inventory of countries that have not made it yet. In future studies, a program that presents graphics and tables for the inventory can be.

References:

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Editorial:

This issue is entirely dedicated to the analysis of carbon emissions into the atmosphere that, as known, is the main cause of global warming. Coincidentally, it comes out together with the Kyoto Protocol that came into effect on February 16, 2005, aiming at controlling the Earth warming caused by the greenhouse effect.

Text for Discussion:

Estimation of Carbon Content in Dry Natural Gás Using the Difference between the High and Low Heat Values

The difference between the high and low heat values permits to estimate the water produced in the combustion process. As a consequence, one can estimate the hydrogen and carbon content in hydrocarbons. The methodology is tested on natural gas.

Article:

Carbon Balance in the Production, Transformation and Use of Energy in Brazil – Methodology and Results with the Top-Bottom Process in the period 1970 - 2002.

The Carbon Balance Project, executed by e&e NGO, aims at supplying a tool for calculating the carbon balance in the production, transformation and use of energy in Brazil and the carbon contained in the emissions of the greenhouse effect gases, and its dissemination in electronic form and in written reports. The objective is to detect – by simultaneously applying the Top-Down and Bottom-Up techniques – the possible omissions in one of the two approaches.

The final report, produced under an agreement with the Ministry of Science and Technology (MCT), is concentrated on the elaboration of the methodology and diagnosis of divergences found; however it already permits to obtain reliable results for the period 1970 – 2002.

The first step is to use the Top-Down model extension on all lines of the energy balance in what might be called the Top-Bottom process whose results are presented

Editorial:

COMING INTO FORCE OF THE KYOTO PROTOCOL

The Protocol came into force on February 16, 2005 without the participation of the United States, that have refused to ratify it. This fact greatly limits its coverage due to the responsibility of this country regarding the present and past emissions and its role in the world leadership. It is estimated that the USA emits about 40% of the greenhouse effect gases in the industrialized countries and 21% of the world emissions; its historical contributions is still larger because the CO2 absorption in the atmosphere is very slow in that country and because it has been the leader of emissions of these gases for a long time

At the end of last year Brazil has delivered an inventory of its emissions in the period 1990-1994. The publication of this document is an important step regarding the Brazilian participation – whose energy matrix is one of the cleanest in the world – in the efforts to prevent the aggravation of global warming.

Economy & Energy – the periodical and the organization – has the pleasure to make known its participation in this effort coordinated by the Ministry of Science and Technology. Economy & Energy has also the honor of having among its collaborators some of the important participants in the international effort for establishing the Protocol.

Taking into account its minor responsibility regarding this phenomenon and its development level, Brazil is not presently obliged to control these emissions. However, the Protocol offers the possibility of participating in the world effort through measures that would reduce the world emissions using "carbon credits" from other countries that would finance this effort.

These countries would make this effort here and not in their respective territories because of economical reasons. For the same reasons, it is convenient for Brazil to pay attention to the consequences of the measures that would be adopted here.

Furthermore, the economic control by external organizations regarding our investment possibilities (even the internal ones) makes the country subject to pressures that might define the viability of new undertakings or their cost.

A serious evaluation of the economical and social impact of each one of the projects and of all of them is indispensable. For example, it is not difficult to foresee that a carbon credit operation might prevent the use of land and therefore reduce or shift food production. This might be probable whenever there would be competition between two economical activities: there would be external subsidies for the first one but not for the second one. The consequence would be reduced production or price increase of food.

Table 10: Comparison of CO2 Emissions in Gg/year for Brazil calculated in the present work with those of the inventory

	FOSSIL	RENEWABLE	TOTAL	FOSSIL COPPE/MCT 2002	BIOMASS COPPE/MCT 2002	TOTAL
1990	198535	189462	387998	202910	190575	393485
1991	209567	187242	396809	213220	188221	401441
1992	213726	183505	397231	217466	184521	401987
1993	222705	181714	404419	226369	181676	408045
1994	232805	191832	424637	236599	192636	429235

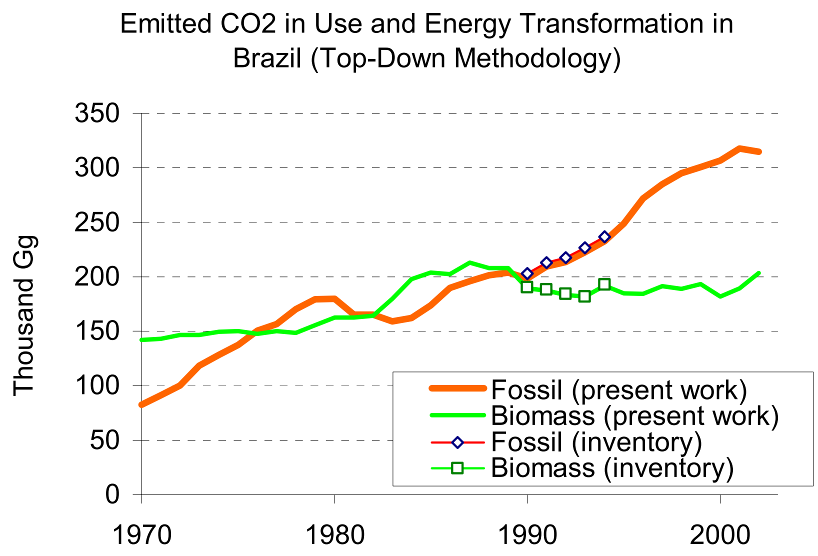

Figure 4: CO2 emissions obtained by the Top-Down methodology adapted to the program's output format.

The agreement between the data obtained here (for the available years) and those of the inventory is very good. It should be pointed out that the calculation routine of the program is completely equivalent to that of IPCC, as demonstrated in Table 5. The small observed differences should be ascribed to the low heat values that in the present approximation are those adopted by BEB and they were not available at the time the inventory was made; there are also small doubts concerning the energy allocations relative to the IPCC methodology. The program developed here is therefore a powerful tool for evaluating the past and projected balances. It can be very useful as well for calculating the

Table 9: CO2 Emissions in Gg/year for Brazil

	PETROLEUM AND ITS PRODUCTS	NATURAL GAS	MINERAL COAL AND PRODUCTS	FOSSIL	RENEWABLE	TOTAL
1970	72791	446	9194	82431	141858	224289
1971	81301	683	9242	91226	142808	234034
1972	89688	746	9852	100285	146324	246609
1973	107707	825	9669	118201	146755	264956
1974	117036	1250	10313	128600	149609	278208
1975	123971	1384	12233	137588	150235	287822
1976	136228	1504	12848	150580	147486	298067
1977	138041	1837	16635	156513	149824	306337
1978	149109	2071	19166	170346	148686	319032
1979	156267	2126	20808	179201	155524	334724
1980	154679	2364	22643	179686	162572	342258
1981	141174	2363	21882	165419	162582	328001
1982	138927	3104	23197	165229	164015	329243
1983	128752	4093	26078	158923	179750	338673
1984	124748	5267	32189	162204	198142	360346
1985	129022	6519	38152	173693	203967	377661
1986	143596	7669	38536	189801	202281	392082
1987	145835	8744	41073	195651	213061	408713
1988	149870	9127	42377	201374	208044	409418
1989	152165	9570	42000	203735	208180	411915
1990	151811	9952	36772	198535	189462	387998
1991	156905	9984	42678	209567	187242	396809
1992	161499	10541	41686	213726	183505	397231
1993	168236	11337	43133	222705	181714	404419
1994	176707	11681	44416	232805	191832	424637
1995	189157	12500	47050	248708	184746	433454
1996	209249	13820	48673	271743	184568	456311
1997	219838	15646	49315	284798	191153	475951
1998	230133	16230	48503	294865	189000	483865
1999	232841	18234	49435	300510	193589	494099
2000	229368	24250	52952	306570	181548	488118
2001	235948	29643	52200	317791	189149	506940
2002	228203	35179	51218	314601	203571	518172

Text for Discussion:

ESTIMATE OF CARBON CONTENT IN DRY NATURAL GAS USING THE DIFFERENCE BETWEEN THE HIGH AND LOW HEAT VALUES

Omar Campos Ferreira.

