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Social features of energy production and use in Brazil: Goals for a sustainable energy future

Márcio Macedo da Costa

Claude Cohen

Roberto Schaeffer

Departamento de Economia
Universidade Federal Fluminense
Rua Tiradentes, 17 - Ingá - Niterói - RJ

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Márcio Macedo da Costa, Claude Cohen and Roberto Schaeffer

Abstract

This paper focuses on the social features of energy production and use in Brazil and discusses the role of the energy policy goals of accessibility, affordability and acceptability in defining a sustainable energy future for the country. The major findings are that social inequalities in Brazil regarding energy use continue to be substantial and important. This can be explained by the fact that, although recent decades have seen significant improvements in energy accessibility all over the country, much more needs to be done to provide affordable, and socially acceptable modern energy carriers to all socio-economic groups in all regions.

Keywords: Energy and social issues; Energy use and income distribution; Sustainable energy development; Energy production and use in Brazil.

1. Introduction

The achievement of sustainable development requires a comprehensive and integrated approach to economic, social end environmental processes. Discourses of sustainable development, however, have historically focused primarily on its environmental and economic dimensions. The significance of social, political and cultural factors — such as poverty, social equity, governance and energy policy — is only beginning to be recognized. Quantification at the macro and sectoral levels through improved monitoring and analytical techniques, as well as standards are now being developed and implemented in order to be able to verify claims about sustainable practices (Najam and Cleveland, 2003).

In the aftermath of the financial crisis at the end of the 20th century, Brazil seems willing to pursue a sound development agenda that will promote economic development with higher economic growth rates than those seen in the past two decades. Addressing sustainable energy development is an important part of this agenda. To qualify as sustainable energy development from a social standpoint, policy actions must have three basic characteristics, which can also be considered as interlinked energy goals: accessibility, affordability and acceptability.

Accessibility to modern energy services means that energy should be physically available for people, regardless of their income level and the region in which they live. Logistic, organizational (e.g., the willingness of the local utility to provide or permit third parties to provide decentralized energy production), and economic reasons drive the kinds and volumes of energy carriers accessible at a particular site.

Affordability refers to the conditions under which people can pay for available energy services. This implies that prices are low enough to allow a minimum level of consumption even for the poorest, and that they reflect the real costs of energy services provided by financially healthy companies.[1]

Acceptability addresses social and environmental issues along the whole energy chain of production, conversion, transport, use and disposal. This relates to those who suffer local or regional negative effects and to society as a whole, who can decide whether or not a particular energy type should be produced or used. The complexity of this vision is increased if we consider global issues, future generations, cultural phenomena and the political arena.

A sustainable energy system, in its three dimensions (accessibility, affordability, and acceptance), is a key factor to guarantee the Brazilian development path is in line with the Millennium Development Goals (MDGs). According to

Corresponding author: Roberto Schaeffer is at the Energy Planning Program, COPPE, Federal University of Rio de Janeiro, Rio de Janeiro, RJ, Brazil. Email: roberto@ppe.ufrj.br

[1] The apparent contradiction between energy prices low enough for everybody and energy prices that reflect the real costs of energy can be dealt with using direct energy rebates for those who cannot afford high tariffs. This policy would avoid the present situation of subsidizing part of the population that actually can afford normal tariffs and would encourage efficient behaviour with respect to energy use.

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the MDGs, the international community is committed to the eradication of poverty and the achievement of sustainable development. Environmental concerns are central to the MDGs, in particular to the specifics of one goal — environment sustainability. Interventions to give access to affordable and acceptable energy, as is the case for electricity and clean fuels for residential use, can help eradicate extreme poverty and reduce child mortality in rural areas. In order to reach these objectives, it is important to reduce the economic burden of energy on low-income households and to increase access to energy for all Brazilian households.

And finally, a fundamental driver for sustainable energy policies is the opportunity for job creation in the energy sector itself, as will be discussed.

This article is a first step towards a full description of the social dimensions of Brazil's current energy situation in the context of sustainable development. Section 2 will give an overview of the energy use in the residential sector of Brazil; section 3 will discuss the social features of energy production and use in the country from the perspectives of Accessibility, Affordability and Acceptability; section 4 will show the potential synergies between energy production and employment creation; and section 5 will present some final considerations.

2. Overview of energy use in the residential sector of Brazil

In the second half of the 20th century, Brazil underwent a transformation from a rural country relying largely on fuelwood for energy use to a mostly urban and industrialized nation using modern commercial forms of energy such as electricity, fossil fuels and modern biomass. Nevertheless, it has not been economically feasible to extend the power grid to many rural and isolated areas, and currently 12 million people (7% of the country's total population of 172 million in 2001) have no access to electricity (MME, 2004).

