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Capital Stock in Latin America: 1950-2000
Marcos Souza e Aumara Feu

Carbon Balance in the Energy Transformation Centers
Carlos Feu Alvim, Omar Campos Ferreira e Frida Eidelman

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Article:

Capital Stock in Latin America: 1950-2000
Marcos Souza e Aumara Feu pag. 02

The capital stock is estimated according to the perpetual inventory method for Latin America countries from 1950 to 2000. The results show a significant decrease of the productivity of the capital from 1960 to mid eighties. From then on, the marginal productivity of the capital that was decreasing starts its recovery. The behavior is similar in Brazil, MERCOSUL and Latin America. If the trend is confirmed, the long run perspectives concerning growth will tend to increase.

Article:

Carbon Balance in the Energy Transformation Centers
Carlos Feu Alvim, Omar Campos Ferreira, Frida Eidelman pag 21

Carbon balance is an important instrument to identify the emission sources of greenhouse effect gases. Since energy use and transformation are fundamental for increasing these gases in the atmosphere, the carbon balance survey can be used to identify sectors and fuels to which priority should be given regarding emissions mitigation. In the case of transformation centers (installations where primary or secondary sources are converted into sub-products or other energy form) the balance indicated some problems regarding the Brazilian inventory calculation. Some problems concerning the National Energy Balance data used here were also identified.

Article:

Capital Stock in Latin America: 1950-2000

[i]

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SUMMARY

The present study calculates the capital stock, according to the perpetual inventory method, of the Latin American countries from 1950 to 2000, at the aggregated level and by type of machines and equipment and construction goods. The series obtained are used as input for analyzing growth in Latin American countries. Additionally, the investment composition and trend of the capital stock in the countries of the region as well as that of the average and marginal productivity of the capital are analyzed. The results show a significant decrease of the average productivity of the capital from 1960 to mid-1980 and show also that this decrease tends to revert if the larger marginal productivity observed in the 90s is maintained.

Key words: capital, investment, productivity, growth and Latin America.

Classification JEL: E22, O54

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[i] This article is part of Marcos Souza's PhD Thesis.

1. Introduction

Capital stock is an explanatory variable in most growth models of economic theory. According to Ferreira, Issler and Pessoa (2003), capital explains 49% of growth when it is considered in the ample sense and 21% when its indirect effect on productivity is not considered.

The weight of this factor on economic growth as well as its relative scarcity in developing countries make the estimate of capital stock, of average and marginal productivity of the capital necessary both for understanding the growth possibilities and for analyzing the growth experience of Latin America countries.

However, there are no series of capital stock that comprise the period and set of the countries analyzed in the present study: 1950-2000 and eighteen Latin America countries[ii]. De Gregório (1992), for example, cannot count on these data when he analyzes the economic factors regarding growth of 12 Latin American countries in the 1950-1985 period.

Nevertheless, Hofman (2000) supplies the capital stock for seven Latin American countries from 1950 to 1994 and so does the *Penn World Table* 5.6 (*PWT* 5.6,) for a sample of 63 countries, among which 13 are Latin American countries for the 1965-1992 period. However, we point out that the new version of the *Penn World Tables*, *PWT* 6.1*,* Heston et al. (2002) does not present the stock series.

Therefore, the aim of the present work is to estimate the aggregated capital inventory and the capital stock by type of goods: machines and equipment and construction goods by means of the perpetual stock method (PIM) for 18 Latin American countries (from 1950 to 2000).

The PIM consists of summing up the past investments, discounting depreciation and it was used for the first time by Goldsmith (1951). Due to its transparency and simplicity, It continues to be widely used in the literature, for example by Hofman (2000), Morandi and Reis (2004) and Aumara Feu (2003)[iii].

As investment is an input for determining the stock, we analyze the behavior and composition of this variable in the period and we also discuss the investment and capital stock effect on the behavior of the marginal and average productivity of the capital.

[ii] Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, El Salvador, Ecuador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay and Venezuela.

[iii] The latter describes in details the methodology for calculating the capital stock in Brazil, according to (PSM).

Preliminarily it should be pointed out that we have found a decrease of the average productivity of the capital in the period as a consequence of a smaller marginal productivity observed from 1960 to mid 1980. This smaller capital productivity would explain part of the poor economic performance in the region in the 1980s and 1990s. However, the good news is that in case the marginal productivity observed in the 1990s persists, we can expect an increase of the average productivity of the capital in the next years.

The present article is divided in four sections, including this introduction and the conclusion. Section 2 describes the methodology used in calculating the capital stock for the Latin American countries from 1950 to 2000 and Section 3 discusses some results such as the composition and behavior of the marginal and average productivity of the capital. The results are presented in the form of tables in the annexes and are analyzed in aggregated form for Latin America and MERCOSUL[iv], emphasizing some relevant behaviors by country, mainly Brazil.

2. Methodology

Application of PIM depends on three factors: (i) estimate of the capital lifetime considered as normal; (ii) depreciation function used for calculating capital depreciation along time and (iii) period of investment series available.

Concerning the first two factors, we will use the lifetime (v) estimated by OECD (1999): 19 years for machine and equipment (*M&EQP*) and 48 years for construction goods (*CONST*) and a linear depreciation function.

It will be assumed that the period when there is no depreciation, lag. period (*m*), is equal to 10% of the lifetime (v) of each good. Therefore, for machines and equipment and construction goods for which the considered lifetimes are 19 and 48 years respectively, there will be a lag of two and five years, respectively.

Hulten (1990), Jorgenson and Sullivan (1981) and Hofman (2000) use a one-year lag whereas OECD uses five years. However we have decided to adopt a fixed lifetime percent value.

On the other hand, in what regards the third factor, we describe in the present section the construction of investment series by country for the

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[iv] In the present article, each time that we mention MERCOSUL we are considering only Argentina, Brazil, Paraguay and Uruguay. MERCOSUL has developed from an economic approximation process between Brazil and Argentina in mid 1980 to the Assuncion Treaty in 1991 signed by Argentina, Brazil, Paraguay and Uruguay. In the XXVII Meeting of the Common Market Council, held in December 2004 in Belo Horizonte, Colombia, Ecuador and Venezuela became MERCOSUL Associate States.

period before 1950. For the moment, it should be made clear that for treating the capital stock as a function of the past investments (PIM) it is necessary a longer investment series.

As an example, for the year considered as the initial one (t_0) and the capital lifetime (v), it is necessary the past investments from v years on before t_0 years. That is, this would represent investments made 19 and 48 years before t_0 for *M&EQP* and for *CONST*, respectively.

Given the capital lifetime *(v)* and the lag period (*m*), exogenous to the model, we can calculate the capital depreciation rate (*o*) as the inverse of the depreciation time (*v-m*), that is, $d = 1/(v-m)$[v]. In this way, in the year *t* an investment made in year *r* will have the age corresponding to $t - r$ and, considering the lag time (*m*), the depreciation time will be $x = t - r - m$.

Graphic 1 represents the accumulated depreciation function (*D*), $D = f(d,x) = dx$, where $d = f(v,m) = 1/(v-m)$ and $x = f(t,r,m) = t - r - m$. This function shows the accumulated depreciation year after year and its image, the survival function (*S*), $S = f(D) = (1-D)$, shows the capital that has not been depreciated yet. As an example, in Graphic 1 we have fixed *m* = 2, *v* = 19 and consequently, $v - m = 17$.

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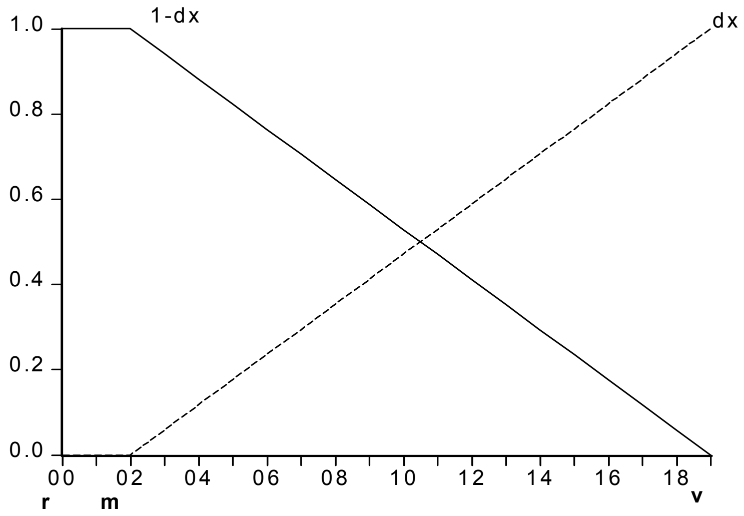
[v] The capital depreciation rate (*d*), in the linear function with lag, is constant from $(m+1)$ on, and the cumulative rate applied increases *d* annually until reaching unity.

Graphic 1: Accumulated Depreciation Function (*D*) and Survival Function (*S*)



Source: Aumara Feu (2003, p. 9).

We observe that when we adopt a depreciation rate with lag on the invested capital good, that is, zero depreciation in the lagging period and constant depreciation until the end of the capital lifetime, the total capital depreciation rate, δ, depends on the investment behavior and on the stock age variation. Therefore, in case of a positive shock on the investment of a country, the capital age of that country would decrease as well as the depreciation rate on that stock.

The behavior described above is due to the considered depreciation function. It would not be that way if the function were linear, without lag and constant depreciation rate on the capital good along the entire lifetime of the good. However, according to the OECD manual (1993) it does not seem plausible to assume that the goods would wear out at the same rate, mainly in the first years of the lifetime.