The Economy and Energy – NGO staff has been developing methods for determining the carbon content in fuels as part of studies for the General Coordination on Climate Change of the Ministry of Science and Technology regarding the atmospheric carbon inventory. The subject is a relevant one in what concerns the Brazilian attitude vis-à-vis the Kyoto Protocol because the establishment of mechanism for clean development was an initiative of the Brazilian Delegation to the Kyoto Conference.

The Brazilian energy matrix is one of the cleanest in the world regarding both the emission of chemical pollutants (CO, non-burned hydrocarbons, SOx, NOx, etc.) and the emission of greenhouse effect gases (CO2, HC, NMOCV´s[i]), except for doubts relative to methane emission. This quality of the matrix is a consequence of the use of hydroelectricity and biomass fuels and it can have important economical effects on the Energy Sector when the Kyoto Protocol comes into force. Then Brazil may sell carbon credits to countries that for some reason cannot reduce their emission to the 1991 level. The position of the United States is contrary to the implementation of the Clean Development Mechanisms because they fear the stagnation of its economy since fossil fuels represents the largest share of energy conversion.

The main objective of the present report is the monitoring of the official information about the carbon content in the products of Transformation Centers (oil refineries, gasification plants, electric power plants, coke plants and distilleries) using the mass/energy balance, the legal specifications of fuels and the respective high and low heat values, checking the coherence of these data through the physical-chemical properties of the components of the fuel mixture.

In the nº 43 issue of the Economy & Energy periodical (http://ecen.com) we have proposed a quick method for determining the carbon content and we gave examples of its application on crude oil and automotive gasoline, obtaining 6% of uncertainty which is typical of the method. This approximation was assigned to uncertainties regarding the fuels specifications and field measurements, in general larger than the

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[i] Non-Methane Volatile Organic Compounds.

uncertainties regarding data from technical publications. However, there are other sources of uncertainties, systematic ones, related to different interpretations of the high and low heat values and even to the explicit - or not - change of the reference physical state.

A compilation of the usual definitions shows that the oldest Thermodynamic texts define the low heat value as the difference between the high heat value and the latent heat of water vapor condensation (L=539 kcal/kg) that is formed in combustion, what is equivalent to considering as reference state that of the combustion product mixture at 100°C and 1 atm when the water vapor is condensed. Other authors, considering that the fuel is initially at 25°C and 1 atm, subtract from the high heat value the condensation latent heat and the cooling heat of the combustion products at the original temperature of the fuel and, in this case, assigning to the combustion gases the average specific heat, between 100°C and 25°C, and assuming the stoichiometric composition of the mixture (fuel + air), it is necessary to take into account the hydrogen content of the original fuel in order to obtain the masses of water vapor and of other gases present as combustion products, what would make the calorific values method meaningless.

Therefore, the verification of the present proposal represents an evaluation of the influence of all these factors on the quick calculation result of the carbon content that, like other quick calculations, can be used as a first approximation, considering that the concentration of greenhouse effect gases is not simply due to the calculated emission of these gases, since the biosphere has reduction mechanisms that are not well known yet.

However, the application of the method to natural gas using data from the 2002 Brazilian Energy Balance did not produce results consistent with the other technical publications within the incertitude range evaluated for the exemplified cases, casting doubts on the validity of the method. In the present study we have tried to remove these doubts by applying the method to dry natural gas (or processed gas, according to several nomenclatures) verifying at each step the data consistency.

Data concerning the Candeias Natural Gas Processing Plant (UPGN) were taken from the www.gasenergia.com.br site that is supported and supervised by PETROBRÁS, as declared on the main page.

Verification schedule.

1 – Conversion of volumetric composition data to mass composition.

2 – Calculation of the high and low heat values, the specific mass and the mixture density relative to that of air using data from the Chemical Engineers´ Handbook, ed. Mc Graw-Hill, 1973 for the physical-chemical properties of substances contained in natural gas.

Table 8: Comparison of Net Carbon Emissions Results (Gg/year)

	FOSSIL	RENEWABLE	TOTAL	FOSSILCOPPE/MCT 2002	BIOMASS COPPE/MCT 2002	TOTAL
1990	54789	57799	112588	55994	58264	114258
1991	57845	57069	114914	58851	57499	116350
1992	58986	55913	114899	60016	56367	116383
1993	61463	55319	116782	62472	55781	118253
1994	64248	58408	122656	65294	58789	124083

The fraction of oxidized carbon (that directly, or through degradation of other compounds in the atmosphere, generates CO2) varies according to the fuel. In the adopted methodology (Top-Down) this correction is carried out using a multiplying factor suggested by IPCC. In two cases (firewood for coal production versus firewood for direct burning and dry natural versus liquids from natural gas) there are specific coefficients. From the carbon mass involved in the transformation, one can calculate the participation of firewood in coal production and that of dry natural gas in consumption. The oxidized fraction for firewood and mineral coal can be obtained and the complement is computed in the other use of each energy source. Using the consumption participation share of humid natural gas (raw material) as dry gas (in the example with 71.1% participation share and 99.5% oxidation) and the consumption complement as natural gas liquids (28.9% with 99% oxidation), one estimates an average coefficient for firewood and humid natural gas that is the weighted average between the two original coefficients. This coefficient is recalculated in each year using the participation shares.[viii]

Table 9 shows the annual results obtained here by primary source and for biomass. The results are compared with the values of the National Inventory in Table 10.

[viii] Within the margin of errors in an evaluation as that of emissions, it would be acceptable the use of the same coefficient for all the years. However, we have tried in the methodology adopted here to make it completely equivalent to that of IPCC and an annual coefficient was calculated for each year for both energy sources.

Table 7: Net Emissions in Gg/year of Carbon

	PETROLEUM AND PRODUCTS	NATURAL GAS	MIN. COAL AND PRODUCTS	FOSSIL	RENEWABLE	TOTAL
1970	20053	122	2560	22735	44268	67003
1971	22397	188	2573	25158	44544	69701
1972	24707	205	2742	27655	45605	73260
1973	29671	227	2691	32590	45730	78319
1974	32241	343	2871	35456	46589	82045
1975	34152	380	3405	37937	46756	84693
1976	37528	413	3577	41518	45898	87416
1977	38028	504	4630	43162	46565	89727
1978	41077	569	5335	46980	46122	93103
1979	43049	584	5792	49424	48137	97561
1980	42611	649	6303	49563	50232	99795
1981	38891	649	6091	45631	50223	95854
1982	38272	852	6457	45581	50558	96139
1983	35469	1124	7259	43852	55284	99136
1984	34366	1446	8960	44772	60854	105626
1985	35543	1790	10620	47953	62520	110473
1986	39558	2105	10727	52390	61888	114278
1987	40175	2400	11432	54007	65164	119170
1988	41287	2506	11794	55587	63570	119156
1989	41919	2628	11689	56236	63565	119801
1990	41821	2733	10235	54789	57799	112588
1991	43224	2742	11878	57845	57069	114914
1992	44490	2894	11602	58986	55913	114899
1993	46346	3113	12004	61463	55319	116782
1994	48680	3207	12362	64248	58408	122656
1995	52109	3432	13095	68636	56216	124852
1996	57644	3794	13547	74985	56114	131099
1997	60561	4295	13726	78582	58139	136721
1998	63397	4455	13500	81352	57510	138862
1999	64144	5006	13759	82908	58896	141804
2000	63187	6658	14738	84583	55218	139801
2001	64999	8141	14528	87669	57583	145252
2002	62866	9661	14255	86782	61984	148766

3 – Calculation of carbon content in natural gas and comparison with the IPCC[ii] data.

