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## Opinion:



The perspectives regarding oil and gas production in the continental platform of Espirito Santo seem promising and they will certainly bring economic benefits to the region. However this does not seem to satisfy its inhabitants who call for benefits for the state besides royalties, small participation in the investments and some correlated services.

## Article:



Analysis of the differences found in the Carbon Emissions Balance in the energy use and transformation in Brazil is presented together with the conclusions of the study that the Economy and Energy organization has carried out for the Ministry of Science and Technology. The results of this study have been presented in the N$^0$ 48, 50 and 51 issues of the e&e periodical. The Carbon Balance is a good diagnosis tool for the greenhouse effect emissions as well as for detecting deficiencies regarding data or methodology.

## Text for Discussion:



The question regarding adherence (or not) to the IAEA's Additional Protocol aiming at strengthening nuclear safeguards has been postponed by the Brazilian Government. Considering the drawbacks of the present formulation, an alternative is proposed.



Opinion:

# Espirito Santo will turn into Bolivia

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I returned to my home state, already retired, in 1997 after three decades of traveling across the country. I came to participate in the state government that had then reached half of its mandate. I found it loaded with projects to which I enthusiastically adhered.

Among the projects, stood out those of the energy area, of which I am a specialist. The main were:

1 - Construction of the Cabiúnas (RJ) - Vitória (ES) gas pipeline to take in the natural gas from the Campos basin and casually from other sources;

2 - Utilization of part of this gas in the mining-metallurgical complex of great Vitória, and its expansion, with the construction of a thermoelectric power plant;

3 - Development of the Peroá and Cangoá natural gas fields, in the north of the state, to be used in the thermoelectric power plant to be constructed in that region;

4 - Establishment of a gas utility company for natural gas distribution to substitute the present concessionaire in order to satisfy the consumption increase of natural gas from the new sources; and

5 - Establishment of an agency for regulating the public services in the state.

I will not try to explain why these initiatives did not materialized as described above. Some of them are being carried out even though aiming at different directions and purposes. However, the main causes of inertia were, no doubt, privatization of the company that would be the main consumption center, the Companhia Vale do Rio Doce, and the economic and political weakness of the state.

The main purpose of the projects was to increase the natural gas market in the state. The native gas would be used here and complemented with gas from elsewhere.

This agenda was discontinued by the following administration that was more enthusiastic about the perspective of exploring and producing petroleum and gas in the costal part of the state. In fact, the expectations are becoming a reality but it seems that petroleum will be refined elsewhere and the gas will serve other markets.

We will keep the royalties, a small participation in investments and some correlated services. Most of the benefits of the new industry - the so-called aggregated values to an extractive activity - will go to the neighboring states that are economically and politically more important.

The previous agenda, one must admit, foresaw a less noble use of gas. For example, processing iron ore pellets is not the best way to use gas, or to use it for electricity generation. However, that use would give a better anchorage for its projects and the thermoelectric plants would increase our autonomy in the fragile situation regarding electric energy offer in the state in the national context that is fragile as well. The noble uses of natural gas are as raw material for the chemical industry and for residential use (including its transformation into LPG - liquefied petroleum gas), industrial, commercial or vehicular uses.

Today the agenda is a different one. The Peroá and Cangoá fields are under development not for electricity generation (the interconnection with CEMIG - MG attenuates the fragility of the state that is at the end of the south-southeast-center-west line) and the present connection of our gas pipelines to the two systems (north and southeast) aims at distributing to other places most of the gas produced here. These places were already short of the product because of the vigorous growth of the national market. Espirito Santo, even counting on the Bolivian gas, was destined to be the cushion of the Brazilian natural gas market.

Considering the recent events in Bolivia, the gas supply from that country is in jeopardy. Petrobrás is worried and is carefully watching the flow off of Espirito Santos´ production, increasing the local investments.

That´s the danger! Espirito Santo will turn into Bolivia because it will supply its gas to the Brazilian thirsty (what would be the appropriate term for gas?) market.

The Bolivian population is against this exploitation situation when its precious reserves of natural gas are drained to a neighbor country.

If some measures are not taken to change this situation, which I believe would come too late, the scenario described here would come true.

This is the future of Espirito Santo. It would turn into Bolivia but without the brave Bolivian people.



*Article:*

**Carbon Balance in the Greenhouse Effect Emissions in the Energy Use and Transformation in Brazil: Comparison between the Extended Top-Down and Bottom-Up Methodologies – Analysis of Results and Conclusions.**

*Carlos Feu Alvim, Frida Eidelman and Omar Campos Ferreira*

**Introduction**

The Economy and Energy Organization has made together with the Ministry of Science and Technology a study about carbon balance in the emissions resulting from the use and transformation of energy. The dissemination of the results of this study has been made by the e&e periodical. The following results have already been published:

- Carbon Balance in the Production, Transformation and Use of Energy in Brazil – Methodology and Results of the Top-Bottom Process in the period 1970 – 2002 (e&e N 48).
- Carbon Balance in the Energy Transformation Centers (e&e N 50).
- Results corresponding to the adopted accounting process that includes the extended Top-Down approach and the use of coefficients calculated in the national inventory for the period 1990-1994 for estimating emissions from 1970 to 2002 by the Bottom-Up process (e&e Nº 51).

In the present issue the results of both methods are compared and some deviations found are pointed out; they should bring about corrections in the inventory of carbon balance and emissions inventory. Suggestions regarding the corrections are presented and they will be the object of a complementary analysis.

**Comparison of Emissions using the two Methods**

The *benemis* program made for calculating emissions permits to obtain synthetic tables grouping energy sources and economical sectors. In the case of the *benemis_c_eee* version the contained carbon data, emissions using the two processes and their comparison can be obtained for each year.

Table 1 shows the values of contained carbon without discounting emissions of the main consuming sectors and energy sources grouped by origin[i].

In the following tables the emissions calculated by the Top-Down (Table 2) and Bottom-Up (Table 3) methods are compared in the aggregated form. Table 4 illustrates the procedure used for the comparison: the

[i] For the transformation centers the masses follow BEN's standards where the values are presented as negative when used in transformation and positive when produced. Presentation of aggregated results does not make sense in this case.

discrepancies relative to these two methods are indicated by colors with limits fixed by percents of deviations (white for differences below 0.1% or zero values, green, between 0.1% and 10%, yellow, between 10% and 30% and red, above that value). Concerning the aggregated tables, there is an additional difficulty namely the aggregation criterion of fuel by origin. In the case of gases, for example, residential gas had different origins along time and in the usual BEN's structure it is presented together with coke plant gas. In the program's present representation by origin it is recorded as mineral gas.

**Table 1: Carbon Contained in Fuels Used in Gg/year, Year 1990**

| | NATURAL GAS | BIOMASS AND OTHER. RENEWABLE | NG AND PETROLEUM PRODUCTS | MINERAL COAL AND PRODUCTS | TOTAL |
|---|---|---|---|---|---|
| FINAL CONSUMPTION NON-ENERG. | 575,0 | 304,2 | 7214,2 | 91,6 | 8185,0 |
| ENERGY SECTOR | 534,5 | 8393,0 | 2980,8 | 284,2 | 12192,5 |
| RESIDENTIAL | 2,8 | 10357,7 | 3816,8 | 0,0 | 14177,3 |
| COMMERCIAL | 0,6 | 176,3 | 576,4 | 0,0 | 753,3 |
| PUBLIC | 1,1 | 5,1 | 139,7 | 0,0 | 145,9 |
| AGRI. AND HUSBANDRY | 0,0 | 2721,8 | 2768,2 | 0,0 | 5490,0 |
| TRANSPORTS (TOTAL) | 1,1 | 3632,5 | 22391,8 | 5,8 | 26031,3 |
| INDUSTRIAL (TOTAL) | 886,6 | 17065,0 | 7515,3 | 8479,7 | 33946,6 |
| Final Consumption (*) | 1426,7 | 42351,3 | 40189,1 | 8769,8 | 92736,9 |

