DEVELOPMENT OF ENERGY CONSUMPTION AND ENERGY EFFICIENCY POTENTIAL IN THE BRAZILIAN INDUSTRIAL SECTOR ACCORDING TO THE INTEGRATED ENERGY PLANNING MODEL (IEPM)

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ABSTRACT

This paper presents the development of energy consumption in the Brazilian industrial sector and energy efficiency potential based on the analysis undertaken through a model developed in the Energy Planning Program at COPPE/UFRJ[1], known as the Integrated Energy Planning Model - IEPM.

The study starts by presenting the IEPM, which is a technical and economic parameter-based model designed to forecast energy supplies and consumption for all economic sectors in Brazil, within three scenarios. Outlines of all three scenarios are presented, as they were constructed according to certain specific assumptions.

The industrial sector was broken down into eleven sub-sectors: food & beverages, ceramics, cement, iron & steel, mining & pelletizing, ferroalloys, non-ferrous metals & others (metallurgy), chemicals, pulp & paper, textiles and other industries (MME, 1998). All these sub-sectors will also be presented as well as the results of the scenario forecasts. Results deriving from these forecasts come from very specific studies that analyze all process steps in each sub-sector in order to propose energy replacements, efficiency improvements or structural production alterations that result in major potential energy consumption reductions.

Last but not least, this paper gives the development forecasts deriving from the three scenarios over ten years, with their contributions to energy efficiency in the Brazilian industrial sector, showing that we can reduce energy consumption in the Brazilian industrial sector by: subtituting less efficient processes by more efficient ones, trough the conversion of final energy into usable energy, basically, in the cement and aluminum industries; replacing equipments and energy sources; modifiyng product mix of several industries (pulp and paper), assigning top priority to producing goods with higher added value that are less energy intensive, and, finally, reducing the share held by some energy intensive sectors in the industrial output.

INTRODUCTION

[1] Post-Graduate Engineering School of Rio de Janeiro Federal University.

This work presents the results of simulating energy demands in Brazil through the use of the Integrated Energy Planning Model - IEPM (MIPE: *Modelo Integrado de Planejamento Energético*) developed under the Energy Planning Program at COPPE/UFRJ (Tolmasquim & Szklo, 1999). This Integrated Energy Planning Model is designed to simulate the energy market in Brazil, divided into the following sectors: energy, industry, agriculture, household, commerce, public administration and transportation, as well as forecasting the Brazilian energy grid through to 2010. This prediction stresses the following aspects: impacts on the energy sector of the pace and content of economic growth; the development of scenario variables such as types of domestic consumption, transportation distribution by mode, urbanization rates and other factors which, although not directly related to the demand forecast, do in fact affect the analysis; and finally, the type of technological choice, in which the energy variable is merely one factor, associated with specific aspects of the technical, social and economic structure of Brazil.

The Integrated Energy Planning Model is a technical and economic forecasting model based on a detailed breakdown of the energy consumption and transformation sectors through to the level of final energy use equipment. The basic forecast indicator is the amount of usable energy required by each item of equipment analyzed, for final use.

The use of this model is based on three core procedures: (1) drawing up macro-economic scenarios for all variables and factors whose development is linked to political decisions and choices that are not necessarily related to the energy sector; (2) detailed analyses of energy demands by types of use in each consumption segment; (3) for each type of final energy use (five types are covered here: direct heating, process heating, electrochemical processes, lighting, and driving power), usable energy demands are established (MME, 1995), as well as savings in the conversion of usable energy into final energy and consequently final energy demands. These procedures are adopted under four separate modules:

- **Module 1**: Macro-Economic Module that defines scenario variables and product distribution among the demand sectors. The scenario variables adopted in the model are: GDP growth rate, GDP composition (industrial product growth, agricultural product growth, and services product growth), population growth rate, urbanization rate, and number of residents/household. This module also defines the composition of industrial op, divided into eleven sub-sectors: food & beverages, ceramics, cement, iron & steel, ferroalloys, mining & pelletizing, non-ferrous metals & others (metallurgy), chemicals, pulp & paper, textiles and other industries. Alterations in the composition of the industrial sector reflect changes in industrial sub-sectors with added value. Two events are analyzed in this module: the development of the average unit value for the industrial sector (US$/ton) and the share of sub-sector movements.
- **Module 2**: Energy Demand Module that defines the analysis variables for each segment of each sector in order to obtain the usable and final energy demands. Since this paper deals exclusively with industrial output, emphasis is placed on the industrial sector forecast variables.
- **Module 3**: Final Energy Consumption Module, which brings together the results of the previous module and the results of the energy consumption figures for the energy sector under Module 4, obtaining both the final energy required by consumption sectors - including the energy sector - as well as the amount of electricity that is self-produced or

co-generated in the consumption sector.

