, together with the extremely low rates of electricity supply, are typical for the low values of HDI (0.361 in DC of Congo, 0.503 in Tanzania compared to 0.968 in Iceland and Norway, in 2006, according to UNIDO (2008)) in poor countries, mainly Least Developing countries (LDC).

[2] K. Yumkella, Director of UNIDO (United Nations Industrial Development Organization—www.unido.org).

[3] Kilograms of oil equivalent (in the original).

[4] Considering this context, IEA has proposed the Energy Development Index (OECD/IEA, 2011) 'in order to better understand the role that energy plays in human development'. According to the agency, EDI is an 'indicator that tracks progress in a country's or region's transition to the use of modern fuels', what confirms the importance of energy for productive use, since it includes key variables related to energy for productive use and energy for public services.

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Table 1
Number and share of people without access to modern energy services in selected countries (2008). *Source* OECD/IEA (2011).

Countries/regions	Without access to electricity		Relying on the traditional use of biomass for cooking	
	Population (million)	Share of population (%)	Population (million)	Share of population (%)
Africa	**587**	**58**	**657**	**65**
Nigeria	76	49	104	67
Ethiopia	69	83	77	93
DR of Congo	59	89	62	94
Tanzania	38	86	41	94
Kenya	33	84	33	83
Other sub-Saharan Africa	310	68	335	74
North Africa	2	1	4	3
Developing Asia	**675**	**19**	**1921**	**54**
India	289	25	836	72
Bangladesh	96	59	143	88
Indonesia	82	36	124	54
Pakistan	64	38	122	72
Myanmar	44	87	48	95
Rest of developing Asia	102	6	648	36
Latin America	**31**	**7**	**85**	**19**
Middle East	**21**	**11**	**0**	**0**
DCs	**1314**	**25**	**2662**	**51**
World	**1317**	**19**	**2662**	**39**

Biomass consumption (traditional biomass) for heating and cooking in such countries is not sustainable, since it relies on wood from deforestation (Goldemberg and Coelho, 2004; Karekesi et al., 2006) and its use present strong impacts on environment and health due to pollutant emissions mainly indoor (AGECC, 2010; GEA, 2012; Sovacool, 2012, among others).

There are several initiatives in DCs but it seems some results are not positive. Sovacool and Dworkin (2012) show that in 10 case studies in Asia, there were four failures mainly due to the lack of political support from Governments and lack of economic affordability.

Palit and Chaurey (2011) analyzed in detail the situation in South Asia. This region accounts for 42% of the population without electricity access (modern energy services[5]) and such situation continues to exist despite the several initiatives and policies for electrification.

For South Africa, Lemaire (2011) discussed the local programs concluding that -private-partnerships can deliver cost-effective energy services but solar home systems do not constitute a solution since the limited power provided generates dissatisfaction among the local consumers. Also the author concludes that such systems do not allow the development of economic activities in the villages, the same conclusion showed in Welle-Strand et al. (2011).

Sanoh et al. (2012) analyzed the situation in Sub-Saharan African countries and concluded that, to achieve the Millennium Development Goals (MDG), all households in the region must have access to basic infrastructure services, mainly electricity access. The challenge is how to allow the access, as well as to bring the costs down—“strategies that lower costs (…) are crucial”.

This issue of affordability is a fundamental aspect of energy access and completely interrelated to the question of energy for productive use, as discussed ahead in this paper. Also here the Brazilian experience with subsidies for electricity access in remote villages is interesting, despite the difficulties still existing, as discussed here.

[5] References cited in this text mention energy access, energy services, modern energy services (or energy carriers) aiming to allow both access to electricity and to modern fuels for cooking and heating. Regarding electricity access, in some cases references mention electricity for productive uses and in others electricity for basic needs.

In another study covering several regions in Dcs (GNESD, 2008) the excellence centers[6] from GNESD[7] have analyzed Urban and Peri-urban Energy Access (UPEA) in several major cities[8] in different DCs around the world (Argentina, Brazil, India, Kenya, Senegal, South Africa, Thailand) and concluded that the main problem on energy access in urban and peri-urban areas is a lack of adequate policies (GNESD, 2008).

The key common findings presented by the *Summary for Policy Makers* of this study (GNESD, 2008) are the following: (i) Lack of strategic planning and long term vision; (ii) Inaccessibility of clean fuels due to nature of settlements (slums); (iii) Inability to afford clean fuels because of upfront connection costs; (iv) Lack of formal monitoring mechanisms; (v) Mistargeted subsidies; (vi) Lack of awareness regarding use of clean fuels.

