Number 260

Searching for Sustainability: The Energy Sector in Brazil

Luiz Pinguelli Rosa
Alexandre Salem Szklo
Mauricio Tiomno Tolmasquim

Latin American Program
Woodrow Wilson International Center for Scholars

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Preface

Dr. Luis Bitencourt[1]

At the end of 2000, Americans were particularly shocked by the effects from the "Californian energy crisis" and a heated debate was developing about the operational model that should be used for the sector, domestically as well as globally. As a result of the dialogue forming on the experience in California, Brazil's own energy situation immediately came to my mind as a case for comparison that merited further exploration. Given the mission statement of *Brazil @ The Wilson Center*—to bring to the attention of the American and Brazilian public themes of mutual interest, particularly those that benefit bilateral relations between the two countries—the rising concerns over energy in the United States and Brazil clearly fulfilled these requisites. At question was not only the operational model, but also assuring the supply of reliable sources of energy. In the case of Brazil, the country's energy sector had been under a process of reorganization vis-à-vis privatization, following the global trend toward the decentralization of public services that began in the late 1980s. As far as I can remember, energy supply always had been a serious and historical concern for Brazil. Moreover, for a country that traditionally had exploited hydroelectric generation, it seemed the time had come to consider new options to meet Brazil's demand for energy.

With these typically academic concerns in mind, we began to organize a seminar at the Wilson Center on the impending concerns for Brazil's energy sector. Interestingly, when I visited the Brazilian Minister of Energy to invite his participation, the reception I received was cold and skeptical. I was assured that there was no need to plan such a meeting since nothing could be farther from the truth than an energy crisis in Brazil. It would be only a few months after my visit to the Ministry of Energy that the Brazilian government announced the worst energy crisis in the country's history and would adopt a dramatic energy-rationing plan.

Fortunately, Brazil @ The Wilson Center decided to proceed with the seminar which proved to be very timely. On April 25, 2001, under the auspices of our sponsor Texaco (presently Chevron-Texaco), *Brazil @ The Wilson Center* held a two-day long seminar gathering energy sector specialists, academics, and politicians from Brazil and the United States. At that time, the overall consensus that emerged from various panels was that Brazil needed to diversify its energy supply while seeking "clean" sources that would ensure the sector's long-term sustainability. Moreover, Brazilian authorities were called upon to promote an intense debate on this subject, engaging society to help define an energy matrix that would be capable of expanding the sector output without harming the country's ecosystem.

[1] Ph.D. World Politics, Catholic University of America; M.A. World Politics, Catholic University of America; M.A. Political Science, Universidade de Brasilia. Director of the Brazil @ The Wilson Center.

This working paper brings together a background summary on the evolution of the sector, written by Program Consultant Craig Fagan, and two of the papers presented in that important conference: **The Deregulation of the Energy Sector in Brazil: A Comparison Between Electrical Energy, Oil and Natural Gas Sectors**, by Luiz Pinguelli Rosa; and **Brazil's Cogeneration Regulatory Framework: In the Light of International Experience**, by Mauricio Tiomno Tolmasquim and Alexandre Salem Szklo. Dr. Pinguelli is the director of COPPE, the Graduate School of Engineering at the Federal University of Rio de Janeiro while both Drs. Tolmasquim and Sklo are from the Energy Planning Program of the Graduate School of Engineering at the Federal University of Rio de Janeiro. Pinguelli's paper addresses the deregulation of the energy sector from a tecnical standpoint while incorporating extensive policy analysis into his argument. He emphasizes the importance of the definition of the energy matrix for Brazil's future and concludes that, overall, the privatization of the electric energy sector in Brazil has had negative results, considering both the final prices for the consumer, the quality of service offered, and the inability of the system to expand electricity generation proportionally to increases in demand.

Tolmasquim's and Szklo's paper is focused on the topic of cogeneration in Brazil, a process that simultaneous generates two or more forms of energy from a single source. They analyze the impact of changes in the country's regulatory structures on the development of cogeneration. Particular attention is paid to Brazil's legal framework for cogenerators and how this has constrained the establishment of such facilities. The authors stress a concern over the misperception of authorities about the potential benefits of cogeneration facilities for Brazil's energy sector. Tolmasquim and Sklo suggest that the current administration has opened the market to competition without adequately distinguishing between cogenerators and independent power producers. As a consequence, the state has been, and will continue to be, unable to encourage energy efficiency as long as private investments are not channeled towards cogeneration projects, which have proven to be more efficient than ordinary power generation plants.

The research papers that make up this publication, as well as the seminar in which they were presented, is evidence of the continued commitment of Brazil @ The Wilson Center and the Latin American Program to bring to light the issues that are at the forefront of concerns for the region. Our dedication to stimulating not only a dialogue but a policy debate on this and other topics will always remain our guide for future projects to come.

Introduction:
The Evolution of A Crisis—A Historical Perspective of Energy in Brazil

Craig M. Fagan[2]

The energy sector in Brazil has evolved out of historical events, political forces, and consumer exigencies. A major refocusing of the sector occurred after the 1973 and 1979 oil-price shocks when Brazilian policy shifted towards diversifying the sources of its energy supply. As Dr. Luiz Pinguelli, notes in his working paper entitled "The Deregulation of Energy in Brazil," this monumental crisis led to several innovations and changes for the country's energy sector. The exploration and promotion of alternative energy sources resulted in the replacement of gasoline for alcohol to power cars (a sugar cane derivative), the construction of off-shore oil facilities, an expansion of hydroelectric generation, and the decision to build a series of nuclear power plants (Anwar I, II, III).[3] The decline in crude oil prices between 1985-86 produced a reevaluation of many of these policies such as the desire for Brazil to become self-sufficient in oil production. Originally, there had been popular backing for Brazil to achieve self-sufficiency in order to end the threat of supply-side shocks and to provide a buffer for the radical fluctuations in world oil prices. The drive to open markets and liberalize economic structures during the 1990's produced a new realignment of official policies towards the sector. The government viewed increased foreign investment as the primary means to promote energy exploration, leveraging international "know how" and financial backing to encounter new sources for its energy supply.

However, the fervor of the 1990's to liberalize Brazil's economic structures is now under scrutiny. Six years after the initial privatization efforts, a clear consensus yet has to be formed in Brazilian policy circles on whether the process has been beneficial for the expansion of the energy sector. As Dr. Luis Bitencourt has noted, this debate over the liberalization of the sector parallels events that have occurred in the state of California. The onset of California's energy crisis following its privatization has underscored the problems that can arise from permitting the private sector (investors and operators) to provide a public good (energy). California began to ardently deregulate its energy sector in 1995 but power generation facilities failed to amplify their installed capacity given the inclusion of a pricing disincentive into the framework used for privatization (i.e. the end tariff was regulated). Following the state's economic expansion during the 1990s, the demand for energy increased and price gauging occurred. Generators would supply power at higher prices to the distributors who, in turn, had to internalize these elevated costs because of the regulated pricing structure found for end-users. In terms of the Brazilian crisis, there were similarities between California and what was occurring in the country at the beginning of May 2001. Privatization and deregulation led to the absence of strategic investments in new generators and energy facilities required for meeting the country's expanding demand. However, the rising costs for electricity in Brazil were transferred to the consumers rather than being absorbed by the distributors as had happened in California.

Although this most recent crisis, *o apagão*, has been declared officially over for Brazil, the problems that were at its root have not been resolved. The future of the energy sector in Brazil will undoubtedly be conditioned by the government's response as well as the historical forces that have placed the country in its current predicament. For these reasons, it is of fundamental importance that national energy policies incorporate certain outstanding issues into their frameworks: the rising consumer cost for the use of energy (6.0% rise in energy taxes a year), insufficient reserves, and the excessive dependence on one source of energy (hydroelectric power). In this sense, the government, in conjunction with key stakeholders (private energy generators and distributors, residential consumers, national industry), can develop a long-term, sustainable strategy that meets both the historical exigencies and evolving demand for energy in Brazil (see Graph 1.1).

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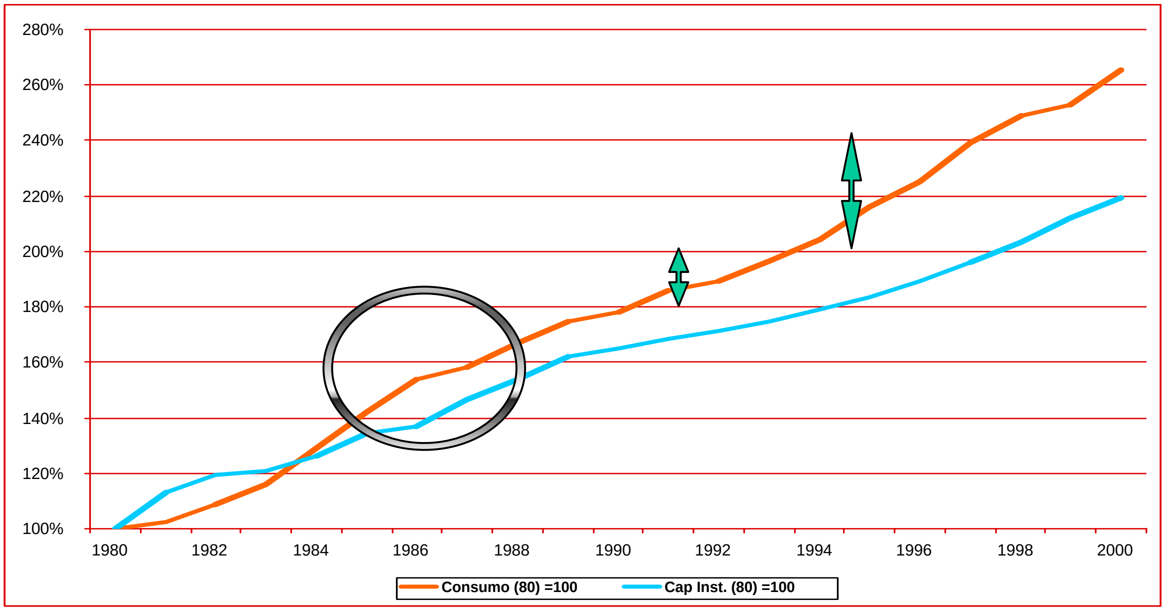
[2] Program Consultant-Latin American Program/Brazil Project. M.A. in Latin American Studies/ Development Economics, School of Advanced International Studies-Johns Hopkins University.

[3]The Anwar Projects were sponsored under a partnership with Germany that originally was signed in 1975.



Graph 1.1: Evolution of Consumer Demand and Installed Capacity, Indexed, 1980-2000

Source: D' Araujo, Roberto Pereira. Presentation: ILUMINA. *Energy and the Environment in Brazil Seminar*. 25 April 2001. Washington, DC: WWICS.

In broader terms, the dynamic linkages that exist between a country's economic growth, its sustainable energy sources, and environmental policies are inextricably connected to the sector and the adoption of related, appropriate policies. The **first** of these relationships—the interplay between economic growth and reliable energy resources—has been revealed in the latest crisis. The most recent experiences of Brazil have demonstrated that rationing and unstable supplies of energy can have severe implications for a country's expansion, at least in the short- if not the long-run. Last year's energy shortfall in Brazil is projected by analysts to have translated into a two-percent or more reduction in economic growth (Gross Domestic Product—GDP) from the original forecasts. The situation is complicated by the fact that one of the principle three regions affected by *o apagão* was the Southeast, the industrial belt of Brazil. Moreover, the composition of the country's principal industries (steel, auto manufacturing, mining) mandates a reliable and constant stream of energy that was not satisfied completely for almost a year (May 2001 through March 2002).