We also emphasize that *d* varies by type of good [vi] and δ, by type of good and by country. However, in order to simplify notation the formulas presented below do not present the distribution by type of good.

[vi] The distribution of the investment series by type of good can be obtained from available data banks. In the present work we have considered for Brazil the percent value of investment by type of good supplied by XX Century Statistics of *IBGE*

So, the capital stock will be calculated according to the capital movement equation:

$$K_{t+1} = \sum_{r=t-v}^{t} I_r - d\sum_{r=t-v}^{t-m}(t-m-r)I_r \ , \qquad [1]$$

where capital *K* in $t+1$ is given by the sum of past investments (*I*) still in the scraping process less the depreciation of these investments, according to the depreciation time of each type of good. The number of years on which the depreciation should apply, $x = t - m - r$, is given by the difference between the previous year (*t*), the lag time (*m*) and the date when the investment was made (*r*).

As mentioned before, the stock formula for the capital stock is based on the sum of past investments. So, in order to calculate the capital stock for construction goods in 1950 we need investment data relative to 1902.

These series are available only for six countries of the sample: :Argentina, Chile, Colombia, Mexico and Venezuela, from Hofmam (1992), and for Brazil, XX Century Statistic from *IBGE*[vii].

We emphasize that when dealing with several countries it is difficult to find aggregated time investment series by type of good and most authors like Ferreira, Pessoa and Issler (2003) and Young (1995) use an estimate of the initial capital and apply the PIM for the following years.

Therefore, for the remaining countries, the initial capital stock was calculated using Equation [1]:

$$K_0 = I_0/(g_i + \delta) \ , \qquad [2]$$

where the initial capital stock depends on the investment level in t_0, on the depreciation rate on the stock, δ, and on the investment growth, g_i.

We observe that Equation [2] assumes that the investment and depreciation rates do not vary with time. However, a constant investment growth rate is not observed in the developing countries that are subject to external shocks most of the time. In the same way, assuming a constant depreciation rate, it does not agree with the estimated rate using PIM with linear depreciation function and lag.

So, by assuming constant rates and fixing the initial year, which can represent an atypical year, Equation [2] biases the stock calculation result, mainly in the case of developing countries that are more subject to structural shocks.

As an exercise aiming at analyzing these questions, we have calculated the initial capital stock according to the two methods, namely PIM and Equation [2], for the six countries that had long investment series available. In this exercise, we have observed that the result differs in a significant way in the countries where the investment series present large variations along time.

We point out the difference persists but it decreases when one considers g_i as the average investment growth rate of the period, t_0 as the year in which the investment rate (*I/Y*) approaches the average value in the period and the average rate δ as a function of the investment behavior. These variables: g_i, t_0 e δ, differ from country to country and g_i, e δ, also vary by type of good.

The result described above shows the initial stock calculation using Equation [2], as well as its erosion from then on, must consider the investment behavior by country.

Therefore, in order to make a more accurate stock calculation for the countries whose investment series after 1950 are not available: (i) we calculate the initial capital stock according to Equation [2], and depreciate that stock by means of a constant depreciation that varies according to the country and the type of good (estimated as specified below) and (ii) adding to the surviving initial capital stock the investment made afterwards, depreciated by the PIM.

2003.For the other countries, we have found data for the years 1950, 1955, 1960, 1965, 1970, 1975 and for the period 1978 - 2002, in several volumes of *Statistical Yearbook for Latin America and the Caribbean*. Therefore, for most countries we have interpolated the investment participation by type of good in the total investment regarding years without data, except for Argentina, Chile Colombia, Mexico and Venezuela, whose data from 1978 to 2002 were incorporated to those made available by Hofmam (1992).

[vii] For 1950 – 2000 period, the *PWT* supplies the investment rate and *per capita* product series at constant 1996 prices, as well as the population of all the countries considered in the present study. Therefore, by multiplying the investment rate by the *per capita* product and by the population we have the investment series at 1996 prices for the 1950-2000 period for the Latin American countries. The investment series supplied by Hofmam (1992) and by *IBGE* were associated with those from *PWT*, according to the corresponding annual variation.

So, for countries that have investment series from 1950 on available, we have:

$$K_{t+1} = K_0(1+\delta)^{t-v} + \sum_{r=t-1950}^{t} I_r - d \sum_{r=t-1950}^{t-m} (t-m-r) I_r \ , \qquad [3]$$

where the stock is the sum of the depreciated initial capital stock, according to a constant geometric depreciation rate that varies from country to country and type of good, and the investments made after 1950 depreciated according to PIM[viii].

We still have to describe how the depreciation rates by country and goods applied to the initial capital stock was calculated. We have used the simplified form proposed by Alvim Silva (2004).

This form shows that, considering a linear depreciation rate on the investment and constant parameters in what concerns the lifetime and the investment growth rate, one can calculate a constant depreciation rate on the capital stock.

According to the author, considering the lifetime (v) and the average investment growth rate (g_i) in the period from t_0 to $t-v$, the depreciation rate δ can be calculated using the following equation:

$$\delta = \frac{(1+e^{c}+e^{2c}+....+e^{(v-1)c})}{(1+2e^{c}+3e^{2c}+....+ve^{(v-1)c})} \ , \qquad [4]$$

where $c = \log(1-g_i)$.

Actually we do not have data regarding investment and consequently data about the respective growth rate (g_i) for the period before $t-v$ in the case of the countries for which it was necessary to estimate the initial capital and depreciation rate applied on it. Therefore, for most countries we have used the product growth rate as a proxy of the investment growth rate[ix].

It should be also mentioned that for Bolivia, the Dominican Republic and Panama, for which data regarding the product for the period before t_0 were not obtained, we have used the average growth of the other countries, except Venezuela (petroleum-exporting country). So, we are assuming that the depreciation on the initial capital stock in these three countries is equal to the average value of the other countries.

[viii] We remember that in the econometric estimates we use 1960 as initial year when part of the investments before 1950 were already scrapped..

[ix] Data regarding product before 1950, were taken from Maddison (1995).

Therefore, we present in the Annex tables relative to the total capital stock series, the machines and equipment stock and construction goods for 18 Latin American economies in the 1950-2000 period, Tables 1, 2 and 3, respectively.

3. Discussing Results

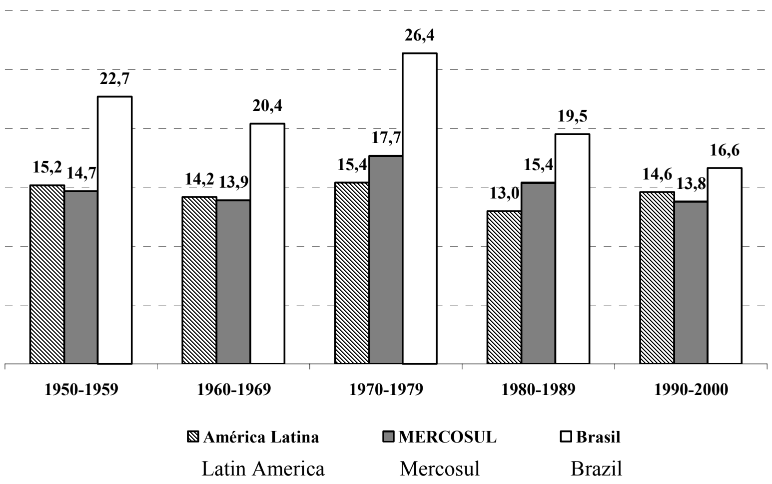
In what follows we will discuss some results of the capital stock obtained according to the methodology presented in the previous section. The capital stock is determinant in what regards long-run economic growth and, from what was deduced in the previous section, it is related in a direct way to the investment rate. Therefore, before presenting the capital stock results we will investigate the investment rate behavior in the 1950-2000 period in the Latin American countries.

It is necessary to mention that until the beginning of the 1980s the largest growth share in Latin America was explained by investment. According to De Gregório (1992, p. 67), in the 1950-1985 period Latin American countries grew at an average rate of 4.2% annually of which 51% are explained by investment, 30% by population growth and 19% by the total productivity growth of factors.

In the case of Brazil, Aumara Feu (2003) finds similar results: in the 1953-1980 period, it is imputed to the Brazilian growth, in the first place – the high investment rates -, and then to the total investment growth of the factors. The author emphasizes that the investment rate effect on growth achieved its potential through the capital productivity in the period.

In Graphic 2 we can see the evolution of the simple average, by decade, of the total investment rate (investment at constant price as a percent of the GDP) of the Latin American countries, of MERCOSUL and of Brazil.

Graphic 2: Total Investment Rate (%): 1950-2000



Source: *PWT* 6.1.

From this graphic we can infer that the total investment rate along the four decades is the same in the three levels, Latin America, MERCOSUL and Brazil: (a) it decrease in the 60s relative to the 50s; (b) it increase in the 70s, presenting the highest average level in the period and (c) it decrease in the 80s and 90s, except for Latin America, that presented a small recovery in the 90s[x].

We point out the high total investment levels in the region during the 70s, a period of fast growth in the region and the high levels in Brazil vis-à-vis the Latin American average along the period.

It should also be mentioned that, according to the Sachs-Warner (Sachs and Warner, 1995 e Wacziarg and Welch, 2003) liberalization indicator, between 1985 and 1996, sixteen Latin American countries were opened to the world economy. Moguillansky and Bielschowsky (2001) denominated this period the transition period, a phase in which the reforms implemented in the region affected the behavior of the economic agents.

