Designing Incentive Policies for Natural-Gas-Fired Combined Heat and Power in Brazil

Alexandre Salem Szklo, DSc.
Jeferson Borgheti Soares, MSc.
Maurício Tiomno Tolmasquim, DSc.
Federal University of Rio de Janeiro, Brazil

ABSTRACT

This article identifies incentive policies for the expansion of natural-gas-fired combined heat and power capacity in Brazil. It analyzes the barriers and the impacts of incentive polices for combined heat and power systems, showing that major barriers can be removed through information dissemination programs and financing. Nevertheless, the key issue is the ability of the policy-maker to assess which scenarios (with similar characteristics) are rated as more likely to succeed by potential investors, and then selecting the most appropriate incentive policy.

Keywords: Natural-Gas-Fired Cogeneration, Incentive Policies.

INTRODUCTION

In recent years, natural gas internal supply has increased, mainly as a result of two macro-policies implemented by the federal government during the late 1990s: (1) first, as a result of a deliberate policy of diversifying Brazil's energy matrix, mainly expanding supplies of natural gas and institutional reforms related to the gas sector, to reduce the nation's excessive dependence on only two primary energy sources (hydropower to generate electricity and oil for the fuels sector). (2) Second, the restructuring of Brazil's energy sector, especially the deregulation of Brazil's electricity market through the introduction of eligible consumers and independent power producers with open access to the transmission grid [1].

Actually, the bottleneck caused by constraints on natural gas supplies was removed through the start-up of operations by the Bolivia-Brazil Gas Pipeline at the end of 1998. Moreover, natural gas reserves located in Santos Basin can also play a significant role in future natural gas markets in Brazil some years ahead. An analysis of the energy consumed by Brazil's industrial sector as a whole from 1998 through 2000 indicates that sectors such as chemicals, food and beverages, pulp and paper, ceramics and textiles consumed more natural gas for generating heat, mainly to the detriment of residual fuel oil. (Natural gas consumption rose by 70.7 TJ, while residual fuel oil consumption dropped by 56.4 TJ.) Consequently, natural gas has managed not only to absorb new projects, but expand through conversions by consumers that have traditionally been supplied by residual fuel oil, especially in the chemical sector. However, there remains a significant potential for using natural-gas-fired combined heat and power (NGCHP).

Compared to conventional gas-fired thermo-power generation, the NGCHP ensures the lowest energy consumption and reduces atmospheric emissions (for instance, those responsible for provoking global climate changes). Additionally, NGCHP plants could serve electricity markets with lower investments in the transmission and distribution grids and networks—and with lower rates of energy loss during transmission. As a distributed power generation option, it may also allow the postponement of high-volume investments that are required for expanding centralized power generation capacity [2].

However, these three main reasons—primary energy conservation, less atmospheric emissions, and a low-cost alternative to centralized power capacity expansion—have not encouraged huge investments in NGCHP systems in Brazil in the past. For instance, the NGCHP economic potential hovers around 1.5 GW in the Brazilian chemical industry [3], while its installed capacity by 2001 did not exceed 0.5 GW, mainly in two petrochemical plants (almost 65% of the installed capacity in the Brazilian chemical sector in 2001).* This is still quite a low figure in view

*The figure mentioned here refers to open cycle gas turbines systems having an average a power ratio of 0.6. When we consider combined cycles, the NGCHP potential in the chemical industry become 150% higher. Yet, in this case, there is a tradeoff between the capital cost increase caused by the combined cycle and the additional revenue derived from the surplus power produced by the NGCHP plant.

of the weight of the chemical segment in the total energy consumed by Brazil's industrial sector. In addition, the characteristics of the nation's chemical plants, which normally operate with high usage factors and steady heat loads and the know-how of the global chemical industry for implementing NGCHP.* Furthermore, Brazilian chemical plants are under heavy pressures to cut costs [4] and show a rising awareness of the importance of power service quality, underscored even more heavily by Brazil's recent power crisis.†

Barriers: Past and Present

As has been discussed by Szkio and Tolmasquin [6], four long-standing barriers explain the historical discrepancy between the NGCHP technical potential and its installed capacity:

- 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. Thermal-power plants operated merely to supplement the main system for only a few hours a year.