From 1980 to 2000, the percentage of households in Brazil supplied with electricity increased from 44% to 93% (Schaeffer *et al*., 2003). Similarly, the percentage of rural households with access to electricity jumped from 22% to 69%. However, regional disparities remained significant, with 39% of rural households in the Northeast region still lacking access to electricity, compared to only 12% of rural households in the Southeast region.

During the same period, the residential sector's share of total energy use dropped from 35% to 17%, (the share of the residential sector in the primary energy consumption dropped from 20.1% in 1980 to 12.9% in 2000, according to Brazil's Energy Research Corporation, *Empresa de Pesquisa Energética* (EPE, 2006) mainly due to increased energy use in the industrial sector, but also because of more efficient appliances and shifts in the mix of primary energy sources.

Electricity, liquefied petroleum gas (LPG[2]) and, later, natural gas experienced high growth rates from 1970 to 2000, replacing the previous dominant role of fuelwood in households. However, fossil and biomass fuels still supply 36% of the energy demand in the residential sector (in 2005, LPG, natural gas, fuelwood, charcoal and other fossil fuels actually supplied together 67.3% of energy use in the residential sector of Brazil; fuelwood alone supplied 37.7%, according to EPE 2006), primarily for cooking and heating water. Wood used to be supplied from heterogeneous tropical forests, called Mata Atlântica (Atlantic tropical rainforest), formerly occurring along the entire Brazilian coast, and although imported coal and oil products have been in the mix since the beginning of the 20th century, wood remained the main energy source in the country until the end of the 1960s. At that point, oil products came to the fore, following industrialization and urban population growths.

Residential wood consumption currently is concentrated in lower-income households in all regions of Brazil. In the Northeast region, more than 70% of the residential fuelwood consumed is used by families with monthly incomes less than half the minimum wage, compared with 50% for Brazil as a whole. These figures indicate that wood-fuelled ovens are mainly restricted to rural areas and the peripheries of cities, where these families usually live (Schaeffer *et al*., 2003).

From 1990 to 2000, electricity use increased by 52.3% and total primary energy by 34.8% (EPE, 2006). As a result of energy rationing during the electricity shortage in 2001, average residential use dropped from 173 kWh per month in 2001 to 134 kWh per month in 2002.

Even among those with access, a large share of low-income families cannot afford basic energy needs. Even when household electricity use is less than 100 kilowatt-hours (kWh) per month, some families have serious difficulties paying their electricity bills. The affordability of LPG for cooking is worsened by the fact that its price is highly dependent on the international price of oil and the exchange rate between the Brazilian Real (R$) and the US dollar (US$). Energy affordability concerns in Brazil are not restricted to the poor. The growing use of expensive natural gas imported from Bolivia for power generation, for example, may affect middle-income families as well, especially after the recent gas crisis between Brazil and Bolivia.

Energy must be not only accessible and affordable, but also acceptable to society. Such acceptance is necessary for ethical and democratic reasons. In Brazil, fears among the

[2] Liquified petroleum gas (also called liquefied petroleum gas, liquid petroleum gas, LPG, LP Gas, or autogas) is a mixture of hydrocarbon gases used as a fuel in heating appliances and vehicles, and increasingly replacing chlorofluorocarbons as an aerosol propellant and a refrigerant to reduce damage to the ozone layer. LPG is manufactured during the refining of crude oil, or extracted from oil or gas streams as they emerge from the ground.

public have hindered the development of nuclear energy. Similarly, the construction of large dams with the potential to affect locals has faced public opposition, even from people who are far removed from the problem areas. The production of charcoal from native forests and with the use of child labour is absolutely unacceptable in the country today and coal-fired power plants with high atmospheric emission factors no longer receive environmental licences.

3. Social features of energy production and use in Brazil

3.1. Accessibility to energy services in Brazil

3.1.1. Access to electricity

Access to electricity is essential for promoting economic development and welfare. There is a general commitment in Brazil to providing universal electricity access, and several measures have been taken to this end, some of which are described in this section. However, the development of a legal/institutional framework capable of coping with all the peculiarities that characterize Brazil's energy sector is still some way off. The privatization of the distribution utilities that occurred in the 1990s did not by itself provide universal access to energy services as expected (USAID, 2002).

Most families with no access to electricity live in areas with lower HDI[3] values, and the income of around 90% of these families (most of them in rural areas) is less than a third of the minimum wage. In the state of Tocantins, in the North region, 73% of rural households do not have access to electricity.

In 2003, the federal government established the Light for All Programme — Programa Luz para Todos (MME, 2004) — under which grid extension costs are not to be charged to low-income families. There is also a publicly stated commitment to provide access to electricity for all families in Brazil by 2008, a step up of the previous goal of extending the electricity grid to the whole country by 2015. Two million new links to the grid spread out across Brazil will be required. The programme forecasts that electricity will be available to 90% of all rural households in 2006, an ambitious milestone given the present level of 73%.