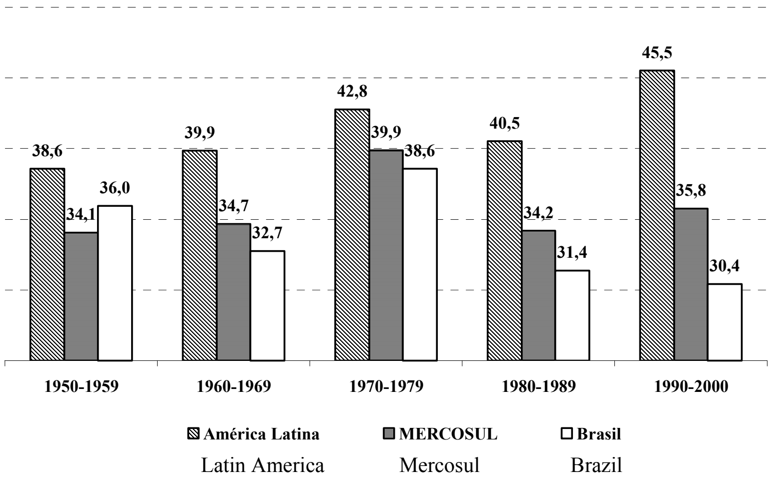
The transition period varies according to the country and, according to Moguillansky and Bielschowsky (2001), it can be divided in two phases: the first one is the rationalization of production and decrease of investment rate and the second one is the modernization of equipment by the enterprises and increase of investment rate.

For most countries of the region, the first phase occurred between mid 1980 and beginning of 1990 and the second one, in the 1990s. In the Latin American case, the behavior concerning investment described by the authors can be observed in Graphic 2.

However, in what concerns Brazil and MERCOSUL, this behavior is not observed in the graphic. This fact can be explained by the delay in the modernization process that, according to Moguillansky and Bielschowsky (2001), started in 1995.

We present in Graphic 3 the behavior of the ratio between investment regarding machines and equipment and total investment. The examination of this ratio is relevant for understanding the stock behavior of this type of good and also because of the empirical evidence of the positive and strong association between investment on equipment and growth[xi].

Graphic 3: Average of the Ratio between Investment in Machines and Equipment and Total Investment (%): 1950-2000



Source: *PWT* 6.1.

As can be observed in the graphic above, except for the 1980s, the Latin American countries have gradually increased the share of total

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[x] The investment recovery as a proportion of the GDP in Latin America is due mainly to the positive variation observed, in decreasing order, in Panama (variation of 80.1% between the 90s and the 80s, corresponding to 10.4 percent points of the GDP in the country), in Chile and in Honduras.

[xi] The empirical evidence can be found in contributions from De Long and Summers (1991) and (1993). According to these authors the nations that have contributed to investments in a more intense way in equipment had a faster growth in the 1960-1985 period relative to those that had the same development level and did not invest. Jones (1994) gives evidence of strong and negative relation between machine price and growth.

investments for machines and equipment, namely from 38.6% in the 1950s to 45,5% in the 1990s[xii].

In the case of the MERCOSUL countries and Brazil there is no defined trend. The share of total investment for machines and equipment in the MERCOSUL member countries follows the behavior observed in the Latin American countries but has small variation, average of 15.1% and the variation coefficient is 0.1% in the period

In Brazil the percent variation of investment for machines and equipment is larger in the 1960s, increases in the 1970s, reaches its maximum value, and decreases in the two following decades; the variation has average value of 21.0% and the variation coefficient is 0.2% in the period.

Analysis of the two graphics presented above shows that in Brazil the production percent for investment is higher than the Latin American average but the share of this investment for machines and equipment is lower than the average in the region.

This characteristic of the Brazilian investment relative to the Latin American average is reflected in the capital stock composition. Table 1 shows the percent of the capital stock of Latin America, MERCOSUL and Brazil, composed of machines and equipment in 1960 and in 2000 and the GDP growth rate in the 1960s and 1990s.

Table 1: GDP growth rate and Proportion of Stock in Machines and Equipment in the Capital Stock(%)

Periods	*Stock in M&EQP*		*Growth*	
	1960	*2000*	*1960-1969*	*1990-1999*
Latin America	31,26	29,25	5,37	3,35
MERCOSUL	29,42	21,30	4,26	3,53
Brazil	26,14	17,17	6,97	1,99

Source: Estimates calculated by the authors.

In this table we point out the reduction of the capital stock share composed of machines and equipment between 1960 and 2000 in Latin America and mainly in MERCOSUL and Brazil. We emphasize that as the

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[xii] The main countries that have influenced the investment behavior for machines and equipment in the region were, Panama, Costa Rica and Honduras (positive effect) and Peru, Venezuela, Ecuador and Brazil (negative effect).

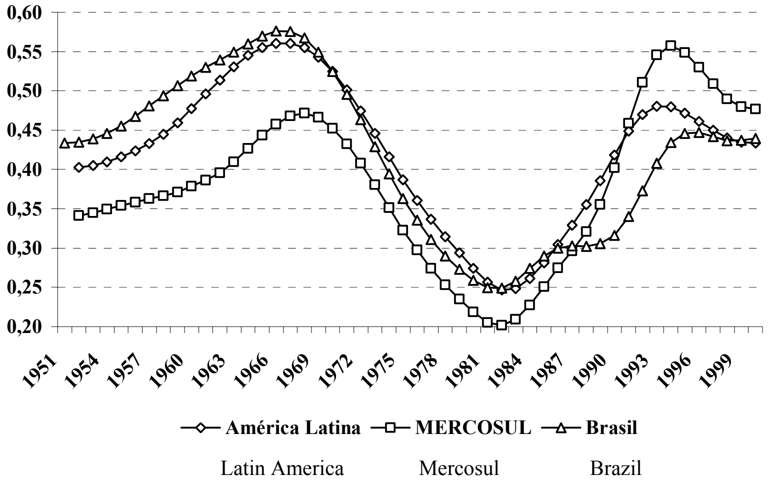
share of investment in machines and equipment in Latin America has increased in the last decade, the share of machine and equipment stock should also increase in the next years.

It should be remembered that the change in investment type and consequently in the composition of the capital stock limits the perspectives of growth in the future due to the clear positive correlation with investments in machines and equipment.

The data of the table above support this evidence by showing that from 1960 to 2000 the stock share of machines and equipment has decreased as well as the region's growth. One can consider that the larger investment in machines and equipment in the last decade in Latin America can be an indication of a larger growth in the region in the next years and also that the investment decreases in this type of good in Brazil is not an optimistic indication for the country.

In what follows , in Graphics 4 and 5, we present, respectively, the marginal product of capital (*MPK*), the relationship between the annual product variation and the annual capital stock variation [xiii], and the average product of capital (*APK*), the ratio between the product and capital stock (inverse of the capital/product ratio), for Latin America, MERCOSUL and Brazil, for the 1951-2000 period.

Graphic 4: Marginal Product of Capital (*MPK*): 1950-2000



Source: Estimates calculated by the authors.

In Graphic 4 one can establish three well defined phases of the *MPK* behavior in Latin America, MERCOSUL and Brazil: (i) increase

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[xiii] Both series were fitted using the Hodrik-Prescott filter.

between 1950 and 1968; (ii) decrease at the beginning of the 70s until mid 80s and (iii) increase in the second half of the 80s until mid 90s. Furthermore, in the second half of the 90s, the *MPK* starts a new decreasing trend but that seems to stabilize at the end of the period.

In Latin America and Brazil the peak of the marginal product of capital occurs in the second half of the 60s whereas in MERCOSUL the maximum value occurs in 1994. In what concerns the *MPK* level difference we observe that until the beginning of the 90s, Brazil and Latin America alternated at the highest level. Presently, this value for MERCOSUL is higher than that of Latin America and Brazil.

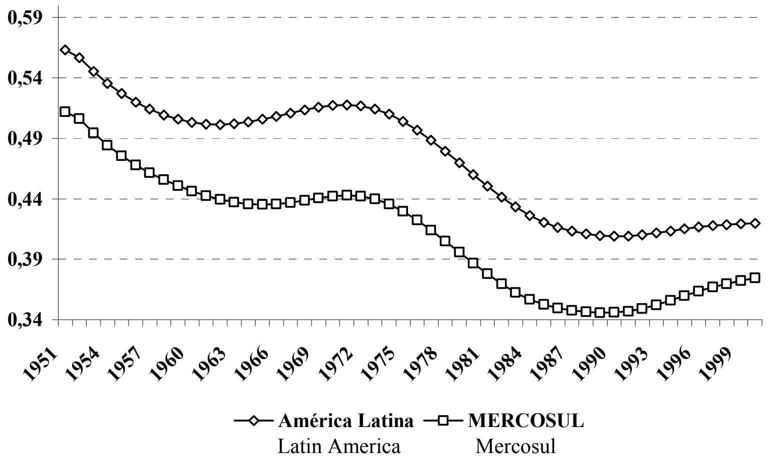
The peak observed in MERCOSUL in 1994 as well as its marginal productivity increase in the 90s is a result of the *MPK* increase observed in Argentina between mid 80s and mid 90s. We point out that the weight of Argentina in the MERCOSUL *MPK* is weighted using the relative income of the country in the region[xiv].

Therefore, according to this proxy for the *MPK*, until the beginning of the 90s the capital revenue was higher in an average Latin America country than in the MERCOSUL countries. As the theory forecasts a higher *MPK* for countries with lower income, this difference was expected due to the relative poverty of an average Latin America country vis-à-vis the Argentina, Brazil , Paraguay and Uruguay bloc.