The **second** issue that arose from the crisis has been the sustainability and viability of Brazil's energy sources. The near exhaustion of the country's energy supplies last year has led to a renewed and vigorous quest for encountering sustainable and alternative sources. One option for such a sustainable supply could be nuclear power. The construction of nuclear reactors in Brazil began in 1975 under a cooperative agreement with Germany to build eight facilities that would produce 10,400 MW by 1990. There have been only three reactors completed from this agreement and the program has since been abandoned because of high cost overruns. Nevertheless, nuclear energy has been reconsidered as a viable option to meet Brazil's growing energy needs. Given patterns of global consumption, current energy demand per capita in Brazil (1.906 kilowatt hours, kWh), which is below the world average (2.260 kWh) and significantly less than industrialized countries like Germany (5.789 kWh), is projected to rise and place further strain on an already frail system.

The **third**, and final, issue for consideration is the linkage between energy policies and the environment. The debate over the increased use of nuclear power and other alternative energy sources to meet rising consumer demand has led to a re-evaluation of sector policies and their impact on Brazil's diverse ecosystem. Current energy exploration and production processes have resulted in increased pollution and an excessive release of emissions. For example, the country's dependency on hydroelectric power has created a negative and direct impact on the environment while the deteriorated infrastructure used in the exploration, refinement, and distribution of fossil fuels has resulted in a series of oil spills and gas leakages over the past two years. Given these concerns, alternative solutions must be devised. As Mauricio Tolmasquim and Alexandre Szklo discuss in their working paper "Brazil's Cogeneration Regulatory Framework: In the Light of International Experience," such facilities may prove to be the best projects to meet the country's energy needs. Unfortunately, the policy framework—in terms of legal codes, regulatory structures, and incentives—does not exist to promote cogeneration projects.

With the subsiding of the crisis, it is important to review the existing energy matrix and attempt to stimulate new projects that will prove the most cost effective, energy efficient, and environmentally-friendly. Brazil could gain substantially from exploiting existing synergies by moving towards sustainable energy sources and promoting more effective social policies. It is within these unofficial guidelines that the country must search out policies that will prevent another *apagão* while pushing the sector forward to respond to the growing energy needs of the Brazilian people.

The Deregulation of the Energy Sector in Brazil
A Comparison between Electrical Energy, Oil and Natural Gas Sectors

Luiz Pinguelli Rosa[4]

1. The Brazilian Energy Sector: From State Intervention to Deregulation

After the 1973 and 1979 oil-price shocks, Brazil's energy policy for the liquid-fuels and electricity sectors adopted a four-prong approach to resolve its dependency on energy derived from fossil fuels:

- A program to replace gasoline with alcohol-derived fuels (*alcool*);
- The intensification of off-shore oil exploration and production;
- The expansion of hydroelectric generation; and,
- A program to generate nuclear electricity through an agreement with Germany.

The success of the first three of these measures was undeniable, in spite of environmental and social problems as well as financial costs, because they mitigated the burden of oil imports on Brazil's economy. However, the decline after 1985-86 in the price of imported oil has called into question the role of alcohol-derived fuel, which is expensive, and the speed at which Brazil should seek oil self-sufficiency (i.e. net exporter vs. net importer). Certain social groups, motivated by nationalistic concerns, opted for achieving oil self-sufficiency because of uncertainties about internationally-securing a reliable supply of oil as well as the possibility of new price increases in fuel. By the 1990s, liberal market economists also began to favor this option for Brazil. They saw it as a means for attracting foreign investment to the country rather than as a way of assuring a constant and secure energy supply. Currently, concern has been directed toward the present mismatch between the slow growth of Brazil's oil reserves (R) and the rising rate of oil production (P). Foreign direct investment (FDI) largely has been directed toward crude oil production in areas that already have been explored by Petrobrás, the state-owned oil company. As a result, there has been little exploration to discover new sites of oil reserves and the presumed oil reserve life (R / P) for Brazil may be lowered, similar to what has happened in Argentina.

It is of fundamental importance to have in mind all these factors that will affect the country's energy policy in order to avoid decisions that are irreversible or, at best, only slowly rectifiable. Unfortunately such a broad purview has not been the case of the present situation in Brazil, where the deregulation of the energy sector in the 1990s has disorganized the country's energy supply. Deregulation has brought the abandonment of pure alcohol-fuelled cars as well as a stoppage in the expansion of hydroelectric power. At the same time, it has produced an increase in the importation of natural gas from Bolivia at elevated costs for the country's electricity generators. As a result, today, Brazil is facing a crisis in the electric energy sector.

Originally, the policy of Brazilian electricity planning aimed to exceed the country's consumption requirements, especially for its industrial sectors. In fact, the annual rate of growth for the supply of electrical energy was above 10 per cent between 1970 and 1980. A long-term extrapolation of this trend led to huge forecasts of installed power, reaching 150,000 MW by the year 2000. This included, beside large hydroelectric

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[4]DSc in Physics and MSc in Nuclear Engineering. Dr. Pinguelli is currently the Director of COPPE – The Graduate School of Engineering of the Federal University of Rio de Janeiro, a professor of Energy Planning at COPPE, and the Coordinator of the International Virtual Institute on Global Changes and of the Integrated Center on Climate Change of Brazil.

plants such as Itaipu (12,600 MW), an important construction program of nuclear reactors; eight reactors generating 10,400 MW by 1990 were planned in cooperation with Germany.[5] This program, initially budgeted to cost a little more than US$10 billion, would actually have cost US$30 billion if they all had been built. Similarly, the cost of Itaipu was approximately US$15 billion, which also surpassed its initial forecast. Even so, the latter's investment per installed kilowatt was far below that of Angra II, the first nuclear reactor to be built out of the agreement signed with Germany in 1975 which started its operations only in 2000. Angra II was the second reactor to be constructed in Brazil, the first being Angra I, a Westinghouse-PWR facility. The program with Germany eventually was stopped, after an expenditure of about US$8 billion, because of the few beneficial results it produced.

Overall, Brazil's economic crisis in the first part of the 1980s, plus the slow return on investments for large projects, led to difficulties for the country's electricity sector. First, the increase in the interest rates on loans provided to Brazil led to a non-energy variable, which had a serious impact on the country's hydroelectric and nuclear programs. Second, the prices of electricity were not adjusted for inflation, a situation that added difficulties and persisted even after the end of the economic crisis. Third, the economic crisis resulted in a situation where the electricity supply (through the initiatives discussed) was increasing as demand stabilized, resulting in the excess being sold at very low prices and in effect subsidizing fuel oil for industries.[6]

1.1. The Electric Energy Shortage

One of the characteristics of the electricity supply in Brazil, until now, has been that it comes almost entirely from hydroelectric plants, with little reliance on imports. An important exception is the electrical energy generated at Itaipu, the largest hydroelectric plant in the world, of which half belongs to Paraguay and is imported by Brazil. But even in this case, the investment was Brazilian, and it was done in accordance with the national electric power sector plan.

After the devaluation of the Brazilian currency, the real (R$), in January 1999, the price of the hydroelectric power from Itaipu scaled up to more than R$60/MWh (US$30/MWh) while the cost of domestic hydroelectric generation was about R$40/MWh (US$20/MWh) by the beginning of 2001. The forecast for thermoelectric energy generated from natural gas is about US$40/MWh. The present challenge is that, while hydroelectricity requires efficient planning for its generation, deregulation has produced the abandonment of such normative strategies as well as a lack of investment in the sector. The result has been a shortage in the electric energy supply (most recently during 2001). Originally, there was a tradition of planning in the public sector for electrical energy under the auspices of Eletrobrás, the state-owned company (which has yet to be fully-privatized).

It is usually assumed that there is a relationship between the growth of electricity consumption and that of the gross national product (GNP), through a coefficient of constant elasticity that is less than unity (one). However, this hypothesis is debatable. In Brazil, such a coefficient has at times in the past surpassed a value of two. This high value reflects, among other factors, the development of electricity-intensive industrial sectors, the increase in urbanization, and overall demographic growth. As the country reaches a higher level of development, this value of elasticity should approach unity or decline to less than one, in line with the developed countries.

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[5] The expansion of hydroelectricity began prior to the oil price shocks, although these reinforced the importance of such facilities. In terms of nuclear power, the adoption of a huge nuclear program in 1975, which was extremely expensive and was stopped partly by the economic crisis and its own problems, was the greatest failure of Brazil's energy policy.

[6] This subsidy for electric energy sold to industrial consumers is still high for Tucurul in the North of Brazil, which is a large supplier of aluminum to multinational manufacturers.

The cutback in public investment by the state due to deregulation and its distorted pattern of such investments in which transmission was neglected, led to a lack of energy production in the Center-west, Southeast and South regions of the country. At the end of 2000 and the beginning of 2001 an exceptional drought occurred which aggravated the problems. Although this was not as strong as others had been in the past, the lack of rain further compromised the energy supply. The extensive dams that were built to accumulate reserves for a period of up to five years were found empty because there was a lack of installed capacity to allow for a rationalized and optimized use of water. This became clear as a nationwide blackout reached several important cities as Brasília, São Paulo, Rio de Janeiro, Belo Horizonte in 1999.

Consequently, the situation that has developed is paradoxical. There is a high risk of an energy crisis for the country's largest consumption centers within the next few years because of the failure to invest in such projects. Yet in the long-term, the existence of hydroelectric power resources in these same areas could by themselves if they were developed, meet the increased demand for energy.[7] To confront this lack of expansion of electric energy following the sector's privatization, the Ministry of Mines and Energy presented in 2000 a plan for private investors to construct 49 thermoelectric power plants, most of them using natural gas. However of those, only 15 are being constructed, with 13 being completed through the initiatives of Petrobrás.

1.2 The Comparison Between Hydroelectric and Thermal Power

A consistent electricity policy should take all these factors into consideration. Brazil's huge hydroelectric potential and other sources of thermal energy, besides nuclear power, must be developed. In this sense, fossil fuels (particularly natural gas), biomass, sugar cane byproducts, and alternative sources of energy (such as urban wastes, wind and solar) should be rationally put to use as is necessary. However, the future role of different energy sources in the generation of electricity will depend on several factors. Relative costs and economic priorities will be the main determinants, but so will the country's monetary policy, its commercial balance, indicators of employment, and Brazil's external dependence. Other important factors include the technological availability of techniques and materials, as well as the social and environmental impacts of the electric energy sector. For example, until now the cost of thermoelectricity has been too high in comparison with hydroelectric energy, for which there is a sufficient potential for its development in decades to come. Even considering that new hydroelectric plant costs have increased, because the waterfalls that are not yet exploited will present more difficulties for dam building, they should be lower than thermal and nuclear electricity costs for a long time to come.[8] Optimally, it also may be possible to avoid some problems and lower the cost of future nuclear plants, which have proven too high as the case of Angra II demonstrates.

Another economic alternative to the potential of hydroelectricity is coal, which is effectively reliable. However, coal presents environmental problems that are worse than those for oil and natural gas, including the "greenhouse effect" from gas emissions. This issue has become a focus of concern after the Climate Convention was passed at the Rio 92 Conference, and which was later reinforced by the Kyoto Protocol. In spite of the negative statements of President Bush concerning U.S. ratification of this agreement, it is probable that the government will use its decision as a bargaining chip for signing the Protocol later. Such issues of atmospheric pollution have become truly a global problem. From this point of view, nuclear energy has an advantage because even hydroelectric reservoirs produce some form of emissions, according to recent results from COPPE as included by the World Commissions on Dams in its report published at the end of 2000. Nevertheless, nuclear energy faces opposition from the urban middle classes on ecological grounds, because of the risks of accidents and radioactive waste. These sentiments have been evident in the discussion about the construction of a third nuclear reactor in Brazil, Angra III.

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[7] At present, Brazil has the second-highest production of hydroelectric power in the world, as a proportion of its total production.