Subsumed in the Light for All Programme is the earlier Energy Programme for Small Communities (PRODEEM — Programa de Desenvolvimento Energético de Estados e Municípios), established in 1994 by the federal government to promote the supply of energy to poor rural communities. PRODEEM was mainly based on rural electrification using photovoltaic (PV) arrays. Three types of stand-alone systems were considered: PV electricity generating systems, PV water pumping systems and PV public lighting systems. PRODEEM comprised 8,748 systems with a total installed capacity of 5.21 Megawatts-peak (MWp) (Galdino and Lima, 2002). However, as the number of installations increased, it became increasingly difficult to monitor all systems and to ensure that maintenance was carried out. Because of operational and financial problems, PRODEEM was eventually restructured, with the main outcomes being its inclusion into the new Light for All Programme, the renewal of the installed PV systems, and the improvement of training for systems maintenance personnel. These actions are still in progress and are called PRC-PRODEEM (Programme for Renewal and Personnel Training of PRODEEM — Programa de Revitalização e Capacitação do PRODEEM).

The Light for All Programme will now give priority to rural electrification in (i) communities removed from their land because of dam construction; (ii) resettlements included in land reform projects; (iii) municipalities with low electrification and HDI indices; (iv) public schools, health centres and water wells; and (v) communities around environmental conservation units.

In isolated communities, some decentralized systems for power generation already exist, with positive regional effects. In the Amazon region (Amazônia), among the products that can be extracted from vegetable species like andiroba (*Carapa guianensis*), patauá (*Oenocarpus bataua Mart.*), uricuri (*Attalea phalerata Mart.*) and copaíba (*Copaifera langsdorfii*) are oils for electricity generation; these are substitutes for diesel, which would have to be transported by river over long distances. For instance, one andiroba tree can produce 140 kilograms of seeds each year, which produce 20 litres of vegetable oil. Assuming 40 trees per hectare (ha) and a consumption of 0.3 litres of oil per kWh, an 18-ha plot is sufficient to support around 20 families (Aquino, 2000).

However, lessons in the Amazônia experience also emphasize that decentralized power generation does not really benefit remote communities if done in isolation (WEC/FAO-ONU, 2000). Electricity availability is a necessary condition for promoting local development, but in order to achieve sustainable energy development in these communities it must be integrated with other activities related to agriculture, education and infrastructure.

3.1.2. Access to fuels

LPG is predominantly used for cooking in Brazil. Its national distribution system is wide, reaching almost 100% of urban areas that are not connected to a pipeline grid. LPG is usually distributed by truck in 13-kilogram bottles; it is estimated that there are 70 million of these bottles in

[3] The Human Development Index (HDI) is a comparative measure of life expectancy, literacy, education, and standard of living for countries worldwide. It is a standard means of measuring well-being. It is used to distinguish whether the country is a developed, developing, or under developed, and also to measure the impact of economic policies on quality of life. The index was developed in 1990 by Pakistani economist Mahbub ul Haq, and has been used since 1993 by the United Nations Development Programme in its annual Human Development Report (UNDP, 2004).

Brazil. Over the years, the distribution companies have helped diffuse LPG throughout the country, establishing some standards for the product, providing technical assistance for consumers and enhancing consumer safety.

The Brazilian government has effectively adopted a social energy policy that supports the supply of energy to the poorest consumers by cross-subsidizing LPG for domestic use through an additional tax on other fuels such as gasoline. One problem, albeit an uncommon one, is that low prices encourage users to use it illegally and dangerously to heat swimming pools or to run vehicles.

Between 1984 and 1999 LPG sales doubled, reaching 12 million cubic metres (m^3). During this period, LPG consumption spread widely among low-income families because of the cross-subsidies. However, as a result of increasing LPG prices, the trend reversed in 1999, and LPG consumption decreased over the next three years. In just one year, between 2001 and 2002, it dropped by 4.8%. Even though the market for oil products imports, including LPG, was opened in January 2002, LPG prices have increased by around 50% since then.[4]

Fuelwood is still widely used for cooking in rural areas mainly in the North and Northeast Regions. The high urbanization rates of the past decades have led to a continuous substitution of LPG for wood. It is worth noting that many households still use two stoves — one for wood and the other for LPG — as a kind of guarantee for when one or the other fuel is lacking. Although wood can be collected for free in some rural areas, LPG is perceived, correctly, as being better suited for quick meals.