However, the argument is not sustained in the 90s, since the marginal product of capital in MERCOSUL is higher than that of Latin America. It should be remembered that the measured *MPK* is an approximation in the same way that this result for MERCOSUL may be related to the investment rate decrease or to the intensity and characteristics of the liberalization process that occurred in the region in the 90s.

[xiv] Calculation of p marginal productivity presented: sum of the net investment variation in the region divided by the sum of the product variation, weights the participation of each country according to relative income of this country in the considered sample. So, the marginal product of capital trend reflects the behavior of the countries with highest income like Brazil, Mexico and Argentina.

Graphic 5: Average Product of Capital (*MPK*): 1950-2000



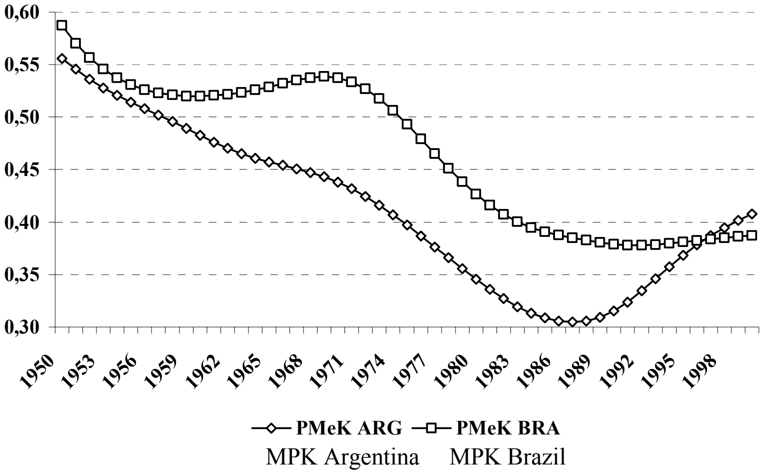
Source: Estimates calculated by the authors.

The *APK*, inverse of the capital/product ratio, has a decreasing trend similar in both of its subdivisions: Latin America and MERCOSUL. In the 90s, the *APK* series seems to be in a stable lower plateau. In MERCOSUL, after reaching the lowest value in the 1989 period, the *APK* presents a slight increasing trend. This was influenced by the Argentine *APK* as shown in Graphic 6.

Therefore, Graphic 5 suggests a change in the *APK* level of the Latin American countries in the last four decades. While the Latin American countries at the beginning of the 60s needed 2 units of the product to generate 1 unit of product, presently they need 2.4 units. The decrease of the average product of capital (16.7%), in spite of the fact that it is foreseen by the theory concerning developing countries[xv], limits the present and future growth when the capital scarcity in the region is taken into account.

[xv] Latin America has grown 5.7% annually on the average in the 60s.

Graphic 6: *APK* of Argentina and Brazil: 1950-2000



Source: Estimates calculated by the authors.

It should be pointed out that, according to Aumara Feu (2003) and Morandi (2004), Argentina and Brazil would have reached the same *APK* value of the developed countries. So, since Brazil and Argentina have a low relative per capita capital income, a *APK* value similar to that of developed countries and a capital factor scarcity, the expected growth was hindered in both countries.

However, we clear out that the *MPK* increase observed in Graphic 4 since the beginning of the second half of the 80s in Latin America, including that of Brazil and Argentina, will be reflected in the *APK* value along time.

Since the average product of capital is a stock variable whereas the marginal productivity is a flow variable, it also should be remembered that incorporating more productive capital to the stock will increase the aggregated value capacity in a gradual way. So, if it is confirmed the *MPK* stability in a higher plateau, the perspective of growth in the long term for both countries will have a higher trend.

4. Conclusion

In the present work we have calculated the capital stock series for 18 Latin American countries. In the methodology adopted, that uses as input the investment by type of goods, machine and equipment and construction goods, we have observed a decrease of investment as a proportion of the GDP in the 80s in Latin America, MERCOSUL and Brazil. In the 90s the decreasing trend persisted, except for Latin America, where it is noticed a small recovery due to a higher investment in some countries like Panama, Chile and Bolivia.

In Brazil we point out the high investment level as a proportion of the GDP as compared with Latin America and MERCOSUL, the decreasing trend of this level as well as the decreasing participation in machines and equipment in the total investment of the country, mainly in the last decade. The investment behavior in Brazil would influence in a negative way the growth perspectives considering the positive correlation between investment and growth according to De Long and Summers (1991) and (1993), if the types of invested goods are machines and equipment.

On the other hand, in Latin America we observe the trend towards increasing investment in machines and equipment as a proportion of total investment as well as the low investment recovery as a proportion of the GDP in the last decade. This trend, even though not confirmed for MERCOSUL and Brazil, is a favorable indicator concerning growth in the region.

We can also infer from the capital stock series calculation that the marginal product capital has decreased between the end of the 60s until mid 80s. This behavior has produced a decrease of the average product of capital that seems to have changed its plateau in the last four decades. The average product of capital decrease (16.7%) would in part explain the weak performance of Latin America in the 80s and 90s.

It should be mentioned, however, that from mid 80s on the marginal product of capital (flow variable) increased. So, in case this result persists as time goes by, soon it will have reflexes on the average capital productivity (stock variable). In this way, should the growth trend be confirmed or even if the marginal product of capital stays in higher plateaus, *ceteris paribus,* the long term perspectives of growth trend for the region will become higher. It should be mentioned that in parallel studies we are analyzing the influence of the capital stock behavior, as well as the commercial liberalization, on the economic growth of Latin American countries in the 1950-2000 period.

Annexed Tables available at Internet: http:ecen.com/eee50/eee50p/ecen_50p

Table 1: Capital Stock in Latin America: 1950-2000 (in constant million 1996 dollars)

Table 2: Capital Stock in Machines and Equipment in Latin America: 1950-2000 (in constant million1996 dollars)

Table 3: Capital Stock in Construction Goods Latin America: 1950-2000 (in constant million 1996 dollars)

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Article:

Carbon Balance in the Transformation Centers

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Introduction

In the No 48 issue of this periodical were published the first results of the study made under the agreement between the MCT and Economy and Energy and they were presented to that Ministry in February 2005. The carbon atoms are conserved in all steps of its cycle. This is also true in what concerns energy in the National Energy Balance (BEN) because what happens is the transformation from one form of energy into another and the energy used in the transformation is accounted for in the energy sector.

The transformation centers are not treated in a homogeneous way in BEN. In some cases it is possible to carry out separately the carbon balance of the raw material and its sub-products (emissions are accounted for in the Energy Sector as a whole); in other cases, emissions must be calculated by the center itself. In what follows, the structure and nomenclature adopted by BEN are listed.

Types of Transformation Centers

BEN has the following types of transformation centers:

- Petroleum Refineries,
- Natural Gas Plants,
- Gasification Plants,
- Coke Plants,
- Distilleries,
- Charcoal Plants,
- Public Service Power Plants,
- Auto-producers Power Plants,
- Nuclear Fuel Cycle,
- Other Transformations

From the carbon balance point of view we can distinguish three (or four) types of transformation:

- Transformation units where carbon enters as a component of the raw material and comes out in the form of a product where the emission of gases containing carbon is not accounted for; in this type of transformation there is no gas emission to the atmosphere (the first five types above);

- Units where it is necessary to account for the sub-products and waste gases containing carbon at the output (charcoal kilns);

- Units that can be treated as consuming centers, where there is no carbon contents in the products (public service power plants and auto-producers).

Finally, there are units such as hydroelectric and nuclear generation plants where there is no carbon both in the input and output and which should not be considered in the carbon balance. The emissions from ancillary equipment of these units such as diesel generators and others should be accounted for in other units such as those corresponding to the Energy Sector.

We will verify that in transformation units of the first type there is an accounting artifice where the emissions are accounted for in the Electric Sector.

In what follows some types of transformation centers will be presented in order to illustrate the adopted approach. It is interesting to notice that even in the case of some transformations where emissions do not appear in the accounting, the balance calculation can be useful because in the process it is verified the coherence between the input data (used in the approach that accounts for the intermediary products) and the results obtained from coefficients determined from the national emission calculation inventory that is assumed to be based on emission measurements (bottom-up) evaluated for a fuel type in the sector, except for cases in which the lack of data has required the use of generic coefficients for its determination.

Figure 1 presents the calculation scheme of Carbon Balance in a petroleum refinery.

The petroleum compounds, used as energy source in the refinery itself, are accounted for as product (output) even though energy consumption and emissions occur physically in the refinery itself. The part consumed in the refinery is recorded as “input” in the Energy Sector accounting, where emissions are recorded as well. The carbon balance must equate for the system composed by the refinery and the Energy Sector.

A similar case occurs in the (humid) natural gas processing units where some liquid sub-products are extracted and that can be directly incorporated to the commercialized products as liquefied petroleum gas (LPG), gasoline or naphtha, a fraction that is treated by refineries and natural gas denominated “dry” (fundamentally methane and ethane).

The "Energy Sector" entity is still used to record all consumption in units connected with it – including transformation centers. This consumption does not include the 'transformed" energy[xvi] which is treated in the corresponding accounting centers.