- Second, Brazil's power sector model lacked clearly-defined mechanisms that would have allowed NGCHP ventures to transfer their energy through the power grid. 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.

---

*For instance, 39% of the total installed capacity in CHP in the USA in 1999 was clustered in its chemical industry (around 18 GW) with 79% of its capacity based on natural gas systems [5].

†In late May 2001, Brazil faced nationwide power rationing that was intended to avert major blackouts before the end of the next rainy season (November-May) to save valuable water in the severely depleted reservoirs. The electricity crisis highlighted the lack of investments in the expansion of the Brazil's power sector during the 1990s, forcing the country to operate its hydropower reservoirs on an annual rather than pluriannual bases. Industrial users were required to reduce consumption by between 15% and 25%, while not undertaking any major expansions requiring new mains connections. This rationing plan lasted for ten months, from June 1, 2001 through February 28, 2002 [1].

- Third, low electricity prices in Brazil discouraged investments in CHP 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.*

- Fourth, and finally, until the late 1990s, supplies of natural gas in Brazil were relatively limited. In 1998, the demand for natural gas, in terms of its share of Brazil's primary energy sources, did not exceed 3%.

However, this historical context is now changing drastically, basically triggered by three factors: the restructuring of Brazil's energy sector, the expansion of the natural gas supply, as well as the crisis that assailed Brazil's power system. First, the deregulation of Brazil's electricity market, through the introduction of eligible consumers and open access for private companies to the transmission grid, dramatically altered the prospects for NGCHP in this market.† It removed the monopolistic barriers to bilateral energy sales between CHP plants and the market, and also introduced new agents, such as energy retailers, into the mix that can participate in the energy market, finding niches for CHP investments. Third-party financing may also be used to expand CHP capacity. Furthermore, within this new context, CHP systems can also constitute a strategy to bridge the gap between energy suppliers and the market [6]—for instance, through joint-ventures of energy supply or distribution companies with industrial companies.

Second, 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 online. Also, authori-

---

*Paradoxically, relatively low electric rates over the past two decades have hampered investments in CHP in Brazil, but they have also fettered the investment capacity of Brazil's entire power sector and, consequently, have enhanced the appeal of CHP plants. While a negative factor in the short-term, this historical barrier has provided justification for inducing fresh investments in CHP over the medium-term, in an attempt to avoid power shortages [2].

†These subjects are specifically covered by Decree 2.003/1996 and the resolutions of the Electricity Regulatory Agency (ANEEL), namely 281/1999, 282/1999 and 286/1999 [2].

zation was granted to import natural gas from Argentina.* Since 1998, the Brazilian regulatory framework guarantees a non-discriminatory access to the existing or under construction gas pipelines.

Finally, the Brazillian electricity supply crisis highlighted other logical reasons for introducing NGCHP systems over the short term. These systems represent: (1) a rapid option for expanding power generation facilities; (2) an instrument for honing 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 (5) a type of protection for energy consumers against power outages and rationing.† Furthermore, the steady natural gas consumption required for a CHP plant—assuming it is operating with an almost uniform thermal load (which is correct for many industrial ventures)—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 CHP plants can ensure regular gas consumption throughout the year, regardless of the availability of surplus electricity from hydroelectric power plants in the rainy season. This emphasizes also that comparisons between CHP and thermal-power plants should consider the operation of these plants in an electric system whose heavy reliance on hydropower results in striking seasonal variation in power availability [2].