Natural gas used in homes is referred to as 'residential gas'. It is currently available through urban pipelines to households in only a few cities that already had distribution networks for city gas, notoriously, Rio de Janeiro and São Paulo. In general, since the beginning of the 1990s, Brazil's natural gas supply has increased due both to higher national production and to imports from Bolivia and Argentina. The state distribution companies have plans to expand their networks, but the increase in home gas consumption will also require large investments for conversion and hook-ups, and to adapt home installations.

3.2. Affordability: Reducing energy use inequalities in Brazil

A principal challenge in dealing with energy use inequalities is to find the right balance between the argument that open energy market prices should reflect the long-term marginal cost of energy and the argument that some degree of subsidies for the poor may be socially desirable. The basic problem is that prices set to cover investment costs may not be affordable to low-income households or enterprises. Among other consequences, some low-income households and enterprises might therefore continue to use traditional non-commercial energy sources and inefficient technologies, with all their attendant health and environmental hazards. The government has two options to promote the desired level of affordability: restricting energy prices or providing low-income consumers with targeted subsidies. Low energy prices are particularly important for those areas of Brazil where LPG and electricity are currently accessible but prices are prohibitive.

Deregulation in automotive fuel prices, which was based on price controls and cross-subsidies since 1950, began in the 1990s. In 2002 all constraints were lifted on prices, profit margins and freight rates. For the household sector, natural gas and LPG prices doubled from 1992 to 2000, corrected for inflation and adjusted for 1990 PPP[5] values.

Electricity prices, on the other hand, are structured to provide discounted basic and minimal service (up to 100 kWh per month and single-phase connections) to low-income groups through a series of cross-subsidized rates. Moreover, policies for inflation control led to a gradual reduction in electricity tariffs during the 1980s[6] (Costa *et al.*, 2006). Despite the fact that energy cross-subsidies do not operate to the same degree in all regions owing to differences in the commercial energy share of total energy use, they allow poor people access to commercial energy services,[7] although in most rural areas the poor still use non-commercial fuelwood as well. This is why in 2000 Brazil's energy Gini index[8] was lower than its income Gini index (see Table 1). Table 1 also shows that during that year the energy inequalities in the North and Northeast regions are greater than the

[4] Opening the market should, by itself, cause the price of oil imports to decrease because of competitiveness. However, the actual outcome is also influenced by other government policies, such as subsidies for national products, and by other factors, such as exchange rate mechanisms, international prices and market structure.

[5] Purchasing power parity (PPP) is in economics the method of using the long-run equilibrium exchange rate of two currencies to equalize the currencies' purchasing power. It is based on the law of one price, the idea that, in an efficient market, identical goods must have only one price. A purchasing power parity exchange rate equalizes the purchasing power of different currencies in their home countries for a given basket of goods. These special exchange rates are often used to compare the standards of living of two or more countries. The adjustments are meant to give a better picture than comparing gross domestic products (GDP) using market exchange rates.

[6] Even though tariffs later returned to the 1980 level, they were stabilized until 1998 when prices again began to increase.

[7] In addition, there is the impact of the informal economy. Some studies show that, for some low-income groups, the real use of electricity is much higher than is reflected in official statistics, as the use of 'unbilled' electricity may be quite high in some situations. For details see Abbud (1999).

[8] The energy Gini index is analogous to the Gini index. It measures the extent to which the energy use of individuals or households deviates from a perfectly equal distribution. A Lorenz curve plots the cumulative percentage of total energy use against the cumulative number of consumers, starting with the poorest individual or household. The energy Gini index measures the area between the Lorenz curve and a hypothetical line of absolute equality, expressed as a percentage of the maximum area under the line. A value of zero represents perfect equality, a value of one, perfect inequality.

Table 1. Energy and income Gini index by region, 2000

Region	Brazil	North (urban)	Northeast	South	Southeast	Midwest
Energy Gini index	0.594	0.674	0.769	0.443	0.461	0.555
Income Gini index	0.608	0.598	0.618	0.585	0.592	0.633

Source: Schaeffer *et al.*, 2003; based on IBGE, 2002.

income inequalities, which can be attributed to the low accessibility of conventional commercial energy sources in these regions.

In presenting these figures it is important to note that for some distribution companies in Brazil, up to 10% of the electricity supply is lost as it is obtained illegally through middlemen. Since privatization took place in the 1990s, distribution companies have made a huge effort to recover the revenues from illegal use. In some cases, common meters have been installed to monitor usage. In others, no meters have been installed yet since the costs were considered too high. In these cases households are charged a flat rate.