Carbon Balance in a Petroleum Refinery

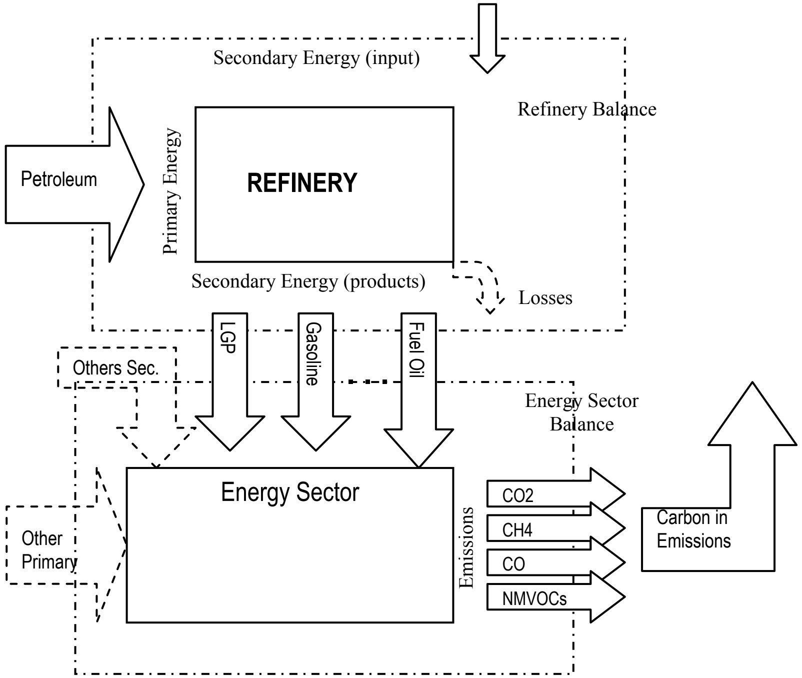

Figure 1: Balance regarding refineries and the Energy Sector

It is also interesting to notice that for petroleum and its "non energy" products that are part of the energy balance, this procedure will be followed in the carbon balance[xvii]. The fact that the treatment is not uniform for all sources requires some methodological adaptations that will be mentioned in due time.

In Figure 2, it is shown the scheme adopted by BEN for distilleries and the carbon balance calculation is illustrated.

Carbon Balance in an Alcohol Distillery

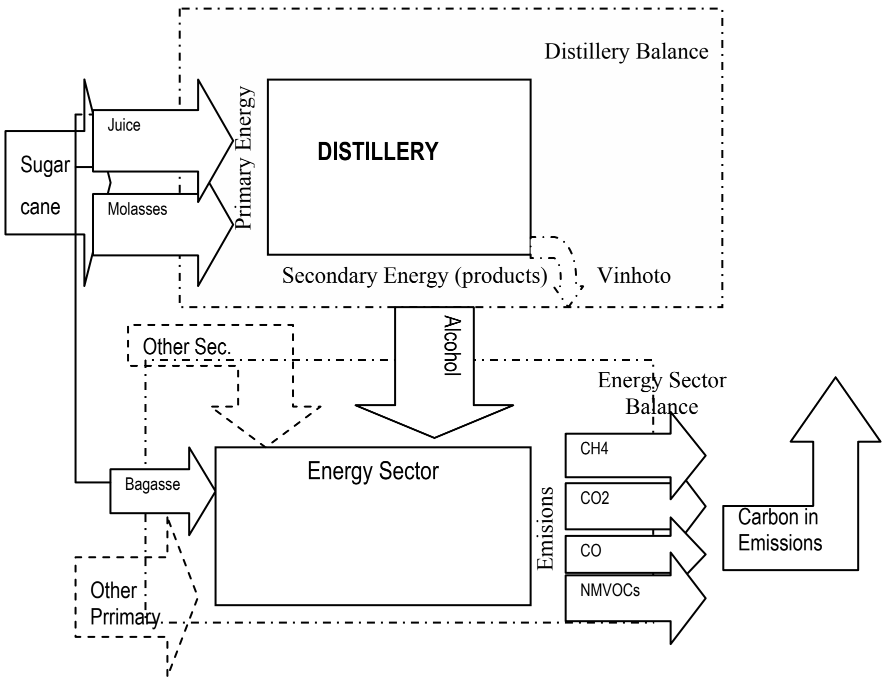

Figure 2 Carbon balance scheme for distilleries, showing that the "sugarcane products" (BEN's denomination) are considered as different forms of primary energy. Bagasse is accounted for in the Energy Sector but *vinhoto* (waste by-product from alcohol distilling) is not explicitly mentioned in BEN. Molasses (sugarcane concentrate present in distilleries annex to sugarcane plants) is also considered as primary energy.

In coke plants (coke production from mineral coal) carbon is accounted for as coke products and the gas that is partially consumed in the process is accounted for in the energy sector. So, it is hoped that the carbon balance can be carried out at this level.

It is hoped that residence gas production (a more noble gas than natural gas distributed for consumption) can also be treated as a carbon balance center. The diversity of raw materials used along the years in this process and the variation of their composition should however cause difficulties in

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[xvi] In the case of refineries, because it regards chemical reactions, where heat generation (consumed energy) and the transformation change of hydrocarbons constitution do not have a defined threshold. The specification of an intermediary product (as fuel oil) in order to be accounted for as a refinery product and energy source used in the energy sector is actually an accounting artifice used to organize an energy balance. In fact, the advantage of introducing the energy sector in the (energy) balance is that it makes the transformation centers accounting more elegant by accounting losses as consumption in the energy sector.

[xvii] The same thing does not happen, for example, with sugar which can be considered as a "non energy" sugarcane product (at least from the energy balance point of view).

the accounting of this type of unit. It should be remembered that this fuel is disappearing in Brazil because of the dry natural gas that is directly distributed to consumers (adaptations in the network and in the appliances were necessary)

In the case of charcoal plants the primary energy (firewood) is transformed into charcoal through partial burning. There is no intermediary product that is adequate to transfer consumption to the energy sector (a part could be credited to carbon monoxide – CO, but this is already done). Furthermore, all gas is used in the transformation process or directly emitted. The carbon balance must be calculated by adding the carbon contained in the product to that constitutes the emissions, as indicated in Figure 3.

Carbon Balance in a Charcoal Plant

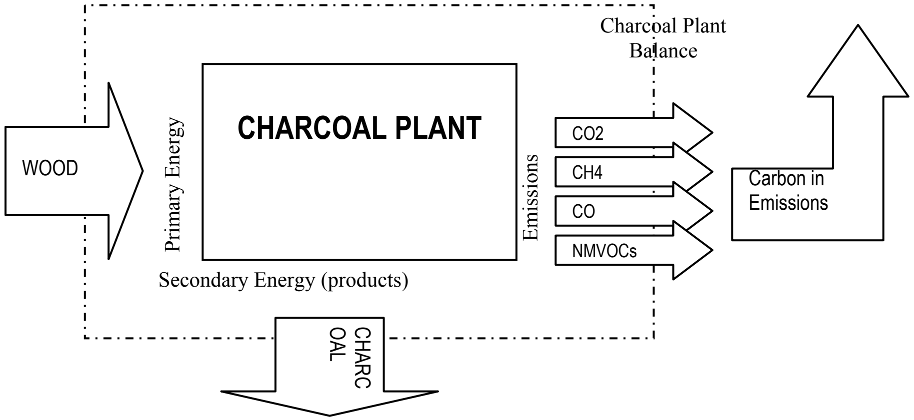

Figure 3: Carbon Balance in a Charcoal Plant.

For electricity generation plants the input values corresponding to the fuel used are available. The carbon balance – which we are dealing with – can be calculated in these units in the same way that it will be done in the consuming sectors because the product (electricity) does not contain carbon. The carbon balance scheme is shown in Figure 4.

Carbon Balance in an Electricity Power Plant

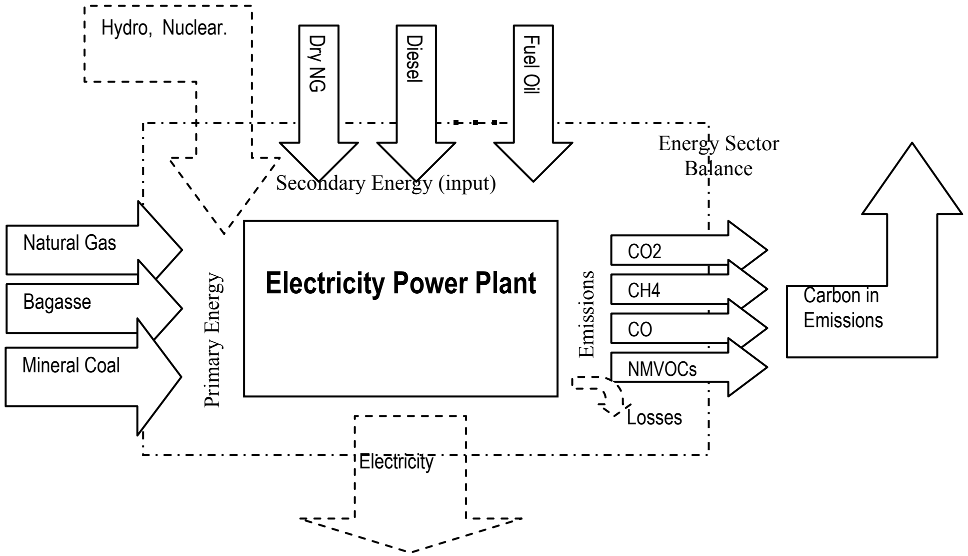

Figure 4: Carbon balance scheme in electricity plants; in the case of auto-producers the balance unit can be "virtual", located, for example, in an industrial plant. The hydroelectric and nuclear input and the "electricity" product that are part of the energy balance do not contribute to the carbon balance The dashed lines products indicate, in this case, the values not included in the balance. In the case of losses, they should be included in the differences found in the carbon balance.