However, like all transition phases, the future is still cloudy. The lack of a specific energy policy designed to encourage NGCHP 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 NGCHP potential. This means also that new

*Although to a lesser extent than the Bolivia-Brazil Gas Pipeline, the Zero Burn-Off Plan is also noteworthy as a factor in boosting the natural gas supplies in Brazil. This was introduced by Petrobras in 1998 to reduce burn-offs of natural gas as much as possible on its offshore rigs.

†The high concentration of energy-intensive industrial segments in Brazil confirms the trend towards such sectors investing in CHP, provided that there is assumed to be a real risk of electricity rationing, with a consequent increase in rates [7]. For instance, Soares et at. [8] showed that the internal rate of return for Brazilian industrial CHP 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 CHP venture.

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. It is worthwhile to identify the links between policies and the qualitative and quantitative goals for the NGCHP installed capacity expansion in the country. Furthermore, the regulations should be grounded in the targets established by the energy policy and periodically reviewed. The market barriers to NGCHP may either multiply or decrease as power markets are deregulated.* Such an aspect is implicit in the results of a survey carried out among Brazilian industrial entrepreneurs, which indicated that five main barriers have hampered the implementation of industrial NGCHP plants (see Table 1).

In the case of the tertiary sector, information barriers are also very important. Indeed, in Brazilian hospitals whose NGCHP technical potential hovers around 500 MW, Szklo et al. [11] identified barriers related to the lack of information among the engineering staff about the advantages of CHP, the lack of training or preparation among their engineering and office staffs for the institutional transition of Brazil's power sector, which should include the renegotiation of electricity rates, and the lack of interaction mechanisms between their engineering staff and the natural gas or power utility planning staff. This interaction could also involve partnerships in drawing up and implementing NGCHP ventures. Consequently, some barriers to investment in NGCHP in Brazil could be surmounted through information and capacity-building programs. It is clear that these programs do not replace but rather supplement possible incentive policies based on electricity rates and investment financing. Another important aspect within this context is the closer involvement of the power utility in developing or encouraging CHP, particularly in sectors where high-quality electricity services are crucial.

---

*It is often thought that market barriers to CHP 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 of barriers. For instance, if competition leads to lower energy prices, CHP will be negatively affected because the incentives for conservation will decline [9]. There are also competitive behaviors of the power producers that may negatively affect the CHP investments, such as buy-out of capacity.

Table 1. Barriers to Industrial NGCHP in Brazil

Barriers	Comments
(1) Back-up rates	√ Because these rates are high, not only do they fail to encourage potential industrial investments in NGCHP plants, but also they prevent incentives for them to host NGCHP plants owned by power distribution utilities.
(2) Retailing CHP electricity	√ Smaller NGCHP 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).
(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, Real) and the costs incurred for gas consumption (quoted in U.S. dollars, US$).
(5) Equipment prices in U.S.	√ The alternative of bringing in foreign funding through dollars foreign private banks means accepting uncertain floating foreign exchange rates, boosting investor risk.*

*Notes: (1) The devaluation of the Real (R$) in Brazil since early March 1999 has undermined the feasibility of CHP schemes, particularly smaller projects. Source: [10].

Proposed Policies

The energy policies designed to boost the NGCHP in Brazil may well:

1. Foster the expansion of NGCHP in segments that do not invest spontaneously in it either because the benefits of NGCHP are not well perceived, or these benefits are not properly appraised, or investors are unwilling to channel funds to an activity outside their core business, or even because there may be market barriers to this investment.

2. Encourage the expansion of more efficient cogeneration systems and the conversion of less efficient systems to more efficient ones, resulting in high fuel savings and encourage rapid expansion of the cogeneration-installed capacity. For instance, incentives designed to encourage the sale of surplus power accelerated the expansion of NGCHP capacity in the USA during the early 1980s and in the Netherlands during the early 1990s.

3. Emphasize additional advantages of CHP projects to the energy system as a whole. As a result of the usual Draconian conditions of the natural gas supply contracts, CHP plants should be viewed as the main contestability element of the Brazilian power system. Because they use part of its energy inputs to produce heat (or steam), CHP plants can maintain a minimum consumption of natural gas during all the year.