Table 1 – Composition of processed NG of Candeias.

Substance	Volume fraction	Specific mass kg/m^3 *	Mass per m^3 of NG - kg	Mass fraction
Methane	0,8856	0,714	0,632	0,800
Ethanol	0,0917	1,339	0,123	0,155
Propanol	0,0042	1,964	0,008	0,010
N_2	0,0120	1,254	0,015	0,019
CO_2	0,0065	1,964	0,013	0,016
Sum	1,000	-	0,791	-

*Calculated by the molecular mass

Relative density in air: 0,791/1,293 = 0,612.
UPGN density = 0,61.
Relative difference 0,002/0,612 = 0,03 (0,3 %).

Table 2 – Heat values.

Substance	Mass fraction	HHV kcal/kg	LHVkcal/kg
Methane	0,800	13265	11954
Ethanol	0,155	12399	11350
Propanol	0,010	12034	11079
N_2	0,019	0	0
CO_2	0,016	0	0
Dry NG	1,000	12650	11430

- Previous table

Calculated HHV = 12650 kcal/kg = 10010 kcal/m^3
HHV UPGN = 12070 Kca/kg = 9549 kcal/m^3
Relative difference = 0,048 (4,8%)

Calculated LHV = 11430 kcal/kg = 9041 kcal/m^3
LHV UPGN = 10090 kcal/kg = 8621 kcal/m^3
Relative difference = 0,049 (4,9%)

[ii] Intergovernmental Panel on Climate Change.

Table 3 – Carbon content calculated by the mixture composition

Substance	Mass fraction	Carbon content
Methane	0,800	0,750
Ethanol	0,155	0,800
Propanol	0,010	0,818
N_2	0,019	0
CO_2	0,016	0,273
Dry NG	1,000	0,737

Table 4 – Carbon content calculated by the heat values of the UPGN.

HHV– LHV		Water mass /kg_{GN}		Hydrogen content		C content = 1 – H_2 content	
		L_1=540	L_2=615	L_1	L_2	L_1	L_2
Calculated	1220	2,26	1,98	0,251	0,220	0,749	0,780
Observed	1170	2,17	1,90	0,241	0,211	0,759	0,789

Notes: L_1 is the water vapor condensation heat at 100°C and 1 atm. L_2 is the sum of L_1 and the cooling heat of the combustion products at 25°C and 1 atm. All heat values are referred to the mass unit (kcal/kg) of the respective substance.

Conclusions.

The largest relative difference between the carbon content calculation results using the fuel composition and using the high and low heat values is less than 0.07 (7%) which is not substantially different from the relative difference for petroleum and automotive gasoline (6%) and it is smaller than the relative uncertainty concerning the high heat value of the processed natural gas (8.6%).

In order to compare our calculations with the IPCC results we have taken the result that presents the largest difference relative to the carbon content calculated using the NG composition (0.789 in Table 4) and have calculated the carbon mass in tones corresponding to 1 TJ of liberated heat.

1 TJ = 1012 J = 0,239 x 1012 cal.

Mass of NG that liberates 1 TJ in complete combustion = 0.239 x 1012 cal /12 x 109 cal/t NG = 19,9 t NG = 19,9 x 0,789 = 15,7 t C /TJ.

The value published by IPCC is 15,5 t C / TJ.

Therefore, we believe that the quick method seems reliable within the accuracy used for calculating carbon balances. Furthermore it permits to take into account differences of fuels from different origins and, in the case of Brazil, to take into account the differences of fuel specifications along time.

Table 6: Example of CO2 Emissions Calculation using Output Lines of the Program

	GROSS OFFER(a)	TOTAL TRANSFORMATION (b)	NON ENERGYFINAL	Retention Coefficient (d)	Oxidation Coefficients(e)	Retained Carbon (f=cxd	Net Carbon Emissions ^(g=a-f)	e Carbon Emissions (h=gxe)	CO2 Emissions (i=hx44/12
PETROLEUM	52726	-54326	0	0,00	0,99	0	52726	52198	191394
HUMID NAT GAS	3478	-3426	0	0,00	0,994	0	3478	3456	12670
DRY NAT GAS	-63	2437	630	0,33	0,995	208	-271	-270	-989
VAPOUR COAL	2126	-1188	0	0,00	0,98	0	2126	2083	7639
NAT. MET. COAL	82	-82	0	0,00	0,98	0	82	81	296
IMP. MET COAL	8937	-8609	0	0,00	0,98	0	8937	8758	32113
OTHER NON REN.	0	0	0	0,00	0	0	0	0	0
FIREWOOD	31108	-13883	0	0,00	0,880	0	31108	27356	100305
SUGARCANE JUICE	4970	-4970	0	0,00	0,99	0	4970	4920	18040
MOLASSES	884	-884	0	0,00	0,99	0	884	875	3207
SUGARCANE PULP	18794	-590	0	0,00	0,88	0	18794	16539	60642
LEACHING	1828	-351	0	0,00	0,99	0	1828	1809	6634
OTHER RECOV.	687	-315	0	0,00	0,994	0	687	683	2504
DIESEL OIL	1554	18737	0	0,00	0,99	0	1554	1538	5641
FUEL OIL	114	10023	0	0,00	0,99	0	114	113	414
GASOLINE	-1710	9461	0	0,00	0,99	0	-1710	-1693	-6206
LPG	1401	3273	0	0,00	0,99	0	1401	1387	5084
NAPHTHA	1944	3403	5136	0,00	0,99	4108	-2165	-2143	-7859
ILLUM. KEROSENE	-3	111	26	0,80	0,99	26	-29	-28	-104
AVIATION KEROSENE	-214	1929	0	1,00	0,99	0	-214	-211	-775
REFINERY GAS	-67	1810	166	0,00	0,99	166	-233	-231	-846
PETROLEUM COKE	-19	636	0	1,00	0,99	0	-19	-19	-69
OTHER PETROLEUM	0	649	0	0,00	0,99	0	0	0	0
TOWN GAS	0	140	0	1,00	0,99	0	0	0	0
MIN. COAL COKE	1322	7301	0	0,00	0,99	0	1322	1295	4749
COKE PLANT GAS	-41	1196	0	0,00	0,98	0	-41	-41	-149
OTH.SEC. TAR	0	231	64	0,00	0,99	64	-64	-63	-231
VEGETAL COAL	-2	3440	0	1,00	0,99	0	-2	-2	-7
ANYDROUS ALCOHOL	150	926	41	0,00	0,99	41	109	107	394
HYDRATED ALCOHOL	323	3069	292	1,00	0,99	292	31	31	112
ASPHALTS	-22	1186	1176	1,00	0,99	1176	-1198	-1186	-4349
LUBRICANTS	-24	599	535	1,00	0,99	535	-559	-553	-2029
SOLVENTS	29	285	297	1,00	0,99	297	-268	-265	-973
OT.NON EN.PET.	16	710	736	1,00	0,99	736	-721	-714	-2616
PET. NG AND RODUCTS	2999	52951	8073	1,00	0,99	7253	-4254	51379	188388
MIN. COAL AND PROD..	12426	-1152	64	0,00		64	12362	12114	44416
FOSSILS	15425	51799	8136	0,00		7317	8107	63492	232805
RENEWABLE	58742	-13557	334	0,00		334	58408	52318	191831
TOTAL	130307	-17072	9100	0,00		7651	122656	115810	424636

In order to avoid double counting, the raw materials produced or imported as well as the products exported or imported are accounted for; the transformations (of primary into secondary energy) carried out in the country should not be considered, as the carbon has already been computed in the raw material.