Based on what was described above, the carbon balance calculation in some transformation units does not involve emissions and it can be carried out from the results of the contained carbon and they will be presented in what follows for the 1970-2002 period.

Carbon Balance in the Refineries

For five transformation centers it is possible to calculate the carbon balance before emissions. The main centers are petroleum refineries.

Table 1 shows the energy and carbon balance for 2002 and also the coefficients in tC/toe (toe of 10000 kcal) or in tC/TJ (1 cal = 4.1855 J).

The carbon balance value has the same precision as that of the energy balance. This can be seen in Table 2; this is also true for the previous years. Furthermore, the carbon balance is negative, which is compatible with transformation losses that are not recorded in BEN. For the petroleum processed between 1970 and 2002 the carbon balance has a difference of only – 0.8% and an average quadratic deviation of 1.0% in the annual values.

Table 1: Energy and Carbon Balance in Petroleum Refineries in Brazil in 2002

	ENERGY thou toe	C MASS thou t (Gg)	tC/toe	tC/TJ
INPUT	84002	70225		
PETROLEUM	83076	69543	0,837	20,0
OTHERS RECOV..	926	682	0,737	17,6
OUTPUT	82939	69558		
DIESEL OIL	27330	23106	0,845	20,2
FUEL OIL	17083	15087	0,883	21,1
CAR GASOLINE .	14445	11427	0,791	18,9
AVIATION GASOLINE	54	44	0,816	19,5
LPG	4657	3353	0,720	17,2
NAPHTHA	6716	5622	0,837	20,0
ILLU. KEROSENE	187	153	0,820	19,6
AVIATION KEROSE	2978	2431	0,816	19,5
REFINERY GAS	3222	2455	0,762	18,2
PETROLEUM COKE	1585	1825	1,151	27,5
OTH. IN PETROLEUM	382	320	0,837	20,0
ASPHALTS	1641	1511	0,921	22,0
LUBRICANTS	728	610	0,837	20,0
SOLVENTS	536	448	0,837	20,0
OTH. NOT IN.PET.	1395	1167	0,837	20,0
BALANCE	-1064	-667		
BALANCE (%) (*)	-1,3%	-1,0%		

(*) (Output-Input)/Input

In Table 2 are presented the carbon balances for refineries in chosen years. Besides the round years (final of decade) the 1990 and 1994 (extreme years of the inventory calculation), 1999 (year when there exist soma evaluations) and 2000 (last calculated year) years were chosen.

Table 2: Carbon Balances for selected years (Carbon Mass in thousand Gg)

	1970	1980	1990	1994	1999	2002
INPUT	21376	46335	50807	54729	68474	70225
PETROLEUM	21376	46335	50711	54326	68022	69543
OTHERS RECOV.	0	0	96	404	452	682
OUTPUT	20817	45876	50784	54047	67824	69558
DIESEL OIL	4798	14146	17804	19282	22748	23106
FUEL OIL	7418	14537	10785	10760	14859	15087
CAR GASOLINE	5822	6792	7050	9076	11278	11427
AVIATION GASOLINE	0	0	46	65	60	44
LPG	708	1952	2504	2887	2955	3353
NAPHTHA	58	2546	5254	4634	6475	5622
ILLU. KEROSE	523	437	167	111	53	153
AVIATION KEROSE	547	1789	2070	1929	2496	2431
REFINERY GAS	177	893	1612	1890	2064	2455
PETROLEUM COKE	0	0	528	636	1328	1825
OTH. IN. PETROLEUM	25	315	3	0	7	320
ASPHALTS	0	0	1141	1186	1375	1511
LUBRICANTS	0	0	572	599	598	610
SOLVENTS	0	0	202	285	298	448
OTH. NOT IN.PET.	742	2469	1046	705	1228	1167
BALANCE	-559	-459	-22	-682	-650	-667
BALANCE (%) (*)	-2,6%	-1,0%	0,0%	-1,2%	-0,9%	-1,0%

(*) (Output-Input)/Input

Carbon and energy balances have, besides that, a very similar behavior along time (Figure 5) what indicates that the coefficients used seem to be valid, in spite of the large variations of the fuel characteristics used in Brazil (mainly in what concerns diesel oil) in the studied period. This change in the fuel characteristics occurred mainly in the period of the petroleum crisis when alcohol fuel (substituting gasoline) and the vigorous process of fuel oil substitution caused an increase in the diesel oil participation in petroleum products consumption. Furthermore, there was (and still there is) a substantial advantage in the price of this fuel by traveled kilometer. Figure 5 shows that in spite of the fuel variations along time, the carbon balance is very similar to that of energy. That is, the variations in the carbon balance are due mainly to variations of the energy accounting and not to the parameters relative to the carbon content.

It should be noticed that BEN presents data concerning carbon content of fuels along the years (toe per m^3 or kg). These data are used in the calculation of carbon content and partly correct these variations. The same may occur when – as it happens in the case of humid natural gas – the transformation from "natural units" (of mass or volume) uses a constant coefficient for converting energy along the years.

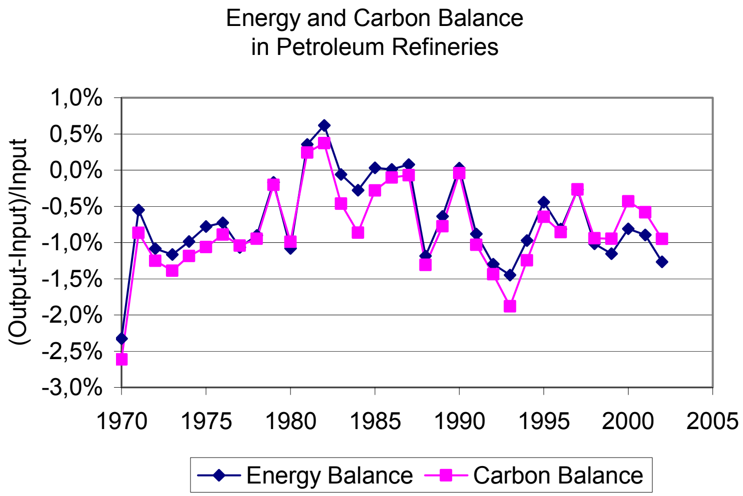

Figure 5: The energy and carbon balances show a similar behavior along the years and a low mass deviation. This indicates the good choice of the carbon content coefficients and the little influence of the different characteristics of fuels in the refineries' carbon balance.

Carbon balance in the natural gas processing units (NGPU)

In the NGPU liquids are extracted from raw (humid) natural gas which condensate at room temperature and (dry) natural gas is produced, mainly methane and ethane. The liquid fractions can be directly incorporated to some products (LPG, naphtha, etc) or processed in refineries. As can be observed in Figure 6, the last option seems to be the preferential destination in recent years, probably because it facilitates the homogenization of the commercialized products and simplifies the NGPU operation.

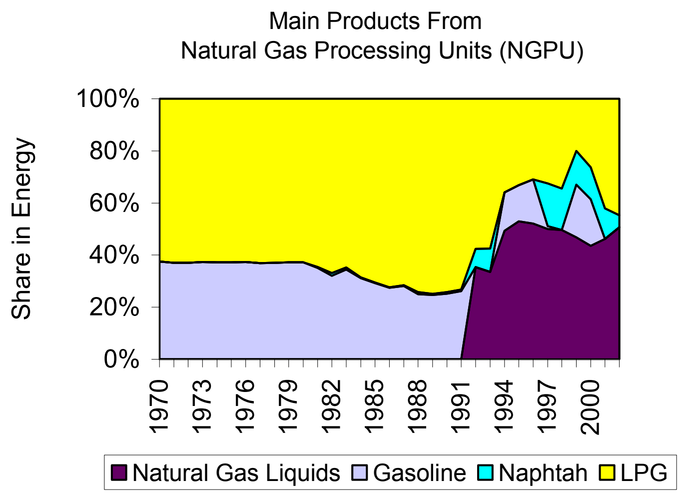

Figure 6: From1992 on about half of the NGPU products in Brazil are constituted by the fraction of natural gas condensates that are listed in BEN as refineries raw material inputs.

The energy and carbon balances are shown in Table 3 for 2002, as well as the factors used to calculate them.

Table 3: Energy and Carbon Balances in the NGPU in 2002.

	ENERGY thou toe	C MASS thou t (Gg)	tC/toe	tC/TJ
INPUT(HUMID NAT.GAS)	**10125**	**6738**		
OUTPUT	**9837**	**6453**		
DRY NAT. GAS	8181	5239	0,640	15,3
OTHERS RECOV..	836	616	0,737	17,6
CAR GASOLINE	0	0		
LPG	755	543	0,720	17,2
NAPHTHA	66	55	0,837	20,0
BALANCE	-287	-285		
BALANCE (%) (*)	-2,8%	-4,2%		

(*) (Output-Input)/Input.

In Table 4 the carbon balance is shown for the chosen years.