**Table 2: Carbon Emissions in Gg/year (1990) – Top Down Method**

| | NATURAL GAS | BIOMASS AND OTHER. RENEWABLE | NG AND PETROLEUM PRODUCTS | MINERAL COAL AND PRODUCTS. | TOTAL |
|---|---|---|---|---|---|
| TRANSFORMATION | 48 | 6997 | 1112 | 1119 | 9277 |
| FINAL CONSUMPTION NON-ENERGY | 358 | 0,0 | 1122 | 0,0 | 1480 |
| ENERGY SECTOR | 532 | 7386 | 2951 | 281 | 11150 |
| RESIDENTIAL | 2,8 | 9553 | 3779 | 0,0 | 13334 |
| COMMERCIAL | 0,6 | 192 | 571 | 0,0 | 763 |
| PUBLIC | 1,1 | 6,7 | 138 | 0,0 | 146 |
| AGRI. AND HUSBANDRY | 0,0 | 2402 | 2741 | 0,0 | 5142 |
| TRANSPORTS (TOTAL) | 1,1 | 3596 | 22168 | 5,7 | 25771 |
| INDUSTRIAL (TOTAL) | 882 | 18879 | 7440 | 8319 | 35520 |
| Final Consumption (*) | 1419 | 42014 | 39787 | 8606 | 91826 |
| TOTAL (GENERAL) | 1825 | 49012 | 42021 | 9725 | 102583 |



**Table 3: Emissions by Sector and by Group of Fuels - Year:1990 - Gg /year Bottom-Up**

| | NATURAL GAS | BIOMASS AND OTHER. RENEWABLE | NG AND PETROLEUM PRODUCTS | MINERAL COAL AND PRODUCTS. | TOTAL |
|---|---|---|---|---|---|
| TRANSFORMATION | 46 | 8115 | 1116 | 1155 | 10431 |
| NON-ENERGY FINAL CONSUMPTION | 362 | 0,0 | 920 | 29 | 1311 |
| ENERGY SECTOR | 493 | 7662 | 2896 | 0,5 | 11052 |
| RESIDENTIAL | 2,7 | 11270 | 3663 | 86 | 15021 |
| COMMERCIAL | 0,5 | 200 | 525 | 33 | 759 |
| PUBLIC | 1,1 | 7,1 | 132 | 4,6 | 145 |
| AGRI. AND HUSBANDRY | 0,0 | 2679 | 2743 | 0,0 | 5421 |
| TRANSPORTS (TOTAL) | 1,1 | 4337 | 24799 | 5,8 | 29143 |
| INDUSTRIAL (TOTAL) | 832 | 19588 | 7365 | 8437 | 36222 |
| Final Consumption (*) | 1330 | 45744 | 42124 | 8566 | 97763 |
| TOTAL (GENERAL) | 1738 | 53858 | 44160 | 9749 | 109505 |

(*) Excludes Transformation

Identifying the problems is easier when one examines the difference by fuel and when the accounts have a larger disaggregating form. This will be carried out in what follows. Preliminarily, it should be observed that in Table 4 the red cells for mineral coal identify problems concerning the fuel by origin, mainly gas. Some deviations pointed out for biomass are due to difficulties already detected in transformation.

Figure 1 shows the emissions by sector and by fuel by origin obtained using coefficients obtained in the Bottom-Up process. The Transport Sector is the largest sector responsible for carbon emissions from fossil sources.

The following tables illustrate the results obtained from calculating the carbon balance (year 1990) and are used in the analysis of the existing problems.

The first two tables (Table 5 and Table 6) show the original carbon content in the fuels used in transformation and consumption. In transformation, the negative masses show (as in BEN) the absorption of an energy source that is transformed into another one and recorded as positive input on the same line. For the transformation centers where emissions are not calculated (Petroleum Refineries, Natural Gas Plants, Gasification Plants, Coke Plants, Distilleries and Other Transformations), the "Total" column on the right points out the faults in the carbon balance. Later on, using the results of the following tables it will be possible to complete the carbon balance of the remaining transformation units.

**Table 4: Comparison of Results of the two Processes, the percent difference relative to the Bottom-Up data (colors classify the deviations)**

| | NATURAL GAS | BIOMASS AND OTHER. RENEWABLE | NG AND PETROLEUM PRODUCTS | MINERAL COAL AND PRODUCTS. | TOTAL |
|---|---|---|---|---|---|
| TRANSFORMATION | -5,1% | 0,0% | 0,0% | 0,0% | 0,0% |
| NON-ENERGY FINAL CONSUMPTION | 1,2% | | -18,0% | | -11,4% |
| ENERGY SECTOR | -7,3% | 3,7% | -1,9% | -99,8% | -0,9% |
| RESIDENTIAL | -5,2% | 18,0% | -3,1% | | 12,7% |
| COMMERCIAL | -5,2% | 4,4% | -7,9% | | -0,6% |
| PUBLIC | -5,2% | 5,2% | -4,6% | | -1,0% |
| AGRI. AND HUSBANDRY | | 11,5% | 0,1% | | 5,4% |
| TRANSPORTS (TOTAL) | -4,0% | 20,6% | 11,9% | 1,2% | 13,1% |
| INDUSTRIAL (TOTAL) | -5,7% | 3,8% | -1,0% | 1,4% | 2,0% |
| Final Consumption (*) | -6,3% | 8,9% | 5,9% | -0,5% | 6,5% |
| TOTAL (GENERAL) | -4,8% | 7,6% | 5,1% | -0,1% | 5,6% |

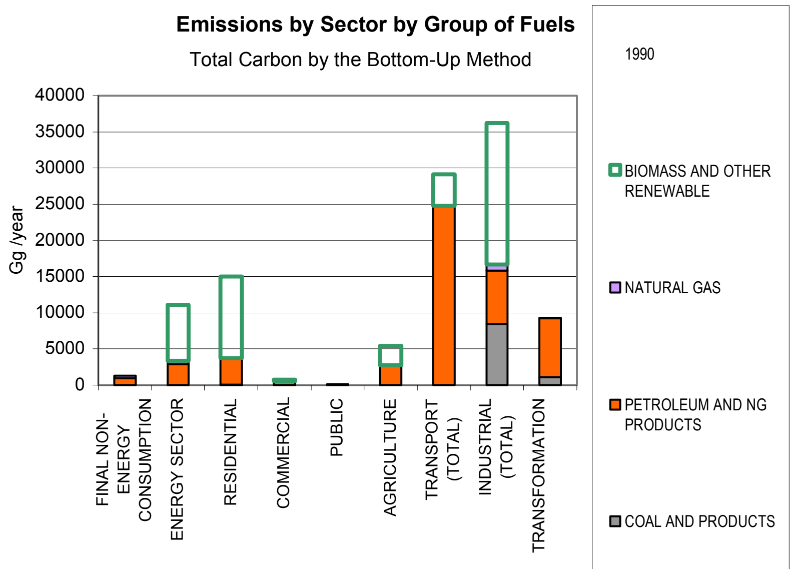


**Figure 1: Values of carbon emitted by sector and by fuel by origin.**

Table 7 present the emissions obtained through the reconstruction of the Bottom-Up process and Table 8 those obtained through the Top-Down process. Table 9 presents the analysis of results and the percent deviations found between the two processes (values relative to the Bottom-Up value)..



**Table 5 –Carbon Content by Activity and by Energy Source**

| | NATU-RAL GAS | STEAM COAL | MET. COAL | FIRE-WOOD | SUGAR-CANE PROD. | OTHER PETRO. PROD. | DIESEL OIL | FUEL OIL | GASO-LINE | LPG |
|---|---|---|---|---|---|---|---|---|---|---|
| **FINAL CONSUMPTION** | 2002 | 1071 | 0 | 19568 | 14099 | 1250 | 17708 | 8574 | 5922 | 4095 |
| NON-EN. FINAL CONSUMPTION | 575 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ENERGY SECTOR | 534 | 0 | 0 | 0 | 8393 | 0 | 362 | 1462 | 0 | 15 |
| RESIDENTIAL | 3 | 0 | 0 | 9961 | 0 | 0 | 0 | 0 | 0 | 3591 |
| COMMERCIAL | 1 | 0 | 0 | 143 | 0 | 0 | 33 | 254 | 0 | 243 |
| PUBLIC | 1 | 0 | 0 | 3 | 0 | 0 | 70 | 48 | 0 | 12 |
| AGR, AND HUSBANDRY | 0 | 0 | 0 | 2715 | 0 | 0 | 2745 | 23 | 0 | 0 |
| HIGHWAY | 1 | 0 | 0 | 0 | 0 | 0 | 13513 | 0 | 5883 | 0 |
| RAILWAY | 0 | 6 | 0 | 3 | 0 | 0 | 442 | 0 | 0 | 0 |
| AIRWAY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 40 | 0 |
| WATER TRANSPORT | 0 | 0 | 0 | 0 | 0 | 0 | 273 | 676 | 0 | 0 |
| CEMMENT | 26 | 630 | 0 | 3 | 0 | 35 | 9 | 867 | 0 | 0 |
| PIG IRON AND STEEL | 213 | 22 | 0 | 0 | 0 | 0 | 36 | 339 | 0 | 17 |
| FERRO-ALLOYS | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MINING AND PELLET. | 57 | 0 | 0 | 0 | 0 | 0 | 66 | 418 | 0 | 1 |
| NON-FERROUS AND O. METALS | 17 | 0 | 0 | 47 | 0 | 0 | 0 | 346 | 0 | 11 |
| CHEMISTRY | 209 | 103 | 0 | 273 | 51 | 0 | 19 | 1403 | 0 | 7 |
| FOOD AND BEVERAGES | 84 | 116 | 0 | 2459 | 5588 | 0 | 16 | 644 | 0 | 13 |
| TEXTILES | 33 | 4 | 0 | 194 | 0 | 0 | 2 | 393 | 0 | 3 |
| PAPER AND CELLULOSE | 35 | 143 | 0 | 941 | 62 | 1168 | 16 | 477 | 0 | 3 |
| CERAMICS | 39 | 38 | 0 | 1953 | 0 | 47 | 5 | 355 | 0 | 23 |
| OTHER IINDUSTRIES | 169 | 10 | 0 | 873 | 5 | 0 | 101 | 737 | 0 | 39 |
| NON-DENTIFIED CONSUMP. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 130 | 0 | 117 |

