Energy economics modeling with hybrid units applied to supply and use tables

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Abstract

Every year the Brazilian Energy Ministry publishes a National Energy Balance, which is a fairly detailed account in physical units of how energy sources are produced, transformed and consumed in the Country. On the other hand, every year the Brazilian statistics authority IBGE publishes a national supply and use table within a two years delay of the publication date, the last issue at the present time being for 2009. This paper explores the possibilities of utilizing this information to work out commodity by commodity input-output models combining the energy and economic data provided by means of hybrid units. It is advocated that considerable methodological gains can be achieved if the procedure is supported by a supply and use table (SUT) framework. The SUT construction features utilizing hybrid units allow the straightforward checking of energy conservation balances between primary and secondary energy flows, and make the procedure accessible for forecasting teams which do not have to be necessarily familiar with input-output mathematics and terminology. Running with common electronic spreadsheets, the model may be applied in conjunction with other software add-ins, thus giving room for merging with a wide variety of forecasting techniques. This also makes it easier to build-up friendly software interfaces, paving the way for customization and direct utilization by decision makers. Examples of application are given in the text.

Introduction

This is an account of the first steps of a research project aimed at contributing for a better integration between energy and economic analysis within a single quantitative framework. With this purpose, procedures for integrating the Brazilian national energy balance with the national supply and use tables utilized in the construction of the Brazilian national accounts will be described.

After brief descriptions of how the Brazilian national energy balance and the Brazilian supply and use tables are organized, a proposition of merging the two tabulations utilizing hybrid units is presented. A note on the importance of observing the energy conservation principle, and the development of an industry technology/commodity by commodity total requirements model follow. The applicability of the procedure is demonstrated by two practical examples, and some ideas to further development are presented at the end of the text.

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 (tons of oil, MWh, etc.), and in a common metric, which is tons of oil equivalent (toe) adjusted for the average oil consumed in Brazil (see the oil tons conversion table at the Appendix 1).

The balance has, in its columns, the fuels produced and consumed in the country, both primary and secondary. By primary is understood the fuel as available in the nature (oil, coal, hydropower, etc.)[1], being the secondary fuels those commercialized for final consumption, either directly, or after transformation processes (refined oil products, electricity, etc.).

In its lines, the balance shows the activities involving in producing, processing and consuming the fuels. The general arrangement of the tabulation is shown in figure 1. The lines and columns headings are shown in detail in Appendix 2.

[1] According to OTA, “primary energy is energy in its most basic form, prior to any additional processing or conversion” (OTA,1990).

Figure 1 – Brazilian energy balance organization

		Primary fuels			Secondary fuels			TOTAL
Supply	Production							
	Imports							
	Changes in Stocks							
	Exports and Bunkers							
	Nonutilized							
Transformation	Petroleum Refineries							
	Natural Gas Plants							
	Gasification Plants							
	Coking Plants							
	Nuclear Cycle							
	Public Utility Power Plants							
	Self-Producers Power Plants							
	Charcoal Plants							
	Distilleries							
	Other Transformations							
	Losses							
Final								
Consumption	Final Non-energy Consumption							
	Final Energy Consumption							
	Energy Sector							
	Residential							
	Commercial							
	Public							
	Agricultural and Livestock							
	Transportation							
	Industrial							
	Cement							
	Pig Iron and Steel							
	Iron-alloys							
	Mining and pelletization							
	Non-ferrous and Other Metals							
	Chemical							
	Food and Beverage							
	Textiles							
	Paper and Pulp							
	Ceramics							
	Others							

The Brazilian supply and use table

Figure 2 shows schematically an n sectors x m products supply and use table in the format adopted by IBGE[2]. Essentially, it presents, in each of its cells, figures corresponding to the activities of taxation, production, and imports in the supply side, and intermediate and final consumption in the use side. Besides, a value added tabulation is also given 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.