Table 4: Carbon Balance in chosen years (mass in Gg)

	1970	1980	1990	1994	1999	2002
INPUT(HUMID NAT. GAS)	380	894	2825	3352	4430	6738
OUTPUT	407	940	2884	3382	4501	6453
DRY NAT. GAS	304	718	2219	2625	3442	5239
OTHERS RECOV.	0	0	0	325	413	616
GASOLINE	28	60	134	98	178	0
LPG	47	102	394	237	177	543
NAPHTHA	0	0	3	0	114	55
BALANCE	-2	-14	-75	-68	-107	-285
BALANCE (%) (*)	6,9%	5,1%	2,1%	0,9%	1,6%	-4,2%

(*) (Output-Input)/Input

In Figure 7 it can be observed than for most of the years the energy balance does not present deviations above expectations except for the last three years. This variation can be considered important and should be due to inadequate values of the lower calorific value in the energy balance itself. Actually it is expected that in the graphic representation the variations due to the energy balance are shown in "parallel" (same direction) curves. In what concerns carbon content, it would be shown in approximation or distance of the curves. This fact (approximation of the curves) seems to be the case in the mentioned figure and it can be explained by the variation of carbon content in the humid gas.

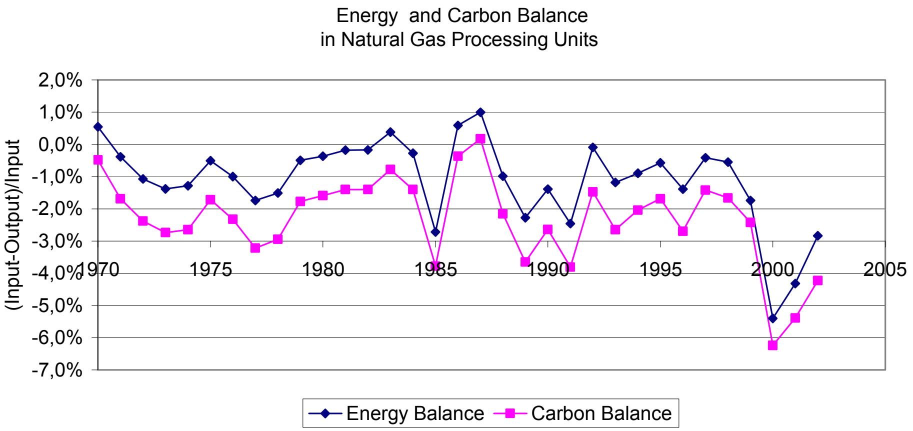

Figure 7: Carbon and energy balances in the NGPUs in Brazil, showing that some deviations in what concerns carbon can be due to the differences of that of energy. It seems also that there is a systematic shifting component between the two balances due to inadequate carbon coefficients.

In 2002 the quantity of processed gas in the NGPUs (6,7 thousand Gg) corresponds to 4.6% of the total carbon mass of the fuels used (gross internal offer) in Brazil. Errors around 6% (as those of 2000) represent 0.3% inaccuracy on the whole. As natural gas is a fuel of growing importance, it would be necessary to pay more attention to the subject [xviii].

Carbon Balance in the Coke Plants

Metallurgical coal is converted into coke (used for steel fabrication) in charcoal kilns in a distillation process without oxygen. As sub-product are produced gases, which are used as fuel in steel plants and in the coking plant itself, and liquids. The energy and carbon balances are shown in Table 5 for the year 2002.

Gases are listed in the balance as coke plants gas and the liquids are listed as tar. BEN has opted to consider them as fully consumed in the steel industry (and nothing in the energy sector). Since a specific coefficient is not available, it was chosen the default coefficient for petroleum for the

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[xviii] Concerning natural gas, problems regarding the apparent inconsistency about the difference between the high and low calorific values and the expected carbon content were identified . It should also be noticed the consistency of the calorific values along time. These values should in principle vary according to the origin of the natural gas (contained products that are condensable at room temperature).

inventory. The same coefficient was used for carbon balance.

Carbon balance for the year 2002 is negative as expected since losses are not accounted for. A 6% deviation, as those observed in the carbon and energy balances, point out to inadequate coefficients or errors regarding raw materials or products calculations. From the point of view of carbon emission importance, the process involves about 7.4 million tons of carbon that represent 4.7% of the carbon gross internal offer. A 6.3% error in the carbon balance means a 0.3% error in the emissions. It should be remembered that, at least in the present case, the error is in the energy balance itself.

Table 5: Energy and Carbon Balance in Coke Plants2002

	ENERGY	C MASS	C Mass /Energy	
	thou toe	thou t (Gg)	tC/toe	tC/TJ
INPUT	6881	7431		
NAT. MET. COAL	63	68	1,080	25,8
IMP. MET. COAL	6819	7363	1,080	25,8
OUTPUT	6721	7901		
MIN. COAL COKE	5126	6565	1,281	30,6
COKE PLANT GAS	1366	1144	0,837	20,0
TARR	229	192	0,837	20,0
BALANCE	-160	470		
BALANCE (%)	-2,3%	6,3%		

The carbon balance for the chosen years are shown in Table 6. The evolution of energy and carbon balance in coke plants in the 1970 / 2002 period can be seen in Figure 8 .

Table 6: Carbon Balance in Coke Plants in Chosen Years

	1970	1980	1990	1994	1999	2002
INPUT	1714	4383	8143	8692	7492	7431
NAT.MET. COAL	496	1083	487	82	21	68
IMP. MET. COAL	1218	3300	7655	8609	7471	7363
OUTPUT	1740	4541	8114	8811	7780	7901
MIN. COAL COKE	1426	3768	6745	7301	6441	6565
COKE PLANT GAS	264	624	1144	1264	1130	1144
OTH.SEC. TARR	50	149	225	246	210	192
BALANCE	26	158	-29	119	289	470
BALANCE (%)	1,5%	3,6%	-0,4%	1,4%	3,9%	6,3%

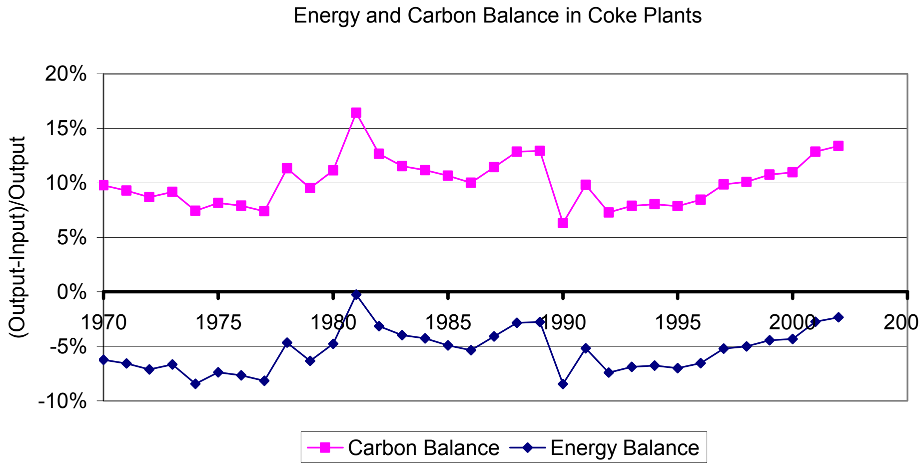

Figure 8: Carbon balance shows a systematic error probably due to inadequate coefficients concerning carbon mass/energy ratio. Balances are also important in the energy source but the differences can be imputed, at least in part, to losses.

Data of Figure 8 confirm problems concerning carbon balance that could be assigned to the use of inadequate coefficients.

Carbon Balance in Gasification Plants

The use of residence gas in 1970 was practically restricted to Rio de Janeiro and São Paulo. Gas for distribution in the existing network was produced in gasification plants. The raw materials used in its fabrication changed between 1970 and 2002 from mineral coal (most of it metallurgical) to naphtha (petroleum product) and finally to dry natural gas. The availability of natural gas for distribution resulted in a residual production in these plants in 2002 and they tend to disappear.

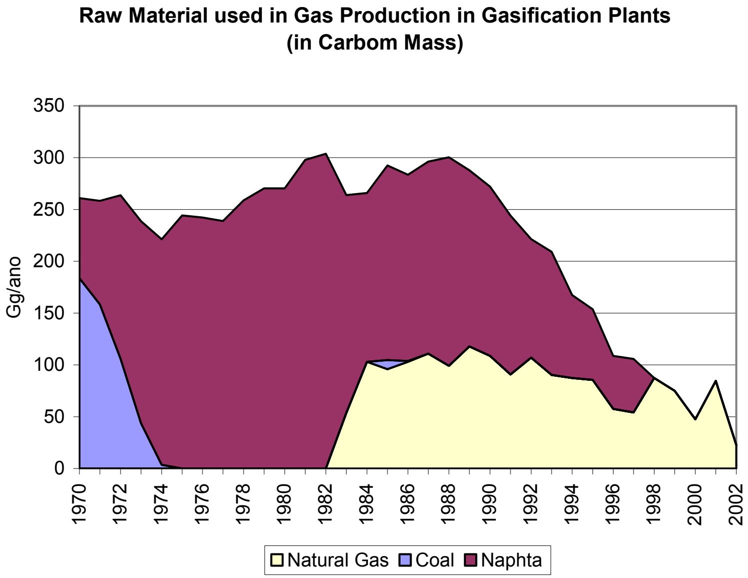

Figure 9: Raw material used in gas production in gasification plants changed from mineral coal to naphtha and from naphtha to natural gas. Since the latter was available, the distribution network began using dry natural gas and the gasification plants are practically deactivated.

Figure 10 shows that the carbon balance is entirely unsatisfactory since deviations greater than 70% and up to 150% can be observed. The energy balance quality also deteriorates along time.