The poor urban households in this survey were found to be using different fuels and their energy demand for cooking and heating is usually met from a mix of sources, including modern and relatively clean sources, such as LPG and kerosene to traditional biomass. Electricity, in spite of still being the focus of national energy policies in most of the countries, is generally used only for lighting and radio or TV.

The need for adequate policies to incentivize electricity access for economic development is stressed by UN-Energy (2011), which presents a set of recommendations aiming to accelerate sustainable electricity development for programs for electricity access in DCs (on- and of-grid areas), identifying the most effective and meaningful best practices of partnerships. This study presents recommendations for adequate policies based in the idea that the improvement of electricity access needs a PPP—public private partnership, considering the global goals of the AGECC report (AGECC, 2010).

It also presents several study cases in different countries on energy supply related to economic development. In particular it is

[6] AFREPREN/FWD in Kenya, ENDA-TM in Dakar, Senegal, Energy Research Centre (ERC), South Africa, Bariloche Foundation, Argentina, CentroClima-COPPE-UFRJ (Rio de Janeiro), CENBIO-IEE-USP in Sao Paulo (Brazil), AIT in Thailand, ERI in China. TERI, India, MEDREC, Tunisia.

[7] GNESD – Global Network on Energy for Sustainable Development – www.gnesd.org – a Type II partnership on Energy launched at World Summit for Sustainable Development (WSSD) organized by the United Nations in Johannesburg, 2002.

[8] Buenos Aires, Argentina; Rio de Janeiro, Sao Paulo, Recife, Brazil; Delhi, India; Nairobi, Kenya; Dakar, Senegal; Cape Town, South Africa; Bangkok, Thailand.

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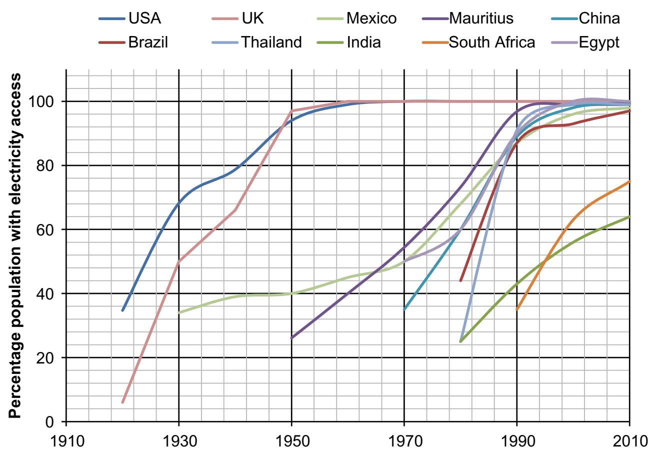

Fig. 1. Historical experience with household electrification in selected countries. *Source*: chapter 19, GEA (2012).

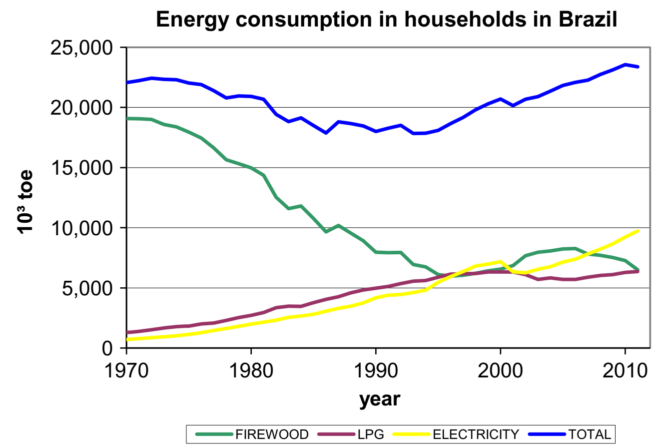

Fig. 2. Historic evolution for electricity, fuel wood and LPG consumption in Brazil. *Source*: Authors elaboration based on BEN (2011). *Note*: toe=(metric) tons of oil equivalent (1 toe=42 GJ).

mentioned that the lack of long term, stable and predictable support policies, as well as formal energy technology development plans can contribute to ineffective partnerships.