In addition to pricing policies, direct income transfers have been used effectively in Brazil since the removal of general fuel subsidies during the oil market liberalization. Targeted direct income subsidies for the poor were established for LPG to offset the negative economic impacts of liberalization on low-income families.[9] Targeted income assistance is generally considered to be more efficient than general subsidies and more cost-effective for the government. Since broader subsidies tend to be more susceptible to abuse by those who do not need, but still receive, them anyway. When low-income people receive money rather than LPG bottles or coupons, they are more likely to develop energy-efficient use patterns (since they keep any money they save), or invest in more efficient appliances. On the other hand, there is no guarantee that increased disposable income leads to more rational spending for greater family welfare. Vouchers are sometimes used for targeted income assistance to avoid (at least in theory) this problem. In the end, however, no form of subsidy is free of abuse.

3.3. Acceptability: Social impacts of energy supply in Brazil

It is commonly said that there is no clean energy: every step in the production, conversion, transport and use of energy has drawbacks. This does not mean that all energy fuels are equally desirable. This section discusses some of the negative social impacts of the most important energy supply technologies in Brazil, as well as political arguments from different social groups.

3.3.1. Hydropower

Brazil has been building large hydropower plants since the 1960s. As of 2006, the total installed hydropower capacity has reached some 75 Gigawatts (GW) (total hydro generation capacity was actually 70.858GW at the end of 2005, according to EPE, 2006). Most of the plants were built during a period when there was very little concern about their environmental and social impacts. Environmental and relocation costs were largely underestimated or not considered at all. There was no prior discussion of technological alternatives for electricity generation, or of the sizes and shapes of the lakes to be created by large dams. People were simply informed that the dam was to be constructed and that they would need to move to another place. They were, very often, inadequately indemnified for their losses in an asymmetrical process of negotiation.

Over the years, and after many bad experiences, people have become more concerned about the dam construction process. Grassroot rural unions, Catholic Church representatives and social-environmental groups have begun to raise public awareness about the negative impacts of large dams and to organize themselves for resistance, strengthening their hand in negotiations. More recently, under social pressure, the power sector has tried to incorporate social organizations into the overall process of building a hydropower plant. At present, there is a well-established organization called MAB — Movimento Nacional dos Atingidos por Barragens (National Movement of those Affected by Dams) that is active throughout the country.

The most negatively impacted by the construction and operation of hydropower plants are those who used to live in the area and have had to move. In most cases, the newly relocated rural populations face substantial loss relative to their previous standard of living. Specific examples in Brazil include the Itaparica, Tucuruí, Sobradinho and Balbina hydropower projects.

The case of the Balbina plant, which led to an increase in malaria in the local Indian populations and a reduction in fishing catches, and which submerged valuable premium wood and 141 archeological sites, illustrates some of the other social impacts associated with dam construction (Franco *et al.*, 1992).

[9] Decree 4 102 of 24 January 2002 provided for low-income people registered in any federal social programmes to receive direct income transfers from the Brazilian government to help purchase LPG.

3.3.2. Nuclear Power

Angra dos Reis, where the only two Brazilian nuclear power plants are located, is 130 km West of Rio de Janeiro and 220 km East of São Paulo, Brazil's two most populated cities.

All spent nuclear fuel is stored at the plants, and the storage facilities can be enlarged if new material needs to be accommodated. Brazil does not have a plan for the long-term storage or disposal of nuclear waste. The emergency plan for accidents is under critical scrutiny.

As is evident from the worldwide range of national decisions on nuclear power — from nuclear bans and phase-outs to heavy reliance on and significant expansion of nuclear power — not all countries think alike. Brazil's Constitution explicitly allows the use of nuclear energy for peaceful ends. Public acceptance is often raised as an issue in connection with nuclear power, and it is difficult to predict whether this will change in the future. No regional or national polls have been carried out so far to assess public opinion on nuclear operations in the country as a whole.

Since 2001, the Ministry of Environment has organized several meetings in connection with the possible completion of a third nuclear power plant, Angra 3, whose civil works begun in 1984 and were stopped in 1986, to review the different perspectives of organized institutions and social movements.[10] The Ministry held meetings with three 'stakeholder groups': entrepreneurs, researchers/scientists and environmentalists. The principal statements from each group, which should not be taken as representative of the whole public of Brazil, are shown in Table 2.

3.3.3. Coal

The expansion of coal activities, located in the South region of the country, faces several constraints and needs to resolve with four major issues:

- Environmental liabilities derived from mining activities in the State of Santa Catarina that affect sustainability and economic development as well as the security of workers and local populations;
- Increased unemployment resulting from the cessation of coking coal production;
- Adverse competition with fuel oil and natural gas for industrial consumption — in particular for the cement and ceramics sectors; and
- Mining health impacts and safety.

In the State of Santa Catarina, coal mining led to contamination of surface and underground water sources through the leaching of metallic compounds. There are many conflicts between economic, social and environmental interests, mainly regarding coal extraction activities and the future availability of unpolluted water.