- **Module 4**: Supply Module, which defines the analysis variables for energy supplies, obtaining both the amounts of primary and secondary energy supplied, as well as energy consumption by the energy sector. The energy supply sectors covered are: electricity, oil and gas, coal and charcoal. For the industrial sector projections, several independent variables[2] were stated as showed below:
- **Food and Beverages :** Added Value x ton, usable energy per ton for each type of energy use, share/source for each type of use, conversion efficiency of each source according to the equipment used, technical potential of bagasse-based cogeneration, and kWh generated per tone of sugar-cane for the Rankine Cycle and STIG Cycle.
- **Ceramics:** Added Value/ton, usable energy per ton for each type of energy use, share/source for each type of use, conversion efficiency of each source according to the equipment used.
- **Cement** This forecast is divided into five steps: *quarrying and crushing raw materials*; *milling and blending unheated materials; homogenizing;* the independent variables are: the *share* of usable energy and energy efficiency by source; for *clinker production and cooling*, the input variables are: clinker production process share (dry / wet process), specific furnace consumption; finally, for *finish grinding,* the input variables are: share x source of usable energy, energetic efficiency x source, cement production mix, and cement additives contents.
- **Iron & Steel:** This forecast is divided into three steps: *Reduction* - usable energy/ton for each type of technology (coke-fired blast-furnace, charcoal-fired blast-furnace and electric furnace), technology share for this step, final energy conversion efficiency for each type of technology; *Steelworks* - usable energy/ton for each type of technology (LD/BOF and Electric Steelworks), technology share for this step; *Rolling* - usable energy/ton for each type of technology (hot and cold rolling); cogeneration potential for bottoming systems.
- **Ferro-Alloys:** Product mix for the industry, Added Value/ton, usable energy/ton for each type of energy use, share /source for each type of use, and conversion efficiency for each type of source, according to the equipment used.
- **Non-Ferrous Metals and Others:** Added Value/ton, aluminum production share in sub-sector production, alumina input for aluminum production, specific electric consumption for alumina production, specific electric power consumption for primary aluminum production (Söderberg and Pre-baked anodes(PBA)), corporate shares in aluminum production.
- **Chemicals:** Added Value/ton, usable energy/ton for each type of energy use, share/source for each type of use, conversion efficiency for each type of source according to the equipment used, natural gas and residual fuel cogeneration technical potential, heat x power ratio for the Rankine Cycle, Brayton Cycle and Combined Cycle (CCGT).
- **Pulp & Paper:** Paper and Pulp production shares in the production of this sub-sector, usable energy/ton for pulp production, share/source for each type of energy used in pulp production, conversion efficiency of each type of source according to the equipment used in pulp production, product mix in the paper industry, usable energy/ton for each type of

[2] CO_2 emission factors are defined for all subsectors as whole

paper and energy use, the efficiency of the paper industry equipment, black liquor production/ton of pulp, black liquor share for cogeneration, and efficiency of cogeneration systems used in the pulp industry.

- **Textile:** Per capita consumption of textile fibbers, usable energy/index number[3] for each energy use, source share for each type of energy use, conversion efficiency for each type of source, according to the equipment used.
- **Mining & Pelletizing:** Added Value/ton, usable energy per ton for each type of energy use, share/source for each type of use, conversion efficiency for each source according to the equipment used.
- **Other Industries:** Added Value/ton, usable energy/ton for each type of energy use, share/source for each type of use, conversion efficiency for each source according to the equipment used.

MACRO-ECONOMIC SCENARIOS

In order to develop this forecast, three macro-economic scenarios were drawn up.

