SCENARIOS BUILDING BY INTEGRATING ENERGY BALANCES AND SUPPLY AND USE TABLES: AN APPLICATION OF INPUT-OUTPUT ANALYSIS

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Abstract

A continuation of work aiming at better integration between energy and economic analysis by merging national energy balances with national supply and use tables is presented. Methodology enhancements include new tools for long-term energy scenarios composed of complete energy balances projections, expressed in physical units, systemically integrated with supply and use tables expressed in monetary units. The results show the ability of the model to capture both economic and energy policy influences on final energy consumption and its environmental impacts highlighting the importance of the structure of economic growth on energy consumption patterns. Alternative trends and indicators for the 2000-2060 time horizon are given as examples along with sensitivity tests.

Introduction

This paper is a follow-up of work previously presented at the 20th International Input-Output Conference held in Bratislava, Eslováquia (PAIXAO, P, 2012). Its subject is the same: to seek for better integration between energy and economic analysis by merging national energy balances with national supply and use tables (SUTs) within a single framework.

While the previous work aimed mainly at the simulation of short-term economic impacts on energy supply and use, in the present case methodology enhancements include tools for long-term energy scenarios development.

These scenarios are composed of complete energy balances projections, expressed in physical units, systemically integrated with supply and use tables expressed in monetary units. The proposed formulation allows the analysis of relations between energy and economic behavior, ranging from aggregate energy flows and economic variables to the supply and demand of specific fuels with sectorial economic activities.

The input-output equations are applied only to economic variables, thus dispensing with the hybrid construction, what improves the accountability of the model and its access by forecasting teams not familiar with input-output mathematics and terminology, paving the way for customization and direct utilization by decision makers.

The model continues to utilize the Excel platform, including routines in Excel Visual Basic.

In what follows there is a description of these new features, including database organization, methodological procedures, and some examples of their application. The results presented must be regarded as initial tests of their feasibility and potentialities, as pointed out on a brief account of possible future developments.

Database

The Brazilian National Energy Balance

Published yearly ever since 1970, the Brazilian National Energy Balance is available in physical units, both specific for each kind of fuel (e.g., tons of oil, MWh), and in a standard metric, which is tons of oil equivalent (toe) adjusted for the average oil consumed in Brazil.

The balance has, in its columns, the primary and secondary fuels produced and consumed in the country. By primary is understood the fuel as found in nature (such as oil, coal, hydropower), being the secondary fuels those made available after transformation processes of primary fuels (such as refined oil products and electricity). In its lines, the balance shows the activities involving in producing, processing and consuming the fuels which, in their turn, are displayed on the columns, see Figure 1. For reasons of space, not all columns are shown. The complete list is available in an appendix at the end of the text.

Figure 1 – Brazilian 2015 energy balance summary

10^3 toe	PRIMARY SOURCES OF ENERGY						SECONDARY SOURCES OF ENERGY								
	OIL	NATURAL GAS	...	SUGAR-CANE PRODUCTS	OTHER PRIMARY SOURCES	TOTAL PRIMARY ENERGY	DIESEL	...	ELECTRICITY	...	ETHANOL	...	TOTAL SECONDARY ENERGY	TOTAL
PRODUCTION	126,127	34,871	...	50,424	16,045	286,277	0	...	0	...	0	...	0	286,277
IMPORTS	15,377	16,198	...	0	0	46,997	5,885	...	2,978	...	432	...	29,204	76,201
STOCK VARIATIONS	-1,165	0	...	0	8	-2,582	313	...	0	...	899	...	1,481	-1,101
TOTAL SUPPLY	140,339	51,069	...	50,424	16,053	330,692	6,199	...	2,978	...	1,331	...	30,685	361,377
EXPORTS	-38,050	0	...	0	0	-38,050	-651	...	-19	...	-1,108	...	-13,654	-51,704
NON-UTILIZED	0	-1,377	...	0	0	-1,377	0	...	0	...	0	...	0	-1,377
REINJECTION	0	-8,722	...	0	0	-8,722	0	...	0	...	0	...	0	-8,722
GROSS DOMESTIC SUPPLY	102,288	40,971	...	50,424	16,053	282,543	5,548	...	2,959	...	223	...	17,031	299,574
TOTAL TRANSFORMATION	-101,841	-21,737	...	-21,757	-9,040	-206,644	42,511	...	49,966	...	15,705	...	177,075	-29,569
OIL REFINERIES	-99,972	0	...	0	-3,783	-103,755	42,248	...	0	...	0	...	103,346	-409
NATURAL GAS PLANTS	0	-3,727	...	0	245	-3,482	0	...	0	...	0	...	3,273	-208
GASIFICATION PLANTS	0	0	...	0	0	0	0	...	0	...	0	...	0	0
COKE PLANTS	0	0	...	0	0	-7,676	0	...	0	...	0	...	7,334	-341
NUCLEAR CYCLE	0	0	...	0	0	-971	0	...	0	...	0	...	955	-15
PUBLIC SERVICE POWER	0	-13,704	...	0	-2,001	-49,162	-2,031	...	41,687	...	0	...	32,686	-16,476
SELF-PRODUCERS POWER	0	-2,706	...	-5,959	-3,913	-14,936	-399	...	8,279	...	0	...	6,748	-8,188
CHARCOAL POWER PLANTS	0	0	...	0	0	-7,810	0	...	0	...	0	...	4,163	-3,647
DISTILLERIES	0	0	...	-15,798	0	-15,798	0	...	0	...	15,705	...	15,705	-93
OTHER TRANSFORMATIONS	-1,869	-1,600	...	0	412	-3,056	2,692	...	0	...	0	...	2,866	-191
LOSSES IN DISTRIBUTION	0	-464	...	0	0	-477	0	...	-7,829	...	-54	...	-8,046	-8,523
FINAL CONSUMPTION	0	18,765	...	28,667	7,013	74,971	48,033	...	45,096	...	15,927	...	186,232	261,203
NON-ENERGY FINAL CONSUMPTION	0	685	...	0	0	685	0	...	0	...	490	...	14,553	15,238
ENERGY FINAL CONSUMPTION	0	18,080	...	28,667	7,013	74,286	48,033	...	45,096	...	15,437	...	171,679	245,966
ENERGY SECTOR	0	6,112	...	13,155	0	19,266	1,338	...	2,741	...	0	...	8,496	27,763
RESIDENTIAL	0	312	...	0	0	6,645	0	...	11,264	...	0	...	18,282	24,927
COMMERCIAL	0	114	...	0	0	208	4	...	7,861	...	0	...	8,376	8,585
PUBLIC	0	43	...	0	0	43	3	...	3,735	...	0	...	4,003	4,047
AGRICULTURAL AND LIVESTOCK	0	0	...	0	0	2,814	6,327	...	2,303	...	13	...	8,666	11,480
TRANSPORTATION - TOTAL	0	1,553	...	0	0	1,553	39,244	...	177	...	15,424	...	82,484	84,037
HIGHWAYS	0	1,553	...	0	0	1,553	38,033	...	0	...	15,424	...	76,714	78,267
RAILROADS	0	0	...	0	0	0	971	...	177	...	0	...	1,148	1,148
AIRWAYS	0	0	...	0	0	0	0	...	0	...	0	...	3,658	3,658
WATERWAYS	0	0	...	0	0	0	240	...	0	...	0	...	965	965
INDUSTRIAL - TOTAL	0	9,947	...	15,512	7,013	43,756	1,117	...	17,015	...	0	...	41,371	85,127
CEMENT	0	12	...	0	330	482	60	...	611	...	0	...	4,262	4,744
PIG-IRON AND STEEL	0	1,223	...	0	0	3,348	29	...	1,609	...	0	...	13,377	16,725
IRON-ALLOYS	0	6	...	0	0	69	6	...	524	...	0	...	1,137	1,206
MINING AND PELLETIZATION	0	657	...	0	0	1,075	395	...	1,095	...	0	...	2,271	3,346
NON-FERROUS AND	0	593	...	0	0	1,282	10	...	2,315	...	0	...	4,364	5,646
CHEMICAL	0	2,222	...	0	85	2,527	18	...	1,940	...	0	...	4,348	6,874
FOOD AND BEVERAGES	0	834	...	15,485	10	18,565	239	...	2,242	...	0	...	2,910	21,475
TEXTILES	0	215	...	0	0	277	2	...	560	...	0	...	618	895
PAPER AND PULP	0	805	...	27	6,529	9,279	173	...	1,864	...	0	...	2,450	11,729
CERAMICS	0	1,324	...	0	59	3,757	24	...	339	...	0	...	856	4,614
OTHERS	0	2,057	...	0	0	3,096	162	...	3,917	...	0	...	4,778	7,874
UNIDENTIFIED CONSUMPTION	0	0	...	0	0	0	0	...	0	...	0	...	0	0
ADJUSTMENTS	-447	-4	...	0	0	-451	-25	...	0	...	53	...	171	-280

The Brazilian supply and use table

Figure 2 shows the arrangement of supply and use tables adopted by IBGE[1]. They show, on the supply table, data corresponding to the activities of products taxation, production, and imports, and, on its use counterpart, intermediate and final consumption.

[1] Instituto Brasileiro de Geografia e Estatística, the national official agency of statistics.

Besides, they also provide a value-added tabulation by sector. The level of occupation by sector is also provided at the bottom of the tables, allowing to systemically relating employment with national accounts variables on a yearly basis.