[8] Even assuming a moderate cost structure for natural gas, only a small part of hydroelectric energy has a higher cost than thermoelectric energy in Brazil.

The other side of the environmentalist debate is the struggle by rural and indigenous populations against their forced removal to make way for dam reservoirs. Their cause may create enough pressure on Brazil's democratic government such that the total use of the country's hydroelectric resources may be impossible. The resolution of this conflict will depend on whether the electric sector can find acceptable ways of relocating these people and compensating them, while preserving the democratic and participatory spirit that failed to materialize in the past. This issue is best demonstrated in the decision to construct hydroelectric dams in the Amazon. The matter has attained an international dimension as a result of the so-called global effects from the destruction of the rainforest and the issue of indigenous land rights. Among the former, one may point to the rise in carbon dioxide (CO_2) that has resulted from forest fires, which are increasing the concentration of the gas in the atmosphere, thereby aggravating the greenhouse effect. Despite the margin of uncertainty in the findings, two facts are undeniable: the number of Amazon fires has reached such a high level that their contribution to the increase of CO_2 in the atmosphere is a sensitive concern in light of the UNCED-92 that took place in Rio de Janeiro; and, the greenhouse effect remains largely a result of the burning of fossil fuels in rich countries. While Brazil's emissions from energy consumption are relatively small, this in no way diminishes the responsibility of the government for the destruction of the rainforest, which was propitiated by a fiscal incentive system for stimulating the occupation of the region through the artificial support of agro-pastoral ventures. A nationalistic attitude in this case has covered up the problem of the low-use of the region's potential, which could be more rational and balanced. Moreover, it has contributed to the irrationality of the having large enterprises in the Amazon.

To escape from the polar opposite choices of either destroying the rainforest completely or preserving it as untouched, a study the region's diverse aspects is fundamental. The biggest problem is that of the indigenous lands, which goes beyond merely social aspects and involves issues of culture and ethics. One example of the problem is the controversy that emerged over the construction of a hydroelectric complex on the Xingu River because of its intrusion into tribal lands. However, according to recent research conducted by the COPPE Energy Planning Program, in collaboration with Eletrobrás, the impacts of hydroelectric plants must be analyzed from the standpoints of biodiversity and the emission of greenhouse gases, in comparison with thermoelectric plants.[9] The results show that, with the exception of a few rare cases, the emissions from hydroelectric facilities are low.

The last point to consider in analyzing the debate over different energy sources is related to the secondary economic effects of the respective investment structures. In terms of employment and job creation, thermoelectricity is less favorable to hydroelectric energy, especially in their construction phases. The number of employees per billion dollars of investment is less than 1000 for thermo power, while it reaches 5000 for hydroelectric plants in Brazil. This issue can be more broadly related to questions of external dependence, which must be discussed vis-à-vis the technological dependence on the different forms of energy. Clearly, external dependence is higher for thermal than for hydroelectric energy. For example, the investment composition for large hydroelectric projects like Itaipu, excluding the cost of interest, is skewed toward domestic inputs. About 20 per cent of a project goes for equipment, most of which is produced in Brazil by multinational and national companies, while about 80 per cent is tied to civil construction, infrastructure, engineering and administrative costs. Most of the latter expenditures are controlled by the state electric company and domestic private-sector companies. The result is a high degree of national participation, despite technological dependence, because of the equipment that is used. The situation for thermal power is completely the reverse. Equipment expenditures account for 80 percent of the investment costs, and the imported turbo-generator that is required to run the facility represents a high percentage of this value; consequently, the share of national components in the project is small.

2. The Institutional Framework of Globalization and Privatization in Latin America

[9] In the case of gas emissions, the study took into consideration the CO_2 and CH_4 emissions resulting from the decay of biomass submerged by the dams' water as compared to the burning of fossil fuels by thermoelectric plants.

The previous Brazilian model for industrial development gave a strong role to multinational companies and foreign capital in areas related to modern industry, sophisticated consumption goods, and heavy industrial manufacturing. The Brazilian market for most of these products through importation was closed, although the domestic supply was controlled by multinational companies that were producing them locally. Such companies were in many cases the ones that were associated with the construction of a national industry in Brazil. This was accomplished through joint ventures, technology transfer contracts, and technical assistance, among other methods. These multinational companies had different degrees of participation within national industries. For example, state companies were important in the infrastructure sector and had almost complete control over energy production through Petrobrás (oil), the Eletrobrás Sytem (electricity), and Nuclebrás (nuclear). However, state industries still depended on the technology controlled by the multinationals. State-owned companies normally worked closely with the Brazilian private sector and foreign multinationals operating within the country. There were some exceptions to this symbiotic relationship such as in the energy sector where the state dominated the control of technology: the use of off-shore oil drilling platforms in deep waters by Petrobrás, the design and construction of large dams and the optimal operation of a hydroelectric system, and the use of alcohol to fuel cars.

Presently, there is no longer an industrial policy to stimulate national production in selected sectors that demonstrate a comparative advantage, although Petrobrás continues to act as a successful state-owned company. A very interesting new development has been the creation, by an initiative of the Ministry of Science and Technology, of a fund to promote technology through monies provided by regulatory agencies, including those for petroleum (ANP), electric energy (ANEEL), and water (ANA). In this sense, it is an extremely opportune moment to discuss the possibilities for broadening scientific and technological collaboration as well as industrial and commercial partnerships in Brazil, especially those in the energy sector.

In Brazil, the generically termed “neoliberal” or “free market” reforms were initiated at the beginning of the 1990s and were belated when compared to the rest of Latin America, especially in relation to Chile, Mexico, and Argentina. The government that began them, under President Fernando Collor de Melo, was stopped short in its tracks by a constitutional impeachment process against him. The dismantling of state agencies aggravated the economic crisis of early 1990s, which worsened the social problems generated by the unequal development process, characterized by a very poor income distribution and the exclusion of significant swaths of the population from any of the benefits. In this sense, it has been impossible to separate economic reforms from poverty concerns in a society that is as unequal as that of Brazil. However a common error has been to ignore social issues, particularly when electric sector deregulation and privatization are considered.

Following the impeachment of Collor de Melo, his replacement, Itamar Franco, sought to stabilize the country's political course. Working with organized civil society, a program, under the leadership of the nationally-acclaimed sociologist Herbert de Souza, was launched to fight poverty and hunger while promoting job creation. Although de Souza passed away, his movement remained alive. This is most evident in the decision by the government of President Fernando Henrique Cardoso to create a similar program called "Community Solidarity" (*Comunidade Solidaria*).

Other policies such as monetary reforms were carried out through the creation of a new currency, the *real* (R$). Although overvalued with respect to the U.S. dollar (US$1.00= R$0.80), this policy permitted the successful control of inflation. Most interestingly, it allowed for the election of the government's candidate to the presidency in 1994: President Femando Henrique Cardoso. His win, and subsequent reelection in the first round, was the result of a solid center-right coalition that stuck to reformist policies. By opening up the investment and economy of Brazil to international players, the Cardoso government sought to attract foreign investment and maintain a stable currency, garnering him popular support because of the common fear that inflation might return. This was, and has been, the trump card of Cardoso’s economic policy.

Yet the decision of the Cardoso government to privatize large state enterprises—such as mining (Vale do Rio Doce), telecommunications (Telebrás), and electric companies—gave rise to an intense controversy in the country. One issue was over the lack of an effective regulatory apparatus, which is still in the making, to face the new situation. Compared with the main Latin American countries that underwent neoliberal reforms before Brazil, the Chilean economy equilibrated itself while Mexico confronted serious problems arising from its monetary crisis and Argentina remained completely unstable.[10]

Thus, if one applied the criterion for a theory to be scientifically true—devised by Karl Popper, an exponent of neoliberalism and science—in order to draw conclusions regarding the truthfulness of neliberal thought, one would find Latin America's experience with open markets does not pass the empirical test. Hence, a thoughtful reflection should look for political options that avoid the negative aspects of neoliberalism while taking advantage of its positive attributes. Privatization must be demonstrated to be beneficial or not, based upon each case and as a theorem of a theory, rather than as a theoretical postulate always true in itself without any demonstrated proof. This has been the case for the privatization of Furnas, the most important Brazilian electrical company, which is currently being discussed.

The exaggerated, anti-interventionist neoliberal policy of such privatizations currently is being reviewed by one of its most influential multilateral proponents: the World Bank. In the *World Development Report*: *The State in a Changing World* (1997), it takes note of the "important role of the State in the East Asian economic miracle" and frets at the "collapse of States" in many parts of the world.[11] The report demonstrates that "the determining factor behind such contrasts is the effectiveness of the State." Both its spirit and its message contrast starkly with the previous year's report, which dealt with the transition to the market economy. This new face of the debate has not only been in developing countries, but also in countries like the United Kingdom. Under the auspices of the Labour Party government, the reform of the energy sector was discussed, though it was done in a moderate way to preserve consolidated aspects of the conservative government's macroeconomic policy. Although everything seems to point to a dynamic British economy that is in good shape in the European context, with an unemployment rate lower than many other countries of the European Union (EU), Thatcher's ultra-liberal economic policy has been under pressure to change. According to the Country Report of the Economist Intelligence Unit (EIU), the challenge in Great Britain is to effect "social changes" by reviewing "negative aspects" such as "cuts in social spending" and by seeking to reduce the "growing distance between the rich and the poor."[12] In this sense, the rationale of the full removal of the state from the market, especially in its regulatory function in privatizations (ex-post), is under revision.

Given the above context, deregulation of the energy sector in Brazil has not come from an economic need of the country or because of pressures to improve the energy supply. Rather, it has been the result of a political decision whose goal is to adopt the international orientation of "globalization" to Latin America. While this policy usually is based on a scenario of making the region externally dependent, the direct impact of deregulation in Brazil has been the exact opposite.

3. The Deregulation of Energy in Brazil

3.1 Changes to the Oil and Natural Gas Monopoly Regime

The evolution in the dominance of oil and natural gas as the principal energy sources in Brazil must be understood in a historical as well as global perspective. Up until the beginning of the twentieth century, coal had been the principal resource used to supply energy demands. However, technological breakthroughs and changes in the availability of energy sources gradually diminished the importance of coal in favor of oil. By

[10] Mercosul—the trade bloc joining Argentina, Brazil, Paraguay, and Uruguay—has become menaced by the Free Trade Agreement of the Americas (FTAA or ALCA) which presently is a matter of intense preoccupation in Brazil.
[11] For more information on the reports finding, see: World Bank. 1997. The World Development Report: The State in a Changing World." Washington, DC: Oxford University Press.
[12] Further details on the United Kingdom's policies can be found in: The Economist Intelligence Unit. 2001. *Country Report: United Kingdom*. London, England: The Economist.

1950, the breakdown of world commercial energy sources was as follows: coal - 59%, oil - 32%, natural gas - 12%, and related primary electricity (hydroelectric and nuclear) - 2%. In 1987, after the end of the 1973 and 1979 oil shocks' acute side-effects, those figures changed to: 32%, 41%, 22%, and 5%, respectively. This switch towards oil should be understood vis-à-vis comparative fuel costs among the energy sources. By the end of the 1980s, these were as follows: coal – US$83 to US$106; oil – US$103 to US$142; and natural gas – US$76 to US$176.[13] In the oil sector, the control of world's supply by the "major" corporate players changed significantly with the advent of national oil enterprises in, for example, Latin America, such as the Mexican company Pemex, the Venezuelan firm PDVSA and the Brazilian-owned Petrobrás. The entrance of these new suppliers dramatically shifted the composition of the world oil supply controlled by the traditional companies (i.e. the "majors"). For example, in 1970, prior to the oil price shocks, such "majors" controlled 61% of the world's oil supply. That total changed to 25% in 1979, the year of the second oil price shock, and reached an all-time low of 19% in 1987, when the international price of oil collapsed and the apparent downfall of OPEC occurred. By the 1990s, the oil industry had changed but the "majors" continued to control nearly 40% of the world market, by acting in the "downstream" refining, transportation and distribution of petroleum in order to compensate for their diminished role in "upstream" processes. By the close of the last decade, a series of mergers among the biggest oil companies led as result to the creation of the three super "majors" that exist today: Exxon, BP-Amoco, and Shell.