The gross internal offer concept actually corresponds to that adopted by IPCC where stock variations and re-injections are accounted for. It excludes as well the production losses that may however be evaluated from the spreadsheet generated by *ben_ee*.

The retained carbon, accounted for in the Top-Down methodology is that corresponding to the non-energy use. In this type of use carbon is not always retained and the IPCC methodology recommends the use of some coefficients (mass percent) in order to take into account the emission by natural evaporation (and subsequent conversion to CO2 in the atmosphere) or by waste burning or degradation. When they are not supplied, one can use evaluated coefficients based on available information. In the present case we have opted, whenever possible, for the values used in the mentioned COPPE/MCT report. The values used in the reference report were 0.8 for naphtha, 0.5 for lubricants, 0.75 for tar and 0.33 for dry natural gas. For other compounds the value 1 was adopted (all carbon retained). In Table 5 the calculation process is illustrated for the year 1994. [vii]

In Table 7 the net emissions (carbon content – retained carbon) are shown for the other years separated into fossil fuels and biomass. The values calculated for the national inventory are also compared in Table 8 with those obtained here.

[vii] According to the authors of the present study, the use of unitary values (100% retention) deserves a revision, mainly for volatile products such as alcohol and solvents.

Article:

CARBON BALANCE IN THE PRODUCTION, TRANSFORMATION AND USE OF ENERGY IN BRAZIL– METHODOLOGY AND RESULTS OF THE TOP-BOTTOM PROCESS FROM 1970 TO 2002.

Technical Staff
Carlos Feu Alvim (coordinator)
Frida Eidelman
Omar Campos Ferreira

1. Carbon Balance Project

The Carbon Balance Project, executed by the NGO Economy and Energy – publisher of this periodical - aims at supplying a tool for calculating the carbon balance in the production, transformation and use of energy in Brazil and for calculating the carbon content in the emissions of greenhouse effect gases, and the dissemination of the results in electronic form and printed reports

The objective is to detect – through the simultaneous application of the Top-Down and Bottom-Up techniques – the possible omissions in one of the two approaches that could be due to incoherence of the coefficients used or flaws in the emissions calculation. The principle used is that carbon atoms do not disappear in the fuel use process and in each phase of the process the original quantity of carbon (contained mass) must be the same as that emitted or captured by some process.

The present study, carried out under an agreement with the Ministry of Science and Technology (MCT), has concentrated on the methodology and diagnoses of the deviations found. Suggestions regarding the treatment of the problems and the establishment of a coherent balance will be presented at the conclusion of the present report. The necessary corrections will be made afterwards.

The comparisons made with the inventory data show that these corrections – mainly in the Top-Down process – are quantitatively not relevant. As a consequence, it is possible to obtain the emissions between 1970 and 2000 with a precision equivalent to that of the Brazilian Inventory.

The Final Report was delivered to the Ministry of Science and Technology – MCT and is available in our electronic address http://ecen.com. This article presents in a concise way some of the results obtained. Other results will be presented in the next issues of this periodical.

The period examined is from 1970 to 2000, corresponding to that of the data available at the Brazilian Energy Balance (BEB), published by the Ministry of Mines and Energy[1], when the project was executed and they were used by the present study.

Table 5: Emissions Calculation using the IPCC Top-Down Method (Suite)

			Carbono Contido			Emissões Líquidas de Carbono		Emissões de Carbono	Emissões de CO2		
			COPPE/MCT	Present work	Desvio	COPPE/MCT	Este Trabalho	Este Trabalho	COPPE/MCT	Este Trabalho	Desvio
Biomass Fuel	Solid Biomass	Direct Wood Burning	17621	17226	-2,3%	15330	17226	17053	56845	56210	-1,1%
		Charcoal Wood	13907	13883	-0,2%	12392	13883	13744	45813	45436	-0,8%
		Sugarcane Bagasse	18937	18794	-0,8%	16665	18794	16539	60642	61104	0,8%
		Biomass Waste	812	687	-18,2%	714	687	683	2504	2619	4,4%
		Charcoal	-4	-2		-3	-2	-2	-7	-12	39,5%
Total Solid	Biomass		51273	50588	-1,4%	45097	50588	48017	165796	165357	-0,3%
Liquid Biomass		Sugarcane Juice	4762	4970	4,2%	4715	4970	4920	18040	17287	-4,4%
		Molasses	902	884	-2,1%	893	884	875	3207	3275	2,1%
		Anhydrous Alcohol	150	150	0,0%	108	109	107	394	395	0,2%
		Hydrated Alcohol	191	323	40,9%	-100	31	31	112	-367	130,6%
		Leaching	1844	1828	-0,9%	1825	1828	1809	6634	6693	0,9%
Total Liquid	Biomass		7849	8154	3,7%	7440	7820	7742	28388	27282	-4,1%
Gaseous	Biomass		0								
Total Biomass	Fuel		59122	58742	-0,6%	52537	58408	55759	194184	192639	-0,8%
General Total			131431	130307	-0,9%	116902	122924	119510	426896	429257	0,5%

Table 5: Emissions Calculation using the IPCC Top-Down Method 1994 Gg/Year

			Contained Carbon			Net Carbon Emissions		C Emissions	CO2 Emissions		
			COPPE/ MCT	Present work	Deviation	COPPE/ MCT	Present work	Present work	COPPE/ MCT	Present work	Deviation
Liquid Fossil	Primary Sources	Petroleum	53105	52726	-0,7%	52574	52726	52198	191394	192770	0,7%
		Liquid NG	758	1041	27,2%	750	1041	1036	3470	2752	-26,1%
	Secondary Sources		-1720	-1710	-0,6%	-1702	-1710	-1693	-6206	-6242	0,6%
		Aviation Kerosene	-214	-214	-0,2%	-211	-214	-211	-775	-775	0,0%
		Illumination Kerosene	-3	-3	-9,8%	-28	-29	-28	-104	-93	-11,6%
		Diesel Oil	1553	1554	0,1%	1538	1554	1538	5641	5638	-0,1%
		Fuel Oil	114	114	0,2%	113	114	113	414	415	0,1%
		LPG	1402	1401	-0,1%	1388	1401	1387	5084	5088	0,1%
		Naphtha	1924	1944	1,0%	-2122	-2165	-2143	-7859	-7780	-1,0%
		Asphalt	-22	-22	-1,7%	-1186	-1198	-1186	-4349	-4350	0,0%
		Lubricants	-24	-24	-0,6%	-290	-291	-288	-1058	-1065	0,7%
		Petroleum Coke	-19	-19	0,5%	-19	-19	-19	-69	-69	-0,4%
		Refinery Gas	0	-67		-179	-233	-231	-846	-658	-28,6%
		Other Secondary Petroleum Products	178	0		176	0	0	0	646	
		Other Non-energy Petrol. Prod.	45	45	-0,4%	-984	-989	-979	-3589	-3608	0,5%
Total Liquid Fossil			57077	56766	-0,5%	49815	49988	49494	181149	182669	0,8%
Solid Fossil	Primary Sources	Metallurgical Coal	9172	9019	-1,7%	8989	9019	8839	32409	32958	1,7%
		Steam Coal	2143	2126	-0,8%	2101	2126	2083	7639	7702	0,8%
	Secondary Sources	Coke	1281	1322	3%	1256	1322	1295	4749	4604	-3,1%
		Other Mineral Coal Tar + coke gas	0	-41		-60	-105	-104	-380	-221	-72,0%
Total Solid Fossil			12596	12426	-1,4%	12284	12362	12114	44416	45043	1,4%
Gaseous Fossil		Dry Natural Gas	2474	2374	-4,2%	2266	2166	2144	7147	8308	14,0%
Total Gaseous Fossil			2474	2374	-4,2%	2266	2166	2144	7147	8308	14,0%
Other Primary Fossil			162	0		191	0	0	0	598	
Total Fossil			72309	71565	-1,0%	64365	64516	63751	232712	236618	1,7%