The decision to adopt these scenarios is based on forecasts by two major state agencies with proven experience in macro-economic analyses. Moreover, the need for up-to-date studies on this topic, as well as consistent indicators (previously correlated), were additional reasons for choosing our scenarios. In fact, for Scenario 3 and Scenario 2, the same GDP growth rate was used to show different energy consumption patterns, emphasizing the role of energy conservation and development paths. These scenarios are presented below.

- **Scenario 1** - Low Growth: based on the external constraints scenario found in the study undertaken by the National Bank for Economic and Social Development (Pinheiro, Giambiagi & Najberg, 1997), which assumes moderate GDP growth of 3.8% p.a., from 2000 onwards, with a trend-based development of the economic structure and no marked alterations or crises. This scenario reflects the constraints on GDP growth imposed by the shortage of foreign exchange earnings and the need to keep foreign debt at manageable levels.[4] The figures considered for demographic growth in this scenario are the same as those used in other scenarios: the annual population growth rate reaches 1.3% from 1995 - 2000, dropping by 1.2% a year from 2000 - 2005 to 0.6% p.a. from 2006 - 2010. This is consequently a scenario based on conservative, trend-driven hypotheses for energy use (with no relevant improvements in industrial energy consumption efficiency[5]) and the development of the Brazilian economy over the period. The sub-sectors share of industrial product remains almost unchanged throughout the forecast period, meaning that energy-intensive industries

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[3] Textile sub-sector production development was correlated to an index number, according to the IBGE database (IBGE, 1997).

[4] In addition to the initial need to curb any expansion of the foreign debt, which would undermine part of the GDP, other motives may be adduced for growth below expectations for Brazil's GDP: lower investment levels in manufactured products with higher added value; moderate export rate growth for products and goods, increasing both the trade and current account deficits.

[5] For example, the specific electric consumption of aluminum production (16.1 kWh/ton - Söderberg, 14.1 kWh/ton - PBA) does not change in the Scenario 2.

(cement, aluminum, ferro-alloys, steel, chemicals, pulp and paper) account for more than 20% of the industrial product.

- **Scenario 2** - High Growth: based on the forecast drawn up by the Institute of Applied Economic Research - IPEA (1997), which assumes sustained growth fostered over the long term, based on restructuring public accounts.[6] The GDP rises by an annual average of 5.6% from 2000 onwards, driven by the industrial sector, particularly the capital goods and consumer durables segments, as well as public utility industrial services, and the building trade. This shows that GDP composition alters over the period, and from 1996 through 2010, industrial output rises from 31.4% to 34.5% of the GDP, while the service sector increases from 57.2% to 61%, and agricultural output shrinks from 11.4% to 9.7%. The industrial sector is slanted largely towards the foreign market, spurring the quest for internationally competitive standards and prompting the restructuring of the more mature segments. The trend towards clustering the population in urban areas, particularly major cities, should continue to expand, although at a slower pace. In this scenario, gains in energy consumption were considered. For example, in the aluminum production, two core hypotheses were considered: first of all, process substitution was assumed among the companies (from Söderberg to PBA); and secondly, the PBA process achieves some technological improvements, reducing its specific electricity consumption from 14.1 kWh/ton to 13.9 kWh/ton.

- **Scenario 3** - Sustainable Development: the same GDP growth rate as the previous scenario, but with appreciable alterations in the energy demand and supply structure, denoting an alternative development model. It takes into consideration not only the need for gains in efficiency and a keener competitive edge for Brazil's production sector, but also the drive towards gains in energy savings and conservation measures. For instance: demand-side management measures, as well as the replacement of equipment with poor conversion rates for final energy into usable energy, or the replacement of energy sources, according to technical and environmental criteria. In the industrial sector, companies endowed with greater technological sophistication or a keener competitive edge are encouraged, while the relative share of some energy-intensive products shrinks, in parallel to the share of products whose production lines are not competitive either potentially or in strategic terms. The environmental variable takes on added direct importance in selecting technological and planning alternatives, particularly in function of inter-energy substitution, seeking less pollutive fuels and technologies that are more efficient with lower environmental risks. Similar to Scenario 2, there is an upsurge in the output of goods with higher added value. In terms of population concentration, the rural exodus is expected to slow down due to a more dynamic agrarian reform process, with investments in infrastructure, incentives for establishing rural cooperatives and agricultural hubs, and the development of biomass-based energy generation options.