## (Final Consumption) – Year 1990 – Gg/year

| LPG | NAPHTHA | KERO-SENE | GAS | MIN. COAL COKE | CHAR-COAL | ETHYL ALCOHOL | O.SEC. PETR. | TAR | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| 4095 | 4150 | 1789 | 234 | 6573 | 3804 | 3934 | 2369 | 188 | 101170 |
| 0 | 4150 | 67 | 0 | 0 | 0 | 304 | 188 | 92 | 8185 |
| 15 | 0 | 3 | 0 | 0 | 0 | 0 | 1139 | 0 | 12193 |
| 3591 | 0 | 105 | 121 | 0 | 396 | 0 | 0 | 0 | 14177 |
| 243 | 0 | 0 | 46 | 0 | 33 | 0 | 0 | 0 | 753 |
| 12 | 0 | 1 | 6 | 0 | 2 | 0 | 3 | 0 | 146 |
| 0 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 5490 |
| 0 | 0 | 0 | 0 | 0 | 0 | 3629 | 0 | 0 | 23026 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 451 |
| 0 | 0 | 1565 | 0 | 0 | 0 | 0 | 0 | 0 | 1605 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 949 |
| 0 | 0 | 1 | 0 | 0 | 217 | 0 | 4 | 0 | 1792 |
| 17 | 0 | 9 | 5 | 6322 | 2706 | 0 | 0 | 97 | 10510 |
| 0 | 0 | 0 | 17 | 33 | 224 | 0 | 0 | 0 | 276 |
| 1 | 0 | 3 | 0 | 126 | 21 | 0 | 0 | 0 | 694 |
| 11 | 0 | 0 | 0 | 92 | 158 | 0 | 403 | 0 | 1074 |
| 7 | 0 | 0 | 1 | 0 | 20 | 0 | 631 | 0 | 2717 |
| 13 | 0 | 7 | 11 | 0 | 0 | 0 | 0 | 0 | 8939 |
| 3 | 0 | 4 | 2 | 0 | 2 | 0 | 0 | 0 | 638 |
| 3 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2849 |
| 23 | 0 | 1 | 6 | 0 | 8 | 0 | 0 | 0 | 2474 |
| 39 | 0 | 20 | 19 | 0 | 10 | 0 | 2 | 0 | 1985 |
| 117 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 248 |



## Table 6: Carbon Content by Activity and by Energy Source

| | PETRO-LEUM | NATU-RAL GAS | STEAM COAL | MET. COAL | FIRE-WOOD | SUGAR-CANE PROD. | OTHER PRIMARY | DIESEL OIL | FUEL OIL |
|---|---|---|---|---|---|---|---|---|---|
| **TRANSFORMATION** | -50711 | -851 | -1039 | -8143 | -16145 | -6178 | -530 | 17390 | 10163 |
| PETROLEUM REFINERIES | -50711 | 0 | 0 | 0 | 0 | 0 | -96 | 17804 | 10785 |
| NATURAL GAS PLANTS | 0 | -605 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| GASIFICATION PLANTS | 0 | -109 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| COKE PLANTS | 0 | 0 | 0 | -8143 | 0 | 0 | 0 | 0 | 0 |
| NUCLEAR FUEL CYCLE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PUB. SERV. POWER PLANTS | 0 | -3 | -1016 | 0 | 0 | 0 | 0 | -386 | -251 |
| AUTOPROD. POWER PLANTS | 0 | -45 | -23 | 0 | -151 | -494 | -496 | -97 | -372 |
| CHARCOAL PLANTS | 0 | 0 | 0 | 0 | -15994 | 0 | 0 | 0 | 0 |
| DISTILLERIES | 0 | 0 | 0 | 0 | 0 | -5684 | -33 | 0 | 0 |
| OTHER TRANSFORMTIONS | 0 | -89 | 0 | 0 | 0 | 0 | 109 | 70 | 0 |

## – Year 1990 - Gg /year (Transformation)

| | GASO-LINE | LPG | NAPHTHA | KERO-SENE | GAS | MIN. COAL COKE | CHAR-COAL | ETHYL ALCOHOL | O.SEC. PETR. | TAR | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 7450 | 3114 | 4004 | 2237 | 252 | 6745 | 4009 | 3652 | 2674 | 202 | -21705 |
| 5 | 7096 | 2504 | 5254 | 2237 | 0 | 0 | 0 | 0 | 2143 | 0 | -2984 |
| | 134 | 394 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -74 |
| | 0 | 0 | -137 | 0 | 252 | 0 | 0 | 0 | 0 | 0 | 6 |
| | 0 | 0 | 0 | 0 | 0 | 6745 | 0 | 0 | 0 | 225 | -1173 |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -1656 |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -18 | -23 | -1719 |
| | 0 | 0 | 0 | 0 | 0 | 0 | 4009 | 0 | 0 | 0 | -11985 |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3652 | 0 | 0 | -2065 |
| | 220 | 216 | -1117 | 0 | 0 | 0 | 0 | 0 | 549 | 0 | -42 |

## Table 7: Emissions by Activity and by Energy Source (Final Consumption

| | NATU-RAL GAS | STEAM COAL | MET. COAL | FIRE-WOOD | SUGAR-CANE PROD. | OTHER PRIMARY | DIE-SEL OIL | FUEL OIL |
|---|---|---|---|---|---|---|---|---|
| **FINAL CONSUMPTION** | 1692 | 1058 | 0 | 19341 | 12874 | 1386 | 17957 | 8378 |
| NON-ENERGY FINAL CONSUMP. | 362 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ENERGY SECTOR | 493 | 0 | 0 | 0 | 7662 | 0 | 362 | 1447 |
| RESIDENTIAL | 3 | 0 | 0 | 10426 | 0 | 0 | 0 | 0 |
| COMMERCIAL | 1 | 0 | 0 | 130 | 0 | 0 | 33 | 251 |
| PUBLIC | 1 | 0 | 0 | 3 | 0 | 0 | 69 | 48 |
| AGRI . AND HUSBANDRY | 0 | 0 | 0 | 2663 | 0 | 0 | 2719 | 23 |
| HIGHWAY | 1 | 0 | 0 | 0 | 0 | 0 | 13778 | 0 |
| RAILWAY | 0 | 6 | 0 | 3 | 0 | 0 | 450 | 0 |
| AIRWAY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| WATER TRANSPORT | 0 | 0 | 0 | 0 | 0 | 0 | 278 | 688 |
| CIMMENT | 24 | 623 | 0 | 2 | 0 | 43 | 9 | 859 |
| PIG IRON AND STEEL | 202 | 21 | 0 | 0 | 0 | 0 | 35 | 336 |
| FERRO-ALLOYS | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MINING AND PELLET. | 53 | 0 | 0 | 0 | 0 | 0 | 65 | 415 |
| NON-FERROUS AND OTH. METAL. | 16 | 0 | 0 | 43 | 0 | 0 | 0 | 343 |
| CHEMISTRY | 196 | 101 | 0 | 247 | 46 | 0 | 19 | 1388 |
| FOOD AND BEVERAGES | 79 | 115 | 0 | 2226 | 5104 | 0 | 16 | 637 |
| TEXTILE | 31 | 4 | 0 | 175 | 0 | 0 | 2 | 389 |
| PAPER AND CELLULOSE | 33 | 141 | 0 | 850 | 57 | 1275 | 15 | 472 |
| CERAMICS | 37 | 37 | 0 | 1779 | 0 | 68 | 5 | 352 |
| OTHER INDUSTRIES | 158 | 10 | 0 | 792 | 5 | 0 | 100 | 730 |
| NON-IDENTIFIED ICONSUMPTION | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TRANSFORMATION** | 46 | 1026 | 0 | 7107 | 451 | 556 | 482 | 616 |
| .PUB. SERV. POWER PLANTS | 3 | 1004 | 0 | 0 | 0 | 0 | 385 | 248 |
| AUTOPROD. POWER PLANTS | 43 | 22 | 0 | 137 | 451 | 556 | 97 | 368 |
| CHARCOAL PLANTS | 0 | 0 | 0 | 6971 | 0 | 0 | 0 | 0 |