2. Methodology

The Carbon Balance will try to establish an accounting of the net input and output of carbon in the activities concerning energy sources. The scheme is analogous to that adopted by BEB and is shown in Figure 1.

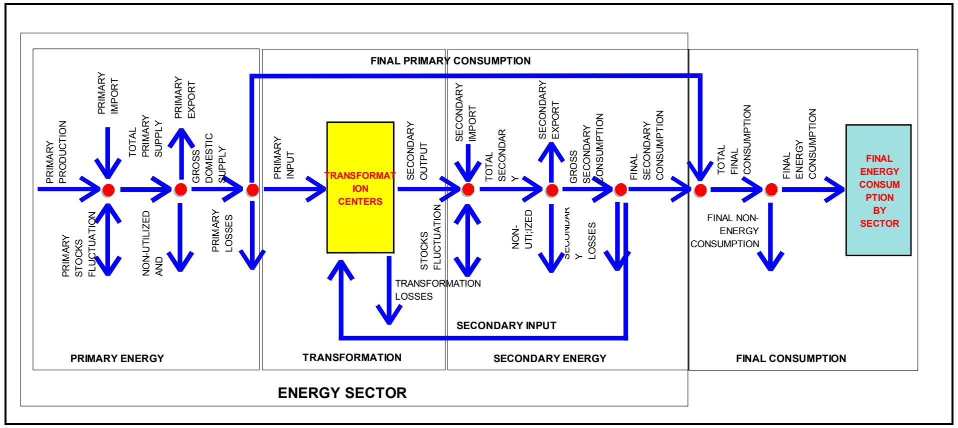

Figure 1: Brazilian Energy Balance Scheme. Source: BEB/MME

Strictly speaking, one could make a carbon balance in each of the steps of the scheme above. The present study is concentrated on the centers of energy transformation and consumption. The treatment of the previous steps is certainly of interest for calculating the balance but it would involve data that are not available at BEB. For example, it would be important to know the characteristics of imported petroleum and of that internally produced in order to check the carbon content at the refineries' input.

The values used in that balance are originally given in natural units that correspond to those used at the origin of information (mass in tones and volume in m^3). In some cases, when the sources are grouped, the units are in tones equivalent petroleum (tep) and a special criterion must be established in order to calculate the emissions.

For the input data, it is necessary to evaluate the mass (or volume) of the emitted gases, its carbon content and the mass of this element that is eventually retained. Whenever available, one must also account for the losses provided that they are a real evaluation; when they are a simple record of the accounting differences, the carbon balance will calculate them. The methodology to compile the results was the object of the previous e&e-MCT agreement (ONG Nº 01.0077.00/2003) and is described in the reports presented whose abstract was published in the e&e periodical.[2].

In the methodology adopted, the emissions are calculated multiplying the values relative to the final use of the energy sources and to some transformations, expressed in energy, by coefficients calculated by surveying the inventory of greenhouse effect gases emissions in Brazil[3]. The coefficients used in the years before the period of the inventory calculation are those used for the first year when it was calculated (1990). The coefficients for the years subsequent to 1999 are those corresponding to that year (last year of the inventory).

For hydrocarbons, an approximation for the carbon content by contained energy can be obtained from the difference between the high and low heat values given by BEB. The methodology and its verification for gasoline was shown in the No 43 issue of this periodical (http://ecen.com/eee43/eee43p/ecen_43p.htm) and that of natural gas, in the present issue. The differences between the heat values fundamentally corresponds to the (latent) heat liberated in the condensation of water vapor formed in the combustion of one unit of fuel mass and the heat removed from the condensed water in order to reduce it to the ambient temperature, considered as 25º (540+75 cal/$g_{\mathbf{water}}$). The difference between the heat values permits to deduce the quantity of water that is formed and consequently the hydrogen contained per unit mass of the fuel. The participation of carbon (in the case of hydrocarbons) is the complement of this participation.

3. Carbon Content in Energy Sources.

The elaboration of carbon balance requires firstly the conversion of BEB's data to carbon mass. The second step is to calculate the emissions that contain carbon.

Both in the carbon content calculation and the emissions evaluation, it is sometimes convenient to have data that are more detailed than that published in BEB's annex pages. It is convenient, for example, to have natural gas as humid and dry gas, hydrated and anhydrous alcohol as well as sugarcane compounds (sugarcane juice, bagasse and molasses) data.

The Ministry of Mines and Energy (MCT) published in 2002 balance data for 49 energy sources and 46 "accounts"[iii]. Economy and Energy – NGO made a computer program (in Visual Basic and Excel) called *ben_ee*, where these data can be obtained in final or equivalent energy, in partial or complete tables. The energy source data can be

[iii] The "accounts" concept corresponds, in the Brazilian Energy Balance (BEB), to accounting points that could be consumption or transformation centers and operations reference to availability (gross offer) of energy sources (production, exports, imports, etc.)