In the Brazilian version, the number of sectors (n) and of products (m) is given in a few alternatives, being its larger dimension 68 sectors by 128 products, and the smaller 12 sectors by 12 products. In this work, a version of 107 lines by 51 columns was adopted.

Regarding tables titles, a brief description follows below.

- ✓ **Production** shows the product output of each industry, summing up to their totals by sector at the bottom line (vector **x**') and by-product at the right column (vector **q**).
- ✓ **Taxes on products** are the taxes charged on activities related to the transactions of goods and services, such as retailing and exports.
- ✓ **Total supply** is the addition of the values of national production and imports as well as taxes and margins and must equate to **Total use** to achieve the supply-demand balance of the economy in a given period, usually one year.
- ✓ **Total use** is the addition of **Intermediate consumption** and **Final demand**
- ✓ **Intermediate consumption** is the section of the use table which shows the transactions needed for the activities of production. Its columns explain the goods and services consumed by a given sector to produce its output. On the other hand, the lines indicate the sales of each sector for production purposes. The intermediate consumption table provides a fair idea of the technology and the productive mode of the country or region tabulated.
- ✓ **Final demand** is the last destination of the production, consisting of exports, private and public consumption, investments and inventory changes.
- ✓ **Value-added items** comprise the compensation of employees, other net taxes on production, consumption of fixed capital and net operating surplus.

Figure 2 – The Brazilian supply and use table framework

SUPPLY TABLE				
Margins + Taxes + National production + Imports	Margins and taxes by product	Production by sector and product Columns = n sectors Lines = m products (Matrix V')	Total production by product (Vector q)	Imports by product
∑ = TOTAL SUPPLY	∑ = Total taxes	∑ = Production by sector (Vector X')	∑ = Total production	∑ = Total imports

USE TABLE				
Intermediate consumption by sector and product Columns = n sectors Lines = m products (Matrix U)	Intermediate consumption by product (Vector u)	Final demand by activity and product Columns = Exports, Public and private consumption, Investments, Inventories change Lines = m products	Final demand totals by product (Vector E)	Intermediate consumption + Final demand
∑ = Intermediate consumption by sector (Vector u')	∑ = Total IC	∑ = Final demand by activity	∑ = Total FD	∑ = TOTAL USE = TOTAL SUPPLY

VALUE ADDED
Columns = n sectors Lines = value added items: labor and capital remuneration, social security, taxes and subsidies on production
Occupation by sector

Methodology

Defining an initial stage

The initial stage, or the projections year zero, is established by merging the Brazilian Supply and Use Table of 2015 at basic prices[2] with the transpose of the Brazilian Energy Balance of the same year. For doing so, the following steps must be observed:

- ✓ To split the energy balance into two tables representing respectively supply and use flows;
- ✓ To express the use tables in basic prices
- ✓ To integrate energy balances in physical units with SUTs in monetary units

Splitting the energy balances into supply and use tables

As the energy balances consist of a single tabulation, negative figures in some instances differentiate use from supply of fuels, as Table 1 exemplifies. The columns show the conciliation between supply and use of fuels with positive and negative signals. Generically, the following relation holds:

Gross domestic supply = Transformation + Losses + Final Consumption + Adjustments

Gross domestic supply = Production + Imports + Stocks increase – Exports – NonUtilized - Reinjection[3]

Some care must be observed when dealing with these figures, extracted from the Brazilian 2015 Energy Balance. As we can see, for oil and natural gas, negative numbers express transformation, while for diesel and electricity a positive figure does the job.

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[2] Basic prices are the prices paid directly to the producers. Purchasers'prices, on the other hand, are the prices paid by the purchasers, including margins realized by wholesalers and retailers, transport margins and taxes invloved in the transactions.
[3] Being the two last terms (NonUtilized and Reinjection) applicable only for natural gas production.

Table 1 - Energy Balance by Fuel, example

(Data from the Brazilian Energy Balance 2015; 1,000 ote)

Activity	Oil	Natural Gas	Diesel	Electricity
GROSS DOMESTIC SUPPLY	102,288	40,971	5,548	2,959
TOTAL TRANSFORMATION	-101,841	-21,737	42,511	49,966
LOSSES IN DISTRIBUTION	0	-464	0	-7,829
FINAL CONSUMPTION	0	-18,765	-48,033	-45,096
ADJUSTMENTS	-447	-4	-25	0
TOTAL	0	0	0	0

The reason is that, in the case of oil and natural gas, the Balance displays transformation as a primary fuel input, or use, for the obtention of secondary fuels for consumption, and negative numbers represent this by convention.

In the case of diesel and electricity, on the other hand, transformation displays outputs, and not inputs, of the transformation processes that produce them, and for this reason, positive numbers are employed.

This happens as a result of expressing both supply and uses of fuels in a single table, having to balance the production and consumption of them.

Let us see now what happens if we represent the same energy flows following the supply and use tables arrangement, as shown in Table 2.

Table 2 - Energy Balance by Fuel, supply and use example

(Data from the Brazilian Energy Balance 2015; 1,000 ote)

Supply	GROSS DOMESTIC SUPPLY	TOTAL TRANSFORMATION	LOSSES IN DISTRIBUTION	FINAL CONSUMPTION	ADJUSTMENTS	TOTAL
Oil	102,288	0	0	0	0	**102,288**
Natural Gas	40,971	0	0	0	0	**40,971**
Diesel	5,548	42,511	0	0	0	**48,058**
Electricity	2,959	49,966	0	0	0	**52,925**
Use						
Oil	0	101,841	0	0	447	**102,288**
Natural Gas	0	21,737	464	18,765	4	**40,971**
Diesel	0	0	0	48,033	25	**48,058**
Electricity	0	0	7,829	45,096	0	**52,925**

The first thing to observe is that the table transposes the data in Figure 3: rows became columns and vice-versa. Besides, all numbers are in black, for all are positive[4]. The balance of each fuel, in its turn, is now expressed by the equality of totals per line, i.e., supply matches use per fuel.

Finally, attention must be drawn to the total figures, which can differ substantially in the two cases. While the total supply figure for oil remains the same, for diesel things are different. The reason is that, in the supply and use mode, transformation into diesel means production, becoming positive and adding up to the gross domestic supply.

[4] Negative numbers, however, can appear in the use tables in the cases of stocks variation and adjustments.

Obtaining use tables at basic prices

The Leontief approach in this work is applied to the Brazilian national economy, which means to distinguish domestic production from imports. On the other hand, the Use Tables are published in purchasers' prices, thus including the imports component. Only the national input-output tables publications make available use tables in basic prices, i.e., free of the imports component. Those tables, however, are published over rather long periods of time.

Therefore, in order to work with more recent data, it is necessary to convert the Use Tables from purchasers' prices to basic prices. The method utilized here was based on GUILHOTO, J.J.M., U.A. SESSO FILHO (2005), but with adjustments to fit the intermediate consumption totals per sector at basic prices with the total value added per sector as published by IBGE[5], whereby the following economic identity must apply per sector :

VP = VA + M+IP+CIpb, where

VP = Gross domestic output

VA = Value Added

M = Imports of goods and services

IP = Taxes on products

CIpb = Intermediate Consumption at basic prices.

Besides, the imports participation by sector was derived from the Input-Output Imports Matrix of 2005, differing from the procedure followed by the method.

Integrating energy balances with supply and use tables

Aggregation

Once the energy balances are converted into the supply and use mode, they are integrated with the supply and use tables, resulting in tabulations where energy flows are expressed both in physical and monetary units, see tables 3 and 4. In their columns, they show twelve sectors obtained both from the aggregation of the Brazilian National Energy Balance of 2015 (MME 2018) and the National Supply and Use Table of 2015 (IBGE 2018).

The Supply and Use Table used as a source has 107 lines representing products and 51 columns representing productive sectors. On the other hand, the Energy Balance, after transposed, has 24 lines representing fuels and 37 columns describing activities related to their production, imports, exports, stock variations, exports, conversion from primary into secondary fuels and final consumption. In the adaptation to the supply and use form, these activities were rearranged into production, intermediate consumption and final demand.

Aggregation was the way followed to conciliate the sectors classification patterns of these two sources of data, which are rather different. Regarding the SUT, out of its 51 columns, only three are directly related to energy. Even so, they aggregate more than one fuel in two cases (oil and natural gas, refining of oil and coke), and electricity with gas and non-energy activities (water, sewage and urban cleaning services).

For this reason, only two energy productive sectors were considered in the integration process. Electricity, regarded as a special case both due to its unique use universality and to its increasing participation in final consumption. And the rest of the energy sector, which actually means mainly oil products: electricity and oil products composed 82% of final energy consumption in Brazil in 2015.

[5] IBGE = Insitituto Brasileiro de Geografia e Estatística, the statistics Brazilian national authority.