[10] As of December 2006, however, a decision has not been reached on whether or not to build the Angra 3 plant.

In general, some urgent measures, such as regeneration of the South region's underground water supply, reuse of the water used in the processing of coal, establishment of territorial limits to mining activities in order to preserve mountains and forests that allow the refilling of the aquifer and improving the quality of underground water in that region are needed.

The recent strong opposition to coal-fired plants scheduled to be built in the States of Paraná, São Paulo and Rio de Janeiro demonstrates awareness of the unsustainability of coal energy paths. In Rio de Janeiro, for instance, local authorities approved the construction of a 1,250-MW imported coal thermal plant. After a tough process that included politicians, industry lobbyists and social and environmental movements, which proved that emissions from the plant would push nitrogen oxide levels above the limits set for the region, the initial license was revoked and the project suspended.

3.3.4. Charcoal production

In Brazil, charcoal is mostly used as an input for pig iron smelters that supply the steel industry. Charcoal production involves hazardous working conditions and extremely precarious living conditions (Dias *et al*., 2002). Charcoal workers face physical risks of chronic fatigue due to lifting and stacking heavy logs, with up to 12 hours of work a day, including shifts during nights and weekends, which increase the risk of accidents on the job and the loss of emotional control. Workers are also subjected to fine dust and smoke inhalation that cause skin irritations, conjunctivitis, and serious respiratory problems such as silicosis (SEJUP, 2000).

More than a century after slavery was abolished in Brazil, forced labour still exists in some rural areas. Even with efforts by the federal government and social movements during the past decade, violations of labour laws are still common, including the use of unregistered workers, low wages and lack of freedom for workers. In some regions, mainly in the States of Pará, Maranhão, Piauí, Tocantins and Mato Grosso, people are recruited by labour contractors called *gatos* (Portuguese for 'cats') to work in remote areas. Increasingly smaller production areas are rented to sub-contractors to avoid regulation and union organizing. Children work alongside their parents in remote areas far from towns, schools or medical facilities, and workers are often prevented from leaving the work premises by armed guards. Workers are often forced to buy food and supplies at inflated prices in company stores and thus constantly find themselves in debt, which represents a perverse indebtness slavery system (Sutton, 1994). In recent years, however, modern industrial-scale charcoal producers have made some improvements in order to comply with social and environmental laws.

Indebtedness slavery also occurs in other economic activities such as sugarcane and other agricultural production. The case of charcoal presented here is just one example of how poor workers are forced to submit to this system. In 1995,

Table 2. Arguments regarding nuclear energy in Brazil according to selected groups in society

	Entrepreneurs (nuclear and construction)	Researchers/scientists	Environmentalists
Safety	Angra 1 does not have a good operational record; Angra 2 is much more reliable in operational terms. The probability of an accident is remote.	The Angra complex must improve its safety measures. Historically there has been a lack of transparency in relevant information regarding operational problems at the plants.	The Angra nuclear complex is not safe; it is mainly the Angra 1 plant that has presented several technical problems. The emergency plan is not reliable and has never proved to be workable.
Fuel-cycle knowledge	Brazil has the sixth largest uranium reserves in the world and has the capacity to enrich uranium domestically.	Mutual inspections of radioactive material between Brazil and Argentina and of Non-Proliferation Treatment procedures are important.	There are problems concerning overburdening in the retired Poços de Caldas region and operational and safety problems in the new uranium mine in Lagoa Real, in the State of Bahia.
Technological issues	Technical skills should be stimulated.	It is important to develop technological nuclear capacity for sovereign reasons; however, military use must be prevented.	Technological capacity should be applied for proved safe industrial and medical uses, besides monitoring and safety.
Importance to electricity supply	Nuclear plants are important for the national electric system.	The contribution of the Angra nuclear plants is relatively small.	Other options exist.
Completion of Angra 3	Angra 3 should be built.	Additional studies are necessary. There is no for or against position.	Construction should not proceed in any way.
Wastes	A solution to the problem of waste storage will be found, but nobody knows when.	Solutions to the problem of waste storage are not yet sufficient.	There is no satisfactory solution to the problem of waste storage. We should not transfer environmental liabilities to future generations.
Costs	Angra 3 should be built because US$750 million have been spent on equipment already. Angra 3 is important to the financial health of Eletronuclear, Brazil's state-owned nuclear electric generation utility. US$20 million are spent annually just to store the equipment already bought.	Costs and investment projections are not reliable. Costs for finalizing the construction of the plant may be much higher than projected (currently an additional US$1.8 billion).	Nuclear plants are too expensive. Other cheaper options are available. There is no reason to subsidize nuclear plants.
Decommissioning	Funding has yet to be defined.	Decommissioning should be funded by tariffs.	There are serious flaws concerning decommissioning funding. No reasonable structure exists. Liabilities will be transferred to future consumers.
Environmental impacts	Nuclear energy is 'clean' because there are no emissions of acids or greenhouse gases.	There are positive aspects regarding atmospheric gases and negative aspects relative to radioactive wastes.	Radioactive wastes represent extremely serious impacts and should be considered unacceptable.