FUEL OIL	GASOLINE	LPG	NAPHTHA	KEROS.	GASWORKS GAS	MIN. COAL COKE	URANIUM W.UO2	ELECTRICITY	CHARCOAL	ETHYL ALCOHOL	OTH. SEC. PET.	PET.NON EN.PROD.	OTH. MIN. C.	SECONDARY EN.	TOTAL
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	137955
50	100	1474	2082	668	0	1841	0	0	5	1	2180	355	0	13338	43265
-39	115	0	-86	23	0	150	0	0	0	341	226	-26	0	1087	1659
11	215	1474	1996	691	0	1991	0	0	5	341	2406	329	0	14426	182879
-6715	-2075	-77	-32	-604	0	0	0	0	-3	-243	-279	-106	0	-10711	-20867
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1411
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-2107
-6704	-1860	1397	1964	87	0	1991	0	0	2	99	2127	224	0	3715	158494
14036	11859	3929	3515	2561	26	6565	0	0	2948	4082	6031	3665	1153	82623	-19070
15087	11471	3353	5622	2584	0	0	0	0	0	0	4800	3737	0	69759	-466
0	0	512	55	0	0	0	0	0	0	0	0	0	0	568	-87
0	0	0	0	0	26	0	0	0	0	0	0	0	0	26	3
0	0	0	0	0	0	6565	0	0	0	0	0	0	1335	7901	470
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-889	0	0	0	0	0	0	0	0	0	0	0	0	0	-1800	-4626
-326	0	0	0	0	0	0	0	0	0	0	-264	0	-182	-956	-4423
0	0	0	0	0	0	0	0	0	2948	0	0	0	0	2948	-8359
0	0	0	0	0	0	0	0	0	0	4082	0	0	0	4082	-1527
164	388	64	-2162	-24	0	0	0	0	0	0	1496	-72	0	96	-46
-8	0	-7	0	0	-4	-9	0	0	-89	-117	-49	0	0	-290	-564
7276	9864	5329	5514	2657	22	8547	0	0	2861	4064	8109	3873	1153	85918	138465
0	0	0	5511	76	0	0	0	0	0	293	125	3873	102	9980	10442
7276	9864	5329	3	2581	22	8547	0	0	2861	3772	7983	0	1052	75938	128023
866	0	7	3	1	0	0	0	0	0	0	2337	0	250	3541	13205
0	0	4396	0	43	18	0	0	0	270	0	0	0	0	4728	14419
334	0	191	0	0	3	0	0	0	36	0	0	0	0	631	829
141	0	293	0	0	0	0	0	0	0	0	0	0	0	578	602
94	0	14	0	0	0	0	0	0	3	0	0	0	0	4148	6394
656	9864	0	0	2523	0	0	0	0	0	3772	0	0	0	38656	39208
0	9830	0	0	0	0	0	0	0	0	3772	0	0	0	34811	35363
0	0	0	0	0	0	0	0	0	0	0	0	0	0	384	384
0	34	0	0	2523	0	0	0	0	0	0	0	0	0	2558	2558
656	0	0	0	0	0	0	0	0	0	0	0	0	0	904	904
5186	0	428	0	13	0	8547	0	0	2552	0	5646	0	801	23656	53364
119	0	0	0	1	0	0	0	0	128	0	2446	0	0	2714	2991
93	0	58	0	2	0	8430	0	0	2208	0	358	0	801	11980	14610
10	0	0	0	0	0	9	0	0	207	0	100	0	0	327	455
667	0	24	0	3	0	0	0	0	0	0	124	0	0	952	1560
769	0	39	0	0	0	108	0	0	5	0	496	0	0	1416	1768
821	0	12	0	1	0	0	0	0	0	0	1810	0	0	2744	4033
757	0	48	0	2	0	0	0	0	0	0	20	0	0	869	17252
173	0	11	0	0	0	0	0	0	0	0	0	0	0	185	434
777	0	22	0	0	0	0	0	0	0	0	0	0	0	831	4961
307	0	109	0	0	0	0	0	0	0	0	58	0	0	481	2856
693	0	104	0	4	0	0	0	0	4	0	233	0	0	1156	2445
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-47	-135	10	35	9	0	-1	0	0	0	0	0	-15	0	-130	-395

Table 4: Contained Carbon by Type of Fuel and "Account" – Gg/Year 2002

ACCOUNT / ENERGY	PETROLEUM	NATURAL GAS	STEAM COAL	MET. COAL	URANIUM (U238)	HYDRAULIC EN.	FIREWOOD	S. CANE PRODUCTS	OTHER	PRIMARY ENERGY	DIESEL OIL
PRODUCTION	62886	10255	2090	68	0	0	29579	28850	4227	137955	0
IMPORTS	16508	3024	0	10394	0	0	0	0	0	29926	4583
CHANGES IN STOCK	757	0	-144	-42	0	0	0	0	0	571	384
TOTAL SUPPLY	80152	13280	1946	10419	0	0	29579	28850	4227	168453	4967
EXPORTS	-10155	0	0	0	0	0	0	0	0	-10155	-577
NON-UTILIZED	0	-1411	0	0	0	0	0	0	0	-1411	0
REINJECTION	0	-2107	0	0	0	0	0	0	0	-2107	0
GROSS DOMESTIC SUPPLY	69997	9762	1946	10419	0	0	29579	28850	4227	154780	4389
TOTAL TRANSFORMATION	-69687	-3091	-1639	-7431	0	0	-11469	-6955	-1422	-101693	22253
PETROLEUM REFINERIES	-69543	0	0	0	0	0	0	0	-682	-70225	23106
NATURAL GAS PLANTS	0	-1271	0	0	0	0	0	0	616	-655	0
GASIFICATION PLANTS	0	-23	0	0	0	0	0	0	0	-23	0
COKING PLANTS	0	0	0	-7431	0	0	0	0	0	-7431	0
NUCLEAR CYCLE	0	0	0	0	0	0	0	0	0	0	0
PUBL. UTIL. POWER PLANTS	0	-1228	-1586	0	0	0	0	0	-13	-2826	-910
SELF.PROD. POWER PLANTS	0	-497	-53	0	0	0	-163	-1346	-1409	-3467	-184
CHARCOAL PLANTS	0	0	0	0	0	0	-11306	0	0	-11306	0
DISTILLERIES	0	0	0	0	0	0	0	-5609	0	-5609	0
OTHER TRANSFORMATIONS	-144	-73	0	0	0	0	0	0	75	-141	241
LOSSES IN DISTRIB./STORAGE	-45	-192	0	-38	0	0	0	0	0	-275	-7
FINAL CONSUMPTION	0	6479	307	2950	0	0	18110	21895	2806	52547	26650
FINAL NON-ENERGY CONSUMPTION	0	462	0	0	0	0	0	0	0	462	0
FINAL ENERGY CONSUMPTION	0	6017	307	2950	0	0	18110	21895	2806	52084	26650
ENERGY SECTOR	0	1663	0	0	0	0	0	8001	0	9664	75
RESIDENTIAL	0	87	0	0	0	0	9605	0	0	9691	0
COMMERCIAL	0	117	0	0	0	0	81	0	0	198	67
PUBLIC	0	24	0	0	0	0	0	0	0	24	145
AGRICULTURE	0	1	0	0	0	0	2245	0	0	2246	4037
TRANSPORTATION -TOTAL	0	552	0	0	0	0	0	0	0	552	21842
HIGHWAYS	0	552	0	0	0	0	0	0	0	552	21210
RAILROADS	0	0	0	0	0	0	0	0	0	0	384
AIRWAYS	0	0	0	0	0	0	0	0	0	0	0
WATERWAYS	0	0	0	0	0	0	0	0	0	0	248
INDUSTRIAL-TOTAL	0	3573	307	2950	0	0	6179	13893	2806	29708	483
CEMENT	0	18	10	136	0	0	0	0	113	277	21
PIG-IRON AND STEEL	0	576	5	2050	0	0	0	0	0	2631	29
FERRO-ALLOYS	0	0	0	47	0	0	81	0	0	128	0
MINING/PELLETIZATION	0	117	0	491	0	0	0	0	0	608	134
NON-FERROUS/OTHER METALS	0	179	0	173	0	0	0	0	0	352	0
CHEMISTRY	0	1044	71	6	0	0	52	0	116	1288	100
FOODS AND BEVERAGES	0	260	54	0	0	0	2205	13863	0	16383	42
TEXTILES	0	152	0	0	0	0	96	0	0	248	1
PAPER AND PULP	0	255	83	0	0	0	1220	30	2544	4131	32
CERAMICS	0	452	30	0	0	0	1860	0	33	2375	6
OTHER INDUSTRIES	0	520	56	48	0	0	665	0	0	1289	118
NON-IDENTIFIED CONSUMPTION	0	0	0	0	0	0	0	0	0	0	0
ADJUSTMENTS	-265	0	0	0	0	0	0	0	0	-265	14

represented in ton equivalent petroleum (tep) in the concept previously adopted by BEB and in the present one[iv], in Low Heat Value (LHV) and High Heat Value (HHV) and in "natural units" (mass and volume).