It should be stressed that the three scenarios outlined above assume a future that is relatively tranquil for the Brazilian economy, which has not been the case as this decade draws to a close. International crises have undermined one of the mainstays of Brazil's long-term strategy: the use of foreign investment to supplement low levels of domestic savings.

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[6] This presupposes a speed-up in public sector reforms in order to re-direct the State towards new functions whereby the Entrepreneur-State becomes the Regulatory State focusing on social welfare services.

With the hike in interest rates (to avoid devaluation of the Real and the potential of marked shrinkage in foreign exchange reserves) in parallel to the fiscal adjustment, the impact of these measures became apparent in November 1997. Reflecting this, 1998 featured a marked downturn in economic activities, with industrial and agricultural production posting appreciable shrinkage, as well as the services sector which continued the slowdown that began during the last quarter of the previous year. However, these forecasts cover a medium-term horizon, with figures that might be considered as accurate averages for the swerving course of the Brazilian economy. This is an important hypothesis for the application of the scenarios outlined above.

SIMULATION RESULTS

Scenario 1

Under Scenario 1, energy consumption in the industrial sector in 2010 rises at an annual rate of 2.7% over the period (Table 1). This is a reasonable result considering that this rate is very close to the 80's one, when national economy followed a low growing path. Energy intensity this year calculated in relation to industrial output reaches 0.304 toe/US$ - 1995.[7]

Food/beverages, non-ferrous metals, paper and pulp and other industries sub-sectors are those who have showed the highest growth rates. Since electricity remained the most-consumed source of energy in the industrial sector, sub-sectors that employ large parts of this source will consequently present a higher growth rate than the others, as it is the case for: Food and Beverages(3.3%), Non Ferrous Metals(3.2%), Paper and Pulp(3.4%) and Other Industries(3.9%).As a matter of fact, electricity accounts for some 48% of total consumption, although its growth over the period was lower than that recorded for 1980 - 1995 at 4.27% p.a., due to only minor gains in efficiency.

These results reflect the conservative hypothesis adopted for this crisis scenario, which works on the basis of low growth rates for the economy with no appreciable technological innovations in relation to either products and processes, as no sweeping changes occur in specific energy consumption in the main industrial processes or in the energy consumption sectors of the national energy system over the forecast period.

Additionally, the composition of Industrial Output [8] remains constant throughout the forecast period, equivalent to the figures for 1995, indicating that the variations in final energy by source are not affected by any alterations in the composition of Industrial Output for final energy consumption. This means that the variation in final energy consumption is due largely to the variation in economic activities. In the specific case of the industrial sector, it should additionally be stressed that products with lower added value predominate in the production profile, and the added value per ton of output remained constant or dropped overall among the sub-sectors, due to the predominance of less-processed products.

This means that percentage variations in the industrial consumption structure are

[7] Constant Dollar - 1995.

[8] The chemicals, pulp & paper, steel, non-ferrous metals & others (metallurgy), cement and ferroalloys subsectors account for over 40% of industrial output in 1995.

minor in this initial scenario

Table 1: Energy Demands - Industrial Sector - Scenarios 1, 2 and 3 (1000 toe)

	Scenario								
	1			*2*			3		
Sub-sector	**1995**	**2000**	**2010**	***1995***	***2000***	***2010***	**1995**	**2000**	**2010**
Food And beverages	14177	16676	23043	*14177*	*15013*	*28151*	14177	14889	25713
Ceramics	2981	3147	3477	*2981*	*3168*	*4583*	2981	3168	4634
Cement	2789	4622	6125	*2789*	*4556*	*7840*	2789	4442	7038
Ferro-alloys	2281	2281	2097	*2281*	*2281*	*1628*	2281	2281	1897
Ironsteel and steel	16577	20301	22651	*16577*	*20438*	*35131*	16577	20302	32660
Non-ferrous metals	9592	11240	15453	*9592*	*11417*	*16317*	9592	10920	14240
Mining & pel.	2771	3086	3694	*2771*	*3151*	*4174*	2771	2832	2620
Paper and wood pulp	6697	7919	11063	*6697*	*7669*	*13292*	6697	7669	13292
Chemicals	7944	8543	9434	*7944*	*8820*	*12197*	7944	8800	11968
Textile	2406	2547	2840	*2406*	*2826*	*5572*	2406	2686	4164
Other industries	8865	10799	15772	*8865*	*11019*	*21525*	8865	11105	22386
Total	77080	91161	115649	*77080*	*90358*	*150410*	77080	89094	140612

Scenario 2

In this scenario, total energy demand in 2010 at 150.4 Mtoe is 30.1% higher than the one for the previous scenario, up 4.6% p.a. (Table 1). Higher energy consumption under this scenario is due to the fact that it is based on the most vigorous economic growth rates with more significant technological innovations than the previous scenario.