Source: MMA (2001).

a Special Mobile Enforcement Group was created, associated with the Ministry of Labour and Employment, to fight against labour irregularities and abuses. From 1995 to 2001, the Group inspected 770 labour units employing some 160,000 people and found 2,232 workers in conditions of slavery (MTE, 2001). In 2003, the Group, with the support of the federal police, managed to free almost 5,000 workers. Despite some improvements — inspections that allow the imprisonment of subcontractors and the gradual improvement of compliance with social and environmental laws — much more has to be done to abolish indebtedness slavery in Brazil and to improve labour conditions in some rural economic activities, including charcoal and sugarcane production.

4. Energy production and employment creation

The creation and maintenance of jobs make the biomass energy chain highly relevant from a social perspective. This is crucial for a developing country like Brazil, where income inequalities contrast with major achievements in agriculture and livestock production. The main employment-related features of energy production and use are as follows:

- Power plants (fossil fuel power plants and hydropower, for instance) create many jobs (1,000–5,000) requiring low qualification and paying low wages during the construction phase (normally lasting not more than 2–5 years and possibly creating subsequent social problems in the region) and fewer jobs (50–200) requiring high qualification and paying high wages during the long-term operation;
- The oil and gas sector requires workers with higher education levels and higher salaries than agribusiness;
- Some recent studies suggest it is possible to create jobs and income while reducing energy use and greenhouse gas emissions by shifting Brazil's production from energy- and import-intensive activities towards value-adding and labour-intensive commodities (see, e.g., Lenzen and Schaeffer, 2004; and Machado *et al.*, 2001). In particular, a recent study concludes that the potential for job creation is higher for energy conservation than for than energy production (see Machado and Schaeffer, 1997); and
- There is a trend towards mechanical harvesting in the sugarcane sector, implying a net loss of jobs in the sector.

4.1. Sugarcane production

The production of ethanol from sugarcane is the most labour-intensive energy activity in Brazil, but new renewable energy sources can also play an important role in the creation of new jobs, especially in rural areas.

Social considerations are among the determinants of the country's Alcohol Programme (PROALCOOL), started in 1975, in which ethanol is used as an automotive fuel, along with economic determinants, such as the reduction of dependence on petroleum, and environmental determinants, such as reduced greenhouse gases emissions. Ethanol production (including agricultural and industrial) supports some 1.5 million jobs in Brazil, with a relatively low index of seasonal work (Guilhoto, 2001). The number of harvest workers was reduced in the past decade owing to the increase in mechanization.[11]

Job creation per unit of energy is three times higher for hydropower and 150 times higher for ethanol production than for oil production (Goldemberg, 2002). This reflects the large number of workers and the low labour cost per employee in the ethanol chain, mainly at the harvesting step of production. The ethanol chain of production, including both the agricultural and the industrial phases, provides the least cost for job creation among different industrial sectors, although there are variations among regions. Estimated investment costs range from US$11,000 per job in the Northeast region to US$23,000 per job in the State of São Paulo (Southeast region), excluding the land costs (Macedo, 2002).

PROALCOOL also has social benefits for end users in the form of reduced health impacts. Atmospheric emissions of sulphur oxides (SO_x), carbon monoxide (CO), particulates and volatile organic compounds (VOCs) from vehicles have been reduced by the programme. Zero net emissions of carbon dioxide (CO_2) from ethanol production also substantially reduce the total CO_2 emissions from the transport sector (Szklo *et al.*, 2005).

4.2. Biodiesel production

In July 2003, the Ministry of Mines and Energy (MME) launched a biodiesel programme to gradually blend biodiesel, made from various indigenous vegetable species — *mamona* and palm oil,[12] among others — with regular diesel fuel and increase its use in the transport sector. The principal objectives of the programme are environmental advantages and job creation. Among the products that can be obtained are B2, diesel with 2% biodiesel content, B5, diesel with 5% biodiesel content, and so on up to B100.

In December 2004, the federal government authorized the commercial use of B2. Using the 2002 Brazilian diesel consumption of 38 billion litres as a reference, the equivalent use of B2 would require the production of 800 thousand litres of biodiesel, which would reduce the diesel imports per year by US$160 million. (MME, 2004) According to the biodiesel programme, biodiesel producers that buy *mamona* and palm oil from small rural producers in the North and Northeast regions can apply for tax breaks.