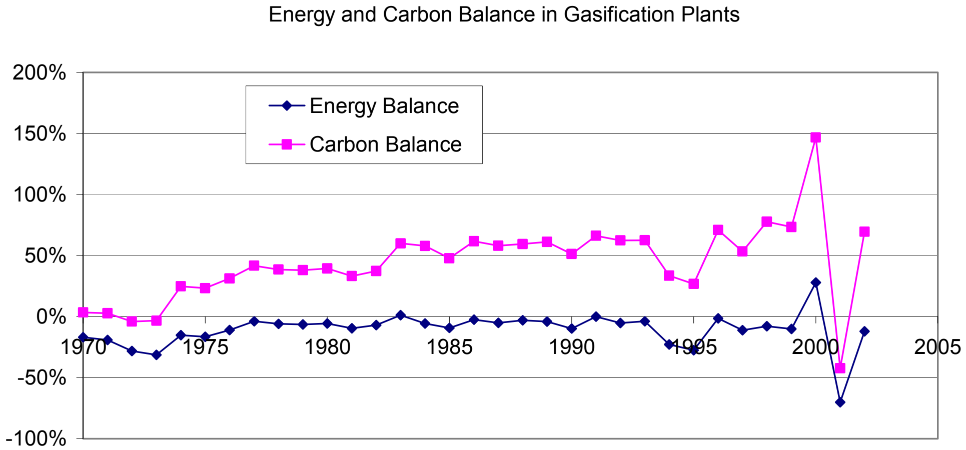

Figure 10: Carbon balance in the gasification plants shows large values along the period, due to the bad quality of the coefficients used. Evolution along years (see previous figure) makes one suppose that the coefficients used for naphtha and natural gas are worse than that of mineral coal.

Energy and carbon balances are shown in Table 7 for 1990[xix]

Table 7: Energy and Carbon Balances in Gasification Plants in 1990

	ENERGY thou toe	C MASS Thou t (Gg)	tC/toe	tC/TJ
INPUT	333	245		
Dry Natural Gas	170	109	0,640	15,3
Mineral Coal	0	0		
Naphtha	163	137	0,837	20,0
OUTPUT	301	372		
RESIDENCE GAS	301	372	1,235	29,5
MIN COAL COKE	0	0		
BALANCE	-32	126		
BALANCE (%)	-9,7%	51,4%		

Examining the coefficients of Table 7, it seems probable that the produced gas (residence gas) has its composition considerably changed when the raw material has changed. The gas produced from coal could contain carbon monoxide, and this would explain the high value of the coefficient used. When this gas was substituted, in order not to change the

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[xix] Using the previous years, the year 2002 presents a low quantity of considered raw material and only of one type (natural gas).

characteristics of the distributed gas, it was chosen to deplete the gas produced from naphtha and from dry natural gas. If, for example, the gas produced from natural gas comes from adding inert gas, the C mass/energy ratio would be much closer to this value relative to natural gas (15,3 tC/TJ) than to the value used (29,5 tC/TJ), which would be adequate for a gas with high carbon monoxide content and this coefficient would then be the adequate one.

In 1990, the carbon mass involved in the transformation (input) would be 245 Gg for a gross internal offer of about 120 thousand Gg, corresponding to 0.2% of the fuel mass used. A 50% error in this evaluation would correspond to 0.1% of the total emissions. Since we are dealing with a fuel that is ending, this imprecision in its evaluation, even though uncomfortable from the methodological point of view, would have no impact on the future emissions. The impact on past emissions should not be higher than the value calculated for 1990.

Carbon Balance in the Alcohol Distilleries

The alcohol sector and hydroelectric generation are the main Brazilian producers of renewable energy. Even though the CO_2 produced by biomass is not computed in the greenhouse effect emissions, the same is not true for methane emissions, which are accounted for. Furthermore, when they are considered as carbon dioxide equivalent using the Kyoto Protocol equivalence (GWP – Global Warming Potential) they can significantly reduce the positive impact assigned to using alcohol. The carbon balance in this type of unit is relevant relative to the Brazilian policy demonstration for attenuating the greenhouse effect.

The carbon balance in the alcohol plants for 2002 is shown in Table 8 and presents a negative balance of 27% in carbon mass. The same happens for the selected years, as can be seen in Figure 11 and Table 9.

Table 8: Energy and Carbon Balances in Distilleries in 2002

	ENERGY Thou toe	C MASS thou t (Gg)	tC/toe	tC/TJ
INPUT	6701	5609		
SUGARCANE JUICE	4797	4016	0,837	20,0
MOLASSES	1904	1594	0,837	20,0
OTHERS RECOVER.	0	0		
OUTPUT	6586	4083	0,620	
ANHYDROUS ALCOHOL	3759	2330	0,620	14,8
HYDRATED ALCOHOL	2828	1753	0,620	14,8
BALANCE	-115	-1527		
BALANCE (%)	-1,7%	-27,2%		

It is expected that there would be a negative balance in the distilleries, since *vinhoto*, that contains organic compounds, is not accounted for. Since this waste can contribute to emissions, including methane, it would be convenient to include it in the carbon balance.

On the other hand, the emission coefficients used for sugarcane juice and molasses were based on generic values recommended for biomass sources in the IPCC methodology. The anhydrous and hydrated alcohol coefficients as well – used in the inventory Top-Down approach – were based on the average emission factor of the national fleet calculated from measurements made by CTESB in vehicles.

As we have a compound of known composition, the emission factor – that correlates the carbon mass with energy – can be obtained with good approximation from the alcohol composition .[xx]. Using this factor, based on pure ethylic alcohol, it would produce a balance with better approximation.

[xx] The lower calorific value (LCV) for ethylic alcohol in the handbook is 6621 kcal/kg or 0.027712 TJ/t. This corresponds to 36.085 t/TJ. For C2H5OH we have 24/46 x 36.085 tC/TJ or 18.8 tC/TJ. The LCV considered by BEN for anhydrous alcohol is 6750 kcal/TJ and consequently, 18.5 tC/TJ

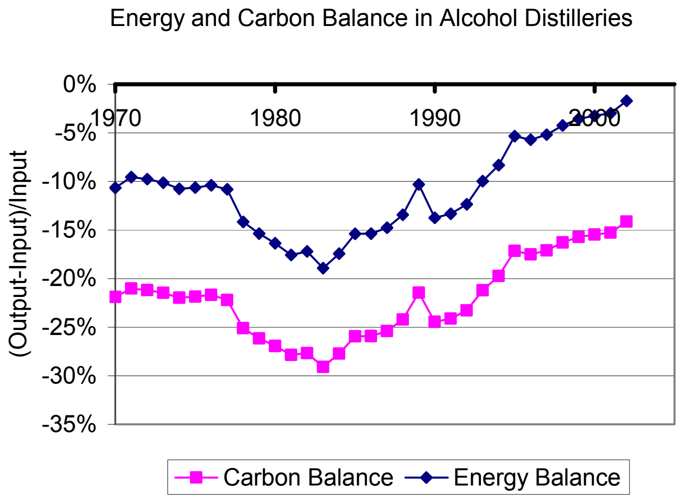

Figure 11: Energy and carbon balance in distilleries that present a large carbon deficit in the formed product.

Table 9: Carbon Mass Balance in Distilleries in Selected Years

	1970	1980	1990	1994	1999	2002
INPUT	304	1928	5718	5885	5872	5609
SUGARCANE JUICE	68	1498	5009	4970	4464	4016
MOLASSES	235	410	675	884	1409	1594
OTHERS RECOVER.	0	19	33	32	0	0
OUTPUT	201	1194	3652	3995	4194	4083
ANYHROUS ALCOHOL	77	720	281	926	2043	2330
HYDRATED ALCOHOL	124	474	3371	3069	2151	1753
BALANCE	-103	-734	-2066	-1890	-1678	-1527
BALANCE (%)	-33,8%	-38,1%	-36,1%	-32,1%	-28,6%	-27,2%

Sugarcane – not considering left-over and leaves – is now the second largest primary energy source according to BEN's criterion, corresponding to 13% in energy, and it has exceeded firewood and hydraulic energy (calorific correspondence). The carbon mass participation is even larger (18% of the total). The carbon and energy balance treatment should deserve more attention in future approaches.

Other Transformation Centers

In other transformation centers (charcoal kilns and electric power plants) the emissions of gases liberated to the atmosphere are accounted for in the units themselves and it is necessary to quantify them in order to determine the carbon balance. This will be shown in the next issue of this periodical together with other consuming centers.

Conclusion

Carbon balance in transformation centers was useful for detecting problems regarding the calculation of carbon gases emissions. The most important problems detected concern the biomass area, specially alcohol production. Furthermore, alcohol presents an apparent error in the carbon content used in the Brazilian inventory that considers only the emitted CO_2.

The coefficients used in the first calculation of the national inventory were most of them generic coefficients for solid and liquid biomass. Due to the importance of the alcohol sector in the Brazilian energy matrix, a more precise treatment would be desirable. It should be noted that, in spite of the fact that CO_2 emissions are not accounted for, those of methane are and they could, for example, reduce the eventual carbon credit due to the use of alcohol engines. The carbon and energy balances in refineries present good results regardless of the large variation in the composition of petroleum products in Brazil after the 1979 petroleum prices shock.

As energy is not conserved in transformation centers due to losses inherent to the processes, BEN does not present systematic energy balance calculation in these centers. However, for some of them (where consumption is calculated in the energy sector) there are apparent gaps in the coefficients that can be corrected in the future editions. An example is the use of the same energy/volume coefficient for humid natural gas in different years in spite of the fact that the percent value of liquid products obtained in the NGPU are different for various years.