As part of the present agreement, the computer program was updated for the available data (1970- 2002) and they are also expressed in carbon content by using coefficients (mass C/energy) for each energy source. The annual data (in energy) are therefore converted to contained carbon and can now also be used for the set of years and generate temporal series.

In another approach that incorporates the Bottom-Up approximation results, the consolidated energy balance results (24 energy sources) and the values calculated by the MCT staff that elaborated the national emissions inventory published in the "Brazilian Communication to the United Nations Framework on Climate Change"[v], were used to calculate the emission coefficients by energy source in each of the economic sectors presented in the balance (consumption) and transformation centers where there are direct emissions.

Using the above mentioned program denominated ben_eec (equivalent energy and carbon balance in the present version), tables with the carbon content by "account" and by energy source as normally presented in BEB were produced.

Comparing the results of the two methodologies, one can evaluate the validity of the carbon mass/energy coefficients used and the eventual errors or omissions in the inventory calculation. The carbon balance will also permit the extrapolation of emission values in the years before and after the inventory period (1990-1994) with more assurance.

It is hoped that the first set of results will be very similar to that corresponding to the Top-Down calculation recommended by the IPCC. The difference should only be the quantity of carbon retained (in the energy source uses) and in the non-oxidized carbon. In an easy way, it is possible to obtain emission values corresponding to this methodology from the results generated in this program. The program and its manual are available at http://ecen.com

Calculation of the Carbon Content

The ben_eec program presents the high and low heat values supplied by the MME. These values could be used for obtaining the carbon content as shown in Annex 1 of the Final Report. Even though the

[iv] In the program the terms "old tep" (10,8 Gcal) and "new tep" (10,0 Gcal) were adopted in order to distinguish the two types of values.

[v] In what follows, the terms National (or Brazilian) Inventory and National Communication refer to this document and the inventory it contains.

results for the year 2002 have been promising, some important differences were found. Besides that, as the objective of the present work is to develop a methodology and make a diagnosis, we have opted in the present step to use the same coefficients values used previously for calculating the emissions inventory. For this reason, we have used the coefficients of COPPE's report to the General Coordination of Climate Change4 that are, most of them, those values recommended by the IPCC5. It should be pointed out that the emissions values found in that reference are those that have been adopted by the already mentioned Brazilian National Communication.

In Table 1 are presented the results of the methodology application based on the heating values and the coefficients used in the present report (actually the same as those of COPPE's report to the MCT mentioned above).

Table 1: Carbon content using the high and low heating values compared with values based on the IPCC values

Year 2002	HHV	LHV	KgH2O/ KgFuel	kgH/ KgFuel	KgC/ KgFuel	Mass of C / Energy	
	a	b	e=(a-b)4,18/ 615	f=e/9	g=1-f	Calculated.	Used
	kcal/kg	kcal/kg				tC/TJ	tC/TJ
Petroleum	10800	10180	1,0081	0,112	0,8880	20,9	20,0
Humid natural gas(1)	11717	11130	0,9545	0,106	0,8939	19,2	15,9
Dry natural gas(1)	11735	11157	0,9398	0,104	0,8956	19,2	15,3
Steam coal	3100	2950	0,2439	0,027	0,9729		25,8
National metalurgical coal	6800	6420	0,6179	0,069	0,9313		25,8
Imported metalurgical coal	7920	7400	0,8455	0,094	0,9061	29,2	25,8
Picked wood	3300	3100	0,3252	0,036	0,9639		29,9
Commercial wood	3300	3100	0,3252	0,036	0,9639		29,9
Sugarcane juice	0	623	-1,0130	-0,113	1,1126		20,0
Molasses	0	1850	-3,0081	-0,334	1,3342		20,0
Sugarcane bagasse (3)	2257	2130	0,2065	0,023	0,9771		29,9
Leaching	3030	2860	0,2764	0,031	0,9693		20,0
Diesel oil	10700	10100	0,9756	0,108	0,8916	21,1	20,2
Average fuel oil	10080	9590	0,7967	0,089	0,9115	22,7	21,1

content table. It should be noted that the present work has used the same data source used by COPPE for the MCT but the data supplied by the MME are different. Particularly, it is already possible to use here the low heat value (LHV) adopted by BEB for defining the ton equivalent petroleum (tep) which was not available in the previous evaluation.

Since the aim of the present report is not to evaluate the emissions, some small divergences were not entirely elucidated and they may be due to energy source data or to how to group smaller fractions of the energy fluxvi. The comparison results were encouraging, with average deviations smaller than 1% that are doubtless much smaller than those implicit in the adopted methodology.

Therefore, it is possible to make an evaluation of the emissions in the long 1970-2002 period that is presented in what follows.

Evaluation of Emissions between 1970 and 2002 or the Use of the Top-Bottom Process

The IPCC methodology was adapted to directly calculate data generated by the ben_eec program. Three lines of the spreadsheet shown in Table 4 were used, namely:

- Gross Internal Offer
- Total Transformation
- Non- Energy Final Consumption

It should be mentioned that the Top-Down methodology starts from the principle that the number of carbon atoms is conserved along the several interactions that finally will result in CO2 emission or of any other gas containing carbon. The IPCC methodology is directed to evaluating the carbon dioxide production.

This methodology consists of accounting for the primary and secondary fuels that enter in the economic system of a country in order to satisfy the needs of human activities (even the non-commercial ones) and that leave the system (retention in materials, net exports and non-oxidation).

vi The uncertainties associated with natural gas and alcohol should be calculated, since problems may occur regarding the heat values used.

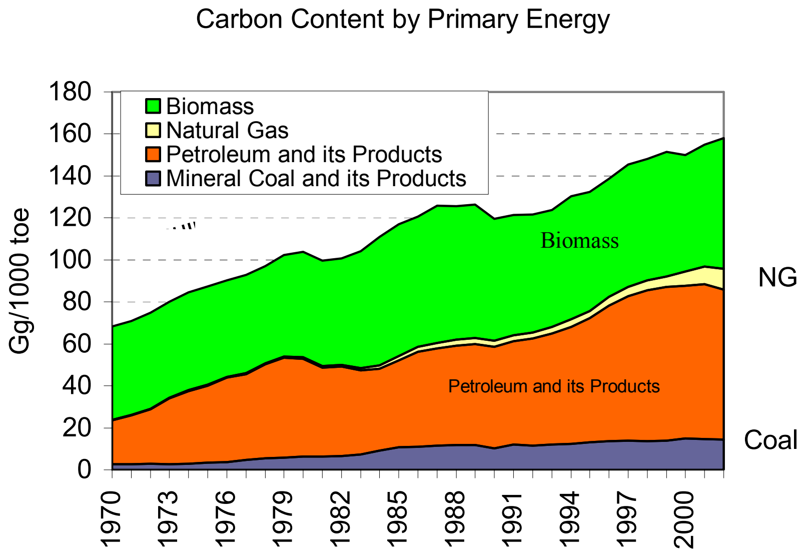

Figure 3: Carbon contained in the energy sources for the main fossil fuels and biomass

Table 4 shows data for 1994 using the division shown in BEB's annexes. Annex 3 of the Final Report contains additional tables for selected years. Tables in this and other formats for additional years can be generated by the program that is annexed to this report.

It is worth while to notice that in the way that the program was made, it can produce almost immediately a Top-Down evaluation of the emissions that contain carbon. The result of such an evaluation is very close to the data corresponding to the line "Gross Internal Offer" of the spreadsheet (49 energy sources) that generated Table 4 (24 energy sources). The program evaluates the quantity of carbon retained in the non-energy uses of the fuels using factors suggested by IPCC and subtracting this quantity from the corresponding item.

