Energy Matrix of the Transport System at São Paulo Metropolitan Region

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Abstract

The worldwide energy consumption is mainly based on fossil fuels, as we can see in table 1. This table also shows that more than 50% of the energy used in Brazil is based on fossil fuels. At São Paulo State (and also in the Metropolitan Region - SPMR), the transportation system represents over one third of all energy matrix [2].

In this scenario, the analysis of this sector is of great importance due to its impacts on environment, health, economy and society.

The energy converted by passenger cars and by the public transportation system were calculated via fuel consumption at SPMR [3–5]. Adding to this information the Mobility Research at SPRM, provided by the METRO company [6], the public transportation are more efficient than cars, and the best performance was for the subway, approximately 24 times more efficient.

The objective of this work is contribute to provide a database for the analysis of environmental impacts derived from energetic options, specially oriented to the physical conceptualization of energy articulated with environment issues.

Table 1: World energy matrix of the year 2012, [1]

Energy Source (Percentage in Participation) - Year 2012						
Region or Country	**Oil**	**Natural Gas**	**Coal**	**Hydro and Renewable**	**Nuclear**	**Others**
World	34.6	23.7	28.0	3.1	1.5	9.1
USA	36.4	27.4	18.2	5.3	2.8	9.9
North America	37.2	27.9	16.1	8.0	2.5	8.3
Europe	36.5	23.6	16.8	12.2	3.6	7.3
Developed Countries	37.8	25.0	18.3	3.2	2.8	6.2
1 Western Europe & former USSR	21.6	43.8	22.4	2.0	2.0	8.3
Developing Countries	32.2	22.6	35.4	3.0	0.55	18.9
Developing Asia	26.8	16.1	55.4	2.9	0.36	0.0
Middle East	51.3	48.1	1.7	0.66	0.01	0.0
Africa	42.6	27.3	25.5	1.1	0.24	3.3
South and Central America	49.6	19.6	4.0	25.7	0.25	0.80
China	19.7	5.0	65.8	9.0	0.30	0.13
Brazil	49.5	9.4	4.2	35.5	0.43	0.90
Brazil (BEN)	41.6	9.9	1.0	46.0	1.5	0.0

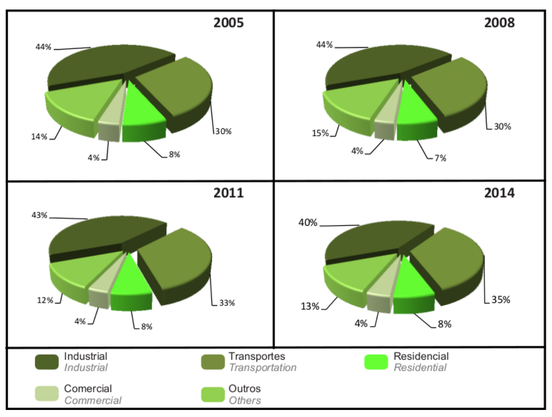

Figure 1: Share of each sector of São Paulo state's energy matrix. Source: [2]

- Energy matrix strongly based on fossil fuels
- Transportation sector at SPMR represents approximately $^1/_3$ of the total energy consumption, as in chart 1
- Efficiency on the use of energy resources
- Pollution on big cities and its impacts on health
- Possibility to contribute to global climate changes

Materials and Methods

- The fuel consumption of the 39 cities within SPMR was collected between the years 2006 and 2014
- The volume was converted into energy using their heat of combustion, table 2
- The subway and urban train electricity consumption was collected from the company's sustainability report [3]
- An estimation of energy consumed for each modal was made

Figure 2: Evolution of the electric energy consumed by the subway. The rise on the difference between the operational and total consumption is due to new stations and construction sites [3].

Figure 3: 23 de Maio Avenue, São Paulo, at rush hour. Photo: A. Kerr.