## and Transformation) – Bottom-Up Method – Year 1990 - Gg /year

| GASO-LINE | LPG | NAPH-THA | KERO-SENE | GAS | MIN. COAL COKE | CHAR-COAL | ETHYL ALCOHOL | O.SEC. PETR. | TAR | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| 8050 | 3942 | 822 | 1710 | 181 | 6266 | 7810 | 4334 | 2088 | 1089 | 99074 |
| 0 | 0 | 822 | 0 | 0 | 0 | 0 | 0 | 0 | 29 | 1311 |
| 0 | 15 | 0 | 3 | 1 | 0 | 0 | 0 | 1070 | 0 | 11052 |
| 0 | 3559 | 0 | 104 | 86 | 0 | 844 | 0 | 0 | 0 | 15021 |
| 0 | 241 | 0 | 0 | 33 | 0 | 70 | 0 | 0 | 0 | 759 |
| 0 | 12 | 0 | 1 | 5 | 0 | 4 | 0 | 3 | 0 | 145 |
| 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 5421 |
| 7998 | 0 | 0 | 0 | 0 | 0 | 0 | 4334 | 0 | 0 | 26111 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 459 |
| 52 | 0 | 0 | 1555 | 0 | 0 | 0 | 0 | 0 | 0 | 1607 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 966 |
| 0 | 0 | 0 | 1 | 0 | 0 | 443 | 0 | 4 | 0 | 2009 |
| 0 | 17 | 0 | 9 | 7 | 6027 | 5528 | 0 | 0 | 1060 | 13241 |
| 0 | 0 | 0 | 0 | 23 | 31 | 458 | 0 | 0 | 0 | 515 |
| 0 | 1 | 0 | 3 | 0 | 120 | 43 | 0 | 0 | 0 | 701 |
| 0 | 11 | 0 | 0 | 0 | 88 | 322 | 0 | 384 | 0 | 1207 |
| 0 | 7 | 0 | 0 | 1 | 0 | 41 | 0 | 624 | 0 | 2670 |
| 0 | 13 | 0 | 7 | 8 | 0 | 0 | 0 | 0 | 0 | 8205 |
| 0 | 3 | 0 | 4 | 2 | 0 | 4 | 0 | 0 | 0 | 615 |
| 0 | 3 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2849 |
| 0 | 22 | 0 | 1 | 4 | 0 | 16 | 0 | 0 | 0 | 2321 |
| 0 | 38 | 0 | 20 | 13 | 0 | 20 | 0 | 2 | 0 | 1889 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 129 | 10431 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1640 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 129 | 1820 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6971 |



## Table 8 Emissions by Activity by Energy Source (Top-Down Method)

| | NATU-RAL GAS | STEAM COAL | MET. COAL | FIRE-WOOD | SUGAR-CANE PROD. | OTHER PRIMARY | DIESEL OIL | FUEL OIL | GASO-LINE |
|---|---|---|---|---|---|---|---|---|---|
| **FINAL CONSUMPTION** | 1777 | 1050 | 0 | 17210 | 12407 | 1200 | 17531 | 8489 | 5863 |
| NON-ENERGY FINAL CONSUMP. | 358 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ENERGY SECTOR | 532 | 0 | 0 | 0 | 7386 | 0 | 359 | 1447 | 0 |
| RESIDENTIAL | 3 | 0 | 0 | 8761 | 0 | 0 | 0 | 0 | 0 |
| COMMERCIAL | 1 | 0 | 0 | 126 | 0 | 0 | 33 | 252 | 0 |
| PÚBLIC | 1 | 0 | 0 | 3 | 0 | 0 | 69 | 48 | 0 |
| AGRI. AND HUSBANDRY | 0 | 0 | 0 | 2387 | 0 | 0 | 2717 | 23 | 0 |
| HIGHWAY | 1 | 0 | 0 | 0 | 0 | 0 | 13378 | 0 | 5824 |
| RAILWAY | 0 | 6 | 0 | 3 | 0 | 0 | 437 | 0 | 0 |
| AIRWAY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 39 |
| WATER TRANSPORT | 0 | 0 | 0 | 0 | 0 | 0 | 270 | 670 | 0 |
| CIMMENT | 26 | 617 | 0 | 2 | 0 | 31 | 9 | 858 | 0 |
| PIG IRON AND STEEL | 212 | 21 | 0 | 0 | 0 | 0 | 35 | 336 | 0 |
| FERRO-ALLOYS | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MINING AND PELLET. | 57 | 0 | 0 | 0 | 0 | 0 | 65 | 414 | 0 |
| NONFERROUS AND OTH. METAL | 17 | 0 | 0 | 42 | 0 | 0 | 0 | 343 | 0 |
| CHEMISTRY | 208 | 101 | 0 | 240 | 45 | 0 | 19 | 1389 | 0 |
| FOOD AND BEVERAGES | 84 | 114 | 0 | 2162 | 4918 | 0 | 16 | 637 | 0 |
| TEXTILE | 33 | 4 | 0 | 171 | 0 | 0 | 2 | 389 | 0 |
| PAPER AND CELLULOSE | 35 | 140 | 0 | 828 | 55 | 1128 | 15 | 473 | 0 |
| CERAMICS | 39 | 37 | 0 | 1717 | 0 | 41 | 5 | 352 | 0 |
| OTHER INDÚSTRIES | 168 | 9 | 0 | 767 | 5 | 0 | 100 | 730 | 0 |
| NON-IDENTIFIED CONSUMP. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 129 | 0 |
| **TRANSFORMATION** | 48 | 1018 | 0 | 6105 | 435 | 457 | 478 | 616 | 0 |
| PUBLIC SERVICE POWER PLANTS | 3 | 996 | 0 | 0 | 0 | 0 | 382 | 248 | 0 |
| AUTOPROD. POWER PLANTS | 45 | 22 | 0 | 133 | 435 | 457 | 96 | 368 | 0 |
| CHARCOAL PLANTS | 0 | 0 | 0 | 5972 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 1825 | 2068 | 0 | 23315 | 12842 | 1658 | 18009 | 9105 | 5863 |

## 1990 - Gg /year

| LPG | NAPHTHA | KERO-SENE | GAS | MIN. COAL COKE | CHAR-COAL | ETHYL ALCOHOL | O.SEC. PETR. | TAR | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| 4054 | 830 | 1705 | 232 | 6442 | 7604 | 3593 | 0 | 96 | 93551 |
| 0 | 830 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1480 |
| 14 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 11150 |
| 3555 | 0 | 104 | 120 | 0 | 792 | 0 | 0 | 0 | 13334 |
| 241 | 0 | 0 | 45 | 0 | 66 | 0 | 0 | 0 | 763 |
| 12 | 0 | 1 | 6 | 0 | 4 | 0 | 0 | 0 | 146 |
| 0 | 0 | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 5142 |
| 0 | 0 | 0 | 0 | 0 | 0 | 3593 | 0 | 0 | 22796 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 446 |
| 0 | 0 | 1550 | 0 | 0 | 0 | 0 | 0 | 0 | 1589 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 940 |
| 0 | 0 | 1 | 0 | 0 | 434 | 0 | 0 | 0 | 1983 |
| 17 | 0 | 9 | 5 | 6196 | 5408 | 0 | 0 | 96 | 13072 |
| 0 | 0 | 0 | 17 | 32 | 448 | 0 | 0 | 0 | 499 |
| 1 | 0 | 3 | 0 | 124 | 42 | 0 | 0 | 0 | 707 |
| 11 | 0 | 0 | 0 | 90 | 315 | 0 | 0 | 0 | 1216 |
| 7 | 0 | 0 | 1 | 0 | 40 | 0 | 0 | 0 | 2674 |
| 13 | 0 | 7 | 11 | 0 | 0 | 0 | 0 | 0 | 7962 |
| 3 | 0 | 4 | 2 | 0 | 4 | 0 | 0 | 0 | 612 |
| 3 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2679 |
| 22 | 0 | 1 | 6 | 0 | 16 | 0 | 0 | 0 | 2236 |
| 38 | 0 | 20 | 18 | 0 | 20 | 0 | 0 | 0 | 1878 |
| 116 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 245 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 9277 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1630 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 1675 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5972 |
| 4054 | 830 | 1705 | 232 | 6442 | 7604 | 3593 | 0 | 118 | 102828 |