In terms of Brazil, over the past 10 years the government has allowed, through a constitutional amendment, the private sector to assume control over certain aspects of the country's fuel sector, with a National Oil Agency (ANP) to oversee the process. Nevertheless, Petrobrás has been maintained as a state enterprise that is permitted to partner up with the "majors" in order to exploit already-known oil and natural gas reserves. To understand this current state of affairs, a retrospective look beginning with the present context is most useful.

Brazil, today, is home to the world's foremost deep-sea offshore oil exploration technology, developed domestically and with cutting-edge "know-how." It has become an example of a technology developed successfully by Brazil on its own, in conjunction with local universities collaborating with the main research center, CENPES, at the UFRJ (Federal University of Rio de Janeiro) campus, which is at the forefront of similar institutes found in developed countries. Thus, CENPES has an important contract with the state to transfer the technology it develops for deep-sea oil exploration to Petrobrás. This reinforces the idea that state-owned Petrobrás has become a business partner for both private foreign capital and multinational enterprises. The development of such oil exploration technologies and the use of strategic international partnerships have yielded fairly satisfactory results, among which one may highlight the increase in national oil production.

The notion of energy as a strategic good that is essential for the production process and well-being of the population has increased the importance of oil exploration activities in Brazil. Moreover, its generation and use have had a great impact on other matters, like the environment. Any energy policy must take into account Brazil's regional peculiarities, disparities in economic development and in power consumption, and diverse environmental conditions. The large volume of financial resources involved, the need for technological maintenance, and long-term maturity rates on investments require the state in Brazil to play a fundamental role in the planning of the sector. This will allow the establishment, from a prospective standpoint, of political directives that can use public and private funds to guarantee that the generation of energy will not become a limiting factor for the country's integrated development.

For those reasons, a constitutional reform has maintained the state's monopoly in the oil sector, although it is no longer held only by Petrobrás, which has become a vertically-integrated enterprise acting throughout the national territory. Originally, the company was responsible for the supply of derivatives and for the production of 70% of the oil consumed. It possessed a refining and transport infrastructure that allowed for the optimization of oil as well as the natural gas supply.

[13] The amounts are expressed in terms of dollars per oil ton equivalent (US$/toe) for Europe.

To evaluate the current institutional framework, it is necessary to highlight some basic aspects of the oil industry in the world, from its early days to the present: business is highly-concentrated among only a few firms; activities are integrated; there is a significant amount of entrepreneurial risk; technological development and innovation are essential for profitability; and capital-intensive activities are promoted to allow for large profit-margins. Private, national, and foreign investments in the Brazilian oil sector will only become a reality if domestic consumption prices match international ones. The existence in the sector of an integrated state-owned enterprise like Petrobrás has allowed for a price structure that rewards the firm by generating a social surplus on the basis of domestic prices that are inferior to international ones. However, though Brazilian reserves for use in the country have increased, it is known that, geologically, there will not be enough oil for export in the future. Therefore, investments in the oil and natural gas sector must aim for:

- greater autonomy in power generation through the increase in reserves and in the production of oil and natural gas;
- increasing and adapting the refining facilities in Brazil;
- improvement in the quality of its byproducts and the environment; and,
- full-use of the Brazil-Bolivia natural gas pipeline that is being opened.

The current institutional model governing the use of the state oil monopoly has allowed for the creation by Petrobrás of new branch facilities for projects to be realized in cooperation with privately-owned enterprises. These should be directed toward other sources of energy, such as natural gas, that limit the monopoly of oil in the generation of electricity. For example, natural gas can contribute to increased productivity, efficiency, and competitiveness of the industrial sector, and, also, to the preservation of the environment in urban centers and more critical industrial areas.

3. 2. The Privatization of the Electric Energy Sector

Unfortunately the deregulation of electric energy in Brazil did not yield the same results as those in the oil sector, where a large state-owned company, Petrobrás, was maintained along with the entrance of foreign competitors.[14] The privatization of the electric sector was based on the British model for deregulation (or "deverticalization") and market structures for competitive power generation and commercialization, allowing for the free entrance by competitors into the transmission and distribution of electricity. In the United Kingdom, generating and distributing enterprises have been created, with a single transmission company linking them together. The generators can sell their power supply, through the transmission network, to any area, and the distributors have access to the grid to supply the markets of other distributors.

In the case of electric power in Brazil, the approval of a new concessions law led to several distributors being privatized and a rise in the tariffs paid for service as compared to international standards. For example, presently the residential "full tariff" in Rio de Janeiro is about US$110/MWh, while in Paris it is US$70 /MWh and in many American cities it is lower than US$60/MWh. This difference can be viewed as a result of the gap that exists between returns on capital for the public and private sector. Typically, private investors aim for a return of 15% to 20% every year, while the public sector (the government and its agencies) desires something between 5% and 10%.

Apart from these returns and costs structures, it is necessary to analyze the efficiency of state-owned enterprises using some empirical evidence in order to account for the existence of administrative deficiencies in the public sector. The Brazilian electric system, while it was predominantly state-owned, had a structure that was diverse from federal and local enterprises, as well as some small private distributors. Eletrobrás served as a holding company with collegiate organs that were responsible for decisions about the expansion and operation

[14] This structure of deregulation could be used for the privatization of electrical generation companies, like Furnas, whose sale to the private sector is now being discussed.

of the hydroelectric system. This network was linked to reservoirs that were reviewed every few years, in such a way as to preserve optimization. The proposal for Electrobrás' privatization, according a study by Coopers and Lybrand Consulting, under a scenario of pure competition would result in the loss of nearly 28% of the power available today. This conclusion reflects the fact that Brazilian electric companies, on average, produce energy at a lower cost than the majority of similar companies in developed countries, as analyzed in a study completed by COPPE. The lower cost structure in Brazil is explained mainly by the country's reliance upon hydroelectric power generation, in which it has a comparative advantage.

Nevertheless, a World Bank study completed in 1992, which was entitled *Energy in Brazil*, recommended the abandonment of hydroelectricity. In the future, this could mean an additional burden, due to CO_2 emissions into the atmosphere by thermoelectric plants. The worsening of the greenhouse effect,[15] part of which is due to such gaseous emissions into the atmosphere, must be taken into account when making the decision to shift away from hydroelectric power. Brazil is more efficient than the United States in its emission of CO_2 per unit of electric energy produced since hydroelectricity avoids the combustion of coal, oil, or natural gas—all of which are needed to operate thermoelectric plants. Nevertheless, in the case of electricity, there has been a strong correlation between privatization and the substitution of thermoelectric for hydroelectric generation, since the former entails less capital and shorter return horizons on investments in the sector. There are high hopes with respect to the use of natural gas, but its share as a percentage of fuels is insufficient for it to play a large role in overall generation, even if one includes the new operation of the Brazil-Bolivia gas pipe. Also, the National Energy Balance of Brazil shows a highly renewable component among the energy matrix, which is exceptionally clean notwithstanding the use of oil and gas. Nevertheless, one still notices the practice of heavy log-burning, which is partly used in the rural countryside to inefficiently supply its energy demands.

4. Final Comments

Other trends to note in changes to the sector are related to privately-owned generators. In Brazil, the role of independent production in electric generation amounts to only a small part of the electricity generation for the nation. Therefore, independent production is an area in which the role of the private sector may be expanded, as long as conditions are favorable in comparison with buying energy from the public network. Independent producers are natural candidates for selling their energy surplus to be distributed to the public network. However, the development of independent producers will depend on incentives, since in general the enterprise must heavily invest in order to both generate independently and yield a surplus.

Whatever approach—pure competition, partial privatization, or state-ownership— is ultimately adopted for the sector, it is critical that the unique characteristics of each energy resource is recognized. One particularly should take note of the difference pointed out between Brazilian hydroelectric facilities and its thermoelectric system, which the former is considered a paradigm for competitive power generation. The environmental problems of power generation that have been discussed in the previous sections, including the issue of renewable energy sources and the problem of global atmospheric pollution due to greenhouse effect (i.e. the heating up of the planet from fossil fuel emissions by the burning of coal, oil, and natural gas), must be incorporated into any debate. For example, the use of natural gas, which has been encouraged by the privatization of the Brazilian energy sector, has been compared to other energy sources for electricity generation. In terms of the expectations for future privatizations, the conclusions at this point are that in Brazil, the state, which has intervened heavily in the electric energy sector, now is promoting its privatization. However, according to the concrete results cited in this paper, the privatization of the electric energy sector in Brazil cannot be considered beneficial, based on the prices for the final customer, the quality of the service, and the inability of the system to expand electricity generation enough to meet increases in demand.

[15] The "greenhouse effect" is a condition that is characterized by the heating up of the Earth's atmosphere as a result of the imbalance between the Sun's radiation of luminous energy and the Earth's thermal radiation back out into space.

Brazil's Cogeneration Regulatory Framework:
In the Light of International Experience

Mauricio Tiomno Tolmasquim[16] and Alexandre Salem Szklo[17]

1. Introduction

This article analyzes the impact that changes to the regulatory structures have had on the development of cogeneration in Brazil. It outlines the basic principles guiding Brazil's energy policy and how their design has promoted the creation of cogeneration systems. Particular stress is placed on the influence of Brazil's legal framework on the expansion of these systems in both quantitative (i.e. the size of the plants) and qualitative (i.e. the technology used and operating schemes applied) terms.

Before embarking on the present study, it is necessary to specify what exactly is meant by cogeneration. Cogeneration is the simultaneous generation of two or more forms of energy from a single source. Compared to conventional thermo-power generation, it ensures the lowest energy consumption and reduces atmospheric emissions (for instance, those responsible for contributing to global climate changes). In addition, cogeneration plants could serve electricity markets by lowering the level of investments required for the transmission and distribution grids, as well as for the overall networks, and with lower rates of energy loss during transmission (Poole et al. 1995; Szklo et al., 2000). As a distributed power generation option, cogeneration also may allow the postponement of high-volume investments that normally are required for expanding a centralized power generation's capacity (Hoff et al. 1996).

However, these three reasons—primary energy conservation, less atmospheric emissions, and a low-cost alternative to centralized power capacity expansion—have not encouraged investments in cogeneration systems in Brazil in the past. Although Brazil's total cogeneration potential hovers between 11 and 17 GW (Hollanda and Fyodorova 2000), while its technical potential for industrial cogeneration was estimated at 12,499 MW (Eletrobrás 1999) in 1998, the installed capacity of the country's cogeneration systems by 2000 did not exceed two GW (Costa 2000). As has been discussed by Szklo and Tolmasquim (2001), four long-standing barriers explain this discrepancy:

- First, the massive bias towards hydroelectric power in Brazil's energy generation matrix had shaped a centralized generation system based on hydroelectric and thermal power. Thermo-power plants operated merely to supplement the main system for only a few hours a year. Due to the availability and low cost of hydroelectric power in Brazil, cogeneration historically had been adopted almost exclusively by industrial segments that recycled their energy wastes in order to generate additional electricity. For instance, in 1998 almost 65% of the installed capacity for Brazil's industrial cogeneration was utilized by distilleries and pulp and paper mills, which processed the by-products of sugar-cane bagasse and black liquor, respectively, to generate power.
- Second, Brazil's power sector model lacked clearly-defined mechanisms that would have allowed cogeneration ventures to transfer their energy through the power grid. This meant that such investments simultaneously were exposed to excessively high reserve power rates and encountered considerable barriers which hampered the smooth flow of their surplus energy to the market. These issues are particularly important for selecting the best technology and operating scheme for cogeneration systems. As shown by the examples of the U.S. (Khrushch et al. 1999; Kolanowski 1999; Zarnikau and Reilley 1996), the Netherlands (IEA 1999; Slingerland 1997; Blok 1993), and more recently France (Batail 1997; Chenard 1998), the possibility of trading surplus electricity can encourage investments in added capacity for cogeneration systems, while redirecting these investments

[16] Energy Planning Program, Graduate School of Engineering, Rio de Janeiro Federal University, Brazil.
[17] Energy Planning Program, Graduate School of Engineering, Rio de Janeiro Federal University, Brazil.

to certain commercial and industrial segments that have long rebuffed any type of combined heat-and-power generation.