Energy intensity this year calculated in relation to industrial output is more than 4% lower than the figure obtained in Scenario 1. This decrease of the energy intensity is due to the hypothesis that the production profile of Brazil's industrial sector is modified, with an increasing share being taken over by goods with higher added value, and a drop in specific consumption (toe/ton of product) among all sectors.

As we can see in Table 1, cement sub-sector shows the highest energy consumption growth rate (7.1%). This structure is fully coherent with the characteristics of this infrastructure sector, which reflects a close correlation with GDP development, and a performance that is generally more marked than that of the economy overall, meaning that during periods of economic growth it expands more than the country in general, and during times of recession, its performance drops below that of the GDP as a whole.

As far as the growth rates of ironsteel and food and beverages sub-sectors are concerned, since these sub-sectors use natural gas, any important change in the share of this source will be reflected in the sub-sector's growth rate. Therefore, as natural gas expanded its share of total industrial consumption from 2.54% in 1995 to 3.30% in 2010[9], and has the

[9] which reveals the increased penetration of this energy source in industry compared to the previous scenario

highest growth rate among the other sources (6.4%), this will affect these sectors. This is due to wider use of this energy source to generate process heat in the food & beverages sub-sector, as well as for cogeneration, at rates higher than those in the previous scenario[10]. A similar situation occurs in the chemicals sub-sector, where it should be noted that the growth rate for this energy source is higher in the second scenario.

In this scenario, it is stressed that the drop in the percentage share of the non-ferrous metals & others (metallurgy) sub-sectors in total industrial consumption is significant due to the high consumption of electricity by the aluminum industry, which is in fact reflected in the share held by electricity in total industrial consumption, down from 48% in 1995 to 46% in 2010. Another sub-sector showing an appreciable drop that reveals a trend to smaller-scale production in certain mature segments under this scenario is ferroalloys. This reflects the hypothesis that the composition of industrial output will alter over the course of forecast period: cement and other industries sub-sectors post an increase in their industrial output share; ferroalloys, mining & pelletizing, non-ferrous metals, chemicals, pulp & paper and textiles shrink,[11] while food & beverages[12], steel and ceramics all remain steady.

Scenario 3

Under Scenario 3, total energy consumption in 2010 reaches 140.7 Mtoe, 6.5% lower than the previous scenario and 21% higher than Scenario 1 (Table 1). The energy intensity calculated in relation to industrial output for the year 2010 is equivalent to 0.271 toe/US$ - 1995, being 6.8% below Scenario 2 and 10.8% below Scenario 1.

This is due to the fact that the GDP growth rate adopted is the same as that for Scenario 2, but with technological changes and the replacement of inefficient, more polluting energy sources by others that are cleaner and more efficient. The variation in the industrial output composition follows that of Scenario 2 in general lines. The main differences are found in the mining & pelletizing, steel and textile sub-sectors, which post a smaller share of industrial energy consumption than under Scenario 2.

According to our scenarios' hypothesis, in this scenario other industries sub-sector rises its share of GDP composition since it has a high added value and shows the highest energy demand growth rate (Table 1). Moreover, chemicals industry's share drops (its energy consumption growth rate is lower than in scenario 2) while its added value rises, which leads to a reduction in its physical output and a consequently lower energy consumption. Another important point is that electricity consumption rises at a lower rate than in the previous scenario, as is also the case for metallurgical coal and coking coal. In the first case, this reflects energy efficiency gains, particularly in the aluminum industry under the non-ferrous metals & others (metallurgy) sub-sector, with the gradual replacement of plants running on

[10] This scenario assumes that natural gas suplly will mainly come from the Brazil-Bolivia Gas-Pipeline, which should be carrying an average of 30 x 10^6 m^3/d by 2003. The natural gas price, according to specialists, should not exceed 2.7 US$/MMBTU, which garantees natural gas consumption in an optimistic scenario.