Previously, UN-Energy (2007) had already discussed EAC[9] and ECOWAS[10] Regional Energy Strategies. As mentioned in the document, these two regions represent a broad range of situations in sub-Saharan African (SSA) countries. "The 20 countries of the 2 regions (out of almost 50 in SSA) include a major oil exporter, many oil importers, electricity exporters and importers, as well as several LDCs and LLDCs[11]". All these countries have a low level of access to modern energy services, particularly in rural areas. Nevertheless other situations exist in Africa, for instance in Northern Africa and within the country members of the Southern Africa Power Pool (SAPP), the most advanced in sub-Saharan Africa.

All these studies have in common the idea that the policies already in place have not had success in promoting energy access in the mentioned regions.

Winkler et al. (2011) discuss access and affordability in DCs (specifically Brazil, South Africa and Bangladesh) and conclude that in many cases local people consider that prices for energy and connection fees are too high. Sanoh et al. (2012) stress that reduction in connection costs is fundamental. It is also discussed that in rural areas, where the demand is low and households are dispersed, electrification may never be achieved.

On the other hand, in Brazil connection to the grid is free of charge (ANEEL, 2010) and it is also mandatory for the utilities to supply electricity access when consumers require it. When this is not feasible in short term, the utility must inform the consumer about the timetable for the connection, as well as costs so the consumer – if desired – can provide it (to be later reimbursed) (ANEEL, 2010). This experience could be replicated in other DCs, following the recommendations from Winkler et al. (2011) and Sanoh et al. (2012).

Birol and Bew-Hammond (2012) presented the need for milestones and specific proposals and terms of reference for new institutional and financial arrangements, based in the experience of countries like Brazil and Vietnam, which also increased the rate of the population with electricity access from 5% to 98% in 35 years, as shown in GEA (2012). Fig. 1 shows that Brazil, China, Egypt, South Africa, India and Mexico have increased energy access in recent years.

The above results show that energy access is indeed a possible achievement in DCs, with the corresponding contribution for poverty alleviation and economic development.

3. LPG program vs reduction in fuel wood consumption

The concept of energy access includes also the access to modern fuels for cooking and heating replacing traditional biomass. Not only GEA (2012) but also OECD/IEA (2011) addresses this issue, among others. Both studies discuss clean cooking facilities to avoid indoor harmful emissions from biomass cook stoves currently used in DCs (UN, nd). These facilities are supposed to be based mainly on biogas systems, liquefied petroleum gas (LPG) and ethanol stoves and advanced biomass cook stoves that have considerably lower emissions and higher efficiencies than traditional three-stone fires for cooking (the so-called 'improved biomass', as discussed in Karekesi et al., 2006).

The Brazilian experience with LPG (distributed even in Amazon rainforest by boat) can be interesting, since the existing fuel wood stoves have been replaced in most households—or, in some cases, co-exist with LPG stoves (to be used when LPG is not economically affordable for the family) (Lucon, Goldemberg and Coelho, 2004). In Brazil in most households the fuel currently used is LPG, not biogas or 'improved biomass', and distributed in a joint program with private investors.

The LPG program in Brazil has its origin more in serendipity than design. Some 40 years ago, fuel wood and charcoal represented more than 80% of the residential energy consumption, since most of the cooking in rural areas and cities alike, leading to a progressive deforestation near the more populated areas and the consequent increase in cost (as shown in Fig. 2)

Cooking with pipe gas was introduced in the country early last century but benefited only a few major cities.

The opportunity to introduce LPG appeared in 1937 when a large provision of such gas was made available due to the discontinuation of intercontinental transportation using the Zeppelin, after the Hindenburg fire in New Jersey. The trips to South America were cancelled and the cylinders of propane were distributed to 166 households. Then the government encouraged such activity through price regulation (Lucon et al., 2004).

Bottles with LPG (13 kg bottles) are distributed by private companies all over the country and sold with affordable prices (initially they were subsidized), even in Amazonian

[9] EAC—East Africa Community (http://www.infrastructureafrica.org/rec/eac-east-africa-community).

[10] ECOWAS—Economic Community for West African States (http://www.infrastructureafrica.org/rec/ecowas-economic-community-west-african-states).

[11] LDCs – Least Developed Countries. LLDCs – Landlocked Developing Countries (http://www.un.org/special-rep/ohrlls/ohrlls/prsp.htm).