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

In the Brazilian version, the number of sectors (n) and of products (m) is given in a few alternatives, being its larger dimension 56 sectors x 110 products, and the smaller 12 sectors x 12 products. Regarding the tables titles, a brief description of them is provided 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 economic transactions, i.e., national consumption, investment, imports and exports.
- ✓ **Total supply** is the addition of the supply activities of production and imports as well as taxes and margins, and must equate to **Total use** so as to achieve the supply-demand balance of the economy in a given period, usually one year.
- ✓ **Intermediate consumption** is the part of the use table where the transactions needed for production are shown. Every good and service consumed by a sector, as shown on its respective column, is for production purposes. On the other hand, the lines show the sales of each sector, always for production purposes. The intermediate consumption table gives 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

Merging the Brazilian national energy balance with the Brazilian SUT

In order to make the Brazilian energy balance compatible with the supply and use tabulations it is necessary, first of all, to proceed to its transposition, so as to have the activities in the columns and the fuels (commodities) in the lines. Besides, it is necessary to separate production from consumption and display them in two different tables, as it is the case with the SUTs. These arrangements are shown respectively in figures 3 and 4.

The matrixes and vectors indicated, and their relations, are described latter (see “Basic model and two practical examples”).

Figure 3 – Hybrid production matrix arrangement

	Primary fuels producers	Secondary fuels producers	Other sectors of the economy (National production)	q*
Prymary fuels	Physical units			Physical units
Secondary fuels		Physical units		Physical units
Rest of the economy			Monetary units	Monetary units
Primary energy totals	**Physical units**			
Secondary energy totals		**Physical units**		
Rest of the economy			**Monetary units**	
x*'	**Physical units**		**Monetary units**	

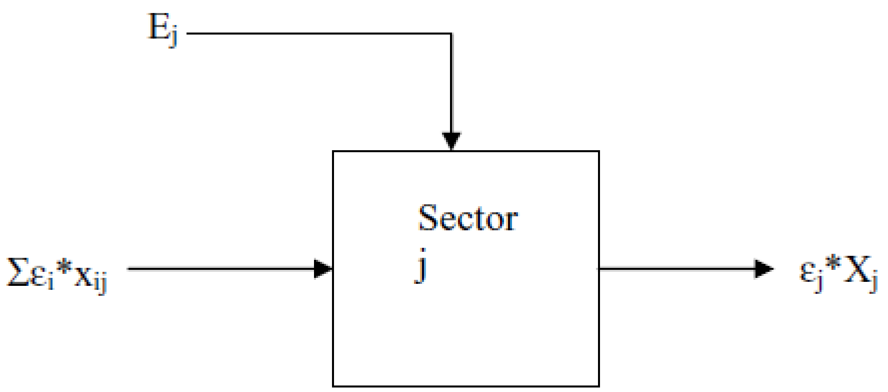
Figure 4 – Hybrid use matrix arrangement

	Hybrid use matrix									
	Intermediate consumption			**Final demand**						
	Primary fuels producers	Secondary fuels producers	Other sectors of the economy (National production)	Exports	Gov	Househ	Invest	Stocks	Non-energetic uses, losses and adjustments	q*
Prymary fuels		Physical units								Physical units
Secondary fuels	Physical units			Physical units						Physical units
Rest of the economy	Monetary units			Monetary units						Monetary units

Observing the energy conservation principle

The energy conservation principle is a well-known thermodynamics law, whereby the sum up of energy supplied is equal to the sum up of energy utilization, including losses. In input - output form, it can be expressed by figure 5.

Figure 5 – The energy conservation principle in input-output form



Source: HANNON, B., 2010

According to the figure, the total energy content of the output of sector j, $\varepsilon_j * X_j$, being ε_j the energy content per unit of output of the sector j, must be equal to the primary energy directly consumed by the sector j, Ej, plus the secondary energy content of the inputs to sector j, $\sum\varepsilon_i * x_{ij}$. Thus, Ej is different than zero only for those sectors where primary energy, or energy provided by nature, is converted into secondary energy, such as the oil refining industry. For all other sectors Ej equals zero[3].

The energy conservation principle requires that the secondary energy produced must be equal to the primary energy needed to produce it. This can be observed by imposing that the total of primary fuels utilized by a secondary energy producing sector must be equal to its total energy output, task that is made easier when one adopts the SUT tabulations. That is, the secondary

[3] Ej, according to BULLARD, C.W.; HERENDEEN, R.A, 1975, is “that energy extracted from the earth by sector j, and is non-zero only for primary energy sectors”.

energy produced by a given energy sector tabulated in the supply table must equal its primary energy consumption as tabulated in the use table.