Table 3 - Energy and Economy Supply Table, Brazil 2005

Physical (1000ote) and monetary (R$ millions) units

Primary energy Physical Secondary energy Physical Primary energy Monetary Secondary energy Monetary Rest of economy Monetary	Agriculture	Mining	Metallurgy	Chemistry	Food and beverages	Textiles	Paper and pulp	Other manufacturing	Commercial and public	Transport	Electricity	Other energy	Total
OIL	0	0	0	0	0	0	0	0	0	0	0	126,127	**126,127**
NATURAL GAS	0	0	0	0	0	0	0	0	0	0	0	34,871	**34,871**
STEAM COAL	0	0	0	0	0	0	0	0	0	0	0	2,459	**2,459**
METALLURGICAL COAL	0	0	0	0	0	0	0	0	0	0	0	0	**0**
URANIUM U3O8	0	0	0	0	0	0	0	0	0	0	0	512	**512**
HYDRAULIC ENERGY	0	0	0	0	0	0	0	0	0	0	0	30,938	**30,938**
FIREWOOD	0	0	0	0	0	0	0	0	0	0	0	24,900	**24,900**
SUGAR-CANE PRODUCTS	0	0	0	0	0	0	0	0	0	0	0	50,424	**50,424**
OTHER PRIMARY SOURCES	0	0	0	0	0	0	0	0	0	0	0	16,702	**16,702**
DIESEL	0	0	0	0	0	0	0	0	0	0	0	44,941	**44,941**
FUEL OIL	0	0	0	0	0	0	0	0	0	0	0	14,188	**14,188**
GASOLINE	0	0	0	0	0	0	0	0	0	0	0	21,518	**21,518**
LPG	0	0	0	0	0	0	0	0	0	0	0	6,367	**6,367**
NAPHTA	0	0	0	0	0	0	0	0	0	0	0	3,545	**3,545**
KEROSENE	0	0	0	0	0	0	0	0	0	0	0	4,656	**4,656**
COKE OVEN GAS	0	0	0	0	0	0	0	0	0	0	0	1,635	**1,635**
COAL COKE	0	0	0	0	0	0	0	0	0	0	0	6,265	**6,265**
URANIUM CONTAINED IN UO2	0	0	0	0	0	0	0	0	0	0	0	955	**955**
ELECTRICITY	0	0	0	0	0	0	0	0	0	0	49,966	0	**49,966**
CHARCOAL	0	0	0	0	0	0	0	0	0	0	0	4,163	**4,163**
ETHANOL	0	0	0	0	0	0	0	0	0	0	0	15,705	**15,705**
OTHER SECONDARIES	0	0	0	0	0	0	0	0	0	0	0	10,946	**10,946**
NON-ENERGY OIL PRODUCTS	0	0	0	0	0	0	0	0	0	0	0	6,181	**6,181**
TAR	0	0	0	0	0	0	0	0	0	0	0	237	**237**
OIL	0	0	0	0	0	0	0	0	0	0	0	103,753	**103,753**
NATURAL GAS	0	0	0	0	0	0	0	0	0	0	0	11,973	**11,973**
STEAM COAL	0	0	0	0	0	0	0	0	0	0	0	240	**240**
METALLURGICAL COAL	0	0	0	0	0	0	0	0	0	0	0	0	**0**
URANIUM U3O8	0	0	0	0	0	0	0	0	0	0	0	2	**2**
HYDRAULIC ENERGY	0	0	0	0	0	0	0	0	0	0	0	19,301	**19,301**
FIREWOOD	0	0	0	0	0	0	0	0	0	0	0	1,683	**1,683**
SUGAR-CANE PRODUCTS	0	0	0	0	0	0	0	0	0	0	0	19,945	**19,945**
OTHER PRIMARY SOURCES	0	0	0	0	0	0	0	0	0	0	0	6,602	**6,602**
DIESEL	0	0	0	0	0	0	0	0	0	0	0	200,820	**200,820**
FUEL OIL	0	0	0	0	0	0	0	0	0	0	0	24,387	**24,387**
GASOLINE	0	0	0	0	0	0	0	0	0	0	0	100,152	**100,152**
LPG	0	0	0	0	0	0	0	0	0	0	0	24,080	**24,080**
NAPHTA	0	0	0	0	0	0	0	0	0	0	0	75	**75**
KEROSENE	0	0	0	0	0	0	0	0	0	0	0	100	**100**
COKE OVEN GAS	0	0	0	0	0	0	0	0	0	0	0	3,070	**3,070**
COAL COKE	0	0	0	0	0	0	0	0	0	0	0	161	**161**
URANIUM CONTAINED IN UO2	0	0	0	0	0	0	0	0	0	0	0	26	**26**
ELECTRICITY	0	0	0	0	0	0	0	0	0	0	291,778	0	**291,778**
CHARCOAL	0	0	0	0	0	0	0	0	0	0	0	5,374	**5,374**
ETHANOL	0	0	0	0	0	0	0	0	0	0	0	77,236	**77,236**
OTHER SECONDARIES	0	0	0	0	0	0	0	0	0	0	0	20,934	**20,934**
NON-ENERGY OIL PRODUCTS	0	0	0	0	0	0	0	0	0	0	0	11,725	**11,725**
TAR	0	0	0	0	0	0	0	0	0	0	0	460	**460**
COMMERCIAL	204	360	6,646	10,583	8,361	583	1,976	21,260	4,034,143	37,482	4,432	919	**4,126,949**
PUBLIC	0	0	0	0	0	0	0	0	1,136,194	0	0	0	**1,136,194**
AGRICULTURAL PRODUCTS	464,440	0	0	0	0	0	0	0	860	42	0	0	**465,342**
HIGHWAYS	0	0	0	0	0	0	0	0	9,404	467,835	31	0	**477,270**
RAILROADS	0	0	0	0	0	0	0	0	0	0	0	0	**0**
AIRWAYS	0	0	0	0	0	0	0	0	0	0	0	0	**0**
WATERWAYS	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CEMENT	0	0	0	0	0	0	0	0	0	0	0	0	**0**
PIG-IRON AND STEEL	0	0	99,813	172	0	9	0	1,064	0	9	0	0	**101,067**
IRON-ALLOYS	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MINING AND PELLETIZATION	0	52,000	647	0	0	0	0	0	0	0	0	0	**52,647**
NON-FERROUS AND	0	16,332	134,584	1,349	169	59	35	7,258	1,144	0	0	0	**160,930**
CHEMICAL	0	483	1,718	394,880	2,800	967	568	4,324	8,236	8	0	427	**414,411**
FOOD AND BEVERAGES	6,153	121	0	1,683	598,811	16	11	260	36,365	7	0	6,708	**650,135**
TEXTILES	0	0	27	1,150	0	36,453	43	1,159	98	0	0	0	**38,930**
PAPER AND PULP	0	0	0	0	0	0	21,448	8	0	0	0	0	**21,456**
CERAMICS	333	17,344	31	316	16	0	0	830	127	0	0	0	**18,997**
OTHERS	7,578	581	6,535	6,692	676	8,343	56,256	1,526,346	17,167	0	2	8,489	**1,638,665**
PRIMARY ENERGY (PhysUn)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**286,933**	286,933
SECONDARY ENERGY (PhysUn)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**49,966**	**141,301**	191,266
TOTAL ENERGY (PhysUn)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**49,966**	**428,234**	478,200
PRIMARY ENERGY (MonUn)	0	0	0	0	0	0	0	0	0	0	0	163,498	**163,498**
SECONDARY ENERGY (MonUn)	0	0	0	0	0	0	0	0	0	0	291,778	468,600	**760,378**
REST OF THE ECONOMY (MonU	478,708	87,221	250,001	416,825	610,833	46,430	80,337	1,562,509	5,243,738	505,383	4,465	16,543	**9,302,993**
TOTAL OUTPUT (MonUn)	**478,708**	**87,221**	**250,001**	**416,825**	**610,833**	**46,430**	**80,337**	**1,562,509**	**5,243,738**	**505,383**	**296,243**	**648,641**	**10,226,869**