It is estimated that in the first phase an area of 1.5 million ha can be cultivated for B2 production. Each family producing 5 ha of *mamona*, an average of 700–1,200 kg per ha (the production *mamona* is estimated in the range of 600 kg/ha to 1200 kg/ha, without irrigation in the Northeast region of Brazil), can earn 2,500–3,500 Brazilian *Reais* (R$) just selling the seeds (primary production with no additional aggregated value), which gives a range of 160–275 *Reais* (R$) per month (MDA, 2004). The upper value is slightly higher than the national minimum wage per month as of December 2004.

In the North region, palm oil is one of the best options for meeting biodiesel demand, with a potential of 3.2 million tonnes of production on 720,000 ha, sufficient for 140,000 families. The net income of a 5-ha family unit can reach six times the minimum wage. For soybean (*Glycine max*), a well-established agro-industrial sector in the country, the potential for B5 is around 1.8 billion litres of oil, requiring the cultivation of an additional 3 million ha (probably more area would be required), leading to 234,000 permanent jobs (Peres, 2004). However, as there are environmental and economic arguments against the uncontrolled expansion of soybeans in Amazonia, biodiesel production from soybeans should be compared with the cultivation of other species that perhaps create more jobs with less impact on the environment

[11] In 1991, harvest workers made up 60% of the total workers in the sugarcane industry (Borges, 1991).

[12] Mamona, *Ricinus communis*, is not indigenous to Brazil, but native of India and naturalized in Brazil. It is sometimes called castorbean or castor oil plant in English; Palm oil, *Elaesis guineensis*, is also not indigenous to Brazil, but native of Central Africa. *It* is called dendê in Portuguese and palm oil plant or African oilpalm in English.

and certainly have a much larger oil production per ha. It should be noted that the production of biodiesel will require not only the oleaginous crops, but also sugarcane.

If Brazil is to be successful in its biodiesel programme, appropriate vegetable species need to be cultivated in different regions in the coming years. Rough estimates indicate that for a demand level of 1.85 billion litres of B5 produced from *mamona*, *dendê* and soybeans, around 1.0 to 1.2 million jobs can be created. The figures are much higher for B20; even in this case, the cultivated area, almost 20 million ha, is only about 25 percent of the estimated area suitable for energy crops in the country. From the supply side, it is reasonable to point out that, considering the potential for *mamona* production in the Northeast region, some 2 million new jobs could be created. In summary, biodiesel production presents many environmental and social benefits and can be a unique alternative for increasing the number and quality of rural jobs in Brazil.

4.3. Renewable energy

Several solar thermal projects for residential use in the state of Minas Gerais and wind-power projects in the South region (the 150 MW Osorio plant) are currently under way. Additionally, outstanding support to renewable energy in the country has been given with the creation of PROINFA — a programme to stimulate new renewable plants (wind, small hydro and biomass) to generate electricity. PROINFA was created by Law 10,438 in 2002. It consolidates several actions undertaken during the 1990's for promoting alternative energy sources for electric power generation in the country. The programme is divided into two phases, aiming at stimulating the electricity generation from three energy sources (wind, biomass and small-scale hydro) in Brazil. During the first phase, completed in 2006 with around 3,000 MW installed, wind power, biomass-based power and small-scale hydro power (SSH) producers are encouraged to sign 15-year long-term contracts, in order to achieve 1,100 MW of installed capacity from each one of these three alternative energy sources. Originally, according to Law 10,438, the second phase of PROINFA established an impressive target: alternative renewable electricity sources should supply 10% of the Brazilian electricity consumption at the end of 20 years, that is, by 2022. Moreover, PROINFA was to support the use of Brazilian made equipment, create jobs and promote the diversification of the Brazilian energy matrix. This second phase, which was originally based on feed-in tariffs, was modified in 2003 to be based on biddings for renewables. These biddings are capped to limit their impact on the final electricity tariff.

5. Final considerations

In sum, energy accessibility, affordability and acceptability are essential in the provision of such basic services as lighting, cooking, refrigeration, telecommunication, education, transportation and mechanical power. These services assist human development by providing preconditions for the development of economic and social activities (Najam and Cleveland, 2003; Spalding-Fecher *et al.*, 2002).

Physical provision of energy services to the people is no longer enough to solve the "energy issue". Sustainable energy development has to include the dimensions of affordability and acceptability as well.

In this vein, if Brazil is to move towards a more sustainable energy future, the expansion of the provision of energy services in the country has to be increasingly selective, and based on modern commercial energy sources, where renewable energy and energy efficiency play an important role. Therefore, future research should address more deeply the link between energy efficiency technologies and energy affordability for the poorest, and subsidies for acquiring modern and efficient facilities that are cost-effective for energy suppliers and the national energy system.

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