By observing this equilibrium requirement, we obtain matrixes of total commodity by commodity energy requirements as the one shown in figure 6, where the sum of the primary energy coefficients of a given sector is equal to the sum of their secondary energy counterparts. That is, for each additional unit of final demand of the sector, the primary energy utilized is equal to the secondary energy produced, unless for the primary energy sectors. In this case, the new unit of energy is supplied by nature, thus comes from outside the economic system, and for that reason we have 1 added to the equality.

The same principle holds for the classical industry by industry version of the total requirements matrix, as observed for instance by MILLER, R.E.; BLAIR, P.D, 2010, p411. In our case, as we are utilizing the SUT framework, the industry technology/commodity by commodity approach is more adequate, having the advantage of accounting for secondary production, which is important for energy analysis, in order to consider, for instance, distributed generation. For this point, see also MILLER and BLAIR, 2010, p413-414.

Figure 6 – Total commodity by commodity energy requirements, Brazil 2008

$(I\text{-}BD)^{-1}$	Oil and Gas	Other primary	Biomass and hydro	Oil refining	Biomass products, coke, gas industry	Utility power plants	Other energy industry	Agriculture	Other mining	Cement	Metallurgy	Other chemical	Food and beverages	Textiles	Paper and pulp	Other industry	Pirivate services	Public services	Transp
Oil and Gas	1,033	0,002	0,002	0,958	0,058	0,125	0,483	0,058	0,080	0,372	0,079	0,052	0,082	0,024	0,147	0,054	0,014	0,011	0,253
Other primary	0,005	1,000	0,000	0,037	0,264	0,066	0,106	0,006	0,012	0,036	0,033	0,007	0,014	0,004	0,029	0,011	0,002	0,002	0,026
Biomass and hydropower	0,015	0,000	1,000	0,056	0,686	0,819	0,439	0,027	0,054	0,125	0,119	0,033	0,058	0,021	0,140	0,045	0,010	0,011	0,063
Oil and coke refining	0,030	0,002	0,002	1,030	0,006	0,008	0,018	0,047	0,063	0,360	0,053	0,036	0,041	0,017	0,046	0,032	0,012	0,008	0,260
Energy chemical	0,009	0,000	0,000	0,009	1,001	0,001	0,004	0,004	0,014	0,051	0,090	0,006	0,007	0,003	0,008	0,013	0,003	0,002	0,059
Electricity	0,005	0,000	0,000	0,004	0,000	1,001	0,002	0,013	0,031	0,058	0,045	0,014	0,016	0,015	0,050	0,017	0,006	0,009	0,005
Other energy industry	0,009	0,000	0,000	0,008	0,000	0,001	1,004	0,028	0,038	0,064	0,043	0,035	0,089	0,014	0,210	0,047	0,006	0,005	0,018
Agriculture	0,008	0,000	0,000	0,007	0,000	0,001	0,004	1,126	0,010	0,018	0,009	0,061	0,367	0,059	0,121	0,023	0,013	0,009	0,009
Other mining	0,005	0,000	0,000	0,005	0,000	0,001	0,003	0,009	1,074	0,014	0,074	0,022	0,006	0,002	0,010	0,016	0,001	0,002	0,003
Cement	0,006	0,000	0,000	0,005	0,000	0,001	0,003	0,002	0,002	1,027	0,002	0,009	0,002	0,001	0,002	0,009	0,001	0,001	0,002
Metallurgy	0,060	0,000	0,000	0,056	0,003	0,007	0,028	0,017	0,053	0,088	1,267	0,035	0,033	0,007	0,053	0,144	0,009	0,012	0,025
Other chemical	0,108	0,000	0,000	0,100	0,006	0,013	0,051	0,265	0,087	0,219	0,121	1,314	0,158	0,088	0,181	0,155	0,037	0,032	0,101
Food and beverages	0,008	0,000	0,000	0,007	0,000	0,001	0,004	0,110	0,010	0,014	0,008	0,028	1,247	0,012	0,025	0,015	0,030	0,019	0,009
Textiles	0,002	0,000	0,000	0,002	0,000	0,000	0,001	0,004	0,013	0,009	0,003	0,006	0,004	1,310	0,012	0,007	0,006	0,002	0,007
Paper and pulp	0,004	0,000	0,000	0,003	0,000	0,000	0,002	0,005	0,011	0,038	0,008	0,017	0,013	0,007	1,187	0,018	0,005	0,004	0,005
Other industry	0,075	0,000	0,000	0,070	0,004	0,009	0,035	0,021	0,056	0,110	0,050	0,044	0,036	0,026	0,066	1,161	0,046	0,060	0,089
Pirivate services	0,222	0,000	0,000	0,206	0,012	0,027	0,104	0,149	0,269	0,373	0,222	0,244	0,249	0,214	0,234	0,267	1,241	0,290	0,269
Public services	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,000	0,000
Transports	0,096	0,000	0,000	0,089	0,005	0,012	0,045	0,051	0,113	0,149	0,087	0,061	0,098	0,047	0,084	0,061	0,032	0,022	1,135
	1,053	1,002	1,002	1,051	1,008	1,011	1,028	0,091	0,146	0,533	0,230	0,092	0,153	0,049	0,315	0,109	0,026	0,024	0,342
	0,053	0,002	0,002	1,051	1,008	1,011	1,028	0,091	0,146	0,533	0,230	0,092	0,153	0,049	0,315	0,109	0,026	0,024	0,342