Table 4 - Energy and Economy Use Table, Brazil 2005

Physical (1000ote) and monetary (R$ millions) units

Primary energy Physical Secondary energy Physical Primary energy Monetary Secondary energy Monetary Rest of economy Monetary	Agriculture	Mining	Metallurgy	Chemistry	Food and beverages	Textiles	Paper and pulp	Other manufacturing	Commercial and public	Transport	Electricity	Other energy	Intermediate Consumption	Final Demand	Total
OIL	0	0	0	0	0	0	0	0	0	0	0	86,638	**86,638**	**39,489**	**126,127**
NATURAL GAS	0	397	1,101	1,344	504	130	487	6,160	95	939	9,922	3,220	**24,299**	**10,572**	**34,871**
STEAM COAL	0	127	855	52	20	0	26	91	0	0	1,353	0	**2,524**	**-65**	**2,459**
METALLURGICAL COAL	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	**0**
URANIUM U3O8	0	0	0	0	0	0	0	0	0	0	0	186	**186**	**326**	**512**
HYDRAULIC ENERGY	0	0	0	0	0	0	0	0	0	0	30,938	0	**30,938**	**0**	**30,938**
FIREWOOD	2,814	0	63	48	2,171	62	1,833	3,252	94	0	420	7,810	**18,566**	**6,334**	**24,900**
SUGAR-CANE PRODUCTS	0	0	0	0	15,485	0	27	13,155	0	0	5,959	15,798	**50,424**	**0**	**50,424**
OTHER PRIMARY SOURCES	0	0	0	85	10	0	6,529	390	0	0	5,914	3,783	**16,710**	**-8**	**16,702**
DIESEL	5,584	348	39	16	211	2	153	1,398	6	34,639	2,145	0	**44,541**	**399**	**44,941**
FUEL OIL	13	157	1,183	196	113	18	324	363	34	687	3,141	0	**6,230**	**7,959**	**14,188**
GASOLINE	0	0	0	0	0	0	0	0	0	44	0	0	**44**	**21,474**	**21,518**
LPG	2	17	63	164	174	28	55	310	499	0	0	0	**1,312**	**5,055**	**6,367**
NAPHTA	0	0	0	0	0	0	0	2,530	0	0	0	1,043	**3,573**	**-27**	**3,545**
KEROSENE	0	0	0	0	0	0	0	2	0	2,474	0	0	**2,476**	**2,180**	**4,656**
COKE OVEN GAS	0	0	1,148	0	0	0	0	188	0	0	245	0	**1,582**	**53**	**1,635**
COAL COKE	0	48	6,192	0	0	0	0	56	0	0	0	0	**6,295**	**-31**	**6,265**
URANIUM CONTAINED IN UO2	0	0	0	0	0	0	0	0	0	0	995	0	**995**	**-40**	**955**
ELECTRICITY	2,173	1,034	4,197	1,830	2,116	528	1,759	7,180	10,943	167	0	0	**31,928**	**18,037**	**49,966**
CHARCOAL	8	0	3,391	18	0	0	0	122	88	0	0	0	**3,627**	**535**	**4,163**
ETHANOL	12	0	0	0	0	0	0	476	0	0	0	0	**488**	**15,217**	**15,705**
OTHER SECONDARIES	0	428	534	1,567	66	0	0	6,666	0	0	560	644	**10,465**	**482**	**10,946**
NON-ENERGY OIL PRODUCTS	0	0	0	0	0	0	0	5,565	0	0	0	0	**5,565**	**616**	**6,181**
TAR	0	0	95	0	0	0	0	134	0	0	8	0	**237**	**0**	**237**
OIL	0	0	0	0	0	0	0	0	0	0	0	51,761	**51,761**	**48,902**	**100,663**
NATURAL GAS	0	203	561	685	257	66	248	3,140	49	479	5,057	1,641	**12,386**	**201**	**12,587**
STEAM COAL	0	14	92	6	2	0	3	10	0	0	145	0	**271**	**-15**	**256**
METALLURGICAL COAL	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	**0**
URANIUM U3O8	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**1**	**1**
HYDRAULIC ENERGY	0	0	0	0	0	0	0	0	0	0	20,349	0	**20,349**	**0**	**20,349**
FIREWOOD	146	0	3	2	113	3	95	169	5	0	22	405	**963**	**689**	**1,652**
SUGAR-CANE PRODUCTS	0	0	0	0	6,458	0	11	5,486	0	0	2,485	6,588	**21,029**	**0**	**21,029**
OTHER PRIMARY SOURCES	0	0	0	35	4	0	2,723	163	0	0	2,466	1,577	**6,969**	**-7**	**6,962**
DIESEL	26,450	1,650	186	76	999	10	724	6,621	28	164,064	10,160	0	**210,967**	**1,195**	**212,162**
FUEL OIL	26	323	2,429	402	232	37	664	744	70	1,410	6,447	0	**12,786**	**11,006**	**23,791**
GASOLINE	0	0	0	0	0	0	0	0	0	271	0	0	**271**	**89,405**	**89,676**
LPG	8	81	303	788	836	134	263	1,490	2,395	0	0	0	**6,297**	**16,223**	**22,520**
NAPHTA	0	0	0	0	0	0	0	57	0	0	0	23	**80**	**0**	**80**
KEROSENE	0	0	0	0	0	0	0	0	0	59	0	0	**59**	**39**	**99**
COKE OVEN GAS	0	0	2,356	0	0	0	0	386	0	0	504	0	**3,246**	**0**	**3,246**
COAL COKE	0	1	168	0	0	0	0	2	0	0	0	0	**171**	**-1**	**170**
URANIUM CONTAINED IN UO2	0	0	0	0	0	0	0	0	0	0	29	0	**29**	**-1**	**28**
ELECTRICITY	16,598	7,894	32,052	13,978	16,159	4,035	13,434	54,831	83,569	1,273	0	0	**243,824**	**54,795**	**298,619**
CHARCOAL	12	0	4,813	26	0	0	0	173	125	0	0	0	**5,148**	**453**	**5,601**
ETHANOL	80	0	0	0	0	0	0	3,083	0	0	0	0	**3,163**	**66,449**	**69,612**
OTHER SECONDARIES	0	879	1,096	3,215	135	0	0	13,682	0	0	1,149	1,322	**21,477**	**560**	**22,037**
NON-ENERGY OIL PRODUCTS	0	0	0	0	0	0	0	11,421	0	0	0	0	**11,421**	**828**	**12,250**
TAR	0	0	194	0	0	0	0	275	0	0	17	0	**486**	**1**	**486**
COMMERCIAL	34,416	13,013	31,188	67,060	109,165	6,567	13,653	215,117	1,020,838	70,778	33,970	54,099	**1,669,862**	**2,457,087**	**4,126,949**
PUBLIC	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**1,136,194**	**1,136,194**
AGRICULTURAL PRODUCTS	21,162	2	627	1,228	175,660	3,072	2,379	9,191	18,808	0	26	18,227	**250,383**	**214,959**	**465,342**
HIGHWAYS	9,496	7,659	11,860	18,089	41,875	1,099	5,872	32,774	95,996	58,850	5,229	29,304	**318,104**	**159,166**	**477,270**
RAILROADS	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	**0**
AIRWAYS	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	**0**
WATERWAYS	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	**0**
CEMENT	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	**0**
PIG-IRON AND STEEL	571	239	19,849	658	203	1	141	40,348	2,032	28	344	1,426	**65,841**	**35,226**	**101,067**
IRON-ALLOYS	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	**0**
MINING AND PELLETIZATION	0	752	8,922	0	0	0	0	104	4	0	0	0	**9,782**	**42,865**	**52,647**
NON-FERROUS AND	992	2,158	27,422	2,378	9,270	65	271	49,740	5,351	98	3,334	1,274	**102,354**	**58,576**	**160,930**
CHEMICAL	77,305	4,216	3,866	84,997	18,731	3,212	6,564	49,804	34,680	7,325	1,535	6,609	**298,845**	**115,566**	**414,411**
FOOD AND BEVERAGES	13,877	21	49	2,389	79,592	0	519	2,100	67,127	57	0	3,461	**169,192**	**480,943**	**650,135**
TEXTILES	504	173	29	360	303	3,741	109	9,856	1,012	48	33	98	**16,267**	**22,663**	**38,930**
PAPER AND PULP	0	0	0	17	0	0	3,116	0	0	0	0	0	**3,133**	**18,323**	**21,456**
CERAMICS	389	307	575	1,518	303	0	3	12,431	494	4	349	740	**17,113**	**1,884**	**18,997**
OTHERS	7,576	7,953	10,819	6,603	11,133	4,726	9,542	285,561	140,809	24,623	15,432	9,206	**533,984**	**1,104,681**	**1,638,665**
PRIMARY ENERGY (PhysUn)	**2,814**	**524**	**2,019**	**1,528**	**18,191**	**192**	**8,901**	**23,048**	**189**	**939**	**54,506**	**117,435**	230,286	56,647	286,933
SECONDARY ENERGY (PhysUn)	**7,793**	**2,033**	**16,842**	**3,791**	**2,680**	**576**	**2,291**	**24,989**	**11,570**	**38,010**	**7,095**	**1,687**	119,358	71,909	191,266
TOTAL ENERGY (PhysUn)	**10,607**	**2,557**	**18,861**	**5,320**	**20,870**	**768**	**11,192**	**48,037**	**11,760**	**38,949**	**61,601**	**119,122**	349,644	128,556	478,200
PRIMARY ENERGY (MonUn)	146	216	656	728	6,834	69	3,080	8,967	53	479	30,525	61,973	113,727	49,771	163,498
SECONDARY ENERGY (MonUn)	43,174	10,828	43,597	18,485	18,360	4,216	15,086	92,765	86,187	167,078	18,305	1,345	519,426	240,952	760,378
REST OF THE ECONOMY (MonUn)	166,288	36,492	115,205	185,297	446,236	22,484	42,170	707,026	1,387,151	161,811	60,253	124,445	3,454,859	5,848,134	9,302,993
TOTAL (MonUn, basic prices)	**209,607**	**47,536**	**159,459**	**204,510**	**471,431**	**26,770**	**60,336**	**808,758**	**1,473,392**	**329,368**	**109,082**	**187,763**	**4,088,012**	**6,138,857**	**10,226,869**
Imports	13,467	4,062	38,848	93,166	26,350	6,423	6,874	190,856	115,323	20,700	16,569	58,612	**591,250**	**251,364**	**842,614**
Taxes on products	16,678	3,628	10,711	23,769	27,053	2,546	4,063	79,458	142,246	23,100	19,643	39,110	**392,005**	**448,181**	**840,186**
TOTAL (MonUn, purchser's prices)	239,752	55,226	209,018	321,445	524,833	35,739	71,273	1,079,073	1,730,961	373,168	145,295	285,486	**5,071,268**	**6,838,401**	**11,909,669**

The remaining of the producing activities were aggregated in other ten sectors, totaling twelve sectors as Tables 3, 4 and 5 show.