4. Improve the energy service infrastructure. This means a focus on improved delivery of energy service rather than metered commodity transactions.

Regarding the incentive policies for NGCHP systems in Brazil, the results presented in [3] for the chemical industry are very elucidative. According to this study, a NGCHP technical potential of 1.4 GW is noted. Moreover, this study established scenarios for variables having significant impact on NGCHP projects, considering six levels of analysis. Therefore, the estimates were structured on the idea of groups or branches of scenarios. This idea arises from the storyline concept for future events,* according to which each scenario offers a possible specific quantitative representation of a storyline, with all scenarios based on a single storyline grouped into a single family. The three first levels of analysis contain variables related to the context of the potential investor in NGCHP plants, meaning that, although they represent driving forces outside the sphere of influence of the NGCHP incentive policies, they shape the storylines that intervene in the economic feasibility of the NGCHP technical potential. For these levels of the tree, the following hypotheses were made:

- For the first level, two evolutions in international oil prices were used both grounded on the benchmark trend and the high oil price scenario [13].

- For the second level, three foreign exchange rates were used: R$ 2.60/US$ 1.00, R$ 3.00/US$ 1.00 and R$ 3.50/US$ 1.00.

- For the power-grid rate, the two options were high growth, through which the electricity rate rises at 10% p.a. and low growth, with the electricity rate rising at 5% p.a.†

Finally, levels 4, 5 and 6 of the scenario tree attempt to measure the effects of possible future incentive policies encouraging cogeneration plants in the Brazilian chemical industry, following the prepared storylines. These policies are focused on:

- Access to lines of credit for cogeneration equipment (level 4 of the scenarios tree) taking the PRICE financing system, with a financing level of 80% at a rate of 14% p.a., in keeping with the current High-Priority Investment Support Program for the Electricity Sector, in the products portfolio of Brazil's National Social and Economic Development Bank [15].

---

*This concept was applied by the IPCC as a basis for the climate change projections [12]. In this study, storyline was defined as a narrative description of a family of scenarios highlighting the main scenario characteristics, relationships between key driving forces, and the dynamic of their evolution.

†According to Aneel [14], from 1997 through 2002, the average rate for Brazil's industrial sector rose by 11% p.a.

- The use of fiscal tools to encourage the use of natural gas, which combine reduction in the tax rates charged on gas sale transactions to end-consumers, and alterations in the depreciation methods currently used in Brazil. In this case, should accelerated depreciation be adopted, the depreciation period would be seven years [16].

- Incentives for selling off surplus electricity. This establishes fair and reasonable rate levels for both surplus electricity sales as well as for the acquisition of back up power. In other words, attempts are made to encourage investors to install systems able to export electricity, with no barriers blocking the acquisition of back up power. In this case, the incentives scenario also assumes that long-term bilateral contracts will be drawn up to cover these transactions.

The Figure 1 summarizes the findings for the twelve simulated scenario families assessed, taking into account the conservative criteria for economic feasibility where the internal rate of return on the projects is equal to at least 25% p.a. This rate reflects high risk awareness among possible investors in NGCHP in Brazil, which is also related to the current transition stage of Brazil's power sector, where many rules are still being established, or have not yet been properly absorbed by possible investors.

As noted, the effect of specific incentive policies tends to step up the economically feasible potential in amounts that are significantly lower than those noted when these policies are deployed together. Access to financing is the stand-alone policy that would be most successful for ensuring the feasibility of the natural gas market for cogeneration purposes in Brazil's chemical sector. Nevertheless, this policy proved to be affected by the storyline under consideration, because to a large extent, the foreign exchange rate has a large impact on the efficacy of financing incentive policies.