- Third, low electricity prices in Brazil discouraged investments in cogeneration until the mid-1990s. Depressed rates resulted in very low remuneration and poor returns on capital for the power sector. Such policies formed part of the inflation-curbing stance of the Brazilian government during the 1980s.[18]
- Fourth, and finally, supplies of natural gas in Brazil were relatively limited until the late 1990s. In 1998, the demand for natural gas in terms of its share of Brazil's primary energy sources did not exceed 3%. However, as the technological development of cogeneration facilities increasingly focused on systems fueled by natural gas, its limited supply hobbled the use of cogeneration systems in Brazil.

In addition to these four long-standing barriers undermining Brazil's cogeneration potential, it is also worthwhile noting that the country responded to the oil price shocks of the 1970s in a manner different from many other nations. In contrast to the United States (Rose and McDonald 1991), Denmark (Hamar 1999) and the Netherlands (Slingerland 1997), which invested heavily in combined heat-and-power generation systems after the oil crises,[19] Brazil opted to focus upon increasing oil production (offshore), expanding hydroelectric power facilities, promoting nuclear thermal power generation, and establishing its “Fuel Alcohol Incentive Program.” Although this last program may well have had an indirect effect on the expansion of bagasse-fired-power generation facilities, it cannot be said that cogeneration historically has constituted a national energy conservation strategy for Brazil (Szklo and Tolmasquim 2001).

However, this historical context now is changing drastically, triggered basically by the restructuring of Brazil's energy sector. These changes have paralleled the expansion of supplies of natural gas and have occurred simultaneously with the crisis which assailed Brazil's power system.

First of all, the deregulation of Brazil's electricity market, through the introduction of consumers’ free election of distributors and open access for private companies to the transmission grid, dramatically has altered the prospects for cogeneration in this market.[20] It removes the monopolistic barriers to bilateral energy sales between cogeneration plants and the market and also introduces new agents such as energy retailers into the mix that can participate in the energy market, finding niches for cogeneration investments. Furthermore, within this new context, cogeneration systems can also constitute a strategy to bridge the gap between energy suppliers and the market (Szklo and Tolmasquim 2001). However, it should be stressed that like all transition phases the future is still cloudy. As this article will discuss, the lack of a specific energy policy designed to encourage cogeneration in Brazil may lead to a situation where market forces introduce elements of risk for investors in power generation, while not necessarily guaranteeing a better use of the country’s cogeneration potential.

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[18] In a paradoxical way, relatively low electric rates over the past two decades have hampered investments in cogeneration in Brazil, but they have also fettered the investment capacity of Brazil’s entire power sector and, consequently, have enhanced the appeal of cogeneration plants. While a negative factor in the short-term, this historical barrier has provided justification for inducing fresh investments into cogeneration facilities over the medium-term in an attempt to avoid power shortages (Szklo 2001).

[19] In the U.S., for instance, cogeneration developed notably after the Purpa Act (established in 1978), against a backdrop where combined heat-and-power facilities were treated as alternatives for promoting primary energy conservation and enhancing competition in power generation. In general terms, the Purpa Act guaranteed the economic feasibility of cogeneration systems, increasing revenues through the sale of surplus power while lowering investment risks (Rose and McDonald 1991).

[20] Brazil's power sector is currently passing through a transition phase, moving from a fully-bundled and monopolistic structure run by state-owned utilities to an unbundled structure based on competition for power generation and the retailing segments, which are run by private power utilities.

With regard to natural gas supplies in Brazil, by the late 1990s, the country's natural gas supplies had increased appreciably, boosted by the Bolivia-Brazil Gas Pipeline coming onstream. In 1999, supplies reached 32.6 Mm^3/day—including 1.1 Mm^3/day imported in the course of the year (ANP 2000). In addition, authorization was granted to import some 69 Mm^3/day of natural gas from Argentina and Bolivia. While uncertainty still prevails over the evolution of the relative prices for energy, the Brazilian gas distribution network remains incipient. It has been somewhat difficult to harmonize the gas supply contract's "take-or-pay" clause with the optimization of the Brazilian electric system, the increased supplies of natural gas, and the recent technological development of gas-fired power generation systems. The last development, particularly for combustion turbine component material (Viswanathan et al. 2000), should open up new horizons for cogeneration in Brazil.

A similar argument has been strengthened by the current elevated risk of a power shortage.[21] In fact, the prospects of an energy crisis in Brazil highlight other logical reasons for introducing cogeneration systems over the short term. These systems represent: (**1**) a rapid option for expanding power generation facilities; (**2**) an instrument for sharpening the competitive edge of industry; (**3**) a mechanism for attracting private capital investments to power generation; (**4**) a method for boosting the reliability of Brazil's power system, and finally (**5**) a type of protection for energy consumers against power outages and rationing.[22]

Furthermore, the steady natural gas consumption required for a cogeneration plant—assuming it is operating with an almost uniform thermal load—is one of its additional advantages when compared to conventional thermo-power plants and particularly when the gas supply contracts include "take-or-pay" clauses. As a matter of fact, some cogeneration plants can ensure regular gas consumption throughout the year, regardless of the availability of surplus electricity from hydroelectric power plants in the rainy season (Szklo 2001).

However, it is not sufficient merely to enumerate these promising prospects of cogeneration systems for Brazil's power sector. New issues are arising, including the intricate nature of the regulatory process, uncertainties over the transition stage, the complexity of power transactions, and difficulties in disseminating information on a liberalized electricity market. While investments still may be channeled to cogeneration systems in Brazil, despite the lack of a specific energy policy supporting these ventures, it is worthwhile to identify the links between official policies and the qualitative and quantitative expansion of combined heat-and-power generation in the country.

2. General Concepts: Energy Policy and Market Barriers

The development of cogeneration systems in any country is directly linked to its regulatory environment. In most countries where cogeneration's installed capacity has expanded significantly, institutional mechanisms have constituted a significant leverage factor for its growth (Nogueira and Santos 1995). In fact, the experiences of countries such as France and the United Kingdom show that neither the high energy efficiency of the cogeneration systems nor the cost reductions of the cogenerator

[21] It is important to note that this working paper was written prior to the energy shortages of May 2001 which gripped many regions of the country (namely the Northeast, Center-West, and Southeast). Energy consumers, individuals and firms alike, were forced to cut usage by between 15-25% to avoid rolling blackouts, in what was termed "o apagão," until March 2002 when all energy rationing was discontinued. For additional information see: http://www.eia.doe.gov/oiaf/ieo/brazilboxtxt.html

[22] The high concentration of energy-intensive industrial segments in Brazil confirms the trend towards such sectors investing in cogeneration, provided that there is assumed to be a real risk of electricity rationing, with a consequent increase in rates (Mello 1995). For instance, Soares et al. (2001) showed that the internal rate of return for Brazilian industrial cogeneration plants rises appreciably if the avoided revenue losses that would have been caused by possible power shortages are included in the economic balance of the cogeneration venture.

firms are able to guarantee investments in combined heat-and-power ventures (Szklo 2001).[23] In most cases, for these ventures to occur,[24] an energy policy has been required to underpin the mechanisms that can lift market barriers and to enumerate the benefits of cogeneration for the market. Disregarding the existence of investments in heat-and-power generation systems without any specific and supportive energy policy, such a policy should aim to:

1. Foster the expansion of cogeneration in segments where investments are not occurring spontaneously either because the benefits of cogeneration are not well perceived or properly appraised, investors are unwilling to channel funds to a sector outside their core activities, or there are market barriers to this investment.
2. Encourage the expansion of, and conversion to, more efficient cogeneration systems in order to achieve high fuel savings. This was one of the guidelines of Denmark's energy policy during the 1980s and 1990s (Danish Energy Agency 1998) and also was incorporated into French energy policy in the late 1990s. In the case of France, a system of buy-back rates awards bonuses to cogeneration plants according to their power generation efficiency levels (Batail 1997).
3. Encourage rapid expansion of the installed capacity for cogeneration systems. For instance, incentives designed to encourage the sale of cogenerated surplus power accelerated the expansion of cogeneration capacity in the U.S. during the early 1980s (Rose and McDonald 1991). This was also the case in the Netherlands during the early 1990s (IEA 1999) and France at the end of this decade (ADEME 1999). In the Netherlands, the 1989 Electricity Act obliged power generation and distribution utilities to purchase surplus electricity produced by new cogeneration plants at the avoided production cost, in order to enhance the competitive edge of the Dutch power generation segment (Blok 1993). In France, Law 2000-108 (February 2000) stipulated that cogeneration plants with a capacity of up to 12 MW would benefit from mandatory purchases of their surplus power, provided that they complied with technical availability criteria and were unable to sign contracts with free consumers under satisfactory conditions (Szklo 2001).[25]
4. Promote the consumption of certain fuels over others, due to either environmental reasons or for issues of a technical and economic nature (such as the availability of energy resources). This has been the type of policy pursued in both the Netherlands and Denmark. These countries specifically encouraged cogeneration systems fired by natural gas or renewable fuels (IEA 1999). For example, from 1992 through to the end of the decade, small Danish cogeneration plants received an additional fee for electricity sold to the grid, provided that this was generated from natural gas or renewable energy sources (Danish Energy Agency 1998).

In general, in order to achieve these targets, a specific cogeneration energy policy should include regulations related to the following areas:

- *Definition of cogeneration*: what are the approval procedures for cogeneration projects (through notification, authorization, or concession) and their *modus operandi* (interconnected or not-interconnected);
- *Transmission of cogenerated electricity*: whether open access to the power transmission grids and distribution networks is established, and what are the responsibilities of the cogeneration venture;

[23] In the case of the United Kingdom, installed cogeneration capacity fails to top four GW, while the economic potential for cogeneration is estimated at 10 to 17 GW. In France, although the economic potential of cogeneration is estimated at five to 10 GW, not including district heating systems (Ceren and Erdyn 1996), installed cogeneration capacity has reached only some 1.3 GW (1998; ADEME 1999).
[24] The case of Finland is an exception to this rule, due to the long tradition of using combined heat and power (CHP) in Finnish industry, which is extremely energy-intensive (Mez and Piening 1999).
[25] A decree issued by the French Government establishes the ceiling capacities for facilities eligible to benefit from mandatory purchases at up to a maximum of 12 MW, by system category and region. These limits are reviewed periodically, keeping pace with market deregulation (*Journal Officie* 2000).

- *Incentives for cogeneration ventures*: whether such benefits cover all cogeneration ventures or only qualified ones, and which types of incentives should be introduced;
- *Qualification of cogeneration ventures*: what is the qualification criteria;[26]
- *Selling off surplus cogenerated power*: who are the consumers that the surplus power can be sold, should it be mandatory for power utilities to acquire it, and which type of buy-back rate would be most appropriate, an administratively-fixed or a freely-negotiated one;
- *Purchase of back-up:* how should back-up power be valued in order to avoid not only unfair and adverse impacts on the power utility but also the imposition of unfavorable conditions on the cogeneration venture;
- *Valuation of the fuel consumed by the cogeneration plant:* should the fuel price paid by the cogeneration venture be regulated and if it is regulated, what characteristics of the cogeneration plant should be stipulated for an incentive policy based on the fuel price.