[11] Notice that Pulp & Paper sub-sector is affected by the Asian crises, which reduces Brazillian pulp exportation. In the case of the textile industry, which is one of the elderests industries in Brazil, we should remember that it has been suffering from a serious problem of technological obsolescence.

[12] Between 1990 and 1996, the food and beverages sub-sector product growth rate followed the GDP growth rate. This scenario assumes that this will continue until 2010.

the Söderberg Paste process by plants using PBA; and in the second case, this is due to the replacement of coking coal in the blast-furnaces used to produce pig iron and steel by charcoal-fired blast-furnaces, while the cement sub-sector recycles kiln exhaust gases. This results in an appreciable shrinkage in the share of the non-ferrous metals & others (metallurgy) sub-sector[13] in total energy consumption, reflected in the share held by electricity in energy consumption by the industrial sector, down from 48% in 1995 to 45% in 2010.

COMPARATIVE SUMMARY OF THE THREE SCENARIOS

Total Final Energy

As noted, based on the results presented, the distinction between the three scenarios occurs basically from the year 2000 onwards (Figure 1).

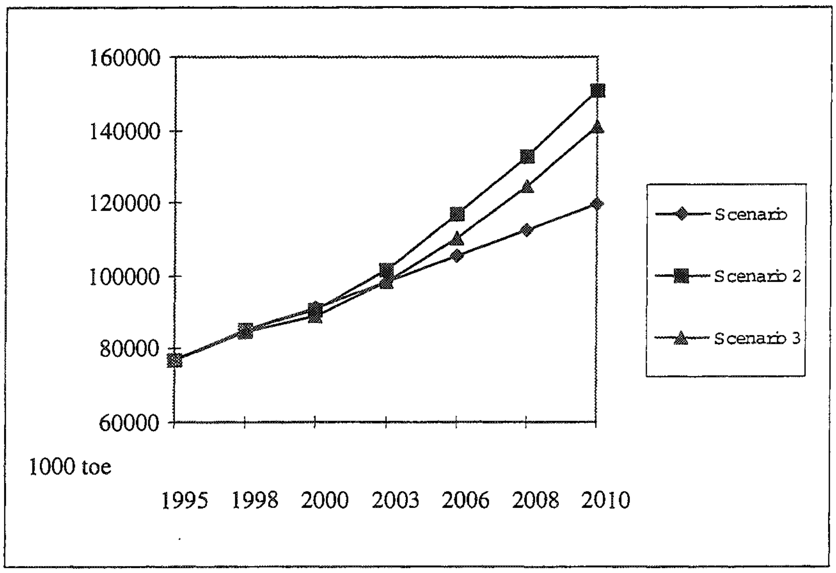

Figure 1: Total Final Energy Industrial Sector Consumption for the three Scenarios

Lower energy consumption is noted in Scenario 3 compared to Scenario 2, due to:

- *substitution of less efficient processes by more efficient processes in terms of converting final energy into usable energy, basically in the cement and aluminum industries;*
- *replacement of equipment and energy sources;*
- *efficiency gains in industrial processes;*
- *alteration in the product mix of an industry, as is the case, for instance in the pulp & paper industry, which is assigning top priority to producing goods with higher added value that are less energy-intensive, such as high-grade papers;*
- *reduction in the share held by some energy-intensive sectors in industrial*

[13] Electricity represents some 90% of energy consumption in the aluminum industry.

output;

- ***Greater use of cogeneration in the chemicals and food & beverages industries.***

Due to the importance of the effect of modifications to industrial processes with gains in efficiency in terms of specific consumption and substitution among energy sources, the results obtained for two selected energy sources are compared below. The main sources used in the industrial sector are: electricity (48.2%), fuel oil (10 %); cane bagasse (9.2%); fuelwood (6.4%) and natural gas (2.6%) due to the predominance of electric starter-motors, engines and heat-based processes during the base-year.

Share of two selected sources: Natural Gas and Electricity

This comparison of energy sources focuses on the development of the share in industrial consumption of natural gas and electricity (Table 2), which highlights the various energy consumption growth rates for the three scenarios under consideration.