In turn, the accelerated depreciation stand-alone policy tends to step up the internal rate of return by up to 5% with the systems under assessment, although without necessarily making them economically feasible. However, it should be emphasized that the application of this type of incentive will lower government income over the initial years of the project while boosting the net profits of private investors. This means that this type of incentive results in a loss of income for the government. Nevertheless, this loss may be offset to a certain extent by the implementation of a project that does not seem feasible from the standpoint of private investment. Additionally, this type of incentive spread out over time should be compared with the possible direct subsidies on the initial investment in the project. These direct subsidies generally include higher risks. Finally, an accelerated depreciation policy can also encourage technological updating of the equipment, because this is a basic assumption for this type of policy.

In turn, the stand-alone adoption of an incentive policy for surplus electricity sales, depending on the storylines under consideration, produces results that are negligible or even nil for underpinning the NGCHP feasibility, except in scenarios relatively favorable to primary energy conservation measures. However, fostering surplus energy sales—with modest results by itself—underpinned 82% of the technical potential when associated with the financing policy for the storylines with the best performance.

Interestingly enough, the combination of incentive policies may increase this potential by a factor of 20 to 50, depending on the oil price, foreign exchange and electricity rate scenarios. Incentive policies applied on a stand-alone basis for financing may increase this potential by up to eighteen times. Consequently, the key issue here is related to the ability to assess which storyline is rated as more probable by possible future investors in NGCHP, and then selecting the most appropriate incentive policy.

Final Remarks—Threshold Target

Finally, bearing in mind the incentive policies previously discussed, the Long-Term Energy Plan of the National Energy Policy Council, the so-called Energy Matrix 2000-2022 ([17]; [18]), established guiding lines that could be considered in this document as starting points (or even threshold targets) for a NGCHP Incentive Program in Brazil:

- Widen use of NGCHP systems in non-traditional sectors, such hospitals, lodging buildings, universities, malls, etc. In this case, the Long-term Energy Plan considered an installed capacity increase from 15 MW in 2005 to 420 MW by 2020.

- Adopt incentive policies mainly based on financing the initial costs of NGCHP systems. The policy based on incentives for selling off surplus electricity should be carefully adopted, relying on rigorous