Furthermore, these regulations should be grounded in the targets established by the energy policy and be designed specifically for promoting the development of a cogeneration system. An important aspect that should be covered by this policy involves market barriers to cogeneration. With widely varying origins, these barriers may either multiply or decrease as power markets are deregulated.[27] Such an aspect is implicit in the results of the recent survey carried out by Tolmasquim et al. (1999) among Brazilian entrepreneurs which indicated that six main economic barriers have hampered the implementation of industrial natural gas-fired cogeneration plants (see Table 1).

In addition to the barriers that have been analyzed in this paper, it is also worth mentioning the problem of the costs associated with connecting a cogenerator to the distribution grid of the country. For cogeneration ventures outside urban zones, these can be so high that it may well undermine the feasibility of the entire project (Sorge 1998). Finally, the lack of information among interested cogenerator investors on the benefits of such systems and the failure to properly appraise these advantages also hamper the wider use of Brazil's potential (Szklo 2001).

Consequently, faced with the current transitory context of Brazil's power sector, as has been characterized by the market barriers blocking cogeneration, the government is directly and indirectly responsible for shaping the manner in which energy is generated vis-à-vis the prevailing regulatory environment.

3. Brazilian Institutional Aspects Related to Cogeneration

Recently passed regulations in Brazil cover not only authorizations and qualifications for cogeneration plants, but also include the retailing of the power that they produce, purchases of back-up power, and the transmission of cogenerated power.

In regards to these institutional aspects, it is first important to stress that, as is quite usual in any transition phase, there is still much uncertainty clouding the future of the energy market in Brazil. There

[26] The determination of qualified facilities is justified when incentives are not going to be given to all cogenerators within a country. Additionally, the qualification of a cogenerator is an attempt to distinguish such a facility from an independent power producer that does not cogenerate electricity.
[27] It is often thought that market barriers to cogeneration can be superceded by deregulating the electricity market. Although this is true for some barriers, particularly those involving access to the transmission grid and the retailing surplus electricity, this may not be true for other types. These include the clout of the regulator in terms of controlling the market and the level to which utilities are concentrated in these markets. In some cases, market deregulation may even prove extremely negative for alternative power generation technologies. For instance, if competition leads to lower energy prices, due to the market bargaining power of the energy suppliers, combined heat and power (CHP) will be negatively affected because the incentives for conservation will decline (Karamanos 1998).

are many loopholes in Brazilian laws regulating cogeneration. In fact, there is no specific energy policy in Brazil designed to foster cogeneration based on any type of clearly defined expansion targets. Nevertheless, a series of regulations already have been issued on cogeneration activities and the Brazilian Government has explicitly recognized that "cogeneration activities foster the rational energy use…" and it is worthwhile "… implementing incentive policies encouraging the rational use of the nation's energy resources" (Public Hearing 004/1999).

Table 1: Economic Barriers to Brazilian Industrial Cogeneration

Barriers	Comments
(1) Back-up rates	✓ As these rates are high, not only do they fail to encourage potential industrial cogenerators to invest in combined heat-and-power (CHP) plants, but also they prevent incentives for them to host cogeneration plants owned by power distribution utilities.
(2) Retailing cogeneration electricity	✓ Smaller cogeneration utilities find it hard to sign long-term contracts, absorb power retailing costs, and look for buyers for their electricity, and are often forced into unfavorable short-term contracts (if they even manage to sign them).
(3) Electricity rates	✓ A possible cut in electricity rates for the potential cogenerator is one of the main strategies employed by the power utilities in order to discourage the arrival of competitors in the system.
(4) End-price of natural gas	✓ The indexation of the natural gas prices that are parallel to rigid supply contracts results in a price gap between the revenues brought in through cogenerated electricity (quoted in Brazilian currency) and the costs incurred for gas consumption (quoted in U.S. dollars, US$).
(5) Financing	✓ According to Brazilian entrepreneurs, financing is available under unfavorable conditions, due to highly volatile interest rates in the Brazilian economy.
(6) Equipment prices in U.S. dollars	✓ The alternative of bringing in foreign funding through international private banks means accepting uncertain floating foreign exchange rates, thus boosting investor risk.(1)

Notes: (1) For instance, the devaluation of the *real* in Brazil since early March 1999 has undermined the feasibility of cogeneration schemes, particularly smaller projects (Costa 2000).
Source: Tolmasquim et al. 1999.

Given that the stated purpose of Brazil's energy policy is "to protect the environment and foster energy conservation … while expanding the use of natural gas on economic bases," (Law 9,478/1997) it may well be expected that some specific incentive mechanisms for cogeneration will be established in the near future. However, it still remains to be seen whether these incentives will be sufficient and based on clearly defined measures with regularly-reviewed targets.

3.1 The Definition and Authorization of Cogeneration Ventures

In terms of the authorization of cogeneration ventures, recent Brazilian regulations have stipulated that independent, as well as self-production power production projects (over 5,000 kW), now only require the government's permission to start up operations (Resolution 112/1999). The measure is in sharp contrast to the laws governing public utility thermo-power plants (over 5,000 kW), whose initiation depends on concessions (Law 8,987/1995). This decision has streamlined the implementation process for medium and large-sized cogeneration plants, while reducing the initial project costs.[28]

Although Brazilian legislation has defined and qualified cogeneration activities, as this article will discuss later, it explicitly has not yet identified the legal definition of a cogenerator agent. In Brazil, depending on the manner in which power is retailed, the cogenerator may act as an independent power producer (IPP) or as a self-producer. The self-producer "is an individual or corporate legal entity, or companies grouped into a consortium, that are awarded a concession or authorization to produce electricity for their own use." Meanwhile, the IPP "is a corporate legal entity or companies grouped together in consortia that are awarded concessions or authorizations to produce electricity and sell it (total or partially), at their own account and risk" (Decree 2003/1996).

Therefore, for self-producing cogenerators, the sale of surplus electricity must be occasional and temporary. Up until 1998, self-producers could sell their surplus electricity only to power utilities, sharply curtailing the possibilities of marketing their surpluses. The transaction capacities of self-producers finally were extended in 1998 to allow for the occasional and temporary sale of surplus electricity to third parties, as authorized by the regulatory agency, ANEEL (Agência Nacional de Energia Eléctrica).

Generally, self-producing cogenerators scale their power generation to match what their own consumption demands are. Since their surplus electricity is sold only sporadically, self-producing generators are recommended not to sign long-term contracts with power retailers, consumers, and distributors, but rather to trade their surplus electricity on the spot market. Therefore, the following operating logic schemes are applicable for them (Szklo and Tolmasquim 2001):

1. In general, if the company "hosting" the cogeneration plant (i.e. the company requiring energy) is the same as the company that operates and invests in it (i.e. the company selling energy), the facility is intended mainly to minimize costs for this company.
2. If the company owning and operating the cogeneration plant (i.e. the company selling energy) is not the same as who is "hosting" it (i.e. the company requiring energy), the self-production plant may try to achieve some strategic targets of the supplier company. Such a strategy may not necessarily minimize the costs for the company demanding energy. These targets may include the upgrading of the quality of the electricity supplied.
3. Given the modulation capacity of some cogeneration technologies, the self-producer may manage its power generation facilities such that it temporarily maximizes its gains from short-term differences between the power that is supplied and demanded. This relatively subtle strategy could be adopted by some Brazilian cogeneration ventures. They could purchase energy on the spot market at low prices when hydroelectric energy is highly available in the system and then sell their surpluses on this market when spot prices peak.
4. Finally, with prior authorization from ANEEL, self-producers may swap energy in economically equivalent amounts, clearly stipulating the costs of the transmission transactions involved, in order to allow consumption by industrial facilities located at places other than that where generation takes place.

On the other hand, when acting as an IPP, a cogenerator is able to sell its electricity to the system on an ongoing basis. It can retail bulk power or electricity to: i.) a publicly-owned power utility; ii.) free consumers; iii.) consumers belonging to an industrial or commercial complex where it supplies thermal

[28] For thermo-power plants with a rated capacity of 5,000 kW or less—whether cogeneration or not—the process is even simpler, with registration requiring only a notification to be forwarded to the regulatory agency (Decree 2003/1996).

energy deriving from the cogeneration process; and, iv.) any consumer that demonstrates to the regulatory agency its power requests, as established by a freely-negotiated contract (when the consumer is "free") or by the regulatory agency (when the consumer is "not free"), have not been met by the utility for a period of 180 days.

Thus, the new context of Brazil's power sector has allowed independent power cogenerators to sign long-term (or bilateral) contracts with their consumers. These agreements reduce the risks associated with investing in cogeneration plants, as the rates for energy sales are independent of the spot market.[29] Also, depending on the sales rates that are fixed through free negotiations, the cogeneration plant may assign top priority to maximizing the net revenues of the independent power producer, rather than minimizing its costs, as has been generally the case for a self-producing cogenerator (Szklo and Tolmasquim 2001).

It is also worthwhile to stress that ANEEL has not issued a formula for how to calculate the buy-back rate. Currently, this rate is *"freely negotiated"* between the cogenerator and the purchaser of the surplus electricity (Law 9,648/1998). Therefore, there may be a market trend to undervalue the benefits of cogeneration. As shown by Busch and Eto (1996), the market tends to evaluate the energy and output power transacted by cogenerators in the short-term, failing to recognize the benefits of the "avoided capacity expansion" prompted by the arrival of new generators into the electric system. Consequently, this trend to undervalue buy-back rates may undermine Brazil's economic cogeneration potential, channeling investments over the short-term to larger-scale cogeneration projects, despite the existence of appreciable technical potential for smaller-scale facilities in the country (Tolmasquim et al. 2001; Lenssen 2000). In general, the energy produced by larger-scale projects is better valued by the market, due to both its higher quality and the bargaining power of bigger cogenerators. Meanwhile, smaller-scale cogenerators find it hard to harmonize a continuous and stable management of their facilities' financial flows because of the dispatch rules that presently guide Brazil's electricity system (Eletrobrás 1999).

The last point to mention is that the new regulatory context in Brazil has made the legal framework of the utmost importance for the authorization of cogeneration projects undertaken by third parties, whether these are equipment companies, retail agents, or even energy utilities. In this regard, project-financing schemes can become a feasible option, given that:

> "the independent power producer and the self-producer may transfer the concession or authorization rights, which include, among others, the electricity to be produced and the revenues deriving from the purchase and sale contracts, as well as the goods and facilities used for production purposes, providing guarantees for [financing] obtained in order to fund the works and services" (Decree 2,003/1996).

3.2 The Qualifications for Cogeneration Plants

Upon looking at the qualifications for cogenerators in Brazil, Brazilian law was designed in principle to offer incentives to high-quality cogenerators to make their surplus electricity available over the short-term. According to Resolution 021/2000, cogeneration plants should comply with the following technical and legal requirements:

i.) Be legally registered with the National Electricity Agency (ANEEL)

ii.) Meet "the minimum requirements for rational energy use through compliance with the following" calculations:

$$\mathbf{Et \geq 0.15\ Ec}$$

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[29] There is some wariness about the volatility of spot market prices for electricity, prompted by the overwhelming weight of hydroelectric-power in Brazil's generation matrix, since these prices are determined largely by the availability of energy from such plants (Szklo and Tolmasquim 2001).

$$\frac{\mathbf{Ee + Et/X}}{\mathbf{Ec}} \geq \mathbf{Fc}$$

Where:
Ec = energy made available from fuel or fuels over the past twelve months;
Ee = electrical-mechanical energy resulting from the sum of the work and the electricity generated over the past twelve months;
Et = thermo-power used, provided by the cogeneration plant and resulting from the sum of the heat effectively consumed over the past twelve months;
Fc = cogeneration factor;
X = weighting factor.