Basic model and two practical examples

Before getting down to the examples, let us have a better look at the commodity by commodity model utilized in their construction. As indicated at the left top of figure 6, the commodity by commodity equivalent to the classical industry by industry Leontief model

$$\mathbf{x^* = (I\text{-}A^*)^{-1}y^*}$$

is given by

$$\mathbf{q^* = (I\text{-}B^*D^*)^{-1}e^*}$$

where the * indicates the use of hybrid units.

The total production, **x***, in its transposed form, is obtained by summing the lines of the Hybrid production matrix, as indicated in figure 3. The total commodities vector, **q***, on the other hand, is obtained by adding the columns of either the hybrid production or the hybrid use matrixes, as indicated by figures 3 and 4. The total final demand per commodity, given by the vector **e***, is obtained directly, from the hybrid use matrix, being exogenous to the model.

The matrix **B*** displays the commodity by sector input coefficients. It is obtained by dividing the intermediate consumption flows of the use matrix by **x*'**, its units thus being either toe/toe, toe/R$, R$/toe or R$/R$. Bearing in mind the hybrid intermediate consumption arrangement of figure 4, these units will be distributed in 4 quadrants, as follows:

	Energy sectors (primary and secondary)	**Nonenergy sectors**
Energy inputs (primary and secondary)	toe/toe 1	toe/R$ 2
Nonenergy inputs	R$/toe 3	R$/R$ 4

Source: OTA, 1990.

The matrix **D***, finally, is the hybrid version of the market share.

Applying this model, two examples were worked out. Figure 7 shows the results of one of them, aimed at showing how the same amount of final demand change may incur in very different total energy impacts.

Figure 7 – Impact of the addition of 0,1% of GDP in the final demand of some sectors, Brazil 2008

	Agriculture	Metallurgy	Other industry	Pirivate services	Transp
Oil and Gas	144	196	134	36	630
Other primary	16	82	26	5	65
Biomass and hydropower	67	297	111	25	157
Oil products	117	132	79	29	648
Biomass products, coke and gas	10	223	34	7	147
Utilities Electricity	32	113	43	15	11
Distributed electricity and other fuels	69	106	116	15	45
Agriculture	2.803	22	57	33	21
Other mining	23	184	39	3	8
Cement	5	4	22	2	6
Metallurgy	42	3.156	359	24	63
Other chemical	660	302	386	91	251
Food and beverages	273	20	37	75	23
Textiles	11	7	17	15	18
Paper and pulp	13	19	44	13	11
Other industry	53	125	2.891	114	221
Pirivate services	371	552	666	3.092	670
Public services	0	0	0	0	0
Transports	127	216	153	80	2.827
Primary fuels (1000toe)	**227**	**574**	**271**	**66**	**852**
Secondary fuels (1000toe)	**227**	**574**	**271**	**66**	**852**
Rest of the economy (MMR$)	**4.381**	**4.608**	**4.671**	**3.541**	**4.120**

The figures in the table show the impact of the same amount of final demand change, namely 2,490 MMR$, which corresponds to 0,1% of the Brazilian GDP of 2008 in 2005 currency units, when applied to the sectors indicated in the headings.