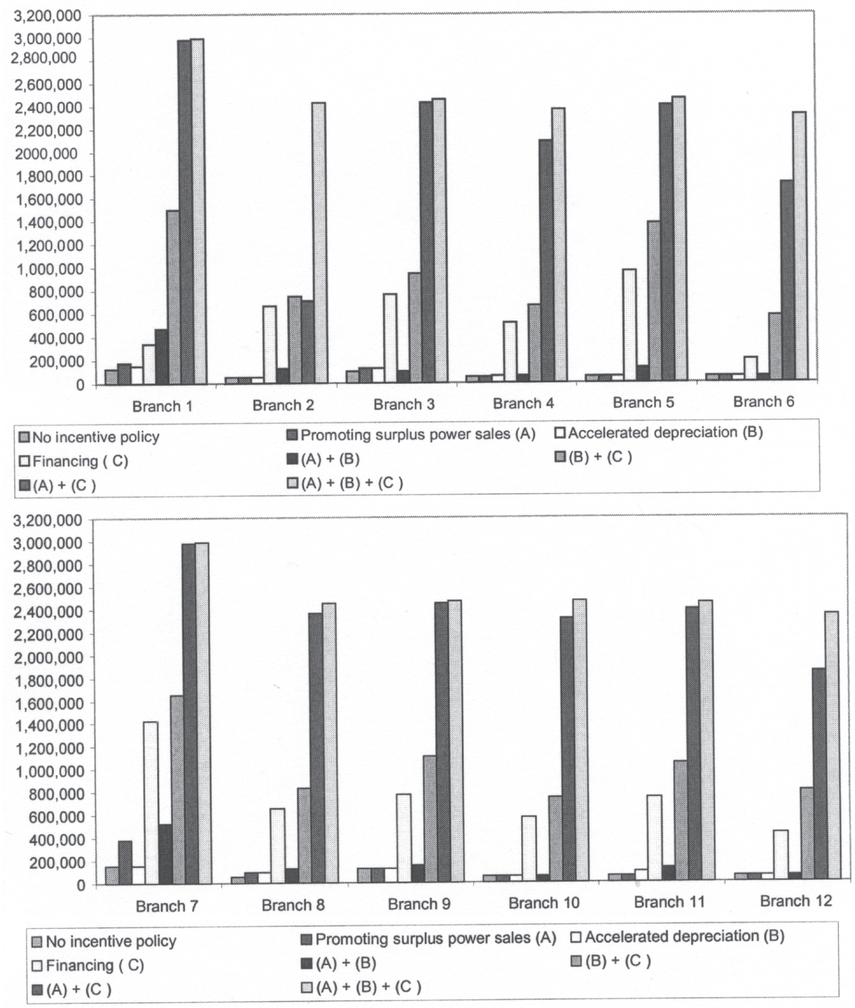

Figure 1. Incentive policy impacts on NGCHP feasibility in Brazil's chemical sector (Gas market 1000 m3/year)

Note: This potential covers the products and processes for which data was available in Brazil in 2000. Consequently, this covers 81% of the total physical output and 78% of the total energy consumption by Brazil's chemical industry.

Legend: Branch 1 corresponds to the business-as-usual scenario for oil prices, at a foreign exchange rate of R$ 2.60/US$ 1.00 and growth at 10% p.a. in the electricity rate. Branch 2 is the same as Branch 1, except for the increase in electricity end-prices at 5% p.a. Branch 3 is the same as Branch 1, except for the foreign exchange rate, which rises to R$ 3.00/US$ 1.00. Branch 4 is the same as Branch 3, except for an increase in the electricity rate, at 5% p.a. Branch 5 is the same as Branch 1, except for the foreign exchange rate, which rises to R$ 3.50/US$ 1.00. Branch 6 is the same as Branch 5, except for an increase in the electricity rate at 5% p.a. Branches 7 through 12 are the same as Branches 1 through 6, except for the international oil price evolution scenario, which becomes the high-price scenario in [13].

qualification criteria and market-oriented mechanisms for fixing the surplus power rates.*

- Encourage capacity building and information dissemination, as well as third-party financing. In this case, a third-party—an ESCO, for instance—finances and carries out the project, with the investment recovered through operational savings over a pre-defined period of time, the so-called BOOT agreement. Third-party financing can also mean joint ventures between energy suppliers (or energy distribution utilities or equipment suppliers) and consumers to build new CHP plants focusing on the energy services demanded by the consumers. Actually, a customization strategy is very cost-effective to the NGCHP installed capacity expansion, and a very interesting way to do that can rely on bidding programs in which ESCOS bid for CHP ventures through performance-based contracting.

Consequently, the gradual and realistic application of these guiding lines in the long-term energy plan of the Brazilian Government guaranteed that at least 5% of the total Brazilian electricity market is served by natural-gas-fired combined heat and power systems by 2020 [17, 18].

Acknowledgments

The authors thank FAPERJ, CNPq and CTPetro for their financial support to this study.

References

1. Schaeffer, R., A. Szklo, and M. Schuller, M. 2002. "Climate Change Mitigation in Developing Countries." In: Chandler, W. (org.). Arlington/Virginia/EUA: Pew Center on Global Climate Change.
2. Szklo, A.S., and M.T. Tolmasquim. 2003. Analysis of Brazil's cogeneration legal framework. Energy Conversion and Management. 44 (3): 369-380.
3. Szklo, A.S., J.B. Soares, and M.T. Tolmasquim. 2004. Economic potential of natural gas-fired cogeneration—analysis of Brazil's chemical industry, Energy Policy. 32 (2004): 1415-1428.
4. ABIQUIM [Associação Brasileira da Indústria química] 2001. Anuário da indústria química brasileira. ABIQUIM, São Paulo. Brasil.