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remote villages. This 13 kg bottle is available in several specialized stores or distributed by trucks or boats (in Amazonia). LPG delivery infrastructure is highly developed in all regions, including rural zones.

Among usual ways of energy consumption for cooking, poor urban or peri-urban population in Brazil rely mostly upon this bottled LPG.

Fig. 2 illustrates the historic evolution on LPG vs fuel wood since 1995. It shows that the increase on firewood consumption is directly related to LPG so when LPG consumption increases the use of firewood is reduced.

In 1996 the share of Brazilian residential energy consumption from fuel wood was equivalent to the fraction using LPG, as showed in Fig. 2. In 2004, 98.48% of urban population still owned traditional cook stoves and 7.61% of rural one did not owned any stove (PNAD, 2010). Even though this high rate for poor population, urban or rural, LPG cook stove is not the only means of cooking because they keep wood fueled stove as a back-up in case they cannot afford LPG (Lucon et al., 2004).

LPG consumption has been rising from the middle of last century until 2002 when the subsidy “Gas Allowance” was removed; from this year on, its consumption decreased at same period wood fuel consumption started to rise. From 2006, with the economic growth in the country, LPG consumption started to increase again since the residential use of traditional biomass has declined significantly (Lucon et al., 2004).

This inversion happened because the residential use of fuel wood for cooking in traditional wood stoves has dwindled over the years. This is due to the growing urbanization (currently less than 20% of the Brazilian population lives in rural areas), to the rise of population's income, and mainly to the availability of LPG. Turned out that, residential consumption of fuel wood has declined from 53.5% of total biomass consumption in 1970 to just 13.8% in 2002.

The positive results of Brazilian LPG program to reduce fuel wood consumption and to reduce deforestation could be replicated in other countries.

4. Electricity access in Brazil vs poverty alleviation

Programs for the promotion of electricity access in Brazil originated some 20 years ago in the state of Sao Paulo when the local government decided to extend electricity lines into the slums surrounding that large city of Sao Paulo (Boa Nova and Goldemberg, 1999).

This was relatively easy to do, since the electricity company was state-owned and the decision was justified on the basis of social equity. Electricity lines were extended to slums and initially no meters were installed. The results were significant since consumption increased fast from the initial estimate of 50 kW h/month up to 175 kW h/month. Soon afterwards, meters were installed but tariffs were staggered according to consumption, benefiting low consumption households. “For the squatters, one of the most praised side-effects of electrification was the fact of receiving the bills with their names and addresses. As a residence document, the electricity bill makes easier the dweller´s access to the credit system. For many people, it works like a symbol of citizenship” (Boa Nova and Goldemberg, 1999).

It was easy to compensate financially the electricity company for the families with low consumption levels by overcharging the large consumers (Boa Nova and Goldemberg, 1999).

What experience showed is that initially 50 kW h per month was sufficient to solve immediate problems of the families, such as lighting in the evening, radio and TV. However, soon the consumers started installing refrigerators and other electrical equipment, including cooking with electricity, which of course required more than 50 kW h/month. Installing meters and charging for the electricity consumed became essential.

Table 2
Discounts included in the electric power social tariff. *Source*: ANEEL, 2011.

Range	Discount (%)
Monthly consumption of up to 30 kW h	65
Monthly consumption from 31 kW h to 100 kW h	40
Monthly consumption from 101 kW h to 220 kW h	10
Monthly consumption above 220 kW h	0

This is actually the fundamental problem the LPT program is facing with electrification in isolated areas, in which PV systems correspond to the preferred option. A PV array for the production of 5 to 10 kW h per month is easy to install but as soon as consumption increases, either for residential consumption or productive process, PV installation only will not be enough, as discussed in further details ahead.

To discuss the Brazilian programs for electricity access, we must distinguish between the interlinked and the isolated systems in which the Brazilian electric system is divided. In the interlinked system, all electric power plants are connected through long transmission lines from Southern to Northern Brazil, mainly along the coast; the isolated system, in Northern region (Brazilian Amazonia), is composed mostly by small thermoelectric power plants (diesel engines with difficulties on logistic for diesel supply through rivers in the rain forest). This region covers an area corresponding to 45% of Brazilian territory and 3% of the population (around 1.2 million consumers)

We will discuss each situation separately in this section.

4.1. *The interlinked system*

An overview of previous Brazilian electrification policies is presented in Goldemberg et al. (2004), Winkler et al. (2011) and a specific discussion on rural electrification in (poor) Northeastern region.