## Table 9: Carbon Balance: Comparison Top-Down X Bottom-Up

| | NATURAL GAS | STEAM COAL | MET. COAL | FIRE-WOOD | SUGAR CANE PRODUCT | OTHER PRIMARY | DIESEL OIL | FUEL OIL | GASOLINE |
|---|---|---|---|---|---|---|---|---|---|
| **FINAL CONSUMPTION** | -4,8% | 0,8% | 0,0% | 12,4% | 3,8% | 15,4% | 2,4% | -1,3% | 37,3% |
| NON-ENERGY FINAL CONSUMPTION | 1,2% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |
| ENERGY SECTOR | -7,3% | 0,0% | 0,0% | 0,0% | 3,7% | 0,0% | 0,8% | 0,0% | 0,0% |
| RESIDENTIAL | -5,2% | 0,0% | 0,0% | 19,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |
| COMMERCIAL | -5,2% | 0,0% | 0,0% | 3,3% | 0,0% | 0,0% | 0,1% | -0,1% | 0,0% |
| PÚBLIC | -5,2% | 0,0% | 0,0% | 3,2% | 0,0% | 0,0% | 0,1% | -0,1% | 0,0% |
| AGR. AND HUSBANDRY | 0,0% | 0,0% | 0,0% | 11,5% | 0,0% | 0,0% | 0,1% | 0,0% | 0,0% |
| HIGHWAY | -4,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 3,0% | 0,0% | 37,3% |
| RAILWAY | 0,0% | 1,2% | 0,0% | 2,6% | 0,0% | 0,0% | 3,0% | 0,0% | 0,0% |
| AIRWAY | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 33,1% |
| WATER TRANSPORT | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 3,0% | 2,7% | 0,0% |
| CEMMENT | -8,3% | 1,0% | 0,0% | 3,6% | 0,0% | 39,2% | 0,0% | 0,1% | 0,0% |
| PIG IRON AND STEEL | -5,1% | 0,5% | 0,0% | 0,0% | 0,0% | 0,0% | 0,1% | 0,0% | 0,0% |
| FERROALLOYS | -5,1% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |
| MINING AND PELLETIZATION | -7,4% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,1% | 0,2% | 0,0% |
| NON_FERROUS AND OTHER METALS | -5,1% | 0,0% | 0,0% | 3,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |
| CHEMISTRY | -5,9% | 0,6% | 0,0% | 2,9% | 3,7% | 0,0% | 0,1% | -0,1% | 0,0% |
| FOOD AND BEVERAGES | -5,2% | 0,7% | 0,0% | 2,9% | 3,8% | 0,0% | 0,1% | 0,0% | 0,0% |
| TEXTILES | -5,2% | 1,1% | 0,0% | 2,9% | 0,0% | 0,0% | 0,1% | 0,0% | 0,0% |
| PAPER AND CELLULOSE | -5,5% | 0,6% | 0,0% | 2,7% | 3,8% | 13,0% | 0,1% | 0,0% | 0,0% |
| CERAMICS | -5,3% | 0,7% | 0,0% | 3,6% | 0,0% | 63,8% | 0,1% | 0,0% | 0,0% |
| OTHER INDUSTRIES | -5,7% | 0,6% | 0,0% | 3,2% | 3,7% | 0,0% | 0,1% | 0,0% | 0,0% |
| NON_IDENTIFIED CONSUMPTION | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | -100,0% | 0,0% |
| **TRANSFORMATION** | -5,1% | 0,8% | 0,0% | 16,4% | 3,7% | 21,6% | 0,8% | -0,1% | 0,0% |
| PUBLIC SERVICE POWER PLANTS | -5,1% | 0,8% | 0,0% | 0,0% | 0,0% | 0,0% | 0,8% | -0,1% | 0,0% |
| AUTO-PRODUCER POWER PLANTS | -5,1% | 0,4% | 0,0% | 2,7% | 3,7% | 21,6% | 0,8% | -0,1% | 0,0% |
| CHARCOAL PLANTS | 0,0% | 0,0% | 0,0% | 16,7% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |

**(values relative to the 2nd)**

| LPG | NAPHTHA | KERO-SENE | GAS | MIN. COKE | CHAR-COAL | ETHYL ALCOHOL | OTHER SEC. PETR. | TAR | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| -2,8% | -0,9% | 0,3% | -22,0% | -2,7% | 2,7% | 20,6% | 0,0% | 1039,0% | 0,0% |
| 0,0% | -0,9% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |
| 0,6% | 0,0% | 0,1% | 39,5% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |
| 0,1% | 0,0% | 0,1% | -28,4% | 0,0% | 6,6% | 0,0% | 0,0% | 0,0% | 0,0% |
| 0,1% | 0,0% | 0,0% | -28,2% | 0,0% | 6,6% | 0,0% | 0,0% | 0,0% | 0,0% |
| 0,1% | 0,0% | 0,1% | -28,4% | 0,0% | 6,6% | 0,0% | 0,0% | 0,0% | 0,0% |
| 0,1% | 0,0% | 0,0% | 0,0% | 0,0% | 6,6% | 0,0% | 0,0% | 0,0% | 0,0% |
| 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 20,6% | 0,0% | 0,0% | 0,0% |
| 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |
| 0,0% | 0,0% | 0,3% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |
| 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |
| 0,0% | 0,0% | 0,2% | 0,0% | 0,0% | 2,2% | 0,0% | 0,0% | 0,0% | 0,0% |
| 0,2% | 0,0% | 0,2% | 36,7% | -2,7% | 2,2% | 0,0% | 0,0% | 1008,7% | 0,0% |
| 0,0% | 0,0% | 0,0% | 39,6% | -2,7% | 2,2% | 0,0% | 0,0% | 0,0% | 0,0% |
| 0,2% | 0,0% | 0,0% | 0,0% | -2,7% | 2,2% | 0,0% | 0,0% | 0,0% | 0,0% |
| 0,2% | 0,0% | 0,0% | 0,0% | -2,7% | 2,2% | 0,0% | 0,0% | 0,0% | 0,0% |
| 0,2% | 0,0% | 0,0% | -28,3% | 0,0% | 2,2% | 0,0% | 0,0% | 0,0% | 0,0% |
| 0,2% | 0,0% | 0,1% | -28,3% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |
| 0,1% | 0,0% | 0,1% | -28,0% | 0,0% | 2,2% | 0,0% | 0,0% | 0,0% | 0,0% |
| 0,1% | 0,0% | 0,0% | -100,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |
| 0,3% | 0,0% | 0,2% | -27,5% | 0,0% | 2,2% | 0,0% | 0,0% | 0,0% | 0,0% |
| 0,2% | 0,0% | 0,2% | -28,3% | 0,0% | 2,2% | 0,0% | 0,0% | 0,0% | 0,0% |
| -100,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |
| 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 467,1% | 12,4% |
| 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,7% |
| 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 467,1% | 8,6% |
| 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |

The critique of the balance is carried out by the process already described in the colors code. In Table 9 the colors indicate the magnitude of discrepancies between the values calculated by the two approaches. The analysis of the transformation centers could be completed using the collected data.

Considering that our aim is to make a diagnosis and not a revision of the coefficients, some energy sources were picked up as a help for this purpose. In order to ease this analysis, we have calculated the relationship



between the emission coefficients and the carbon content in the carbon mass conservation of gasoline, firewood and fuel alcohol. We have also picked up the cases of diesel oil and charcoal to allow a comparison with the three fuels identified as those that deserve more attention.

### Carbon Balance in Transformation

The carbon balance results for the transformation centers are shown in Table 10.