Table 2: Growth rates for main energy sources 1995 - 2010

Growth rate (% p.a.)	Scenario 1	Scenario 2	Scenario 3
Final Energy	2.9	4.5	4.0
Natural Gas	4.4	6.4	7.9
Electricity	2.8	4.2	3.6

The expansion of **natural gas** in Scenario 3 is impressive. Its consumption increases mainly in the chemical[14] and food & beverages[15] industries, particularly in cogeneration plants, and throughout the industrial sector in general through the replacement of fuel oil consumed in industrial boilers. The arrival of gas may well ease out the consumption of fuel oil, although this energy source substitution is dependent on economic and environmental criteria. In Scenario 3, greater stress on environmental issues also explains the increased penetration of natural gas. In the other industries sub-sector, the shift from fuelwood to LPG and natural gas for producing process heat for cogeneration purposes is another factor boosting the share held by natural gas. In the cement sub-sector, natural gas is easing out fuel oil to some extent for direct heating in production kilns, and in the ceramics sub-sector there is a marked shift away from the use of fuelwood for firing pieces.

In terms of **electricity**, from the year 2000 onwards its share in total industrial consumption drops, compared to the previous two scenarios due to its replacement in processes used by the cement and aluminum[16] industries, as well as the shrinkage in the share of total consumption held by industries that are electricity-intensive.

In Scenario 1, electricity demands rose by 2.8 % a year, below the figure for 1980 - 1995, due to limited gains in efficiency: the non-ferrous sub-sector which accounts for 22.4%

[14] Replacement of fuel oil, mainly in electricity cogeneration trough topping systems.

[15] Replacement of fuel oil for process heat steam generation and direct heating.

[16] In fact, specific electricity consumption to produce primary aluminum drops from 4.4 toe/ton to 4.3 toe/ton.

of electricity demands in the base year introduced no substantial technological alterations. In Scenario 2, gains in efficiency are noted in high-consumption sectors such as non-ferrous metals and other industries, accounting for growth below the rate noted for the final demand. In this sense, Scenario 3 shows the most marked shrinkage, in function of the variation in the composition of industrial output, with a reduced share for the electricity-intensive segments. Due to major gains in efficiency in sub-sectors such as non-ferrous metals through upgrading PBA plants for primary aluminum production, electricity use rose more slowly than in Scenario 2. Additionally, good use is being made of cogeneration potential in sub-sectors such as pig iron and cement, reducing the demands for electricity supplied by the power generation segment by recycling kiln exhaust gases. This results in a difference of 6.5 million toe between electricity consumption in the latter two scenarios for the year 2010.

CONCLUSION

Like any analysis based on scenarios, this study is subject to weak points that are inherent in forecasting, due to difficulties in projecting economic situations over a twelve-year period. However, it should be stressed that as this is a highly disaggregated model, swings in the economic situation are more easily included, meaning that this forecast structure is not invalidated.

In fact, the development of energy consumption in Brazil's industrial sector is closely linked to the composition of its industrial output which, reveals a link between the course of Brazil's industrial policy and energy consumption nationwide. In fact, the comparison of the three scenarios highlights very different routes for the development of energy consumption, shaped by the GDP growth rate and the structure of its Industrial Output. The influence of the energy-intensive industries, which are generally focused on the foreign market, in total energy consumption by this sector endows these industries with an important role in the forecast. For instance, in Scenario 3 much of the shrinkage in electricity consumption by the industrial sector is due to the lower share of the aluminum industry under the non-ferrous metals & others (metallurgy) sub-sector in terms of industrial output.

However, regardless of the actual structure of Brazil's industrial output, there are potential gains in energy efficiency to be achieved over a horizon stretching to the year 2010. Outstanding among them are: the substitution of processes for converting final energy into usable energy in the cement and aluminum industries; alterations in the product mix of specific industries, as is under way in the pulp and paper industry, for instance; and finally, making better use of the cogeneration potential of the chemical and food & beverages industries. In fact, as presented, these measurements would allow a reduction in energy intensity within Brazil's industrial sector of some 6.4% by the year 2010.[17]

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[17] Difference noted between Scenarios 2 and 3, for which the same GDP growth rate was used.

revision of this paper

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