Figure 4: Subway train, São Paulo. Photo. A. Kerr

Table 2: Heat of combustion of each fuel analyzed [2]

Fuel	Heat of Combustion ($^{kJ}/_{kg}$)
Gasoline	4.24×10^4
Ethanol	2.49×10^4
Diesel	4.26×10^4
Automotive gas (per m^3)	3.58×10^4

- Gasoline
- Ethanol
- Automotive Gas

} Individual transport modal

- Diesel } – Cargo transport; – Mass transportation (bus)
- Electricity } – Subway; – Urban train

Results

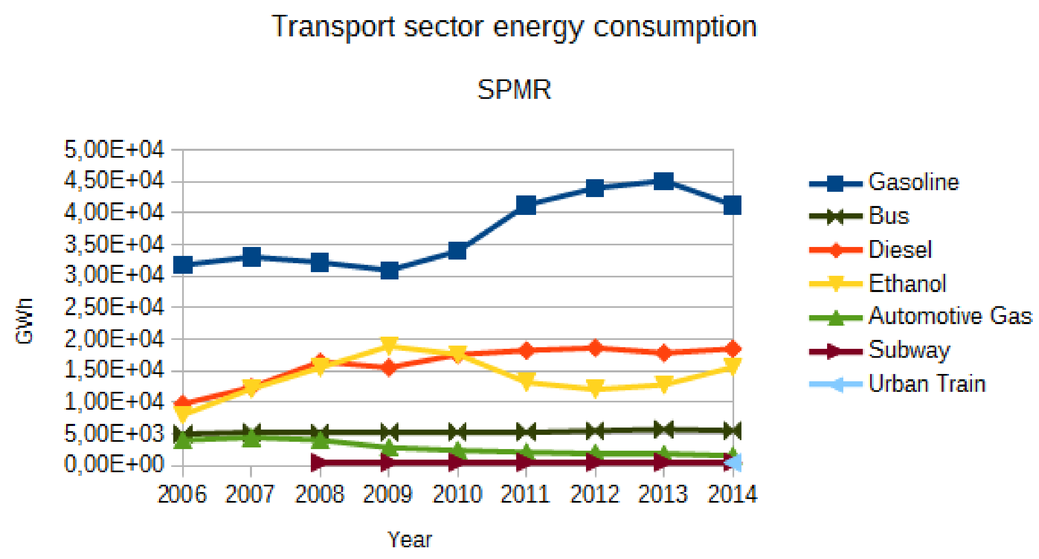

Figure 5: Evolution of the energy consumption for each modal of transportation between the years of 2006 and 2014.

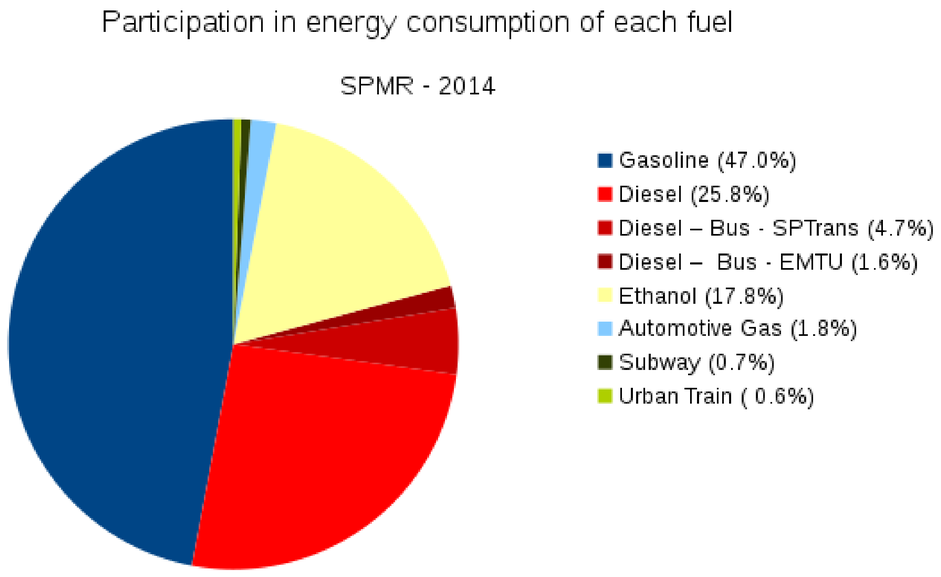

Figure 6: Particioation of each modal in energy consumption in the year 2014.

Table 3: Energy spent per travel for each modal, using the Mobility Research at SPMR from Metro [6].

Modal	Energy per Travel (kWh)	Factor relative to the subway
Passenger Cars	11.6	24.2
Subway	0.5	1
Bus	1.2	2.5
Urban Train	0.6	1.3

Conclusions

- Public transportation represents better energy efficiency, specially on rails.
- This work supplies information and enables the conceptualization of energy using the transportation area, and may be used in courses related to environment or devoted to improve high school teachers ability to deal these issues with their students.

References

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Acknowledgements

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