**Table 10: Carbon Balance in the Transformation Units for the Year1990 calculating the emissions by Bottom-Up and Top-Down Processes**

| | C Balance | Raw Material | Balance % | Emissions Bottom-Up | Balance | Balance % | Emissions Top-Down | Balance | Balance % |
|---|---|---|---|---|---|---|---|---|---|
| PETROLEUM REFINERIES | -22 | -50711 | 0,0% | | | 0,0% | | | 0,0% |
| NATURAL GAS PLANTS | -75 | -2909 | -2,6% | | | -2,6% | | | -2,6% |
| GASIFICATION PLANTS | 6 | -245 | 2,6% | | | 2,6% | | | 2,6% |
| COKE PLANTS | -29 | -8143 | -0,4% | | | -0,4% | | | -0,4% |
| .NUCLEAR FUEL CYCLE | | | | | | | | | 0,0% |
| PUBLIC SERVICE POWER PLANTS | -1656 | -1656 | -100,0% | 1640 | -16 | -1,0% | 1630 | -27 | -1,6% |
| AUTOPROD. POWER PLANTS | -1798 | -1798 | -100,0% | 1820 | 22 | 1,2% | 1675 | -123 | -6,8% |
| CHARCOAL PLANTS | -11984 | -15994 | -74,9% | 6971 | -5013 | -31,3% | 10057 | -1927 | -12,1% |
| DISTILLERIES | -2066 | -5684 | -36,3% | | | -36,3% | | | -36,3% |
| OTHER TRANSFOR-MATIONS | -42 | -1205 | -3,5% | | | -3,5% | | | -3,5% |

Including in Table 10 the emission calculated by the two methodologies, the carbon balances present satisfactory results for most transformation units. In the autoproducers power plants some important differences were detected in the results of the two methodologies that may be assigned to emissions calculation in the use of "other primary" and tar (Cf. Table 9). In the charcoal plants the emissions are underestimated but the bigger problem seems to be in the Bottom-Up methodology. In an attempt to equate the matter, firewood will be analyzed in what follows as it presents deviations relative to the two methods. The case of distilleries has already been previously commented and there are problems in the carbon mass/ energy coefficients both for alcohol (that will analyzed in what follows) and the raw material (sugarcane juice and molasses) for which a generic coefficient is applied.

## Emission Coefficients and Carbon Conservation

The emission coefficients used by the *benemis* program use the results of the emission calculations carried out by the Bottom-Up process. Since the carbon mass is conserved, these coefficients must have a relationship so that, for example, if an automobile emits less carbon monoxide (CO), the $CO_2$ quantity or other carbon compounds must increase. The relationship regarding the coefficients is shown in the following box.

The emissions of each sector are divided by the energy contained in the fuel, and the result is a coefficient that corresponds to the ratio: t of gas/toe of fuel. We could name these coefficients (for $CO_2$, $CH_4$, CO and NMOV) $e_1$, $e_2$, $e_3$ and $e_4$..

For an **En** energy contained in the fuel, the mass emitted in the form of a gas **i** will be:

$M_i = En.\ e_i$

Naming $c_1$, $c_2$, $c_3$ and $c_4$, the carbon content of each gas, the contained carbon mass would be:

$M_i.\ c_i = En.\ e_i.\ c_i$

If **fc** corresponds to the carbon mass per energy factor (tC/tep) and **M** and **c** represent the mass and the carbon content of the fuel then:

M.c = fc.En

Since it is assumed that the carbon mass emitted (in the Top-Down process) is equal to M.c.fox (were **fox** is the oxidation factor)

$M.c.fox\ . = M.c_1+M.c_2+M.c_3+M.c_4$

or

$fc.\ En.fox = En.\ e_1.\ c_1 + En.\ e_2.\ c_2 + En.\ e_3.\ c_3 + En.\ e_4.\ c_4$

or, dividing both sides of the equation by En:

$fc.fox = e_1.\ c_1 + e_2.\ c_2 + e_3.\ c_3 + e_4.\ c_4$

or $fc = (\Sigma\ e_i.\ c_i) / fox$

since fox is, in general, very close to1 then:

$fc \approx e_1.\ c_1 + e_2.\ c_2 + e_3.\ c_3 + e_4.\ c_4$

That is, the emission factors have implicitly a relationship with the carbon content and once these factors are known, (as the carbon contents for $CO_2$, CO and $CH_4$ are constant and perfectly determined and practically constant for NMOVC), one can obtain fc (tC/tep),

Since fc varies only according to the fuel composition, in practice these coefficients must have a relationship among them so that the carbon mass is conserved.

The relationship between the emission factor and the carbon mass in the fuel will be used in the emission coefficient analysis.



## Analysis of Gasoline and Diesel Oil Emissions

Gasoline presents one of the most important discrepancies between carbon emissions evaluated by the two methods. In effect in 1990 the carbon mass calculated by the Bottom-Up method is 8050 Gg while it is 5863 Gg by the Top-Down one, with a 37% difference relative to the result from the second method.

According to BEN, in 1990 we had:

7485 thousand toe of gasoline or 313 thousand TJ and 5922 Gg (or thousand t) of Carbon;

Using the 0.04186 tC/toe and18,9 tC/TJ factors and assuming that 99% of the carbon undergoes oxidation (not retained) we have 5863 Gg of carbon by the Top-Down process.

Gasoline consumption in 1990 in Brazil was 7485 thousand toe (9606 thousand $m^3$), that corresponds to a mass of 7041 thousand t[ii]. This mass contains 6125 thousand t (Gg) of C, using the carbon content used previously in the present study [iii] that is only 3.4% different from the carbon mass calculated using the IPCCC factor.

Therefore, the carbon mass calculated from emissions in the Bottom-Up process (8050 Gg) exceeds that of the gasoline itself. The carbon mass and that of contained carbon (of the gases and the total) are shown in Table 11. The data are compared with those published by the Brazilian Declaration and it differs only in the NMVOC value that should be reevaluated after the MCT supplies the coefficients used here.

[ii] Consumption in 1990 was 9543 thousand $m^3$ of automotive gasoline and 63 thousand of aviation gasoline. Considering the respective specific masses (0.740 and 0.720 t/$m^3$, respectively) we have a mass of 7041 thousand t of gasoline.
[iii] Bases for calculating the emission of green house effect gases. Omar Campos Ferreira http://ecen.com/eee43/eee43p/balanco_carb_omar.htm

**Table 11: Gas Emissions and Masses of Contained Carbon for Gasoline (year 1990) and carbon/ implicit energy factor in the emission coefficients used.**

| | Mass Inventory Gg | Emission Factor e Gg/tep | Mass *benemis* Gg | Carbon Content c kg C/ kg | C Mass Inventory Gg | C Mass *benemis* Gg | Product e.c |
|---|---|---|---|---|---|---|---|
| $CO_2$ | 21620 | 2,888 | 21620 | 0,2727 | 5896 | 5896 | 0,7877 |
| CO | 4316 | 0,577 | 4316 | 0,4286 | 1850 | 1850 | 0,2471 |
| $CH_4$ | 5 | 0,00067 | 5 | 0,3158 | 2 | 2 | 0,0002 |
| NMVOC | 807 | 0,108 | 375 | 0,8000 | 646 | 300 | 0,0862 |
| Carbon | | | | | 8393 | 8048 | |
| $\Sigma e_i.c_i$ | | | | | | | 1,121 r |
| $fc = (\Sigma e_i.. c_i) / fox$ | | | (tC/tep) | fox = 0,99 | | | 1,133 |
| $fc = (\Sigma e_i.. c_i) / fox$ | | | (tC/TJ) | | | | 27,1 |

The carbon mass/energy factor for gasoline should be 27.1tC/TJ in order to correspond to the emission factor, instead of IPCC's 18.9 that was adequate for carbon balance in refineries.

The difference found is assigned to a procedure suggested by IPCC where in the case of $CO_2$ the total carbon mass obtained would be indicated. Even then it seems convenient in the future to avoid this double counting of emissions. It would be prudent, at least, to make explicit the procedure adopted and warn that all emitted carbon mass is considered in the $CO_2$ emissions. An additional observation is that in a Bottom-Up process it would be expected that emissions would be based on experimental values (in the case, measurements that represent the fleet).

In the future, a modification will be introduced in the *benemis* program so that one can have emission coherent with the carbon balance (avoiding double counting).

The same emission evaluation was carried out for diesel oil (Table 12). The results were compared with those of the inventory. In the Top-Down methodology the contained carbon (17789 Gg in Table 6) and the carbon emissions (17531 Gg in Table 8) were evaluated and they are not much different from those calculated in the Bottom-Up process (17955 Gg in Table 7). The calculated fc value (20,7 tC/TJ) is not much different from the value recommended by IPCC (20,2 tC/TJ) as well, and the small difference could be caused by the relative importance of the small emissions that only correspond to 2.3% of the total emission.