In 2003, the LPT program was established by the Federal Government, with the aim of providing free electricity access for 10 million people in rural areas in Brazil by 2008. It has defined that “energy must be the way for social and economic development (…), contributing to poverty alleviation and increase the families revenues”. In 2011, a new phase was established for the period 2011–2014 since the Census, 2010 from IBGE (2010) has realized that there were still households without electricity access mainly in Northern and Northeastern regions (MME, nd).

According to the program, utilities are obliged to provide electricity access for free when required by the consumer (otherwise they have to inform deadlines to provide the access) (ANEEL, 2010).

This Program is coordinated by the Ministry of Mines and Energy, implemented by Eletrobras (the holding company of the Brazilian electric sector) and executed by the utilities and rural co-operatives. For meeting the initial goal, R$ 20 billion (around US$ 10 billion, Nov 2011) was invested, being almost 70% from Federal Government. The assessment of electric exclusion in the country showed that the families with no energy access are mostly low-income families, in locations with a low Human Development Index—HDI (MME, 2010, MME, 2011a,b)

One of the important tools related to the program is that Brazil has adopted the Performance-Based Regulation—PBR. Opposed to the concept of “Traditional regulation”, PBR is a regulatory approach that focuses on desired, measurable outcomes, rather than prescriptive processes, techniques, or procedures. Performance-based regulation leads to defined results without specific direction regarding how those results are to be obtained to ensure affordable tariffs to be paid by the so-called 'captive' electricity customers. A performance-based, price-capped and multi-year tariff is used to achieve high-quality, reliable and universal service. Tariffs in Brazil, in general, are relatively high compared to many other countries, especially those with incentives such Canada with a comparable proportion of hydroelectric generation in its energy matrix. However, it should be noted that the Brazilian tariff on average is more than 30% tax, a significantly larger percentage than imposed in most other countries (USAID, 2009).

The Low Income Tariff (LIT) or 'social' tariff provides large discounts to low kW h consumers. The discount percentiles applied in energy bills are presented in Table 2.

This discussion on affordability is strongly related to the opportunity of using energy for productive uses, as discussed in this paper and also in several others (OECD/IEA, 2011; GEA, 2012; Welle-Strand et al., 2011). The situation in remote villages (Isolated System) will be discussed in the next Section 4.2.

Regarding affordability issues, it is important to note the recent (September, 2012) decision of Brazilian Federal Government to reduce electricity prices all over the country (MME, 2012). This decision was mainly to give incentives to Brazilian industries but it also collaborates to increase the affordability of electricity access mainly for low income households.

According to the Household Census of 2010 accomplished by the Federal Government (IBGE, 2010), Brazil has achieved the level of 98.73% of universalization of electric power access in urban and rural areas (in the interlinked system), compared to 74.90% in 1981 and 94.54% in year 2000 as shown in Table 3.

Considering urban households, rates are still higher. Out of the over 49.2 million households in cities, only 133,000 of them are still with no access to electricity, as showed in Table 4. It can be observed that even in North and Northeastern regions the rates for urban energy access are quite high, almost 100%.

The situation in rural areas also shows an important increase in electricity access when compared to year 2000 (92.6% in 2010 against 71.0% in 2000). However it must be considered that the figures shown by the statistics do not include remote villages in Amazonian region. Table 5 compares such figures in urban and rural areas for electricity access in year 2000 and year 2010.

The data presented here show that the universalization of access to electric power in cities and peri-urban areas is almost a reality in Brazil.

Table 3
Historic figures for electricity access in Brazil. *Source*: IBGE, 2000, 2010.

Year	1981	1990	2000	2010
Energy access	74.90	87.78	94.54	98.73

Note: Both rural and urban households are included.

Table 4
Electricity access rates in urban households for each region in Brazil in 2010. *Source* IBGE, 2010.

	Households with electricity	Households without electricity	% Electricity Access
Brazil	49,093,032	133,097	99.7
North region	2,993,228	19,122	99.4
Northeast region	11,137,927	61,887	99.4
Center-west region	3,851,820	7,655	99.8
Southeast region	23,510,520	28,905	99.9
South region	7,599,537	15,528	99.8

Table 5
Evolution on electricity access in urban and rural areas in Brazil. *Source* IBGE, 2000, 2010.