More precisely, it would be necessary to use two more lines of the spreadsheet to subsidize the calculations. Using the Non-Energy Final Consumption line, one evaluates the carbon retained in the non-energy uses. The "Total Transformation" line can be used to evaluate an oxidation coefficient in cases where the data "division" used (49X46) has more than one IPCC coefficient. This occurs only in the cases of natural gas (liquids of natural gas and dry gas) and firewood (coal production and other uses).

In Table 5 the results obtained by the Top-Down (COPPE/MCT) process are compared with those calculated here using the carbon

Year 2002	HHV	LHV	KgH2O/ KgComb	kgH/ KgComb	KgC/ KgComb	Mass of C / Energy	
	a	b	e=(a-b)4,18/ 615	f=e/9	g=1-f	Calculated.	Used
	kcal/kg	kcal/kg				tC/TJ	tC/TJ
Automotive gasoline	11170	10400	1,2520	0,139	0,8609	19,8	18,9
Aviation gasoline	11290	10600	1,1220	0,125	0,8753	19,7	19,5
Liquefied petroleum gas	11740	11100	1,0407	0,116	0,8844	19,0	17,2
Naphtha	11300	10630	1,0894	0,121	0,8790	19,8	20,0
Illumination kerosene	10940	10400	0,8780	0,098	0,9024	20,7	19,6
Aviation kerosene	11090	10400	1,1220	0,125	0,8753	20,1	19,5
Coke plant gas (4)	4500	4300	0,3252	0,036	0,9639		18,2
Town gas Rio de Janeiro (4)	3900	3800	0,1626	0,018	0,9819		18,2
Town gas São Paulo (4)	4700	4500	0,3252	0,036	0,9639		18,2
Mineral coal coke	7300	6900	0,6504	0,072	0,9277	32,1	30,6
Vegetal coal	6800	6460	0,5528	0,061	0,9386		29,9
Anhydrous ethyl alcohol	7090	6750	0,5528	0,061	0,9386		14,81
Hydrated ethyl alcohol	6650	6300	0,5691	0,063	0,9368		14,81
Refinery gas	8800	8400	0,6504	0,072	0,9277	26,4	18,2
Petroleum coke	8500	8390	0,1789	0,020	0,9801	27,9	27,5
Other petroleum energy sources	10800	10180	1,0081	0,112	0,8880	20,8	20,0
Other Secondary - Tar	9000	8550	0,7317	0,081	0,9187	26,2	20,0
Asphalt	10300	9790	0,8293	0,092	0,9079	22,1	22,0
Lubricants	10770	10120	1,0569	0,117	0,8826	20,8	20,0
Solvents	11240	10550	1,1220	0,125	0,8753	19,8	20,0
Other petroleum Non-Energy	10800	10180	1,0081	0,112	0,8880	20,8	20,0

Results for the Contained Carbon

The ben_eec program supplies the contained carbon by "account" and by energy source. In Table 2 are given the contained carbon values in the energy sources of the Energy Balance for petroleum and its products (including the liquids from natural gas), for natural gas and for mineral coal and its products. It is also shown the sum of the carbon mass from fossil fuels and that from biomass. The values obtained are compared with the national inventory and they show good agreement.

Table 2: Carbon Content in Energy Sources Used in Brazil from 1970 to 2002

	PETROLEUM AND ITS PRODUCTS	NATURAL GAS	. MINERAL COAL AND ITS PRODUCTS	FOSSIL FUELS	BIOMASS	TOTAL
1970	21068	123	2595	23786	44399	68185
1971	23396	192	2613	26201	44645	70846
1972	26103	215	2784	29101	45705	74806
1973	31311	241	2737	34289	45818	80108
1974	34607	359	2914	37880	46705	84585
1975	36603	397	3459	40460	46874	87334
1976	40186	441	3640	44266	45998	90264
1977	40933	527	4668	46128	46696	92824
1978	44712	630	5421	50763	46240	97003
1979	47451	655	5868	53975	48244	102219
1980	46432	733	6403	53568	50388	103955
1981	42538	709	6181	49428	50354	99782
1982	42509	941	6574	50024	50683	100707
1983	39832	1273	7401	48505	55525	104030
1984	38983	1609	9143	49735	61072	110807
1985	41368	1966	10799	54133	62778	116911
1986	45312	2298	10916	58526	62129	120655
1987	46318	2606	11537	60461	65387	125849
1988	47359	2714	11851	61923	63783	125706
1989	48068	2854	11745	62667	63799	126466
1990	48205	2909	10326	61441	58103	119544
1991	49282	2927	11978	64187	57287	121473
1992	50771	3088	11642	65501	56134	121635
1993	52751	3306	12051	68107	55602	123709
1994	55725	3415	12426	71565	58742	130307
1995	58957	3609	13150	75717	56595	132312
1996	64639	3957	13687	82282	56472	138754
1997	68738	4345	13911	86994	58465	145459
1998	72024	4534	13659	90217	57886	148103
1999	73149	5156	13873	92178	59275	151453
2000	72662	6813	14856	94331	55613	149944
2001	73866	8289	14643	96798	58001	154799
2002	71547	9803	14356	95706	62280	157985

Table 3: Comparison between the Obtained Carbon Content and those of the Brazilian Inventory

	Present study			COPPE for MCT		
	FOSSIL FUELS	BIOMASS	TOTAL	FOSSIL FUELS	BIOMASS	TOTAL
1990	61441	58103	119544	62345	58567	120912
1991	64187	57287	121473	64903	57716	122619
1992	65501	56134	121635	66259	56587	122846
1993	68107	55602	123709	68832	56063	124895
1994	71565	58742	130307	72311	59122	131433

Figure 2 represents the evolution of the contained carbon in the energy sources used in Brazil compared with that of the national inventory

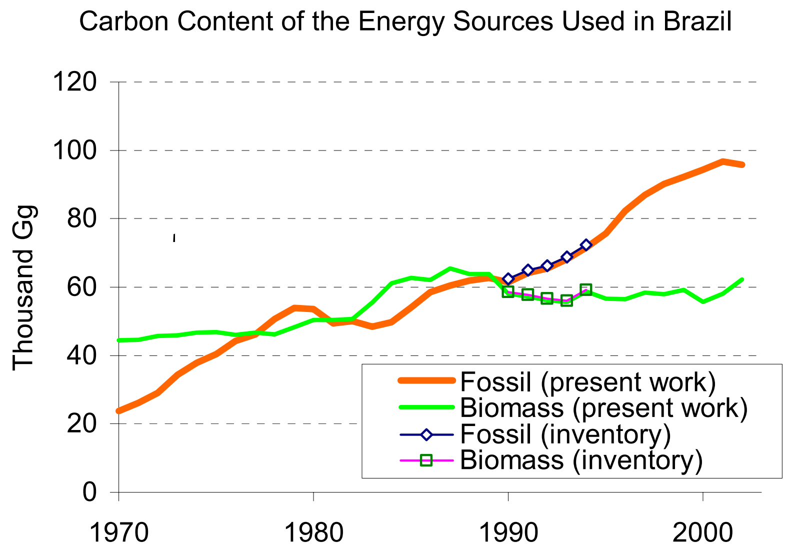

Figure 2: Carbon content in the energy sources used in Brazil obtained in the present work compared with data from the National Inventory.

Figure 3 shows the evolution of the carbon content of energy sources used in Brazil by primary fossil energy and in biomass