Final Demand

Besides production activities and intermediate consumption, the SUTs also include final consumption activities, as Table 4 shows. Besides the activities proper of the tabulation in monetary units (exports, consumption, investment and stocks variations), other specific to the energy sector were added: Non-utilized, Reinjection (those two specific to natural gas), Losses in Distribution and Adjustments. All the final demand activities are aggregated into just one column in Figure 5 for space reasons.

Value Added

Table 5 – Value Added and Employment Level, Brazil 2005

	Agriculture	Mining	Metallurgy	Chemistry	Food and beverages	Textiles	Paper and pulp	Other manufacturing	Commercial and public	Transport	Electricity	Other energy	Intermediate Consumption
Gross Value Added (R$ millions)	238,956	31,995	40,983	95,380	86,000	10,691	9,064	483,436	3,512,777	132,215	157,789	356,314	**5,155,601**
Labor input (persons)	13,137,526	219,107	949,497	884,857	2,347,617	619,475	201,698	14,719,927	63,278,074	4,711,100	677,421	198,777	**101,945,076**

Table 5, although short, shows some important data for systemic energy-economy analysis: Value Added and Labor Input.

Among countless applications, value-added shed light on income distribution behavior over time, including for the Electricity and Other Energy sectors. Labor input, also shown on the table, besides paving the way for assessing impacts on the employment level, again including the electricity and other energy sectors, allows, along with value-added, to explore the effects of alternative productivity scenarios.

Integration with national accounts

The SUT tables also allow to work out important links to the national accounts, giving room to monitor their economic consistency. The three classical approaches to measure GDP, for instance, can be easily worked out form the tables:

> Production approach: GDP = Total output – intermediate consumption at purchasers'prices + taxes on products = 10,226,869 - 5,071,268 + 840,186 = 5,995,787
>
> Income approach: GDP = value added + taxes on products = 5,995,787
>
> Expenditure approach: GDP = final demand at purchasers'prices - exports at purchasers'prices = 5,995,787

These values are in R$ million of 2015 and correspond to the Brazilian 2015 National Accounts. The identities hold in any projection.

Projections

The model allows the projection of full energy balances on a yearly basis in integration with corresponding supply and use tables, complete with production, intermediate consumption, final consumption, value added, occupation, and imports. In other words, for each year of the projection horizon the full set of tables, as shown in figure 1 (energy balances) and the SUTs (tables 3 to 5) is provided.

Any time horizon can be chosen, and other exogenous relevant variable projections available, such as population and CO2 emissions, can be associated with the exercise. In the examples shown below, the time horizon selected was 2060.

Input-output model

For a given economy, the traditional Leontief model is given by the equation

$\mathbf{x} = (\mathbf{I}-\mathbf{A})^{-1}\mathbf{y}$, being

$\mathbf{x}$ = column vector of total production by sector

$\mathbf{y}$ = column vector of final demand by sector

$\mathbf{I}$ = the identity matrix,

$\mathbf{A}$ = the technical sector by sector coefficient matrix,

The expression $(\mathbf{I}-\mathbf{A})^{-1}$ is known as the Leontief inverse and has the property of, when multiplied by the final economic demand of a country or region (**y**)[6], returns the total economic production required (**x**).

In our case, the same relation is employed, but in a commodity by commodity, or product by product, basis, more adequate when dealing with production and consumption of fuels[7]:

$\mathbf{q} = (\mathbf{I}-\mathbf{BD})^{-1}\mathbf{e}$, where

$\mathbf{q}$ is a column vector expressing the total of commodities produced in a given economy,

$\mathbf{B}$ is the technical commodity by sector coefficient matrix,

$\mathbf{D}$ is the market share matrix, and

$\mathbf{e}$ is the column vector of commodities final demand.[8]

This equation allows to derive, given an initial stage, the future total economic production **q** associated to an exogenous future final demand **e** in monetary units. To get energy data in physical units the same proportion physical/monetary units observed at the initial stage is adopted. These proportions can evolve to non-linear relations by employing other model-algorithms easily available, and friendly with Excel, such as Systems Dynamics.

The energy conservation issue

One advantage of working simultaneously with SUT's and energy balances is to accomplish with one of the significant concerns of Input-Output Analysis when applied to the relations between energy and economy: the observation of the energy conservation principle, or the First Principle of Thermodynamics. [9]

In simple terms, this principle establishes that "*energy can be transformed from one form to another, but can be neither created nor destroyed*".

The observation of the principle can be verified on the lines of the balances. More precisely, on the Total Transformation lines. As Figure 1 shows, those lines display how fuels are transformed from primary to secondary energy. Their totals (last column on the right) must be negative, as shown. Otherwise, the conservation principle would not hold, for the production of secondary fuels cannot amount to a higher figure than the primary fuels utilize for their obtention.

[6] Basically exports, consumption, investment and stocks variation.

[7] EUROPEAN COMISSION (2008), p341: *"Product-by-product tables are well suited for many other specific analytical purposes which are related to homogeneous production units (productivity, comparison of cost structures, employment effects,* ***energy policy****, environmental policy, etc.)."*

[8] More about this in MILLER, R.E.; BLAIR, P.D, chapter 5 p.190.

[9] See for instance MILLER, R.E.; BLAIR, P.D 2009, chapt.9 and BULLARD, C.W.; HERENDEEN, R.A, 1975.

Results

The procedure allows comparative projections of any economic and energy variables contained in the supply and use tables and the energy balances. Below some examples are shown shown, under the form of trends and indicators.