Year		Households		
		Total	Urban	Rural
2000	Total	44,721,434	37,363,856	7357,579
	Electricity access	94.5	97.0	71.0
2010	Total	57,324,185	49,226,767	8097,418
	Electricity access	98.73	99.7	92.6

4.2. Isolated systems

The isolated system had in 2008 1267 small power plants installed and operating with diesel engines, with a total installed power of 3068 MW (Rendeiro and Nogueira, 2008).

These diesel fueled power plants are heavily subsidized through a special policy – *Conta Consumo de Combustiveis* – CCC (Fuel Account Consumption in English), since diesel costs are high for remote villages not covered by CCC, due to the high transportation costs by boat through the rainforest.

CCC policy was created in 1973. Around 90% of diesel costs were covered by Eletrobras (and distributed among all Brazilian electricity consumers of interlinked system). Now they are covered directly by the Brazilian Government (*Tesouro Nacional*—National Treasure in English). In 2007, CCC expenditures were 4.3 billion BRL[12], four times the expenditures in 2001.

Considering the difficulties related to diesel-fueled generators, the use of local sources for electricity production in remote villages seems to be fundamental (Coelho et al., 2004, 2005; Velazquez et al., 2010).

In 2002 a new law (10438/02) established that CCC subsidies could be used for the replacement of fossil fuel for power generation by small hydro, PV systems, biomass, natural and others (like the gas pipeline Coari–Manaus crossing the rain forest). Payments of subsidies are per month based on the amount of diesel oil equivalent avoided.

In the current phase of the LPT program, focused mainly on isolated regions, the challenge is significant, considering the geographic conditions of more than 5000 remote villages in Brazilian Amazon (Di Lascio et al., 2006)—a huge number considering the existing diesel plants, 1267 plants (Rendeiro and Nogueira, 2008). The existing energy supply systems – relying mainly in the old (and inefficient) diesel engines and PV programs – are not enough to contribute for a local economic development since the power produced is limited to lighting, water pump, etc., as also discussed in Lemaire (2011) and Welle-Strand et al., 2011).

In 2007 there were nine biomass power plants in Amazonia and Para State with 22.05 MW installed. This shows there is a large room for the replacement of diesel engines, as well as to supply energy needs in the remaining 3733 villages not having electricity access. Considering an average of 100 kW-demand per village

[12] US$ 2.12 billion (exchange rate=2.0272 BRL/US$. Banco Central do Brasil) (http://www.bcb.gov.br/), accessed in 20 October 2012.

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(Rendeiro and Nogueira, 2008), there is a demand of 373 MW not supplied.

In fact, aiming to increase electricity access in a sustainable way in these villages, it is necessary to develop electricity access systems based in local energy sources like small hydro and biomass (agricultural residues and local vegetable oils), as being started in several pilot projects in the region. Such systems allow higher installed power, collaborating to the development of economic activities (Coelho et al., 2004, 2005 Velazquez et al., 2010).

When using agro-industrial residues from sawmills to produce electricity to households around the mill, results are more positive than the implementation of local small power plants to be operated by the community (or the local utility) itself, since the mill itself takes care of O&M, without the need of the participation of the local utility, which in general is not so interested on these projects (Velazquez et al., 2010).

The existing difficulties against the use of local biomass residues to replace DO can be summarized as follow (Coelho et al., 2004, 2005; Velazquez et al., 2010):

(i) There is a lack of interest of utilities for alternative sources such biomass residues and SVO. Projects funded by government agencies show failures in the follow up since local utilities are not interested in covering O&M costs. Utilities claim that requirements from ANEEL (Agencia Nacional de Energia Eletrica—Brazilian Regulatory Agency for Electricity[13]) are too strict concerning failures and interruptions and new systems still being adapted would not comply with these exigencies.
(ii) There is a need to improve coordination among different government institutions to support the permanence of alternative sources when LPT arrives (grid access). The systems already installed could be used in other villages without energy access.

5. Discussions

LPG is a practical business oriented solution to solve the cooking problem and associated problems resulting from the use of fuel wood. It requires a minimum interference of the Government in the regulatory system.

On the other hand, electricity access relies primarily on social programs, at least on philanthropic grounds. As consumption increases, the cost of electricity has to be paid through some financial engineering.

If electrification “per se” – particularly in rural areas and isolated communities that cannot be reached by the grid (such as remote villages in Amazonia) – can be a prime factor in promoting development, this is still an open question. Other economic factors are involved besides access such as infrastructure. As discussed here, not only energy for productive use but also infrastructure are fundamental issues.