The bottom lines show the total impacts in primary and secondary energy consumption, which, by the energy conservation principle, are always the same. We can see that the fuel figures change rather dramatically, by a factor of more than 10 if we compare the private services and the transport sectors. The effects on the economic activity, on the other hand, vary in a much lower degree, as the last line indicates.

Besides, in spite of its high energy renewable fuels participation in the total consumption, the figures show also that oil, which by far is the dominant share of the oil/natural gas mix in Brazil, is the dominant fuel in all cases, with the exception of metallurgy, which is a heavy consumer of hydroelectricity, and also biomass, for charcoal is utilized as a reducer in many steel mills in Brazil. Transport, on the other hand, is the major energy and oil consumer, as it should be expected. In short, the exercise shows the importance of the adoption of a given development model as far as energy consumption is concerned.

Our second example takes advantage of the SUT's commodity by industry feature in what concerns the possibility of taking secondary production into account. The supposition, now, is one of a 10% shift in the share of electricity generation from centralized to self-production, with no change in the final demand. The results are displayed in figure 8.

As we can see, an increase of 81 thousand of oil tons equivalent in both primary and secondary energy is indicated, and the bulk of the impact is concentrated in the primary fuels, with a decrease of 1.524 tons of oil equivalent in the production of biomass and hydropower, compensated by increases of another primary fuels and mainly oil and natural gas, the three figures summing up to the 81 tons.

Here one can point out a remarkable advantage that comes along the use of SUT tables in this sort of analysis, which is the mapping of secondary impacts. Starting with figure 9, where the mapping of the impact in total production is shown, we can notice that, as far as electricity is concerned, the shift was actually much greater, for 3.978 tons of oil equivalent (46.260 MWh) of electricity produced by the utilities is substituted by 3.984 tons of self-generated

Figure 8 – Impact of an increase of 10% in the self-generation market share in total production

Oil and Gas	**1.394**
Other primary	**211**
Biomass and hydropower	**-1.524**
Oil products	**51**
Biomass products, coke and gas	**12**
Electricity	**7**
Distributed electricity and other fuels	**11**
Agriculture	**10**
Other mining	**7**
Cement	**8**
Metallurgy	**82**
Other chemical	**146**
Food and beverages	**10**
Textiles	**3**
Paper and pulp	**5**
Other industry	**102**
Pirivate services	**299**
Public services	**0**
Transports	**130**
Primary fuels (1000toe)	**81**
Secondary fuels (1000toe)	**81**
Rest of the economy (MMR$)	**801**

power, accounted for under "Other energy industry", the magnitude of this impact being masked by the small overall result of 7 tons shown in table 8.

This means that the decrease of hydropower production was actually largely offset by an increase in the consumption of sugar cane products[4], which is a major fuel for electricity self-generation in Brazil.

[4] Although sugar cane products and biomass in general must be accounted for also as primary fuels, one must remember that those latter are not considered as part of the economic activity. So, in the cases where they are commercialized as secondary fuels, they were accounted for separately, as "other fuels" produced by "other energy industries". That is the case with oil, natural gas, coal, uranium, firewood, sugar cane products, and other primary fuels destined for final consumption.

Figure 9 – Mapping of the impact of an increase of 10% in the self-generation market share in total production

Total supply		Oil and Gas	Other primary	Biomass and hydro	Oil refining	Biomass products, coke, gas industry	Utility power plants	Other energy industry	Agricul ture	Other mining	Cement	Metallurgy	Other chemical	Food and beverages	Textiles	Paper and pulp	Other industry	Pirivate services	Public services	Transp
Oil and Gas	1.394	1.394	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other primary	**211**	0	211	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass and hydropower	**-1.524**	0	0	-1.524	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil products	**51**	0	0	0	47	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Biomass products, coke and gas	**12**	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Electricity	**7**	0	0	0	0	0	-3.978	3.984	0	0	0	0	0	0	0	0	0	0	0	0
Other fuels	**11**	0	0	0	1	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	**10**	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
Other mining	**7**	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0
Cement	**8**	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0
Metallurgy	**82**	0	0	0	0	0	0	0	0	0	0	80	0	0	0	0	1	0	0	0
Other chemical	**146**	0	0	0	0	0	0	0	1	0	0	0	142	2	0	0	0	0	0	0
Food and beverages	**10**	0	0	0	0	0	0	0	1	0	0	0	0	10	0	0	0	0	0	0
Textiles	**3**	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Paper and pulp	**5**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0
Other industry	**102**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	101	0	0	0
Pirivate services	**299**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	294	2	2
Public services	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Transports	**130**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	128
Primary fuels (1000toe)	**81**	**1.394**	**211**	**-1.524**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Secondary fuels (1000toe)	**81**	**0**	**0**	**0**	**48**	**14**	**-3.978**	**3.997**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Rest of the economy (MMR$)	**801**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**12**	**7**	**8**	**81**	**143**	**12**	**3**	**5**	**102**	**295**	**4**	**130**
	x*'	**1.394**	**211**	**-1.524**	**48**	**14**	**-3.978**	**3.997**	**12**	**7**	**8**	**81**	**143**	**12**	**3**	**5**	**102**	**295**	**4**	**130**