As noted, the first requirement for a cogenerator to qualify is quite reasonable, prompted by the condition for having its projects approved. The second requirement is based on two sets of differentiation criteria:

- First, a qualified facility should really be a cogeneration plant, meaning that it should generate a minimum amount of thermal energy (in this case, 15% of the fuel energy entering the cogeneration plant). This is an interesting aspect for qualification, preserving the status of the beneficiary cogenerator and distinguishing it from IPP. As shown before, this distinction currently is not included in the Brazilian legislation covering the authorization of cogenerators. The justification for this first distinction lies in the core advantage of cogeneration over independent power production by thermo-power plants: fuel savings.
- This outcome leads to the second differentiation criterion that is applied among cogenerators. The group is divided into those who actually ensure the desired fuel savings —and consequently warrant qualification—and those who fall below the required level. According to these criteria, a minimum level of energy efficiency is required in order for the cogenerator to qualify. The qualification formula is based on the concept of Fuel Savings Rate (FSR), which is defined as the percentage of fuel savings due to the cogeneration system compared to independent heat and power generation schemes. For cogeneration that is based on fossil fuel consumption, the minimum acceptable FSR is 15%, while for biomass materials it is 5%.

Consequently, cogenerators that meet these qualifications should allow for more efficient systems and lead to the conversion of less efficient systems into more effective options, provided that these producers are compensated for their additional investments. As greater electricity efficiency and a higher power-to-heat ratio for cogeneration plants occur, it will mean that the properly qualified cogenerators are supplying the surplus energy. However, it is extremely important for these producers that the purchase mechanisms for their services be correctly defined. In other words, merely qualifying cogenerators according to high efficiency benchmarks is not enough to ensure that they will produce surplus power. If they have no way of disposing of their output, they most likely will be faced with two possibilities:

1. The first is to continue the tendency of not having the regulatory agency as a direct actor in surplus power sales. In this case, the lack of other significant incentives could possibly lead to qualifying only existing cogenerators (within the system), regardless of what has been awarded or any other qualifications. As noted, this undermines the purpose of such qualifications.
2. The second is a drastic shift in the trend noted above. This has occurred in countries such as the U.S., the Netherlands, and more recently France (Szklo 2001). In these countries, the government has ordered that part or all of the energy made available by the qualified cogenerator mandatorily be acquired by the utilities during a specified amount of time, should no purchaser appear on the market that is willing to pay a fair and reasonable price. However, a similar stipulation in Brazil, as defined by Resolution 021/2000, has been insufficient. It places no limits on the size of the cogeneration

plant, which would avoid possible opportunistic expansion, nor does it stipulate any reliability criteria for the energy sold by the qualified cogenerator.[30] On these aspects, recent French legislation introducing cogeneration incentives is exemplary. First, the qualification of French cogeneration plants depends on their size (with a ceiling of 12 MW) based on the logic that smaller-capacity cogeneration plants cannot allocate the necessary investments without government incentives and consequently warrant a specific support policy.[31] Second, the qualification for French cogeneration plants depends on the reliability of their power that is supplied, such that 95% must be produced in winter, from November 1–March 31 (*Journal Officiel* 2000).

In fact, as already has been noted in this article, the current situation of cogenerators in the Brazilian market is best described by their tendency to have freely negotiated energy transactions through long-term contracts. In principle, the prices and quantities transacted should depend on the reliability of the energy that is supplied by the cogenerator. This leads to the assumption that this reliability should already be implicit in the long-term contracts signed between cogenerators and purchasers. What cannot be assumed is that the price paid to the cogenerator will compensate its costs and encourage it to seek qualification. Consequently, free negotiations may prove insufficient to stimulate potential cogenerators to meet the qualifications. Moreover, the definition used for surplus power purchase mechanisms by qualified cogenerators requires that a quality criterion be expressly stipulated for their energy, which in contrast to other countries like France Brazilian law still does not cover.

In addition, and in contrast to the U.S., the qualification requirements for Brazilian cogeneration plants do not impose constraints over their ownership. After the Purpa Act, in order for a cogeneration plant in the U.S. to be rated as a qualifying facility and to benefit from incentive measures, utilities could not hold more than 50% of its shares (FERC 1999). As noted, such a requirement curtails incentives for plants controlled by power utilities, resulting in advantages and disadvantages for the development of cogeneration systems:

- Initially, non-qualifying cogeneration facilities controlled by power utilities ensure the arrival of fresh competitors to the system, including small-scale cogenerators, which had been one of the main objectives of the Purpa Act in the U.S. (Fox-Penner 1990). This stipulation also assures greater transparency in the commercial relationships between qualified cogenerators and utilities, avoiding that the latter benefits from the incentives awarded to qualified plants or skews market prices.
- The downside is that this measure discourages the possibility of future investments by power utilities in cogeneration ventures. While this stipulation in the U.S. is still aligned with one of the targets of the Purpa Act, to pave the way for the arrival of new competitors to the system, it has produced ambiguous results in terms of another of its objectives: to encourage power conservation. In this sense, it is not who is the owner of the cogeneration plant that is important, but rather what are the benefits offered to the power system vis-à-vis energy efficiency.

All these considerations are important for including as possible targets for cogeneration systems in Brazil.[32] The qualifying of a cogenerator is not an end point in itself, but rather a way of helping

[30] Opportunistic cogeneration is the phrase coined by Batail (1997) for U.S. CHP plants (which could also be applied to Dutch plants with similar characteristics) that profit from the benefit of mandatory purchases of surplus electricity at high rates, for operating only as independent power producers. In some parts of the United States and the Netherlands, this resulted in an over-installed capacity during the first half of the 1990s (Slingerland 1997; Kolanowski 1999).

[31] In other words, this logic assumes that large-scale cogenerators in France are better-equipped to obtain advantages and contract conditions for their power supplies. They would already be leaning towards cogeneration as the European energy markets opens up, thus not requiring any specific incentive mechanisms.

[32] Along general lines, the following should be defined: (1) what are the capacity and the specific characteristics of the cogeneration systems that will be given incentives in Brazil; (2) whether the objective is to provide incentives only for systems that are potentially feasible in economic terms; (3) whether the goal is also to determine the

implement clearly-outlined incentive policies. These policies should address potential cogenerators that either have not allocated investments or have done so in an ineffective way due to the lack of institutional incentives. Otherwise, the qualifications that currently have been adopted in Brazil may prove inaccurate or even trigger negative results for the power system as a whole.

For instance, the Purpa Act in the U.S. necessarily has not produced results that always have been positive, although over the past two decades it has encouraged the implementation of small and medium cogeneration systems. In certain U.S. states, particularly New York and California, the buy-back rates for long-term contracts were so high that they over-remunerated cogeneration facilities (Zweifel and Beck 1987). This penalized the utilities, which were forced to deal with qualified cogenerators as a *stranded cost* once the power market was deregulated and to complete the so-called "buy-out" of certain cogenerators (Zarnikau and Reilley 1996).[33] Furthermore, the mandatory purchase of this surplus power, with no stringent qualification criteria defined, meant that utilities with generous reserve margins were exposed to surplus installed capacity (Kolanwski 1999).

Consequently, there are some valuable lessons that can be applied to Brazil. First, it is worthwhile to stress the importance of having qualifications for cogenerators included into Brazilian law. Second, it should be recognized that these changes should be followed by other resolutions introducing incentives for applicable cogenerators. Third, it is necessary to emphasize that without the inclusion of targets for qualified cogeneration plants and systematized energy policy guidelines prior to the introduction of the qualifications, they will become merely a poorly-deployed energy policy tool.

3.3 Shipment and Connections

Another significant market barrier that has blocked the development of cogeneration in Brazil is access to the country's power transmission grids and distribution networks. Among the policy areas listed in this article, this is the aspect that best has been advanced under current Brazilian law.

The rights granted to Brazil's IPPs and self-producers assure that these two groups have open access to the country's transmission grids and distribution networks. Three resolutions issued by ANEEL—namely 281/1999, 282/1999, and 286/1999—allocate the duties and responsibilities of each power transmission and distribution agent, explain the rules for transmitting cogenerated power, and stipulate the charges to be paid by the cogenerator. Following these guidelines, it is the responsibility of the cogenerator to reimburse the costs of the services rendered by the grids and networks, including the expenses incurred by the project, as well as construction work, equipment, metering, operation, and maintenance of the connection points (Table 2).

The technical aspects of linking the cogenerator to the power transmission grids and distribution networks are beyond the scope of this article. However, it is worthwhile noting that the process requires mutual commitments that involve the establishment of technical and commercial conditions between the two interconnecting systems. Parallel operating instructions for the cogenerator and the distribution/transmission system should form part of the technical documentation attached to the connection contracts, including specific guidelines tailored to the nature of each energy swap. Furthermore, the cogenerator also should be responsible for installing adequate protective devices within its generators to promptly switch off or block operations whenever any disturbance occurs in the power system or at its own facility. This would be in addition to the accurate synchronization of its generators with those of the power utility's system.

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feasibility of systems that are technically possible; and finally, (4) what is the review period for the targets established.

[33] A capacity buy-out consists of two basic types of behavior: the first is characterized by utility purchases of new capacity to be installed by cogenerators; and the second is based on when the utility cuts the rates applied to existing or potential cogenerators.

3.4 Retailing Surplus Power

The main distinction between cogenerators as IPPs and self-producers lies in the way they retail their surplus electricity. Consequently, the expansion of cogeneration in Brazil by quantity (installed capacity) and quality (type of system installed) depends directly on the manner in which the nation's power sector is restructured. This restructuring has introduced a new institutional model for power retailing, culminating in the establishment of the Wholesale Energy Market (WEM) in 1998.

Another benchmark factor in this process has been the introduction of "free consumers," which has shrunk the captive segment of the electricity market. Under this new context, there are two ways of purchasing electricity; it either can be done on the spot market through the WEM or through long-term bilateral contracts.[34] Consumers that do not participate on the WEM are known as "captive consumers" and are still supplied by distribution concessionaires whose rates are controlled by ANEEL. It should be stressed that there will be a transition phase for the introduction of the WEM in Brazil. The initial power supply contracts signed by utilities and consumers will remain effective, although their share of the market will be reduced by 25% a year from 2003 onwards. Consequently, after 2007, the market should be virtually unregulated, other than the hydroelectric power generated by Itaipu and Brazil's nuclear power complex. Nevertheless, due to the specific characteristics of Brazil's power sector (generation) and its high level of coordination, it is expected that the spot market will account for only 15% of the total energy produced and retailed by the end of this transition phase (Vinhaes and de Santana 1999).[35]

Table 2: Duties and Responsibilities - Power Transmission and Its District Agents

Agent	Basic Duties and Responsibilities
National System Operator	✓ Should be involved in the coordination and control of power transmission operations in the interconnected systems and administer such services for the network's basic grid.
Power Transmission Utilities	✓ Should provide information to interested parties and foster commercial relationships with users by negotiating connection contracts with them, at times with the intervention of the National System Operator (NSO). Should also supply the NSO with monthly reports on the quantities metered for users connected directly to its transmission facilities.
Power Distribution Utilities	✓ Should foster commercial relationships with users related to the use of the power distribution systems and their connection to facilities. This includes: metering user connection points and billing for the charges from the connection and use of the power transmission and distribution systems; separating out the power distribution and transmission portions; and contracting access to the basic network to ensure the demands of its own market can be met (as well as those of free consumers and power generation plants).
Transmission and Distribution Systems Users	✓ Based on where access will take place, should be responsible for carrying out the studies, completing the designs, and implementing the facilities to guarantee the exclusive use and connection to the public power system.