Obermaier et al. (2012) show that in Northeastern Brazil, despite efforts on electrification, rural access “seems to provide limited impact. Therefore it is important to integrate rural electrification into broader rural development strategies.

As discussed by Winkler et al. (2011), Welle-Strand et al. (2011), Obermaier et al. (2012) and Sovacool (2012), among several others, affordability is an essential issue to allow the economic sustainability of the systems. Welfarism can provide energy for basic needs but it is not enough to provide economic development and poverty alleviation.

There is a difference between access and affordability which reminds us of the debates on famine and starvation insights discussed by Sen (2000). According to him, most of the dramatic events of famine around the world were not due to a physical shortage of food but a problem of affordability, even if food was available. Poorly designed policies and bad government generate unemployment and more poverty in already impoverished areas, aggravating the difficulties in paying for the food. Similarly, the physical access to modern energy services does not seem to be an insurmountable problem; but it is less clear if such access is translated into poverty alleviation and economic progress. In India, for example, evidences exists (Dasappa et al., 2011) that where villages are connected to the electricity grid, only the better off can afford to link to it. This problem is discussed in the literature by GEA (2012) (in the definition of energy access proposed), Winkler et al. (2011), Obermaier et al. (2012) and Lemaire (2011), among others.

In remote villages in Amazonia as well as in other DCs there is a need for adequate policies such as:

(i) To reduce the timetable for the utilities to supply the mandatory access
(ii) To incentivize the use of local energy sources by local utilities
(iii) To supply electricity enough for productive uses to allow the economic development of the villages and the economic sustainability of the electricity supply
(iv) To discuss the use of more flexible criteria for the quality of electricity supply by other sources (not diesel oil) to incentivize the utilities to invest on such sources
(v) To keep connection free

Regarding the local energy sources, the use of PV systems, small hydro and biomass-based systems, is starting being used in Brazilian isolated systems and also in several regions worldwide and could be improved to allow the increase of energy access mainly in remote areas in DCs.

The experiences in Brazil with PV systems in remote villages in Amazonia show that the energy access provided by such systems is enough to provide basic needs such as lighting and pumping water. However to develop productive activities – to allow the payment for the electricity – it is necessary higher installed power. This is why Brazilian Government has funded pilot plants in Amazonia using existing local energy sources such as biomass residues and SVO and should keep funding it (Coelho et al., 2004, 2005; Velazquez et al., 2010). Also India has developed small scale biomass gasifier systems (Dasappa et al., 2011) like the ones installed in Amazonian remote villages. It is also important to notice that recently the IEA have included, in the statistics provided, a new index (Energy Development Index), aiming to include figures for productive use of energy in DCs (OECD/IEA, 2011).

The challenge still existing in these remote villages (Coelho et al., 2004, 2005) is very similar to the one in rural areas in other DCs Goldemberg et al, 2011 and the lessons learned – and still being learned – could be used in those countries.

Developing countries have a high potential to produce biomass due to more favorable climate conditions and lower labor costs and this can be possible to be done in a sustainable way (Coelho et al., 2012). The production and use of biomass for electricity production can also help to develop economic activities in such villages, making energy supply economically sustainable and affordable for the local population.

The use of agro-industrial residues to produce electricity for rural households in remote villages in Amazonia is similar to those in sugar mills and tea factories in Sub Saharan African countries, where the electricity surplus being generated will supply households around the industries, in the “Cogen for Africa” GEF/Project.

[13] www.aneel.gov.br.

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Table 6
Energy ladder and possible energy supply in DCs. *Sources*: (a) and (b) AGECC (2010), Sovacool (2012); (c) authors elaboration.

	Categories[a]	Energy services[b]	Possible energy supply[c]
First phase	Basic human needs (lighting, cooking and heating)	50–100 kW h per person per year (pp, py); 50–100 kgoe[d]	PV systems; firewood
Second phase	Productive uses (water pumping, irrigation, agricultural processes; heating, cooking)	500–1000 kW h pp, py; 150 kgoe	SHS, SVO, small-scale gasifiers; LPG
Third phase	Modern uses (domestic appliances; private transportation; industrial activities)	2000 kW h (and above) pp, py; 250–450 kgoe	Grid extension, electricity surplus from agro-industrial plants/biomass-based cogeneration; LPG

[d] kgoe = quilograms of oil equivalent.