*This could be, for instance, a competitive bidding for a fixed market share.

5. Energy Information Administration (EIA). 2000. The market and technical potential for combined heat and power in the industrial sector. Prepared for EIA/DOE. Washington, DC.
6. Szklo, A.S. and M.T. Tolmasquim. 2001. Strategic cogeneration—fresh horizons for the development of cogeneration in Brazil, Applied Energy. 69 (4): 257-268.
7. Mello, J. 1995. Vale a pena investir em autoprodução com as novas regras do setor elétrico? Eletricidade Moderna, n. 256, p. 64-71.
8. Soares, J.B., A.S. Szklo, and M.T. Tolmasquim. 2001. Incentive policies for natural gas-fired cogeneration in Brazil's industrial sector –– case studies: chemical plant and pulp mill. Energy Policy. 29 (3): 205-215.
9. Karamanos, P. 1997. "Cogeneration and District Heating: Constraints and Opportunities." The Journal of Energy and Development, 22: 245-274.
10. Tolmasquim, M.T., A.S. Szklo, J.B. Soares, V.C. Neto, and A. Sugyama. 1999. Avaliação dos potenciais técnico e econômico e identificação das principais barreiras à implantação da cogeração no Brasil em setores selecionados. Convênio Procel-Eletrobrás/COPPE. Rio de Janeiro.
11. Szklo, A.S., J.B. Soares, and M.T. Tolmasquim. 2004. Energy consumption indicators and CHP technical potential in the Brazilian hospital sector. Energy conversion and management. Volume 45, Issues 13-14, pp. 2075-2091.
12. Intergovernamental Panel on Climate Change (IPCC). 2001. In: Watson, R. and the Core Writing Teams (Eds.), Climate Change 2001: Synthesis Report. A Contribution of Working Groups I, II and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.
13. EIA, 2002. World Energy Outlook. Available at http://www.eia.doe.gov.
14. Aneel (Agência Nacional de Energia Elétrica), 2002. Tarifas de energia elétrica no Brasil em 2002. Disponível em: http://www.aneel.gov.br.
15. BNDES. 2002. Programas do BNDES para Apoio Financeiro a Investimentos em Energia. Disponível em http://www.bndes.gov.br/produtos/.nanciamento/programa.as.
16. Kranz, N., and E. Worrell. 2001. Effects of a shortened depreciation

schedule on the investment costs for combined heat and power systems. Technical Report, LBNL-49518.
17. Ministry of Mines and Energy (MME). 2002. Balanço Energético Nacional. Brasília/DF.
18. MME. 2003. Long Term Plan 2000-2022. Brasilia: Ministry of Mines and Energy, Republic of Brazil. www.mme.gov.br

---

ABOUT THE AUTHORS

Alexandre Salem Szklo, DSc., Professor; **Jeferson Borgheti Soares**, MSc., Researcher; and **Maurício Tiomno Tolmasquim**, DSc., Professor are from Center for Energy and Environmental Economics (CENERGIA), Energy Planning Program, Post-Graduate School of Engineering at the Federal University of Rio de Janeiro. Each of the authors is involved with combined heat and power, natural gas policy, energy efficiency, and energy technologies and have performed several studies on these subject. The authors may be contacted at the Center for Energy and Environmental Economics, CENERGIA, Energy Planning Program Post-Graduate School of Engineering, Rio de Janeiro Federal University, P.O. Box 68.565 -Ilha do Fundão, 21945 970 Rio de Janeiro, Brazil (Ilha do Fundão, Centro de Tecnologia, Cidade Universitária, Bloco C, Sala C-211, 21945 970 Rio de Janeiro, Brazil). Their phone number is +55 21 2562 8764, fax number is +55 21 2562 8777, and e-mail addresses are: szklo@ppe.ufrj.br, borgheti@ppe.ufrj.br, and tolmasquim@ppe.ufrj.br.