[34] In other words, only energy flows not covered by contracts will be traded directly on Brazil's WEM.
[35] Although small compared to the long-term bilateral transactions market, the spot market is nevertheless quite important for the cogenerator who trades its intermittent surplus power. Furthermore, with the rising share held by gas-fired thermo-power generation in Brazil's energy grid, the spot market may well become a benchmark for the prices set in bilateral contracts (Szklo 2001).

Furthermore, the operations of Brazil's power generation sector are still centralized and assigned to the NSO. This situation has resulted because of the complexity of Brazil's power generation sector and in spite of the introduction of the WEM. Presently, the power generation system is dispatched through optimization methods that strive to achieve an efficient management of the available water resources by minimizing operating costs and trimming power shortage risks.

The nature of operations for the WEM and the observation that much of the energy will be transacted through long-term contracts have prompted Vinhaes and de Santana (1999) to forecast that competition in Brazil's power sector will occur more *through* markets than *in* them. This means that the main competition among utilities will be found during the concessioning process rather than within the operations of the markets themselves. Given the centralization of dispatch operations, it will not be easy for these to favor cogeneration systems, except for a small amount of energy produced by Brazilian hydroelectric-power plants.

Nevertheless, in certain situations, it may be possible to have the sale of cogenerated power surpluses on Brazil's WEM without the introduction of a specific trading structure for cogenerators. In this case, and following in the footsteps of the U.S. after its 1992 Energy Policy Act, the "power retailer" agent—introduced by Brazilian law in 1998 (Law 9,648/1998)—could become important for project development and building up a cogeneration market.

3.5 Supplementary Demands

As already noted in this article, a guaranteed supply of supplementary reserve electricity *at fair, reasonable prices* is a significant condition for having a policy that encourages the development of cogeneration systems. In other words, the failure to include such an aspect discourages investments by independent power producers in cogeneration facilities. This occurs because the power distribution utility will not make energy available to the cogenerator when the system is halted, forcing it to install additional equipment on a stand-by basis, or the back-up rates are so excessively high that they over-remunerate the utility for the reserve capacity in its grid.

In Brazil, Resolution 371/1999 regulates contracts and the sale of reserve capacity by self-producers or producers, distinguishing between emergency consumption that is subject to a user's fee, and contracted emergency demand, which is charged even if no consumption occurs. Pursuant to this resolution, the electricity required during the downtime of cogeneration plants may be acquired directly on Brazil's WEM or through bilateral power purchase contracts that are freely negotiated. Consequently, similar to what occurs in trading surplus cogenerated power through bilateral contracts, only clearly-outlined energy blocks can be sold over the long-term.[36] In view of the difficulty in establishing bilateral contracts for relatively small amounts of electricity and the unfeasibility of having them for unforeseen consumption, it is expected that a relevant portion of the emergency power consumption absorbed by the cogeneration plants will be handled by the WEM. However, this will endow the emergency consumption rate with a high level of uncertainty, which may discourage investments in cogeneration—particularly for small-scale operators. A possible solution to this problem could be to introduce contracts between the utility and the cogenerator covering two-way energy swaps, with the cogenerator taking on the role of providing the reserve capacity to the utility, and vice-versa.

With regard to cogenerators' reserve capacity, which is limited to 30 MW, contracts should be implemented for at least one year between self-producers or IPPs and for the distribution utility in the area where the consumer unit is located. To determine the monthly value of the reserve capacity, the charges for use of the power transmission system should be multiplied by its usage factor. By regulating

[36] For example, when Columbian Chemicals installed a cogeneration plant to operate as an independent power producer supplying 4.1 MW to the Bandeirante power distribution utility in São Paulo state, it signed a ten-year agreement covering electricity sales and purchases during scheduled halts.

these charges, with transmission activities treated as “natural monopolies” in the new model for Brazil's power sector, the appraised value of the reserve capacity also is regulated. To a certain extent, such a regulatory mechanism will tend to protect the cogenerator from possible defensive strategies deployed by power utilities.

It still remains to be seen whether the cogenerators in Brazil will be offered incentives through discounts on cogenerated power transmission charges, and if they will be extended to the charges paid for reserve capacity.[37] Should this prove to be the case, the cogenerators will benefit doubly, transmitting their surplus power and acquiring their back-up supplies. However, it should be stressed that the origins of the energy transacted—both surplus and back-up—differ, just like the effects of these two measures; there are discounts taken on charges for the use of the system to sell-off surpluses and for purchasing back-up supplies. In the former, the discount may favor the generation of surplus power and its retailing, while in the latter, discounting may either encourage investments in cogeneration systems or increase demand for reserve capacity, which can not always be desirable for a power system.

4. Incentives for Cogeneration in Brazil and the Thermo-Power Plant Emergency Program

With the passage of Edict 212/2000 on July 25, 2000,[38] the Brazilian Government defined the general lines of what now has become called the Cogeneration Incentive Program. Due to the unparalleled nature of its emergency aspects, criticisms of the edict will be treated in a separate topic of this article. Instead, this section will focus upon the nature of the law and its implications for promoting cogeneration systems in Brazil.

This edict has its own legal character, listing among its goals, “the rational uses of sources of energy designed to enhance the value of energy resources…while also protecting the environment and fostering energy conservation.” Nevertheless, it has been effectively limited to extending the benefits of qualified cogeneration systems to high-priority thermo-generation plants or to those projects included under the Thermo-Power Emergency Program. Consequently, it seems quite reasonable to view the Cogeneration Incentive Program through the logic and justifications set out by the Thermo-Power Priority Program 2000-2003, as introduced by Decree 3,371/2000 and covered by the provisions of Edict 43/2000.[39] The purpose of this program is to provide short-term incentives for private investors and expand the installed thermo-power generation capacity of the country. Towards these ends, it strives to reduce the risks of thermo-power projects, particularly those related to the sale of electricity on Brazil's WEM and the purchase of natural gas. Unfortunately, the Thermo-Power Priority Program has re-instituted a practice that now is challenged by those urging the restructuring of Brazil's power sector: the inclusion of subsidies for private interest groups with ample bargaining power in the market. The result has been a weakening of the related regulatory agencies, a fact that may encourage investors to postpone fresh investments into the sector in order to await new government incentives for themselves.

In keeping step with Brazil's Thermo-Power Priority Program, the Cogeneration Incentive Program stipulates that the incentives awarded to high-priority thermo-power plants can be extended to cogeneration plants if they fulfill two basic requirements: i.) meet qualification standards and ii.) commence commercial operations prior to December 31, 2003. This deadline for the start-up of operations effectively will assure that benefits are awarded to cogeneration plants, rather than mandating that first they “assign [a] high value to energy resources, protecting the environment and encouraging energy conservation” as stated in Edict 212/2000. In this sense, the principle objective of these power

[37] This type of discount is already granted in Brazil to small hydroelectric-power plants, where rates are at least 50% lower for electricity’s transmission and distribution (Law 9,427/1996).
[38] On August 1, a rider to this Edict was added before it was actually instituted by the Brazilian government.
[39] This program initially ranked 49 thermo-power projects as a high priority, with 2003 set as the deadline for the start-up of their operations, and a forecast for an installed capacity of 17,105 MW, of which 15.319 MW would be generated by natural gas.

plants is to help reduce the risks for shortfalls in Brazil's electricity system, which has become a greater concern after the experiences of 2001.

However, this unparalleled objective of Brazil's cogeneration incentive policy requires some reflection and provisos:

- First, the qualifications outlined for cogenerators under Brazilian law—as explained in this paper—are insufficient to handle the incentives covered in Edict 212/2000. In reality, any incentive mechanism that wishes to ensure the purchasing of surplus power also is required to fix the quality of the energy supplied.
- Second, “qualified projects” commonly are identified as “priority projects,” since this classification serves as a policy tool for defining which projects will receive incentives. This issue is linked to the deadlock that exists between devising short-term and long-term solutions. However, there is no mention in Edict 212/2000 for the regular review of long-term benefits (up to twenty years) that are awarded to qualified power plants. Furthermore, not all the qualified projects can be rated as a high-priority, meaning that such a qualification in Resolution 021/2000 or the incentive defined in Edict 212/2000 is inappropriate.
- Third, there is no formal treatment of how to analyze the value of the “sell” rates for cogenerated power surpluses. This measure is vital, as it allows for a revision of the rates based on a reasonable criterion that could permit future comparative analyses between cogeneration and thermo-power.
- Fourth, the Cogeneration Incentive Program establishes a deadline for the start-up of operations by 2003, meaning that a new incentives program will have to be introduced that will not focus only on the problem of shortfalls in energy supplies. New power plants with operational start-up dates after 2003 and with characteristics that ensure their qualification should also be able to benefit from this incentive to some extent (or these power plants will not be encouraged to meet the qualifications).
- Finally, as already has been stressed, the incentives policy for cogeneration plays a vital role in establishing expansion targets, ensuring reliability and high-quality cogenerated power supplies, and channeling investments into specific niches in the power market. However, there is no mention of these targets in the incentives program under analysis here.

In view of these provisos, it should be noted that the potential Brazilian cogeneration market—all of which could qualify under the criteria stipulated in Resolution 021/2000—will not be covered entirely by the incentives of Edict 212/2000.

5. Conclusions

Spurred by high risks of further shortfalls and difficulties in obtaining funds for its expansion, Brazil is restructuring its power sector. As discussed in this paper, the imminence of another crisis underscores some of the advantages of cogeneration systems as compared to conventional power schemes, opening up market niches for the development of combined power generation in Brazil. Furthermore, free access to the transmission grids and distribution networks and the introduction of unfettered consumers into the Brazilian power market also will encourage investments by power utilities and cogeneration facilities to preserve and diversify their markets. In this last instance, apart from offering an efficient alternative that helps to decentralize power generation, cogeneration also can play a strategic role in bridging the gap between supply and demand.

However, within this context, particular attention should be paid to the trend for cogeneration investments to focus on consumers with heavy bargaining power in the energy market. This practice has been at the detriment of cogeneration by smaller enterprises in Brazil's industrial and commercial sectors. In fact, no targets have been established for the development of any cogeneration facilities in the country, although such systems have been acknowledged for their advantages as an alternative source of energy with high thermo-dynamic efficiency levels. To the contrary, the current regulatory environment has opened up the market to competition in certain instances without adequately distinguishing between cogenerators and IPPs. Less encouragement is being given to cogeneration systems with attributes of environmental and power sustainability, while a higher value has been assigned to their strategic characteristics of supplying major industrial consumers and power distribution utilities, and diversifying the activities of agents in this market.[40]

Despite the possibility of convergence between these two types of attributes—environmental and power sustainability, on one hand, and strategic value, on the other—it will be hard to ensure free negotiations between cogenerators and the market, as covered under Brazilian law, in a manner that favors facilities with less bargaining power. Even if cogenerators are able to meet the established qualifications, they are still dependant on either incentives or benefits for their projects to be viable.

Instead of the prevailing regulatory environment, cogeneration incentives should be viewed as a way for the state to encourage energy efficiency by channeling private investments toward specific technological projects that are more efficient. One option would be for the state to systematically take over and coordinate the role of supplying the market not only over the short term and in cases of contingencies—as expressed in Edict 212/2000—but also over the medium and long term. However, even here the introduction of targets for expanding cogeneration in Brazil is essential and should still precede, justify, and validate any institutional framework that is chosen.

[40] It is worthwhile noting that cogeneration systems are found on the border between where environmental and energy policies converge. On the one hand, they help cut atmospheric emissions and save fuel (compared to conventional thermo-power systems), while, on the other, they encourage the arrival of new competitors into power generation. They also are located in areas along where these policies diverge, since power sector deregulation and environmental policies may seek conflicting objectives, given that not all environmental targets are covered by the market.

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