**Table 12: : Gas Emissions and Masses of Contained Carbon for Diesel Oil (year 1990) and carbon/ implicit energy factor in the emission coefficients used.**

| | Mass Inventory Gg | Emission Factor e Gg/tep | Mass *benemis* Gg | Carbon Content c kg C/ kg | C Mass Inventory Gg | C Mass *benemis* Gg | Product e.c |
|---|---|---|---|---|---|---|---|
| $CO_2$ | 65680 | 3,070 | 64296 | 0,2727 | 17913 | 17535 | 0,837 |
| CO | 715 | 0,034 | 711 | 0,4286 | 306 | 305 | 0,015 |
| $CH_4$ | 5 | 0,000 | 5 | 0,3158 | 2 | 2 | 0,000 |
| NMVOC | 141 | 0,007 | 142 | 0,8000 | 113 | 113 | 0,005 |
| Carbon | | | | | 18334 | 17955 | |
| $\Sigma e_i.c_i$ | | | | | | | 0,857 |
| $fc = (\Sigma e_i.. c_i) / fox$ | | | (tC/tep) | fox = 0,99 | | | 0,866 |
| $fc = (\Sigma e_i.. c_i) / fox$ | | | (tC/TJ) | | | | 20,7 |

**Analysis of Firewood Emissions**

Firewood is another energy source (besides gasoline and alcohol) in which the carbon monoxide in the emissions is important and its analysis is of interest.

The contained carbon value from the Top-Down method (17210 Gg) is lower than that from the Bottom-Up method (19341 Gg), as in the case of gasoline. However, the coefficients used are less trustworthy than those of gasoline and consequently the calculation of the carbon mass is also less trustworthy. The fc value (25.5 tC/TJ) is lower than that indicated by the IPCC and used in the Top-Down approximation (fc=29.9 tC/TJ). Its calculation is shown in Table 13.

**Table 13: Emissions for firewood (year 1990) and calculation of the fc coefficient (carbon mass / energy) corresponding to emissions**

| | Mass<br>Gg | Emission Factor<br>e<br>Gg/tep | Carbon Content<br>c<br>kg C/ kg | C Mass<br>Gg | Product<br>e.c |
|---|---|---|---|---|---|
| $CO_2$ | 63146 | 3,015 | 0,2727 | 17222 | 0,822 |
| CO | 4283 | 0,204 | 0,4286 | 1836 | 0,088 |
| $CH_4$ | 88 | 0,00421 | 0,3158 | 28 | 0,001 |
| NMVOC | 272 | 0,013 | 0,8000 | 217 | 0,010 |
| Carbon | | | | 19302 | |
| $\Sigma e_i.c_i$ | | | | | 0,922 |
| $fc = (\Sigma e_i.. c_i) / fox$ | | | (tC/tep) | fox = 0,87 | 1,059 |
| $fc = (\Sigma e_i.. c_i) / fox$ | | | (tC/TJ) | | 25,3 |

Regarding the values for charcoal (Table 14) it has a carbon mass/energy factor compatible with that recommended by IPCC (fc=29,9 tC/TJ) and presents a 2.6% difference in carbon emissions.

**Table 14: Emissions for charcoal (year 1990) and calculation of the fc coefficient (carbon mass / energy) corresponding to emissions**

| | Mass<br>*benemis*<br>Gg | Emission Factor<br>e<br>Gg/tep | Carbon Content<br>c<br>kg C/ kg | C Mass<br>*benemis*<br>Gg | Product<br>e.c |
|---|---|---|---|---|---|
| CO2 | 26664 | 4,122 | 0,2727 | 7272 | 1,124 |
| CO | 1117 | 0,173 | 0,4286 | 479 | 0,074 |
| CH4 | 51 | 0,00795 | 0,3158 | 16 | 0,003 |
| NMVOC | 26 | 0,004 | 0,8000 | 21 | 0,003 |
| Carbon | | | | 7787 | |
| $\Sigma e_i.c_i$ | | | | | 1,204 |
| $fc = (\Sigma e_i.. c_i) / fox$ | | | (tC/tep) | fox = 0,99 | 1,216 |
| $fc = (\Sigma e_i.. c_i) / fox$ | | | (tC/TJ) | | 29,1 |

**Analysis of Alcohol Emissions**

In the case of alcohol the carbon mass / energy coefficient in the Top-Down method is incoherent with the value obtained using pure ethanol data. The emission values were transferred to Table 15. The calculated carbon mass in emissions (4333 Gg) exceeds the mass calculated in the Top-Down process



(3652 Gg) that must be underestimated due to the C mass/ energy used (14.81 tC/TJ), also underestimated.

However, the carbon mass is coherent with the value expected from the carbon content in ethanol. In fact, the alcohol mass (anhydrous +hydrated) is 9063 thousand t of alcohol that corresponds to about 8900 thousand t of pure ethanol. From the chemical formula of ethanol and from the atomic masses involved we conclude that 24/46 of the ethanol mass is made up of carbon. Therefore we have a mass of approximately 4600 thousand t of this element in alcohol consumption in 1990. This estimate is also coherent with the carbon mass in the emitted gases. That is, in this case the Bottom-Up approximation seems trustworthy and the fc value found (17.9 tC/TJ) is coherent with the expected value for ethanol.

**Table15: Emissions for alcohol (year 1990) and calculation of the fc coefficient (carbon mass / energy) corresponding to emissions**

| | Mass<br>*benemis*<br>Gg | Emission Factor<br>e<br>Gg/tep | Carbon Content<br>c<br>kg C/ kg | C Mass<br>*benemis*<br>Gg | Product<br>e.c |
|---|---|---|---|---|---|
| CO2 | 13437 | 2,295 | 0,2727 | 3665 | 0,626 |
| CO | 1316 | 0,225 | 0,4286 | 564 | 0,096 |
| CH4 | 2 | 0,00030 | 0,3158 | 1 | 0,000 |
| NMVOC | 130 | 0,022 | 0,8000 | 104 | 0,018 |
| Carbon | | | | 4333 | |
| $\Sigma e_i.c_i$ | | | | | 0,740 |
| $fc = (\Sigma e_i.. c_i) / fox$ | | | (tC/tep) | fox = 0,99 | 0,748 |
| $fc = (\Sigma e_i.. c_i) / fox$ | | | (tC/TJ) | | 17,9 |

***6. Conclusions***

The Carbon Balance carried out here is an excellent diagnosis tool for Emissions Inventory. The To-Down and Bottom-Up methodologies are compared allowing a critique of the results and identification of errors.

Furthermore, the calculation programs that were developed permit to estimate emissions between 1970 and 2002, extending to five years the results of the inventory (in the energy area) compiled by the MCT (1990 to 1994)

In the methodological aspect, the highlights were:

- Extension of the Top-Down method to the transformation and consumption centers in an approximation called Top-Bottom;

- Survey of Carbon and Energy Balance in the transformation centers;
- Demonstration of the correlation existing among the emission coefficients and carbon content and the carbon mass/energy factor;
- Identification and evaluation of the double counting in the Bottom-Up procedure where the carbon volume of some fuels can be overestimated in up to 30%;
- Methodology for calculating the carbon and hydrogen content in fuels using the low and high heat values of hydrocarbons.

In the calculation tools we point out:

- A program that calculates emission using the Top-Down process directly from data of an energy source balance extended in a methodology equivalent to that of IPCC. (*ben_eec*);
- A program that evaluates carbon emissions using energy source data and emission coefficients by type of use of fuel included in BEN (*benemis_eee_c*);
- A program that supplies the carbon emissions calculated by the two methodologies in the "account" and energy source of BEN and the differences found in both forms (*benemis_eee_c*);
- Comparison between the results of the two emission calculation methodologies using summary tables with color codes (*benemis_eee_c*).

Concerning the results – that was not the main objective of the study – it should be pointed out:

- Evaluation by the Top-Down process of emissions in the use and transformation of energy between 1970 and 2002;
- Extension of the evaluation of emissions using coefficients taken from the Bottom-Up methodology for the period 1970 to 2002.



Regarding diagnosis, the following points should be noticed:

- Identification of problems relative to the high and low heat values whose coherence should be revised[iv]; the most notorious case BEN is that of natural gas;
- Carbon balance in some transformation centers show important differences between the input and output carbon mass that are larger for biomass; the most important case (according to the diagnosis) is that concerning the incorrect carbon mass/energy coefficients for alcohol; differences were also detected in the energy balance that may be due to inadequate heat values data;
- Carbon balances show important results for fuels where emissions of other gases containing carbon are larger than $CO_2$ due to the double counting in the calculation; the largest difference refers to gasoline mainly in years when carbon monoxide was more accentuated;
- Identification of inaccuracy regarding energy allocation by fuel of origin that might influence the emission accounting (biomass X fossil fuels).

Recommendations for future studies:

- Elaboration of a program (from *ben_eec*) that can generate graphics and tables for the inventory in the Top-Down methodology;
- Study the carbon content coefficients for biomass, notably in the alcohol and vegetal coal production;
- Analysis of consistency regarding BEN's high and low heat values and those from Petrobrás and other sources;
- Development of procedures for evaluating hydrogen (and carbon) content in a fuel using the difference between the high and low heat values;
- Proposition of a coherent set of emission coefficients and carbon content from the analysis of the carbon and energy sources balance values.