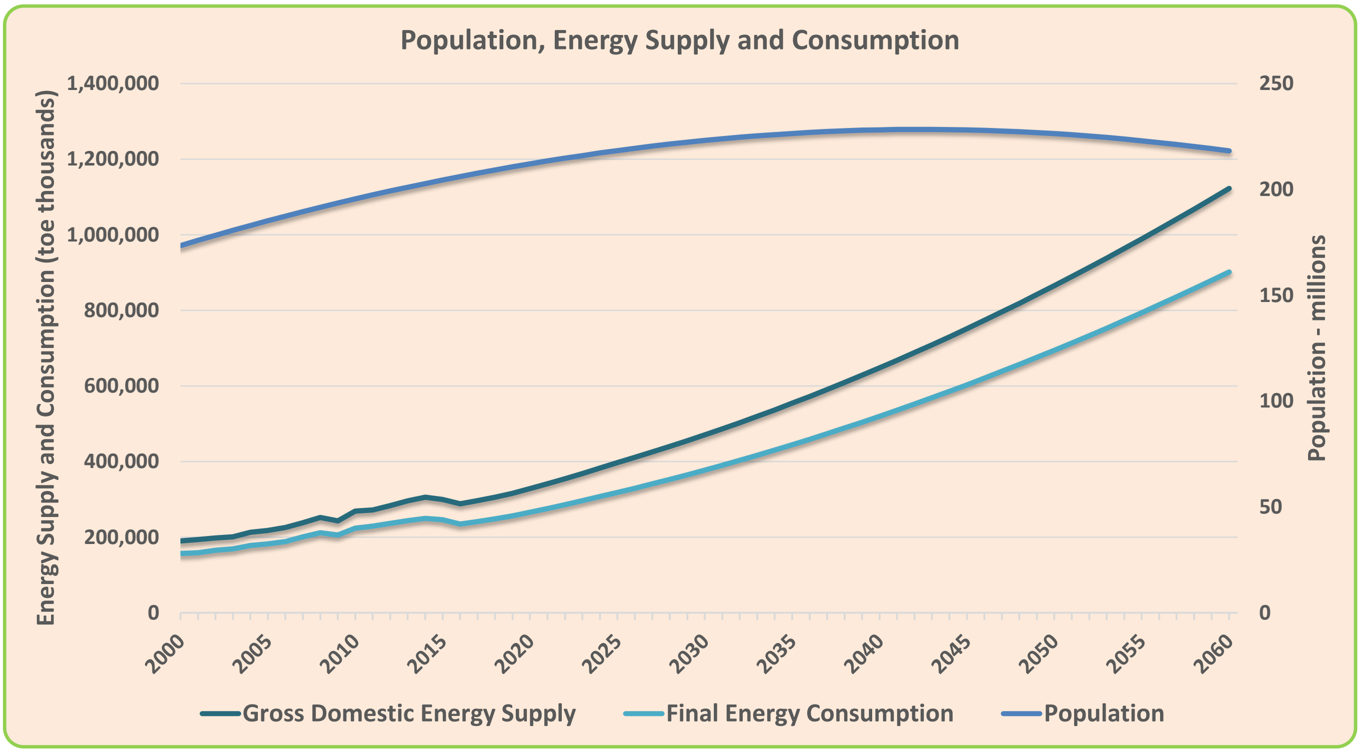
Trends

Reference projections

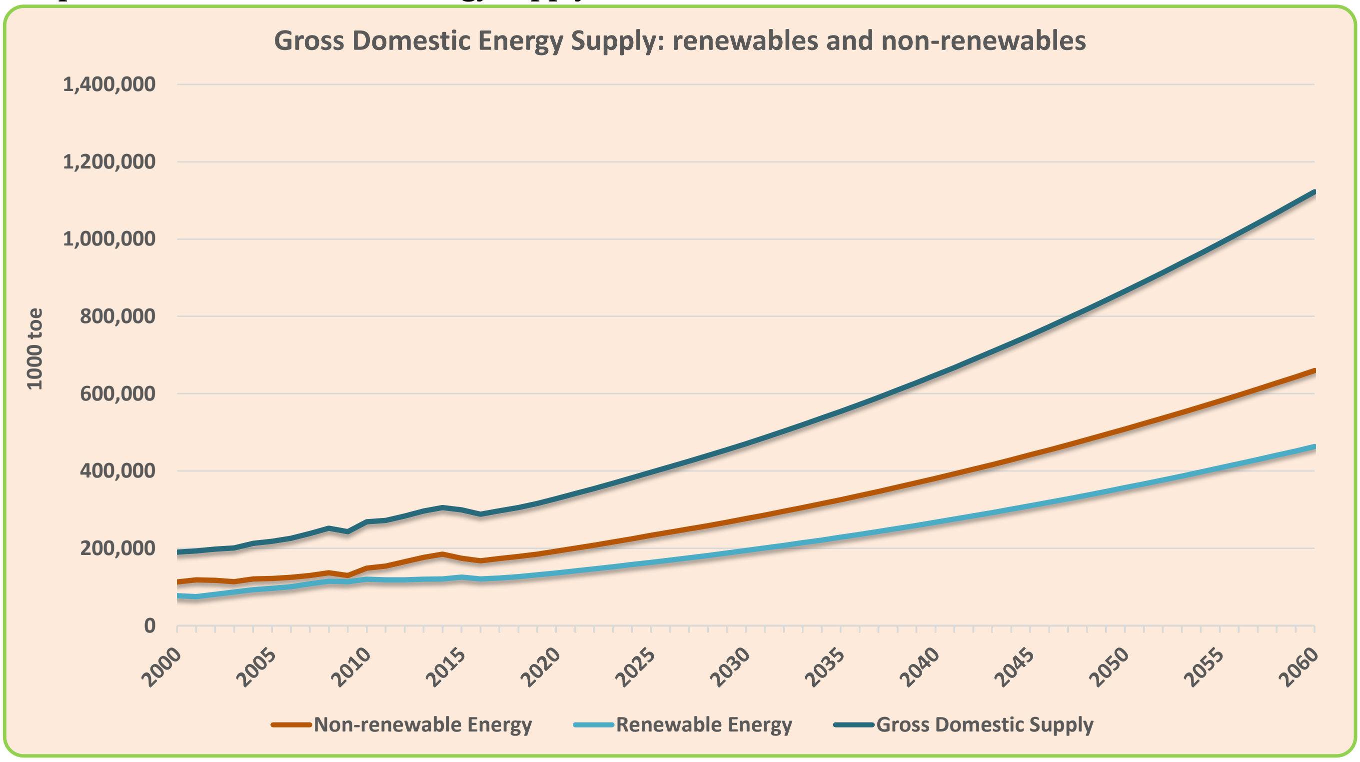
The following seven graphs show the yearly evolution of some key variables from 2000 to 2060.

Graphs 1 to 4 correspond to the basic case, or reference projection. Relations between population growth and energy supply and consumption are on Graph1, the supply of renewable and non-renewable energy on Graph2, energy supply and CO_2 emissions on Graph3, and energy consumption by productive sector and GDP on Graph 4.

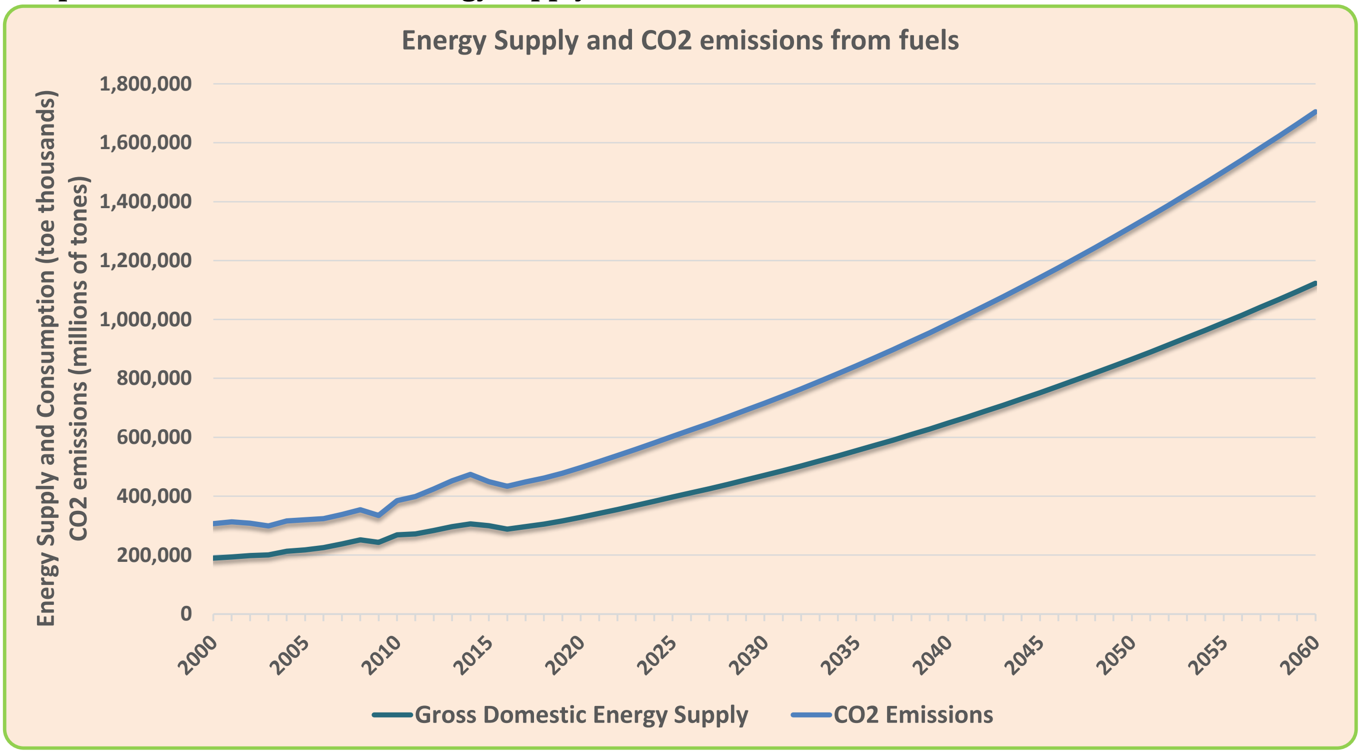
Graph 1 - Basic case: Brazil, population, energy supply and consumption, 2000-2060



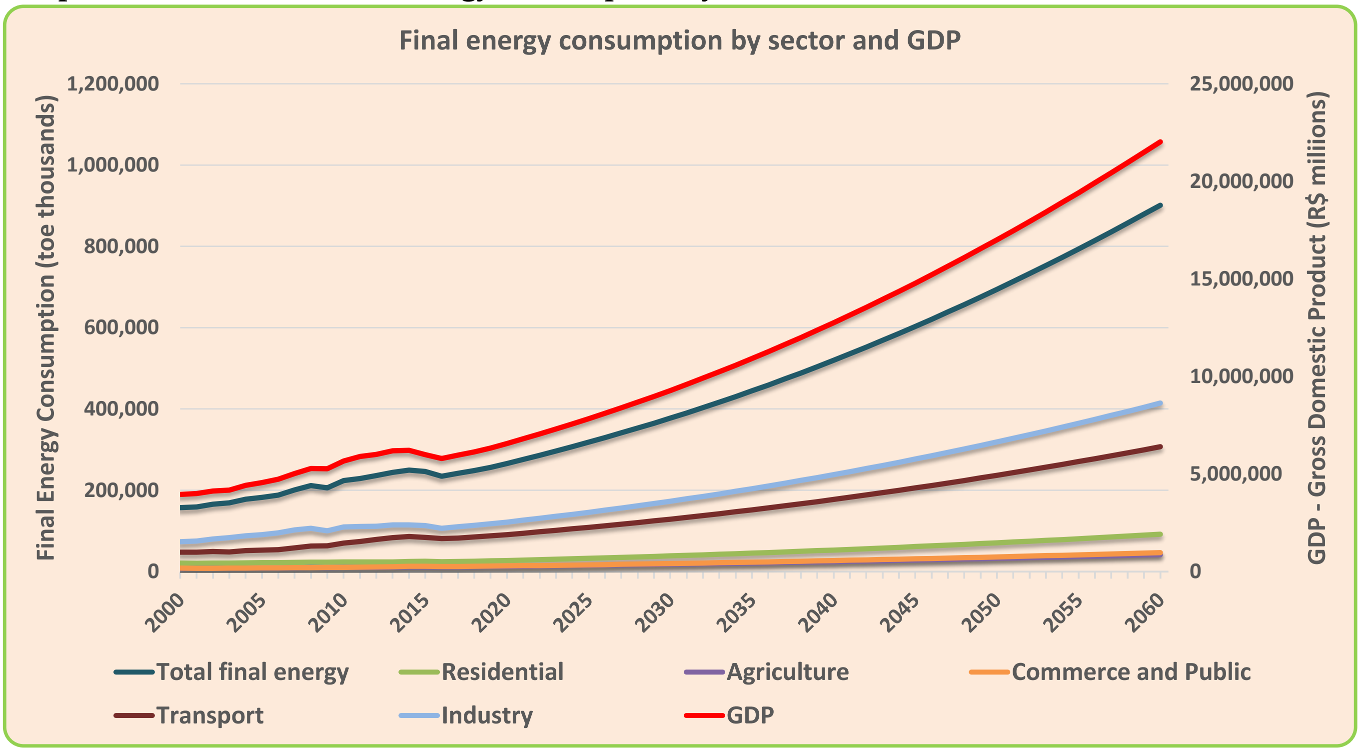
Graph 2 - Basic case: Brazil, energy supply, renewables and non-renewables, 2000-2060



Graph 3 - Basic case: Brazil, energy supply, CO2 emissions from fuels 2000-2060



Graph 4 - Basic case: Brazil, energy consumption by sector and GDP 2000-2060



Sensitivity Analysis

The examples below are destined to illustrate how the model responds to some sensitivity tests. All projections depart from fixed demographic and economic hypothesis as in Table 6.