The "Cogen for Africa Project", funded by GEF-UNEP-AfDB[14], is an extremely important experience being now developed in Sub-Saharan countries[15] and could be expanded to other DCs[16].

This projects aims to introduce more efficient technologies for the energy conversion from biomass residues (mainly sugarcane bagasse from sugar production and wood chips from eucalyptus plantations) in the region, contributing to increase the electricity generation in rural areas of such countries. Considering the huge deficit on energy access in the region, as discussed above, and the use of agro-industrial residues locally available, the electricity surplus generated by the sugar mills and tea factories can be distributed in the villages close to the plants. Then the benefits from electricity access allowing poverty alleviation and economic development are associated to the positive environmental impacts of using sustainable biomass (a renewable energy source)[17].

The WEO's definition of access considers a minimum level of electricity consumption, depending on the location of the household—if it is in a rural or an urban area. The initial estimated level of electricity consumption for rural households is assumed by WEO to be 250 kW h per year and, for urban households, to be 500 kW h per year. In fact, this definition of electricity access includes an initial period of growing consumption but WEO consider it is important to note that "eradication of energy poverty is a long-term endeavor". In WEO's analysis, the average level of electricity consumption per capita across all those households newly connected over the period is expected to be 800 kW h in 2030. These figures could be compared to the results of electrification in slums in Sao Paulo City in 1999, where a monthly consumption of 50 kW h increased to 175 kW h/month in 10 years (equivalent to 2100 kW h/year) (Boa Nova and Goldemberg, 1999).

Table 6 ahead illustrates these aspects, showing energy ladder together with the possible energy sources for each category.

These figures are well illustrated by Brazilian experience. The first and second phases correspond to the experience in isolated systems and the third one corresponds to the interlinked system.

However in most DCs there is a lack of funds not only to provide energy access but also for infrastructure in general, and these two issues must be addressed jointly, as stressed by Welle-Strand et al. (2011) and discussed in Birol and Bew-Hammond (2012). As proposed by Birol and Bew-Hammond (2012), public-private partnerships (PPP) could eventually be a good option, but the implementation of adequate policies by governments seems to be essential to support this partnership and make energy access affordable for basic needs and for productive use, aiming to reduce poverty and allow economic development.

[14] GEF—Global Environmental Facility. UNEP—United Nations Environment Program. AfDB—African Development Bank.

[15] http://www.afrepren.org/cogen/index.htm.

[16] According to UNEP, 'Cogeneration for Africa' is an innovative and first-of-its-kind clean energy regional initiative funded by GEF (Global Environment Facility). The initiative is co-implemented by UNEP (United Nations Environment Programme) and AfDB (African Development Bank) and executed by AFREPREN/FWD (Energy, Environment and Development Network for Africa). (…) It seeks to significantly scale up the use of efficient cogeneration systems initially in seven Eastern and Southern African countries (Kenya, Ethiopia, Malawi, Sudan, Uganda, Tanzania and Swaziland). (Cogen for Africa Project, 2012).

[17] Information from field visits in Sub Saharan African plants by S. Coelho (coordinator of the Mid Term Review by invitation of UNEP-Nairobi) (2011).

6. Conclusion

Progress in solving the problem of energy access to 2.7 billion people has been slow despite innumerous efforts in that direction.

At the level of basic energy services there were many projects on improved cooking stoves, biogas production and the production of small amounts of electricity to households using small hydropower plants, photovoltaic panels and wind machines.

These efforts were mainly decentralized conducted by non-governmental organizations. In some cases mini-grids were installed to supply a few houses or villages.

The use of biomass to produce electricity at the level of kilowatts and higher is possible and is being installed in the Amazonia and Sub-Saharan countries.

The amount of energy produced (at level of kilowatts for electricity) general was small and not sufficient for significant economic activity.

Although basic living conditions and access improved in many case the livelihood of people, it is nuclear yet if poverty and income distribution have been changed significantly.

The centralized approach based on extending electricity lines to slum areas and distant villages previously not connected to the grid adopted in Brazil has succeeded in making electricity access universal and allowed increased economic activity with megawatts of electricity available. The strategy procedure is making significant progress in other countries, particularly Mauritius, South Africa, China and Egypt.

In addition to that efficient system of distributing LPG bottles eliminated almost completely primitive cooking procedures that were contributing to deforestation.

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