On the other hand, one may ask the reason for the additional 7 toe of electricity. The answer can be obtained from figure 10, where the impact is mapped in the intermediate consumption side, and it is possible to verify that this additional consumption was mainly originated due to the increase of economic activity in the metallurgy, other chemical, other industry and private services sectors, in result of the new generation distribution mode.

Figure 10 – Mapping of the impact of an increase of 10% in the self-generation market share in total intermediate consumption

Total intermediate consumption		Oil and Gas	Other primary	Biomass and hydro	Oil refining	Biomass products, coke, gas industry	Utility power plants	Other energy industry	Agricul ture	Other mining	Cement	Metallurgy	Other chemical	Food and beverages	Textiles	Paper and pulp	Other industry	Pirivate services	Public services	Transp
Oil and Gas	**1.394**	0	0	0	47	1	-318	1.664	0	0	0	0	0	0	0	0	0	0	0	0
Other primary	**211**	0	0	0	1	4	-239	446	0	0	0	0	0	0	0	0	0	0	0	0
Biomass and hydropower	**-1.524**	0	0	0	0	10	-3.420	1.887	0	0	0	0	0	0	0	0	0	0	0	0
Oil products	**51**	14	0	0	0	0	0	0	0	0	2	2	2	0	0	0	1	0	0	30
Biomass products, coke and gas	**12**	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	7
Electricity	**7**	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	1	1	0	0
Other fuels	**11**	0	0	0	0	0	0	0	0	0	0	2	3	1	0	1	3	0	0	1
Agriculture	**10**	0	0	0	0	0	0	0	1	0	0	0	5	3	0	0	1	0	0	0
Other mining	**7**	0	0	0	0	0	0	0	0	0	0	4	2	0	0	0	0	0	0	0
Cement	**8**	6	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
Metallurgy	**82**	52	0	0	0	0	0	0	0	0	0	17	2	0	0	0	10	0	0	0
Other chemical	**146**	88	0	0	0	0	0	0	2	0	1	5	31	0	0	0	8	4	0	6
Food and beverages	**10**	0	0	0	0	0	0	0	1	0	0	0	1	2	0	0	0	6	0	0
Textiles	**3**	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
Paper and pulp	**5**	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	0	0
Other industry	**102**	69	0	0	0	0	0	0	0	0	0	2	3	0	0	0	12	9	0	6
Pirivate services	**299**	184	0	0	0	0	0	0	1	1	1	8	18	1	0	0	14	52	1	18
Public services	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Transports	**130**	99	0	0	0	0	0	0	0	1	1	4	4	1	0	0	3	5	0	12
Primary fuels (1000toe)	**81**	**0**	**0**	**0**	**48**	**14**	**-3.978**	**3.997**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Secondary fuels (1000toe)	**81**	**14**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**3**	**12**	**5**	**1**	**0**	**1**	**4**	**1**	**0**	**38**
Rest of the economy (MMR$)	**801**	**498**	**0**	**0**	**0**	**0**	**0**	**0**	**5**	**3**	**4**	**39**	**68**	**8**	**1**	**3**	**51**	**78**	**1**	**42**

Possible developments

This is a report on a research project that is in its starting steps. The results of the examples given, due to considerable further examination, should be better considered as an agenda for further checking and study. They also indicate that the procedure deserves to be exploited for a number of alternative applications, among them being considered at the moment:

- ✓ Development of alternative scenarios of energy consumption in function of alternative development models;
- ✓ Further exploration of the relation $\mathbf{q^* = (I\text{-}B^*D^*)^{-1}e^*}$ so as to improve the understanding the technology x market-share relationship (technology deployed by the market share as suggested by the product **B*D***; or technology deployed by the final demand as suggested by $\mathbf{(I\text{-}B^*D^*)^{-1}e^*}$).
- ✓ Regionalization of the procedure to states and electric regions;
- ✓ Impact of new energy conversion technologies on overall energy intensity, employment and income.
- ✓ Environmental impact.