Table 6 – Fixed hypotheses

	2015	2020	2040	2060
Population (millions)	204	212	228	218
GDP/cap (US$ PPP 2015)	15,716	16,586	29,956	54,103
GDP/cap growth	-4.3%	3.0%	3.0%	3.0%

The sensitivity analysis consisted in running the model under alternative hypotheses of diesel and electricity consumption, as well as of GDP composition under the expenditure approach. The simulations were done first separately and then together.

Regarding diesel, its consumption in transport would gradually give way to electricity until complete interchange of monetary technical coefficients[10] in 2060. In other words, the technical coefficient for diesel in 2015 (0.325) was gradually reduced to the value of the technical coefficient of electricity in the same year (0.003) in 2060 and vice-versa.

In the case of GDP composition, remembering the expenditure approach,

GDP = Final Demand in purchasers'prices – Imports,

And taking into account that

Final Demand = Exports + Governmental Consumption + Personal Consumption + Investment + Stocks Variation,

the following alternative hypotheses were formulated:

[10] Relation between the values of fuel consumption and total output of the transport sector in monetary units.

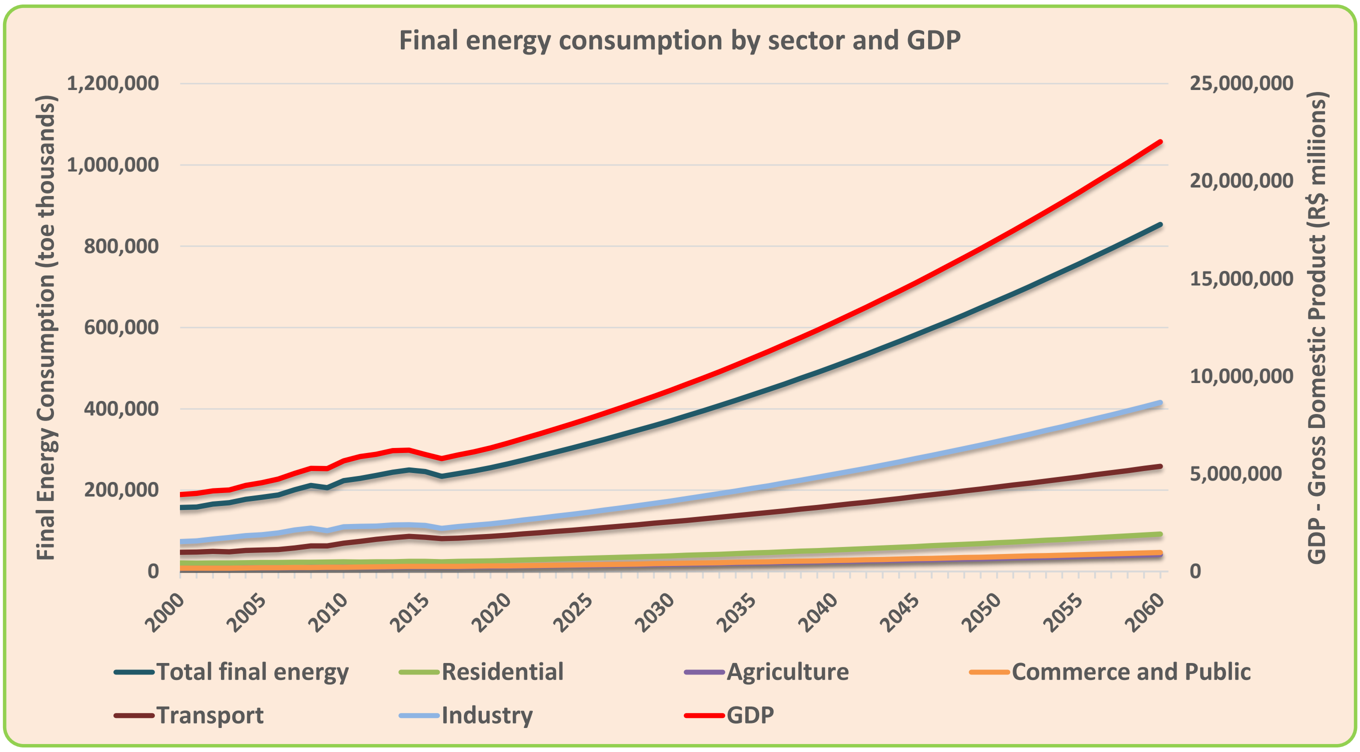
1. The relation Personal Consumption/GDP gradually reduces from 64% in 2015 (observed data) to 50% in 2060, giving room for an increase of Investment/GDP from 18% in 2015 (observed data) to 40% in 2060.
2. Imports/Investment remains approximately constant to 0.8 until 2060.

These hypotheses are alternative to the basic case, or reference scenario, where:

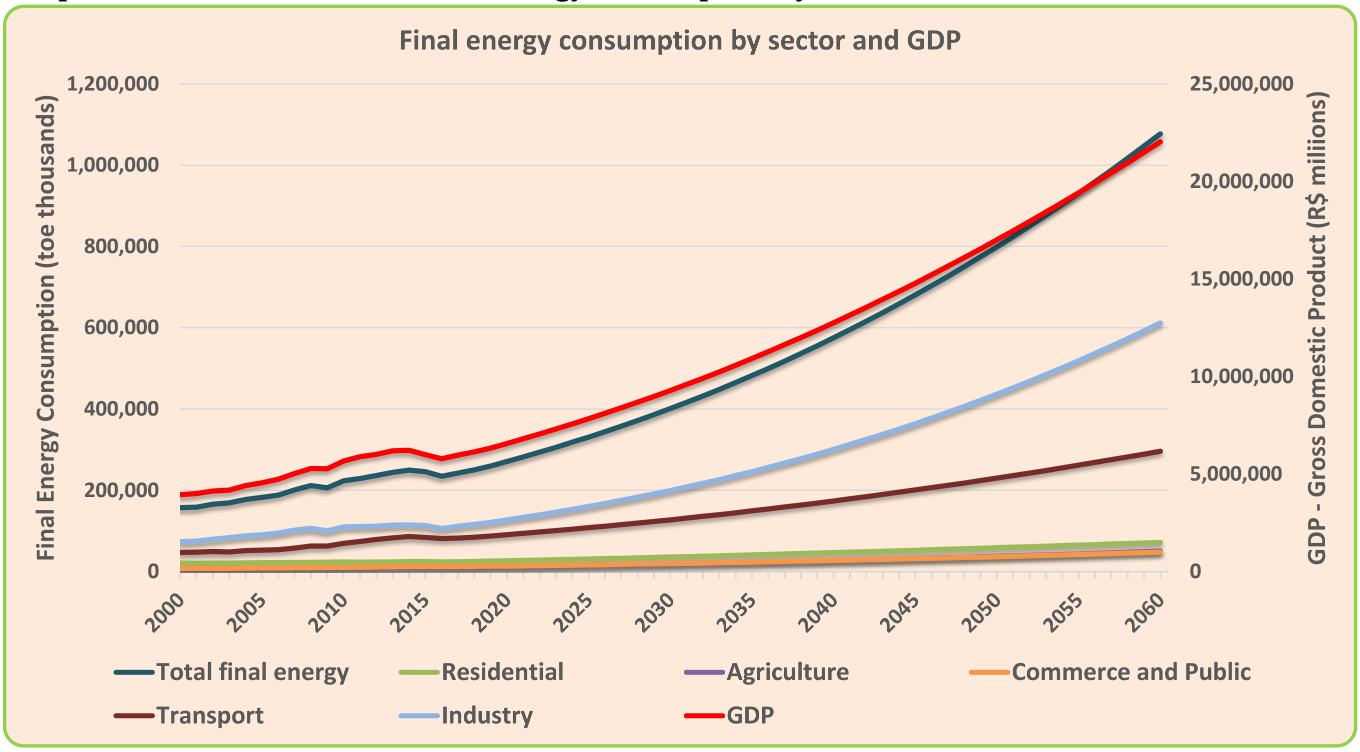
1. Personal Consumption/GDP and Investment/GDP remain at their historical values of respectively around 0.64 and 0.18,
2. Imports/Investment is the same as above.

Graphs 5, 6 and 7 show the results.