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[iv] The conversion values in the IPCC recommendations regarding the HHV and LHV are based on a very simplified hypothesis that does not take into account the carbon content in each type of fuel.

**List of Annexes to the MCT Report, available only in Portuguese at the Internet: http://ecen.com**

Annex 1: Contained Carbon, Equivalent Energy and Energy Balance 49 X 46 - ben_eec Program- User's Manual

Annex 2: Tables of Contained Carbon in Fuels in Selected Years

Annex 3: Results Of Carbon Balance in Selected Years

Annex 4: Goal 1 Report of the Carbon Balance Project



Text for Discussion:

**Alternative to the Additional Protocol of the Nuclear Safeguards Agreement with the IAEA**

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**Introduction**

The nuclear proliferation matter has undergone important changes in the last years:

- India and Pakistan have declared and demonstrated their capability of exploding nuclear warfare artifacts;
- North Korea has admitted nuclear activities for warfare purposes;
- Iran has its nuclear program, allegedly for pacific purposes, which is refutable;
- Nuclear proliferation risk and that of other weapons of mass destruction were used by the United State and Great Britain as a pretext for invading Iraq in spite of the negative results of the UN inspections;
- The big nuclear powers have not only practically disregarded the disarmament policy previously announced but have also resumed old projects like the American "Stars War";
- Finally, in the USA a new concept foresees the use of specific nuclear weapons against countries that do not have them. This doctrine and the use of force against Iraq not considering the conclusions of the UN's inspectors (through the International Atomic Energy Agency) have weakened the best arguments about the practical uselessness of new countries looking for nuclear weapons.

In this panorama, it is of no surprise the total failure of the UN Conference for revising the Non-Proliferation Treaty, the NPT, held in May 2005.

Brazil, that has been pointed out as a concern to the safeguard area and object of international pressure to adhere to the strengthening Additional Protocol of the IAEA had its situation changed:

● The question regarding the inspection methodology for the Resende Enrichment Plant has been settled with the IAEA without disclosing the technical details that Brazil wanted to protect (one camera permits to watch the top of the centrifuges);

● The Brazilian policy of preserving enrichment technology has been recognized as efficient regarding non-proliferation and it has not been recorded any leak of information or participation of Brazilian technicians in non-pacific projects abroad.

The present petroleum prices crisis and the global warming problems associated with the greenhouse effect have led many countries to consider increasing the share of nuclear energy in their energy matrix in the next decades. Countries where the nuclear option has been kept open like China and Japan have announced the intention of intensifying their programs. In Brazil, it seems probable the resuming of the Angra 3 construction.

This will inevitably bring again to discussion the adhesion of Brazil (probably together with Argentina) to the Additional Protocol model that the IAEA has approved for strengthening nuclear safeguards. This Protocol has already been signed by practically all countries where nuclear energy has a relevant role and it does not seem possible that Brazil can indefinitely postpone its decision about adhesion (or not) to this Protocol. Since many times decisions of this type have been taken abruptly (like Brazil's adhesion to the NPT), it is better to have mature ideas about the matter and, if this is the case, to have viable alternatives.

Complementing our previous considerations about the Additional Protocol of the Safeguards Agreement with the International Atomic Energy Agency – IAEA, whose inconveniences we have also pointed out[v], we present schematically in the present note a proposition of an alternative system that, according to our point of view, strengthens the existing safeguards without the inconveniences of the Protocol that is now proposed to the countries.

**The problems of the Additional Protocol**

From our point of view The Additional Protocol presents a series of inconveniences for the signatory country since it makes its nuclear activities more vulnerable regarding technology. This vulnerability is reinforced in countries where the nuclear activity is governmental and is not protected by private rights guaranteed by the country's legislation and respected by the Protocol as well. It also presents risks for the international community because the inevitable increase of the number of persons who know details of the installations and of the technologies involved increases the risk of proliferation at the world level and of dissemination of information about the installations and this may increase the probability of terrorist attacks against nuclear installations.

However, one cannot disregard that the system in force before the safeguards strengthening measures had faults because it did not consider some possibility of non-declared activities and the existence of non-declared materials from non-controlled activities in a country signatory of a safeguards agreement. These faults were partially removed by additional measures within the existing legal frame (without the Additional Protocol); there are some gaps

[v] Are the New Nuclear Safeguards Safe? e&e No 38, http://ecen.com/eee38/ecen_38.htm/



left that this Protocol tries to fill concerning non-declared materials and installations. The alternative system proposed here is based on the fact that proliferation inevitably involves highly specific nuclear material and its early detection is the best way to prevent proliferation and identify the existence of an eventual clandestine program.

The proposed system would continued to be centered on nuclear materials, it would avoid intrusive and potentially proliferating inspections and visits as those to centrifuge plants and would offer as a counterpart a commitment of not using direct use materials such as highly enriched uranium and plutonium with isotopic purity. It would also offer a verification system using environmental samples that could trigger progressive access to installations where there are suspicions of activities that are contrary to the commitments made.

**Proposed system**

The alternative to the present system would start from the following base:

• Acknowledgment that it is necessary to verify the existence in a country of non-declared nuclear material and non-declared installations for its manipulation and use;

• The new alternative strengthened safeguards system, as the one previous to the Protocol, would continue to be centered on nuclear material and would use the environmental detection even as traces;

• The safeguards application would be extended to the complete nuclear fuel cycle as in the Additional Protocol;

• The countries signatory of the new system would made the additional commitment of neither using nor producing nuclear material of direct use in nuclear weapons or with characteristics similar to that material;

• Specifically, the country would make the additional commitment of neither using nor producing highly enriched Uranium; a practical limit of 30 or 25% would be fixed in order to facilitate its application and to avoid false alarms. In the reprocessing area there would be the commitment of only reprocessing fuel with a burn up that supplies the material inadequate to be used in nuclear weapons (a minimum Pu240/Pu239 ratio would be established). The occasional use of U233 resulting from Thorium irradiation would be made with fuel elements where the natural Uranium mixture, before reprocessing, would guarantee the presence of U238 together with the produced U233. The new commitments would be the base for environmental verifications.

• The duration of this commitment could be indefinite or it could be canceled with a minimum notice period to be fixed (for example, 2 years). In this case, as renouncing this additional commitment would make unviable the application of the new system, it would be foresee the automatic acceptance of the Additional Protocol procedures starting on the data the renounce is made public.

• Any public circulation area could be used for environmental sampling by the inspecting agencies aiming at detecting the presence of prohibited materials. Likewise, any circulating area in the declared installations could be used for that purpose.

• The occasional detection of prohibited material would cause the detailed sampling – with adequate mechanisms to be used as counterproof by independent authorities – in the circulation area of the installation involved. A new evidence of the existence of forbidden material would require explanations from the involved country regarding the material and the concerned activities.

• In the case of Brazil and Argentina, the commitment agreement would be established as an additive to the Brazil-Argentina Bilateral Agreement and its fulfillment would be verified by ABACC. In this additive it would be foreseen the possible verification by the IAEA within the Additive to the Quadripartite Agreement (as in the original agreement, the bilateral verification would be started independent from the IAEA).

• An alternative to the bilateral commitment would be an agreement open to adherence of other countries renouncing to materials whose isotopic composition (defined by the agreement) could facilitate access to material of direct use in nuclear weapons.

• The information supplied to the inspecting agencies would consider the non-dissemination of information that might increase the risk of the installations' integrity and the dissemination of sensitive technologies.

**Advantages and disadvantages of the proposed solution**

Advantages:

The advantage of the proposal is that its adoption would make the countries that have not yet accepted the Additional Protocol change their present defensive attitude to an offensive one against proliferation. In fact the refusal of the present version of the Additional Protocol would be based on the argument that it actually favors the proliferation. As an exchange currency, the countries that adhere to the new system would be offering something substantial since the commitment would make it possible to create a zone free of proliferating nuclear materials in a way that does not exist even in signatory countries.



Disadvantages:

It is possible that the proposal does not entirely remove the existing pressures regarding the signature of the Protocol in the present form. Another disadvantage is that renouncing it implies giving up some possible nuclear applications. The most evident one is reactors for satellites; it would also make unviable some special research reactor such as those of high flux. However, based on peaceful applications normally considered for the medium term in the countries that eventually would sign it, there would not be considerable harm for future activities and even the naval reactor – including submarines – would be preserved. In effect, even though the nuclear powers use high enrichments in submarines, the Brazilian program planners declare that enrichments below 20% already give acceptable autonomy to the submarine in its foreseen defensive purposes.

*(*) The author has alternatively been Assistant Secretary and Secretary of the Brazil-Argentina Agency for Nuclear Materials Account and Control – ABACC since its establishment until 2002.*