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Appendixes

1. *Tons of oil equivalent conversion table*

Multiplicar por para / de	J	BTU	cal	kWh	to Multiply by / from
Joule (J)	1	$947,8 \times 10^{-6}$	0,23884	$277,7 \times 10^{-9}$	*Joule (J)*
British Thermal Unit (BTU)	$1,055 \times 10^{3}$	1	252	$293,07 \times 10^{-6}$	*British Thermal Unit (BTU)*
Caloria (cal)	4,1868	$3,968 \times 10^{-3}$	1	$1,163 \times 10^{-6}$	*calorie (cal)*
Quilowatt-hora (kWh)	$3,6 \times 10^{6}$	3412	860×10^{3}	1	*kilowatt-hour (kWh)*
Tonelada equivalente de petróleo (tep)	$41,87 \times 10^{9}$	$39,68 \times 10^{6}$	10×10^{9}	$11,63 \times 10^{3}$	*Tons of oil equivalent (toe)*
Barril equivalente de petróleo (bep)	$5,95 \times 10^{9}$	$5,63 \times 10^{6}$	$1,42 \times 10^{9}$	$1,65 \times 10^{3}$	*barrels of oil equivalent (boe)*

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Source: EPE, 2012.

2. *Lines and columns of the Brazilian energy balance*

Lines

1 Produção/Production

2 Importação/Imports

3 Variação de Estoques/ Changes in Stocks

4 Oferta Total/Total Supply

5 Exportação/Exports and Bunkers

6 Energia Não- Aproveitada/Nonutilized

7 Reinjeção/Reinjection

8 Oferta Interna Bruta/ Gross Domestic Supply

9 Total Transformação/ Total Transformation

9.1 Refinarias de Petróleo/Petroleum Refineries

9.2 Plantas de Gás Natural/Natural Gas Plants

9.3 Usinas de Gaseificação/ Gasification Plants

9.4 Coquerias/Coking Plants

9.5 Ciclo Combustível Nuclear/Nuclear Cycle

9.6 Centrais Elétricas De Serviços Públicos/ Public Utility Power Plants

9.7 Centrais Elétricas Autoprodutoras/ Self-Producers Power Plants

9.8 Carvoarias/Charcoal Plants

9.9 Destilarias/

9.10 Outras Transformações/Other Transformations

10 Perdas na Distribuição e Armazenagem/Losses in Distribution and Storage

11 Consumo Final/Final Consumption

11.1 Consumo Final Não-Energético/ Final Non-energy Consumption

11.2 Consumo Final Energético/Final Energy Consumption

11.2.1 Setor Energético/ Energy Sector

11.2.2 Residencial/ Residential

11.2.3 Comercial/ Commercial

11.2.4 Público/Public

11.2.5 Agropecuário/ Agricultural and Livestock

11.2.6 Transportes – Total/Transportation

11.2.6.1 Rodoviário/ Highways

11.2.6.2 Ferroviário/

11.2.6.3 Aéreo/Airways

11.2.6.4 Hidroviário/ Waterways

11.2.7 Industrial – Total/Industrial

11.2.7.1 Cimento/ Cement

11.2.7.2 Ferro-gusa e Aço/Pig Iron and Steel

11.2.7.3 Ferroligas/ Iron-alloys

11.2.7.4 Mineração e Pelotização/Mining and pelletizations Pelletization

11.2.7.5 Não-Ferrosos e Outros Metálicos/ Non-ferrous and Other Metals

11.2.7.6 Química/ Chemical

11.2.7.7 Alimentos e Bebidas/Food and Beverage

11.2.7.8 Têxtil/Textiles

11.2.7.9 Papel e Celulose/Paper and Pulp

11.2.7.10 Cerâmica/ Ceramics

11.2.7.11 Outros/Others

11.2.8 Consumo Não-identificado/ Unidentified Consumption

12 Ajustes/Adjustments

Columns

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