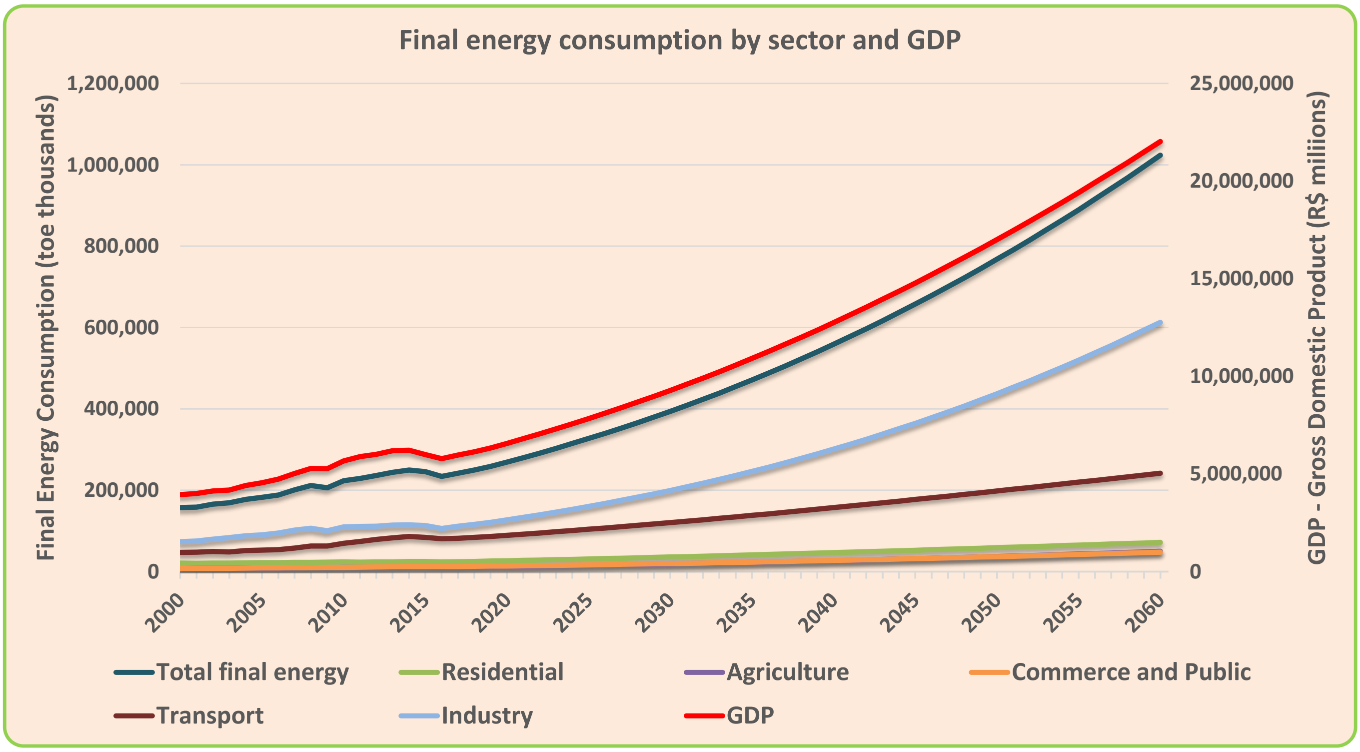
Graph 5 - Substitution of diesel by electricity: Brazil, energy consumption by sector and GDP 2000-2060



Graph 6 - More investment: Brazil, energy consumption by sector and GDP 2000-2060



Graph 7 -More investment and substitution of diesel: Brazil, energy consumption by sector and GDP 2000-2060



Indicators

Indicators are useful to analyze behavior by specifying direct relations between variables of diverse nature. They are an important complement to trend analysis, and here there is a selection aimed at add to the sensitivity analysis shown above. One shall take care when considering per capita figures, for official forecasts of the Brazilian population growth point to a decline from around 2040 on, as Graph 1 indicates.

Table 7 – Indicators: Basic case

	2015	2020	2040	2060
Families consumption/GDP	64.0%	63.4%	63.7%	64.0%
Investment/GDP	17.8%	16.7%	17.4%	18.0%
Exports/GDP	12.9%	12.7%	12.3%	11.9%
Imports/GDP	14.1%	13.3%	13.9%	14.4%
Final energy consump/cap (toe)	1.20	1.25	2.28	4.13
Electriciy cons/final energy consumption	18.3%	18.4%	18.4%	18.4%
Diesel consumption/Final energy consumption	19.5%	19.5%	19.5%	19.4%
CO2/cap (ton)	2.20	2.35	4.32	7.82
CO2/Final energy consumption	1.83	1.87	1.90	1.89

Table 8 - Indicators: Substitution of diesel by electricity

	2015	2020	2040	2060
Families consumption/GDP	64.0%	63.4%	63.7%	64.0%
Investment/GDP	17.8%	16.7%	17.4%	18.0%
Exports/GDP	12.9%	12.7%	12.3%	11.9%
Imports/GDP	14.1%	13.3%	13.9%	14.4%
Final energy consump/cap (toe)	1.20	1.25	2.21	3.91
Electriciy cons/final energy consumption	18.3%	19.5%	23.9%	28.4%
Diesel consumption/Final energy consumption	19.5%	18.0%	12.0%	5.8%
CO2/cap (ton)	2.20	2.32	4.06	6.99
CO2/Final energy consumption	1.83	1.86	1.84	1.79

Table 9 – Indicators: More investment

	2015	2020	2040	2060
Families consumption/GDP	64.0%	62.2%	56.1%	50.0%
Investment/GDP	17.8%	18.7%	29.4%	40.0%
Exports/GDP	12.9%	13.5%	17.6%	21.5%
Imports/GDP	14.1%	14.9%	23.5%	32.0%
Final energy consump/cap (toe)	1.20	1.28	2.52	4.94
Electriciy cons/final energy consumption	18.3%	18.4%	18.2%	18.2%
Diesel consumption/Final energy consumption	19.5%	19.4%	19.1%	18.7%
CO2/cap (ton)	2.20	2.39	4.80	9.43
CO2/Final energy consumption	1.83	1.87	1.91	1.91

Table 10 – Indicators: More investment and substitution of diesel

	2015	2020	2040	2060
Families consumption/GDP	64.0%	62.2%	56.1%	50.0%
Investment/GDP	17.8%	18.7%	29.4%	40.0%
Exports/GDP	12.9%	13.5%	17.6%	21.5%
Imports/GDP	14.1%	14.9%	23.5%	32.0%
Final energy consump/cap (toe)	1.20	1.27	2.45	4.69
Electriciy cons/final energy consumption	18.3%	19.4%	23.5%	27.5%
Diesel consumption/Final energy consumption	19.5%	18.0%	11.9%	6.0%
CO2/cap (ton)	2.20	2.36	4.53	8.51
CO2/Final energy consumption	1.83	1.86	1.85	1.81

Final remarks and conclusions

The results show the ability of the model to capture both economic and energy policies influences on final energy consumption and its environmental impacts. The sensitivity analysis examples, for instance, point out their increase with higher investment policy, in spite of keeping the same GDP per capita growth, given the effort to boost exports to face the imports acceleration required. Besides, even with substantial electricity substitution for diesel, those impacts, despite mitigated, are still higher than in the basic case, if higher investment policies are maintained. This highlights the importance of the structure of economic growth on energy consumption.

On the structural side, all obtained projections have a systemic coherence achieved by construction. In what concerns monetary units, they observe equilibrium balances imposed by the supply and use tables, enabling, for instance, the derivation of GDP under its three approaches from any result. Besides, one can also mention the identity between the supply and use of products, and still other identities proper to the systems of national accounts, such as between total output and intermediate consumption at purchasers' prices plus value added. On the energy/physical units side, identities are also observed between the total supply per fuel versus the flows in the transformation processes and the final energy demand, as imposed by the energy balances.

These features confer to the methodology two essential attributes expected for scenarios exercises: consistency and accountability. Another important attribute, resilience, has passed the test of several alternative projections, some of them shown on the examples above, each one for a time horizon of 45 years, returning perfectly balanced integrations of SUTs with energy balances for each of these years.

The final economic demand hypotheses formulations, observing national account identities, leads to the satisfaction of another critical attribute: plausibility. Nevertheless, the relation between results in monetary units with results in physical units, along with how results compare with other projections, require further testing. However, this is just a matter of applying and adjusting the model, being more of an exercise of practicing its use.

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Appendix

Columns of the Brazilian National Energy Balance

01 Petróleo / Petroleum

02 Gás Natural / Natural Gas

03 Carvão Vapor / Steam Coal

04 Carvão Metalúrgico / Metal. Coal

05 Urânio U3 O8 / Uranium U3O8

06 Energia Hidráulica / Hydro Energy

07 Lenha / Firewood

08 Produtos da Cana / Sugar-cane Products

09 Outras Fontes Primárias / Other Primary

10 Energia Primária Total / Total Primary

11 Óleo Diesel / Diesel Oil

12 Óleo Combustível / Fuel Oil

13 Gasolina / Gasoline

14 GLP / LPG

15 Nafta / Naphtha

16 Querosene / Kerosene

17 Gás Cidade e Coqueria / Gas Coke

18 Coque de Carvão Mineral / Coal Coke

19 Urânio contido no UO2 / Uranium in UO2

20 Eletricidade / Electricity

21 Carvão Vegetal / Charcoall

22 Álcool Etílico Anidro e Hidratado / Alcohol Ethyl Anhydrous and Hydrated

23 Outras Sec. de Petróleo / Other Oil Secundaries

24 Produtos Não En. do Petr. / Non-energy Oil products.

25 Alcatrão / Tar

26 Energia Secund. Total / Total Second. Energy

27 Energia Total / Total Energy